This newsletter was originally published in electronic form by the Joint Astronomy Centre on their web site. This PDF version was created using the web pages still available in August 2014. The most important pages are preserved. The missing pages tend to be administrative in nature and are unlikely to have historical value.





#### September 2000 Issue Number 15

Downloadable files containing the majority of the contents will shortly be available in postscript, gzipped postscript, and Adobe Acrobat (pdf) format.

#### **GENERAL ANNOUNCEMENTS**

From the Director's Desk Call for Proposals for Semester 01A Pointing Problem Revised Sky Opacities JCMT Board Report May 2000

#### PATT INFORMATION

PATT Application Deadline Electronic Submissions Flexible Scheduling Guidelines

#### **INSTRUMENTATION UPDATE**

Heterodyne Instrumentation SCUBA and SCUBA Polarimeter FTS SPIFI MPI 800GHz Receiver (RxE)

#### SCIENCE HIGHLIGHTS

<u>The Orion B Molecular Cloud (front cover)</u> <u>A New View of M82</u> <u>The Sub-millimetre Moon</u> JCMT Allocations for Semester 00B JCMT Working Schedule

FUTURE INSTRUMENTATION SCUBA-2 ROVER - A Roving Polarimeter

#### **STATISTICS**

Weather/Fault Stats for Semester 99B Weather Stats for Semester 00A Operational Stats for 2000 Publication Statistics <u>The Mon OB1 Dark Cloud</u> <u>Cluster Formation in Large Globules</u> <u>Scan-Map Polarimetry of the Crab (back cover)</u> <u>Star formation in the early Universe</u> <u>SCUBA sources, failed stars, and the dark matter</u> <u>NGC6334</u> JAC Internal Science Seminars

#### **ABOUT THE NEWSLETTER**

Points of Contact Next Submission Deadline Last Word



back to:> The JCMT Home Page

Gerald Moriarty-Schieven

## From the Director's Desk

Starting off a Newsletter with talk of yet another six months of poor weather on the summit and yet more changes of staff now seems to becoming standard. However, the good news is that there was one excellent spell of dry weather in August, which lasted almost a week; the best we have seen so far this year. This poor trend of weather prompted me to ask for an analysis of the CSO tau and seeing measures for the past four years to see just how they pattern has affected the ratio of band 1 to 5 weather for allocating and scheduling (see later). Major progress has been made on completing three facility projects, which is important for the development programme and for staff morale.

On the staffing side, recruitment continues to be difficult, and continues to be necessary due to staff changes. Mary Fuka retired in May after ten years of excellent service. Mary was responsible for much of the telescope software that has been so reliable over the years. Two TSSs, Jeff Cox and Rusty Luthe left in July, Jeff for Gemini South, and Rusty to the CFHT. Both had held long and distinguished careers as will be testified by visiting observers. Ian Pain, the JAC senior mechanical engineer, returned to the UK after five years at the JAC, he is now at the UKATC in Edinburgh. On the recruitment front we have recruited Ian's replacement (Tomas Chylek), a senior instrument technician for the JCMT (Ken Brown) a Junior Software Engineer for the JAC (Mathew Rippa taking over some of Mary's responsibilities) and two new Telescope Support Specialists (Jim Hoge and Jonathan Kemp). Teresa Dorward (PPARC finance assistant) will be leaving us for the La Palma site and her replacement, Chelo Gomez arrives in September (from La Palma!).

Two further and major impacts on staffing regarded Wayne Holland and Graeme Watt. Wayne was appointed as the project scientist for the exciting new SCUBA-2 instrument, which is great for SCUBA-2 but leaves a huge hole at the JCMT in terms of knowledge of SCUBA. Wayne is truly 'Mr SCUBA' and he will be sorely missed. This new position takes effect from September 1st, although he will remain on-site until early in 2001. Graeme Watt will be leaving the JCMT to return to PPARC (Swindon) as Technology Co-ordinator, a new and very important and growing role within PPARC. Graeme will effectively transfer over in late September and will leave Hawaii in early 2001. Graeme was one of the original day-one support astronomers for the JCMT and in his role of scheduler, through extensive and time-consuming efforts, he has managed to satisfy most users with regard to satisfying the often conflicting requirements of scheduling. He also takes away a huge amount of knowledge built up over the years.

These latter two departures have caused a rethink to the management of the JCMT and individual roles and responsibilities. Let me first take the post of Telescope Manager, the responsibilities of which had been redefined after Wayne took over this post last year. For a number of reasons, including the success of the Chief Engineer in clearly defining the areas of responsibility for upkeep and maintenance, the general improvement in the facility reliability (see later for the instruments) and the simplification of the Development Projects, opportunity was taken for a major management reorganisation. The development projects are now much smaller in number, albeit larger in individual size. Also, all of the external instruments now have a dedicated project manager who is directly responsible for the production of the instrument, and so the requirements for the Head of Instrument Development have changed. The reorganisation has removed the latter post and Per Friberg's duties have been redefined to include those of the Telescope Manager. This was

agreed by the JCMT Board after internal discussion. From September 1st Per becomes Associate Director of the JCMT with responsibilities previously undertaken by the Telescope Manager along with responsibilities for some of the individual new instruments. Aspects of his previous workload will be taken up by myself (overall financial management of the Development Fund, SCUBA-2 overseeing), the Finance Office (day-to-day financial management and allocations/outturns etc), and other support astronomers. This represents quite a change and unfortunately leaves Per with a very sizeable line-management task. I'm sure everyone will rally round to support Per in his new work. I will also revert back to taking the scientific overview and quality issue of the JCMT as opposed to the Telescope Manager. For telescope scheduling and the post of ITAC secretary, Gerald Moriarty-Schieven has bravely stepped in and taken over from Graeme. Plans for other changes of duties are still being worked through, although it is clear that support will be very tight over the coming months as there are more duties to allocate than bodies to take them on. Patience from users will be appreciated.

Another new aspect that arose since the last Newsletter is the use of volunteer support astronomers to act as TSSs. This was approved by the Board in May as a trial venture that would enable sixteen hour observing shifts to be maximised during a period of lack of TSSs. This has turned out to be much more complex than was originally anticipated due to the need for more extensive training on safety issues. Everyone should be well aware that safety of personnel is my prime responsibility and in response to a potentially serious accident at the summit, a programme of intensive training leading to formal TSS certification for both telescopes has been put in place.

Moving onto the telescope facility, overall this has been very reliable apart from the occasional glitches that affected one or two users. I am very pleased to be able to report that the new Telescope Control System has been commissioned and is working well. This project turned out to be far more complex than expected and great credit goes to Nick Rees and Firmin Oliveira for its successful completion. The work on the surface project to install the new panel adjuster electronics has just been very successful (see the JCMT web-page) and so work now turns to understanding how to use these with new software to make an active surface that is best matched to conditions at all times. Replacing the old adjustment system had the potential to scramble the dish if the team had not planned the work meticulously. The new holography system will now be fully commissioned in the next month or so.

Turning to the instruments, I am very pleased to note that RxA3 is now back in service, thanks to high dedication by the JCMT staff. RxB3 is now more reliable and SCUBA has done well after a scare in the summer when excess noise appeared and subsequently disappeared. On the other hand, SCUBA has just suffered an unexpected warm-up due to problems with the liquid nitrogen cold-trap. I remain concerned about the lack of applications to use RxW, which continues to pose questions regarding the requirement for a high frequency array receiver. The C-band in RxW has always been very competitive and after the replacement of the D-band mixers, this frequency is also highly competitive. However, the applications to undertake high frequency astronomy with RxW continues to languish, being only 7% of total applications for semester 00B, the same as for the SCUBA polarimeter. In this light, SCUBA continues to dominate with 58% of the application for time. I would be grateful to hear from potential high frequency users as to what they perceive as any problems or why they believe there are such a low number of applications and what we might do about it. After discussions at the ITAC it was agreed that we will undertake a trial for semester 01A with RxW being offered in blocks of time. This has advantages for us in that we can support it much better in concentrated blocks and the TSSs can remain current in its tuning characteristics. I am hoping that RxW applications will increase this time round otherwise I'm sure the Board will be enquiring about the strategic future of high frequency heterodyne astronomy at the JCMT. SPIFI was totally weathered out in spite of a flexibly scheduled run of over three weeks, and the Max Planck 800 GHz receiver fared little better, although

it was proven that it was working well and is very competitive in terms of its sensitivity. Both are expected to be available for use in semester 01A.

I am delighted to note the exciting science contributions to the Newsletter. On a personal note I found the lunar scan-map to be absolutely excellent, although for some reason the reproduction on the web-page does not appear as spectacular as I have seen. It is a little known fact that the first observing I did on Mauna Kea was in 1973 on the UH 88-inch, trying to map M82 at 400 microns. With one thing and another the only thing we got out of the run was a rather rudimentary map of the Moon, which was duly written up and published to ensure funding for another expedition. The comparison between that and what SCUBA has just achieved is rather like Galileo's depiction of the rings of Saturn compared to the HST view! A major project has just been completed and submitted for publication: the two-colour continuum mapping of the Galactic Centre region. This produced some spectacular data that will feature strongly in the next Newsletter. SCUBA continues to dominate the conference scene on galaxies in the early Universe, as was shown at the Amherst meeting and the IAU at Manchester. The recent press releases concerning the discovery of planets around nearby stars, especially Epsilon Eridani, brought about more attention to the SCUBA images of these systems.

I hope that users will have logged on and noticed the new JCMT web-pages. These have proved to be very popular and changes will continue as we refine the system to make the information more readily accessible for users and the general public. It is our intention that all our information will be web-based and so ready access and retrieval is an important matter in overall web-design. Thanks go to Robin Phillips for this work. Suggestions for improvements/additions are always welcome - please send to Robin. The Newsletter will continue to be web-based, unless there is significant pressure to add a paper version (which costs more money and effort of course).

The November Board meeting is going to be very important with regard to the future development and operation of the JCMT. SCUBA-2 remains the highest priority instrument but is expensive and the problem remains as to how to fund it and the high frequency heterodyne array, CHAMP-D, over and above the current level of the Development Fund. The Board asked me to produce a series of potential operational models whereby funds from operations are used to increase those available for new instrumentation. This will be the focus of an email exploder that will be issued in the next few weeks regarding users' inputs to the debate. This is clearly a very important potential milestone and users are invited to make their input through the JCMT Advisory Panel. At the moment the SCUBA-2 proof-of-concept phase is being funded by PPARC alone.

Finally, let me close by extending my sincere thanks to two long-standing members who retired from the JCMT Board at the last meeting, Don Morton and Ewine van Dishoeck. I would also like to extend congratulations to Ewine on behalf of all JCMT users for her recent award of the highly prestigious Spinoza Prize (the highest scientific award in the Netherlands) in recognition of her world-leading research on the chemistry of the interstellar medium, much of which was undertaken using the JCMT.

Back to: The JCMT Newsletter Index

Ian Robson

Back to: The JCMT Newsletter Index

# **Pointing problem**

A problem has been detected that seems to result from the change of direction of the elevation motion of the antenna. The first indications were from transit tracking experiments in Dec 1999 and March 2000. The problem reveals itself most obviously as a 4" change in elevation pointing during tracking through transit, although examination of all-sky pointing datasets reveals it to be pervasive. Further details, our strategy to combat it in software, and subsequent attempts to estimate the efficacy of those measures are described at http://www.jach.hawaii.edu/JACpublic/JCMT/Facility\_description/Pointing/problems.html

Back to: The JCMT Newsletter Index

Iain Coulson

#### Back to: The JCMT Newsletter Index

### **Calculating Sky Opacities**

There has recently been a concentrated effort to better characterise the extinction corrections in the different SCUBA filters and update the previous work on the relationships between these and and the CSO Tau value.

This work involves a new interpretation of CSO Tau data, and a re-analysis of the parameters used in our skydip model. We have also determined the criteria for which a skydip can be deemed trustworthy.

Through this process, the overall calibration of SCUBA has been refined, and the reasons for the typically poor 450 micron skydip fits better understood. This has implications for existing datasets, depending on how they were calibrated, although any error is likely to be minimal unless 450 micron skydips were used.

The full report can be accessed <u>here</u>. It includes revised CSO Tau relations, recommended data reduction techniques, and guidelines for determining how badly existing datasets have been affected.

Back to: The JCMT Newsletter Index

Elese Archibald



Next: Summary

둾

### Joint Astronomy Centre

**James Clerk Maxwell Telescope** 

Elese N. Archibald, Jeff W. Wagg & Tim Jenness

25 Oct. 2000 SCD System Note 2.2

# Calculating Sky Opacities: a re-analysis for SCUBA data

Postscript Version

- <u>Summary</u>
- Introduction
- Accurate skydip reduction
- <u>CSO Tau</u>
- <u>Revised CSO Tau relations</u>
- <u>Recommended Data-Reduction Techniques</u>
  - Data taken before February 4, 1998
- Implications for data taken before October 11, 1999
- Acknowledgements
- Addendum Revisions to this Document
- About this document ...

# Next Up Previous Next: Introduction Up: Contents Previous: Contents

# Summary

To accurately correct SCUBA data for atmospheric extinction, the zenith sky opacity, Tau, must be known. This is less crucial at 850 $\mu$ m; in good weather, Tau<sub>850</sub><0.3, and at low airmass, A<1.5, a 20% error in Tau<sub>850</sub> alters the measured source flux by 5-10% at most. However, in worse conditions and particularly at 450 $\mu$ m, an error in Tau can severely affect the measured source flux.

The JCMT staff have recently made a concentrated effort to better characterise the extinction corrections in the different SCUBA filters and to update the previous work on the relationships between these and the CSO Tau value. In this process, the overall calibration of SCUBA has been refined and the reasons for the typically poor  $450\mu m$  skydip fits better understood.

This has implications for existing datasets, depending on how they were calibrated. Data taken at 850 $\mu$ m are unlikely to be significantly affected, as are data taken at 450 $\mu$ m using the original CSO Tau relations to estimate Tau<sub>450</sub>. If data have been calibrated using 450- $\mu$ m skydips, the source flux could be in error by 50%

or more in the most extreme cases. In general, the error (particularly at  $450\mu$ m) increases with Tau. This error, whether at  $850\mu$ m or  $450\mu$ m, depends very much on the individual circumstances, and observers are encouraged to investigate their own situation using methods described in this document.

This document explains some of the history behind the calibration process, the recent work, and how to get the best out of the various measurements of Tau that are available. Improvements over previous methods are presented and these will minimise the potential errors in determining the source flux.

Next Up Previous

Next: Introduction Up: Contents Previous: Contents Elese Archibald 2000-10-25 Next Up Previous Next: Accurate skydip reduction Up: Contents Previous: Summary

### Introduction

The two most common methods of estimating Tau are performing a skydip and extrapolating from the CSO Tau monitor, which measures the zenith sky opacity at 225 GHz at a fixed azimuth. Tau can also be derived using a secant plot, but this requires a meaningful number of measurements of a bright source over a range of airmasses in very stable conditions to be accurate.

Skydips measure the sky brightness temperature over a range of elevations (usually between 80 and 15 degrees). When performing a skydip, SCUBA alternates between observing the sky, observing a hot load, and observing a cold load at each elevation. The physical temperature of the hot and cold loads can be measured, and are adjusted to match the bandwidth and central wavelengths of the various filters. Thus the loads serve to calibrate the observations of the sky itself. A model describing both the atmosphere (assuming a plane-parallel form) and the optical system is then fit to data in order to estimate the zenith sky opacity.

Ed Chapin (University of Victoria) analysed the skydip and CSO Tau data taken before May 1998, and derived the following correlations between  $Tau_{850}$ ,  $Tau_{450}$ , and  $Tau_{CSO}$  (refer also to Figure 1):

 $Tau_{850} = 4.3 * (Tau_{CSO} - 0.006)$  $Tau_{450} = 25 * (Tau_{CSO} - 0.011)$ 



Figure 1: CSO Tau relations for data taken prior to May 1998. The left plot shows the  $Tau_{850}$ - $Tau_{CSO}$  correlation, the right plot shows the  $Tau_{450}$ - $Tau_{CSO}$  correlation.

These relations have been regarded as an essential tool for reducing data. In this document, we present a re-analysis of

how best to determine the sky opacity, including a new interpretation of CSO Tau data and new measurements of the temperatures of the hot and cold loads used to calibrate skydips. Combining this information, we present revised CSO Tau relations.

Before proceeding, we need to mention the SCUBA Upgrade Project, which was completed on October 11, 1999. New blocking filters were installed which have better transmission than the old ones (~10% improvement at 850µm, ~20% improvement at 450µm). As before, they are designed to cut out extraneous radiation that would otherwise be detected by the bolometers. The sensitivity of all filters will have been affected by this change. In addition, two new wideband filters centred at 450µm and 850µm (450W:850W) were installed. Their transmission profiles are shown here. The narrowband predecessors (450N:850N) are still available, although at 450µm the new wideband filter is considerably more sensitive under all weather conditions.

We have re-analysed the data for the pre-upgrade 450N:850N narrowband filters, the post-upgrade 450N:850N narrowband filters, and for the new 450W:850W wideband filter system. Please note that so far we have only been able to re-analyse the 450-µm and 850-µm data. We have not yet tackled the 350-µm, 750-µm, 1350-µm or 2000-µm filters.

Next Up Previous

**Next:** <u>Accurate skydip reduction</u> **Up:** <u>Contents</u> **Previous:** <u>Summary</u> Elese Archibald 2000-10-25

### Accurate skydip reduction

In principle, the skydip method should be able to derive accurate Tau values. However, the overhead involved means it is only practical to perform a skydip every 1.5-2 hours, and quite often the frequency is even less. Furthermore, in mediocre-poor weather, the skydip model has always had trouble fitting to the 450-µm data, usually over-estimating the Tau, and hence over-estimating the source flux.

There are three realistic causes for the poor fits. The first is the saturation of the atmosphere at high airmass. The second is the atmosphere losing its plane-parallel nature; when this happens the atmospheric model we use is strictly no longer valid (this can also occur when the atmosphere occasionally becomes `layered', i.e. a very distinctive `step' is seen which again compromises our relatively simple model). The third is the suspicion that the load temperatures (T\_HOT and T\_COLD) used by the model are incorrect. Accurately measuring these temperatures is a non-trivial task, and depends, for example, on an accurate knowledge of the reflectivity and emissivity of the cryostat window (see below).





We have investigated the location of the hot-load temperature sensor and have re-analysed the engineering data taken in October 1999. Accounting for the emissivity and reflectivity of the cryostat window, and the `mis-location' of the hot load temperature sensor, new values for T\_HOT and T\_COLD have been derived. These values are displayed in Table 1. In order to estimate Tau, the skydip fitting routine also requires  $\eta_{tel}$  (the transmission of the telescope). We have re-examined the values of  $\eta_{tel}$ , and as a result have updated the value at 850µm, although this

change does not significantly affect the value of Tau estimated by the skydip routine. The recommended values of  $\eta_{\text{tel}}$  are also included in Table <u>1</u>.

Table 1: Updated values of T\_HOT and T\_COLD for the narrowband and wideband 450:850 filter systems. Note, the

new value of T\_HOT is expressed as the temperature measured by the telescope (T\_measured - this is the value stored in the header of the data file) minus a small correction ed.

factor. The value of	<b>7 tel</b> at	850µm has	also	been	revis
----------------------	-----------------	-----------	------	------	-------

Filter	T_HOT	T_COLD	$\eta_{ m tel}$
450W	T_measured - 3K	95K	0.75
850W	T_measured - 1K	90K	0.85
450N	T_measured - 3K	102K	0.75
850N	T_measured - 1K	92K	0.85

When the new values of T\_HOT, T\_COLD and  $\eta_{\text{tel}}$  are used to analyse the skydips taken on October 17, 1999, the skydips display remarkable agreement with the corresponding secant plots. These new values were applied to skydips in a range of weather conditions,  $0.5 < \text{Tau}_{450} < 3.5$ , and with one exception (very noisy data) the skydip model provided excellent fits to all of the data.

At first glance, this indicated that we had found the cause of the typically poor 450-µm skydip fits. A closer analysis of 450µm skydips revealed that in many cases, using the revised values of T\_HOT and T\_COLD does yield trustworthy fits to the data. However, we have also discovered an instability in the fitting algorithm, which although it does not affect all of the 450µm skydips, does corrupt a large number of them. Thus, we do not recommend that individual 450-µm skydips be blindly trusted. As mentioned in Section 5, in constructing our CSO Tau relations we have been careful to exclude skydips obviously affected by the instability.

On March 13, 2000, the online software was updated to support the new value of T\_COLD. On April 25, 2000, it was updated to support the new value of net. Data taken after these dates will have the correct values of T\_COLD and net stored in the file header. Updating the software to support the new values of T\_HOT is less trivial. A single value of T\_HOT is stored in the data headers. Both the online system and SURF need to be modified to adjust the temperature in a wavelength-dependent manner. The change to the on-line fitting routine is unlikely to happen in the near future.

For observers at the telescope, the on-line 850-µm skydip fits, used in conjunction with the revised CSO Tau relations given in Section 5, will be more than adequate for planning observations. For off-line data reduction, version 1.6 of SURF uses the correct values of T\_HOT, T\_COLD, and net for all skydips.



Next: CSO Tau Up: Contents Previous: Introduction Elese Archibald 2000-10-25

# Next Up Previous Next: Revised CSO Tau relations Up: Contents Previous: Accurate skydip reduction

### CSO Tau

The CSO Tau Monitor measures the 225 GHz opacity every 10 minutes, more frequently than the rate at which skydips are taken with the JCMT, albeit at a fixed azimuth. Comparing the skydip values to the CSO Tau Monitor values yields relations between  $Tau_{CSO} \& Tau_{850}$  and  $Tau_{CSO} \& Tau_{450}$ . If the scatter about these relations is small, then the CSO Tau monitor can be used to measure the opacity more frequently than the skydips, with no additional overhead.

As mentioned above, these relations have been derived already, but there is some worry about using them, especially given the discovery that the previous values of T\_HOT and T\_COLD were incorrect. The CSO Tau values also tend to spike up and down quite a lot, which may or may not be representative of the sky itself. In addition, the relations have only been calculated for the narrowband filters, and may be different for the new wideband system.

Before recalculating the relations for both the narrowband and wideband filter systems, taking into account the revised values of T\_HOT, T\_COLD and  $\eta_{\text{tel}}$ , we wish to describe a new method of handling the CSO Tau data, that reduces the scatter in the CSO Tau relations even further.





Currently, ORAC-DR reads the CSO Tau from the data-file headers. However, the CSO Tau Monitor may update more frequently than the rate at which observations are taken. We extract the Tau directly from the CSO archive, and plot this `high resolution' CSO Tau data as a function of time. A polynomial is then fit to the data to track the large scale variations in CSO Tau as opposed to the small-scale noise.

The high resolution data for two different nights are shown in Figure <u>3</u>. There are several points worth noting:

1.

Using the relations derived in Section 5, we have also plotted the CSO Tau predicted by the 850-µm skydips taken each night. It is striking how well the skydips track the CSO Tau, even when one would imagine that the CSO was moving around too much to be useful.

2.

The high resolution CSO data show a significant amount of noise, but do track long time-scale ( $\sim$ 2 hour) variations very well. This noise is more than one would expect given the measurement errors quoted in the CSO Tau archive. It is possible that this small-scale noise is due to instrumental noise and does not represent the behaviour of the sky. This is supported, but not proven, by the good correlation between the skydips and the polynomial fit. From experience at the telescope, we have noticed that sometimes the CSO Tau fluctuates, while the skydips indicate a uniform sky.

This work seems to indicate that the polynomial fits (i.e. the `smoothed' CSO Tau data) may be the best representation of the 225 GHz optical depth. Work is currently in progress to archive the polynomial fits and make them available to the general user community.

A note of caution, however - although in general the polynomial fits are very good, on some nights (especially when there is a large level of scatter and variability in the CSO Tau data) they may not provide an accurate description of the 225 GHz optical depth. Thus, the smoothed CSO Tau data should not be used blindly nor taken as a replacement for performing skydips. Version 1.1 of ORAC-DR supports the polynomial fits if requested on the command line.

Next Up Previous

Next: <u>Revised CSO Tau relations</u> Up: <u>Contents</u> Previous: <u>Accurate skydip reduction</u> Elese Archibald 2000-10-25

### **Revised CSO Tau relations**

We have generated revised Tau relations by comparing the smoothed CSO Tau data to skydips analysed with the correct values of T\_HOT, T\_COLD and maintenance of the correct values of T\_HOT, T\_COLD and Tau.

 Table 2: Revised Tau relations. The relations have been constructed using smoothed CSO Tau data and skydips reduced with the revised values of T\_HOT, T\_COLD, and Thel.

Eilter Sustan	Time David	$Tau_{Y}=a(Tau_{X}-b)$				
Filler System	Time Period		Tau <sub>X</sub>	а	b	
	Feb. 04, 1998-Oct. 10, 1999 (pre-upgrade)	Tau <sub>850</sub>	Tau <sub>CSO</sub>	3.99±0.02	$0.004 \pm 0.001$	
450N:850N		Tau <sub>450</sub>	Tau <sub>CSO</sub>	23.5±0.2	$0.012 \pm 0.001$	
		Tau <sub>450</sub>	Tau <sub>850</sub>	5.92±0.04	$0.032 \pm 0.002$	
450W:850W	Dec. 05, 1999-Sept. 30, 2000 (post-upgrade)	Tau <sub>850</sub>	Tau <sub>CSO</sub>	4.02±0.03	$0.001 \pm 0.001$	
		Tau <sub>450</sub>	Tau <sub>CSO</sub>	26.2±0.3	$0.014 \pm 0.001$	
		Tau <sub>450</sub>	Tau <sub>850</sub>	6.52±0.08	0.049±0.004	

Figure 4: Revised Tau relations for the pre-upgrade narrowband 450N:850N filter system. The relations have been constructed using smoothed CSO Tau data and skydips reduced with the revised values of T\_HOT, T\_COLD, and The left plot depicts the relationship between the skydips and CSO Tau. The blue points are the Tau<sub>450</sub>-Tau<sub>CSO</sub> correlation, the red points are the Tau<sub>450</sub>-Tau<sub>CSO</sub> correlation. The right plot depicts the Tau<sub>450</sub>-Tau<sub>aso</sub> correlation (turquoise data) derived from comparing 450-µm and 850-µm skydips. Models of the form *Tau<sub>y</sub>=a*(*Tau<sub>x</sub>*-b) have been fit to the data in every case.



Figure 5: Revised Tau relations for the wideband 450W:850W filter system. The relations have been constructed using smoothed CSO Tau data and skydips reduced with the revised values of T\_HOT, T\_COLD, and The left plot depicts the relationship between the skydips and CSO Tau. The blue points are the  $Tau_{450}$ - $Tau_{CSO}$  correlation, the red points are the  $Tau_{450}$ - $Tau_{CSO}$  correlation. The right plot depicts the relationship between the skydips and CSO Tau. The blue points are the  $Tau_{450}$ - $Tau_{CSO}$  correlation, the red points are the  $Tau_{450}$ - $Tau_{CSO}$  correlation (turquoise data) derived from comparing 450- $\mu$ m and 850- $\mu$ m skydips. Models of the form  $Tau_{\gamma}$ -*a* ( $Tau_{\gamma}$ -*b*) have been fit to the data in every case.



The method used to construct these relations is as follows:

1.

2.

3.

4.

We threw out skydips for which the model failed to fit the data or for which the fitting algorithm became unstable returning unbelievable values for the parameters. This involved discarding  $\sim$ 20% of the data at 850µm and  $\sim$ 50% of the data at 450µm.

We ignored data taken when the CSO Tau monitor was broken.

If either the CSO Tau monitor or the skydip indicated a non-physical value of Tau, i.e. negative or zero, we ignored the observation.

We restricted the datasets to Tau<sub>CSO</sub><0.2 (SCUBA is not used in weather conditions worse than this).

5.

A model of the form  $Tau_{y}=a(Tau_{x}-b)$  was fit to the data to derive the Tau relations.

#### 6.

At 450 $\mu$ m, the model was only fit to data taken in Grade 3 weather conditions or better, i.e. Tau<sub>CSO</sub><0.12. The reasons for this were twofold: (i) 450 $\mu$ m observations are not recommended in worse weather conditions and (ii) we do not have much data for Tau<sub>CSO</sub>>0.12. However, fitting to the entire dataset yields an identical relation, suggesting our relation holds in Grade 4 weather.

The relations have been calculated for the narrowband pre-upgrade and the wideband filter systems at both  $850\mu$ m and  $450\mu$ m. They are displayed in Table 2, Figure 4, and Figure 5. Note, there is a lack of post-upgrade narrowband data owing to the CSO Tau monitor being broken for about 3 weeks in November 1999, and the SCUBA filter drum problem, which has necessitated operation in the wideband filter position only since December 1999 (further details on the filter drum problem can be found here). The small number of data points means we are not yet able to construct robust relations for the post-upgrade narrowband filters. However, we do not expect these relations to differ from those estimated for the pre-upgrade narrowband system. In Figure 6, we overlay the pre-upgrade relations on the post-upgrade data, demonstrating that the pre-upgrade relations are a good approximation.



Given the lack of post-upgrade narrowband data, we will restrict the following discussion to the wideband filters and the pre-upgrade narrowband system.

Looking carefully at the revised relations, there are several points worth mentioning:

#### 1.

For each filter system, we have derived two sets of relations: the first compares the skydips at 450µm and 850µm with the CSO Tau data, the second compares the 450µm and 850µm skydip data directly. For both the wideband and the pre-upgrade narrowband filters, the 450-850 skydip relation agrees remarkably well with what one would expect given the CSO Tau relations.

2.

3.

Comparing the wideband and pre-upgrade narrowband filters to each other, the wideband CSO Tau relations are steeper at  $450\mu$ m but are almost identical at  $850\mu$ m. The difference at  $450\mu$ m is to be expected given the lower central wavelength of the wideband filter (at  $850\mu$ m, the narrow and wideband filters have almost identical central wavelengths).

There is a small difference between the re-analysed narrow pre-upgrade relations presented here and the original relations calculated by Ed Chapin. This will affect data reduced using the old values of T\_HOT and T\_COLD and the original relations. The extent to which the data reduction will have been affected is discussed in Section  $\underline{7}$ .

4.

The new relations display relatively little scatter, even in the poorest weather conditions, providing hope for meaningful 450- $\mu$ m calibration in Grade 3 weather. Figure <u>7</u> gives an example of how much the scatter has been reduced by the new analyses presented here.

 $Figure \ 7: \ The \ pre-upgrade \ narrowband \ Tau_{850} \ Tau_{CSO} \ relation \ before \ and \ after \ the \ analyses \ presented \ here \ were$ 



5.

If the submillimetre opacity is due solely to water vapour, the Tau relations for the different filters are expected to intercept the origin: if there is no water vapour in the atmosphere,  $Tau_{CSO}$ ,  $Tau_{850}$  and  $Tau_{450}$  will all equal zero. However, we have found evidence for non-zero intercepts. Assuming the straight-line model can be extrapolated to the intercept, these intercepts could be explained by ozone contributing to the opacity at 225GHz, with a small contribution at 850 $\mu$ m and little/no contribution at 450 $\mu$ m. The ozone contribution is relatively invariant for long periods of time, and these offsets should be constant.

6.

We have taken care only to include 450-µm skydips for which the fit and output parameters are believable. Thus, in spite of the instability in the 450-µm fitting algorithm, we believe the relations presented here to be trustworthy.

Version 1.1 of ORAC-DR supports these new relations.

Next: Up Previous Next: Recommended Data-Reduction Techniques Up: Contents Previous: CSO Tau Elese Archibald 2000-10-25 
 Next
 Up
 Previous

 Next:
 Data taken before February
 Up: Contents
 Previous: Revised CSO Tau relations

### **Recommended Data-Reduction Techniques**

When reducing SCUBA data it is suggested that the following procedure be followed:

1.

For 850- $\mu$ m data, both the skydips (with the updated values of T\_HOT, T\_COLD and  $\eta_{tel}$ ) and the revised CSO Tau relations are trustworthy. Given the infrequency of skydip measurements, we recommend that when the CSO Tau monitor is working, the polynomial fits be used in conjunction with the revised relations. However, if observers are concerned that the CSO Tau measurements are obtained at a fixed azimuth, the skydips will be more than sufficient for data reduction.

2.

For 450- $\mu$ m data, individual skydips cannot be trusted. However, the revised CSO Tau relations were constructed with extreme care (Section <u>5</u>), and are believed to be solid. To reduce 450- $\mu$ m data, we suggest using either the polynomial fits to the CSO Tau or the 850- $\mu$ m skydips, in conjunction with the new relations.

3.

For post-upgrade narrowband data, there are not enough data to construct CSO Tau relations. There is no *a priori* reason for these relations to differ from the pre-upgrade relations. The pre-upgrade relations should be a good approximation until more data are available to confirm this.

• Data taken before February 4, 1998

Next Up Previous

**Next:** Data taken before February Up: Contents Previous: Revised CSO Tau relations Elese Archibald 2000-10-25 Next: Implications for data taken Up: Recommended Data-Reduction Techniques Previous: Recommended Data-Reduction Techniques

### Data taken before February 4, 1998

For data taken before February 4, 1998, the value of T\_HOT was not recorded. Instead, T\_AMB (the ambient temperature in the telescope dome) was stored in the data header. In order to reduce skydips taken prior to this date, we have attempted to determine the relationship between T\_HOT and T\_AMB (see Figure 8).



The relationship seems to be linear, and is almost a 1:1 correspondence. However, there is considerable scatter, which may be due to a thermal time lag between T\_AMB and T\_HOT. The extent of the scatter is more than a few degrees Kelvin, enough to make a 450- $\mu$ m skydip fit or fail. Furthermore, the scatter is larger than the corrections applied to T\_HOT. Thus, we cannot use the T\_HOT/T\_AMB correlation to determine T\_HOT and accurately reduce the skydips taken during this period.

For data taken before February 4, 1998, it is suggested that people use the revised narrowband pre-upgrade CSO Tau relations. Where the CSO Tau monitor was not working, there is only one option - reduce the 850- $\mu$ m skydip using T\_AMB (the 850- $\mu$ m skydips are more impervious to errors in T\_HOT) and then use the Tau<sub>450</sub>-Tau<sub>850</sub> relation to derive Tau<sub>450</sub>.

Next Up Previous

Next: Implications for data taken Up: Recommended Data-Reduction Techniques Previous: Recommended Data-Reduction Techniques Elese Archibald 2000-10-25

### Implications for data taken before October 11, 1999

The discovery that the recorded values of T\_HOT and T\_COLD were in error has implications for narrowband data taken before the upgrades. The skydip reduction will be different with the revised values, and as we have shown, the CSO Tau relations change once this error is taken into account.

Unfortunately, it is very difficult to quantify the extent to which data (in terms of measured signal in mJy) will have been affected. It depends very much on the individual case. The error will be greater for sources observed at high airmass, and for those observed in wet and/or variable conditions. This error is minimal for 850- $\mu$ m data, but can be significant at 450 $\mu$ m depending on how Tau<sub>450</sub> was estimated. If the original CSO Tau relations were used, the error in the data is

likely to be acceptable, however, observers are still encouraged to investigate their own case. On the other hand, if 450-µm skydips were relied upon, the error in the data could be very large indeed, especially in poor weather conditions as the skydip fits were increasingly poor with increasing Tau. The error also depends on the calibration source; if it was observed at a similar Tau and airmass to the target source, the effect of measuring an incorrect Tau is mitigated somewhat.

A preliminary investigation of a few sample cases indicates that some of the data may not have been that badly affected - at most a few percent at  $850\mu$ m, and maybe 10-15% at  $450\mu$ m. However, these numbers represent the `best-case scenario'. Under less favourable conditions, we have seen the error in the flux be as much as 10% at  $850\mu$ m and over 50% at  $450\mu$ m. In some extreme cases, the situation could be worse than this.

As mentioned above, quantifying this error is very difficult given the number of factors it depends on. Observers are encouraged to re-reduce observations, especially those taken at 450µm, using the new relations or skydip values, to see how badly their individual situation is affected.

A theoretical calculation can also be made to determine the extent to which an individual observation will have been affected. Consider observations of a source and a calibrator, reduced with two different methods of determining Tau. The difference in the source flux estimated by the two methods is:

$$J_{s}^{1} / J_{s}^{2} = e^{A_{s}(Tau_{s}^{1} - Tau_{s}^{2}) - A_{c}(Tau_{c}^{1} - Tau_{c}^{2})}$$

where J is the above-atmosphere flux, A is the airmass, Tau is the zenith sky opacity, the subscript s' refers to the source, the subscript c' refers to the calibrator, the superscript 1' refers to the first method of estimating Tau, and the superscript 2' refers to the second method of estimating Tau.

Observers are further encouraged to use this equation, given the airmasses and Taus at which their data was taken, to get a feel for how large or small the errors are.

Next Up Previous

Next: Acknowledgements Up: Contents Previous: Data taken before February Elese Archibald 2000-10-25

# Acknowledgements

We wish to thank Wayne Holland, Remo Tilanus, Jason Stevens, Bill Duncan, Ian Robson, and Iain Coulson for extremely helpful discussions and suggestions.

# **Addendum: Revisions to this Document**

This is a revised version of the document. There are only two significant changes: (i) the wideband filter dataset has doubled and we have updated the relations accordingly (ii) we have updated the information regarding which software releases use the revised skydip parameters, the polynomial fits, and the new relations.

# About this document ...

This document was generated using the LaTeX2HTML translator Version 98.2 beta6 (August 14th, 1998)

Copyright © 1993, 1994, 1995, 1996, <u>Nikos Drakos</u>, Computer Based Learning Unit, University of Leeds. Copyright © 1997, 1998, <u>Ross Moore</u>, Mathematics Department, Macquarie University, Sydney.

The command line arguments were: **latex2html** <u>tau\_analysis.tex</u>

The translation was initiated by Elese Archibald on 2000-10-25

#### Back to: The JCMT Newsletter Index

### **PATT Application Deadline**

#### Deadlines for receipt of all JCMT applications for semester 01A is:

#### 30 September 2000

Note that the effective deadline for Canadian proposals is 8am PST October 2 in Victoria, and for UK/International proposals is 8am HST October 2 in Hilo.

#### Please read the next article - <u>Electronic Submission Update</u> 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.

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

#### **Country paying salary of Principal Investigator**

#### Back to: The JCMT Newsletter Index

#### SCUBA-2 : The Next Generation Bolometer Camera for the James Clerk Maxwell Telescope

#### Introduction

The next generation continuum camera for the JCMT ("SCUBA-2") is now well into the development phase. Following a successful <u>Conceptual Design Review</u> (in October 1999) and <u>Pixel Architecture Downselect</u> (May 2000), work on the instrument is now gaining momentum rapidly. During the past year the project has been enthusiastically received by both the JCMT Board and Advisory Panel, whilst PPARC approved a "proof-of-concept" funding that will most likely last about 2 years. The JCMT Board will review the project again at the November 2000 meeting. This is a short article which is meant to give a brief overview of the proposed instrument.

#### Scientific goals

The scientific goals of SCUBA-2 evolved primarily from consultation with the JCMT community during 1999. The key requirements are: the ability to make very deep images - reaching the background confusion limit in only about an hour of integration time; to generate high fidelity images at two wavebands simultaneously; to map large areas of sky (several square degrees) to a reasonable depth in only a few hours; carry out photometry of known-position point-sources to a high accuracy.

These goals dictate that the per-pixel sensitivity should be at least as good as the (recently) upgraded SCUBA, and that the field-of-view should be maximised (at least 8 arcmin in diameter is possible with JCMT). In terms of producing high fidelity images near or at the confusion limit, both the techniques of jiggling and sky chopping (currently employed with SCUBA) are major obstacles. Work is currently underway on defining the SCUBA-2 observing modes, but a major departure from the existing SCUBA methodology is that the arrays will fully sample the image plane (jiggling not necessary)and will most likely be D.C. coupled (sky chopping is no longer required). In principle, this will make observing with SCUBA-2 considerably more straightforward than with SCUBA!

SCUBA-2 will therefore instantaneously sample the sky - in a "point-and-shoot" mode similar to a CCD camera. This will produce fully-sampled images in much less time than required for SCUBA leading to improved image fidelity. Having D.C. coupled arrays will potentially allow more large-scale source structure to be visible, easier and more accurate flat-fielding (using the sky), and as the subtracted D.C. level is proportional to the sky brightness, it should allow the sky transmission to be continuously corrected for.

The <u>Scientific Case</u> for the instrument is well established and can be viewed on the <u>SCUBA-2 homepage</u>. As an example of the anticipated capabilities consider the case of large-scale extragalactic surveys designed to study source counts. Figure 1 is taken from the scientific case (but is updated following a revision of the instrument projected performance) and shows the expected detection rate (sources/hour) as a function of 5-s depth. These simulations, carried out by Andrew Blain, show that a SCUBA-2 (see next section for baseline design) will be a very powerful survey instrument and will be able to detect ~ 20 galaxies per hour at the optimum depth. As the figure shows SCUBA-2 will be <u>very competitive</u> with any instrument currently being proposed (and is likely to be available ahead of facilities like FIRST-SPIRE and even ALMA . It should also be noted that SCUBA-2 will be <u>complementary</u> to many facilities - particularly the airborne and space observatories and ALMA. Furthermore, although ALMA will be a very powerful survey instrument operating in a compact mode, it seems clear that that this might not be the best use of such a huge interferometer. Wide-field bolometer arrays (such as SCUBA-2) will become vital to carry out large-scale surveys, areas of which are then subsequently followed-up by high-resolution



**Figure 1** : The detection rates as a function of 5-s depth for a variety of instrument surveys including an 8-arcmin diameter f-o-v for SCUBA-2. Lines stop at the confusion limit on the left and where there is only 1 source on the sky on the right. The underlying model is the "Modified Gaussian" model described by Blain et al. (MNRAS 302, 1999). Many thanks to Andrew Blain for providing this figure.

Table 1 gives several more examples of the types of observations that could be carried out with SCUBA-2 together with an estimate of the decrease in integration time required for SCUBA-2 over that of SCUBA.

Type of observation (l =850m m)	Integration Time (hours)			
	SCUBA ***** SCUBA-2			
Point-source photometry to 5-s flux of 2 mJy	7.3	0.6		
Map of the Hubble Deep Field to noise level of 0.5mJy <sup>1</sup>	32	0.5		
Galactic plane survey $(20^{\prime} 2^{\circ})$ to noise level of 30mJy	850	0.9		
Survey of 5 <sup>°</sup> diameter molecular cloud to noise of 10mJy	4700	5		

Table 1 : Examples of various observations and integration times achievable with SCUBA-2.

<sup>1</sup>Note that a much bigger area will be imaged with SCUBA-2!

#### Instrument specification and design

Following the recent review meetings, the baseline specification is now well-established. SCUBA-2 will consist of two arrays operating simultaneously at both 450 and 850mm. The field-of-view on the sky will be a <u>minimum of 8</u> <u>`8 arcminutes</u> for each array. This means that to fully-sample the sky, with a pixel spacing of 0.5Fl (required for full Nyquist sampling), 25,600 and 6,400 pixels will be needed at 450 and 850mm respectively (c.f. 131 *in total* for SCUBA!). Each pixel will have diffraction limited resolution and a sensitivity dominated by the sky background photon noise.

The SCUBA-2 arrays will utilise new technology <u>Transition Edge Sensors (TES)</u> as the detecting element. TES devices have a number of very attractive advantages over more conventional bolometers: they are very sensitive to small amounts of incoming power since the biasing arrangement (in the transition region between the normal and superconducting states) make their resistance is a very steep function of temperature; the extremely sharp n-s transition region gives rise to strong <u>electro-thermal feedback</u> which can significantly speed up the device (allowing potential novel fast-scanning observing modes); under a voltage bias the pixel becomes "self-biasing" - meaning that only a single bias line is needed (thereby simplifying the electronics and the number of wires). The TES devices will be bonded to a low heat-capacity silicon membrane which will contain a radiation absorbing metal film.

Multiplexing the signal readout is a crucial area of the instrument design. This will be achieved by using <u>SQUID</u> <u>amplifiers</u> which are well-matched to the low-impedance TES devices. The construction of a single pixel is illustrated in Figure 3, together with what a 16 <sup>-</sup> 16 array might look like. The first-stage SQUID multiplexer will be buried in the silicon substrate interconnect chip. Ribbon cables will take the detector signals to the outside world. The TES arrays, together with the SQUID readouts, will be developed under a contract to the National Institute of Standards and Technology (NIST) who are world-leaders in these technology areas.

For a number of reasons the <u>detector operating temperature</u> still has to be below 200 mK, and so a dilution or adiabatic demagnetisation refrigerator will be required. Although the SCUBA fridge has had a number of problems over the years, new designs of dilution system are likely to be considerably more reliable, as well as less bulky. We are currently looking at options for fridges and also the prospects of constructing a liquid cryo-free system (i.e. not using liquid helium and saving on running costs).



**Figure 2** : On the left is a basic schematic diagram of a single pixel design. The TES device is represented as the square in the centre of the absorber. On the right is what a  $16 \cdot 16$  array might look like. Each pixel will be about 1mm on a side for the 850mm array and 0.5mm for the 450 array (with a small wall in between).

#### **Technical challenges**

Without a doubt SCUBA-2 is a very ambitious project, and as such there are several major technical challenges to be overcome. Primary amongst these are the manufacture of the TES detector arrays and SQUID amplifier readouts. A number of issues associated with the mechanical and electromagnetic design of the pixels have yet to be addressed. The adoption of a filled array design of 0.5 Fl spaced pixels also has potential problems. Since the field-of-view of the array will be defined by a cold stop, and not by a conventional feedhorn, the control of stray light (which could degrade detector sensitivity) presents a major challenge.

Another of the main challenges we face with SCUBA-2 is how to re-image the large telescope field-of-view out onto the Nasmyth platform, in such a way that the resulting image plane is flat and (relatively) aberration-free. A complex optical design is currently being investigated and in figure 3 we show what the optical path may actually look like. As mentioned above, key aspects of the internal optical system will be the need for high quality baffling and control of potential stray light.



**Figure 3** : A preliminary outline of a possible optical design (CAD drawing by Ian Pain). The field-of-view is some 600mm in diameter at the tertiary mirror of the telescope, and has to be re-imaged to an array of about 125mm in diameter with minimum distortion and aberrations.

#### **Delivery schedule**

SCUBA-2 is being built as a collaboration between primarily the UKATC (current Project Manager : William Duncan), NIST (PM : Kent Irwin), QMW (PM: Steven Rinehart), University of Edinburgh (PM : Alan Gundlach) and the JAC (current PM : Wayne Holland). Within 2 years of the start of the NIST contract we hope to produce a small prototype array which will act as a proof-of-concept device. If all goes well, we anticipate delivery of the final instrument before the end of 2005.

#### Summary

SCUBA-2 will allow the JCMT to fulfill its ultimate potential. The improved sensitivity and large field-of-view will allow the productivity of the JCMT to increase many fold - especially in an era when submillimetre interferometry with the SMA and the first heterodyne cameras will mean less time available for continuum astronomy. All areas of astronomy are expected to benefit, but perhaps the most exciting prospect that SCUBA-2 will offer is in the statistical significance of wide-field surveys. Only a tiny fraction of the "submillimetre sky" has so far been surveyed, and the construction a SCUBA-2 camera, for a very modest investment, will have a major impact on all areas of astronomy.

Wayne Holland, Ian Robson & William Duncan

#### More information

A preliminary homepage is now available for <u>SCUBA-2</u>. This page is still under construction but more information can be found on the scientific goals, current status and available documentation. Please contact the SCUBA-2 Project Scientist (<u>Wayne Holland</u>) for more details.

Back to: The JCMT Newsletter Index

Wayne Holland

Back to: The JCMT Newsletter Index

# A Short Walk with ROVER.....

For some time the JCMT has offered (somewhat ad hoc) an observing mode for <u>spectral-line polarimetry</u>. Ordinary emission lines, like CO, from ordinary molecular clouds possess a small degree of polarization if a magnetic field is present (not a lot of people know this!). Given some knowledge of source geometry, such as that a cloud is rotating, it's possible to detect the magnetic field direction in every velocity channel of a spectrum and turn this into a semi-3-D map of the magnetic field. Not surprisingly, this is very difficult - for anyone who has tried SCUBA polarimetry, now imagine that you are trying to pick up similar few-percent signal variations in bandpasses 10,000 times narrower!

At the end of last year, we won a PPARC grant to develop a new polarimeter - the idea is to exploit the interesting underlying physics by observing different transitions of several molecules, as well as the basic field mapping. Hence ROVER - the Roving Polarimeter - will be available collaboratively at the JCMT but is also planned to travel to some other observatories to observe lines in the 2 and 3 mm windows.

Since the start of the project in March, most of the work has been in the background (planning the control system, observing modes etc.) but look for ROVER on the JCMT in the next year or so! There is a link to a preliminary web page <u>here</u> and you can, of course, apply to use the existing polarimeter (see the call for proposals). The main technical difference between the two systems is that only simple and somewhat inefficient observing modes are possible at present - in the future, with ROVER and array receivers, there will be true millimetre spectropolarimetry.

Further reading: Goldreich P. & Kylafis N.D. (1981); ApJ 243, L75 (first paper to describe the physics of millimetre line polarization).

Jane Greaves

Back to: The JCMT Newsletter Index

Jane Greaves

### Weather and Fault Statistics for Semester 99B

The following tables present the weather loss and fault loss for semester 99B. A more detailed description of how these tables are created is also available <u>here</u>.

Month	Available	Extended	Lost to weather					
			Primary	%	Backup	%		
August	504.0	26.1	166.1	33.0	150.6	29.9		
September	477.0	12.1	71.0	14.9	40.3	8.4		
October	474.8	16.2	110.5	23.3	70.5	14.8		
November	471.5	12.4	205.3	43.5	151.8	32.2		
December	394.0	15.8	194.2	49.3	172.5	43.8		
January '00	429.0	28.9	138.5	33.0	96.9	23.1		
Totals	2741.3	111.7	885.6	32.3	682.6	24.9		

#### Table 1: JCMT weather statistics.

August504.015.90.58.80.02.81.0September477.049.431.04.90.24.40.0October474.829.93.025.70.00.20.0November471.565.40.063.90.01.40.0December394.05.90.50.00.01.91.5January'00420.014.00.38.62.40.90.3	1.9 9.0 1.0 0.2 2.0 1.0
P(nrs)       2/41.3       1/9.6       35.3       111.9       2.6       11.6       2.8         B(hrs)       18.5       0.5       14.1       0.5       0.9       0.0	15.1 2.5

**Table 2:** *JCMT* fault statistics. Wherever possible the faults are categorised into ANT = antenna; INS = instrument; COMP = computer hardware; SOFT = software; CAR = carousel; with the remainder going to <math>OTH = other. The figures in the table may not appear to add up correctly due to rounding in the original program. P defines the time lost from Primary projects. The category B(hrs) is the time lost to Backup projects.

Modified: 10 March 2000 by Graeme Watt

JCMT image here<sup>T</sup>

Г

### Weather Statistics for Semester 00A

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

Month	Available	Extended	Lost to weather		Lost to weather	
			Primary	%	Backup	%
Feb	375.5	14.5	98.5	26.2	36.0	9.6
Mar	263.0	8.2	69.3	26.3	33.7	12.8
Apr	478.0	13.3	105.0	22.0	75.3	15.8
May	472.0	12.6	314.8	66.7	200.0	42.4
Jun	373.0	14.8	119.0	31.9	60.3	16.2
Jul	512.0	5.7	314.8	61.5	210.3	41.1
Totals	2473.5	69.1	1021.4	41.3	615.6	24.9

Iain Coulson

### **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.

<u>**RxA3**</u>

<u>RxB3</u>

<u>RxW</u>

**Heterodyne Polarimetry** 

**DAS Spectrometer guide** 

**DAS ''non-standard'' configurations** 

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

Back to: The JCMT Newsletter Index

Gerald Moriarty-Schieven



### SPIFI: The South Pole Imaging Fabry-Perot Interferometer



Back to: The JCMT Newsletter Index

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 is expected to be available for use during the semester. Current best estimates of sensitivities and other parameters will be posted on the web page at the <u>Cornell Astronomy Department Site</u>.

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 <u>Prof. G.J.</u> <u>Stacey</u> at Cornell University (stacey@astrosun.tn.cornell.edu) to arrange collaborative efforts.

Back to: The JCMT Newsletter Index

Gerald Moriarty-Schieven



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 01A 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 (<u>stark@mpifr-bonn.mpg.de</u>) to arrange collaborative efforts.

#### A Submillimeter Dust and Gas Study of the Orion B Molecular Cloud

George F. Mitchell (Saint Mary's University), Doug Johnstone (University of Toronto), Gerald Moriarty-Schieven (Joint Astronomy Centre/National Research Council of Canada), Michel Fich (University of Waterloo), & N. F. H. Tothill (Saint Mary's University)



Using SCUBA on the JCMT, we obtained a map of 850 um continuum emission from the Orion B molecular cloud. The map (shown above right) is 20'x40' in extent and covers much of the northern half of the GMC. Above left we show an image extracted from the Digitized Sky Survey with contours of 850 um superposed. We identify 67 discrete continuum sources. Many of the sources, or clumps, are grouped in three regions, near NGC 2071IR, NGC 2068, and HH 24-26 (LBS23). Masses of the sources range from 0.2 to 12 M<sub>o</sub>.

About half of the area of our 850 um map is covered by the current release of the 2MASS infrared survey. Of 40 clumps covered by the 2MASS, 14 have associated infrared sources detected in J, H, and K. Maps of <sup>13</sup>CO J=2-1 and C<sup>18</sup>O J=2-1 line emission were obtained for two regions in order to find the gas column density. Formaldehyde spectra were obtained towards eight of the continuum clumps to determine the gas kinetic temperature. Three of the clumps with measured temperatures are hot ( $T_{kin} > 80K$ ) while the other

five are cold ( $T_{kin} > 20K$ ). The gas-to-dust ratios differ substantially between the two regions mapped in CO. In the NGC 2068 region we find close to constant ratios of dust to gas emission, except in one compact source. However in the HH 24-26 region the dust to gas emission ratio varies substantially with some of the brightest dust continuum sources almost absent in CO emission. One explanation is that CO molecules have frozen onto grains in the dense cores. Why this freeze-out should happen in the HH 24-26 cores but not in the NGC 2068 cores remains unexplained.

The paper has been submitted to The Astrophysical Journal. A gzipped preprint (1.9MB) is available here.

Back to: The JCMT Newsletter Index

Gerald Moriarty-Schieven

# First magnetic field mapping around a starburst galaxy nucleus: a new view of M82

#### J.S. Greaves, W.S. Holland, T. Jenness & T.G. Hawarden (Joint Astronomy Centre)

Magnetic fields may play an important role in starburst galaxies, channeling the flow of gas towards the nucleus - but this hypothesis has never been directly tested. Optical polarimetry can trace preferential extinction along the long axes of magnetically aligned grains but is confused by scattering, while radio polarimetry detects synchrotron emission from electrons spiralling around field lines, but is affected by Faraday dispersion.

Recent developments in submillimetre polarimetry allow us to use thermal emission from dust grains to not only detect the aligning field, but concentrate on the dense nuclear regions of active star formation (rather than foreground dust and diffuse gas). The first target with the SCUBA Polarimeter was the M82 starburst galaxy, which lies nearby at about 3.25 Mpc and has a dusty 1 kpc-wide torus symmetrical about the nucleus. There are at least 100 stellar superclusters inside the torus, plus a powerful wind that blows grains up into the halo (Alton et al. 1999).



Figure 1: vectors (derived from 850 micron polarimetry) show the magnetic field directions, superimposed on a smoothed image of the dust emission (at 450 microns). Vectors above the 50% flux level are shown in blue, and those below in red, for clarity. The polarization percentage ranges from 0.7-9.1% and the median significance level is 6-sigma so the directions are defined to within about 5 degrees.

This image shows the polarimetry results (see also Greaves et al. 2000). The magnetic field appears quite organised, with two main components visible. In the bright torus, the vectors point towards the nucleus, and

since partially ionized material flows more easily along field lines than across them, this field structure assist in channelling clouds towards the starburst nucleus. Outside the torus, the vectors mainly lie parallel to the flux contours, suggesting a bubble-shaped field with a diameter of at least 1 kpc. This has never been seen in another galaxy before, although there may be a counterpart in changes of magnetic field direction over large scales in the solar vicinity (Vallee 1997).

Many normal galaxies have poloidal fields driven by winds, or flattened fields in the plane of spiral arms. M82 shows these features in near-IR polarimetry (Jones 1998), where cold dust is traced in absorption, but the submiilimetre polarimetry traces an entirely new configuration in the dust of star-forming regions. In the

future, we hope to model the magnetised wind, and also to observe more starbursts to test the universality of these phenomena.

Alton P.B., Davies J.I. & Bianchi S., 1999, A&A 343, 51 Greaves, J.S., Holland, W.S., Jenness, T. & Hawarden, T.G., 2000, Nature 404, 732 Jones, T.J., 1998, BAAS 193, abstr. 76.03 Vall'ee J.P., 1997, Fund. Cosmic Phys. 19, 1

#### Back to: The JCMT Newsletter Index

Jane Greaves

### The moon at 850 microns

Nick Jessop, Iain Coulson, Jane Greaves, Wayne Holland & Tim Jenness (Joint Astronomy Centre)



On the night of July 15, 2000 <u>Jane Greaves</u> mapped the moon using SCUBA's fast scan mapping. The initial results were so much fun that Iain Coulson and Nick Jessop decided to repeat it 6 nights later. The resulting images (reduced using a slightly modified version of <u>ORAC-DR</u>) are shown above. <u>Tim Jenness</u> helped a lot in the data processing.

What does it mean? At 850 microns the emission is due to thermal emission from the top centimetre or so of the moons surface. It is not due to reflection as in visible images. The emission is from a modified black-body function. Due to the fact that the emission is from the Rayleigh-Jeans tail, to a first approximation the brightness is proportional to the temperature. The image is a temperature map of the moons surface! We're hoping the weather gets bad enough that we can map a couple more phases of the moon (these images were taken on 2 nights when the telescope would ordinarily have been closed due to the poor conditions).

Back to: The JCMT Newsletter Index

<u>Nick Jessop</u>

### SCUBA Maps of Massive CS Cores in the Mon OB1 Dark Cloud

G. Wolf-Chase (U Chicago/Adler Planetarium & Astron. Mus.), G. Moriarty-Schieven (JAC/NRC), M. Fich (U Waterloo), & M. Barsony (JPL)



Although details of the formation of isolated low-mass stars are not complete, a fairly well-understood broad picture has emerged in recent years. In contrast, the formation of stars in high-mass cores is poorly understood. In order to investigate the masses and evolutionary stages of stars forming in massive cores, we are undertaking a complete SCUBA survey of the massive CS cores in the Mon OB1 dark cloud (Wolf-Chase, Walker, & Lada 1995, ApJ 442, 197 [WWL95]). This figure presents our 850 micron map of one of these cores (SCL: WWL95), and helps elucidate the presence of a number of individual clumps within the core, as well as more extended dust emission. Well-sampled spectral energy distributions (SEDs) are required to characterize these clumps and to distinguish between evolutionary classes of Young Stellar Objects (YSOs), but current determinations of SEDs are extremely limited: there are few sets of measured SEDs that cover a significant range in protostellar mass, evolutionary class, and the complete wavelength range from the mid-infrared to the submillimetre. A useful constraint on the evolutionary class of a protostar is the presence, size, and energetics of an outflow. In the Mon OB1 dark cloud, we have a unique opportunity to study the properties of YSOs that are forming in massive CS cores (WWL95), and for which we have a complete survey of outflows (Margulis, Lada, & Snell 1998, ApJ, 333, 316; Wolf-Chase, Moriarty-Schieven, Fich, & Barsony, in preparation).

Many YSO SEDs have been constructed from low-resolution IRAS data. We have created a technique using high-iteration HIRES-processing and modeling of IRAS data together with SCUBA data that has been very useful in extracting multiple source SEDs in confused regions (Aumann, Fowler, & Melnyk 1990, AJ, 99, 1674; Hurt & Barsony 1996, ApJL, 460, L45; Barsony et al. 1998, ApJ, 509, 733; O'Linger et al. 1999, ApJ, 515, 696; Wolf-Chase, Moriarty-Schieven, Fich, & Barsony, in preparation). Our completed SCUBA survey will allow us to construct new SEDs for all of the YSOs in the CS cores, which will allow determination of the physical parameters and evolutionary stages of the stars forming in these cores, and will allow a preliminary investigation into the question of whether massive cores necessarily form higher-mass stars. Questions such as this can only be addressed by studying YSOs that are still deeply embedded in their natal cloud cores. Once a YSO has reached the pre-main sequence stage, many of these cores have already been dispersed (e.g., WWL95; Wolf-Chase & Walker 1995, ApJ, 447, 244).

Back to: The JCMT Newsletter Index

### **Ongoing Cluster Formation in Large Globules**

T. L. Huard, D.A. Weintraub (Vanderbilt U), G. Sandell (NRAO)

Most of the molecular clouds of small angular extent are physically small and nearby. Such clouds, known as Bok globules, are often sites of star formation typically containing only a few forming stars. However, some clouds of small angular extent are actually physically large and distant (beyond 1 kpc). Since these ``large globules'' are much more massive than Bok globules, star formation within such globules tends to produce small stellar clusters rather than aggregates of only a few stars.



The three large globules CB 3, CB 34, and L810 were mapped at 450 um and 850 um using SCUBA on the JCMT. These globules are known to be associated with small clusters of near-infrared YSOs, representing evolved protostars that had formed in the large globules. Our maps of these large globules reveal submillimeter sources. presumably the thermal emission from the dust surrounding protostars embedded within the globules. These submillimeter sources have

rather large sizes 0.07-0.2 pc and have masses 1-40 M<sub>o</sub>, at least an order of magnitude greater than those of

low-mass protostars found in Bok globules. The submillimeter sources detected toward the large globules probably represent clusters of young protostars rather than individual sources. If the large globules in this study are similar to nearby star-forming cores (e.g. NGC 1333 and Rho Oph) for which near-infrared and submillimeter observations have revealed clusters of embedded Class 0 and Class I protostars, then the submillimeter sources detected in our survey are not likely to be submillimeter counterparts to the near-infrared YSOs. Rather, the submillimeter sources may be small clusters of young, Class 0 protostars perhaps blended with a slightly more evolved Class I protostar. The detection of submillimeter sources toward the clusters of evolved near-infrared YSOs within CB 3, CB 34, and L810, the large sizes and masses derived for these submillimeter sources, and comparisons made between these distant sources and those within nearby star forming regions suggest that these large globules are currently adding members to the YSO clusters. Our results suggest that cluster formation in large globules is a process that occurs over

millions of years, consistent with previous studies of cluster formation in nearby large molecular clouds such as Orion, Rho Ophiuchus, and Serpens.

The 850 micron map of the YSO cluster embedded within CB 34 is shown above. Besides showing dust emission extended across much of the region containing the evolved, near-infrared YSO cluster, this map reveals several submillimeter sources. The positions of these sources are identified by asterisks and the beamsize is represented by the circle in the upper right corner of the map. The positions of the known near-infrared sources within the field are identified by open diamonds and plus signs, where the plus signs are those sources exhibiting near-infrared excesses and therefore thought to be YSOs associated with the globule.

A preprint of this paper, accepted for publication in Astronomy & Astrophysics, is available here.

Back to: <u>The JCMT Newsletter Index</u>

Gerald Moriarty-Schieven

# SCAN-MAP POLARIMETRY WITH SCUBA: THE CRAB NEBULA

#### J.S. Greaves, W.S. Holland & T. Jenness (Joint Astronomy Centre)

Although SCUBA has had an imaging polarimetry mode since 1998, it has always been difficult to observe large sources. The problems of chopping onto nearby emission are exacerbated in polarimetry because of potentially chopping onto an area with differently oriented polarization, and thus corrupting the source measurement in both degree and direction.

In January 2000 we made the first successful observations with scan-map polarimetry, imaging a source substantially bigger than the SCUBA field-of-view. We used the `EmersonII' scanning technique, where different sized chop throws in both RA and Dec are used to reconstruct the image in Fourier space. To minimise sky variations, the maps were made as rapidly as possible, by using the minimum number of chop throws (four) and scanning at twice the usual rate (giving 6" sampling).

The test source



Output from POLCAL

data to 1 arcmin resolution and compared it to the 9 mm polarimetry results of Flett & Henderson (1979;

MNRAS 189, 867). The vector directions were found to be the same within a few degrees, and the level variations e.g. to the north-west are also consistent.

The results have not yet been scientifically analysed, but magnetic fields are thought to be very important for the evolution of the Crab, particularly in the wispy filaments that envelop the ionized gas. Radio and far-infrared polarimetry have both suffered from problems, respectively Faraday depolarization and possible contamination by dust emission. The SCUBA data show the highest percentages and may give the best high-resolution picture so far of the magnetic field. There is remarkably uniform polarization across the main nebula, running along the long axis of the structure (the jet axis). A major deviation occurs where the vectors appear to circle the cavity north-west of the bright core - confirming a link between the physical and magnetic structures.

Scan-map polarimetry at 850 microns will be available in semester 01A, but potential observers are cautioned that stable sky conditions are required over timescales of about an hour (somewhat longer than with jiggle maps), and that observing and data reduction are not yet automated. It is not recommended to attempt scan-map polarimetry of very faint (<< 1Jy/beam) or very extended (<< 10 arcmin) clouds, due to the long times over which the sky would have to be stable. The polarized fluxes (S x p) in the Crab Nebula are about 0.5 Jy/beam x 10% or 50 mJy; this is equivalent to attempting to detect 2.5% polarization in a 2 Jy/beam dust cloud, for example. However, since a fractional change in sky transmission causes more error for less polarized sources, getting good S/N may be more difficult than for the Crab.

Back to: The JCMT Newsletter Index

Jane Greaves

# **Star formation in high-density environments in the** <u>early Universe</u>

#### <u>Rob Ivison</u> (University College London), Ian Smail (Durham), James Dunlop (Edinburgh)

After struggling with the first batch of SCUBA's photom.t data - a painful effort to convince ourselves that a coadded flux for 8C1435+635 that bounced from a big, fat zero mJy one night to 20mJy the next night could in fact be trusted to the required sub-mJy accuracy (Ivison et al. 1998, ApJ, 494, 211) - we became converts to map64.t. Even if it did take umpteen times longer to reach the required flux levels, seeing a beam-sized source appear at the expected position gave tremendous faith in a source's reality and the potential for serendipitous detections was too tempting to pass up, particularly at a time when submm cosmology could boast a measly dozen submm-selected galaxies.

Subsequent efforts to nail high-redshift radio galaxies with SCUBA involved both photom.t (Archibald et al. 2000, astro-ph/0002083) and map64.t (Ivison et al. 2000, astro-ph/0005234). In the mapping project, serendipitous detections came thick and fast; the rate of detections seemed to far exceed those of blank-field surveys, and it quickly became apparent that there might be an over-density of submm sources in the fields of distant radio galaxies (e.g. Figure 1).



*Figure 1: a*) *Full 850-micron image of the* z = 3.8 *radio galaxy, 4C41.17; b*) 450-micron image of 4C41.17, smoothed to a resolution of 10'' FWHM; c) *Central, cleaned portion of the 850-micron image.* 

Indeed, biased galaxy-formation theories predict that massive galaxies at high redshifts should act as signposts to high-density environments which subsequently evolve into the cores of the richest clusters seen at the present day. These regions are expected to be characterised by over-densities of young galaxies, probably including a population of dusty, interaction-driven starbursts - the progenitors of massive cluster ellipticals.

It seems quite plausible that by mapping high-redshift AGN we have stumbled upon this population of clustered submm galaxies. We have undertaken searches in the fields of half-a-dozen radio galaxies and quasars at  $z \sim 4$ , with the same number of fields slated for 2000/01. Our maps are extremely deep - down at the mJy rms level at 850 microns - and they reveal an order-of-magnitude over-density of luminous submm galaxies compared to typical fields. The likelihood of finding such an over-density in random fields is <0.002.

If we believe that the redshifts are the same as the signpost galaxies - an aspect of the study that we are working hard on via deep imaging with OVRO, IRAM, VLA, WHT, Gemini and Keck - then they have bolometric luminosities,  $>10^{13} L_0$ , which implies star-formation rates (SFRs) consistent with those required to form a massive galaxy in a fraction of a Gyr.

Our target fields also appear to exhibit over-densities of extremely red objects (EROs), some of which may be associated with the submm sources (Figure 2), and Lyman-break galaxies. In a paper detailing the acquisition and analysis of our data in the 4C41.17 field (Ivison et al. 2000, astro-ph/0005234) we have proposed that the over-densities of both submm and ERO sources in these fields represent young dusty, starburst galaxies forming within proto-clusters centred on the high-redshift radio galaxies and quasars, clusters which are also traced by a less-obscured population of Lyman-break galaxies.



**Figure 2:** KPNO 2.1-m K'-band imaging and HST F702W images of 25x25" regions around the submm sources near 4C41.17. For HzRG850.1, the optical data are from Keck II. EROs are marked with squares; 850-micron positions are marked with 6"- or 8"-diameter black circles (an ellipse for HzRG850.2); the 450-micron position of HzRG850.1 is marked with a white circle.



Figure 3: K'-band images of regions around 4C41.17. 850-micron data are shown as contours. Red solid circles denote EROs (R-K > 6). Two EROs are probably associated with the blended sub-mm galaxy, HzRG850.2. For the other sub-mm galaxies (HzRG850.1, 4C41.17), green dashed circles denote the likeliest counterparts (faint and red, in the case of HzRG850.1, though a bona fide ERO could also be responsible for the sub-mm emission).

We have introduced a nomenclature for their classification, analogous to that used for proto-stars (Andre, Ward-Thompson & Barsony 1994, ApJ, 406, 122) and building upon the evolutionary scheme for ULIRGs

proposed by Sanders et al. (1988, ApJ, 325, 74). For operational purposes we based this scheme on the typical depths achieved in follow-up observations (I ~ 26, K ~ 21) and the properties of typical submm galaxies (Ivison et al. 2000, MNRAS, 315, 209).

We defined the following classes: Class 0, very-highly obscured sources, where there is no plausible optical or near-IR counterpart; Class I, highly obscured sources, where only a near-IR counterpart exists (often EROs); and Class II, where an obvious optical counterpart is seen (IIa: pure starburst; IIb: type-II AGN; IIc: type-I AGN). The latter class may overlap with the most massive examples of Lyman-break objects.

Figure 1 demonstrates that the 4C41.17 field contains several extremely luminous submm galaxies, possibly in a structure associated with the radio galaxy. The density of sources brighter than 8mJy is 1220 +/- 860/deg^2, well above the weighted mean 8-mJy blank-field count (134 +/- 57/deg^2). The standard probabilistic methodology used in studies of clustering and confusion suggests that on average we would have to observe more than 600 typical blank fields before finding a configuration of the type seen towards 4C41.17.

Turning to the optical and near-IR imaging of this field, there are several possible counterparts to HzRG850.1, the bright submm galaxy to the south-east of the map centre (Figures 2 and 3). The bluest is 850.1.K1 (Class II), a source detected in U and thus probably a low-redshift, blue galaxy, unlikely to be associated with the SCUBA source. Another two galaxies, 850.1.K2 and 850.1.K3 (both Class I) have similar very red colours, V-K ~ 7. The similar colours of 850.1.K2 and 850.1.K3, combined with the fact that HzRG850.1 is spatially extended, suggests that both these galaxies may be jointly responsible for the submm emission; however, we also note some very faint emission in V and K to the west of 850.1.K2 that underlies the submm emission, and in V alone to the south.

For HzRG850.2, to the north-east of the map centre, three faint galaxies are visible in K. The bluer of these, 850.2.K1, lies just within the error ellipse, while the others, 850.2.K2 and 850.2.K3, are much redder, R-K > 6.4, and lie on the edge of the nominal error ellipse. In a deep HST F702W image, both 850.2.K1 and 850.2.K2 are each resolved into two components, while 850.2.K3 cannot be seen (R > 26). For 850.2.K1 the sub-components both appear to be galaxies, while in 850.2.K2 they may either be two galaxies or a single system crossed by a dust lane. As with HzRG850.1, it is extremely plausible that both of these counterparts may be contributing to the submm emission from HzRG850.2, given its morphology.

The remaining SCUBA sources lie in comparatively shallow regions of the near-IR and optical images and do not show unambiguous identifications.

In summary, HzRG850.1 and HzRG850.2 are likely to be associated with EROs (Class I sources). It is interesting that our success in obtaining candidate identifications, in particular the association with EROs, correlates with the observed flux density of the submm emission. Is it possible that the brightest submm sources are typically associated with Class I or II counterparts (e.g. HR10, SMM J09429+4658, SMM J02399-0136, SMM J14011+0252, SMM J00266+1708 as well as the brightest sources found by the UK's 8-mJy survey, the Dutch cluster survey and the latest 1.3-mm survey with MAMBO at IRAM) whereas fainter submm sources typically have Class 0 counterparts.

Can these submm sources can be unambiguously placed at high redshifts, strengthening the case for their association with 4C41.17? We are reliant on redshift-sensitive parameters: the 450- to 850-micron flux ratio and the 850-micron to 1.4-GHz flux ratio. The observed 450- to 850-micron flux ratios for 4C41.17 and HzRG850.1 are  $3.2 \pm - 0.8$  and  $2.2 \pm - 0.6$ , consistent with their being at the same redshift, with best-fit values  $z \sim 3.8$  and  $z \sim 4.8$ . These limits are supported by constraints from the 850-micron to 1.4-GHz flux

ratio which yields a robust limit of z > 1.2 for HzRG850.1. The limits for HzRG850.2 and HzRG850.3 are slightly weaker, but they are certainly not local galaxies.

The extreme colours, V-K ~ 7, of the probable galaxy counterparts to HzRG850.1 and HzRG850.2 also suggests that these systems lie at high redshift. If these galaxies do lie at z = 3.8 then they are very luminous, in excess of 50 L\*, although we note that luminosities close to this are found for the confirmed Class II counterparts SMM J02399-0136 (z = 2.8) and SMM J14011+0252 (z = 2.6).

We conclude that the available constraints suggest that the over-density of bright submm galaxies, at least in the 4C41.17 field, is likely to lie at z > 2.8 and is thus consistent with being associated with the radio galaxy (though spectroscopic confirmation is clearly a top priority). This suggests that in addition to the over-density of Lyman-break galaxies identified around 4C41.17, we should also add a comparably numerous population of highly-obscured and very luminous submm galaxies.

Back to: The JCMT Newsletter Index

Gerald Moriarty-Schieven

# SCUBA SOURCES, FAILED STARS, and the DARK MATTER

#### Andy Lawrence (ROE/ATC)

SCUBA seems to be a kind of zoom facility to take us straight to the high-redshift universe - several groups have made deep SCUBA surveys and claimed identifications with very faint galaxies at z=1-5. These exciting results imply that most of the star formation in the young universe occurred in luminous dusty starbursts. However, one worry is that the IDs are usually ambiguous, because of the large submm beamwidth. In the one published example of an interferometer detection (HDF850.1 - Downes et al A&A 347, 809, 1999) the arcsecond position is completely blank even to the depth of the Hubble Deep Field. But what if SCUBA is actually detecting a new class of astronomical object, so cold that it emits ONLY in the submm? If HDF850.1 is a local object, it has a temperature of around 7K. I tested various ideas against the observational constraints. It was easy to rule out, for example, a vast population of very cold brown dwarfs, or of comets just past Neptune. But it was not so easy to rule out the possibility of small dusty gas clouds in the local interstellar medium - at a distance of around 100pc.

What we have to go on is the flux of such objects, their surface sky density, the lack of extinction holes all over the sky, and the dynamical limits imposed by local star motions on any disk dark matter. If we postulate a mass for our clouds and assume a standard gas to dust ratio and a temperature of 7K, we can get a characteristic luminosity, distance, and so space density. Such objects cannot be less than about a tenth of a Jupiter mass or they contain too much mass. On the other hand they cannot be bigger than about ten Jupiter masses or we would have noticed black spots on the sky. At around a Jupiter mass they would be tenth of an arcsecond across but cover maybe one part in ten million of the sky. However... they would be ten times as common as stars; the nearest one (somewhere on the sky!) would be just past the Oort cloud, and the local mass density would be around 0.1 solar masses per cubic parsec, still hideable in local disk dynamics, but quite close to the predicted local density of halo dark matter .. could SCUBA sources be the dark matter???

Over the last few years there has in fact been a minor industry of astronomers arguing that halo dark matter could be hidden in cold molecular material and wouldn't have been detected (eg Pfenniger, Combes and Martinet A&A 285, 79, 1994; Walker and Wardle ApJ 498, L125, 1998; Sciama 2000, MNRAS 312, 33) and indeed they have generally argued that Jupiter mass clumps are preferred. So perhaps SCUBA has now SEEN the dark matter? However... my calculations concern typical faint SCUBA sources at around 2 mJy, deduced to be at a distance of 100 pc.. if this population continued through the halo to 10kpc, the FIR background measured by COBE would be exceeded by a vast amount. In fact, faint SCUBA sources cannot extend by more than a factor of a few without exceeding the background (Hughes et al Nature 294, 241, 1998). This is consistent either with sources at z=3, or with sources at 100pc, implying a Galactic Plane population ... but not with halo dark matter. Such objects would still be of great importance however, not just because of completing the cosmic inventory, but because they may represent the end point for most collapsing clouds - cold dark clouds rather than brown dwarfs could be the true failed stars.

Well, this could all be an interesting fantasy. Obviously at least some SCUBA sources are high-z galaxies.

But if even a quarter or a third are local objects it will be important for cosmology, as the z=3-5 claims will be selectively removed. The idea is definitely if not trivially testable, for example by conducting bright submm source counts, looking for black spots in HST elliptical galaxy images, or looking for rare stellar switch-off events.

A paper is in press in MNRAS describing all this in much more detail, and will be on astro-ph shortly.

Back to: <u>The JCMT Newsletter Index</u>

Gerald Moriarty-Schieven

# **Star Formation in NGC 6334 I and I(N)**

# W.H. McCutcheon (U of British Columbia), G. Sandell (NRAO, H.E. Matthews (JAC/NRC), T.B.H. Kuiper (JPL), E.C. Sutton (U Illinois), W.C. Danchi (UC Berkeley), and T.Sato (Kwantlen Univ College)

The northern section of the molecular cloud complex NGC 6334 has been mapped in the CO and CS spectral line emission and in continuum emission at a wavelength of 1300um. Our observations highlight the two dominant sources, I and I(N), and a host of weaker sources. NGC 6334 I is associated with a cometary ultracompact HII region and a hot, compact core  $lt;\sim10$  in size. Mid-IR and CH3OH observations indicate that it is also associated with at least two protostellar sources, each of which may drive a molecular outflow. For region I we confirm the extreme high velocity outflow first discovered by Bachiller & Cernicharo (1990) and find that it is very energetic with a mechanical luminosity of 390 L<sub>o</sub>. A dynamical age for the outflow is

~3000 years. We also find a weaker outflow originating from the vicinity of NGC 6334 I. In CO and CS this outflow is quite prominent to the NW, but much less so on the eastern side of I, where there is very little molecular gas. Spectral survey data show a molecular environment at position I which is rich in methanol, methyl formate, and dimethyl ether, with lines ranging in energy up to 900 K above the ground state. NGC 6334 I(N) is more dense than I, but cooler, and has none of the high excitation lines observed toward I. I(N) also has an associated outflow, but it is less energetic than the outflow from I. The fully sampled continuum map shows a network of filaments, voids, and cores, many of which are likely to be sites of star formation. A striking feature is a narrow, linear ridge that defines the western boundary. It is unclear if there is a connection between this filament and the many potential sites of star formation, or if the filament existed prior to the star formation activity.



**Fig. 1 (left):** Map of the CO J=3-2 line emission integrated over the velocity ranges -40 to -12 km s<sup>-1</sup> (blue), and +3-+35 km s<sup>-1</sup> (red) to indicate the blue and red shifted wings. The contour levels are 20, 40, 60, 80, 100, 150, 200, 250, 500, 750, 1000, 1250, 1500, and 2000 K km s<sup>-1</sup>. The sampling interval over most of the map is

10". The principal features, NGC 6334I, I(N), and I(NW), are labelled. Also shown are the positions of the HII-regions E and F (Rodriguez, Canto & Moran 1982; Harvey & Gatley 1983),  $CH_3OH$  maser (Menten & Batrla 1989; Norris et al. 1993; Ellingsen et al. 1996; Norris et al. 1998; Kogan & Slysh 1998), OH maser (Forster & Caswell 1989),  $H_2O$  maser (Moran & Rodriguez 1980; Forster & Caswell 1989),  $NH_3$  maser (Kraemer & Jackson 1995),  $H_2$  knot (Davis & Eisloffel 1995), 20 um sources IRS-I-1,2,3 (Harvey & Gatley 1983), and sub-mm sources (this paper; Sandell 2000). For the methanol masers in I(N), the one labelled is believed to be Class II. The others in I(N) are Class I. The methanol masers in I belong to both classes.

**Fig. 2 (right):** Map of the 1300 um emission around both I(N) and I. The contours are 0.05, 0.1, 0.15, 0.2, 0.25, 0.35, 0.45, 0.6, 0.8, 1.0, 1.25, 1.5, 2.0, 3.0, 4.0, 4.5 Jy/beam. The map has been reduced with DBMEM and smoothed with a 6", Gaussian. All continuum sources identified by Sandell (2000) are marked by the star symbol (black or white) and all sources except I and I(N) are labelled with the prefix SM.

Back to: The JCMT Newsletter Index

Gerald Moriarty-Schieven

Back to: The JCMT Newsletter Index

### **JAC Internal Science Seminars**

Coming to the JCMT to observe? We'd love to hear about your current research. The JAC and Gemini now operate a joint seminar series, and with visitors from Subaru, the CSO, the IfA, the SMA, and other facilities you can be assured of a varied and interested audience. The average attendance at JAC/Gemini seminars over the past year was about 15+/-6 people.

If you'd like to volunteer to give a seminar, please contact Gerald Moriarty-Schieven.

A list of those given to date this year and arranged for the future can be viewed here

If you'd like to be notified of upcoming seminars, please join the seminars emailing list. Just send <u>me</u> a note and I'd be happy to add your name.

Back to: The JCMT Newsletter Index

Gerald Moriarty-Schieven

Back to: <u>The JCMT Newsletter Index</u>

### **Points of Contact**

Joint Astronomy Centre, 660 North A'ohoku Place, University Park, Hilo, Hawaii 96720, USA

Telephone: +1-808-961 3756 (answerphone) +1-808-935 4332 Fax: +1-808-961 6516

e-mail: jach.hawaii.edu

#### Mauna Kea

Hale Pohaku: +1-808-935 7606 JCMT Carousel: +1-808-935 0852 Fax in JCMT control room: +1-808-935 5493

#### **Distribution:**

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

#### **Newsletter Editor:**

Gerald Moriarty-Schieven (at the JAC)

Telephone: +1-808-969-6531 Fax: +1-808-961-6516 E-mail: g.moriarty-schieven@jach.hawaii.edu

#### **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

Back to: <u>The JCMT Newsletter Index</u>

Back to: <u>The JCMT Newsletter Index</u>

### NEXT ISSUE DEADLINE

The deadline for submission of science and/or technical articles for the next issue of this Newsletter is **15 February 2001**. *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).

Back to: <u>The JCMT Newsletter Index</u>

#### Back to: The JCMT Newsletter Index

### THE LAST WORD

Many thanks to those who answered my plea for science articles. As you can see I received a good number, ranging from cosmology to galactic structure to star formation to the solar system. Even a "wacky" article (according to its author - I'll leave it as an exercise to the reader to guess which one this is).

I'd be very pleased to hear any comments you have about the newsletter, either positive or negative (but please be gentle). I'll also entertain suggestions on how to "improve" it. And of course I'd appreciate any contribution you might like to make that's remotely connected to the observatory.

We are looking into the possiblility of resuming publication of a hardcopy edition of the newsletter, possibly for the next issue. If this appeals to you (or repels you!), or you have any comments or suggestions, or would like to volunteer to contribute to the next newsletter, *please let me know!!!!!* 

Mahalo nui loa!

Gerald Moriarty-Schieven

Back to: The JCMT Newsletter Index