

# JAMES CLERK MAXWELL TELESCOPE

## **Annual Report**

**1994**

**The James Clerk Maxwell Telescope (JCMT) facility is operated by the Joint Astronomy Centre, Hilo (JAC) on behalf of the three participating agencies:**

**The United Kingdom Particle Physics and Astronomy Research Council (PPARC)**

**The National Research Council of Canada (NRC)**

**De Nederlandse Organisatie voor Wetenschappelijk Onderzoek (NWO)**

**Front cover:**

*The James Clerk Maxwell Telescope and Carousel*

**Back cover:**

*The molecular outflow source RNO43 — see section 2.8 for details*

**JAMES CLERK MAXWELL TELESCOPE**

**Annual Report**

**of the**

**James Clerk Maxwell Telescope Board**

**1994**



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**Figure i:** *The Cassegrain cabin located behind the primary reflector contains most of the JCMT heterodyne instruments. The Nasmyth platform on the right of the photograph is the current location of UKT14 and is where SCUBA will be installed.*

## Foreword

*by Professor David Williams, Chairman of the JCMT Board*

**O**n behalf of the Board of the James Clerk Maxwell Telescope I have great pleasure in presenting to the national agencies and to the astronomical community the Annual Report of the JCMT Board for the year 1994, the seventh full year of operation of the telescope.

The scientific output from the telescope, reported in some detail here, is tremendously exciting, and demonstrates that the telescope is making fundamental contributions to a wide range of astronomy from solar system studies, to interstellar medium and star forming regions, to extragalactic work. Clearly, the telescope has now achieved that significant level of maturity and performance that has been its goal since its inception. The quality of the science reported here speaks for itself; it is also worth emphasising the record high publication rate of papers based on JCMT observations. The project has gained its present level of success at least as rapidly as other world class telescopes; the telescope and its instrumentation are innovative and set the standards in this area of science.

The continuing successful development of the telescope's instrumentation in sometimes difficult financial circumstances is due to the commitment of the three national funding agencies, in Canada, the Netherlands, and the United Kingdom. In these pages, you will read that the Board has approved a development plan which extends until the end of the century. The instruments currently under construction represent truly international collaborations; they are progressing well and will, when in operation, dramatically enhance present capabilities in both continuum and line observations. The success of the interferometry runs with the Caltech Submillimeter Observatory has encouraged the Board to develop the JCMT-CSO interferometer, so that sub-arcsecond resolution at sub-millimetre wavelengths will soon open up entirely new astronomical horizons.

Professor Ian Robson, Director JCMT, brings to the project tremendous enthusiasm, commitment, and energy, and is the driving force in many of the new developments. He is ably supported by his staff in Hawaii and in Edinburgh. In particular, the work of Dr Adrian Russell (Head of the Instrumentation Programme Management Group) requires a special mention; this programme is a key one for the JCMT, and the fact that it is in such excellent shape is substantially due to Adrian's efforts. On behalf of the Board I congratulate the Director JCMT and all the staff on their work and achievements in 1994, and I commend to everyone the contents of this Report. I hope that you will have as much pleasure in reading it as I have.

**Figure ii:** *The Secondary Mirror Unit (SMU) is shown on its tetrapod above the primary surface. The small (0.75 m diameter) secondary mirror is mounted on a table which can be adjusted in all three axes to provide accurate focussing. Vibrators on the mountings allow the mirror to be tilted in any direction.*

# Introduction

*by Professor Ian Robson, Director of the JCMT*

1994 saw continued progress on planned improvements to the JCMT and the overall performance can be said to be excellent. It is very encouraging to see the output from the JCMT undergo a major increase, with 64 papers being published in refereed journals. This compares extremely well with similar optical/infrared facilities at equivalent stages in their development.

Significant management effort was expended on three areas during the year: assessing and implementing changes to the working week at the JAC; assessing scenarios of funding options for the JCMT; producing the five year development plan. This latter task was a major undertaking and the resulting plan provides for the continued upgrading of the facility and its instruments with the aim of ensuring that the James Clerk Maxwell Telescope continues to enable the user community to produce world-leading astronomical science well into the next century. The plan was put together in close consultation with the JCMT Advisory panel and a number of working groups that I set up. The prioritised and costed plan which was accepted by the Board identifies a number of key developments for the facility. These are:

- a programme of upgrades to the instruments including: continued SIS junction research and development; conversion of the current 230GHz receiver to a wide-band and more sensitive instrument; conversion of the 480GHz receiver to an 800-900GHz receiver; provision of a polarimeter module for SCUBA; R&D into wide-band mixer development for extragalactic applications; high frequency mixer investigations.
- continued development to increase the efficiency of the facility including: improvements in software (such as on-the-fly spectral line mapping); new antenna control software and reduction of observing overheads; moves towards flexible, queue scheduled and serviced observing to match better the requirements of the programmes to the pertaining conditions.
- upgrading the surface to maximise the performance at high frequencies.
- a move towards high sensitivity, high spatial resolution observations by undertaking experiments in phase retrieval using the JCMT-CSO two-element interferometer and to investigate potential collaboration with the Smithsonian Submillimeter Array.
- the establishment of a focal plane heterodyne array programme commencing with the provision of a 16 pixel 345GHz focal plane array and new digital spectrometer.
- to maintain an overview of developments in 1mm VLBI experiments and to report back to the Board at a time when the JCMT might seek to become a partner in such experiments.

No new receivers were commissioned during 1994 but RxB3, RxW and SCUBA are expected to arrive during 1995. A number of important milestones were achieved in Hawaii in terms of the development of the facility. The first phase of the surface upgrades was undertaken with the welding of the cone-bars (which had become slightly loose since installation in 1986) and the changes to the focal length to bring the focus in agreement with the shapes of the individual panels (thereby

rectifying a problem inherent since construction). Both of these were extremely successful, producing an excellent surface accuracy and a noticeable reduction in the level of 'out-of-homology' that had been apparent in moving from the zenith to low elevations. Unfortunately, a mishap in October caused a problem which produced severe beam degradation and significant effort had to be invested in order to rectify this.

The scientific highlight of the year was the Jupiter-comet Shoemaker-Levy 9 encounter. The impact of the cometary fragments and Jupiter was investigated by two teams using the JCMT and this is described in detail later in this Report. The scientific discoveries from these data are excellent and important. Regrettably, at the time of the impact, the most powerful hurricane ever recorded in the mid Pacific bore down on Hawaii. There was great concern that hurricane Emilia might deviate from its projected path of just skirting south of the Islands to a northerly direction which could have caused havoc similar to hurricane Iniki in 1992. Thankfully, this did not happen, but nevertheless it brought thick cirrus and heavy showers and severely hampered the JCMT observations during the latter part of the comet encounter.

Two other highlights spring to mind. The brilliant results from the high frequency 690GHz RxG were attributable to a new and much more sensitive SIS receiver used at a time which coincided with by far the best extended period of low opacity for many semesters. This highlights the value of matching programmes to required weather conditions and, in this respect, the first of the experiments in flexible scheduling was successfully carried out. The JCMT-CSO interferometer was opened up to the user community and a number of results were obtained, including observations at 345GHz.

A notable aspect of operations was the requirement to replace the filament lamp encoders. After a lengthy review of options, it was decided to upgrade to 24-bit *led* encoders. Major efforts were undertaken by the science group to characterise and document the calibration of the heterodyne instruments and provide a database of standard spectra. This and other information is now housed on the JAC/JCMT home page of the World Wide Web. We expect this to become our major information medium within the next year.

Because of the need to look towards a more efficient operation due to financial pressures from funding agencies, new working practices that will have the effect of reducing overtime were introduced in August. There have been a number of staff changes which are listed elsewhere in this Report and a number of posts remain unfilled until the future funding and direction are determined which is expected to be in early 1995. It was with great regret and reluctance that I accepted the resignation of Dr Adrian Russell, the Head of the JCMT Instrumentation Programme Management Group at the end of the year. He has now taken up the post of UK Gemini Project Manager. Adrian achieved an enormous amount during his tenure at the JCMT and the strength and great promise of the JCMT future instrument development programme owes much to his individual talents, skills and abilities. He will be sorely missed.



## **1. The James Clerk Maxwell Telescope Facility**

**S**ituated at an altitude of 4092 m close to the summit of Mauna Kea Hawaii, the 15-metre James Clerk Maxwell Telescope is the largest facility in the world designed specifically to operate in the submillimetre region of the spectrum. It is owned and operated by the United Kingdom, Canada and the Netherlands (the ‘Partner Countries’) on behalf of astronomers worldwide. It is managed by the PPARC’s Joint Astronomy Centre (JAC) in Hilo, Hawaii with assistance from the Royal Observatory Edinburgh (ROE). The JAC is also responsible for the operation of the United Kingdom Infrared Telescope (UKIRT) on Mauna Kea.

The development and operation of the JCMT is overseen by the JCMT Board.

### **1.1 The Telescope & Carousel**

The 15-metre diameter primary reflector of the JCMT is made up of 276 individual lightweight panels. Each panel consists of a thin aluminium skin bonded to an aluminium honeycomb and is attached at three points to the backing structure of the antenna. The alignment of the mechanical panels can be adjusted by means of stepper motors at the mounting points. The backing structure is designed to maintain a parabolic figure as gravity distorts the antenna as it tips to different elevations. The surface accuracy is routinely measured and adjustments required to each panel are calculated by making observations of a coherent millimetre source located on top of the UKIRT building or by utilising the in- and out-of-focus images of a bright planet. The sub-reflector or secondary mirror can be adjusted in three axes to compensate for changes in focus as well as changes in the figure of the primary. In addition, the secondary can be tilted or chopped in two axes in order to perform sky background cancellation.

The JCMT carousel co-rotates with the antenna and is designed to protect the telescope from the elements and to provide a safe and comfortable working environment for astronomers and engineers. An important feature of the carousel is the membrane which is deployed in front of the antenna at all times and is transparent at millimetre and sub-millimetre wavelengths,. In addition to providing protection from the wind, the membrane performs the useful function of scattering the visible and near-infrared radiation, providing protection from the solar ‘heat’ which could damage the antenna and thus allowing daytime astronomical observations including direct observations of the Sun itself.

### **1.2 Instrumentation**

Receivers for the telescope can be located either in one of the bays of the Cassegrain cabin or on the two Nasmyth platforms located at the ends of the elevation bearing. A number of receivers can be accommodated on the telescope at the same time and are selected by a moveable tertiary mirror located in the centre of the Cassegrain cabin. Usually at least three heterodyne receivers, covering the atmospheric windows between 270 and 490 GHz, are mounted in the cabin while the bolometer system, UKT14 occupies one of the Nasmyth platforms and the Max Planck Institut für Extraterrestrische Physik (MPE) high frequency receiver, RxG, the other. The line receivers are designated according to the frequency band in which they operate. Band A covers 220 - 280 GHz, Band B 320 - 370 GHz, and Band C 460 - 495 GHz.

### **1.3 The International Agreements**

Under the terms of the Tripartite Agreement (reproduced in the 1990 Annual Report), the partner countries jointly undertake the operation, maintenance and development of the facility with the resources provided for this purpose in the proportion UK: 55%, Canada: 25% and the Netherlands: 20%. In accordance with the Operating and Site Development Agreement, 10% of the total observing time is set aside for use by the University of Hawaii. The remaining observing time available is allocated by the Panel for the Allocation of Telescope Time (PATT) on the basis of scientific merit and technical feasibility. Use of the telescope is not restricted to applicants from partner countries. National Time Allocation Groups (TAGs) referee, assess and nominate allocations for applications from their own countries. These time allocations are later combined and awarded by an International Time Allocation Committee (ITAC). Applications from applicants from outwith the partner countries are assessed and nominated by the ITAC. The JCMT Development Fund provides resources for the development of state-of-the-art receivers, bolometers and for enhancing the capability of the JCMT.

On 1st April 1994, the UK Science and Engineering Research Council (SERC) was replaced by the Particle Physics and Astronomy Research Council (PPARC) and all JCMT references to 'SERC' should be taken to be equivalent to 'PPARC'.

### **1.4 The JCMT Board**

The international partners set up the James Clerk Maxwell Telescope Board to oversee the operation of the JCMT, to foster and develop collaboration between their astronomers in the use of the facility, and to endeavour to maintain the JCMT in the forefront of world astronomy. In particular, the JCMT Board (i) oversees the development of the facility; (ii) determines (with the advice of users and of the Director JCMT) the programme of operation and maintenance of the facility; (iii) approves annual budgets and forward estimates and (iv) determines the arrangements for the allocation of observing time.

The JCMT Board comprises four persons appointed by the PPARC, two appointed by the NRC, two appointed by the NWO, and one appointed by the University of Hawaii (membership in Appendix D). Two meetings of the JCMT Board were held in 1994, on 9th & 10th May in Hilo, Hawaii and one scheduled for 22nd & 23rd November in Leiden, Netherlands. [The November meeting was actually postponed until 23rd & 24th January 1995 but any relevant details are contained within the current Annual Report in order to avoid confusion with the two Board meetings which will be held in 1995.]

The JCMT Board has set up the JCMT Advisory Panel to advise it and the Director on the scientific operation and development of the facility. This Panel (membership in Appendix D) met twice in 1994, on 26th April at QMW, London and on 16th & 17th November in Dwingeloo, Netherlands.

## 2. Scientific Report

The highlight of 1994 was the encounter of the fragments of comet Shoemaker-Levy 9 with the gas-giant planet Jupiter in July. Observations of the impact sites were undertaken with the JCMT and are reported in summary below together with a selection of other astronomical programmes. The allocations of observing time are set out in Appendix A. Preliminary results from some of these investigations have been reported in the two issues of the new *JCMT Newsletter* and these along with further 1994 results are summarized here to illustrate the range of investigations underway.

### 2.1 Shoemaker-Levy 9 Collision with Jupiter

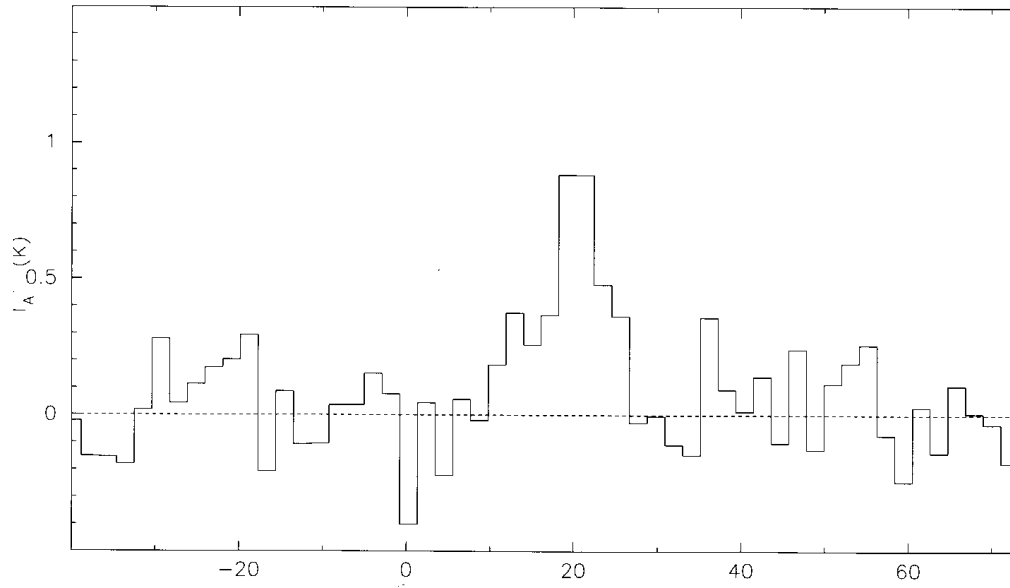
The collision of comet Shoemaker-Levy 9 with Jupiter in July was observed with just about every major astronomical facility in the world. This was not just a single ‘event’, but a bombardment of cometary fragments stretched over 10 days. At the JCMT, the encounter was observed by a large consortium of UK, Canadian, US and French astronomers.

In the atmospheres of the giant planets, spectral lines can arise either due to emission in the stratosphere, producing narrow lines (typically 20 MHz wide), or due to absorption in the troposphere against the background thermal emission from the planet’s interior, producing strongly pressure-broadened absorption lines (typically 10 GHz wide). The JCMT heterodyne receivers were used to search for possible stratospheric emission lines, and the FTS to look for the much broader tropospheric absorption features. Spectral line observations involved beam-switching and alternating between the impact site on the southern hemisphere of Jupiter and a corresponding reference point on the northern hemisphere. Initial worries that, because of Jupiter’s very strong continuum emission, the observations would be severely affected by tracking errors or standing wave effects, proved groundless. The JCMT made the only confirmed submillimetre detections of the event. The fact that this was achieved in very poor observing conditions testifies to the quality of the telescope systems and receivers.

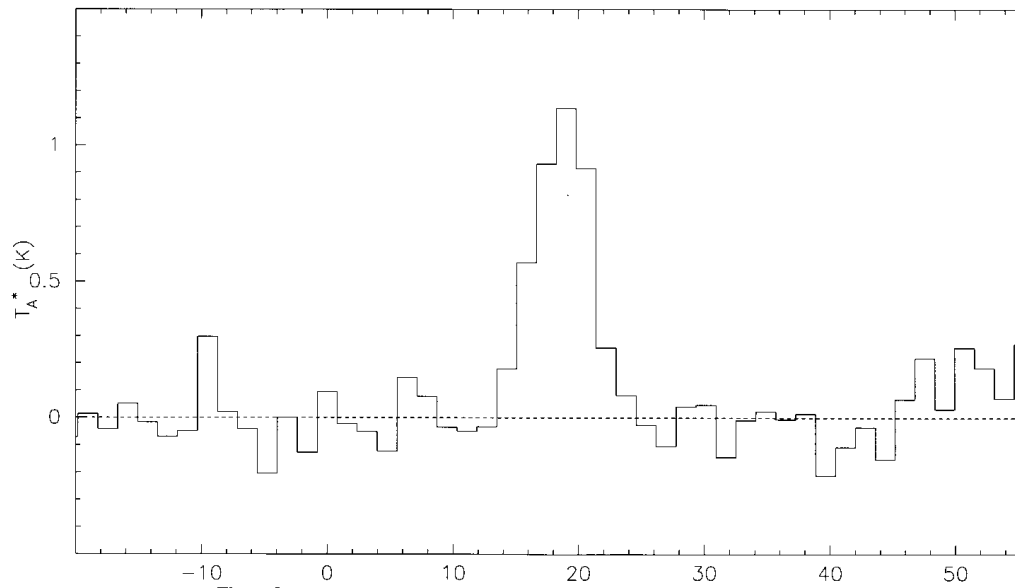
Observations of HCN 4-3 (354 GHz) at the site of impact of fragment C resulted in a clear detection (Figure 1a). A couple of days later observations at the impact site of fragment G resulted in another very strong HCN 4-3 line (Figure 1b). Two measurements of the HCN 3-2 (266 GHz) line at the impact site of fragment R were taken 48 hrs apart (Figure 2a, b).

Within a few months the data indicated that HCN had changed to absorption. The implication was that the hot gas, which had initially been seen in emission, had cooled sufficiently that it was now colder than the background of Jupiter, and was located in a stratospheric haze layer.

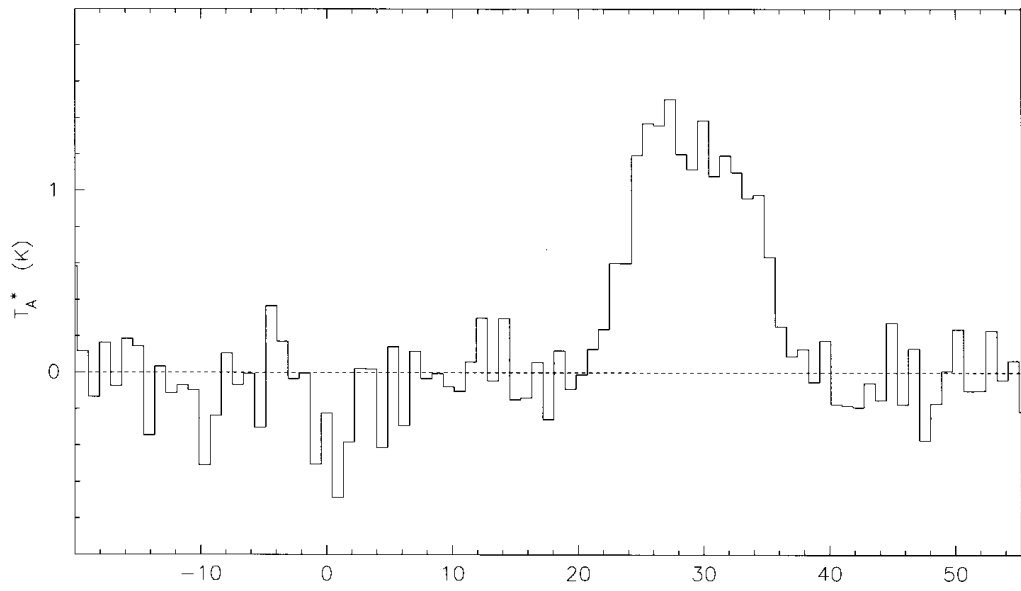
This raises questions of how long the HCN molecules could exist before being destroyed; how quickly they would migrate away from the specific impact sites in longitude; whether they would disperse in latitude; and whether other species could be found in the haze. The HCN is still there although it appears that CO (seen by other facilities) has faded away. There does not appear to have been any appreciable north-south migration of HCN, probably due to the rapid rotation of Jupiter.



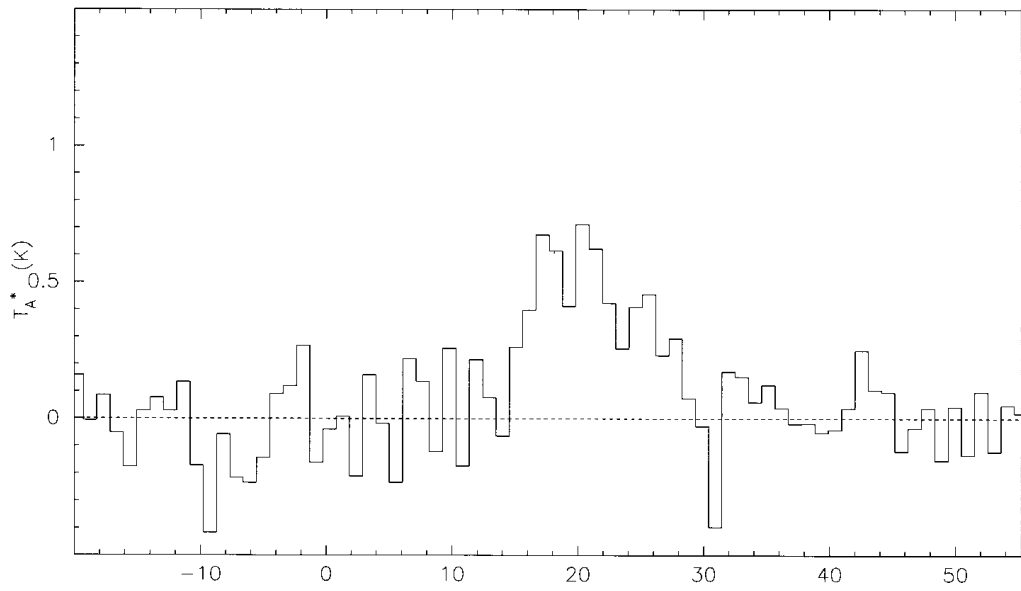
**Figure 1(a):** *HCN 4-3 detection from Jupiter after impact of comet fragment C. The x axis is the velocity offset (in km/s) in the geocentric frame.*



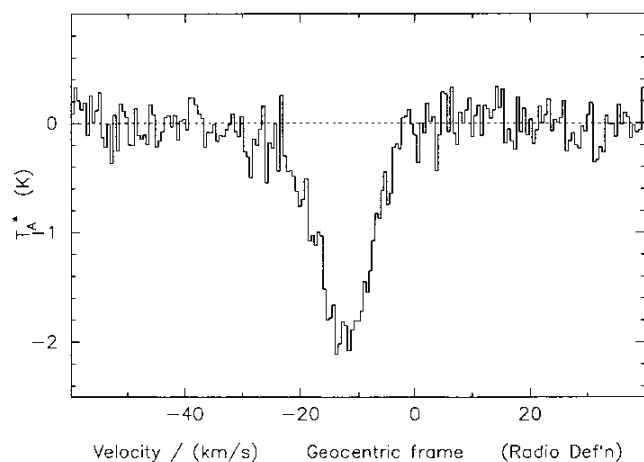
**Figure 1(b):** *HCN 4-3 detection from Jupiter after impact of comet fragment G. The x axis is the velocity offset (in km/s) in the geocentric frame.*



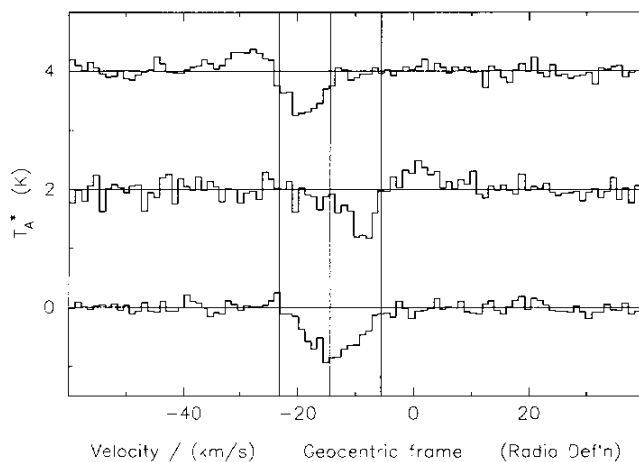
**Figure 2(a):** *HCN 3-2 detection on Jupiter at impact site of comet fragment R. The x axis is the velocity offset (in km/s) in the geocentric frame.*



**Figure 2(b):** *HCN 3-2 detection on Jupiter at impact site of comet fragment R taken 48 hours later. The x axis is the velocity offset (in km/s) in the geocentric frame.*



**Figure 3.** A typical spectrum of the  $J=4-3$  HCN line in absorption against the disk of Jupiter. This spectrum was taken on 21 December 1994 towards the impact site of one of the largest fragments (G), about an hour before the site's transit. A baselevel has been fitted to put the line profile at zero level; typically the true baselevel in such spectra is close to  $100 \text{ K} T_a^*$  due to the background from Jupiter.



**Figure 4.** Observations of HCN 4-3 towards the East limb (top), West limb (middle) and middle of the southern impact zone (bottom) of Jupiter on 24 December. Towards the Eastern limb gas at and beyond the limb is approaching the observer; at the same time some absorption is picked up from less blueshifted gas seen against the disk of the planet. The two components partially cancel each other, and lead to apparently narrow line components. The opposite effect is seen on the (receding) western limb. On the meridian the usual absorption line is visible. Spectra intensities are normalised to a Jupiter background of 100 K.

On the morning of December 21 a rather strange ‘P-Cygni’ profile was observed towards the eastern limb (Figure 3). It is suggested that while the absorption was still due to cold gas seen against the disk of Jupiter, the emission (prominent in Figure 4) was due to gas in the Jovian stratosphere seen projected against colder sky beyond the limb.

HCN is not normally present at detectable levels in Jupiter's atmosphere but, given the small size of the impact regions, it is clear that it was produced in large quantities by many of the impacts. The line widths (generally  $<10 \text{ km s}^{-1}$ ) are much greater than the thermal line widths expected anywhere in Jupiter's observable atmosphere. If the line width is due to pressure broadening, it fixes the altitude at which HCN is situated and implies that the emission originates from the upper stratosphere rather than from deeper levels in the atmosphere. The observed cooling of the molecules implies a substantial cooling of Jupiter's stratosphere due to material tossed up by the explosive impacts. The origin of this HCN is uncertain but it seems likely that it was formed by shock chemistry in the impacts. It is thought to be unlikely that it is being dredged up from the deep atmosphere. The HCN persisted over timescales of at least six months following the collisions. The molecules are probably shielded against photolysis by solar radiation by methane, and other means have to be investigated for the eventual demise of HCN. It is expected that HCN may last for several more months, and perhaps years.

Although the FTS is ideally suited to the detection of broad tropospheric absorption features, observations proved very difficult due to the unstable atmospheric conditions. The observing strategy for the FTS component of the run was to point at the central meridian of the planet, offset towards the south pole to observe the impact sites rotating through the field of view at  $-44$  degrees S latitude. An equal number of spectra were taken in this position and in a corresponding position in the northern hemisphere. Spectra in the  $1100\text{-}\mu\text{m}$  band of UKT14 revealed a repeatable absorption feature in the southern hemisphere,  $\sim 5\%$  of the continuum background, centred on coincident lines of HCN and  $\text{PH}_3$ . Measurements with the  $850\text{-}\mu\text{m}$  filter may enable the observers to distinguish between these species by revealing (or not) the HCN 4-3 absorption. Data taken in the  $750\text{-}\mu\text{m}$  band of UKT14 did not reveal any  $\text{H}_2\text{S}$  absorption features. Several transitions occur in this filter and it is inferred that tropospheric  $\text{H}_2\text{S}$  was not generated by the impacts.

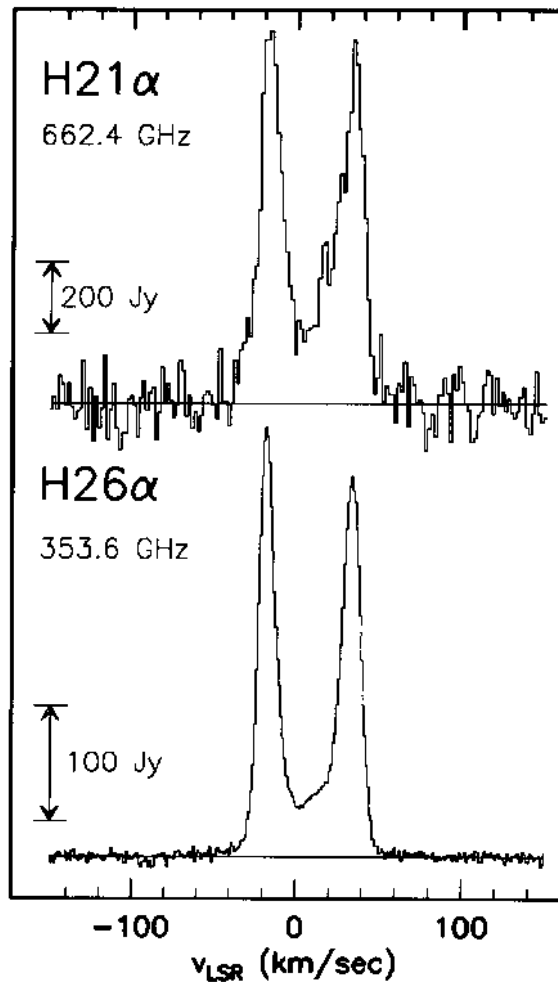
Many molecules, such as  $\text{H}_3^+$ ,  $\text{CH}_4^+$  and other hydrocarbons,  $\text{NH}_3$  and  $\text{PH}_3$ , are already well known in the near and middle infrared. The detection of tropospheric HCN or  $\text{PH}_3$ , whichever it turns out to be, is unique and will also have significant implications for the chemical models. It will be important to continue looking at HCN in Jupiter with the JCMT.

## 2.2 Hydrogen Recombination Line Masers

Maser activity in radio recombination line emission has so far been detected only in the circumstellar shell of MWC349. Investigations show that maser activity begins near 100 GHz with the maser line flux growing rapidly with increasing frequency. The systematic increase of maser line flux from 100 to 250 GHz suggested that the maser might be even stronger at submillimetre wavelengths. The masing emission probes denser regions of the sources with increasing frequency. It is known that a range of densities up to values of at least  $10^{10} \text{ cm}^{-3}$  exists in the circumstellar disks.

Thum & Matthews have observed the 353.6 GHz transition several times with both the JCMT and the 30 m IRAM telescope and it follows the predicted pattern of increasing line flux and saturation. With the JCMT they used FANATIC to detect a higher frequency transition of

H21 $\alpha$  at 662.4 GHz. The high-quality detection of H21 $\alpha$  is shown in Figure 5, constituting the highest frequency recombination line observed with radio techniques and at the same time the highest frequency astrophysical maser of any kind.



**Figure 5.** Spectra of the H21 $\alpha$  transition at 662.4 GHz (top) and of the H26 $\alpha$  transition (bottom), both obtained with the JCMT on March 9, 1994 within the space of 4 hours. For the H21 $\alpha$  line, a new SIS receiver built by the MPE group was used. The sky opacity at zenith was  $\sim 0.75$ , integration time was 1.1 hours.

The most striking feature from the H21 $\alpha$  spectrum is that the maser flux is still rising, with the increase above 250 GHz described by a power law spectral index  $a = 3.4$ . The velocity separation of the blue and red spikes of the H21 $\alpha$  transition is found to be  $50.6 \pm 0.2 \text{ km s}^{-1}$ , indistinguishable from the H26 $\alpha$  value.

Given the highly controversial physical nature of MWC349, considerable effort has been spent searching for other submillimetre masers in a large variety of astronomical objects, so far in vain. The maser in MWC349 has been monitored at many transitions over the previous 5 years.

The basic double-peaked pattern is remarkably stable with only minute variations of the spike velocity separation, in contrast with the considerable independent intensity changes of the spikes. This is not the behavior expected from a disk created by violent mass loss, typical of the final stages of a star's life. The pattern relates more naturally to a steady and massive disk, such as those built up by accretion. The high central mass derived from the disk rotation and the high ionizing luminosity required by the presence of an ionized wind and the maser then suggest a scenario in which a massive zero-age main sequence star is observed during the fleeting period in its evolution when it is no longer obscured by the nascent cloud, yet the high luminosity and powerful wind have not yet succeeded in fully destroying its accretion disk.

### 2.3 Continuum Observations of Sagittarius A\*

Sgr A\* is a compact synchrotron radio source located at or very close to the dynamical centre of the Galaxy. It is believed to be a starved black hole of roughly  $2 \times 10^6 M_{\odot}$ . The radio spectrum below 100 GHz is flat or slightly inverted and varies on time scales of a few months, whilst in the millimetre and submillimetre range the spectrum rises more steeply. No positive detections of Sgr A\* at far-infrared and mid-infrared wavelengths have been reported, but upper limits in the 8-18 micron range indicate that the spectrum must drop by more than an order of magnitude between the submillimetre and the mid-infrared regime. The exact point of this turnover has been a matter of some debate in recent years.

Zylka, Ward-Thompson & Mezger obtained the first observations of a series with long-term status on JCMT to answer the two questions: At what point in the submillimetre regime does the spectrum turn over? What is the nature of the variability of the submillimetre spectrum? To answer the first question SgrA\* was mapped at 600  $\mu\text{m}$ , in addition to 800  $\mu\text{m}$  & 450  $\mu\text{m}$ . The second question will be tackled on return visits to JCMT in subsequent semesters to repeat the observations.

Figure 6 shows the UKT14 results in the form of isophotal contour maps of the region at 800  $\mu\text{m}$ , 600  $\mu\text{m}$  & 450  $\mu\text{m}$ . The bright source seen at the centre of each map is SgrA\*. These maps represent the first detections of SgrA\* at 600  $\mu\text{m}$  and 450  $\mu\text{m}$ . These new maps show structure in the surrounding region consistent with that seen in 800  $\mu\text{m}$  & 1100  $\mu\text{m}$  data. The circum-nuclear disk extends over the central 12 pc of the Galaxy. At a galacto-centric radius of  $\sim 1$  pc the dust and hydrogen column densities drop to low values and form a central cavity. The submillimetre images show that the bottom of this cavity is rather flat with Sgr A\* located at the centre. The spectrum appears flat throughout the submillimetre regime.

It is intended to repeat the 800- $\mu\text{m}$  measurements on a six-monthly timescale, using the same telescope, with the same calibration, to check whether any variation is real, or simply an artefact of different calibrations. The detection at 450  $\mu\text{m}$  is higher than a previous upper limit of 1.5 Jy which may indicate that the source is variable at this wavelength on timescales of order 2 years.

**Figure 6:** Averaged JCMT images of the central 2 arcminutes of the Galaxy obtained with the UKT14 bolometer at 800  $\mu\text{m}$ , 600  $\mu\text{m}$  & 450  $\mu\text{m}$ . Contours are drawn in equidistant steps of 1 Jy/beam beginning at 2 Jy/beam. Axes are labelled in arcseconds offset relative to the position of SgrA\*.

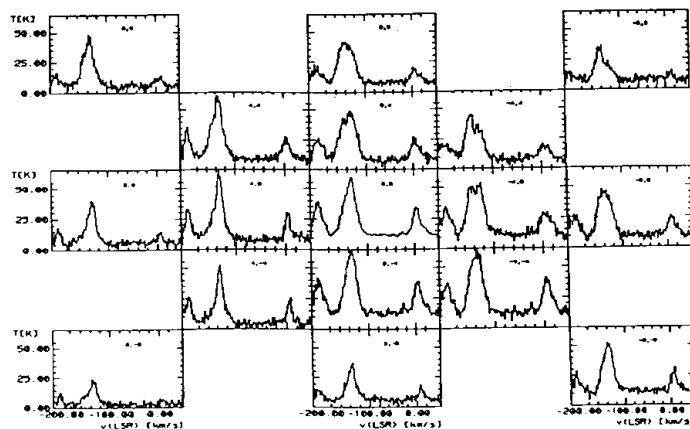
These new data have resolved some of the existing paradoxes associated with the spectrum of SgrA\*, by ruling out a dust model for the emission mechanism. Detections at 450 and 600  $\mu\text{m}$  will enable accurate modelling of the synchrotron emission mechanism which these data appear to support. Due to the variable nature of this mechanism it is proposed to continue monitoring this source with the JCMT to constrain the model more tightly.

## 2.4 First Observations with FANATIC - son of RxG

FANATIC replaces the Schottky RxG, which had been in operation at the JCMT for the past several years. This new system saw first light on the JCMT in March 1994. FANATIC's mixer is an SIS tunnel junction which was fabricated at the Institut de Radio Astronome Millimetrique (IRAM) in Grenoble, France. The instrument is tuneable over a range from 660-695 GHz. Two highlights of the first scientific use of the instrument on the JCMT are detailed below:

### (a) Mapping in, and a Spectral Line Survey of, the Orion Core

Wideband spectral line observations are complementary to spatial mapping. While spatial mapping yields information on the extent and excitation centres of sources, line observations yield information on the dynamics, energetics and chemistry within a beam. In order to get both spectral and spatial information about the excited gas in the Orion hot core and plateau areas, Harris *et al.* have spatially mapped the region in the  $\text{H}^{13}\text{CN}$  J=8-7 line and have measured the spectrum from 685-692 GHz with FANATIC.



**Figure 7:** Map of the  $\text{H}^{13}\text{CN}$  J=8-7 line in the Orion core. The temperature scale is  $T_r^*$ , with  $\eta(\text{fss})=0.2$ , appropriate for coupling to a Jupiter sized source.

For the mapping part of the program, the  $\text{H}^{13}\text{CN}$  J=8-7 line was chosen to point out the regions with dense, highly excited gas. Figure 7 displays the spectra from the map made on a 4 arcsec grid. The emission in this line is very compact, suggestive of a centrally condensed density distribution in the core region. The size of the  $\text{H}^{13}\text{CN}$  core emitting region is 4-6 arcseconds, similar to that of the  $\text{NH}_3$  and millimeter continuum regions.

The position of the  $\text{H}^{13}\text{CN}$  peak was targeted for the spectral survey. The frequency range from 685.3 to 692.1 GHz was chosen for the scan because of the plethora of strong lines present in this band. Based on linewidth, two types of lines are seen in the survey: broad lines coming from the plateau region, and strong, narrow lines presumably arising from the compact ridge. Interestingly, lines with widths characteristic of the hot core region are not seen.

Lines of SO are especially prominent and broad, exhibiting widths which indicate that they arise from the plateau. Also seen are narrow lines of  $\text{CH}_3\text{OH}$  attributable to the compact ridge. The sensitivity limit of the survey is a few degrees, and it is somewhat surprising that the forest of lines which appear in Orion surveys at lower frequencies is not evident. In particular, no lines from heavy species such as ethyl cyanide, methyl formate, or dimethyl ether are detected, nor are any species with line temperatures of 5-10 K. This may be in part due to the fact that the high frequencies are beyond the peaks of the excitation curves for the heavy molecules, which contribute so many lines in lower frequency surveys.

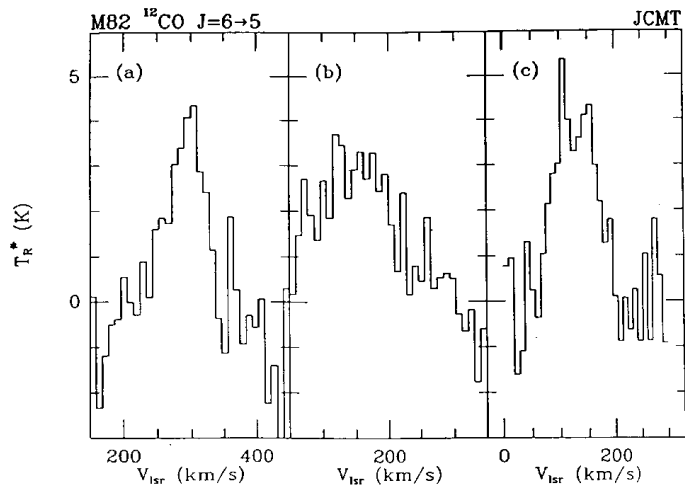
### **(b) Extended Warm Dense Gas in M82:**

The mid-J lines of CO can be used as a very sensitive diagnostic of the temperature and excitation properties of the molecular gas present in the nuclei of starburst galaxies. In nearly all nuclei where multiple lines of  $^{12}\text{CO}$  have been observed the emission is found to be optically thick. The distribution of CO intensity with increasing J is rather flat, and then the intensity decreases as the CO becomes subthermally excited. The transition at which this ‘rollover’ occurs is very sensitive to the pressure of the molecular gas. For those galaxies with large UV radiation fields and warm molecular gas, as is the case for starburst and active galaxies, the rollover is likely to occur somewhere in the mid-J transition range.

With the increased sensitivity of FANATIC over the RxG Schottky system, it has become possible to map the distribution of the warm, dense gas as traced by the CO 6-5 line in a number of nearby bright galaxies. The nucleus of M82 has been studied in detail. The distribution of the 6-5 line has been mapped around both the NE and SW low-J CO lobes, in the nucleus itself, and along the major axis. The extent of the 6-5 emission is large with line detections throughout the central 20", in the nucleus as well as in the CO lobes (see Figure 8).

The 6-5 lines are peaked at the positions of the NE and SW lobes, similar to the distribution of low-J  $^{12}\text{CO}$ . The emission is distributed throughout the nucleus and does not appear concentrated in a nuclear core nor associated with the clusters of supernova remnants.

Such a distribution, and the large extent of the 6-5 emission, indicates that the gas is primarily being heated by large scale processes, and not by the input of energetic photons into the ISM by supernovae. The fact that the emission is so widespread means that clouds with bulk temperatures of about 50 K are prevalent in the central regions of M82. M82 may not be unique among starburst galaxies. Previous 6-5 observations of NGC 253 with the Schottky RxG show that the 6-5 emission is also extended in that galaxy. Indeed, the gas which gives rise to the mid-J CO emission may well comprise a significant percentage of the molecular gas from galactic nuclei.



**Figure 8:** Sample spectra from a  $^{12}\text{CO}$   $J=6-5$  map in M82: (a) the peak of the NE CO lobe; (b) the nucleus; and (c) the peak of the SW CO lobe. The temperature scale is  $T_R^*$ , with  $\eta(fss)=0.2$ , appropriate for coupling to a Jupiter sized source.

## 2.5 Extended CO Emission around Young Stellar Objects

MacLeod & Avery have observed an unusual outflow source in Taurus, which appears to be partially hidden behind a strong absorbing screen of very cold, dense gas. The outflow is centred on IRAS 04368+2557, and most of the JCMT CO  $J=3-2$  spectra show very strong self-absorption. This young stellar object was observed with FANATIC in March 1994.

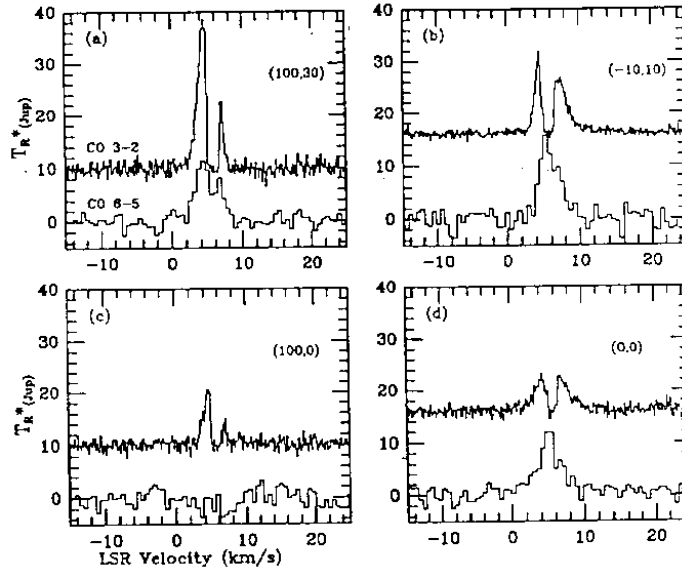
The grid map showed that the central source was extended over a region at least  $16'' \times 16''$ . Strong emission was detected at several positions well out in both lobes of the outflow, notably at hot spots on the CO  $J=3-2$  map, as shown in Figure 9.

Four CO  $J=6-5$  spectra are shown in Figure 10, superimposed on the CO  $J=3-2$  JCMT spectra from the same positions. The  $J=6-5$  spectra at  $(\Delta\alpha = 0, \Delta\delta = 0)$ , at the position of the IRAS source, and  $(-10,10)$  (Figure 10d & b respectively) show a central peak rather than a central dip, indicating that the dip in the  $J=3-2$  spectrum is due to self-absorption and not two separate velocity components.

This conclusion is supported by  $^{13}\text{CO}$  and  $\text{C}^{18}\text{O}$ , in which the central absorption is much less prominent. The situation is not so clear at  $(100,30)$  (Figure 10a), where some hint of a dip in the  $J=6-5$  spectrum exists. Figure 10c illustrates that no  $J=6-5$  emission is detected at the southern tip of the blue-shifted CO  $J=3-2$  hot spot.

In all, some 20 positions were observed in CO  $J=6-5$  of which 16 were detections. These observations represent the first time that a highly excited CO transition has been detected in the outer regions of a low-luminosity bipolar outflow.

**Figure 9:** JCMT map (both greyscale and contours) of the CO J=3-2 bipolar outflow surrounding IRAS 04368+2557 in Taurus. The map center is at RA(1950) =  $04^{\text{h}} 36^{\text{m}} 49.^{\text{s}} 30$ , Dec(1950) =  $+25^{\circ} 57' 16''$ . The upper half of the figure shows the blue lobe, with emission integrated over  $2 \text{ km s}^{-1} < v_{\text{LSR}} < 5 \text{ km s}^{-1}$ . The lower half of the figure shows the red lobe, with emission integrated over  $7 \text{ km s}^{-1} < v_{\text{LSR}} < 10 \text{ km s}^{-1}$ .



**Figure 10:** JCMT spectra at selected points within the outflow. The upper spectrum in each box is CO J=3-2, while the lower spectrum is CO J=6-5. The ordinate  $T_R^*$  (Jup) is  $T_R^*$  calculated from the main beam efficiency measured on Jupiter.

The upper energy level of the J=6-5 transition of CO is 116 K above the ground state, so there must be a relatively high excitation temperature in the core and at the hot spots. In particular, the J=6-5 emission at the CO J=3-2 hot spots may be arising from shocks occurring at the point where a stellar wind or neutral jet is colliding with dense clumps in the ambient medium.

IRAS 04368+2557 is a relatively cool young stellar source with a continuum flux density rising steeply throughout the infrared. It has an associated ammonia core which is calculated to have a radius of 0.08 pc, and a mass of  $2.4 M_{\odot}$ . This core has a high visual extinction of  $\sim 1000$  magnitudes. Continuum mapping at 800 and 450 microns suggests that 04368 is a low-mass star at a very early stage of formation.

Nearby outflow sources in Taurus, such as IRAS 04368+2557, provide an excellent opportunity to study with high spatial resolution the complex interaction which takes place between outflowing gas and the surrounding interstellar medium during the formation of low mass stars.

## 2.6 Probing Magnetic Fields in Protostellar Regions

Holland, Greaves & Ward-Thompson used the JCMT in June 1994 to make further polarimetric observations of star formation regions. Observations were carried out of VLA1623, a very young protostellar candidate in Rho Oph A, to test whether the magnetic field direction alters in the vicinity of this object, compared to that in the rest of the cloud core. They also observed a double core system in S106, comprising a massive young stellar object (S106 IR) and a submillimetre source which may be another protostar candidate (S106 FIR), to investigate if their magnetic fields were related.

The procedure used the facility polarimeter, in conjunction with the facility photometer UKT14, to observe at 800 microns, where the instrumental polarization is minimum (0.5%) and the spatial resolution is high (14" beam). The inferred magnetic field directions lie perpendicular to the polarisation vectors on the figures.

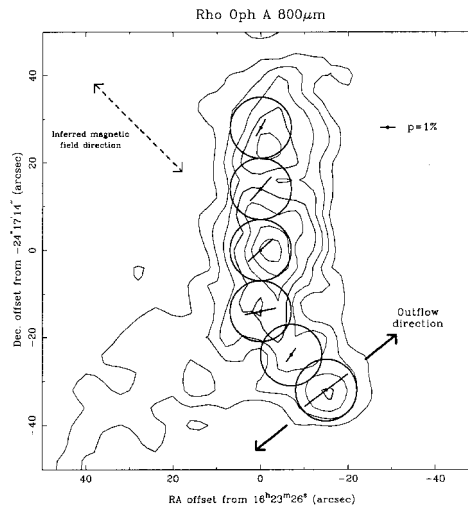
### (a) Low-mass star formation: the case of VLA1623

The Rho Oph A core is a region of low-mass star formation, which has recently been shown to contain one of the youngest protostar candidates yet discovered, the prototype Class 0 source VLA1623. This source has an extended and extremely highly-collimated bipolar outflow aligned roughly NW-SE and recent interferometer measurements show no evidence for a circumstellar disk. The question therefore arises as to what is collimating the bipolar outflow. One possible answer is that the large-scale magnetic field of the cloud is responsible for the outflow collimation. In this scenario the large-scale magnetic field in the molecular cloud should lie parallel to the direction of the bipolar outflow. The results for Rho Oph A are shown in Figure 11.

The three most southerly points are those obtained in the recent run. As the figure shows, the magnetic field deduced from the polarisation vectors is roughly parallel throughout the cloud core, lying roughly NE-SW, *i.e.* perpendicular to the direction of the bipolar outflow. There is

no evidence for any change in direction of the magnetic field from SM1 to VLA1623, where the field is aligned with the previous points, and also lies perpendicular to the outflow.

These results indicate that the large-scale field cannot be collimating the outflow. There is no apparent disk, and these observers have suggested a ‘cored-apple’ structure through which the outflow emerges. Further modelling is required to see if this structure, threaded by a toroidal or planar magnetic field, can collimate the outflowing gas.



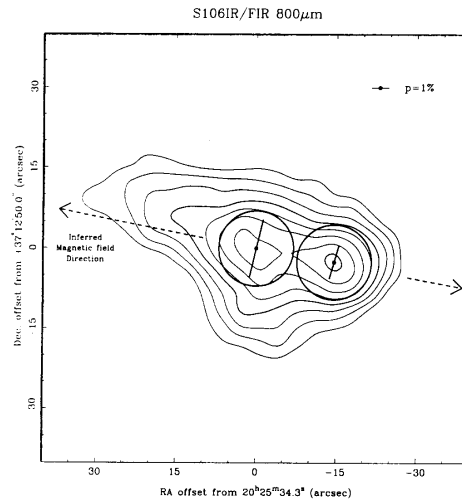
**Figure 11:** *Polarisation map of SM1/VLA1623 at 800 microns. The direction of polarisation appears roughly constant across the whole region, implying a magnetic field direction running roughly NE-SW through the cloud, even at the position of VLA1623, the southernmost polarisation vector.*

### (b) High-mass star formation: the case of S106

The S106 HII region has a bipolar morphology, aligned roughly N-S, bisected by a lane of obscuration running approximately E-W. At the centre of the system lies the near-infrared source S106-IR. The dark lane was originally hypothesised to be a circumstellar disk but recent high resolution 450-micron observations showed that the supposed disk breaks up into a number of fragments, the brightest of which, S106-FIR, is a candidate protostar. Submillimetre polarimetry of S106-IR and S106-FIR was undertaken to ascertain the magnetic field direction in these two sources, and to look for any correlation between the two.

Figure 12 shows an 800-micron isophotal contour map of S106, with the two submillimetre polarisation measurements at the positions of S106-IR and S106-FIR superposed. The dark lane of optical obscuration appears as an approximately E-W band of emission at 800 microns. It can be seen that the two sources are both polarised in a similar direction, and that the inferred magnetic field (perpendicular to the polarisation vectors) lies roughly along the lane of 800-micron emission. The alignment of the field directions in the two young objects may have interesting implications for our understanding of the formation of binary star systems.

Recent Zeeman observations detected a strong magnetic field in the lobes of the S106 HII region, with a much reduced field in the vicinity of the dark lane. This was interpreted as a large-scale magnetic field, aligned N-S, parallel to the alignment of the bipolar HII region, which is pinched into an hour-glass shape in the vicinity of the central star. The present observations appear to contradict this scenario, by showing that the field is lying roughly E-W in the vicinity of the star.



**Figure 12:** Polarisation map of S106IR/S106FIR at 800 microns. The direction of polarisation of the two sources infers a magnetic field direction parallel to the broad lane of 800-micron emission.

The following hypothesis is suggested to explain both the present data, and the Zeeman data. The large-scale magnetic field lies N-S along the bipolar HII region, but close to the star the field may be twisted into a toroidal morphology around the central star. The resultant field lies parallel to the dust lane in the small JCMT beam, but diverges back to the large-scale N-S field on larger scales. At the centre, the two competing field directions are seen simultaneously in the larger beam Zeeman observations, causing an apparent reduction in the observed magnitude of the magnetic field.

## 2.7 Polarisation measurements in DR21 and NGC 7538

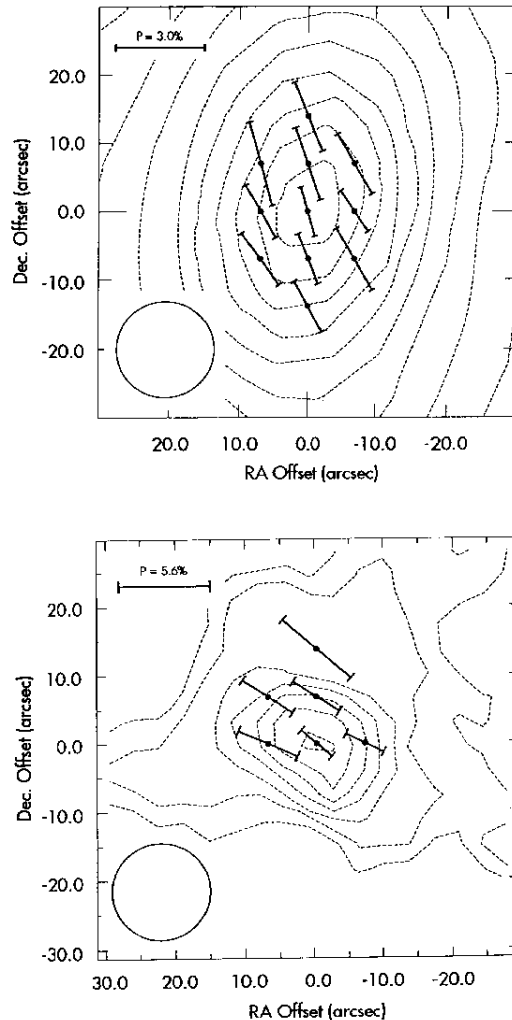
The role of magnetic fields in both the initial collapse of molecular clouds to form protostars and their subsequent evolution to the main-sequence via the outflow phase, is still unclear. Gravitational collapse may follow the magnetic field lines of the parent molecular cloud, producing a flattened, slowly rotating core, which will continue to collapse as turbulent and magnetic support is lost due to ambipolar diffusion. One might then expect a correlation between the outflow axis and the magnetic field lines of the parent molecular cloud.

Minchin & Murray have detected 800 micron polarization at the flux peak and positions around the outflow sources DR21 and NGC7538. The polarimetric data for both DR21 and IRS11 are

shown in Figures 13a and 13b respectively. The directions of the polarization vectors are extremely uniform and the dispersions are identical.

The direction of the magnetic field around DR21 is not aligned with either the direction of the outflow axis or the major axis of the submillimetre circumstellar dust structure. As the DR21 region is extremely complex, possibly containing 3 outflows in close proximity, the non-alignment may not be significant.

For NGC7538-IRS11 the magnetic field is aligned with the outflow axis, implying that within the resolution of the observations (14'' FWHM) the circumstellar magnetic field is poloidal.



**Figure 13:** (a) The observed polarization data for DR21 overlaid on contours of the 800 micron continuum emission; (b) The observed polarization data for NGC 7538-IRS11 overlaid on logarithmic contours of 800 micron continuum emission. The position of each observation is shown as a small filled circle and the size of the 800 micron telescope beam is shown in the bottom left-hand corner (14''). The data points are represented by bold lines, the direction of which indicates the position angle of the polarization.

The directions of the molecular outflows, magnetic fields and dust ridges for both IRS11 and its neighbour IRS1 (60''/0.9 pc to the north) are identical. As IRS1 and IRS11 are linked by an arm of submillimetre emission and form an elongated dust ridge orthogonal to the ambient magnetic field of the NGC7538 region, part of the cloud may have collapsed along the magnetic field lines to produce the core from which IRS1 and IRS11 have formed.

A marked increase in the observed percentage polarization from DR21 at longer wavelengths implies the grain composition cannot be predominantly silicate, but is mainly graphite/metallic, and may require grains of different magnetic susceptibility or varying elongation to also be at different temperatures along the observed line of sight.

The percentage polarization at the position of the flux peak for each outflow source is low compared to that at the offset positions. This has been noted for several other outflow sources and is commonly referred to as a polarization 'hole'. It is unlikely that either the effect of flux contamination by unpolarized line emission or reduced grain alignment/changes in the grain size distribution or composition could be responsible. The most plausible explanation is a change in the magnetic field alignment in the vicinity of the outflow source. Poloidal magnetic field lines may become directed closer to the observers line of sight in the vicinity of the outflow source, or the magnetic field lines close to the outflow source may become twisted, possibly due to the presence of a toroidal field in a circumstellar disc.

## **2.8 L1582B - A Molecular Superjet**

The picture on the back cover of this Annual Report is a CO J=2-1 map of the bipolar outflow associated with RNO43 in the L1582B dark cloud. These data were taken by Bence, Richer & Padman using the JCMT. As shown by the scale bar, this outflow (which is nearly in the plane of the sky) is at least 4 pc long.

This source is one of a select few that show both collimated molecular outflow and optical emission associated with a so-called 'optical jet'. On the cover Figure the H $\alpha$  optical emission is overlaid on the CO map. Since the H $\alpha$  emission is generally thought to be indicative of shocks at a velocity of at least several tens of km/s, this seems to be excellent evidence for a molecular outflow driven *directly* by the optical jet. This could indicate a highly collimated, mostly neutral jet, which is ejected from the unseen star at a speed of about 300 km/s. As the jet propagates through the surrounding cloud it generates the familiar 2-shock structure: since the shocks are highly radiative the shocked material cools rapidly into a dense swept-up shell, which then generates the observed optical emission. As the shell cools further and continues to expand away from the jet, it sweeps up molecular material that forms the observed CO outflow.

One remarkable feature of the CO map is just how lumpy the outflow is. Channel maps show that there are very high velocity features associated with each of the bowshocks, and that the CO excitation is high there.

It is worth noting that the tails of individual CO bow shocks do not extend all the way back to the source. In the observers' model this is a consequence of the relatively short cooling time for the hot

molecular material. Assuming a velocity of 300 km/s and a distance of 450 parsec, the 150 arcsecond tail corresponds to a cooling time of only 1000 years, which is much less than the dynamical timescale. The observed hotspots are therefore the sites of *current* interaction between jet-fragments and the ambient cloud. It looks as though the jet fragment is rather denser than the environment, and therefore should appear to move with something like the true jet speed

The inner region has been mapped with almost full sampling, as shown in the blow-up on the cover. Numerical modelling of the Cygnus-A region shows that the nice fluffy cocoons observed around the bowshocks result from the interaction of an *underdense* jet with the surrounding medium when the cooling time scale is *long* with respect to the dynamical time. With a (molecular) cooling time of around a 1000 years, which is about the same as the dynamical timescale of the ‘inner’ outflow, this also seems fairly reasonable. These observers have hypothesised that for NGC 2024, the jet in the inner regions of the source is less dense than the surrounding cloud, and perhaps the same is true here; presumably the cloud density falls off fairly rapidly away from the far-infrared source, but this is something that can be fairly readily checked.

Whatever the final extent of the L1582B outflow may prove to be, it is already clear that it has managed to shock a very large volume of its parent cloud, and furthermore, the cloud retains a memory of this shock, in the form of broadened lines, long after any particular shock has passed by. So indeed it looks as though outflows can do a lot to keep the interstellar medium stirred up.

## 2.9 Cooling Flow Gas in NGC 1275

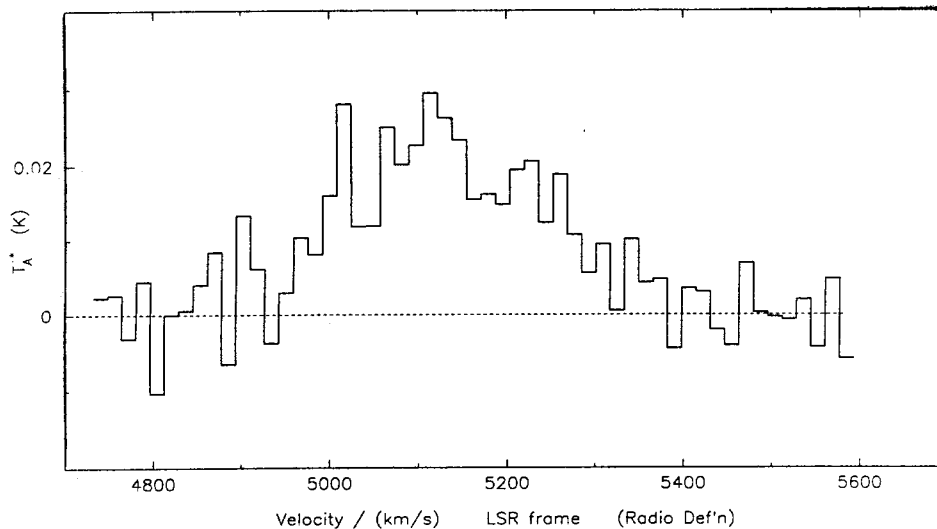
X-ray data have revealed evidence for the infall of typically several hundred solar masses of gas per year in many galaxy clusters, with these cooling flows focussed onto centrally-located giant elliptical galaxies. However, the fate of this infalling gas is still largely a mystery, as there is little evidence for it at other wavelengths. On average,  $10^{11}$  —  $10^{12}$  solar masses of material should be deposited in a Hubble time, and some fraction of this material should be found in cool atomic and/or molecular clouds. However, NGC 1275, the giant elliptical galaxy at the centre of the rich Perseus cluster, is the only cluster cooling flow galaxy which has been detected in CO. NGC 1275 thus presents a rare opportunity to learn about the physical conditions of cooling flow gas.

Bridges & Irwin used the JCMT in November 1994 to observe NGC 1275 in CO emission. They observed  $^{13}\text{CO}$  (2-1) at the galaxy centre and also obtained a 9-point map in  $^{12}\text{CO}$  (2-1) with 7 of the points lying within 20 arcseconds of the galaxy centre and 2 points 40 and 60 arcseconds from the centre.

Figure 14 shows the  $^{12}\text{CO}$  (2-1) at the galaxy centre. The beam size at 230 GHz of 20 arcsecs corresponds to 6.8 kpc at the distance of NGC 1275 ( $H_0 = 75$  km/s/Mpc). The  $^{12}\text{CO}$  detection is quite strong, and  $^{13}\text{CO}$  (2-1) is also detected, though these data are noisy and require better baseline subtraction. The  $^{13}\text{CO}$  (2-1) data provide an important constraint for subsequent analysis using a radiative-transfer code. There also appears to be a velocity offset of 50-100 km/s between the  $^{12}\text{CO}$  and  $^{13}\text{CO}$  emission at this position. A weak detection of  $^{12}\text{CO}$  (2-1) emission as far as 1 arcminute from the galaxy centre, corresponding to  $\sim 20$  kpc, has also been

made. This is still well within the cooling radius of  $\sim 100\text{-}200$  kpc however, and it is important to carry out further mapping to determine the CO distribution in this galaxy/cluster.

More time is being requested to acquire CO (3-2) data, at least for the central position which, together with the CO (2-1) data and maps, should enable constraints to be placed on the density, kinetic temperature, and CO content of the molecular gas in this most unusual region. These data will thus eventually lead to a much better idea of the physical conditions in cooling flow gas, and may shed some light on the nature and final state of the inferred large amounts of infalling material.



**Figure 14:** *The average of 7 x 10-minute scans (obtained in beam-switching mode) for  $^{12}\text{CO}$  (2-1) at centre of the NGC 1275 galaxy. These data have been binned by 20 channels, giving a velocity resolution of 16 km/s, and are baseline-subtracted.*

## 2.10 Results from Short Baseline Interferometry

There was just one short-baseline interferometry run linking the JCMT with the Caltech Submillimetre Observatory's telescope during 1994, and that took place in late October and early November. Unfortunately the weather conditions were generally rather poor, with a substantial snowfall in the middle of the run, but it was possible to obtain some useful astronomical observations and a good deal of progress was made on improving the performance of the instrument.

The most interesting new results were on the young stellar system known as NGC 1333 — IRAS 4. Earlier single-dish observations with the JCMT had shown that this consists of two dense objects about 30 arcseconds apart which appeared to contain protostars deeply embedded in dust and gas. With the interferometer it was possible to resolve further structure in each of these. The visibility

data on the north-western source IRAS 4A can be fitted by a simple binary with a 1.8 arcsecond separation, whereas that on 4B requires a more complicated model — there are apparently at least 3 components and probably more.

Data were also obtained on the recombination-line maser source MWC349. The interesting question here is the angular separation of the spectral features. The results from this run were encouraging, although more observations will be required before the desired accuracy can be achieved.

The technical highlight of the run was a successful first test of the interferometer at 493 GHz. This required additional frequency offsetting stages in both the LO and IF systems, because of the different designs of the JCMT and CSO receivers at this frequency. The system was tested both on an artificial source and on one astronomical object — a quasar — but the bad weather prevented any new scientific results. Other important steps were: 1) the installation of a new system to transfer the 10 MHz frequency reference between the telescopes — this overcame problems of phase jumps seen on previous runs; 2) a big improvement in the phase stability — this was a result of better baseline determination and corrections to some terms involved in modelling the atmosphere; and 3) a much improved software system for communicating between the telescopes, enabling all the actions to be controlled from one console.



### 3. Operations

One of the major events of the year was the successful commissioning of the visitor instrument from the Max Planck group. This is a 600 GHz SIS receiver, FANATIC which replaces their earlier instrument, RxG. Some details of this project are described earlier in the science highlights. Other operational details are described briefly below.

#### 3.1 Weather and Usage Statistics

The weather and usage statistics for the 12-month period from 1st February 1994 to 31st January 1995 (PATT Semesters 94A and 94B) are compared with values for previous years in the following table. The percentage Fault Loss to Primary Programmes is defined as: Fault Loss / Time Observed. Further details can be found in Appendix C. The figures in the table may not add correctly due to rounding and to errors in the earlier datasets. Calculation errors from previous Annual Reports have been corrected here. The figures do not include values for Backup Programs although these are displayed in the Appendix.

	R & S		T & U		V & W		X & Y		94A & 94B	
	Hrs	%	Hrs	%	Hrs	%	Hrs	%	Hrs	%
Time Available	4680	100	4662	100	5015	100	5661	100	5724	100
Time Observed	3522	75	3946	85	3829	77	4476	79	4458	78
Weather Loss	911	19	470	10	919	18	1026	18	1266	22
Clear Fault Loss	240	6.4	246	6.4	267	6.5	159	3.4	213	4.8

Poor weather was evident for the first couple of months of 94A but improved in March to provide excellent conditions over a seven day period for the commissioning of the new high-frequency instrument, FANATIC. During this time the CSO tau never exceeded 0.07 and was below 0.04 for more than 70% of the period. After a relatively dry spell in the middle of semester 94A the weather deteriorated drastically in July, culminating in hurricane Emilia, the most powerful hurricane ever recorded in mid-Pacific, with sustained winds of 160 mph and gusts to 200 mph. Several other storms followed in close succession resulting in an average time loss to weather of 25% for the semester as a whole. The bad weather continued well into semester 94B with only an extended period of dry conditions in December helping to maintain the loss at about 25%.

An unacceptably high fault loss in February led to modifications to procedures for: release into service after system alterations; correct application of end-of-day checks and the methodology of systematic diagnosis of problems when they occur. Unfortunately these niggling problem areas have continued throughout both semester 94A and 94B. Although the bulk of the problems during 94A in the Antenna and Software categories are attributable to one-off problems (in particular a severe failure of the Secondary Mirror Unit (SMU)), at least some faults could have been prevented by more systematic procedures.

### **3.2 Antenna & Carousel Status**

After completion of the second focal length change and post-engineering adjustments, in April attention was turned to the problem of the loss of homology. Flexure in the joints at the top of the cone-bars (of tens of microns in some instances) became a prime suspect as the cause of the problem. After some preliminary tests in June, all twelve joints were wedged and then the wedges were welded into place. As anticipated, this distorted the surface and poor weather combined with failure of the measuring equipment prevented holographic and out-of-focus maps being taken until after August. In October, 450 micron beam maps gave an exceptionally poor result. Extensive investigations revealed that the secondary mirror may have been damaged during testing in September. In November, the surface was adjusted to take out any deformations due to the secondary and this has resulted in the best surface ever. Further testing in December revealed that welding the cone-bars has cured the homology problem to the accuracy which can currently be measured (10%).

The SMU suffered a catastrophic failure in May, when an electrical fault caused damage to all four vibrators, a stinger and a flex pivot. The damage was repaired within two days but chopping was restricted to E-W for the remainder of semester 94A. In September, the SMU was restored to complete operation with improved interlocks and other hardware upgrades.

The new inclinometer system has been in use since September. This is a major improvement over the old system and has already contributed to increased pointing accuracy and reliability.

Very little down-time to carousel faults has been logged since the completion of the bogey work on main drives and roof units. Work on the power and grounding systems has proceeded extremely well.

### **3.3 Receiver Status**

No new instruments were commissioned during the year and considerable effort has been placed into maintaining and upgrading present instrumentation. Support has also been given to two visiting instruments, the Max Planck group's new 600 GHz SIS receiver (FANATIC) and the Canadian FTS.

RxA2 continues to suffer from cryogenic problems, mainly due to the poor hold-time. The phase-lock has been replaced with the unit from RxB2 which should remove a major source of faults and also provide an improved performance for observing narrow lines.

RxB3i and RxC2 have shown excellent sensitivity and reliability throughout the year .

A programme of standard spectrum observations was instituted in March as part of improved start-of-shift checks, and also to improve the understanding of the heterodyne instruments' performance. Analysis of these data suggest that in most cases the line intensities are consistent

but, on some occasions, the observed spectrum deviates significantly from the standard (in intensity or lineshape). The majority of deviant cases can be explained by known hardware problems or poor observing technique but further studies are required for the small remaining cases.

UKT14 continues to be the most used instrument and survived the year with little trouble other than irritating problems with an occasionally sticking filter wheel drive. New micro-switches have been installed to cure this problem.

There have been a number of improvements made to the DAS in 1994. The baseline problems seen in 1993 were reduced significantly by the replacing the total power detectors and optimising their frequency response. Software improvements have been made in the areas of calibration and real-time display. Two sampler modules were diagnosed as faulty and returned to NFRA for repair.

### **3.4 Software**

The majority of software work on the on-line systems continues to be devoted to the development of the heterodyne instrument software and support for engineering projects. Considerable effort has been put into the DAS D-task to include improved diagnostics, continuously updated calibration, and display of the updated spectrum at the end of each cycle. Work continues on support for the development of RxW and RxB3 control software at the well-found labs alongside modifications of existing D-tasks to cope with in-house upgrades to the hardware (*e.g.* the installation of the RxB2 phase-lock on RxA2). Other examples of engineering support include the development of data-acquisition software for the carousel strain-gauge and inclinometry systems.

Improvements continue to be made to the Unix systems, including the installation of workstations at the summit and Hale Pohaku and the release of beta-test Unix versions of SPECX and JCMTDR. A new system for visiting observer accounts was released at the start of semester 94B. Progress on the new Sybase telescope management system continues, observations are now routinely being inserted into the database and a number of utilities are available for monitoring the status of the facility (*e.g.* receiver temperature as a function of time) are under development. The JCMT software wish-list has been revived and work has started on an overhaul of the local utility software, in order to improve functionality and portability.

### **3.5 ROE Support Group**

Unfortunately, distribution of the Annual Report (and of the JCMT Newsletter Number 3) was slower than anticipated and new methods are under investigation to improve production techniques, increase the mailing list and speed up the distribution. Two issues of the JCMT Newsletter were published during 1994.

Observers' data continued to be added to the archive database at ROE. From 1st December 1994 the ROE Vaxes are no longer directly accessible externally. It is the intention that the new JAC database will automatically forward astronomical data to the Canadian Astronomical Data Centre (CADC) and this will shortly become the formal data archive.

**Figure 15:** *The Telescope category includes time for calibration, collimation, surface adjustment & efficiency measures.*

## 4. Instrumentation Programme

This section outlines the progress made on the JCMT instrumentation programme during the year 1994. The activities carried out under the auspices of the Development Fund are summarised and set against the current instrumentation plan.

### 4.1 Long Term Development Plan

After being endorsed in principle at several meetings, the Board has now approved a development plan for the JCMT which extends to the end of the Century.

#### 4.1.1 Upgrades programme

The Upgrades Programme has long been identified as a key part of the JCMT long-term instrumentation development plan. Its goal is to keep our current instruments state of the art by a series of upgrades. The Board has funded HIA to undertake two projects for the Upgrades programme:

*The Development of Heterodyne Mixers to Upgrade JCMT Receivers.* This programme is targeted at developing low noise mixers at all JCMT wavebands; first at A-band, followed sequentially by B, C, D and ultimately E-band. Once a viable upgrade has been identified an additional proposal will be made to perform the actual receiver upgrade.

*The Conversion of Receiver B3i to Receiver A3.* This work will produce a new A-band receiver based on RxB3i by autumn 1996. Once RxB3i is converted to RxA3 we will have a fully automatic single polarisation facility receiver with a noise temperature of 50K DSB (goal). The IF bandwidth will be increased to 1.5 GHz to allow extragalactic observations. A dual polarisation option for RxA3 is currently under review.

#### 4.1.2 SIS Junctions

The entire heterodyne instrument development programme for the JCMT is reliant on the provision of SIS junctions. Currently the best performance is being obtained using RUG (University of Groningen — SRON) Niobium devices. The present contract is funded through FY 1995/96 and the Board has endorsed the principle of extending this contract to the end of 1999 (the duration of the Development Fund). RUG—SRON will be able to meet the requirements of both the Upgrades Programme, the Array Programme, and the present commitments on the Innovative New Projects Programme.

#### 4.1.3 Heterodyne Focal Plane Arrays

The provision of heterodyne focal plane arrays for the JCMT should be seen as the first step in a long-term new programme for the next Century. It is anticipated that dual polarisation instruments will effectively become quantum noise limited by the year 2000 (at least at A, B, C & D-bands). Under these circumstances, the only way to increase data rates is to move to focal plane arrays.

A detailed proposal to build a B-band focal plane array system for the JCMT has been produced by the B-band array working group. This will deliver phase 1 of the B-band array—a 16 pixel B-band camera (SWIFT), a  $16 \times 2$  GHz bandwidth spectrometer (MIDAS), and the necessary infrastructure by 1999. Due to limitations of funding and other calls on the Development Fund, the Board has approved funds for an intensive R&D phase to allow us to move towards the completion of phase 1.

#### 4.1.4 Interferometry

The JCMT Advisory Panel highly recommended the move to sub-arcsecond resolution astronomy by the end of the decade. This goal would best be achieved through a significant involvement with the Smithsonian (Sub Millimeter Array) project. The Board has approved a programme which involves continued upgrades to the JCMT-CSO interferometer, together with providing the necessary infrastructure to allow a link to be made with the SMA.

## 4.2 Current Instrumentation Programme

The instruments currently under development and construction are SCUBA, RxB3 and RxW.

## 4.3 Status of Instruments Under Construction

### 4.3.1 SCUBA -- ROE (/QMW/Maynooth)

During the past 9 months, a major series of modifications to SCUBA have been carried out in order to cure two major problems which were preventing the achievement of stable noise performance within specification. These modifications have been completed and SCUBA reassembled and cooled, and preliminary results are now available.

The two problems were radio frequency (RF) interference and microphonics. The RF problem has been solved by a more or less brute force method, whereby *all* possible points of entry into the cryostat or analogue part of the external signal processing electronics have been RF-filtered and shielded. The microphonics problem has proved far more subtle and has only been reduced with an innovative development of a new design of superconducting ribbon cable, which has also meant redesigning the array printed circuit boards.

The modifications have been extremely successful in reducing the RF and microphonics problems. Detector and electronics noise is within specification and more importantly is now very stable. Photon-noise limited sensitivity has been demonstrated under a simulated Mauna Kea background at  $850 \mu\text{m}$  and is reproducible. These results were obtained with the closed cycle cooler switched off. With the closed cycle coolers on there is still a residual detectable level of microphonic pickup. RF pickup appears to have been eliminated. Optical tests have now been started, which form the first part of the laboratory commissioning of SCUBA observing modes proper.

#### 4.3.2 RxW -- MRAO (/Maynooth/RUG-SRON)

Since the last report, RxW has continued to make good progress. At the last project meeting on 5th September further excellent C-band mixer results were reported. The latest junction produces noise temperatures as low as 60K in the test Dewar. If the performance in the receiver is as low as 70-80K, we can expect to see an order of magnitude increase in data taking speed over RxC2.

After careful evaluation, SRON have been chosen to supply the production D-band mixers for RxW.

#### 4.3.3 RxB3 -- HIA (/RAL/UKC/RUG-SRON)

At the RxB3 project meeting on the 26th September, progress on RxB3 was reviewed. The expected delivery date of the receiver has been revised to summer 1995.

At the project meeting a new performance specification and goal was agreed. The specification is better than 100K across the band with a goal of 70K. If this goal is achieved then we can look forward to a full order of magnitude increase in speed over the best performance of RxB3i.

Recent testing of the most recent batch of devices from RUG has produced noise temperatures of around 80K at 345 GHz.

### 4.4 Innovative New Projects

At its May 1994 meeting the JCMT Board approved three innovative new instrumentation projects. These were as a result of the call for proposals published in the last JCMT newsletter.

The response was very encouraging with six excellent proposals. The proposals were first refereed for scientific merit by a referee from each of the partner countries plus a specialist referee, and then were placed in priority order by the JCMT Advisory Panel.

The three proposals which were funded are:

- Proposal to upgrade Receiver C2 to E-band (800 to 900 GHz). *B.N. Ellison, L.T. Little & W.R.F. Dent*

When RxW (which will operate at both C- & D-bands) is delivered in 1995, RxC2 will be returned to RAL and will be refurbished as an E-band receiver.

- A Proposal to Investigate the Design of SIS Receivers for Submillimetre-Wave Extragalactic Astronomy. *S. Withington, R.E. Hills & R.G. McMahon*

This proposal is to investigate a number of technical developments aimed at improving the telescope for extragalactic spectral line work. As part of the study a prototype broad band SIS mixer will be developed and tested.

- *A Common User Polarimeter for SCUBA. P.A.R Ade, A.G. Murray, M.J. Griffin, W.K. Gear, J.P. Vallée, P. Bastien, W.S. Holland & M. Tamura*

This is the first step towards the development of a facility polarimeter for SCUBA. The work will involve assessing the viability of using the existing UKT14 polarimeter with SCUBA and the development of achromatic wave plates and associated hardware for a common user polarimeter.

## JCMT Shared Operations Costs & Outturns 1994/95

	\$k	£k
<b>1 MAUNA KEA OBSERVATORY</b>		
1.1 Utilities, Telephones	81,600	0
1.2 Telescope maintenance, development	45,800	0
1.3 Building maintenance, development	30,000	0
1.4 Road maintenance, snow clearing	24,000	0
1.5 Cryogenes	159,900	0
1.6 Receiver maintenance	39,600	0
1.7 Computer systems	46,300	0
1.8 Projects	<u>214,000</u>	<u>0</u>
<b>    subtotal 1</b>	<b><u>641,023</u></b>	<b><u>0</u></b>
<b>2 MID-LEVEL FACILITY</b>		
2.2 Daily lodging at Hale Pohaku	110,100	0
2.3 Library	6,200	0
2.4 Visitor Centre, Emergency services	9,700	0
2.5 Computer systems	<u>1,700</u>	<u>0</u>
<b>    subtotal 2</b>	<b><u>127,740</u></b>	<b><u>0</u></b>
<b>3 SEA-LEVEL FACILITY</b>		
3.1.1 Office equipment	18,100	0
3.1.2 Hilo telecoms	22,200	0
3.1.3 Hilo utilities	43,700	0
3.1.4-9 Post/admin/safety/etc	49,200	0
3.1.11 Library	14,700	0
3.1.12 Building maintenance	29,200	0
3.2 Vehicle procurement & maintenance	71,200	0
3.3 Computer systems	81,700	0
3.4 Computer communications	16,100	0
3.5 Projects	<u>69,900</u>	<u>0</u>
<b>    subtotal 3</b>	<b><u>415,816</u></b>	<b><u>0</u></b>
<b>4 STAFF COSTS</b>		
4.2 Locally recruited staff	1,367,100	0
4.2.1 Director	95,000	0
4.3 Travel/subs/conf/training	<u>79,600</u>	<u>0</u>
<b>    subtotal 4</b>	<b><u>1,541,620</u></b>	<b><u>0</u></b>
5.1 JCMT Fellowship	<u>70,100</u>	<u>0</u>
<b>    subtotal 5</b>	<b><u>70,089</u></b>	<b><u>0</u></b>
<b>6 ROE SUPPORT</b>		
6.1 Scientific admin, travel, interactive management	0	37,400
6.1.2 Interactive Management	0	22,400
6.2.1 Computer systems	0	1,700
6.2.2 Data lines	0	0
6.2.3 Archiving	0	0
6.3 Support at telescope	<u>0</u>	<u>0</u>
<b>    subtotal 6</b>	<b><u>0</u></b>	<b><u>61,533</u></b>
<b>TOTAL</b>	<b>2,796,288</b>	<b>61,533</b>
Allocation & carryover (target outturn)	2,258,623	87,550
Receipts	<u>534,871</u>	<u>0</u>
Difference from Board Allocation	2,794	-26,017

note: subtotals do not necessary add within headings due to rounding on the individual items.

## 5. Financial Statement

Financial statements are given for the JCMT Internationally Shared Operations Costs and for the JCMT Development Fund. The statements give information on the outturns for the year ended 31 March 1994. The partners contribute to these costs in the proportion UK (55%), Canada (25%) and the Netherlands (20%). The staff costs of the separate partner countries are not shown, on the understanding that the partner countries contribute staff at their own cost in approximately these proportions.

### 5.1 Shared Operations Costs

The costs are divided into subtotals associated with the telescope facility on Mauna Kea, the mid-level facility at Hale Pohaku, the sea-level facility in Hilo and the JCMT support in Edinburgh. The staff costs shown correspond to the cost of the local staff employed primarily by the Research Corporation of the University of Hawaii.

The JCMT Board approved an allocation for 1994/95 of \$2,284,000 and added a carryover of \$74,027 from the previous year. The Director was requested to manage an underspend of \$99,404 in 1994/95. Taking into account the carry-over and the planned underspend, the outturn is a small overspend of \$2,794.

### 5.2 Development Fund

The JCMT Development Fund is funded at a level of £500k per annum. The partner countries contribute in proportion UK (55%), Canada (25%) and the Netherlands (20%).

The primary purpose of the Development Fund is to provide front rank receivers, bolometers and spectrometers for the JCMT, and to enhance the facility. It is expected that in the long term the partner countries will receive funds in proportion to their contributions.

#### JCMT Development Fund — Outturns Summary

	94/5 £k	Cumulative £k	% nat.share
UK	181.2	2312.6	61.0
Canada	0	665.4	17.5
Netherlands	36.3	815.9	21.5
Shared	158.2	*	*
Total	375.7		

\* In calculating the % national share, the costs in the 'shared' row have been apportioned to UK, Canada, and Netherlands in the ratios 55:25:20.

## JCMT Development Fund — Outturns 1994/95

Approved Projects	Prime Contractor	Approved by Board £k	Spend to 31/3/95 £k	Outturn 1994/95 £k
<b>Netherlands Contracts</b>				
DAS software	NFRA	15.0	21.9	18.8
SIS junctions	SRON	196.9	131.1	<u>17.5</u>
				<b>36.3</b>
<b>Canadian Contracts</b>				
MIDAS	HIA	201.7+185 <sup>†</sup>	0.0	0.0
Rx B3	HIA	233.0	219.8 <sup>¶</sup>	<u>0.0</u>
				<b>0.0</b>
<b>UK Contracts</b>				
Rx W	MRAO	225.0	297.7	100.0
SIS junction	Cambridge *	67.5	47.0	13.3
SCUBA	ROE	790+47 <sup>†</sup>	782.9	61.0
D-band mixer	RAL	46.5	31.1	<u>0.3</u>
				<b>174.6</b>
<b>International Contracts</b>				
Optics design	Maynooth	20.0	16.2	6.7
<b>Other Approved Expenditure</b>				
Management travel				0.0
Facility upgrades				<u>158.2</u>
				<b>164.8</b>
<b>OUTTURN TOTAL</b>				<b>375.7</b>

\* Department of Metallurgy, Cambridge University.

† Additional expenditure approved during 1994-95.

¶ This is accumulated spend for both Canadian & UK segments.

## Appendix A: Time Allocation - Semesters 94A and 94B

Most proposals come from collaborations, but for brevity only the principal applicants and their institutions (when they submitted the application) are given below.

### Semester 94A (1st February 1994 → 31st July 1994)

L W Avery, HIA	A targeted search for shock-enhanced interstellar chemicals
P Bastien, University of Montréal	Submillimetre polarisation survey of molecular clouds
P H Coleman, University of Groningen	Blazars in nearby radio galaxies
J T Daines, University of Calgary	Submillimetre continuum spectra of ultra-compact HII regions
G R Davis, University of Saskatchewan	Search for tropospheric HCN in Jupiter
Th de Jong, SRON	CI in IRC+10216
W R F Dent, JAC	The gas:dust ratio around Vega
W R F Dent, JAC	Temperature structure in massive disks and the usefulness of molecular thermometers
W R F Dent, JAC	Relationship between the optical and molecular jets in HH111
W R F Dent, JAC	The $^{12}\text{C}/^{13}\text{C}$ ratio in dark clouds
J P Emerson, QMW	Millimetre polarisation and dust grain alignment in disks of young stellar objects
A Evans, University of Keele	Millimetre continuum observations of carbon stars
A S Evans, University of Hawaii	Submillimetre spectroscopy of high redshift radio galaxies
W K Gear, ROE	Millimetre polarimetry of blazars: are jets in BL Lacs and quasars the same or different ?
M J Griffin, QMW	Does high-velocity outflow begin in the earliest stages of star formation? - a survey of L1641

M J Griffin, QMW	The luminosity:circumstellar mass relationship for young stellar objects: a submillimetre survey of L1641
A I Harris, MPE	A short-submillimetre line survey of the Orion-KL region
F P Helmich, Leiden Observatory	W3 chemistry
Th Henning, Leiden Observatory	CS in disks around very young stars
R E Hills, MRAO	Continued search for C <sup>+</sup> emission (and other lines) from high redshift quasars
R E Hills, MRAO	CO excitation and gas masses of infrared luminous galaxies
W S Holland, JAC	Investigating the magnetic field structure around candidate protostellar objects
F P Israel, Leiden Observatory	CI in galaxy centres
R J Ivison, University of Toronto	Are there masers in symbiotic Miras?
W J Jaffe, Leiden Observatory	Nuclear disks in Virgo ellipticals
D Jewitt, University of Hawaii	Submillimetre continuum studies of comets
G Joncas, University Laval	G104.7+2.8S, a supernova remnant-molecular cloud interaction site?
S Kwok, University of Calgary	CO emission from planetary nebulae with large infrared excesses
E F Ladd, University of Hawaii	Submillimetre continuum observations of stellar density enhancements
E F Ladd, University of Hawaii	Observations of star-forming dense cores with rare isotopes of CO
A N Lasenby, MRAO	High negative velocity emission in the Galactic Centre

S -W Lee, Queen's University	CO observations of NGC3044
L T Little, UKC	CI/CO ratio in molecular cloud cores associated with low mass young stellar objects
L T Little, UKC	CI/CO observations of massive molecular cloud cores
M S Longair, MRAO	A study of dust in high redshift radio galaxies
G H Macdonald, UKC	The circumstellar structure of IRAS 18265-1517
J M MacLeod, HIA	Observations of dense, warm gas associated with the young stellar object IRAS 04368+2557
A P Marscher, University of Boston	Multifrequency monitoring of $\gamma$ -ray bright blazars
R D Mathieu, University of Wisconsin	The evolution of disks around young binary stars
H E Matthews, JAC	A high-frequency hydrogen recombination line maser
H E Matthews, JAC	A search for vibrationally excited NH <sub>3</sub> in galactic sources
W H McCutcheon, UBC	A 335-365 GHz line search in NGC6334 I and I(North)
G K Miley, Leiden Observatory	Radio galaxies at $z > 2$
G K Miley, Leiden Observatory	CO in $z = 2.9$ galaxy
N R Minchin, QMW	CI observations of the edge-illuminated molecular clouds S140 and M17SW
G F Mitchell, St. Marys University	Optical jets, molecular outflows and neutral winds
D A Naylor, University of Lethbridge	Search for tropospheric CO in Neptune
G S Orton, JPL	Observations of the collision between comet Shoemaker-Levy and Jupiter

T Owen, University of Hawaii	CO and HCN on Neptune
T Owen, University of Hawaii	Comet Shoemaker-Levy strikes Jupiter
P P Papadopoulos, University of Toronto	CO J=3-2, 2-1 in Seyfert galaxies
N A Patel, University of Massachusetts	Neutral carbon and carbon monoxide observations of bright rims in IC1396
P J Puxley, ROE	A study of the dust content of HII regions
J M C Rawlings, UMIST	High resolution observations of HCO <sup>+</sup> and H <sub>2</sub> CO in dense cores
H J A Röttgering, MRAO	CO emission in powerful compact radio sources
S M Rucinski, ISTS	Rho Oph B1 at high transitions of formaldehyde
D B Sanders, University of Hawaii	CO(3-2) and CO(2-1) survey of the galactic plane
D Scott, UC Berkeley	Search for CII emission from high redshift absorption systems
P F Scott, MRAO	Studies of embedded far-infrared sources in the vicinity of H <sub>2</sub> O masers
M C Senay, University of Hawaii	CO emission from comets
L J Tacconi, MPE	Mid-J CO observations of galaxies: subthermally excited gas?
J Tauber, ESTEC, Netherlands	Photodissociation in NGC7023
M D Thornley, University of Maryland	Temperature variations of molecular gas in nearby flocculent galaxies
J P Vallée, HIA	Submillimetre survey of magnetic field directions in molecular disks
E F van Dishoeck, Leiden Observatory	Ionisation in molecular clouds

C E Walker, University of Arizona	A study of [CII] towards optically selected damped Ly- $\alpha$ systems
D Ward-Thompson, ROE	Compact prestellar clumps in L1689S
D Ward-Thompson, ROE	A bolometer survey of newly-discovered candidate protostars
G D Watt, ROE	A search for NH <sub>2</sub> in dark cloud regions
G A Welch, St. Marys University	Distribution and kinematics of molecular gas in the dwarf elliptical NGC205
G J White, QMW	Observations of the centre of the Galaxy in CI and CO J = 4-3
C D Wilson, McMaster University	The temperature of molecular clouds in M33
C D Wilson, McMaster University	The origin of the large scale distribution of atomic carbon in M17
M P Womack, Northern Arizona University	A sensitive search for CO emission from Pluto's atmosphere
R Zylka, MPI Bonn	The variability of Sgr A* - a black hole in the Galactic Centre?

**Semester 94B (1st August 1994 -- 31st January 1995)**

C A Aspin, JAC	C <sup>18</sup> O 2-1 observations of the young stellar cluster in NGC1333
M J Barlow, UCL	Submillimetre observations of Vega-excess stars
T J Bridges, Queen's University	A CO(J=3-2) map of NGC1275 (Perseus A)
J Carpenter, University of Hawaii	Kinematics of molecular cloud cores
J Carpenter, University of Hawaii	The structure of massive dense cores
K C Chambers, University of Hawaii	Search for CII emission from high redshift radio galaxies
J K Davies, JAC	Molecular content of comet P/Borrelly

W R F Dent, JAC	CO clumps in a symmetrical high-collimation CO jet
W R F Dent, JAC	Correlation between molecular gas and dust in HH progenitors
J G Doyle, Armagh Observatory	Are all dust shells different? Discovering the chemical nature of and emissivity law for circumstellar dust
C Dudley, University of Hawaii	1.1 mm observations of IRAS 0857+39
J P Emerson, QMW	Mapping the submillimetre continuum structure of embedded young stellar objects
A Evans, University of Keele	Millimetre continuum observations of cataclysmic variables
A S Evans, University of Hawaii	Submillimetre spectroscopy of high redshift galaxies
J Giannakopoulou, University of Waterloo	Hot molecular gas near a giant extragalactic HII region
J S Greaves, JAC	Density threshold for star formation
M J Griffin, QMW	The luminosity:circumstellar mass relationship for young stellar objects: a submillimetre survey of L1641
R Hajjar, University of Montréal	Mapping and photometry of disks around young stellar objects
T I Hasagawa, St. Mary's University	Observations of non-dissociative shocks in molecular clouds
F P Helmich, Leiden Observatory	The chemical evolution of the W3 molecular cloud
Th Henning, University-Sternwarte Jena	CS and other molecules towards disk-like structures around very young stars - a continuation
R E Hills, MRAO	A search for C <sup>+</sup> emission in a galaxy at redshift 4.26
R E Hills, MRAO	Protostellar observations with the JCMT-CSO interferometer
M R Hogerheijde, Leiden Observatory	HCO <sup>+</sup> 3-2 and 4-3 maps of a sample of young stellar objects in Taurus: probing the physical structure of the surrounding envelope

D H Hughes, University of Oxford	Nearby blue compact galaxies as templates for high-redshift galaxies
F P Israel, Leiden Observatory	CI and CO J = 4-3 in centres of galaxies
W J Jaffe, Leiden Observatory	CI 490 GHz emission from cooling flows
S Kwok, University of Calgary	CI in carbon-rich proto-planetary nebulae
E F Ladd, University of Hawaii	Submillimetre continuum observations of stellar density enhancements
S -W Lee, Queen's University	CO observations of NGC3044
L T Little, UKC	Mass determination of protostellar clumps in L1630
M S Longair, MRAO	A study of dust in $z \sim 1$ radio-galaxies
J M MacLeod, HIA	A search for high-velocity, neutral jets in outflows
A P Marscher, University of Boston	Multifrequency monitoring of $\gamma$ -ray bright blazars
R D Mathieu, University of Wisconsin	The evolution of disks around young binary stars
H E Matthews, JAC	Neutral carbon in optically-thin shells around evolved stars
H E Matthews, JAC	A search for $\text{NH}_2$ in cold dark interstellar clouds
H E Matthews, JAC	Submillimetre photometry of the Earth-grazing asteroid 1620 Geographos
I M McHardy, University of Southampton	Shocked jet models for blazars: simultaneous JCMT/ROSAT/GRO/VLBI/UKIRT monitoring of 3C273 and 3C279
G K Miley, Leiden Observatory	Continued search for CO in radio-galaxies at redshifts greater than 2
N R Minchin, QMW	CI observations of edge-illuminated molecular clouds
N R Minchin, QMW	CI observations of molecular outflows

G F Mitchell, St. Mary's University	A search for triggered star formation in NGC7129
S Molinari, CNR, Bologna	Dust properties of progenitors of ultracompact HII regions
G Moriarty-Schieven, DRAO	Mapping dense gas in circumprotostellar environments
R Padman, MRAO	The jets and bowshocks in RNO43
R Padman, MRAO	Interferometric studies of multiple - Tauri star systems
P P Papadopoulos, University of Toronto	Temperature, density gradients of the molecular gas in Seyferts
H J A Röttgering, MRAO	CO emission in powerful compact radio sources
H J A Röttgering, MRAO	CO observations of radio/IRAS post-starburst active galactic nuclei and high redshift quasars
A P G Russell, ROE	To test whether CI/CO is enhanced in shocked regions
D B Sanders, University of Hawaii	The molecular gas properties of Seyfert galaxy nuclei
D Scott, UC Berkeley	Search for CII emission from high-z absorption system
P F Scott, MRAO	Line observations of a new sample of far-infrared embedded cores
E R Seaquist, University of Toronto	H27 $\alpha$ recombination line in M82
M C Senay, University of Hawaii	CO emission from comets
C J Skinner,	CO observations of red giants
R P Tilanus, JAC	A thermometer for the radio-lobe galaxy NGC3079
J P Vallée, HIA	Submillimetre polarimetry of molecular clouds
E F van Dishoeck, Leiden Observatory	HCO <sup>+</sup> 4-3 emission and absorption towards T Tauri

D Ward-Thompson, ROE	Submillimetre spectral energy distribution of protostellar cores in Bok globules
G J White, QMW	A comprehensive study of CO fractionation in molecular clouds
C D Wilson, McMaster University	Molecular clouds in IC10: is our nearest northern neighbour a starburst galaxy?
B Zuckerman, UC Los Angeles	Gas in dusty protoplanetary systems
R Zylka, MPI Bonn	The variability of Sgr A* - a black hole in the Galactic Centre?

### **Service Observing**

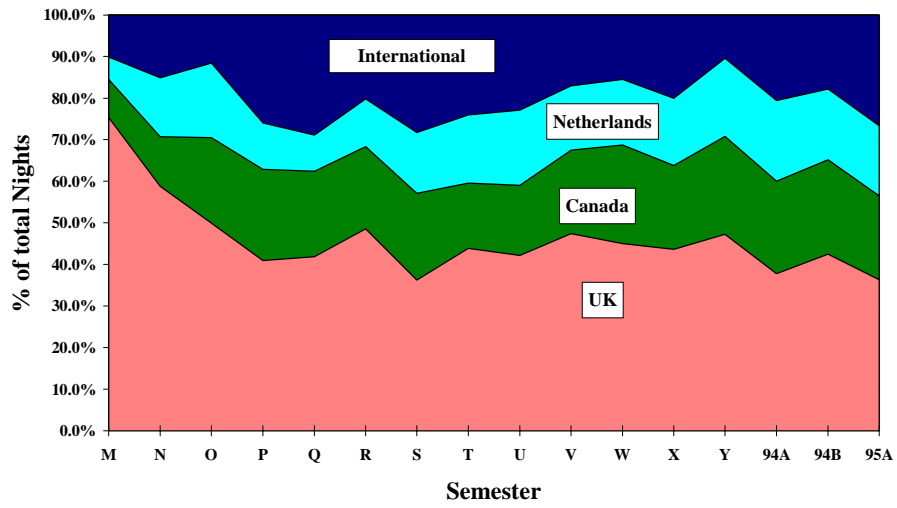
During 1994, the partner countries continued to participate in a Service Programme. The UK Service Programme is open to International applications. The total number of shifts given to service observing was 24:16:10 for UK:Canada:Netherlands respectively.

### **Interferometry payback to CSO**

The agreement for operating the JCMT-CSO interferometer is that for each shift awarded time from the PATT an equivalent number of shifts would be given to the CSO team. The interferometer was only operational for community use during Semester 94B with the UK being awarded 9 shifts and the Netherlands awarded 2 shifts. Thus 11 shifts of James Clerk Maxwell Telescope time were given to the CSO team to complete the interferometry run.

### **Distribution of Time by Partner Country (by JCMT Board formula)**

Prior to the split into national TAGs, the division of applications was made purely on the basis of the nationality of the Principal Investigator. Since the split only those applications with no collaborators from the partner countries are treated as 'International'. Thus the number of applications in this category appears to have decreased. Although the allocation procedures have been modified, the statistics (shown in Figure B1) show that there has been no significant decrease in the time awarded to International proposals. Nevertheless, the Board is committed to International applications and wishes to monitor the allocation of time to fully International proposals. The success rate for all categories of application remains around 40%.

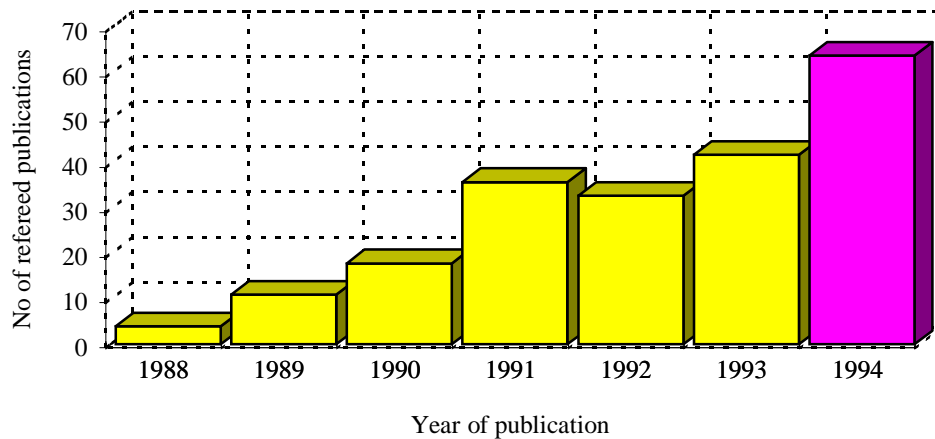


**Figure B1:** *Distribution of observing time by partner country and the JCMT Board formula for attribution of time.*

## Appendix B: List of Publications 1994

This year has seen a yet another increase in the number of papers based on JCMT observations. The running total of **64** papers published in refereed journal is significantly more than the total figure for 1993 of 42. These numbers compare extremely favourably with those for other major facilities at similar stages of their development.

### JCMT Publication History



#### 1994 Publications in refereed journals

Avery, L.W., Bell, M.B., Cunningham, C.T., Feldman, P.A., Hayward, R.H., MacLeod, J.M., Matthews, H.E. & Wade, J.D.: *Submillimeter molecular line observations of IRC+10216: searches for MgH, SiH<sub>2</sub>, and HCO<sup>+</sup>, and detection of hot HCN*, *Astrophys. J.* **426**, 737, 1994.

Baas, F., Israel, F.P. & Koornneef, J.: *Molecules in the starburst galaxy Henize 2-10*, *Astron. Astrophys.* **284**, 403, 1994.

Blake, G.A., van Dishoeck, E.F., Jansen, D.J., Groesbeck, T.D. & Mundy, L.G.: *Molecular abundances and low-mass star formation: I. Si- and S-bearing species toward IRAS 16293-2422*, *Astrophys. J.* **428**, 680, 1994.

Bloom, S.D., Marscher, A.P., Gear, W.K., Terasranta, H., Valtaoja, E., Aller, H.D. & Aller M.F.: *Radio, millimeter-submillimeter, and infrared spectra of flat-spectrum extragalactic radio sources*, *Astron. J.*, **108**, 398, 1994.

Davies, C.J., Dent, W.R.F., Matthews, H.E., Aspin, C. & Lightfoot, J.F.: *Submillimetre and near-infrared observations of L1448: a curving H<sub>2</sub> jet with multiple bowshocks*, *M.N.R.A.S.* **266**, 933, 1994.

- Devereux, N., Taniguchi, Y., Sanders, D.B., Nakai, N. & Young, J.S.:  *$^{12}\text{CO}(3-2)$  and  $(1-0)$  emission line observations of nearby starburst galaxy nuclei*, *Astron. J.*, **107**, 2006, 1994.
- Dunlop, J.S., Hughes, D.H., Rawlings, S., Eales, S.A. & Ward, M.J.: *Detection of a large mass of dust in a radio galaxy at redshift  $z=3.8$* , *Nature*, **370**, 347, 1994.
- Gear, W.K., Stevens J.A., Hughes, D.H., Litchfield, S.J., Robson, E.I., Teräsraanta, H., Valtaoja, E., Steppe, H., Aller, M.F. & Aller, H.D.: *A comparison of the radio-submillimetre spectra of BL Lacertae objects and flat-spectrum radio quasars*, *M.N.R.A.S.* **267**, 167, 1994.
- Greaves, J.S., Murray, A.G. & Holland, W.S.: *Investigating the magnetic field structure around star formation cores*, *Astron. Astrophys.* **284**, L19, 1994.
- Hasegawa, T., Mitchell, G.F., Matthews, H.E. & Tacconi, L.: *Submillimeter observations of CO in the W3 core*, *Astrophys. J.* **426**, 215, 1994.
- Helmich, F.P., Jansen, D.J., de Graauw, T., Groesbeck, T.D. & van Dishoeck, E.F.: *Physical and chemical variations within the W3 star-forming region*, *Astron. Astrophys.* **283**, 626, 1994.
- Hobson, M.P.: *The structure and dynamics of M17SW*, *Astrophys. Sp. Sci.* **216**, 159, 1994.
- Hobson, M.P., Jenness, T., Padman, R. & Scott, P.F.: *High-resolution  $\text{C}^{17}\text{O}$  observations of M17SW: III. Analysis of density and velocity structure*, *M.N.R.A.S.* **266**, 972, 1994.
- Hu, J.Y., te Lintel Hekkert, P., Slijkhuis, S., Baas, F., Sahai, R. & Wood, P.R.: *A systematic study of IRAS selected proto-planetary nebula candidates. II. OH and CO observations*, *Astron. Astrophys. Suppl.* **103**, 301, 1994.
- Hughes, D.H., Gear, W.K. & Robson, E.I.: *The submillimetre structure of the starburst nucleus in M82: a diffraction-limited 450-micron map*, *M.N.R.A.S.* **270**, 641, 1994.
- Isaak, K.G., McMahon, R.G., Hills, R.E. & Withington, S.: *Observations of high-redshift objects at submillimetre wavelengths*, *M.N.R.A.S.* **269**, L28, 1994.
- Iverson, R.J. & Seaquist, E.R.: *The latest spectral peregrinations of RX Puppis*, *M.N.R.A.S.* **268**, 561, 1994.
- Jaffe, W. & McNamara, B.R.: *HI and CO in the nuclear disk of NGC 4261*, *Astrophys. J.* **434**, 110, 1994.
- Janson, D.J., van Dishoeck, E.F. & Black, J.H.: *Physical and chemical structure of the IC63 nebula: I. Millimeter and far-infrared observations*, *Astron. Astrophys.* **282**, 605, 1994.
- Jenson, E.L.N., Mathieu, R.D. & Fuller, G.A.: *A connection between submillimeter continuum flux and separation in young binaries*, *Astrophys. J.* **429**, L29, 1994.

- Jewitt, D.C.: *Heat from Pluto*, *Astron. J.*, **107**, 372, 1994.
- Jewitt, D.C.: *Submillimeter constraints on dust near Lindros' post T Tauri stars*, *Astron. J.*, **108**, 661, 1994.
- Kastner, J.H., Weintraub, D.A., Snell, R.L., Sandell, G., Aspin, C., Hughes, D.H. & Baas, F.: *The massive molecular outflow from CRL 2136 IRS 1*, *Astrophys. J.* **425**, 695, 1994.
- van Langevelde, H.J., van Dishoeck, E.F. & Blake, G.A.: *Evidence for HCO<sup>+</sup> infall toward T Tauri?* *Astrophys. J.* **425**, L45, 1994.
- Lay, O.P., Carlstrom, J.E., Hills, R.E. & Phillips, T.G.: *Protostellar accretion disks resolved with the JCMT-CSO interferometer*, *Astrophys. J.* **434**, L75, 1994.
- Little, L.T., Gibb, A.G., Heaton, B.D., Ellison, B.D. & Claude, S.M.X.: *The CI/CO ratio in the molecular cloud G34.3 + 0.2*, *M.N.R.A.S.* **271**, 649, 1994.
- Mannings, V.: *Submillimetre observations of Herbig Ae/Be systems*, *M.N.R.A.S.* **271**, 587, 1994.
- Mannings, V. & Emerson, J.P.: *Dust in discs around T Tauri stars: grain growth?* *M.N.R.A.S.* **267**, 361, 1994.
- Maraschi, L., Grandi, P., Urry, C.M., Wehrle, A.E., Madejski, G.M., Fink, H.H., Ghisellini, G., Hartman, R.C., Koratkar, A.P., von Montigny, C., Pian, E., Thomas, H.C., Treves, A., Aller, M.F., Aller, H.D., Bailyn, C.D., Balonek, T.J., Bock, H., Collmar, W., Glass, I.S., Litchfield, S.J., McHardy, I.M., Méndez, R., Pesce, J., Reuter, H.P., Robson, E.I., Steppe, H., Stevens, J.A., Teräsranta, H. & Wagner, S.J.: *The 1993 multiwavelength campaign on 3C279: The radio to gamma-ray energy distribution in low state*, *Astrophys. J.*, **435**, L91, 1994.
- Marshall, J. & Lasenby, A.N.: *CO observations of high negative velocity gas towards the Galactic Centre*, *M.N.R.A.S.* **269**, 619, 1994.
- McNamara, B.R. & Jaffe, W.: *Sensitive limits on the molecular gas content of cluster cooling flows*, *Astron. Astrophys.* **281**, 673, 1994.
- Minchin, N.R. & Murray A.G.: *Submillimetre polarimetric mapping of DR21 and NGC7538 - IRS11: tracing the circumstellar magnetic field*, *Astron. Astrophys.* **286**, 579, 1994.
- Minchin, N.R., White, G.J., Stutzki, J. & Krause, D.: *C I emission from the outflow and PDR in S140*, *Astron. Astrophys.* **291**, 250, 1994.
- Mitchell, G.F., Hasegawa, T., Dent, W.R.F. & Matthews, H.E.: *A molecular outflow driven by an optical jet*, *Astrophys. J.* **436**, L177, 1994.
- Mitchell, G.F. & Matthews, H.E.: *A molecular jet from LkH $\alpha$  234*, *Astrophys. J.* **423**, L55, 1994.

- Moriarty-Schieven, G.H., Wannier, P.G., Keene, J. & Tamura, M.: *Circumprotostellar environments. II. Envelopes, activity, and evolution*, *Astrophys. J.* **436**, 800, 1994.
- Oldham P.G., Griffin, M.J., Richardson, K.J. & Sandell, G.: *W3 - a study of a site of massive star formation: I. Continuum and C<sup>18</sup>O observations and comparison as mass tracers*, *Astron. Astrophys.* **284**, 559, 1994.
- Padman, R. & Richer, J.S.: *Interactions between molecular outflows and optical jets*, *Astrophys. Sp. Sci.* **216**, 129, 1994.
- Phillips, J.A. & Chandler, C.J.: *A search for circumstellar material around pulsars*, *Astrophys. J.* **420**, L83, 1994.
- Richardson, K.J., Sandell, G., Cunningham, C.T. & Davies, S.R.: *DR21(OH), a cluster in the making: I. Observations in carbon monosulphide and methanol*, *Astron. Astrophys.* **286**, 555, 1994.
- Sandell, G.: *Secondary calibrators at submillimetre wavelengths*, *M.N.R.A.S.* **271**, 75, 1994.
- Sandell, G., Knee, I.B.G., Aspin, C., Robson, E.I. & Russell, A.P.G.: *A molecular jet and bow shock in the low mass protostellar binary NGC 1333-IRAS 2*, *Astron. Astrophys.* **285**, L1, 1994.
- Sandell, G. & Weintraub, D.A.: *A submillimetre protostar near LkH $\alpha$  198*, *Astron. Astrophys.* **292**, L1, 1994.
- Scott, A.D., Rawlings, J.M.C. & Evans, A.: *The previous incarnation of the old nova GK Persei*, *M.N.R.A.S.* **269**, 707, 1994.
- Seaquist, E.R., Purton, C.R. & Bell, M.B.: *Millimeter recombination lines and the state of the ionized gas in M82*, *Astrophys. J.* **429**, 612, 1994.
- Senay, M.C. & Jewitt, D.: *Coma formation driven by carbon monoxide release from comet Schwassmann-Wachmann 1*, *Nature*, **371**, 229, 1994.
- Stark, R. & van Dishoeck, E.F.: *Detection of [C I] 492-GHz emission from a high-latitude translucent cloud*, *Astron. Astrophys.* **286**, L43, 1994.
- Stevens, J.A. & Robson, E.I.: *On improving the calibration of millimetre and submillimetre photometry at the James Clerk Maxwell Telescope*, *M.N.R.A.S.* **270**, L75, 1994.
- Stevens, J.A., Litchfield, S.J., Robson, E.I., Hughes, D.H., Gear, W.K., Teräsanta, H., Valtaoja, E. & Tornikoski, M.: *Multifrequency observations of blazars. V. Long-term millimeter, submillimeter, and infrared monitoring*, *Astrophys. J.* **437**, 91, 1994.
- Sylvester, R.J., Barlow, M.J. & Skinner, C.J.: *Millimetre photometry and infrared spectroscopy of Vega-excess stars*, *Astrophys. Sp. Sci.* **212**, 261, 1994.

- Tafalla, M., Bachiller, R. & Wright, M.C.H.: *Dense clumps in the Monoceros R2 outflow*, *Astrophys. J.* **432**, L127, 1994.
- Thum, C., Matthews, H.E., Harris, A.I., Tacconi, L.J., Schuster, K.F. & Martin-Pintado, J.: *Detection of H21  $\alpha$  maser emission at 662 GHz in MWC349*, *Astron. Astrophys.* **288**, L25, 1994.
- Thum, C., Matthews, H.E., Martin-Pintado, J., Serabyn, E., Planesas, P. & Bachiller, R.: *A submillimeter recombination line maser in MWC349*, *Astron. Astrophys.* **283**, 582, 1994.
- Vallée, J.P.: *NGC 7027 at millimeter wavelengths: radial gradient of the ionised shell density*, *Astro. Lett. and Communications*, **29**, 253, 1994.
- Vallée, J.P. & MacLeod, J.M.: *JCMT observations of the ionizing stars in the H II region W40*, *Astron. J.*, **108**, 998, 1994.
- van der Veen, W.E.C.J., Waters, L.B.F.M., Trams, N.R. & Matthews, H.E.: *A study of dust shells around high latitude supergiants*, *Astron. Astrophys.* **285**, 551, 1994.
- Ward-Thompson, D., Scott, P.F., Hills, R.E. & Andre, P.: *A submillimetre continuum survey of pre-protostellar cores*, *M.N.R.A.S.* **268**, 276, 1994.
- Webb, J.R., Shrader, C.R., Balonek, T.J., Crenshaw, D.M., Kazanas, D., Clements, S., Smith, A.G., Nair, A.D., Leacock, R.J., Gombola, P.P., Sadun, A., Miller, H.R., Robson, I., Fujimoto, R., Makino, F., Kii, T., Aller, H., Aller, M., Hughes, P., Valtaoja, E., Teräsranta, H., Salonen, E., Tornikoski, M. & Chism, W.: *The multifrequency spectral evolution of blazar 3C345 during the 1991 outburst*, *Astrophys. J.* **422**, 570, 1994.
- Weintraub, D.A. & Stern S.A.: *A reinterpretation of millimeter observations of nearby IRAS excess stars*, *Astron. J.*, **108**, 701, 1994.
- Welch, G.A. & Mitchell, G.F.: *A study of molecular gas in the center of the S0 galaxy NGC4710*, *Astrophys. J.* **427**, 770, 1994.
- White, G.J.: *CO and C I observations of shock-excited gas in IC443C*, *Astron. Astrophys.* **283**, L25, 1994.
- White, G.J., Ellison, B., Claude, S., Dent, W.R.F. & Matheson, D.N.: *CO and C I maps of the starburst galaxy M82*, *Astron. Astrophys.* **284**, L23, 1994.
- Wilson, C.D.: *First observations of individual molecular clouds in the irregular galaxy NGC 6822*, *Astrophys. J.* **434**, L11, 1994.

## Appendix C: Telescope Performance

### Weather Statistics

In order to track-down better the amount of allocated time lost through weather and other faults, semester X saw the introduction of primary and backup time lost. This procedure proved extremely useful and the practise has been continued. Statistics for both semester 94A and semester 94B are shown in Table C1 while graphical representation of the data is presented in Figure C1. These tables supercede those in recent JCMT Newsletters which were found to contain some minor errors in the calculations.

Month (1994)	Hours available	extended hours used	primary prog. lost to weather(hours)	%	backup prog. lost to weather(hours)	%
February	448.0	12.6	165.5	36.9	6.0	1.3
March	496.0	41.7	163.5	33.0	1.5	0.3
April	449.0	27.6	40.3	9.0	0.0	0.0
May	488.0	22.8	58.0	11.9	0.0	0.0
June	480.0	36.3	68.0	14.2	0.0	0.0
July	496.0	28.9	180.8	36.4	12.0	2.4
<b>Total</b>	2857.0	169.9	676.1	23.7	19.5	0.7

Month (1994)	Hours available	extended hours used	primary prog. lost to weather(hours)	%	backup prog. lost to weather(hours)	%
August	493.0	24.3	110.1	22.3	5.0	1.0
September	424.0	7.9	162.5	38.3	8.0	1.9
October	496.0	18.1	40.5	8.2	10.5	2.1
November	480.0	23.5	189.7	39.5	4.0	0.8
December	477.5	19.9	17.0	3.6	0.0	0.0
January	496.0	34.2	69.8	14.1	1.8	0.4
<b>Total</b>	2866.5	127.9	589.6	20.6	29.3	1.0

**Table C1:** JCMT weather statistics for semester 94A & semester 94B.

The importance of having satisfactory backup programmes available is clearly demonstrated from the table, with less than 1% of the backup time being lost to weather.

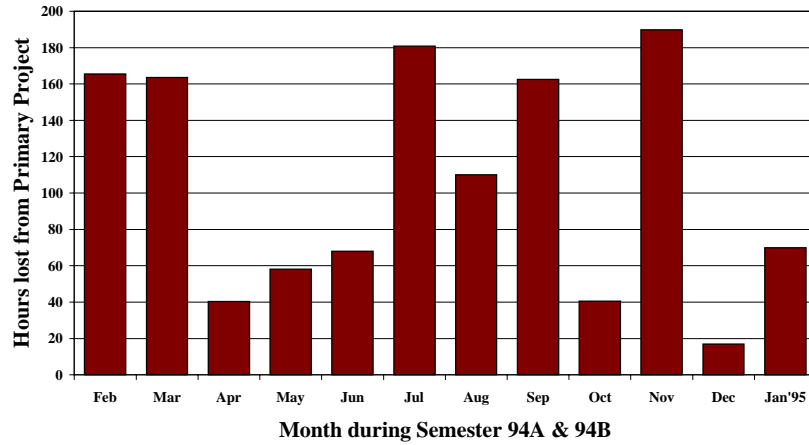


Figure C1: JCMT weather statistics for semester 94a & semester 94B.

### Engineering & Commissioning Requirements

The percentage requirements for engineering and commissioning as shown in Figure C2 for each semester of operation of the JCMT. The values given are for time allocated by the PATT and in some cases do not actually represent the total time used for engineering and commissioning.

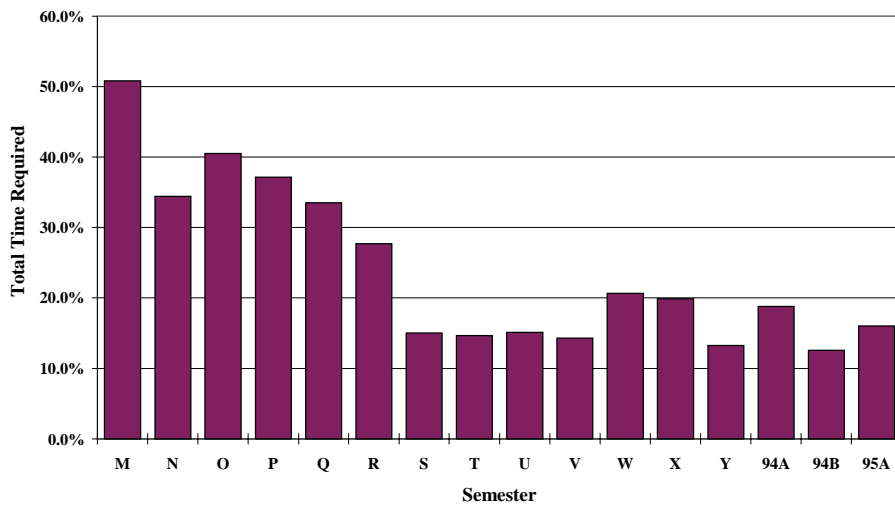
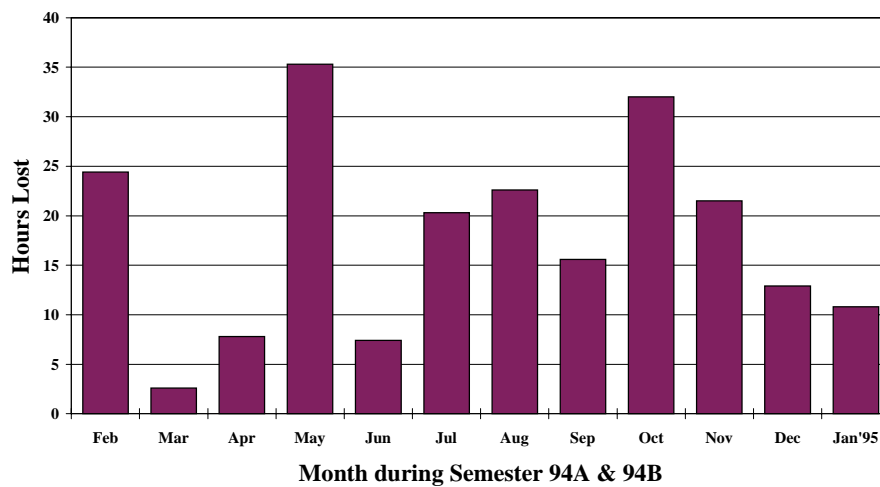


Figure C2: JCMT engineering & commissioning usage.

The general trend in the engineering requirements has now reached a steady-state figure which is significantly less than that of the early semesters when many repairs and modifications were required to keep the JCMT in an operational state. Instrument commissioning has a tendency to distort the general trend of the E & C requirements.

### Fault Statistics

Table C2 displays the faults recorded during 1994 for semesters 94A and 94B. The figures indicate a total of **4.8%** of the time available to primary programmes was lost to faults over the reporting period. At present, use of extended hours and loss to backup programmes are not taken into account but are reported for completeness. These tables supercede those in recent JCMT Newsletters which were found to contain some minor errors in the calculations. Much progress has been made in producing new maintenance and inspection systems to identify faults before they cause telescope down-time. Figure C3 shows the total hours lost through faults for each month.



**Figure C3:** JCMT fault statistics for semesters 94A & 94B.

Month (1994)	Hours available	Total	ANT	INS	COMP	SOFT	CAR	OTH
February	448.0	24.4	5.3	11.7	0.3	7.0	0.0	0.1
March	496.0	2.6	0.0	1.5	0.0	0.0	0.0	1.1
April	449.0	7.8	1.2	3.3	0.0	0.0	0.0	3.3
May	488.0	35.3	24.5	9.2	0.3	1.3	0.0	0.0
June	480.0	7.4	0.0	2.3	2.7	0.2	0.0	2.2
July	496.0	20.3	0.3	10.8	6.6	0.6	0.0	2.0
<b>P(hrs)</b>	2857.0	97.8	31.3	38.8	9.9	9.1	0.0	8.7
<b>B(hrs)</b>		8.9	0.0	6.2	1.4	0.0	0.0	1.3

Month (1994)	Hours available	Total	ANT	INS	COMP	SOFT	CAR	OTH
August	493.0	22.5	8.0	9.1	1.0	0.8	0.0	3.7
September	424.0	15.6	3.6	10.9	0.0	0.0	0.2	0.9
October	496.0	31.9	3.1	18.3	4.0	5.8	0.0	0.8
November	480.0	21.5	3.8	12.1	5.0	0.0	0.0	0.6
December	477.5	12.8	2.4	6.9	0.0	1.2	0.0	2.4
January	496.0	10.7	2.3	5.1	1.7	0.8	0.9	0.0
<b>P(hrs)</b>	2866.5	115.0	23.2	56.9	11.7	7.6	1.1	7.4
<b>B(hrs)</b>		1.3	0.1	1.2	0.0	0.0	0.0	0.0

**Table C2:** JCMT fault statistics for semester 94A & 94B. Wherever possible the faults are categorised into ANT = antenna; INS = instrument; COMP = computer hardware; SOFT = software; CAR = carousel; with the remainder going to OTH = other. P defines the time lost from Primary projects. The category B(hrs) is the time lost to Backup projects.

## Appendix D: Membership of Board and Advisory Panel

### JCMT Board as at December 1994

**Chairman:**

Prof. D.A. Williams                      University College, London, UK.

**Vice Chairman:**

Prof. Dr. H.R. Butcher                      Radiosterrewacht Dwingeloo, The Netherlands

Dr. B.H. Andrew                      Herzberg Institute of Astrophysics, National Research  
Council, Ottawa, Canada

Prof. Dr. W.B. Burton                      Sterrewacht Leiden, The Netherlands

Dr. D.N.B. Hall                      University of Hawaii, Honolulu, USA

alt. Prof. G.C. Wynn-Williams

Dr. G.F. Mitchell                      Saint Mary's University, Halifax, Canada

Dr. P.G. Murdin                      PPARC, Swindon, UK

Dr. M.J. Griffin                      Queen Mary and Westfield College, London, UK

Prof. R.E. Hills                      MRAO, Cambridge, UK

**Secretary:**

Miss R.L. Sirey                      PPARC, Swindon, UK

**Minute Secretary:**

Dr. C. Vincent                      PPARC, Swindon, UK

### JCMT Advisory Panel as at December 1994

**Chairman:**

Prof. R.E. Hills                      MRAO, Cambridge, UK

Dr. L.W. Avery                      Herzberg Institute of Astrophysics, National Research  
Council, Ottawa, Canada

Prof. J. Irwin                      Queens University, Kingston, Ontario, Canada

Dr. D. Ward-Thompson                      ROE, Edinburgh, UK

Dr. M.J. Griffin                      Queen Mary and Westfield College, London, UK

Prof. G.J. White                      Queen Mary and Westfield College, London, UK

Dr. D.B. Sanders                      University of Hawaii, Honolulu, USA

Dr. R.P. Tilanus                      JAC, Hilo, Hawaii

**Secretary:**

Dr C. Vincent                      PPARC, Swindon, UK

## Appendix E: JCMT Staff List as at December 1994

**Hawaii:** (JAC indicates shared between JCMT and UKIRT)

### International

Ian Robson (JCMT, 5% PPARC)

### PPARC

Bill Dent (JCMT)  
Per Friberg (JCMT)  
Wayne Holland (JCMT)  
Richard Prestage (JCMT)  
James Scobbie (JCMT)  
Simon Craig (JAC) (returned July 31)  
Ian Midson (JAC)  
Phil Moore (JAC)  
Derek McCall (JAC)  
Ian Pain (JAC) (from Oct 30)

### RCUH (JCMT)

Iain Coulson  
Jeff Cox  
Donna DeLorm  
Mary Fuka  
Alan Hatakeyama  
William Lundin  
John Luthe  
Goeran Sandell  
Firmin Oliveira  
Kimberley Pisciotta  
James Pomeroy  
John White

### Netherlands (all JCMT)

Fred Baas  
Remo Tilanus  
Rob Millenaar (returned July 19)  
Denis Urbain\*  
Nigel Atkins (from Oct 03)

### RCUH (JAC)

Jay Tsutsumi  
Clayton Ah Hee  
Sidney Arakaki  
Vernon DeMattos  
Dayna Oda-Kell  
Darrell DeCambra  
Marjorie Dougherty  
David Fuselier  
Mark Horita  
Karl Kawauchi (resigned  
Oct 07)  
Nash Kobayashi  
Bernadette Leite  
Gynna Loper  
Manuel Martinez  
Douglas Reed  
Henry Stilmack

### Canada (all JCMT)

Steve Brooke  
Joe Fletcher  
Neal Masuda\*  
  
Henry Matthews  
Chris Purton

\* RCUH paid by partner country

### Royal Observatory Edinburgh:

Adrian Russell (100% JCMT)  
Phil Williams (50% JCMT)  
Bill Duncan (50% JCMT) (resigned Aug 31)  
Graeme Watt (50% JCMT)  
Dorothy Skedd (30% JCMT)

## Appendix F: Addresses

### JCMT Hawaii:

Joint Astronomy Centre           Tel: (1)-808-961-3756  
660 N. A'Ohoku Place               (1)-808-935-4332 (answering machine)  
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Hilo, HI 96720                    E-mail: 315280809053 (PSS)  
United States of America            JACH.HAWAII.EDU (Internet)

JCMT Offices at Hale Pohaku       Tel: (1)-808-935-9911

JCMT Control Room                Tel: (1)-808-935-0852  
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## Appendix G: Abbreviations

CSO	Caltech Submillimeter Observatory, Hawaii, USA
DAS	Dutch autocorrelation spectrometer
DRAO	Dominion Radio Astrophysical Observatory, Penticton, Canada
DSB	double side-band (receiver temperature)
FTS	Fourier transform spectrometer
GRO	Gamma-ray Observatory
HIA	Herzberg Institute of Astrophysics, Ottawa, Canada
IRAM	Instituto de Radioastronomia Milimetrica, Spain
IRAS	infrared astronomical satellite
ITAC	international time allocation committee (part of PATT)
JAC	Joint Astronomy Centre, Hilo, Hawaii, USA
JCMT	James Clerk Maxwell Telescope, Hawaii, USA
JPL	Jet Propulsion Laboratory, Pasadena, USA
MIDAS	multiple input digital autocorrelation spectrometer
MIT	Massachusetts Institute of Technology, Boston, USA
MPE	Max-Planck-Institut für Extraterrestrische Physik, Garching, Germany
MPI	Max-Planck-Institut für Radio Astronomie, Bonn, Germany
MRAO	Mullard Radio Astronomy Observatory, Cambridge, UK
NFRA	Netherlands Foundation for Radio Astronomy, Dwingeloo
NRAO	National Radio Astronomy Observatory, Charlottesville, USA
NRC	National Research Council of Canada
NWO	Nederlandse Organisatie voor Wetenschappelijk Onderzoek
PATT	Panel for the Allocation of Telescope Time
QMW	Queen Mary Westfield College, London, UK
RAL	Rutherford Appleton Laboratory, Chilton, UK
ROE	Royal Observatory, Edinburgh, UK
ROSAT	Röntgen satellite
RUG	University of Groningen, Netherlands
SCUBA	submillimetre common-user bolometer array
SERC	Science and Engineering Research Council, UK
SIS	superconductor-insulator-superconductor (detector)
SMA	Smithsonian Millimeter Array
SMU	secondary mirror unit
SRON	Space Research Organisation Netherlands, Groningen, The Netherlands
SWIFT	Sub-mm Wave Imaging Front-end
TAG	time allocation group (part of PATT)
UBC	University of British Columbia, Vancouver, Canada
UCL	University College London, London, UK
UCLA	University College at Los Angeles, USA
UKC	University of Kent at Canterbury, UK
UKIRT	United Kingdom Infrared Telescope, Hawaii, USA
UMIST	University of Manchester Institute of Science & Technology, UK
VLA	Very Large Array, Socorro, USA
VLBI	very long baseline interferometry