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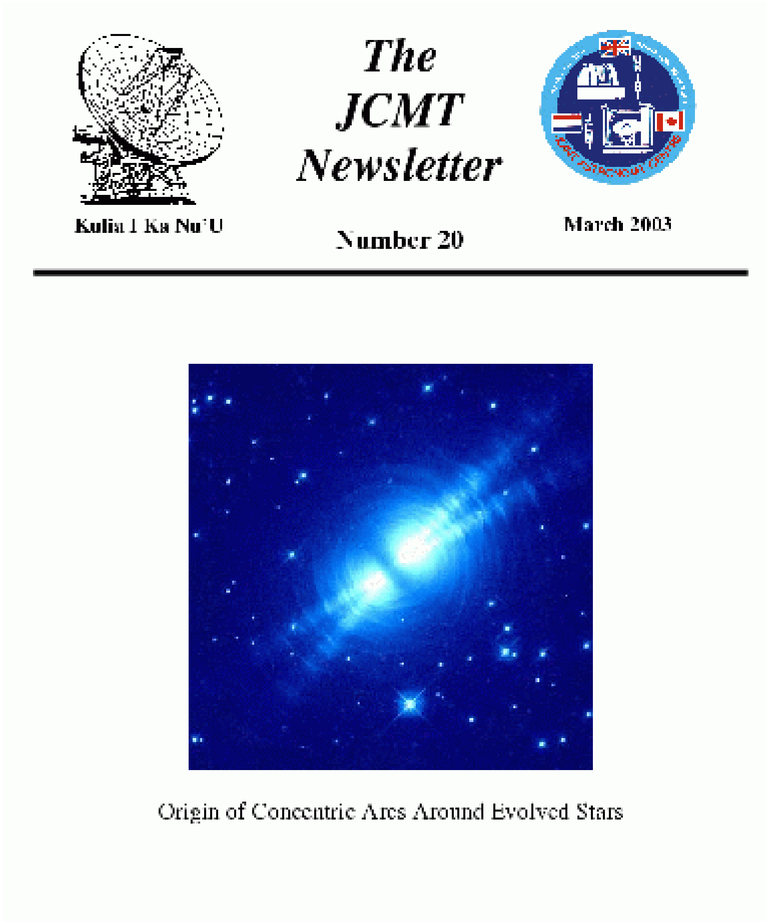
# The JCMT Newsletter



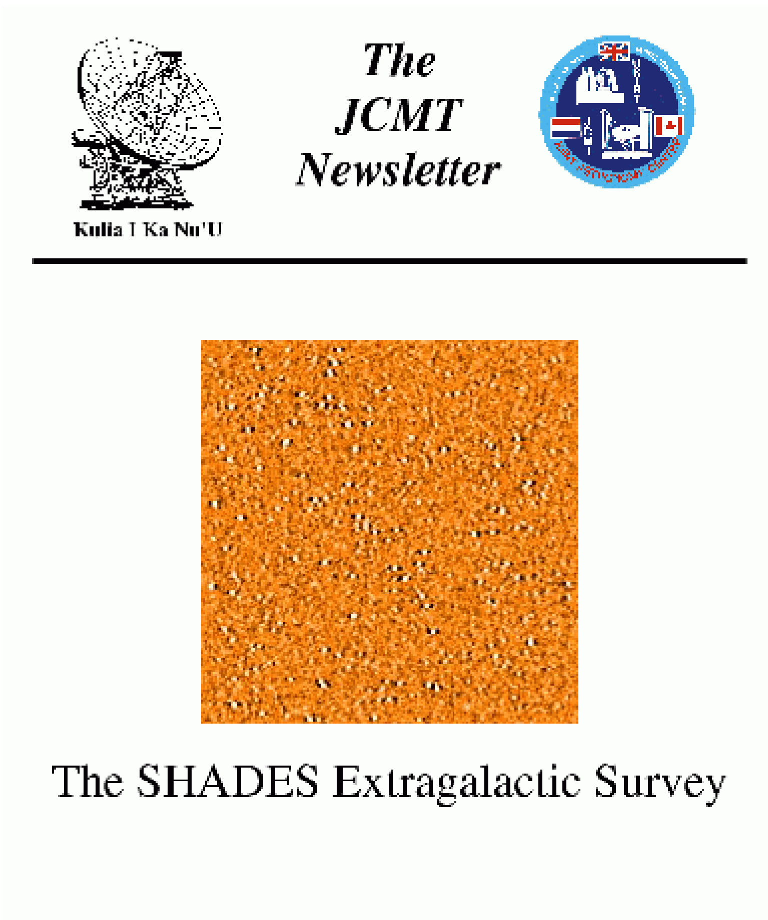

# March 2003 Issue Number 20

*STATISTICS*



*ABOUT THE NEWSLETTER*



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*Gerald Moriarty-Schieven*

# From the Director's Desk

Six months ago, when I wrote my first column for the JCMT Newsletter, the weather was atrocious and had been so for several months. The sense that the poor observing conditions were continuing without an end in sight exerted a pervasive influence on staff and observers alike, reminiscent of an endless Canadian prairie winter. Happily, the onset of a small El Nino improved the situation considerably over the past few months, and several excellent science results were obtained. Some of these are reported elsewhere in this Newsletter.

At the time of writing this column, I am pleased to report that the instruments and the telescope are all performing well. In particular, an in-house project to bring the figure of the primary mirror under active control has made excellent progress: thanks in part to the provision of a new holography receiver and analysis software by MRAO, we now have most of the surface under control. The current accuracy is 25µm, and the objective of this project is a surface accuracy of 21µm - although we have high hopes of ultimately getting down to below 20µm. This achievement comes at an appropriate time, since we will soon be commissioning our first 200µm instrument on the telescope (about which more below).

The other major change in the past six months is more obvious to observers: the installation and commissioning of the Observation Management Project (OMP). The objective of this project is to provide cradle-to-grave software support for managing observation projects in a fully-flexible scheduling environment. The three components of the OMP are a set of observation submission tools, a database query tool, and a feedback mechanism. The SCUBA observing tool was released to the community for semester 02B, and a heterodyne version has been introduced for internal JAC use for semester 03A. Although the learning curve for this management system has occasionally been steep for both observers and staff, the feedback we have received has been very positive. I am convinced that the OMP will pave the way for a major enhancement of the scientific productivity of the JCMT.

The heterodyne receivers continue to perform well. Rob Millenaar recently visited from Dwingeloo to carry out a refurbishment of the DAS, including the repair of a number of boards and the provision of additional spares. The DAS has served the JCMT well over several years, but its age is showing. This should be the last major engineering work on the DAS before it is replaced by ACSIS.

Users will recall that a major SCUBA upgrade was carried out in the summer of 2002 during the JCMT shutdown, with the support of Wayne Holland. The two main objectives of this work were the replacement of the indium seals and the repair of the filter drum. A long series of operational problems were encountered following this work, and a further repair to the cryogenic support system was undertaken in November 2002. Although the cryogenic fault was successfully repaired by the JAC engineering team, the two original problems unfortunately remain: replacement of the indium seals did not solve the helium migration problem, with the result that the SCUBA noise can be up to 25% high; and the filter drum remains inoperable at low temperatures. Both of these issues are under active review.

SCUBA was scheduled to be joined, in early 2003, by a new 200µm photometric instrument called THUMPER. THUMPER is funded entirely by PPARC rather than through the JCMT partnership, but with the Board's agreement is being provided to the JCMT as a common-user instrument for use by the entire community. It is currently being built by the Astronomy Instrumentation Group at the University of Wales, Cardiff. The instrument has been designed such that, from the user's point of view, it will simply look like an additional SCUBA channel. THUMPER is now scheduled to arrive at the telescope in the autumn of 2003, and will be commissioned during the remainder of semester 03B.

Looking further into the future, it will not surprise readers of this column to learn that one of my first major tasks upon assuming the Directorship was the development of a detailed long-term financial plan for the JCMT. The plan is currently with the Board for its consideration, but I can provide a summary of some of the salient points from the observer's point of view.

As the community will no doubt recall from past discussions, the JCMT will increasingly concentrate on wide-field, survey mode observations from 2006 onwards. The facility instruments will be HARP-B/ACSIS and SCUBA-2. Both HARP-B and ACSIS are making good progress, although the schedule slippage in both programmes is a major concern; I currently expect to commission ACSIS in March 2004 and HARP-B later that year.

The status of the SCUBA-2 project is unfortunately rather mixed at the time of writing. On the positive side, a proof-of-concept review of the detector array technology was held at the ATC on 21/22 November 2002. This was a critical hurdle for the project since the detectors were always the major technical risk and final approval, by both PPARC and the JCMT Board, was contingent on this review being negotiated successfully. I am delighted to report that the project passed this test with flying colours, and I can state with some conviction that there are now no major technical obstacles to the development of the SCUBA-2 instrument. On the negative side, however, my report in the previous newsletter that all of the funding was in place was, in retrospect, premature; the total cost of the project has increased significantly over the last few months. It is now clear that additional funding, likely from additional partners, will be required if the instrument is to be built to specification. This is now one of my top priorities, and I am optimistic that, with the bulk of the funds already in place, it should be possible to secure the remainder.

These new instruments will completely replace the current suite over the next three years. The long-term plan assumes that this replacement will take place according to the following schedule, which has been approved by the Board. First, receiver B3 will be retired in late 2004, having been replaced by HARP-B. SCUBA and THUMPER will then be retired in March 2005, to allow for six months of infrastructure work on the telescope in preparation for the arrival of SCUBA-2 in November 2005. Finally, receivers A3 and W will be retired a year later, in March 2006, to ensure that users have a choice of instruments during the hiatus between SCUBA and SCUBA-2. The continuing presence of RxA3 on the telescope will also ensure that poor-weather observing remains possible. Beyond April 2006, the JCMT will be fully into survey-mode observing with an instrumentation suite designed explicitly for this purpose: HARP-B/ACSIS and SCUBA-2.

These plans take no account, at the moment, of the JCMT's commitment to conduct linked interferometry with the SMA. This is a critical component of the JCMT's future, and I will be working on an implementation plan over the next few months. The instrument dispositions in the previous paragraph may come under review as this plan is developed.

Moving back to the present, I am pleased to announce the arrival of two new support astronomers. Jamie Leech and Vicki Barnard both arrived at the JAC in October as recent PhD graduates from Cambridge. Jamie worked on the laboratory development of HARP technology, and his role at the JAC will be 50% JCMT support astronomer, 50% ACSIS software. Vicki has used SCUBA on several occasions for extragalactic studies, and will make use of this experience by joining Remo Tilanus in supporting SCUBA. These appointments temporarily brought the JAC to a full complement of JCMT support astronomers, a circumstance which will end shortly with the departure of Robin Phillips in mid-March for the University of Lethbridge in Canada. Robin has filled a number of roles at the JAC: his primary responsibility has been the support of the heterodyne receivers, but he has also looked after the Water Vapour Radiometer and has assisted the work of the JCMT in a variety of other ways. His dedication to the success of the observatory has been exemplary. In his new position, Robin will be working with IRMA, the mid-infrared opacity-monitoring system being developed at Lethbridge; I wish him every success.

Robin's departure is one of several factors which has prompted me to restructure the JCMT group at the JAC. Because this redeployment is currently before the Board for approval, I cannot at present divulge the specifics; but I can certainly state that one objective of the reorganisation is to devote more effort to two specific aspects of the JCMT operations: reduction of the JCMT fault rate and management of the external development projects. I will release the details of the this reorganization to the community as soon as I am able.

I advised users in my last column that the Board had decided to review the function of the JCMT Advisory Panel. The outcome of the review was that future appointments to the JCMT Board (other than the agency representatives) should be identifiable users of the telescope, to ensure that the user perspective is brought fully into the Board's deliberations. On this basis, the Advisory Panel was disbanded. Users who seek input into the operation of the telescope or its policies are always welcome to contact me directly.

Finally, I remind users of two issues which I raised in the previous newsletter and in my letters to PIs of successful applications for telescope time in semester 03A. First, all visiting observers are firmly requested to give a 15-minute presentation at the JAC before ascending to Hale Pohaku. These presentations should focus on your observing programme: the science goals, the relevance of JCMT observations, and the observing plan. The benefits for observers and staff scientists alike are considerable. I have asked the support astronomers to contact all visiting observers in advance to arrange for this. Second, all visiting observers are invited to see me at the JAC when they come down the mountain for an exit interview. This is your chance to tell me how your run went and what we can do better next time.

It remains my personal objective to ensure that the JCMT maintains a standard of scientific and technical excellence second to none in the world. The progress we have made over the last six months, and the long-term plan we have identified for the future, are critical steps in achieving this goal.

Professor Gary Davis
Director JCMT
4 March 2003

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*Gary Davis - Director JCMT*

The Nightwatchman

Edition 5

Spring 2003

Hilo, March 1

## TSS Support

JCMT's TSS corps has continued without substantial change over the last six months. However, some changes are expected in the near future.

The first change is that JCMT is currently recruiting for a fifth TSS to supplement the current collection of full-time TSSs and support scientists serving as part-time TSSs. This position is expected to be filled in the late spring or early summer.

The other change is that Robin Phillips, who has frequently served in a TSS capacity in addition to his support scientist duties, will be leaving this month to take a position at the University of Lethbridge in Alberta, Canada, with David Naylor's group. Having provided extensive support for heterodyne instrumentation and summit troubleshooting, Robin will certainly be missed by our group and we'd like to thank Robin for his dedication and skill devoted to JCMT's instrumentation suite. Also, Robin played a large role in developing the program whereby support scientists would take occasional TSS shifts on the summit, thereby integrating TSSs and support scientists to a greater degree while also supplementing support scientists' familiarity with the nighttime operation of JCMT instrumentation.

## The OMP

As continuum observing did last semester, heterodyne observing has also obtained a new look and feel this month. The Observation Management Project (OMP) continues moving forward full tilt. The OMP now supports the vast majority of heterodyne observing modes, released as an early-delivery for the ACSIS instrument and amended for use with our current suite of heterodyne instrumentation. From now on, the OMP will provide an interface to observing for heterodyne investigators and observers alike, but with a few caveats.

First, investigators whose applications for observing time have been submitted this semester have performed that submission using old-style heterodyne observing templates. This is because the heterodyne Observing Tool (OT) is still under development. Those old-style heterodyne observing templates are received by support scientists and then manually entered into the development version of the heterodyne OT by the appropriate support scientists.

Once this step happens, all interaction by heterodyne investigators and observers happens in a fairly routine manner just as with continuum observing. The online OMP feedback system handles both local and remote interaction with all heterodyne projects, observations, and associated bookkeeping in a manner similar to that for continuum observing. When at the telescope, the Query Tool (QT) displays suitable heterodyne observing programs right along with their continuum counterparts, with all projects intermingled according to the rankings given by the telescope allocation committees.

Unlike continuum observing, actually executing a heterodyne program displayed in the QT is performed by the TSS who receives an on-the-fly translation of the support scientist-prepared OT program and implements it in the old-style, command-line heterodyne observing mode, but with fallback access to the original heterodyne project template created by the investigator to insure that the observations are performed in the spirit of the original heterodyne observing template.

Going back to the issue of the OT, all heterodyne investigators who visit JCMT to observe their projects have the option of being given a tutorial in the use of the heterodyne OT by JAC staff if they wish and those investigators may then subsequently use the heterodyne OT to edit and amend their programs that have been entered by support scientists from their originally-submitted old-style observing template.

This development version of the OT that supports heterodyne observing is currently available both on-site at JAC and at the summit at JCMT. It is also scheduled to be released fully to the community in semester 03B with the expectation that it will be used for program preparation by all heterodyne investigators as the old-style heterodyne observing templates will be phased out. Then, the OT will support full, native development of observing programs for both continuum and heterodyne observing modes.

La Citation du Semestre

I often think that the night is more alive and more richly colored than the day.

Vincent van Gogh

Happy summer eclipse chasing (total lunar and annular solar lunar)!

Jonathan Kemp

www.jach.hawaii.edu/~jkemp

j.kemp@jach.hawaii.edu

# New JAC Summit Support Station

This is a picture of the new JAC Summit Support Station, located in the JAC terminal room in Hilo. It includes two replicas of the 3-headed TSS machines located at UKIRT and JCMT as well as a Polycom unit with two TV screens that allow for videoconferencing with the summit sites. The Summit Support Station will be used for trouble-shooting, extra support from JAC staff during hardware and software comissioning as well as facilitating communication between the obervers and their support scientists.

If you'd like to recall what it looked like before, click here.

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*Gerald Moriarty-Schieven*

# *THUMPER* in Semester 03B

*THUMPER*, a 7-element bolometer array operating at 200µm, is expected to arrive at the JCMT in September 2003 to be commissioned during semester 03B. See the article in the March 2002 JCMT Newsletter, or go directly to the THUMPER web pages for more information on this instrument. Proposals are not being solicited for semester 03B using *THUMPER*, but potential commissioning projects may be considered. Contact Derek.Ward-Thompson@astro.cf.ac.uk for more information.

Because THUMPER requires excellent (grade 1) weather for commissioning, once the instrument is on the telescope the commissioning process will be "flexed" with all regular science programs. Special commissioning shifts will be "hard-wired" into the schedule to pay back those projects which are overidden by THUMPER.

Once the instrument has been commissioned, it will become a common-user instrument.

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*Derek Ward-Thompson - Cardiff*

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# PATT Application Deadline

**Deadlines for receipt of JCMT applications for semester 03B is now different for different queues:**

# *United Kindom*

The deadline for receipt of proposals for the UK queue is officially **midnight (Hawaii time (10am GST)) on 15 March**. Since this date falls on a weekend, proposals will be accepted until 9am Hawaii time on the morning of Monday, 17 March.

# *Netherlands*

The deadline for receipt of proposals for the NL queue is officially **midnight (NL time) on 31 March**.

# *International*

The deadline for receipt of proposals for the International queue is officially **midnight (Hawaii time) on 31 March**. Unofficially proposals will be accepted until 9am (HST) on 1 April.

# *Canada*

For deadlines, proposal submission procedures, etc., please consult **http://www.hia-iha.nrc-cnrc.gc.ca/mag/ctag-policy_e.html**.

**Please read the article - Electronic Submission Update before filling in your application forms for the forth-coming semester. Note that paper submissions are no longer accepted by *any* queue.** Note also that the proposal latex template has been changed somewhat. Please consult Electronic Submission Update about downloading a new proposal template.

To ensure prompt processing, please ensure that your applications are sent to the correct email address in the correct format. 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. If none of the investigators is employed in or by one of the partner countries, then the proposal should be submitted to the International Queue. Members of the JAC staff in Hawaii count as International unless they are the PI on an application, when it should be forwarded to the appropriate national TAG.

**Country paying salary of Principal Investigator**

| | | |
|---|---|---|
| **Canada** | **Netherlands** | **UK or International** |

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# Weather Statistics for Semester 02B

The following tables present the weather loss for semester 02B. For losses dut to faults see the the Operational Stats. A more detailed description of how these tables are created is also available here.

| Month | Available | Extended | Lost to weather | | Lost to weather | |
|---|---|---|---|---|---|---|
| | | | Primary | % | Backup | % |
| Aug | 408.0 | 17.4 | 272.2 | 66.7 | 192.9 | 47.3 |
| Sep | 431.0 | 6.7 | 236.9 | 55.0 | 86.4 | 20.1 |
| Oct | 503.0 | 13.1 | 226.7 | 45.1 | 138.5 | 27.5 |
| Nov | 463.8 | 16.9 | 147.6 | 31.8 | 22.1 | 4.8 |
| Dec | 440.0 | 30.4 | 69.8 | 15.9 | 22.9 | 5.2 |
| Jan | 367.9 | 12.7 | 104.2 | 28.3 | 39.8 | 10.8 |
| | | | | | | |
| Totals | 2613.7 | 97.2 | 1057.4 | 40.5 | 502.6 | 19.2 |

*Iain Coulson*

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# Weather Statistics for Semester 02A

The following tables present the weather loss for semester 02A. Take a deep breath before looking further. The anomalous values for July 2002 are due to the shutdown. For losses dut to faults see the the Operational Stats. A more detailed description of how these tables are created is also available here.

| Month | Available | Extended | Lost to weather | | Lost to weather | |
|---|---|---|---|---|---|---|
| | | | Primary | % | Backup | % |
| Feb | 448.0 | 9.3 | 160.3 | 35.8 | 135.5 | 30.2 |
| Mar | 496.0 | 12.3 | 261.5 | 52.7 | 158.4 | 31.9 |
| Apr | 424.0 | 16.8 | 177.4 | 41.8 | 66.0 | 15.6 |
| May | 484.0 | 3.0 | 367.8 | 76.0 | 249.9 | 51.6 |
| Jun | 470.0 | 18.5 | 115.3 | 24.5 | 48.8 | 10.4 |
| Jul | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Totals | 2322.0 | 59.9 | 1082.3 | 46.6 | 658.6 | 28.4 |

*Iain Coulson*

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# JCMT Heterodyne Instrumentation Status

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

**Status** of current receivers.

**RxA3**

**RxB3**

**RxW**

**Heterodyne Polarimetry**

**DAS Spectrometer guide**

**DAS "non-standard" configurations**

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

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*Gerald Moriarty-Schieven*

JCMT image

# JCMT Heterodyne Receivers

## Summary and Status

### Purpose

This page offers a summary of the basic characteristics of the current heterodyne (spectral line) instrumentation of the JCMT, with a forward look to the next semester. Links are provided to other pages, where more detailed information can be found regarding performance and operational details. It is very likely that the present page will be more up-to-date than the detailed pages. For a more general introduction and other information about the heterodyne instrumentation, please see the Guide for Prospective Users.

### Overview

The JCMT operates facility heterodyne instruments in four frequency bands, known as A, B, C and D in order of increasing frequency. The basic characteristics of these systems are given below.

| **Receiver system** | **A** | **B** | **C** | **D** |
|---|---|---|---|---|
| Tuning range (GHz) | 211 - 279 | 312 - 370 | 425 - 510 | 626 - 710 |
| Beamwidth (HPBW, arcsec) | 20 | 14 | 11 | 8 |
| Beam Efficiency | 0.69 | 0.63 | 0.52 | 0.30 |

Recent actual performance of the receivers can be obtained from the Calibration Database.

Recent efficiency and beam shape information tends to be sparse, primarily as a result of the inaccessibility of useful planets and a lack of useful test time. Poor weather, technical faults, and receiver unavailability during September 2001 and May 2002 thwarted the most recent extended campaigns.

Note however that there are not likely to be any significant changes in basic calibration data in the past three years, especially at the longer wavelengths. SCUBA observations also indicate that the beam shape has been good, as might be expected from the continuing campaign for improved control of the antenna surface.

Click on the following for a short summary and recent updates:

- **A-band** (e.g. 230 GHz)
- **B-band** (e.g. 345 GHz)
- **C and D-band** (e.g. 460, 690 GHz)
- **DAS** (spectrometer backend to the above)

Questions should be directed to the undersigned.

## Receiver A3 - 230 GHz

This receiver provides spectral coverage from about 211 to 279GHz, the lowest frequency band in which the JCMT operates for spectral line observations. The extreme frequencies can be reached with a suitable choice of sideband. A3 has a single channel with a low-noise SIS mixer having a typical noise temperature Trec(DSB) of about 70K over most of its range. A **hump in the noise temperatures** occurs between local oscillator frequencies of 245 and 260 GHz, which appeared subsequent to leaving HIA. Although A3 does not have a single-sideband filter, one can avoid the side-effects of this feature for almost all common spectral lines with a suitable choice of sideband (note that the sideband ratio is not unity especially near this "hump"; see results of tests using $HC_3N$ lines). Also, **close to 219.56 GHz** ($C^{18}O$ 2-1) tuning to the upper sideband is recommended, as a local oscillator fault leads to a tuning offset for the lower sideband. For further information see the A3 Web pages and the User's Guide.

### Current Status

Especially during periods of relatively poor sky transmission A3 sees extensive use. It has worked reliably throughout most of the past two years, following extensive repairs to the helium cryostat and subsequent reintegration of the receiver in July 2000. Its present performance (last surveyed in February 2002; see compendium of results in this figure) continues to show some worsening of the noise "hump" since first delivered, although the frequency range affected does not appear to have expanded. Click here for **historical performance** (DSB receiver temperature vs time) from first light until August 2002 for the LO frequency range 226 through 236 GHz.

### Anticipated for semester 04A

A3 should be in service with nominal performance, although we will be monitoring the noise "hump" for further changes.

## Receiver B3 - 345 GHz

B3 has two low-noise tunerless SIS mixers which are tuned to the same frequency using a common local oscillator. The receiver tunes automatically between LO frequencies of 310 to 366 GHz; i.e. sky frequencies from 306 to 370 GHz should be accessible with one or both mixers. Observations slightly outside this range may be possible, although some manual adjustment may be required. Note that at the extremes of the frequency range the receiver noise temperature increases very substantially, and in the worse cases one or both mixers may not show true heterodyne behavior. The most recent extensive performance data, obtained in February 2002, is shown in the attached plot; this can be compared with the situation in March 2000. In both cases the mixer noise temperatures are color-coded - green for channel A, red for channel B.

B3 is usually used in single-sideband mode (i.e. the image sideband is suppressed), although observations are sometimes made in double-sideband mode. Both channels of B3 are capable of observing a spectral window up to 920 MHz wide simultaneously. Using a single channel allows one to observe with the spectrometer maximum of 1.8 GHz instantaneous bandwidth.

As always, we recommend obtaining "standard spectra", and observing either Mars or Uranus if possible to establish the veracity or otherwise of the temperature scale.

For additional information, refer to the B3 Web pages, and/or the User's Guide.

### Current Status

For the most part B3 has been functioning reliably in the past year or so. Considerable effort in that time frame on the part of technical staff have done much to smooth over some remaining rough edges in B3's operation. The most recent data indicate that the characteristics of the multiplier (which was replaced in early 2002 following damage during a storm) have shifted the overall useful frequency range slightly downwards over that available until that time.

We have had some difficulty in the past year with frequent observations of **low signal strengths**; the origin of these effects has never been completely clear - in view of the large number of changes to the telescope and its infrastructure it has been difficult to make controlled experiments to isolate the cause, except to note that similar problems appear to have affected the other heterodyne receivers. Observers are urged to make careful observations of test sources. The **historical performance** averaged over all frequencies since first light show a marked and steady increase in the receiver temperatures with time.

### Anticipated for semester 04A

B3 should be available with unchanged performance: typical DSB Trec values of between 120 and 160 K (i.e. SSB Trec's should be 250-320 K) can be expected, except at the extremes of the frequency range (outside about 315 - 365 GHz).

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## Receiver W - 460 and 690 GHz

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This receiver consists of four mixers, two for use around 460 GHz ("C" band), and two designed for use over the 660-690 GHz region ("D" band), all mounted within a single cryostat. The two C-band channels, or the two D-band channels are normally used simultaneously to achieve improved sensitivity. The D-band mixers have tunerless (non-adjustable) backshorts, while the C-band mixers may be optimised. Receiver W is not configured to allow simultaneous operation with C and D bands, however. Receiver W is usually operated in single-sideband mode. Additional information can be found in the User's Guide and on the Receiver W Web pages.

The **C-band mixers** have a typical DSB Trec value of about 150-200K over the operating range of about 430 to 510GHz. Data obtained in mid-October 2001 are shown for the C-band region.

Overall during the past year receiver W has been used rather sporadically at D-band, a result of the relatively low coincidence rate of user demand and excellent sky conditions. The D-band mixers have a DSB Trec of typically 350-450K at midband. Receiver temperatures (see D-band plot of SSB values here) were surveyed in August 2001; at 660 and 691 GHz the DSB values for channels A/B were 317/376 and 441/372 K respectively. During 2001 one of the two **D-band mixers** suffered a failure and was replaced; it appears to be offer better performance than its predecessor. A failure of the LO control in the first part of 2002 removed the option of using D-band.

**Basic instrumental parameters at both C and D bands remain extremely scarce**, however. We had hoped to obtain a significant amount of "E&C" time in the early part of semester 01B to help rectify the situation, but poor weather conditions did not allow useful observing to be done. Observations scheduled for May 2002 were also ineffective due to problems with W and poor weather. Hence as always it would be extremely valuable for observers at C and D bands to make efficiency measurements and beam maps on planets.

### Current Status

The receiver is working reasonably well, although very few observations have been carried out at D-band.
July 2003 - Mixer A of C-Band is not working. It was sent to the UK for repair.

### Anticipated for semester 04A

We expect current performance characteristics to be unchanged.

## Spectrometer backend ("DAS")

The DAS is an autocorrelating spectrometer which provides the signal processing for all heterodyne instruments at the JCMT. Possible sampled bandwidths are 125, 250, 500, or 920MHz wide with one or two inputs (i.e. one or two mixers), or 1800 MHz with one input channel. The narrowest bands correspond to a spectral resolution of 95kHz (190kHz using two input channels). At 1.8GHz bandwidth the spectral resolution is about 1.5MHz. Some special configurations can be used to allow more than one line to be observed at the same time if the lines are suitably situated in frequency space. 1MHz corresponds to 0.87km/s at 345GHz. See the User's Guide for further information.

### Current Status

The DAS is operating normally in all modes. Improved environmental control installed in last couple of years has been a welcome positive change. In recent times the DAS has suffered a number of faults associated with individual subbands, with particularly strong sensitivity to unstable input signals; this appears to be fixed after an extended visit by ("Doctor DAS") Rob Millenaar. Mahalo, Rob!

### Anticipated for semester 04A

We expect the DAS to be operating normally. The new ACSIS correlator is expected to arrive within this timeframe, although it is not likely to impact regular observing during semester 04A.

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**For internal JAC use:**
Log form
Tests form
View previous reports

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JCMT home page A3 pages B3 pages W C/D pages

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Please address any comments, suggestions or requests regarding this Web page to Per Friberg

Updated: 28 July 2003

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# Lethbridge Fourier Transform Spectrometer

It is likely that the Lethbridge FTS will be available for use during semester 03B. Further information is available at:

http://www.uleth.ca/phy/naylor/fts.shtml

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

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*Gerald Moriarty-Schieven*

# SPIFI: The South Pole Imaging Fabry-Perot Interferometer

SPIFI, the South Pole Imaging Fabry-Perot Interferometer, will not be available for use at the JCMT during semester 03B. For further information consult Cornell Astronomy Department Site.

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*Gerald Moriarty-Schieven*

# Max-Planck-Institut 800 GHz Instrument

The MPIfR/SRON heterodyne receiver (MPIRE) has been "retired", and will not be returning to the JCMT.

Further details can be found at:

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



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

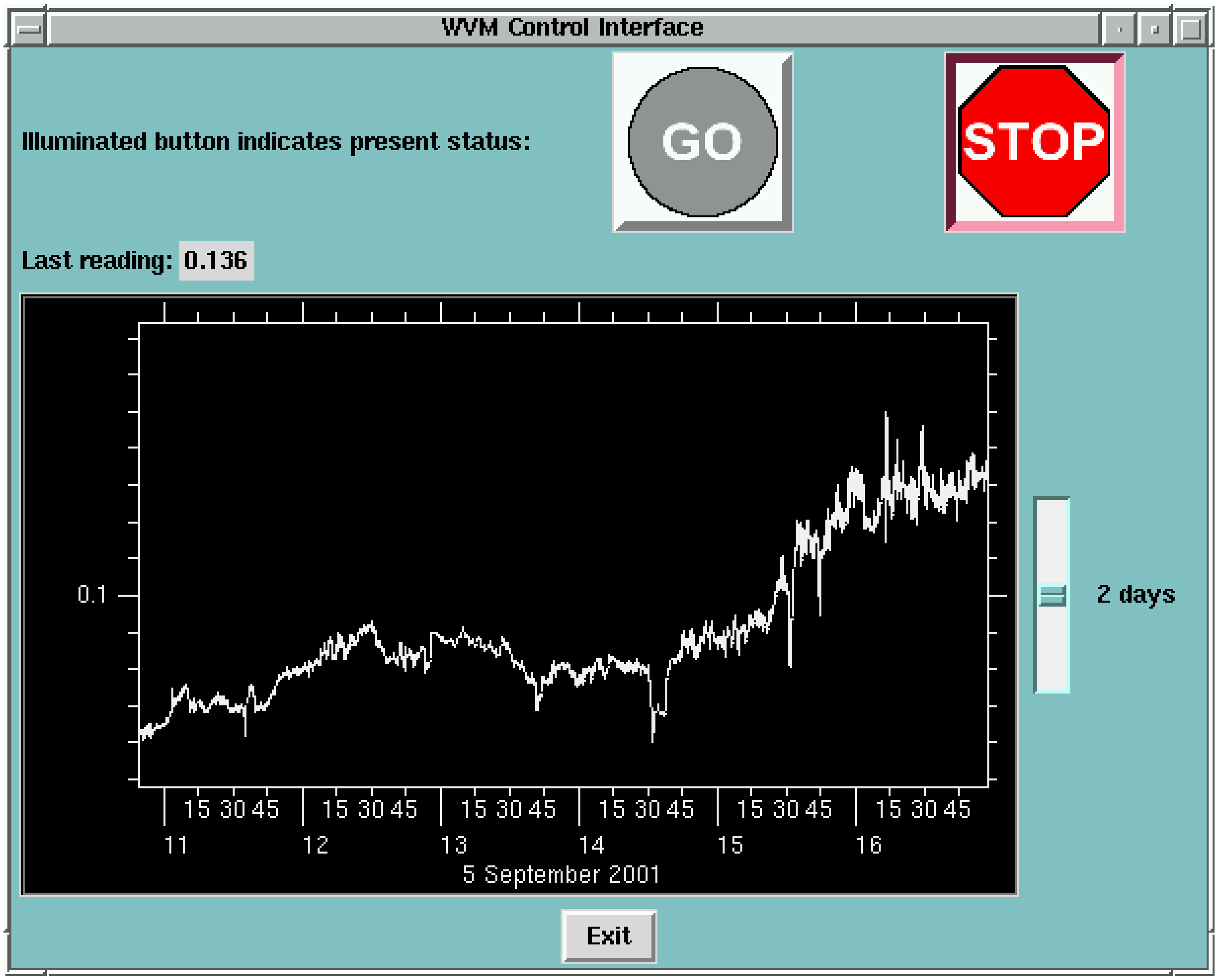
# The JCMT 183GHz WVM

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

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

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

There is now a web-based interface which will allow you to download WVM data or display the same data in graphical form, for any date for which data are available. This interface is available here.

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*Bernd Weferling*

# Tau, Seeing, and Sensitivities

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

The SCUBA integration-time calculator is available here.

The heterodyne integration-time calculator is available here.

---

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

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

---

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

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*Gerald Moriarty-Schieven*

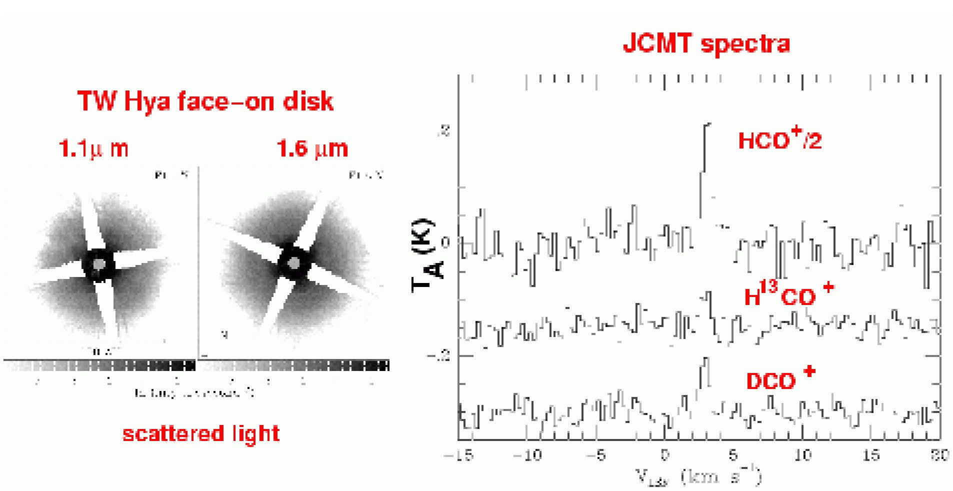
# Detection of $DCO^+$ in the TW Hya circumstellar disk

Ewine van Dishoeck, Wing-Fai Thi & Gerd-Jan van Zadelhoff
*Leiden Observatory, The Netherlands*

The chemical composition of disks around pre-main sequence stars is an active topic of research, not only because disks provide the material from which future planetary systems are made, but also because molecules are excellent probes of the physical processes in disks. Molecules other than CO are only just starting to be revealed in disks (e.g., Dutrey et al. 1997, A&A 317, L55; Kastner et al. 1997, Science 277, 67; Qi 2001, PhD thesis Caltech). Most of these studies focus on the lower rotational transitions of the molecules. In late 1998, our group started a JCMT program using the new dual polarization receiver B3 to search for high frequency transitions. In disks, the densities are sufficiently high ($10^6$-$10^8$ $cm^{-3}$) that the higher-J transitions are at least as strong as the lower-J lines. Moreover, the beam is smaller at high frequencies, reducing the beam dilution of the emission.

During our first run, we succeeded in detecting several lines at the level of $T_A^*$~0.05-0.2 K in about 2 hours of telescope time each, testifying to the excellent performance of receiver B3. Previous studies on other telescopes often required almost an entire night of integration per line. We subsequently pursued the project looking for other molecules, the results of which will be published in Thi et al. (2003, submitted).

Of particular interest is the first detection of the $DCO^+$ ion in a circumstellar disk (see Figure). The $DCO^+$ J=5-4 line at 360.169 GHz was detected, together with the $HCO^+$ and $H^{13}CO^+$ J=4-3 lines at 356.734 and 346.998 GHz, in the disk around the isolated T Tauri star TW Hya. This is one of the nearest T Tauri stars at a distance of only 56 pc and has an age of 7-15 Myr, somewhat older than most classical T Tauri stars. The disk has a (gas + dust) mass of ~0.02 M_Sun and a size of ~200 AU, corresponding to a 3.6" radius at 56 pc. Because the disk is seen nearly face-on, the molecular lines do not show the characteristic profiles of a rotating disk but are single peaked.




*JCMT detection of the $DCO^+$ J=5-4 line, together with the $HCO^+$ J=4-3 and $H^{13}CO^+$ J=4-3 lines, in the disk around the pre-main sequence star TW Hya. The $H^{13}CO^+$ and $DCO^+$ spectra have been shifted by -0.15 and -0.3 K, respectively, for clarity. The near-infrared scattered light HST images by Weinberger et al. (2002, ApJ 566, 409) are shown on the left.*

The three lines allow an accurate value of the $DCO^+/HCO^+$ ratio of 0.035+-0.015 to be determined. This value for the TW Hya disk is close to that found in cold pre-stellar cores but somewhat higher than that measured in the envelope around the low-mass protostar IRAS 16293-2422 which has started to heat its surroundings. It is also close to the DCN/HCN ratio obtained for pristine cometary material in the jet of comet Hale-Bopp (Blake et al. 1999, Nature 398, 213).

Deuterated molecules are excellent probes of the temperature history of interstellar and circumstellar gas. It is well known that the abundances of deuterated molecules in cold regions are enhanced by orders of magnitude over the elemental [D]/[H] abundance ratio of 1.5 x $10^{-5}$ through a process called fractionation: at temperatures below ~50 K, the $H_3^+$ + HD -> $H_2D^+$ + $H_2$ reaction is driven strongly in the forward direction. $H_2D^+$ can subsequently transfer a deuteron to the abundant CO molecule, leading to enhanced $DCO^+$. Moreover, the $DCO^+/HCO^+$ ratio is increased if the main destroyer of $H_3^+$, i.e. CO, is depleted onto grains. Thus, the $DCO^+/HCO^+$ ratio traces both low temperatures and the level of depletion. The observed $DCO^+/HCO^+$ of 0.035 is consistent with theoretical models of flaring disks of Aikawa et al. (2002, A&A 386, 622) which consider gas-phase fractionation processes within a realistic 2-D temperature distribution and which include the effects of freeze-out onto grains. Most of the emission is found to arise from an intermediate layer of the disk, where temperatures are 20-30 K and densities at least $10^6$ cm$^{-3}$.

The similarity of the deuterium fractionation ratios in cold clouds, disks and pristine cometary material suggests that the gas spends most of its lifetime at low temperatures and is incorporated in disks before the envelope is heated, i.e., before the class I stage. Alternatively, the ratio may be reset in disks by low-temperature gas-phase chemistry. Searches for other deuterated molecules which are likely incorporated as ices (e.g., $CH_3OH$) can distinguish these scenarios. An exciting future prospect is to probe the D/H ratio down to planet-forming regions with ALMA.

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*Ewine van Dishoeck - Leiden*

# JCMT/SCUBA detections of cold dust disks in the MBM12 young association

Michiel Hogerheijde
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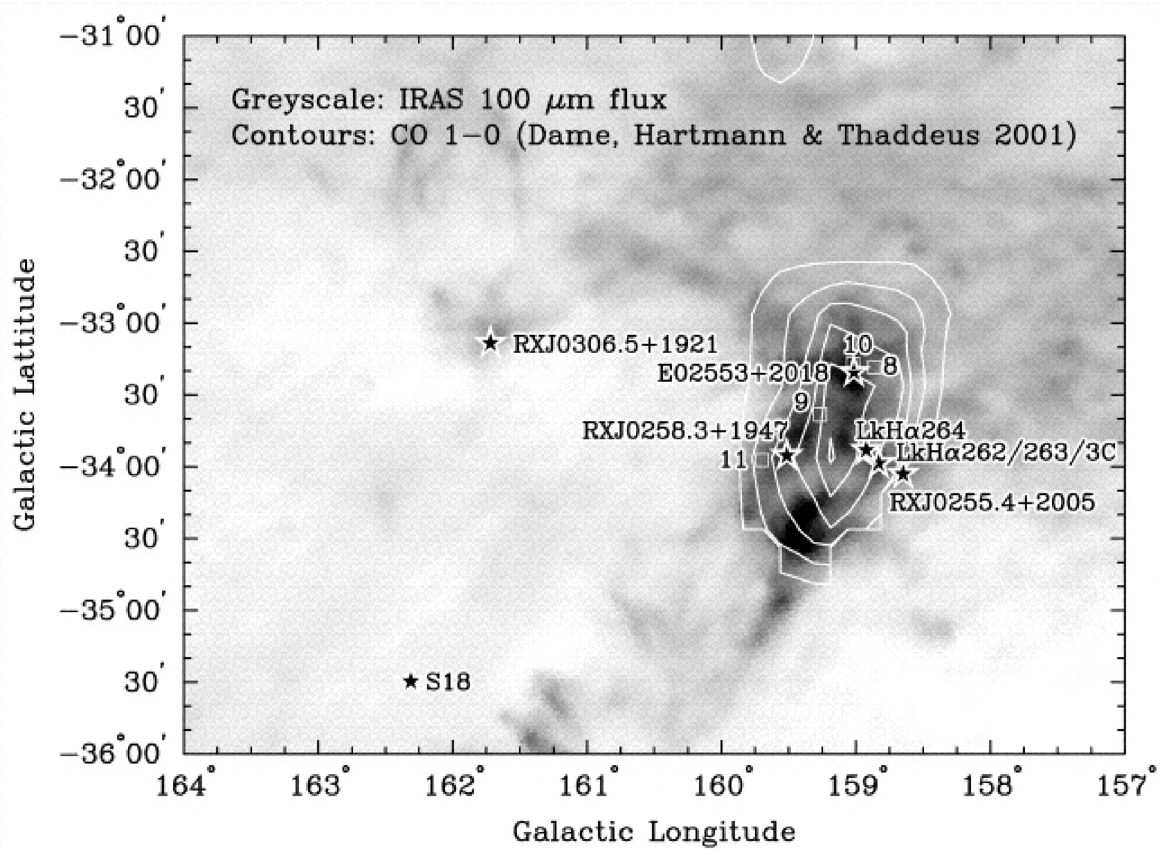
Doug Johnstone
*Herzberg Institute of Astrophysics, National Research Council of Canada*
Isamu Matsuyama
*University of Toronto*
Ray Jayawardhana
*UC Berkeley*
& Muzerolle
*Steward Observatory, University of Arizona*




We report the detection of continuum emission at lambda = 850µm and 450µm from disks around four classical T Tauri systems in the MBM 12 young association (d ~ 275 pc). Assuming an average dust temperature of 25 K and typical dust properties, derived disk masses are 0.002 Solar masses for LkHa 263 A+B+C, 0.006 Solar masses¯ for S 18 A+B, 0.027 for LkHa 262, and 0.041 Solar masses for LkHa 264A. Our result for LkHa 263 is consistent with the reported value of 0.0018 Solar masses for the edge-on disk around LkHa C, but our data do not resolve this system. The detection of significant reservoirs of cold dust around classical T Tauri stars in MBM 12 with K- and L-band excess shows that these objects have not (yet) dispersed their disk material. These findings are consistent, although not uniquely, with an inside-out dispersal scenario for disks in this region. Our limited sample supports the finding that close binary systems (LkHa 263 and S 18) have less massive disks than single stars or wide binaries (LkHa 262 and 264). A paper is in preparation.

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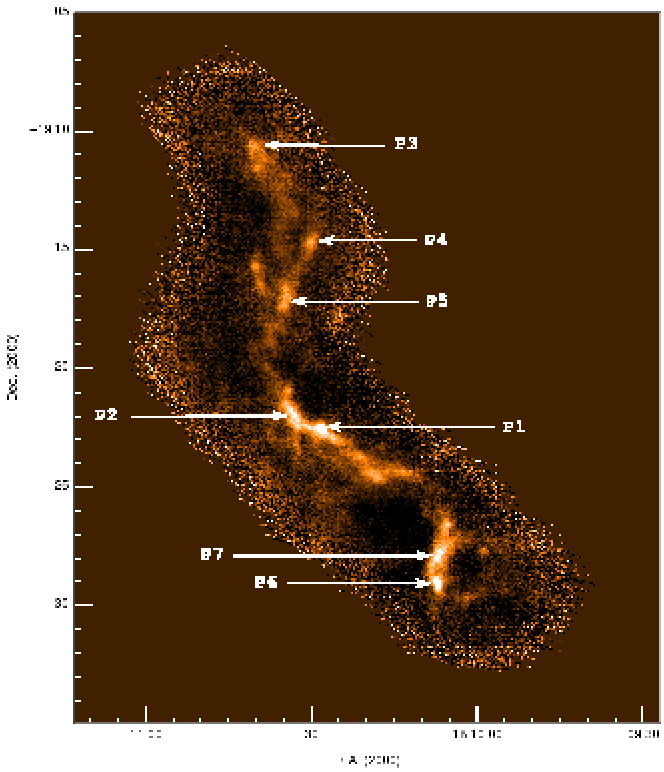
# The G11.11-0.12 Infrared-Dark Cloud: Anomalous Dust and a Non-Magnetic Isothermal Model

Doug Johnstone, Jason Fiege, Russell Redman, Paul Feldman
*Herzberg Institute of Astrophysics, National Research Council of Canada*
& S. Carey
*California Institute of Technology*




The G11.11-0.12 Infrared-Dark Cloud (see March 2000 Newsletter article) has a filamentary appearance, both in absorption against the diffuse 8 m Galactic background, and in emission from cold dust at 850 m. Detailed comparison of the dust properties at these two wavelengths reveals that standard models for the diffuse interstellar dust in the Galaxy are not consistent with the observations. The ratio of absorption coefficients within the cloud is , which is well below that expected for the diffuse ISM where $\kappa_8/\k . This may be due to the formation of ice mantles on the dust and grain coagulation, both of which are expected within dense regions of molecular clouds. The radial structure of the filament is examined, using the 850μm emission as a probe of the underlying column density. The profile is well represented by a marginally resolved central region and a steeply falling envelope, with $\Sigma( , where $\a , indicating that G11.11-0.12 is the first observed filament with a profile similar to that of an isothermal cylinder. The observations are fit by a self-consistent isothermal model with $\Sigm g cm^sup>-2 and $r_0$ = 0.12 pc in the northern segment and $\Sigm g cm$^{-2}$ and $r_0$ = 0.1 pc in the southern segment.

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*Doug Johnstone - HIA/NRC*

# Shades of SHADES - The SCUBA HAlf Degree Extra-galactic Survey

J. S. Dunlop
*University of Edinburgh*
***and a consortium of more than 60 astronomers***

---

Towards the end of 2002, the first SCUBA data were taken in what is designed to be the most ambitious extragalactic survey undertaken to date at the JCMT.

This major, collaborative, UK-led survey, now named SHADES (The SCUBA HAlf Degree Extra-galactic Survey) will ultimately cover 0.5 sq. degrees to a 4sigma detection limit of $S_{850}$ = 8mJy and will in effect require approximately one third of the usable UK time on the JCMT over the next 3 years.

This survey is designed to maximise the impact of the JCMT on cosmology over this period by answering the three fundamental questions:

i) What is the cosmic history of massive dust-enshrouded star-formation activity?

ii) Are SCUBA sources the progenitors of present-day massive ellipticals?

iii) What fraction of SCUBA sources harbour a dust-obscured AGN?

To address these issues requires a wide-area survey yielding a substantial (~200) sample of bright unconfused sub-mm sources with meaningful redshift estimates ($\Delta z \sim \pm 0.5$). Given this information we can **answer the first question** with the addition of sufficiently deep and unconfused far-infrared photometry to constrain the bolometric luminosities. Crude but near-complete redshift information is also sufficient for us to **answer the second question** provided our survey covers sufficient area and contains enough sources to measure the clustering of bright SCUBA sources on scales up to ~10Mpc. To **answer the third question** requires additional measurements of the rest-frame mid-infrared SEDs of the sources with SIRTF.

To meet these requirements our team is undertaking a combined SCUBA + *BLAST* survey of two well-studied fields (accessible to both facilities). Prior to the launch of *Herschel*, the balloon-borne far-infrared telescope *BLAST* offers the only means by which to measure unconfused 500µm, 350µm and 250µm flux densities for a substantial number of SCUBA-selected sub-mm sources. For those SCUBA sources *detected* by *BLAST* we will be able to determine their sub-mm-far-infrared SEDs and hence estimate their redshifts to an accuracy delta-z ~ +/- 5 (as we demonstrate from extensive simulations). The SCUBA sources *not detected* by *BLAST* are expected to lie at $z > 4$, and will thus form a key sample for direct spectroscopic CO redshift measurement, feasible for $z > 4$ sources due to appearance of two CO lines within the 35-GHz bandwidth expected to be available on the LMT and/or GBT by 2004.

The resulting dataset will provide sufficient information (even prior to completion of follow-up observations at other wavelengths) to delineate the evolution of far-infrared luminosity density as a function of redshift, and to measure the spatial clustering of SCUBA sources. Moreover, *given* these redshift constraints we can exploit the power of mid-infrared observations with *SIRTF* to constrain the fraction of SCUBA sources which house obscured AGN.

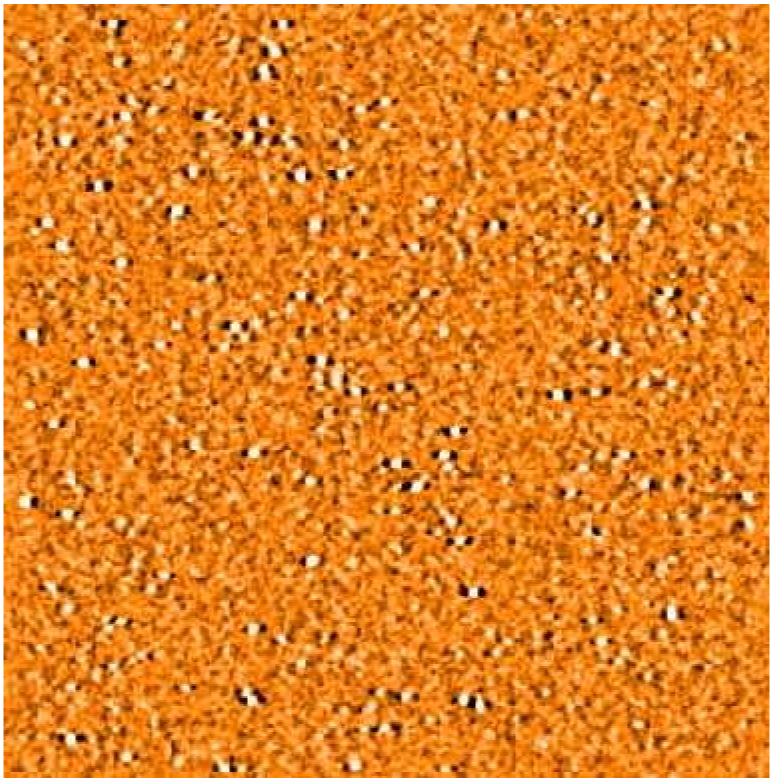
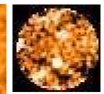
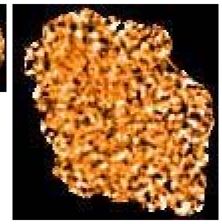

**Figure:** *The large image shows a complete simulation of the sort of 850µm map, covering 0.5 sq. degrees, which will result from this programme. This map has been produced from an N-body simulation and the image shown here incorporates real bolometer noise from the 8-mJy survey, and the real SCUBA beam (including negative sidelobes) assuming a 30-arcsec EW chop). The strong clustering anticipated if SCUBA sources are the projenitors of massive ellipticals is clear in this synthetic image. Due to the limitations of greyscale representation, we have made this 300 Megabyte image available for detailed inspection by anonymous ftp* (`ftp://ftp.roe.ac.uk/pub/jsd/scuba_blast/scuba_blast.fits.gz`). *For comparison, the SCUBA surveys of the HDF (Hughes et al. 1998) and the ELAIS N2 field of the 8-mJy survey (Scott et al. 2002) are shown, roughly to scale, in the center and to the right respectively.*

The legacy value of this survey is potentially enormous as these important basic results can be refined and enhanced through the wealth of supporting deep multi-frequency data in our chosen fields (e.g. deep XMM and VLA images of both fields are already available, and the UKIRT WFCAM Ultra Deep Survey, with supporting optical ESO surveys will be centred on the Subaru Deep Field). We also plan further follow-up from Hawaii (UKIRT, Gemini North, Subaru, Keck, CSO) and Chile (Gemini South, VLT, VISTA, and ultimately ALMA) as well as mm imaging/spectroscopy with the Mexican LMT.

We aim to complete the survey over 3 years. To achieve this the survey requires (and has now been provisionally awarded) 30 good-weather shifts on the JCMT for 6 semesters.

A prediction (i.e. a synthesized image) of the sort of results we can expect from SHADES is shown in Figure 1, which also indicates the scale of this new survey as compared with some extragalactic surveys which have already been completed at the JCMT since the advent of SCUBA.

Further details on this project can be found by visiting the SHADES website at Edinburgh (http://www.roe.ac.uk/ifa/shades). This website also provides links to the websites of the key supporting facilities involved in maximising the science output of the SCUBA data (such as BLAST and WFCAM). It also contains a full listing of the members of the international SHADES team, and links to the home pages of all collaborating institutions.

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# Formation of concentric arcs around evolved stars detected in high rotational transitions of CO?


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*MPIfR*

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Rens Waters

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Jan Cami

*NASA Ames*

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*(UvAmsterdam*


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While they are on the Asymptotic Giant Branch (AGB), stars of solar-type shed their entire envelope through a dusty wind, and evolve toward Planetary Nebulae. This mass loss does not occur at a constant rate. It is generally believed that a moderate rate (of $10^{-7}$ solar masses per year) is followed by a sudden increase in mass loss to a few times $10^{-5}$ solar masses per year. This abrupt increase is usually referred to as the superwind, and is needed to explain the formation of the Planetary Nebula. Recently it became clear that the mass-loss rate of AGB stars is even more variable, with the detection of circumstellar concentric arcs around post-AGB stars (Sahai et al. 1998, ApJ 493, 301; Kwok et al. 1998, ApJ 501, L117; Mauron & Huggins 1999, A&A 349, 203). The origin of these arcs are presumably mass-loss modulations during the mass-loss phase on the AGB. Using JCMT observations of the CO rotational transitions in all available frequency bands, we have studied the gas properties of the outflow of a number of AGB stars and conclude that the observed line strengths can be explained by mass-loss modulations on time scales corresponding to the spacing of the concentric arcs around post-AGB stars.

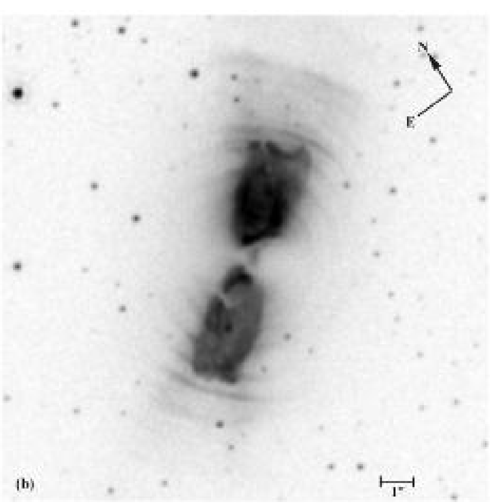


*Figure 1: The concentric arcs around post-AGB star IRAS 17150-3224 observed with HST WFPC2 at 606 nm. The arcs are due to mass-loss modulations and the spacing between them correspond to time scales of 200-1000 years, depending on distance and outflow velocity. We may have witnessed the formation of similar structures in the outflow of AGB stars. Figure adopted from Kwok et al. 1998, ApJ 501, L117.*

The mass-loss history of evolved stars can be probed by observing different rotational transitions of CO. While the lower rotational transitions have lower excitation temperatures and are formed in the cooler gas located more outward, the higher transitions trace the inner regions. The formation of the lines in stellar outflows gives rise to distinct line profiles, which depend on the physical properties of the outflow. Many studies have focussed on determination of the mass-loss rate, assuming it is constant, by analyzing the profiles one or two rotational transitions (see e.g. Morris, 1980, ApJ 236, 823). More recently,there have been attempts to include the superwind (as a density jump) in some models (e.g. Justtanont et al. 1996, ApJ 456, 337), but with only a few rotational transitions accessible, modelling a more complex mass-loss history did not seem feasible.

But the situation has changed. The MPIfR/SRON 800 GHz receiver at the JCMT has made the CO(7-6) transition accessible. We have observed this transition for a number of AGB stars and combined it with observations of the lower transitions CO(6-5), CO(4-3), CO(3-2) and CO(2-1) which have been obtained using the other heterodyne detectors available at the JCMT. This set of transitions trace the outflow of evolved stars from a few hundred stellar radii in case of CO(7-6) to a few thousand stellar radii using the CO(2-1) transition. The observed line intensities were not compatible with a constant mass loss rate or a superwind described by a jump in the mass loss of a factor of ~100. The lines due to the highest transitions were observed to be less bright than expected. For one object, WX Psc, we determined the mass loss rate for each line independently. We found that the highest mass loss rate was traced by the CO(2-1) transition, and that the rate decreased with higher J, i.e. when more inward regions were probed. The lowest rate was detected with the CO(6-5) line and followed by a slightly higher value for the CO(7-6) transition. This change in trend was continued when the dust mass-loss rate was taken into account, which originates even further inwards and probes yet higher mass loss.

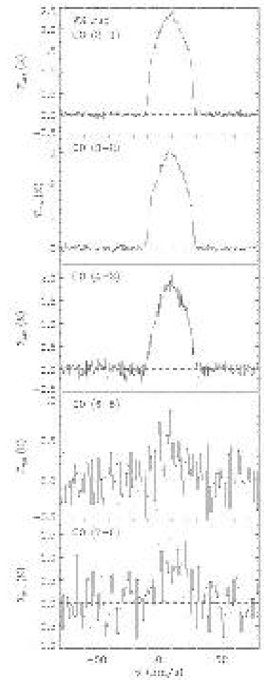

*Figure 2. JCMT observations of the rotational transitions of CO in WX Psc. The parabolic profile is typical for optically thick CO gas in the outflow. The intensities of the CO(4-3), CO(6-5) and CO(7-6) are too low to be consistent with a constant mass-loss rate or a superwind phase.*

From the outflow velocity, which could also be derived from the CO line profiles, we could determine the ejection time scale corresponding to the distance between the various line formation regions corresponding to maximum mass loss. We find that this time scale is a few hundred years, and this, combined with the amplitude of the variation, which is about a factor of 50, is consistent with the mass-loss modulations that supposedly occurred in the AGB progenitors of the post-AGB stars that show circumstellar concentric arcs of enhanced emission. Thus, we are able to witness the birth of these arcs by observing a sequence of CO rotational transitions. Although we could perform these calculations only for one object in our sample, it is clear that the line strengths arising from the other AGB stars are also inconsistent with neither a constant outflow nor a superwind phase, but that a more complex mass-loss history is taking place.

Studying the mass-loss history of AGB stars will help us to understand the stellar evolution on the AGB, the shaping of Planetary Nebulae and the formation of galactic dust. Observing the high and low rotational transitions of CO provides a powerful tool to do this.

This work has been submitted to Astronomy & Astrophysics.

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*Ciska Kemper*

# Astrochemistry in Orion

Doug Johnstone
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A.M.S Boonman, & Ewine van Dishoeck
*Sterrewacht, Leiden University*

Cornerstone molecules (CO, $H_2CO$, $CH_3OH$, HCN, HNC, CN, CS, SO) were observed toward seven sub-millimeter bright sources in the Orion molecular cloud in order to quantify the range of conditions for which individual molecular line tracers provide physical and chemical information. Five of the sources observed were protostellar, ranging in energetics from 1 - 500 $L_{sun}$, while the other two sources were located at a shock front and within a photodissociation region (PDR).

Statistical equilibrium calculations were used to deduce from the measured line strengths the physical conditions within each source and the abundance of each molecule. In all cases except the shock and the PDR, the abundance of CO with respect to $H_2$ appears significantly below (factor of ten) the general molecular cloud value of $10^{-4}$. Formaldehyde measurements were used to determine the mean temperature and density for the gas in each source. Clear trends exist between the derived abundance of CO, $H_2CO$, $CH_3OH$, HCN, and CS and the temperature of the source, with hotter sources having higher abundances. Determining whether this is due to a linear progression of abundance with temperature or sharp jumps at particular temperatures will require more detailed modeling.

The shape of the CO 3-2 line profile provides evidence for internal energetic events (outflows) in all but one of the protostellar sources, and shows an extreme kinematic signature in the shock region. In general, the CO line and its isotopes do not significantly contaminate the 850µm broadband flux (less than 10%); however, in the shock region the CO lines alone account for more than two thirds of the measured sub-millimeter flux. In the energetic sources, the combined flux from all other measured molecular lines provides up to an additional few percent of line contamination. The observed methanol transitions require high temperatures (T>50 K), and thus energetic sources, within all but one of the observed protostellar sources. The same conclusion is obtained from observations of the CS 7-6 transition. Analysis of the HCN and HNC 4-3 transitions provides further support for high densities $n > 10^7$ $cm^{-3}$ in all the protostellar sources.

This paper has been submitted to A&A.

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*Doug Johnstone - HIA/NRC*

# A redshift survey of submillimetre galaxies

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Andrew Blain
*CalTech*
Rob Ivison
*Astronomy Technology Centre, Royal Observatory Edinburgh*
& Ian Smail
*University of Durham*

---

A significant fraction of the energy emitted when the Universe was young came from very luminous galaxies largely hidden at optical wavelengths by shrouds of interstellar dust grains, and now resides in the cosmic background radiation at wavelengths near 1mm (Fixsen et al. 1998). The first real insight into the origin of the far-IR/submm background came with the first deep fields observed by the SCUBA submm camera on the JCMT (Smail, Ivison & Blain 1997). Close to 100% of the submm background has now been resolved with the deepest SCUBA maps which exploit a sensitivity boost from gravitational lenses (Smail et al. 2002, Cowie et al. 2002). However, the near-IR/optical faintness of the submm galaxy population conspires with the modest positional precision available from the large (15 arcsec) SCUBA beam and the large surface density of unrelated optically-faint galaxies to render positional coincidence alone inadequate to identify counterparts. This problem is compounded by the small field of view of SCUBA: compiling large samples of submm galaxies is slow, with roughly one detected every night. Because of these difficulties, robust spectroscopic redshifts, a crucial element in understanding their nature and evolution (Blain et al. 1999), have been published for only a handful of submm sources, all atypically bright at optical wavelengths (e.g., Ivison et al. 1998, Barger et al. 1999).

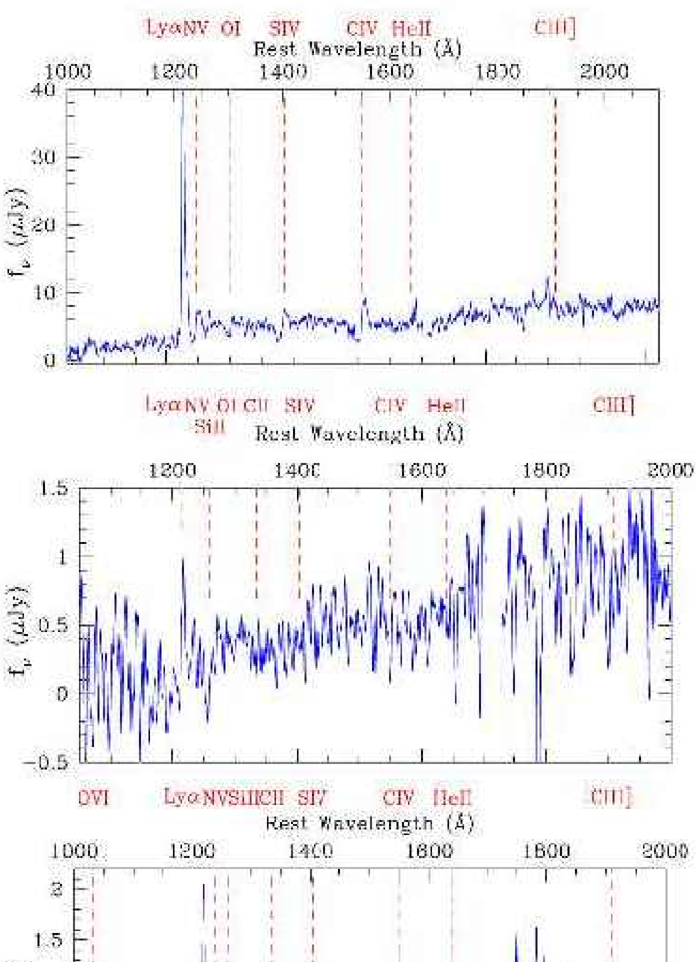
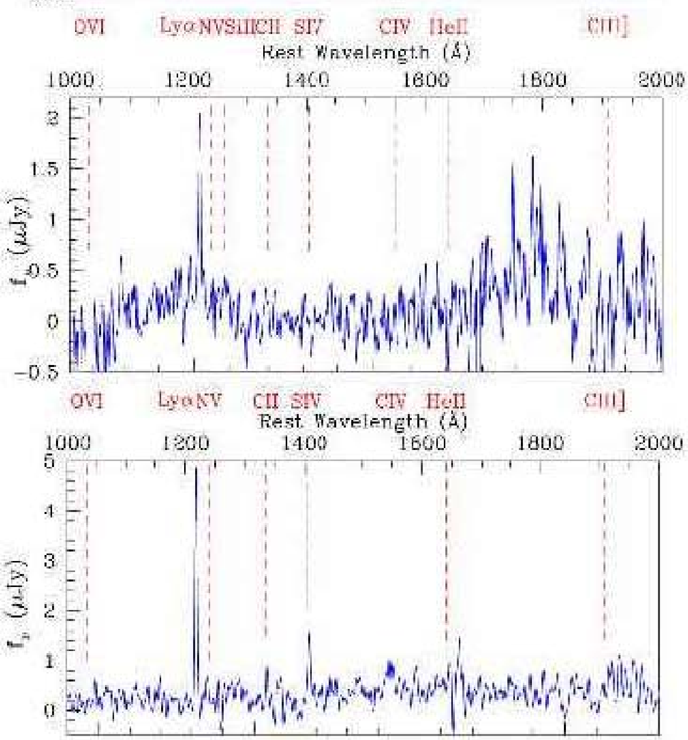



*Figure 1. Four representative rest-UV spectra for our submm galaxies. spanning the I = 22.2-26.4 range, ordered brightest (a) to faintest (d). While the optically brightest and faintest sources show AGN characteristics in their spectra, the sources between do not reveal any signs of AGN. Source (b) appears as a typical Lyman-break galaxy. Source (c) is the least compelling of the four, with only a single strong emission line feature, which we interpret as Lyman-alpha. However this source has recently been detected in Balmer-alpha (Smail et al. in prep). Spectroscopic exposures times were 1.5-6.0 hr. One-dimensional spectra were extracted and compared with template spectra and emission-line catalogues to identify redshifts. Most identifications are based on multiple lines, most prominently the Ly-alpha line which varies tremendously in both flux (ranging from 1 to 60uJy) and rest-frame equivalent width (3 to >100A). Weaker stellar/interstellar/AGN features and/or continuum breaks were detected in the spectra, strengthening the redshift identifications. Our highest S/N spectrum (SMMJ163650.0+405733 - Smail et al. 2003) includes features indicative of strong starburst activity (P-Cygni wind absorption profiles,*




*stellar/interstellar absorption lines). Narrow-line Type-II AGN with enhanced NV and/or CIV emission are consistent with half of our spectra. Despite this evidence for AGN in these galaxies, they appear to be relatively weak in energetic terms as compared to those identified in X-ray or optical surveys.*

We have been able to overcome these problems by taking advantage of 1.4-GHz radio data from the Very Large Array (VLA) radio telescope. These deep images have fine (~2 arcsec) spatial resolution and a large (30 arcmin FWHM) field of view. They are sensitive to the synchrotron radio emission from cosmic-ray electrons accelerated in the supernovae explosions of the same high-mass stars that heat the dust and generate the far-IR/submm emission. Hence a deep radio image should be an efficient route to pinpoint the positions of many submm galaxies. This is confirmed in fields with both submm and radio observations (Ivison et al. 2002, Chapman et al. 2003a): radio counterparts brighter than 30 uJy can be found for 60-70% of submm galaxies brighter than 5 mJy at 850 µm (which have a surface density of 450 per square degree and contribute about 20% of the submm background). Moreover, the accurate radio positions mean that SCUBA's efficient `photometry' mode can be used to search for submm galaxies (Barger, Cowie, & Richards 2000; Chapman et al. 2001, 2002), raising the detection rate to around ten per night.

With a large sample (~100) of radio identified SCUBA galaxies in hand (Chapman et al. 2002, 2003a; Ivison et al. 2002), we initiated a multi-object optical spectroscopy program in March 2002, using the Keck 10-m telescopes and the LRIS-Blue spectrograph. In 8 clear nights we have targetted 62 radio-detected submm galaxies mostly brighter than 5 mJy at 850µm, and with optical magnitudes in the range I-mag = 22-27. We measured robust redshifts for 35 submm galaxies (preliminary results in Chapman et al. 2003b), representative of the blank-field population (Figs. 1 & 2). This represents an order of magnitude increase over previously published redshift samples, and importantly allows the first constraint on the optically faint majority of the SCUBA galaxies. The redshifts span the range z = 0.7-3.7, with a median of 2.4 and an interquartile range of 1.9-2.8 (Fig. 2). These redshifts allow dust temperatures ($T_d$) and bolometric luminosities to be determined, assuming that the tight correlation between far-IR and radio emission observed at low redshifts (Condon 1992) remains valid. If the radio emission is boosted by an AGN then both temperature and luminosity are overestimated. There are no obvious cases in the present sample in this category. Typical values are of order 35 K and several $10^{12}$ $L_o$ respectively.

To quantify the whole submm population using this survey we must account for several selection effects. In particular, requiring a radio identification prior to spectroscopy limits the maximum redshift. Studies of galaxies at low and moderate redshifts suggest that changes in the dust properties, especially the dust temperature $T_d$, modify the relative strength of the emission in the submm and radio wavebands (Blain et al. 2002). This results in a range for the maximum redshift detected in the radio: hot sources can be observed out much higher redshifts than cold sources.

The relationship between different classes of high-redshift galaxy is critical for our understanding of galaxy evolution. Our spectroscopy shows that the submm galaxies are coeval with the important populations of star-forming galaxies and quasars detected at z=2-3 using optical and X-ray techniques (Boyle et al. 2000; Barger et al. 2002; Steidel et al. 1999, 2002). We can use their relative space densities to compare and relate these populations. In a 1000 $Mpc^3$ box at z~2.5, there are 10 Lyman-break galaxies with R-mag < 25.5 and 1 submm galaxy from our sample (with 850µm flux > 5mJy), but the single submm galaxy produces a comparable bolometric luminosity to the

10 Lyman-break galaxies.

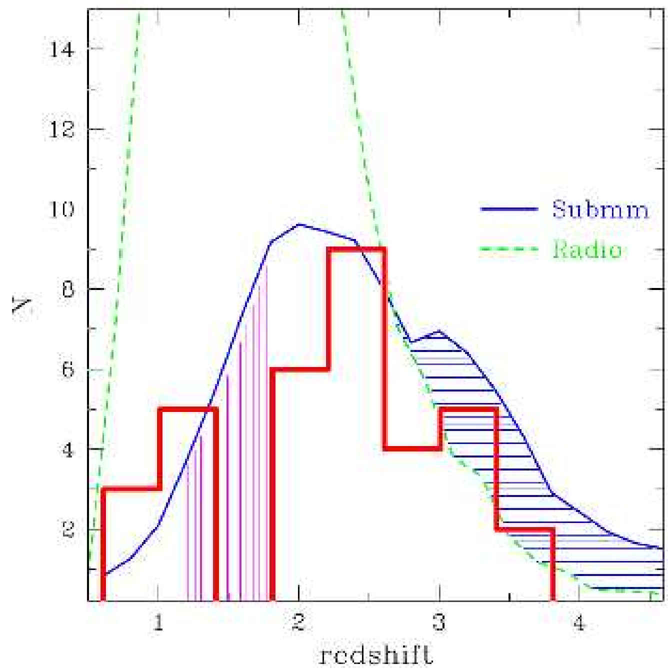



*Figure 2. The redshift histogram of our submm galaxy sample. We describe the selection effects using an evolving model of the local far-IR luminosity function, in which the dusty galaxies are represented by a range of template spectral energy distributions. The model has been tuned to fit the statistical properties of the submm-radio galaxy population. We plot the predicted redshift distributions for submm galaxies with flux densities S(850µm)>5mJy (solid line) and radio sources with S(1.4GHz)=30-500uJy (dashed line). We expect to miss sources lying between the submm and radio model curves due to our requirement of a radio detection to pinpoint the submm source. The apparent deficit between model and data at z~1.5 may be indicative of the difficulty in obtaining spectra in the spectroscopic desert that spans the range 1.2*

*We are rapidly approaching a statistically useful sample of SCUBA galaxies with redshifts, however we are already close to exhausting the supply of radio identified examples. Two ongoing projects using SCUBA to followup faint radio sources are underway this semester (PI: Smail, UK; PI: Chapman, international). Both programs are seeking to rapidly uncover large samples of submm galaxies with precise radio positions for Keck optical spectroscopy. These programs are expected to increase our sample size of SCUBA sources with redshifts by 50%. The Smail program was awarded grade 1 weather to additionally attempt 450µm detections as a means to further constrain the SED peak for sources with spectroscopic redshifts, an independent check on the dust temperature and therefore the bolometric luminosity extrapolations. This highly efficient observing mode with SCUBA provides a complementary approach to the blank field mapping campaigns underway with the "SHADES" consortium (see article by Dunlop in this issue). Several exciting studies are underway with this new and expanding sample: the redshift clustering, the dust temperature distribution, the UV spectroscopic properties, a comparison with MAMBO millimeter sources having spectroscopic redshifts, and over the longterm, a detailed comparison with optically selected galaxies and absorption systems at similar redshifts to our SCUBA sample.*

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*Scott Chapman*

# SCUBA observations of the host galaxies of four dark gamma-ray bursts

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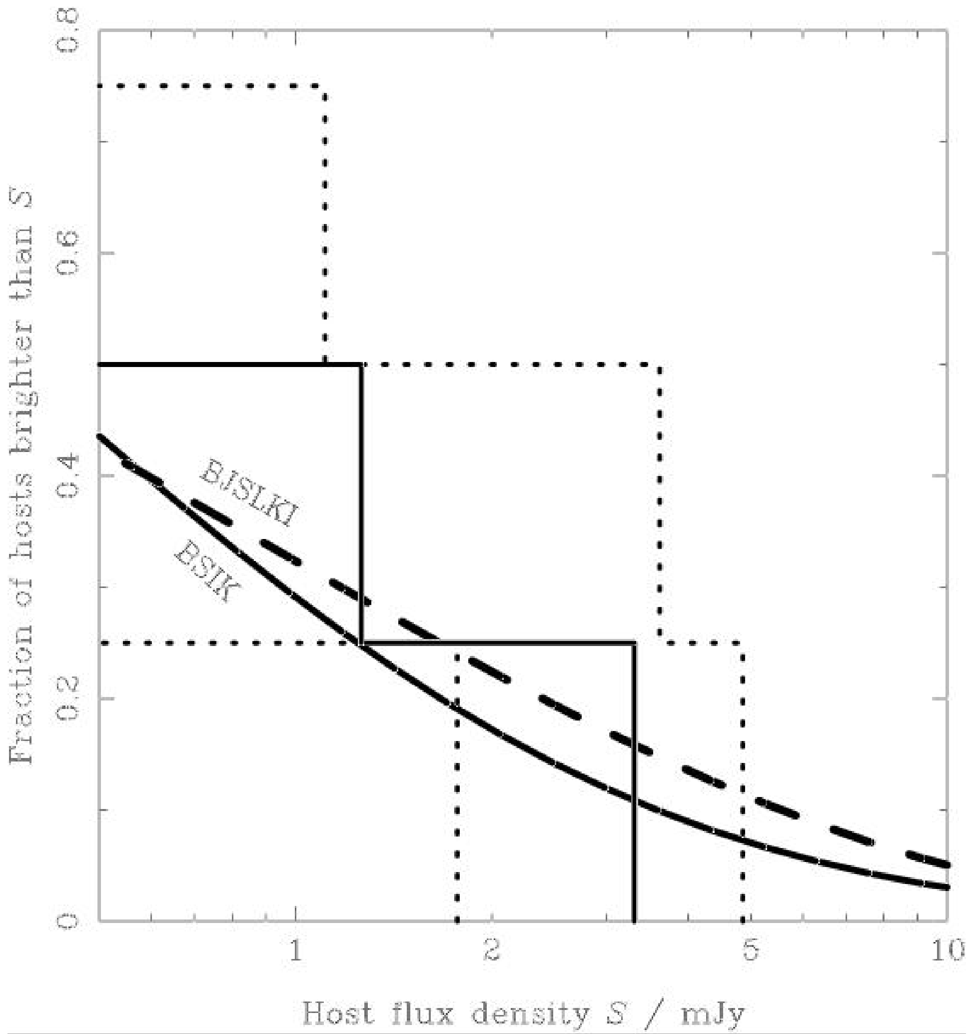
(This article is based on the work published in Barnard et al., 2003, MNRAS 338, 1-6. Please see this paper for citations of work referred to below.)

Gamma-ray bursts (GRBs) are the focus of much current astronomy research and yet many questions remain unanswered about these hugely energetic phenomena. Whilst it is now clear that the GRB population is extragalactic, the actual cause and progenitors of these massive explosions are not yet certain. Most models currently involve the endpoints in the evolution of massive stars, and so the host galaxies of GRBs are expected to have high star-formation rates. These ideas are supported by studies of the relative rates of star formation and GRB explosions in the Universe as a whole, which suggest a strong correlation.




Radiation from the site of GRBs comes in three major phases: the initial explosion, during which the GRB may be the most luminous object in the Universe; followed by the afterglow as an ultrarelativistic shock wave passes through the surrounding ISM; followed eventually by emission from the host galaxy of the GRB progenitor. The recent increase in GRB research was sparked by the detection of the first afterglow (GRB 970508), essentially because the afterglow is relatively long-lasting and passes through a range of wavelengths, which allows far better positional accuracy than the glimpses of brief high-energy initial explosion radiation.

Afterglows from GRBs have now been observed at nearly all wavelengths, and the information garnered by following the evolution of a GRB's afterglow has led to the general acceptance of the synchrotron fireball model. Details such as polarisation and collimation of afterglows are now the focus of research.

However, there is a large fraction of GRBs for which, despite rapid and deep searches, optical afterglows were not found. This fraction is around 50 per cent and so these 'dark' GRBs may represent an important population. It is not clear however whether these GRBs are intrinsically different objects to those with optically bright afterglows, or whether their optical faintness depends on their surroundings. Several authors have suggested that the apparent optical faintness of these GRBs may be due to obscuring dust along the line of sight. Since the energy of the shock wave is expected to clear out dust in the GRB's vicinity, this explanation would require the GRBs to be located in generally dusty galaxies. This, in combination with the expected high star-formation rates of GRB host galaxies, makes them a target for SCUBA observations.

We observed a small sample of optically dark GRBs (with good positions from radio and/or X-ray afterglows) with SCUBA in photometry mode. Four host galaxies were observed. Of these, only one appears to represent a possible detection, and this has been confirmed by combining our result with that of another group (see Berger et al., astro-ph/0210645, and the March 2002 article). Overall, we find that the 'dark' GRB host galaxy population is no more likely to be dusty than the general galaxy population. This is illustrated in figure 1, where the results of our sample are compared with two galaxy evolution models (marked BSIK and BJSLKI) which represent the SCUBA galaxy population. In this figure, the fraction of hosts with 850μm flux density greater than the value S is plotted. The smooth curves correspond to the two models, whilst the solid stepped line shows the cumulative results from our sample (and the dotted lines represent 1 sigma errors).

This result indicates that to characterise the optically dark GRB population as residing in dusty host galaxies is incorrect; in fact a variety of explanations probably need to be applied to the whole population. This is further reinforced by the findings of other researchers that some GRB hosts are bright in the submillimetre even when the optical afterglow was observed. Hence the optical afterglow of a GRB is not a reliable guide to the submillimetre luminosity of the host galaxy. We are currently completing a wider survey of all GRBs, to further understand the links between the GRB host galaxy population and the SCUBA galaxy population.

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