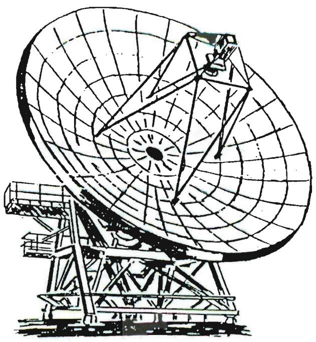
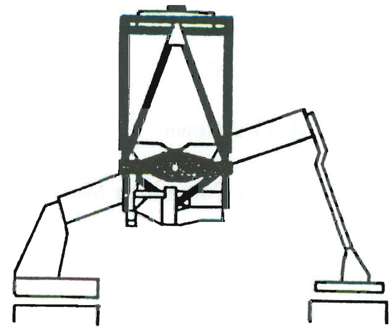
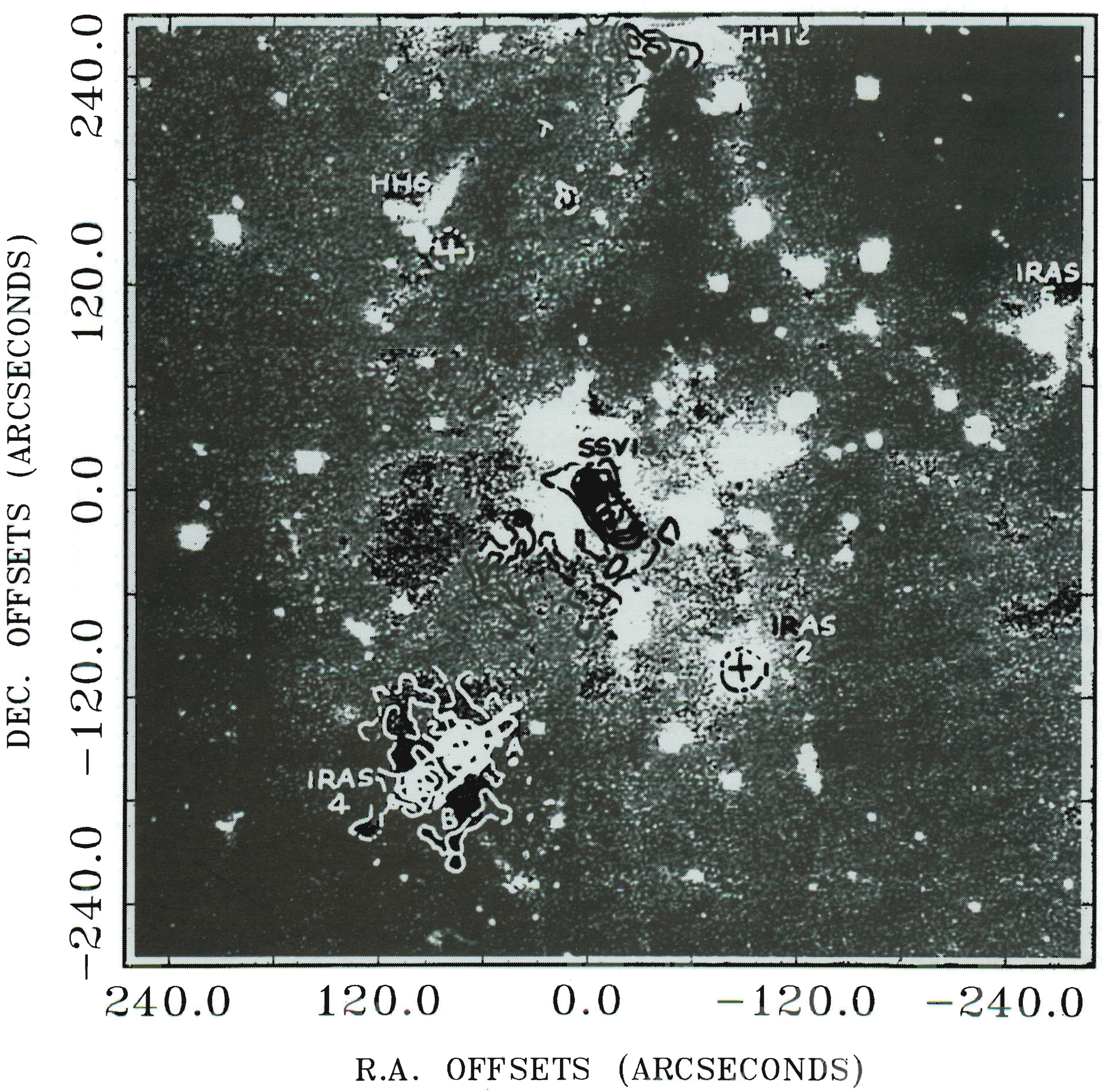


THE JCMT - UKIRT NEWSLETTER

Kulia I Ka Nu'u

Number 1 March 1991





Contents

COVER PICTURE:

An IRCAM mosaic of NGC1333 at K overlaid by JCMT 800μm contour maps of several of the IRAS sources in the region. The axes offsets are in arcseconds from the position of SSV13 (0,0). Not all the region was mapped with JCMT at 800μm and hence continuum emission may well be present at locations other than those shown.

Editorial

Welcome to the first edition of the new JCMT-UKIRT Newsletter. It was decided to merge the former UKIRT Newsletter and Protostar to reflect the common ground and complementarity of the two telescopes, their organisation, management, and scientific interests. For non-Hawaiians, Kulia I Ka Nu'u translates as 'Strive for the heights', and is the motto of the Joint Astronomy Centre. Appropriately, this issue includes a paper on NGC 1333 based on observations made with both telescopes. There is also news of two newly commissioned instruments, Receiver B2 on JCMT and CGS 4 on UKIRT.

PATT News

Please note that the two PATT semesters are to be repositioned. Semester U will be short so that future PATT semesters will run from February to July, and August to January. Consequently,

Semester U September 1991 - January 1992, proposals deadline 30 April 1991;

Semester V February 1992 to July 1992, proposals deadline 30 September 1991;

Semester W August 1992 to January 1993, proposals deadline 30 March 1992.

The next PATT meeting is currently scheduled for either 2-3 or 3-4 July 1991.

The allocation of PATT time and the UKIRT and JCMT schedules for Semester T are included in the PATT Newsletter. The schedules are accessible as a Starlink news item, and copies of the allocations and schedules can be supplied to anyone who does not normally receive the PATT Newsletter.

With effect from applications for Semester U, PATT has agreed to an extra page which should contain technical justifications only.

Users Committee Meetings

UKIRT Users Committee: 1991 March 18-19;
JCMT Users Committee: 1991 April 8-9.

Total Eclipse in July

There will be a total solar eclipse over Mauna Kea on 1991 July 11, with totality from 7.28 to 7.32 Hawaiian time. After a separate Announcement of Opportunity an international consortium led by C. Lindsey has been allocated time on JCMT. The elevation of the sun at the time of the eclipse means that it will be inaccessible to UKIRT.

Accommodation requests from observers using either telescope in July should be made immediately, since there is a very heavy demand on hotel accommodation at that time.

Hale Pohaku Rooms

When requesting a room reservation at Hale Pohaku in future, please specify whether you require smoking or non-smoking accommodation.

The next large telescope

In December SERC agreed in principle to negotiate with the USA and Canada to establish a partnership to build and operate two 8-metre optical/infraredtelescopes, one to be sited on Mauna Kea and the other in Chile. It is anticipated that the Joint Astronomy Centre and ROE will have significant roles in this exciting new project.

People

SERC was 25 years old in 1990, and commemorative plaques were presented to staff with 25 years' service. Recipients included David Beattie at JAC, and Russell Eberst and Alex McLachlan of ROE Hawaii Division.

Dr Paul Murdin, Deputy Director of RGO, has been appointed interim Director of ROE, pending appointment of a successor to Professor Malcolm Longair who has become the Jacksonian Professor in the University of Cambridge.

Dr Peredur Williams is responsible for JCMT affairs at ROE.

Dr Walter Gear (ROE) is Project Scientist for the JCMT Intrumentation Programme.

Dr Ko Hummel has recently arrived to be the Netherlands JCMT staff member at ROE.

Dr Phil Puxley has joined the staff of Hawaii Division at ROE; he will be at JAC until July.

Dr Phil James has been appointed to a Research Fellowship at the ROE, in the Hawaii Division.

UKIRT News

First light on CGS 4

On the night of Monday 4 February at 7:50 Hawaiian time, CGS 4 detected its first star. Having been cooled over the weekend, CGS 4 was attached and aligned to UKIRT on Monday afternoon. As a result of the outstanding help we received from the JAC staff we were ready to open the dome by 7:30 that evening - six days ahead of schedule The first star came straight down the slit.

Preliminary alignment checks showed that CGS 4 was already well aligned to UKIRT's optical axis and the instrument through-put was actually better than expected. The read noise on the telescope, with drives and dome running, was $40e^-$/integration (in non-destructive read) and the combined dark current and background was 13 e^-/second. Our first reduced 2μm spectra of BS 1552 was taken at 6:36 UT (20:36 HST).

We continued to observe throughout the night, making a total of 186 observations using both the low and high resolution modes of the spectrometer. The bright planetary nebula NGC 2440 was our first emission line object, which was followed by a spectacular long-slit 2μm image of the proto-planetary nebula M1-16. This showed concentrated ionic Brackett γ emission near the existing star but extended molecular hydrogen emission all along our 90 arcsecond slit, which we had aligned to the bipolar flow. Several lines of molecular hydrogen were seen, the ratio of 1-0 S(1)/1-0 S(0) appearing surprisingly uniform along the flow. Switching to the échelle grating we measured the spatial and velocity structure of the 1-0 S(1) emission which in the first few frames revealed red and blue shifted lobes separated by approximately 70km s^{-1}. The signal levels we were detecting were about 30 photons/second/channel at this point.

As the galactic plane moved away we switched to extra-galactic objects, taking a K window spectrum of the Seyfert galaxy NGC 4151. This was followed by an attempt to measure the 1.6μm spectrum of a 16.8 magnitude red-shift 2.08 quasar. The continuum was clearly visible in our first 180 second object-sky pair at a level of 15 photons/s. Our final observation at 6 am in the morning was to use the échelle to resolve the velocity structure of molecular hydrogen emission in the interacting galaxy NGC 6240. This revealed a beautifully symmetric broad line profile extending over the entire 2400km s^{-1} coverage of the CGS 4 array, adding to the controversy surrounding this high luminosity object.

Both the software and hardware performed flawlessly all night. We used the CGS 4 EXEC system to call up objects, control the telescope and sequence the observations. As there was no apparent flexure, peaking up and pointing also proved easier than expected.

CGS 4 is now the world's most sensitive infrared spectrometer in use on a telescope. This confirms UKIRT's lead as the premiere infrared ground-based observatory.

Congratulations and thanks to everybody on the Project Team, the T & C Division at Edinburgh, the UKIRT Instrumentation programme and the JAC staff, without whom none of this would have been possible.

Matt Mountain, at JAC
6 February 1991

Availability of UKIRT instruments during Semester U

UKT6 Single channel 1-5μm photometer; 2.3-4.6μm CVF

UKT8 Single channel L', N, Q & narrow band 10μm photometer

UKT9 Single channel 1-5μm photometer, 1.35-2.6μm CVF

UKT10 2-banger; J or H, and fixed K filter

UKT16 8-banger; N, Q, 30μm and narrow band 10μm

CGS3 8-22μm grating spectrometer; 32 channels, resolving powers of ~80 - 300 at 10μm and ~100 at 20μm. Beam sizes from 2" to 8" diameter.
CGS3 and IRCAM both use the north port of ISU2, and thus are mutually exclusive.

CGS4 1-5μm 58x62 array; echelle, 75 l/mm and 150 l/mm gratings; long and short focal length cameras (the long focal length camera effectively doubles the resolution of a given grating and halves the pixel size, from 3.6" to 1.8")

After an initial commissioning period extending through Semester T, it is expected that CGS4 will be available for full scientific use in Semester U in all of the above modes. However, the status of CGS4 will not be certain until the time of the next PATT meeting, when the commissioning phase is further along. Potential applicants for CGS4 programs should note any future updates on CGS4 performance and availability.

Due to the several configurations of gratings and focal lengths in CGS4, and the need to minimise the number of change-overs, which require one week of down time, some configurations may be avoided during certain semesters, while others may be scheduled during limited periods (at some inconvenience to some observers). If more than one CGS4 configuration is acceptable to the applicant, please indicate this on the proposal.

Barring problems with CGS4, CGS2 (7 channel, 1.0-5.4μm grating spectrometer) and the 3-5μm FPs will not be available during Semester U.

IRCAMs 1 & 2 58x62 array, 1-5μm photometric and various narrow band filters; 0.6" per pixel (36" field of view), 1.2" per pixel (72" fov), 2.4" (100" fov)

IRPOL 1-5μm polarimeter for IRCAM, UKT6, UKT9 and CGS4. Note that the unvignetted field of view of IRCAM through IRPOL is ~35"; hence optimal usage of IRCAM+IRPOL is with 0.6" pixels.

CORONAGRAPH A coronagraph for use with IRCAM is available, subject to the agreement of, and collaboration with, Dr Ben Zuckerman of UCLA, who is its owner. Applicants should discuss any such proposals with Dr Zuckerman before submission of the application.

FABRY-PEROT's 2μm: 12, 25, 90 and 300km/s resolutions; can be used with IRCAM and with UKT9; unvignetted field of view through IRCAM is ~60".

VISPHOT Single channel visible B or V band photometer; can be operated simultaneously with any of the above single channel instruments and with UKT10.

Tom Geballe
Joint Astronomy Centre

Notes on thermal observing at UKIRT.

UKT8

UKT8 was used successfully on several occasions this year. It has also been scheduled regularly for service observing, unfortunately without much luck with the weather. In June there was a difficult-to-trace electrical problem. Although time was lost because the dewar had to be warmed up, most of it was not good 10μm weather. The observers were given AICDT time to make up for this (and obtained much better data than they would have on their originally scheduled night)

In spring 1990 a night of engineering time was allocated to UKT8 in order to investigate the thermal IR performance following recentering of the secondary last winter. A full analysis and report of the results is in preparation. The 1σ 1sec noise derived from ~1/2 hour integrations was ~350 mJy in the N filter. Particularly on timescales longer than ~1/2 hour the S/N did not increase as $t^{0.5}$.

Since recentering the secondary, the thermal offsets have become smaller. If the collimation is adjusted for zero offset at the zenith, then the offset does still increase when the telescope is slewed elsewhere. However it is now always true that the resulting offset can be zeroed by driving the collimation at most ~ 150 units (previously there were some places in the sky where a zero offset could not be obtained). A detailed comparison of the offset behaviour compared to other measures of top end movement is in progress. The major source is the collimation drift when the telescope is slewed and thus the variability of the offsets around the sky is expected to improve considerably following the top end work. The on-line zero points file has been updated, including the narrow band filters and preliminary on-line data reduction in either Jy or mags is now working properly.

UKT16 (8-banger)

UKT16 itself worked well in June with sensitivity per pixel similar to UKT8. On line mapping software was installed and tested during an AIC night. The telescope can now be moved automatically between map positions and there is an on-line plotting task to plot contour maps of the (unevenly sampled) data. Unfortunately the maps made with UKT16 were limited by the chopper motion, so that plots of stars were smeared by ~2 arcsec along the chop direction. Data has been taken and tests are in progress of correlated noise removal techniques for UKT16 data.

Tom Geballe & Gillian Wright
JAC

Transmission Profiles for Filters in UKIRT Instrumentation

Copies of manufacturers' or other test laboratory transmission profiles of filters used in UKIRT instruments are available on request, from the UKIRT group at ROE. Many of these filters have been digitised (by hand, reading from the laboratory test graphs) and are available as files on the ROE Starlink VAX. These files are accessible to users by reading or copying from the directory REVAD::DISK$USER3:[UKIRT.FILTERS]

Filters included to date, with their respective file names, are listed below. Wavelengths are measured with the filters at 77K, close to their operating temperature within the cryostats.

Filters in IRCAM

File	Filter Description
i) Broad-band filters	
JBARR.DAT	Broad-band J filter
HBARR.DAT	" " H filter
KOCLI.DAT	" " K filter
ii) Narrow-band filters	
NBLFILT.DAT	L filter (3.406 μm)
I206FILT.DAT	2.06μm (HeII) filter
I210FILT.DAT	2.10μm 'continuum'
I212FILT.DAT	2.122μm 1-0S(1) H_2 line
I216FILT.DAT	2.166μm Brackett γ line
I221FILT.DAT	2.21μm 'continuum'
I234FILT.DAT band-head	2.34μm 1st overtone CO
I242FILT.DAT	2.42μm Q-branch H_2 line(s)
I308FILT.DAT	3.08μm 'ice' feature
I328FILT.DAT	3.28μm 'dust' feature
I340FILT.DAT	3.40μm 'continuum'
I400FILT.DAT	4.00μm 'continuum'
I405FILT.DAT	4.05μm Brackett α line

UKT9 and UKT6 Photometers

File	Filter Description
FILTER.DAT	J,H,K broad-band and L' narrow-band filters (combined file);
JFILT.DAT	Broad-band J filter
HFILT.DAT	" " H "
KFILT.DAT	" " K "
LFILT.DAT	" " L' "

Andy Longmore
ROE

IRCAM News

Closed cycle cooler

One of our cryostats (IRCAM 1) has been converted to operation with a two-stage closed cycle Helium refrigerator. The system has been very reliable and requires minimal maintenance. The array operating temperature remains 35.0°K. No interference with array operation (noise etc.) has been observed. We plan to convert the second cryostat, IRCAM 2, to closed cycle cooler operation early in 1991.

Pixel scale

Observers should note that the IRCAM optics are not achromatic, which means that small scale pixel changes occur with wavelength. The table below shows the size of these changes relative to K band - it is copied from the IRCAM manual.

nominal	J	H	K	L
0".62 /pixel	1.04	1.01	1.00	0.99
1".24 /pixel	1.017	1.004	1.00	0.996

eg. The 0".62 nominal pixel scale at J is actually 0".64 /pixel.

X2 warm magnifier

A 2-times afocal achromatic magnifier is now available for higher resolution work. The magnifier simply screws into the IRCAM window bracket in place of the usual warm baffle and results in an effective pixel scale of 0.31 "/pixel when used with IRCAM in the 0.62" mode. Tests so far show it to be optically excellent, giving seeing limited images without obvious degradation to the PSF. We are however experiencing problems with thermal backgrounds at K and L. In no case has a factor of 4 reduction in the background level been observed. Background flux per pixel at K is about the same as without the magnifier, while the L band flux per pixel is up by a factor of 2. We feel some improvements can be made, and tests are continuing. The magnifier is now available for use at J,H and K.

Snapshot mode

A snapshot mode is available with IRCAM allowing frames to be taken at up to 3 per second, and this mode has been used a number of times now for occultation work. However, such a large amount of data is generated in even half an hour of observing, that we have great difficulty organizing storage and further processing. We therefore ask observers only to request IRCAM for this type of work if the spatial information is indeed essential. Otherwise observers should note that we have both fast photometry (DC coupled) and fast normal photometry (3 frames per second with chopping) modes available with our aperture photometers UKT9 and UKT6.

Mark Casali
JAC

Remote Observing

In UKIRT Newsletter no. 22 an announcement was made that in Semester T successful PATT applicants would be able to opt for remote observing with UKIRT. Unfortunately the 56 kbit/sec dedicated line from ROE to JACH has still not been released by Hawaii Telephone because of high error rates occuring in the mainland US. However, it could become available at any time so please contact Roger Clowes on REVAD::RGC (DECnet) or RGC@UK.AC.ROE.STARLINK (Janet) for the latest information.

Even if the line is not available it might be possible to satisfy your remote-observing requirements using the existing network links involving various combinations of SPAN, Janet and Internet.

Roger Clowes
ROE

UKIRT Service Observing

Just a reminder that the UKIRT service observing programme provides the opportunity to have short (about 2 hour) observations made on your behalf by UKIRT staff astronomers. If you are not familiar with the programme then read the appropriate section in the UKIRT_INFORM system, or read [UKIRTSERV]UKIRTSERV.OBS and UKIRTSERV.HOW on the ROE STARLINK VAX or e-mail your questions to UKIRTSERV at ROE. To be put on our mailing list and receive details of schedules, deadlines and instrument availability send your e-mail address to UKIRTSERV on the ROE STARLINK VAX (UK.AC.ROE. STAR).

Please remember to tell us if you complete your observation during a normal PATT run, or wish to withdraw it for other reasons, so we can delete it from our target list. We also would be pleased to know when and where you publish your data, so we can keep our files up to date.

A number of users will be aware that a survey was conducted late last year of all applications submitted between 1 June 1988 and 30 May 1990. The return rate for the questionnaires was about 80%, a pretty clear indication that our users are a conscientious group. The results of the survey will form part of a report to the next UUC and, subject to the approval of this committee, will be summarised in the next UKIRT newsletter. Many respondents said they had papers in preparation so we look forward to seeing the preprints soon.

Schedule for semester T

Following a reduced allocation in Semester S to provide extra AIC time required for other purposes, PATT has increased its allocation from 9 to 10 nights of Service for this semester. At present these are scheduled as follows but can be subject to late changes for operational reasons or due to demand for particular instruments. Applications can be submitted at any time; formal reminders will be sent out about 3 weeks before each run.

Date (Hawaii)	Instruments Available	Deadline
Mar 1-3	CGS4 IRCAM 0.6 pixel mode	18 February
May 27	CGS3, CGS4	13 May
June 14-15	IRCAM 1.2 pixel mode	30 May
July 6-9	CGS4, IRCAM 0.6 pixel mode	4 June

Report on Semester R and S to date.

Since the last UKIRT newsletter a total of 49 applications have been recieved. Nine of these were rejected and the remainder were graded as follows, 16 A, 17 AB and 7 B.

Although partially affected by weather, the long August run (the last portion of Semester R) was quite successful as were the nights of September 30th and October 2nd. At this point we seem to have upset the mountain spirits because the October 3rd, Dec 21st, AIC time in January and the Jan 27th and February 3rd nights were all virtually lost to weather problems. Despite the poor weather towards the end of the period, we did attempt a total of 25 proposals. Of these 18 programmes were completed (11 A grades, 6 AB grades,1 B grade), 5 were partially completed (4 A and 1 AB grades) and 2 are monitoring programmes.

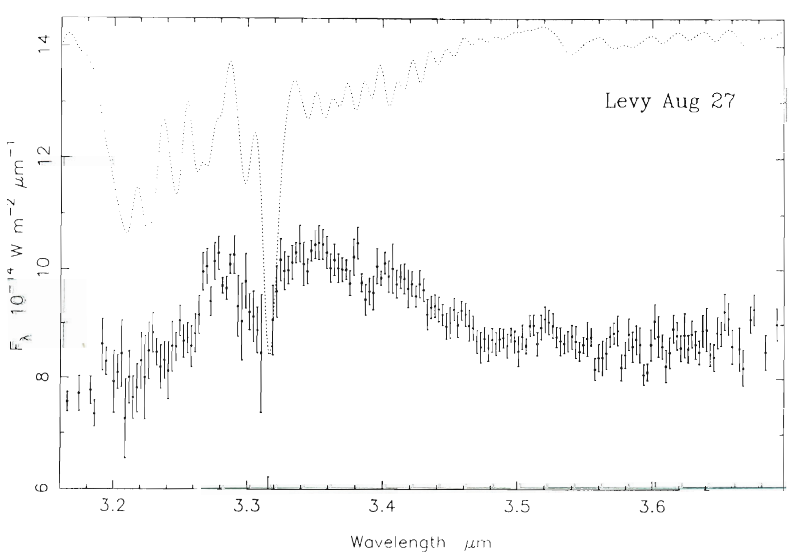
As usual for Service, the wide range of programmes meant that many aspects of astronomy were touched upon. A good 3 µm spectrum of Comet Levy was obtained and this showed emission lines at 3.28 and 3.4 µm. This data makes an interesting comparison to a similar spectrum of Comet Austin recorded during the May Service run. Photometry of Saturn's moon Titan was taken to confirm a rather unexpected result from another telescope and the UKIRT data was well received by the applicant. JHKL and MNQ data was taken of several Wolf-Rayet stars and CGS2 spectra of the galactic centre were made to search (unsuccessfully as it turned out) for H_2 lines. A number of star forming regions were subjected to IRCAM and CGS2 observations.

Outside the Milky Way several IRCAM images of nearby galaxies were taken as part of a feasibility study for a programme to search for buried supernovae. Unfortunately the poor weather has so far prevented the necessary follow up observations. Several deep K band searches were made in pursuit of objects detected at various other wavelengths. Few positive detections have been reported yet but a few frames snatched between the clouds in January look promising for one high redshift galaxy seeker. JHKL and MNQ observations of active galaxies were also undertaken.

During the August run one astronomer was able to 'eavesdrop' on his Service observations and provide feedback on the data as it came in. This was a useful exercise since it enabled the Service observers to stop taking data once the applicant was satisified. Observers interested in eavesdroping on future Service runs are invited to contact ROE.

Observers and TO's who obtained data on behalf of service applicants during this period included Colin Aspin, Joel Aycock, Mark Casali, John Davies, Tom Geballe, Dolores Walther, and Thor Wold. As usual, thanks to them and to our assessors.

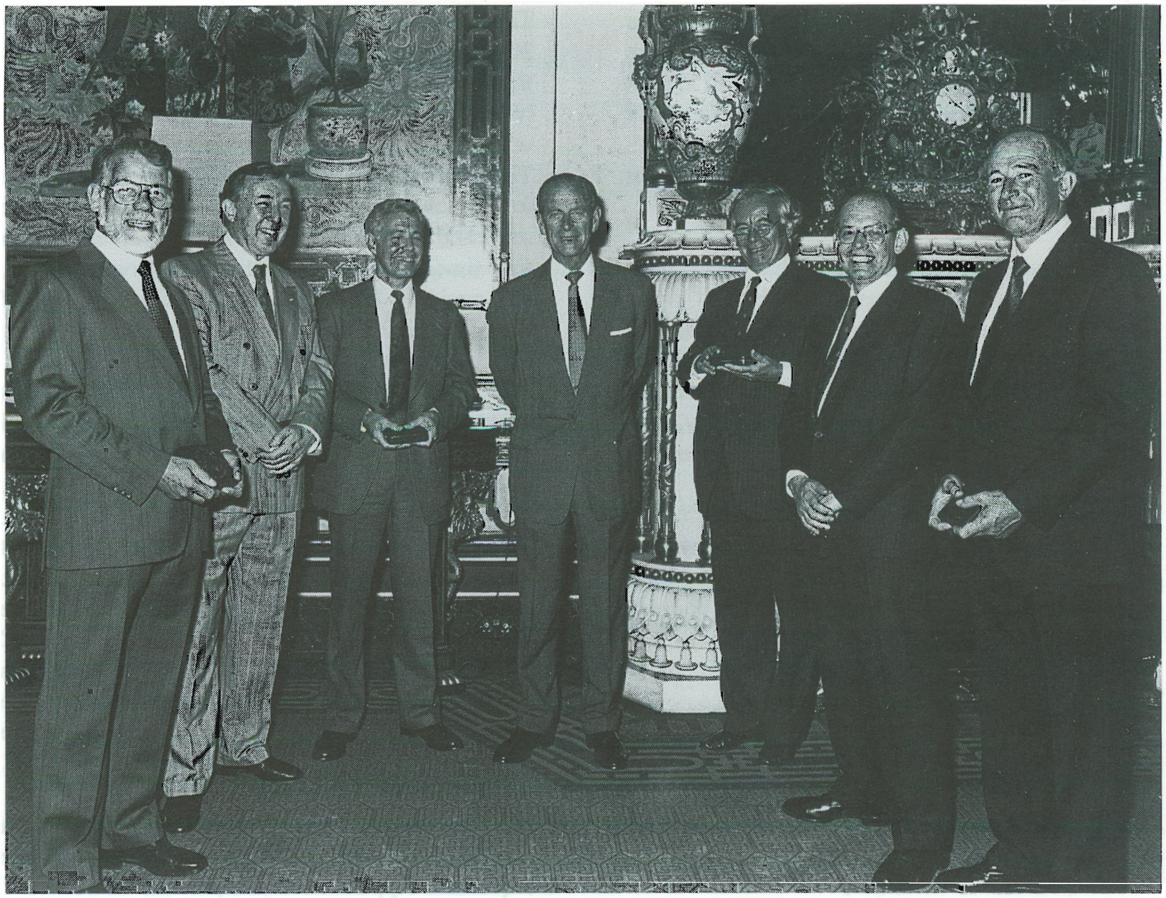
John Davies, Russell Eberst.
ROE.



The 3µm spectrum of Comet Levy, taken during UKIRT Service observations
From a paper submitted to MNRAS by Davies, Green & Geballe.

CGS 2 - flat-fielding

Phil Puxley has a routine to flat-field CGS 2 data which works on ASCII data files (wavelength, signal, error). Prospective users need to extract the ASCII data from their HDS or (Figaro) DST structures; the routine is then easy to use and robust. Anyone interested in using this routine is invited to contact Phil (username PJP).



The 1990 MacRobert Award goes to the JCMT

The MacRobert Award was instituted in 1968 with the aim of honouring individuals or small teams. It is presented by the Fellowship of Engineering, London, for an outstanding contribution by way of innovation in engineering or the physical technologies or in the application of the physical sciences which has enhanced or will enhance UK prestige and prosperity.

The 1990 prize was awarded at a ceremony in London on October 16th to the team responsible for the development, design, installation and commissioning of the JCMT. Medals were presented by the Duke of Edinburgh at a private ceremony at Buckingham Palace to Professor Sir William Mitchell (recently retired as Chairman of the SERC), Dr Ron Newport (Project Leader), Dr Jim Hall (Deputy Project Leader), Brian Edwards (Project Engineer), Prof Richard Hills (Project Scientist) and Jean Casse (Project Leader, NWO). This was followed by a press conference at the Science Museum (where there didn't seem to be many press) attended by VIP's, members of the Fellowship of Engineering and Dutch, Cambridge and SERC people associated with the JCMT. It was a distinguished, be-suited, "Mr President, M'Lords and Ladies..." sort of occasion.

The President of the Fellowship of Engineering remarked that this year's award was a little unusual, in that it was given to an organisation which was not overtly commercial. The citation noted the problems that faced the team designing the JCMT - the accuracy required, the problems of installing a precise instrument of that size at that altitude. What had appealed to the Fellowship of Engineering were the many innovative designs in all the fields of engineering, civil, mechanical and structural, electrical and electronic, and in materials technology. They were also impressed by the linking of good science and good technology. As examples they cited the panels that make up the surface of the dish, the panel adjusters, and the membrane.

Ron Newport gave a presentation about the JCMT - material that will be familiar to most who read this (but did you know that the JCMT could resolve a grass-skirted Hawaiian on a beach on Maui?). Ron acknowledged Richard Hills' involvement with the project since 1974, and made much of Richard's dash back from Mauna Kea (where he had been commissioning receiver B2 and assisting with improvements to the dish surface) to be present at this ceremony.

Questions were invited (the press were silent) from members of the audience, and they covered topics such as the telescope's "targetting" mechanism, how far the telescope could see, what commercial "spin off" there had been, what sort of maintenance was needed, remote observing, interferometry, how much it had cost, and the international dimension.

The Science Museum each year mounts a display on the prize winning project, so the event then moved to the entrance vestibule where an exhibition about the JCMT was formally opened. It consists of a model of the JCMT surrounded by Mauna Kea look-alike, a video, and a number of back-lit colour panels about the telescope and its science. The exhibit will be seen by over half a million people in the three months it is there.

Jocelyn Bell Burnell
ROE

Note from the Chairman of the JCMT TAG

At the PATT meeting in December, the JCMT TAG continued the policy of offering flexible scheduling to observers whose projects need very good weather. Under this arrangement, high- and low-frequency proposals are scheduled together for a period equal to the sum of their allocated times. At the start of the shift, the principal observer of the high-frequency project can decide (using whatever weather information is available) whether or not he/she wants to use that shift. If the conditions are not good enough for high-frequency work, the shift is used for the low-frequency programme. Throughout the flexibly-scheduled period, the high-frequency observer can continue to accept or reject shifts in this way until all of the shifts allocated to his/her programme have been claimed. Proposals which specifically ask for flexible scheduling need not specify a poor-weather back-up programme.

This scheme is intended to ensure that the roughly 30% fraction of good submillimetre weather is used most effectively, and it is hoped that applicants whose scientific programmes need good weather will avail themselves of it whenever they are able. The disadvantage of having to stay at the telescope for a longer period should be offset by the increased probability of having a successful run first time, thereby completing the project sooner, and avoiding the tedious and costly necessity of repeated applications and repeated observing runs.

Once again, the TAG also recognised the benefits of JACH staff being able to make use of small amounts of PATT-allocated time for certain essential calibration measurements (beamshapes, efficiencies, telescope pointing, sky dips, etc). Such measurements are very important, and must sometimes be made under good weather conditions, and when suitable sources are available. For these reasons, it is not feasible to rely purely on AIC time to carry them out. Observers are asked to cooperate fully with JACH staff in this matter. The disruption to any individual programme should be minimal, and the benefits to all users are obvious.

In future semesters, the TAG would like to see a significant increase in the average amount of time requested. Applicants should not take the view that a request for a substantial amount of time will in any way count against their proposal. At the semester T meeting, in several cases where it was judged to be nesessary or beneficial, the TAG awarded more time than had been requested. Allocating time in larger blocks will have a number of advantages: it will enhance the overall efficiency and scientific output of the JCMT by ensuring that more observational projects are properly completed without multiple observing trips; it will make it easier to schedule and run the telescope; and it will reduce travel costs. When feasibility is not in doubt, applicants are therefore encouraged to apply for enough time to carry out their programmes thoroughly.

Matt Griffin
QMW

Extended Operating Hours on JCMT

As most of you will be aware the principal reason for siting the JCMT on Mauna Kea is to make use of the exceptionally dry conditions which can occur there. As experienced observers will know, these periods of dry weather, essential for sub-mm work, often come in blocks of a few days and sometimes persist for 24 hours per day. In order to make maximum use of these times it has become the practice when possible to extend the length of the observing 'night' on the JCMT. This has resulted in a far more effective use of the dry weather particularly with RxG. Of course it is not just high frequency observations which can benefit from extended observing hours. At 230GHz for example one should be able to observe for almost 90% of the time. So that in principle there is no reason to limit the JCMT 'night' for any type of observation (with the exception of solar of course). Observers should be aware then that the possibility exists of extending the JCMT shifts at both ends (ie starting first shift earlier and finishing second shift later).

There are some guidelines which must be strictly obeyed however. These are as follows:

i) While the telescope operators will normally be willing to oblige, they are not required to do so. Observers should discuss the possibility with their TO and support scientist. If the TO is not willing then that is that. This is particularly important when considering starting the first shift early which will involve a disruption to meal schedules.

ii) Engineering and commissioning work is often done during the day. This work must take precedence over extending observing hours.

iii) Observers must be prepared to give up the telescope promptly at the end of the shift and must not automatically expect to get access to the telescope before the start of their shift. This scheme is offered on a best efforts basis to make best use of the telescope.

On a related issue, we have been able over recent semesters to reduce dramatically the number of shifts requested for engineering and commissioning work. This has been done however on the understanding that small amounts of time may be taken for such essential work during scheduled observing time. Observers should realize that this is being done to maximise the scientific output of the telescope and their cooperation is appreciated.

Observers Reports and Scientific Feedback

Observers are reminded of the importance of returning completed observing reports promptly after their run. These forms are important from several points of view. They are used to gather statistics on telescope usage; they bring problems as well as successes to light and finally they give one form of scientific feedback on the use of the telescope. This latter point is a very important one. However observers should not rely on the report form alone to feedback their scientific results. All observers are invited to give seminars at the JAC. There is a box to tick on the booking form if you are willing to give a talk. We also need to receive pre-prints and/or off-prints; copies would be welcome at ROE and JAC. Finally we would like to just chat about the results you obtain. In the end these things will allow us to give a better service.

Richard Wade
JAC

Receiver B2 Commissioned

A new dual-channel heterodyne receiver covering the frequency range 330-360 GHz was installed on the JCMT in September 1990. The purpose of this instrument, built at MRAO by a team led by Stafford Withington, and using mixers developed by Dave Matheson's group at RAL, is to provide a straight-forward "work-horse" receiver, easy to use and highly reliable. The design is similar to that used for receiver A, with hot and cold calibration sources followed by a polarization splitter, then a pair of Martin-Puplett interferometers which couple in the LO signal and two Schottky diode mixers cooled by a closed-cycle fridge. New features include control and monitoring of the interferometer positions from the VAX and a proper phase-lock system built by Dennis Bly (instead of an EIP counter), which means that there are no intrinsic limitations on the frequency resolution obtainable.

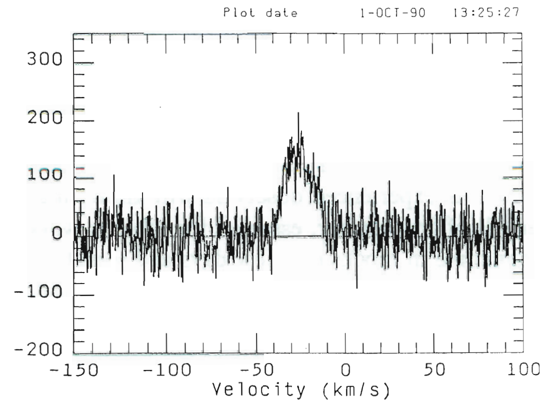
The installation of the receiver went smoothly. There were a few frights when various devices behaved in strange ways when they were first turned on, but those got sorted out after a few days on the mountain. (This response to first exposure to Mauna Kea has been known to occur in people as well as electronics.) The most urgent message back to Cambridge at that stage was a request for a shipment of English tea, the US version having been deemed to be inadequately strong to counter the working conditions. All the various cryogenic, electronic, mechanical, and software elements came together by the afternoon of 1st October and so it was decided to try for a spectrum. The result is shown in the figures - basically it all worked! Given that the commissioning was not due to start until the night of 2nd October, this was very satisfying.

There was in fact plenty to do during the receiver commissioning period. The JCMT system is sufficiently complex that taking it through all the possible modes of operation and understanding all the peculiar phenomena that occur is pretty challenging. A number of subtle problems had to be dug out - like the PTS synthesizer that resets to local control if the least significant digit happens to be a 1! Much effort was devoted to setting up the VAX algorithms so that the procedures for tuning up would be simple and quick, and a lot of work went into measuring efficiencies, beam shapes, etc. Another problem that is becoming more of a limitation at these wavelengths is that there are few, if any, good calibration objects for a telescope with as much gain as the JCMT. The planets are generally significantly resolved that one has to try to take into account things like limb darkening when estimating coupling efficiences. Lower order problems also occur: a good deal of worry about non-circular beam profiles could have been avoided by recalling that Saturn has some non-circularly-symmetric appendages (Galileo, circa 1610) which do contribute a good deal of flux at 345 GHz!

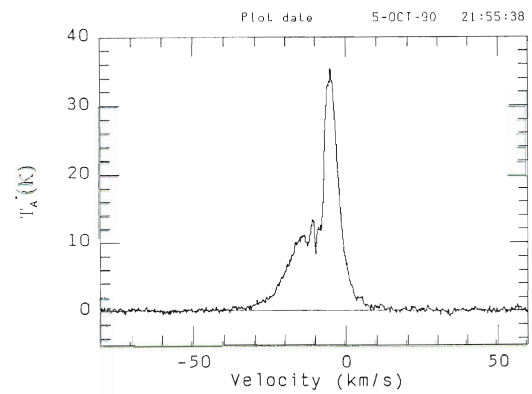
There was also some worry that one of the channels had a significantly poorer coupling to the telescope than the other. (It seems to be an unavoidable consequence of building dual-channel receivers that people always ask what is wrong with the less good channel, not why is the better channel so good.) Towards the end of the commissioning the problem was traced to a mirror which had got out of alignment. So with this and a lot of other details cleared up we were pleased to have the receiver accepted by JCMT and to see it go into use as a common-user system the following week.

Heartfelt thanks go to all who worked so hard on the project, including those already mentioned, and Rob Baldwin, Hugh Gibson, Colin Hall and Dennis Molloy from MRAO, Brian Ellison and Brian Moyna from RAL, the software specialists Mary Fuka, Alistair Glasse, John Lighfoot and Chris Mayer and support scientists Fred Baas and Per Friberg, and to the many others who contributed in various ways to the success of the project.

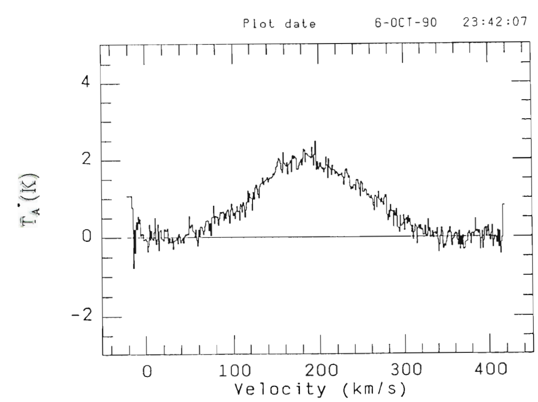
Richard Hills
MRAO



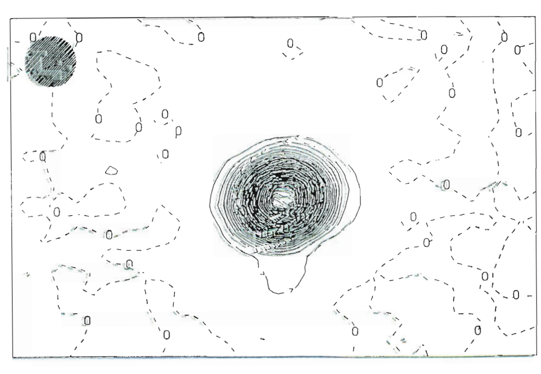
The first spectrum. IRC+10216 happened to be well-placed



A better spectrum - S140 (2.5 minutes integration on souce & 2.5 off).



An extragalactic object - NGC 253. 2 minutes integration on source



Beam map on Mars. Bottom contour is 2%

JCMT Instrumentation for Semester U and Observational Sensitivities.

The band 220 - 280 GHz: receiver A1

Receiver A1 nominally covers the frequency range 220 - 280 GHz. There are two mixer sets: A1(lower) operates well up to 245 GHz, while A1(upper) is better at frequencies above 245 GHz. Frequencies somewhat outside this range may be accessible with some degradation of performance. The three Gunn oscillators which cover the complete tuning range will be replaced (in May 1991?) by a Gunn oscillator capable of a wide tuning range .

Receiver A1 is a dual-channel device, receptive to both polarizations. However, to date Receiver A1 has been operated in a 'hybrid' mode, i.e. with one mixer installed for each of the upper and lower frequency ranges. The present single-channel spectrometer backend (AOSC) permits observations in only one frequency band, and in a single polarization at a given time. A single-sideband filter should be available for users requiring rejection of the image sideband; it should be specifically requested in the proposal.

On the telescope, typical double-sideband receiver temperatures for A1 at the band centres are 350°K and 650°K for the lower and upper bands respectively, corresponding to single sideband system temperatures of about 900°K and 1500°K respectively in the best cases. Receiver temperatures increase with distance from the band centres; at 272 GHz and above receiver temperatures can be 1000°K and greater.

The band 310 - 380 GHz: receivers B2 and B3(i)

Two new receivers in this frequency range underwent commissioning tests in late 1990. B2 is a dual-channel Schottky mixer system built by MRAO and RAL; B3(i) is an single-channel SIS receiver developed by the HIA/Kent/RAL consortium and currently in an interim configuration pending the full dual-channel system. B2 is essentially fully commissioned; further work is needed on the SIS receiver. Receiver B1 has been retired.

Receiver B2 has a tuning range from 330 to 360 GHz; frequencies outside this range are not accessible. Receiver temperature performance is fairly constant; at band centre, the minimum value is ~550°K, rising to about 700°K at 330 GHz for the better of the two mixers. The second mixer has a receiver temperature ~100°K greater. System temperatures obtainable on the sky under good conditions are therefore between 1500 and 2000°K.

The abilities of Receiver B3(i) have not yet been fully explored; after mixed success last November and additional subsequent work, further tests are likely in February. The coupling between receiver optics and telescope now appears to be satisfactory. There is a major disparity between the broadband receiver noise temperature and that indicated by the observed strengths of astronomical lines (which are reduced in intensity by about a factor of 2.5 when compared with results from B2). We suspect there is a problem with the mixer and/or the mixer block. The receiver will be returned to HIA after the end of March for investigation before returning to JCMT for further commissioning; hopefully it can be offered to users some time in Semester U. It should cover the frequency range ~306 to 380 GHz, with a receiver temperature projected to better than 300K throughout the band. If these numbers are reflected in the spectral line performance, they correspond to a system temperature of about 900K under good conditions.

Users should not assume that B3(i) will be available during semester U; proposals for the frequency range 330 - 360 GHz should include time estimates based on the performance figures given for B2. Proposals requiring frequencies below 330 GHz or above 360 GHz may be accepted on a 'shared risks' basis, depending on progress on B3(i), and scheduled contingent on the status of the receiver.

460 - 490 GHz; receivers C1 and C2(i)

Receiver C1 should be available in its final form in semester U for use at frequencies close to the CO J=4-3 (461.04 GHz) and neutral carbon $^3P_1$-$^3P_0$ (492.16 GHz) lines. Actual ranges are ± 1.0 GHz at 461 GHz and -1.0 to +0.52 GHz at 492 GHz. The standing waves which plagued the earliest observations have been eliminated and mixer improvement at 492 GHz realised; work by Dennis Bly and Rachael Padman in January 1991 has seen the completion of the new LO system and hot load.

Receiver C1 is a heterodyne receiver for the 450 to 500 GHz waveband, using InSb 'hot electron' bolometers as mixers. Because of the finite time constant of this form of mixing, the practical single-sideband IF bandwidth is a little less than 2 MHz. It is therefore necessary to 'sweep' the local oscillator frequency across the line to obtain a spectrum. This leads to the major consideration when planning observations with this type of receiver: if one observes a spectrum covering n channels the effective system temperature will be be increased by √(2n). Since the mixers respond to both sidebands, the normal resolution is less than 4 MHz (about 2.6 km/sec), but higher resolutions can be obtained by switching in filters (with double-sideband widths between 500 kHz and 4 MHz) in the IF chain. Two mixers, sensitive to orthogonal linear polarizations, are provided.

Although the operation of C1 is now straightforward and routine, the atmosphere prevents useful observations for more than one-half of the time on average, so users should be prepare a suitable backup programme. Typical receiver temperatures are better than 800°K at 461 GHz, and ~1300°K at 492 GHz for each mixer, or ~550° and 900°K if both mixers are used at the same frequency. Under reasonable sky conditions, total system temperatures, after atmospheric and telescope losses, are (very) approximately 3000°K and 7000°K per channel, or 30000 and 70000°K respectively for a 50-channel spectrum.

A second receiver [C2(i)] for this band is under construction at RAL, and may be commissioned at JCMT in semester U. Few predictions can be made for the performance of this (single-channel SIS) receiver, except that it is likely to cover the complete range from 450 to 500 GHz with a receiver temperature of the order of 500K (DSB). Proposals cannot be accepted for C2(i) yet, but if it were available at the time of observations, proposals for C1 could make use of it.

The 690 and 800 GHz windows: Receiver 'G'

Thanks to the continuing arrangement with Reinhard Genzel and his group at the Institut für Extraterrestrische Physik in Garching, Receiver G should be offered once again for users in Semester U. Interested users should contact either Prof. R. Genzel or Dr. A. Harris to arrange collaborative efforts. Described in 'Protostar' (Sept. 1988), the instrument is largely self-contained. Because LO power is provided by an infrared-pumped laser, only certain discrete frequencies can be accessed, in the regions around the CO J=6-5 and 7-6 lines at about 690 and 800 GHz respectively. Three laser lines are used commonly: $^{15}NH_3$ (802.986 GHz), HCOOH (692.951 GHz) and CH_3I (670.463 GHz). Other possibilities are available, and individuals wishing to observe at other frequencies should first check with the MPE group. In the 800 GHz region, the HCN and HCO+ (J=9-8) lines can be observed, along with the neutral carbon ($^3P_2$-$^3P_1$) transition. Note that the J=6-5 transition of CO is much easier to detect than the CO(7-6) line, since the telescope is much more efficient at the lower frequency. In general the IF bandwidth is about 1 GHz, with coverage in the IF between 1 and 10 GHz, with some gaps. One 'on-board' 1100 MHz AOS having a spectral resolutions of about 500 kHz is provided.

Receiver G is mounted on the right Nasmyth platform of the JCMT. Typical double-sideband receiver temperatures range from 3000 through 4500 K; specifically, at CO(6-5) and ^{13}CO(6-5) receiver temperatures of 3000 and 3500 K are obtained. The resulting single-sideband system temperatures are extremely sensitive to atmospheric conditions, but are likely to be of the order of 55000 K or more, under practical conditions. It is likely that about one month (December?) will be set aside specifically for observations with Receiver G; interested users should develop proposals with this in mind, and be aware that a low-frequency back-up proposal requesting no time (Protostar, Sept. 1989, p. 12) is also required.

Spectrometer Backends

The new Digital Autocorrelation Spectrometer (DAS) built at Dwingeloo will provide considerably expanded capabilities in terms of frequency resolution and IF configuration over that available to date. Commissioning at JCMT is scheduled for mid-1991, and may even be offered to users late in semester T. The DAS has 2048 delay channels, divided into 16 analogue sections each 125 MHz wide, with a total maximum bandwidth of 2 GHz. It will be able to accept up to eight IF inputs, with spectral resolutions of between 0.1 and 1.0 MHz. The most commonly used configurations will probably be the dual-polarization modes, with maximum 1 GHz bandwidth per channel and 1MHz resolution; higher resolutions give proportionately lower total bandwidth per IF channel.

The AOSC is an acousto-optical spectrometer which offers a resolution of ~330 kHz and a total bandwidth of 500 MHz for a single IF channel. It is expected to provide the backup spectrometer capability at the JCMT.

Approximate rms sensitivities after 30 minutes' integration (spectral line)

Below is a table of the calculated rms noise in Kelvin after a total observation time of 30 minutes (15 minutes each on source and on a reference position), for three different values of atmospheric transmission. There have been requests for a table of measured results obtained in actual observing runs; such a tabulation would be neither complete nor consistent, since the available information was taken under a wide range of conditions. However, in my experience the values listed represent what is actually observed. It is also my experience that the rms noise decreases as √(total integration time) except in pathological cases.

The rms noise values also scale directly with system temperature, and thus depend critically on atmospheric conditions. The system temperatures and rms noise quoted should be achieved under 'typical' conditions (approximately 1.5mm of water vapour), and will rise rapidly as the weather worsens. In parentheses, the expected values of the rms noise are given for 'exceptional' and 'poor' weather conditions (about 0.5 and 5 mm of water vapour respectively). Although these should be taken as a guide only, it is clear from this table that atmospheric conditions affect receiver B, C and G observations strongly, and poor conditions render work at the higher frequencies impossible. One should always have a contingency plan, in case of poor weather. Observations are usually possible at 230 GHz. One should include overheads for 'dead' time during observations. Although it depends on the efficiency of the observing technique used and the relative positions of sources in the program, in general one can expect to spend about 25% more time in telescope movement and software overheads. Observations made in a beam-switched mode seem to require somewhat higher overheads. Additional time is required for careful pointing and focus measurements, particularly in the early evening and after dawn.

Continuum Observations: UKT14

The UKT14 bolometer system will be available during Semester U with filters permitting observations at 2, 1.3, 1.1, 0.85, 0.8, 0.75, 0.6, 0.45 and 0.35 mm. The narrow-band 0.75-mm filter has recently been installed and is being tested. The previously-available 1-mm ultra-wideband filter has been retired. Improved filters for the longer wavelengths may be in place at this time. The aperture of the bolometer can be adjusted between 21 and 65 mm. Sensitivities (in terms of NEFD - noise-equivalent flux density) range from typically 0.3 Jy/√(Hz) at the longer wavelengths (with the exception of the 2mm band, which is poorly matched to the antenna), through to 10 Jy/√(Hz) or more at the highest frequencies under good photometric conditions. Only about 30% of all nights permit meaningful results at 450 and 350μ, however. The properties of UKT14 with various available filters and apertures are tabulated below. The value of the NEFD given is that which should be obtained under 'good' conditions (but see below) for a 65mm aperture (normal for photometry; maps are usually made with a diffraction-limited beam using the apertures given); users should use this to estimate time requirements. In parenthesis, values for the 'best' and 'poor' atmospheric conditions are given, simply to indicate typical ranges obtained.

The dominant contribution to the noise in a UKT14 measurement originates from the atmosphere, and since this most definitely does not obey gaussian statistics, there is a time in every longer integration after which the noise level will not decrease. That is, it is not just the transmission of the atmosphere which influences the signal/noise ratio, but the

Freq (GHz)	Receiver	T(rx) (K)	T(sys) (K)	dv (MHz)	Rms noise (K)	η_{fss}	η_l	Notes
230	A1	350	960	0.33	0.08 (0.07,0.11)	.69	.91	
270	A1	650	1600	0.33	0.13 (0.11,0.18)	.63	.90	
330	B2	680	2140	0.33	0.18 (0.16,0.67)			
345	B2	560	1720	0.33	0.14 (0.12,0.32)	.60	.90	
461	C1	560	30800	4.00	0.72 (0.41, *)	.73?		1,2,3
492	C1	900	76000	4.00	1.79 (1.25, *)			1,2,3
690	G	3000	48300	1.00	2.28 (0.97, *)			2,3
810	G	4000	78800	1.00	3.71 (1.43, *)			2,3

Notes:

(1) This assumes a total of 50 channels in the spectrum and dual-channel operation.

(2) An '*' means that observations are not possible when conditions are 'poor'; the rms noise is effectively infinite.

(3) Awaiting reports or further commissioning for η_{fss}, η_l, where η_{fss} is the efficiency allowing for forward spillover and scattering.

major effect is correlated noise due to atmospheric microstructure. The degree of atmospheric instability is reflected in the time beyond which the signal/noise ratio does not improve. Atmospheric stability does not appear to be correlated with improved transmission, but rather the converse. Thus it is difficult to provide further guidance on the effect of differing atmospheric conditions. To combat this effect it is usual to combine a number of short measurements (say 5 minutes each), rather than one longer one, and derive the mean flux density and standard deviation from the set of signals. The length of each integration will be judged from the atmospheric conditions at the time of the observations. When writing proposals, it is appropriate to choose an NEFD corresponding to "good" conditions, rather than "best". On average, this gives reasonable time estimates. A major problem until recently has been obtaining good calibration of UKT14 data. Introduction of in-line chopper-wheel calibration should remove much of this difficulty; skydip measurements can now be made routinely and appear to provide reliable results. Work is well advanced to relate the observed opacities from skydip measurements to those obtained from planetary observations.

UKT14 polarimeter

The Aberdeen/QMW polarimeter will be available during semester U as an optional accessory for the UKT14 bolometer system in step and integrate mode (i.e. photometry is performed at each of a number of waveplate position angles).

The effective NEFD of the polarimeter/UKT14 combination is NEFD(p) = 2xNEFD/P, where P is the degree of polarization of the source. The additional factor of 2 arises because only one polarization is detected. Thus the detection of the polarized signal from a 20% polarized source will take $(2/0.2)^2 = 100$ times longer than the detection of the unpolarized object using UKT14 alone. The polarimeter is subject to the same atmospheric noise problems that afflict UKT14 measurements.

Overheads in UKT14 observations

In continuum photometry and mapping, the careful observer will spend a significant amount of time in frequent calibration measurements. This time is to be added to the normal 25% or so which is added to allow for telescope movement and so forth. The actual 'astronomical' overhead will depend on the program goals, observing techniques, and source strengths, and may range from about 20% extra up to 80% or more in the most extreme cases. In estimating this overhead, mapping programs tend to consume the lowest overheads, while photometry of strong sources result in high overheads. Higher-frequency observations demand greater overheads, because of the need to carry out more frequent pointing and calibration checks.

Henry Matthews
JAC

Filter (mm)	Wave-length (micron)	Centre Freq. (GHz)	Band-width (GHz)	Aper-ture (mm)	Beam-width (arcsec)	NEFD (65mm ap.) Jy.√(sec)	Notes
2.0	2000	150	40	65	28	2.0 (2.0,3.0)	1
1.3	1300	233	64	65	21	0.3 (0.3,0.5)	
1.1	1100	264	75	65	19	0.3 (0.3,0.7)	
0.85	850	354	30	47	16	0.8 (0.7,5.0)	
0.8	761	394	103	47	14	0.7 (0.5,5.0)	
0.75	730	411	28	47	14	not available	2
0.6	625	480	119	36	9	not available	3
0.45	438	685	84	27	7	6.0 (4.0, *)	4
0.35	345	870	249	21	6	12. (8.0, *)	4

Notes:
(1) At this wavelength the UKT14 optics is poorly coupled to the JCMT.
(2) Not yet commissioned. Values will be somewhat greater than for the 0.85mm filter.
(3) This filter is best avoided. It is difficult to obtain consistent calibrations, due to deep atmospheric absorption lines in the window.
(4) Observations are not possible under 'poor' conditions at these wavelengths. What constitutes 'poor' is very subjective!

Short-Baseline Interferometry

Work has started on the link to join JCMT and the Caltech Submillimeter Observatory (CSO) in a fixed-baseline heterodyne interferometer. To keep the project straightforward and to get us on the air quickly it was planned to copy the technology in use at the mm-wave interferometer at Owens Valley. But the low-loss coaxial cable as used in their link is thick and almost rigid and could not be pulled through the existing cable ducts on Mauna Kea. New ducts would cost as much as the rest of the project, so it was decided to switch to fibre-optic links. The cables are thin and flexible and should be easy to pull, but the link suddenly becomes a development project. For intermediate frequency signals, a fibre link is likely to be easier in many ways than a coax link because of its much lower loss, and the Australia Telescope has implemented a fibre IF system with success. The local oscillator link is more tricky, and no interferometer yet uses fibres. The LO link always has to have the better phase stability, and work is under way at Owens Valley on how best to lock the local oscillators when photon noise in the fibre system is likely to be the main limiting factor.

The choice of fibres is interesting. Phase-stability is a major issue; as ambient temperature increases the cable gets longer and the signal takes longer to get through, delaying the phase and spoiling the observation. A beautiful solution exists, which was our first choice. The fibre is contained in a pressure-tight sheath, and the space between them is filled with a strange fluid with a carefully-designed coefficient of thermal expansion. As the temperature falls the pressure increases and squeezes the fibre, lengthening it by as much as its own thermal coefficient shortens it. The result is a cable with two orders of magnitude better phase-stability than if uncompensated, a really nice invention - so nice that the person who thinks he invented it wants royalties from the manufacturer, and the resulting legal problems make its availability doubtful so we may have to settle for the best of the rest.

The Smithsonian project progresses apace. Visitors to JCMT this last year may have noted a rogue rack of equipment in the basement. This was the electronics for Colin Masson's site-testing interferometer. Two small satellite-TV dishes were aimed at a synchronous satellite above the continental USA. By monitoring the phase fluctuations in the centimetre-wave signal from this satellite it is possible to calculate the mm and submm phase fluctuations. Initial results suggest that Mauna Kea is every bit as good as was hoped for interferometry.

Adrian Webster
ROE

Progress on SCUBA

SCUBA (Submillimetre Common-User Bolometer Array) is the submillimetre camera being built at ROE for JCMT. It has 2 arrays, each with a field of view of roughly two and a half arcminutes; one operates at 850 or 750 μm and the other at 450 or 350 μm. In addition there are individual pixels to allow observations at 1.1, 1.3 and 2.0 mm. All the detectors are cooled to 0.1 K by a ^{3}He/^{4}He dilution refrigerator and the whole instrument will be mounted on the left-hand Nasmyth platform of JCMT currently occupied by UKT14. Because the detectors (131 of them) are much more sensitive than those in UKT14, SCUBA will be able to acquire data thousands of times faster than UKT14.

Considerable progress has been made over the past few months. Particularly exciting has been the development of the first prototype bolometric detectors to the required specification. The first production models of the bolometers in their SCUBA mounting structures are being made as I write. More obviously impressive to the innocent eye is the working refrigeration system and phase 1 cryostat which has now been commissioned at ROE. Even those of us familiar with the full-size drawings have found ourselves stunned by the scale of our own creation. The commissioning went remarkably well with no major problems.

The data acquisition electronics is progressing well through its manufacturing stage, and combined with the refrigerator and first production models of the bolometers and mounts mean that before the summer we will be taking the first test data with genuine SCUBA 0.1 K bolometers and processing it with the SCUBA transputer-based data acquisition system. Before you ask why it isn't being delivered to the telescope then I should point out that not only do an awful lot more bolometers need to be made and tested, but we haven't yet started the manufacture of all the final SCUBA optics; the tests this summer will be with a simple infrared illuminator and lens system inside a closed cryostat!

We still expect delivery to the telescope in August 1992.

Walter Gear
ROE

The JCMT Support Scientist Corner

I will discuss observing strategies with UKT14, especially when it is used for mapping. During the last year we have gained access to several tools, which make calibration of UKT14 much easier.

We now have access to the CSO sky monitor, which continuously measures the sky opacity at 1.3mm. This information helps us to plan an observing run much more efficiently, because we know what the sky will look like and we can plan our observations based on this information. Since this unit provides a continuous measure of the sky opacity, this information can also be used when trying to calibrate the UKT14 data after a run.

Work on the calibration unit is also starting to pay off. It has indeed been very valuable to obtain skydip data every night, and Bill Duncan has worked extremely hard on the analysis software for the UKT14 skydips. Although his software has not yet been installed at the summit, it now appears that we can get reliable opacities from the skydips. Direct UKT14 calibration is expected to speed up the observations and it will definitely result in more accurate calibration. Incidentally, the analysis of the skydips shows that the responsivity of the 800μm filter is a quite a strong function of the water vapor along the line of sight, and therefore the gain conversion factor is really a function of elevation as well as of the total precipitable water. Although we have always suspected this, it has not been possible to derive this reliably from conventional photometry. The same effect is seen in other filters as well, and even more strongly in the 600μm filter, which lies in a very poor atmospheric window. It also appears that the telescope has a drop in gain at very high elevations, and it is wise to avoid observations close to zenith. Most observers avoid this regime anyway, because pointing and tracking is more unreliable due to the high speed tracking of the telescope.

The recent improvements in the telescope surface have improved the aperture efficiency at 450μm and 350μm, but calibrating 450μm maps is still very difficult, and few - if any - really know how it should be done. First of all one should remember, that even if the rms surface accuracy of JCMT is as good as ~30μm, the telescope will have significant error lobes at short wavelengths. Although most of the error pattern is down by a factor of 10 or more, the error lobe is quite extended and will therefore pick up a lot of power on an extended source. With a large chop, say 90 - 200", very little of the error pattern is cancelled out, and the integrated power over the error pattern will amount to more than what is received through the main beam. What I mean by this is that if we map a planet over say 1 - 2 arcmin, and integrate over the whole calibrated map (which is normally calibrated in Jy/(main beam)), we will find that the total flux is more than twice that of the planet. This is true both at 450μm and 350μm. A large chop will also change the beam due to coma. The best results are therefore obtained by keeping the chop throw as small as possible. For point source photometry this does not really matter, but it is rather crucial for mapping.

This is the way I map at 450μm:

1) I always use the diffraction limited beam. I map on-the-fly in dual beam mode and restore the data later. To me it is an advantage to utilize the resolution fully; I can smooth the map later to coarsen the resolution and increase signal to noise.

2) I use a very small chop throw, 20", or at most 30" for maps up to 3 arcmin in size. The dominant noise source in 450μm and 350μm mapping is always the sky. Therefore, even though I map over an area more than 3 times the chop throw, the degradation due to the map size is much less than the more effective sky cancellation, which I achieve by using a small chop. I also use very short integration times - as short as I possibly can, i.e 1 - 2 sec/pixel (sampling interval). Again, short integration times mean that it takes less time for the positive and the negative beam to move through the same point in space and hence I achieve a better cancellation if the atmosphere varies.

I don't know if this technique can be used to map a very faint source (like a galaxy) - nobody has ever tried. If an individual map is basically noise, then restoring the map will just amplify the noise. In this case it will not help to coadd such restored maps. The signal is lost forever. I know from my own experience that I tend to lose extended emission, even on a strong source, if I make a dual beam map during poor weather conditions. Some of this extended emission, however, can be retrieved, if I smooth the map before restoring.

The chopper driver for the secondary has recently been rebuilt and on-the-fly mapping is now also possible in equatorial or descriptive coordinate systems (although we have no software yet to deal with such maps). RA/Dec mapping can be a very valuable tool for mapping faint sources. Since we can map exactly the same area many times, the unrestored maps can now be coadded before restoring. One should therefore be able to map even a faint galaxy with this technique, without having to worry whether the beam is distorted due to the chop throw, or whether one is chopping far enough to really be off the source.

3) I over-sample heavily. For 450μm I typically use a sampling interval of 2", whereas the HPBW is ~7.5" at best. Since nearby pixels are closely correlated I can apply just a little bit of smoothing to the map and gain a lot in S/N while losing hardly anything in resolution. In maps with good S/N one should easily be able to retrieve additional resolution by applying Maximum Entropy Methods. Unfortunately we do not yet have MEM software at JCMT, but when we do, it will be easy to reprocess the maps.

4) I always make beam maps of planets. I try to do one each night, but like most observers I get carried away occasionally and try to squeeze in as much science as possible. It is quite clear that the beam shape is a strong function of how well the telescope is focussed, not only in z (along the axis), but also in x and y (orthogonal to the axis). The beam maps provide of course a direct method to measure the contribution from extended emission (~60% in 1 $arcmin^2$ at 450μm and a 20" chop before the last change of telescope surface). It also gives a measure of the HPBW. Unfortunately I do find variation in the beam size, in the amount of coma sidelobes, and overall error lobe contribution, but I cannot yet really say where these variations come from. It could be due to elevation dependent effects, thermal gradients over the backup structure and support of the dish, or it may just be poor focussing or sometimes a lousy atmosphere (refraction noise). I have several times found the beam to be elliptical even at 800μm, while at other times it appears perfectly nice and symmetric.

Above I have outlined the way I carry out mapping with UKT14, but it is quite clear that it can be done differently. However, whatever approach you choose, make sure that you do enough calibration and beam maps and make sure that you take your beam maps with exactly the same technique. JCMT does provide very good spatial resolution, but there is no reason to be satisfied by just getting nice looking maps if one can get calibrated data. Astronomy is not just glossy pictures, it is understanding the physics behind them.

G Sandell
Joint Astronomy Centre

JCMT Data Reduction Notes

This is the first in an occasional series of articles dealing with the reduction of JCMT data. Since it is the first, I'll begin by giving a brief description of the data reduction tools available and their normal mode of use.

The **SPECX** package written by Rachael Padman is recommended for the reduction and analysis of spectral line data. SPECX uses its own command line interpreter and manipulates spectra in a pop-down stack. Some of its major capabilities are:

- listing and display of spectra on a graphics terminal, with hardcopy on a variety of printers;
- single and multiple spectrum arithmetic, spectrum averaging, etc;
- fitting and removal of polynomial, harmonic and gaussian baselines;
- filtering and editing spectra;
- determination of important line parameters (peak intensity, width, etc);
- fourier transform and power spectrum calculations;
- user calibration of data;
- assembly of reduced individual spectra into a map file, contouring of any plane or planes in the resulting cube;
- the ability to write macro-command sequences and indirect command files.

SPECX uses its own data file format, so it is not possible to directly access reduced spectra from other analysis packages (eg. Figaro on Starlink). However, there is a facility for writing spectra and maps to ASCII files.

SPECX has extensive on-line HELP information. In addition, a complete (143 page) description is given on systems with SPECX version 6 installed in SPECX_V6-0A.TEX. A shorter description of the incremental changes between versions 5.4 and 6.0 is given in REL_V6-0A.TEX.

Version 5.4 is currently available on Starlink machines in the UK while version 6.0 is running at the JCMT and at the Joint Astronomy Centre in Hilo. Starlink will move to version 6.0 in the next few months; in the meantime UK users should note that dump files (SPECX.DMP) from version 6 are incompatible with version 5.4 and should be deleted before data analysis is resumed at their home institution.

In the next item Rachael gives some ideas on how to get the best out of SPECX version 6.

NOD2 is the recommended package for the reduction of photometric maps obtained with UKT14. Originally developed at the Max Planck Institut für Radioastronomie at Bonn, the package was adopted as an interim measure by the JCMT to gain access to certain algorithms which were not available elsewhere. These routines include:-

'RESTOR' - reconstructs the equivalent single-beam map from data taken by the telescope scanning over the source in the direction of the secondary chopper throw.

'CONVERT' - creates an RA-Dec map from the Az-El results produced by the JCMT.

Extensions have been added to perform JCMT-specific operations, and to output results in a form suitable for further analysis using the IRCAM reduction package on Starlink. Reduced maps can also be output in FITS format. The JCMT extensions are:-

'MAKMAP' - converts the raw data in a JCMT *.GSD file to NOD2 format.

'JCMT_TOOLKIT' - can be used to scale (calibrate) maps, correct the raw data for atmospheric extinction, or flag bad pixels.

'NOD2SDF' - converts a NOD2 file to a Starlink HDS format readable by the IRCAM data reduction package.

NOD2 itself can be used to plot the data to a Tektronic-compatible graphics terminal, but cannot produce hardcopy. It is recommended that users read 'A NOD2 Primer' by G. Sandell before attacking their data; this can be found in PRIMER.DOC in the 'NOD2' directory at any Starlink node. NOD2 is available at the JCMT, at the JAC, and at all Starlink sites in the UK.

Work has been under way for some time to implement the necessary sections of NOD2 as applications in the Figaro data analysis package on Starlink. This work should be completed and the additions released in the next 2 or 3 months. When everyone is satisfied with the Figaro version, NOD2 will be dispensed with.

Stand-alone copies of SPECX and NOD2 can be obtained from Richard Prestage at the JAC or from John Lightfoot (JFL) at ROE.

J Lightfoot
ROE

SPECX Notes

One (well deserved) criticism of SPECX is that the map file format is somewhat simplistic, and in particular that it does not allow for the integration time and system temperature to be stored for each individual spectrum. It is thus not possible to average spectra into the map with the appropriate weighting for their signal-to-noise ratio. I thought it might be useful to discuss briefly two ways of overcoming this deficiency, both of which are available in V6.0A and later versions.

The simplest and most straightforward is obviously to keep the individual spectra in an ordinary SPECX data file, with one spectrum per map point. With the aid of an INDEX listing, you can then identify the spectrum appropriate to the particular map point, READ it, AVERAGE in the new spectrum, and then REWRITE the spectrum to the data file. At any time when you want to make a map, you just transfer the data to the .MAP file (using the ADD-TO-MAP command), and proceed in the usual way. This last step can be simplified greatly by the use of the DO command:

```
>> replace = t
>> DO i 1 no_map_pts
INSERT> read-spectrum in_file i
INSERT> add-to-map
INSERT> ^z
>>
```

The first line tells SPECX that it is OK to overwrite any existing spectrum at that map point, so you don't need to open a new map all the time - you just keep updating the same one. "No_map_pts" is a predeclared variable that tells you the current number of spectra in the last opened map file, while "in_file" is another variable that tells you the number of the file you read from last time round. So this is all very easy. There is also another slightly messier way of doing this, that circumvents the intermediate SPECX data file. The trick is to realize that in general you have rather more spectral data points than you actually intend to use, so that there is no loss in sacrificing a few points at one end of the spectrum to hold relevant information. In the example **map_av.spx** I copy the integration time and system temperature from the scan header into the first and second data points respectively before adding the spectrum into the map. The other command file (**fetch.spx**) copies these parameters back into the header when the spectrum is extracted from the map.

Map_av.spx also illustrates the use of the error trapping facility to test whether or not the map already contains a spectrum at the particular map point. On the first attempt to include the spectrum in the map, the "replace" variable is set false, so that an error number 58 is returned if the spectrum already exists. This error is trapped, and SPECX then extracts the existing spectrum, averages it with the new one, and replaces the new average spectrum in the map file. (Information on error messages and predeclared variables is given in appendices to the user manual.)

You could then declare two command symbols - MAP-AVERAGE and FETCH say - so that from then on the use of the command files is indistinguishable from that of any "built-in" command:

```
>> MAP-AVERAGE := @map_av
>> FETCH       := @fetch
```

Of course this idea can be extended to lots of other uses. For example, the ratio of the integrated intensities in two related lines is sometimes directly related to the gas kinetic temperature. It is quite a simple matter to measure these integrated intensities, perform the necessary mathematical operations, and rewrite the deduced temperature instead of yet another data point that you didn't really need. In order to make a map of this parameter, just set the x-axis scale to channels (SET-X-SCALE 1) and make a contour map of the particular channel of interest. All the facilities of the 2-D interactive graphics, including measurement of integrated intensity, and maximum and minimum on the map, are now available to you.

Rachael Padman
MRAO

fetch.spx

Gets a spectrum from a map and restores the integration time and system temperature

```
get-spectrum-from-map ?\?\?

int_time = data(1)
tsys(1) = data(2)
data(1) = data(3)
data(2) = data(3)

return
```

map_av.spx

Command file to average a spectrum into the map. Checks whether there is already a spectrum in the map at this position, and if not inserts the current one: if there is it extracts the current one and averages the two together before reinserting it.

```
declare scan_npts     i4
declare save_severity i4
declare save_d1       r4
declare save_d2       r4

print '    Average into map'

last_error    = 0
replace       = false
save_severity = severity
set-error-return F

scan_npts = npts(1)

save_d1  = data(1)
save_d2  = data(2)
data(1)  = int_time
data(2)  = tsys(1)
add-to-map
severity = save_severity

if ( last_error = 58 )
  print '...averaging with existing spectrum'
  get-spectrum-from-map \\ ra_offset, dec_offset

  if (npts(1)<>scan_npts)
    print ' '
    print '   Map and spectrum have different #points!'
    pop-stack
    data(1) = save_d1
    data(2) = save_d2
    return
  endif

  int_time = data(1)
  tsys(1)  = data(2)
  average-spectra
  data(1)  = int_time
  data(2)  = tsys(1)

  replace = true
  add-to-map
  replace = false

else
  print 'Spectrum added directly into map'
  print ' '

endif

 data(1) = save_d1
 data(2) = save_d2

return
```

1990 Refereed Papers from JCMT Observations

Now that the scientific output of JCMT is ramping up, we need to maintain a list of scientific papers based on observations made with the JCMT as a measure of the productivity of the telescope - and its users! Here is a list of those published in refereed journals in 1990 - more than in 1988 and 1989 added together. Space prohibits listing conference contributions here. No fewer that 21 contributions based on JCMT work were published in the proceedings of the Kona Symposium (Submillimetre Astronomy, eds. G D Watt and A S Webster, Kluwer 1990). Please send any additions and corrections to the following list by e-mail to: JPV@uk.ac.roe.starlink (before June 1991) or to Mrs Dorothy Skedd at the Royal Observatory Edinburgh.

Adams, F.C., Emerson, J.P., Fuller, G.A.
Submillimeter photometry and disk masses of T Tauri disk systems.
1990, Astrophys. J., 357, 606.

Avery, L.W., Hayashi, S.S., White, G.J.
The unusual morphology of the high-velocity gas in L723: one outflow or two?
1990, Astrophys. J., 357, 524.

Chandler, C.J., Gear, W.K., Sandell, G., Hayashi, S., Duncan, W.D., Griffin, M.J., Hazell, A.S.
B335 - protostar or embedded pre-main-sequence star?
1990, M.N.R.A.S., 243, 330.

Davis, C.J., Dent, W.R., Bell Burnell, S.J.
HCO^+ observations of Herbig-Haro objects 1 & 2.
1990, M.N.R.A.S., 244, 173.

Duncan, W.D., Robson, E.I., Ade, P.A., Griffin, M.J., Sandell, G.
A millimetre/submillimetre common user photometer for the JCMT.
1990, M.N.R.A.S., 243, 126.

Goldsmith, P.F., Lis, D.C., Hills, R.E., Lasenby, J.
High angular resolution submillimeter observations of Sgr B2.
1990, Astrophys. J., 350, 186.

Graf, U.U., Genzel, R., Harris, I., Hills, R.E., Russell, A.P., Stutzki, J.
Detection of an isotopic short submillimeter CO line: column densities of warm gas in molecular clouds.
1990, Astrophys. J., 358, L49.

Hoare, M.G.
The dust content of two carbon-rich planetary nebulae.
1990, M.N.R.A.S., 244, 193.

Hughes, D.H., Gear, W.K., Robson, E.I.
A submillimetre and millimetre halo in M82.
1990, M.N.R.A.S., 244, 759.

Israel, F.P., Baas, F., Maloney, P.R.
CO J=2-1 observations of the central region of NGC 3628.
1990, Astron. Astrophys., 237, 17.

Jewitt, D., Luu, J.
The Submillimeter Radio Continuum of Comet P/Brorsen-Metcalf.
1990, Astrophys. J., 365, 738.

Lindsey, C.A., Yee, S., Roellig, T.L., Hills, R., Brock, D., Duncan, W., Watt, G., Webster, A., Jeffries, J.T.
Submm observations of the Sun from the JCMT.
1990, Astrophys. J., 353, L53.

Little, L.T., Heaton, B.D., Dent, W.R.
The outflow and compact core of the molecular cloud GGD12-15.
1990, Astron. & Astrophys., 232, 173.

Sandell, G., Aspin, C., Duncan, W.D., Robson, E.I., Dent, W.R.
SSV 13 - a disk collimated outflow?
1990, Astron. & Astrophys., 232, 347.

Sasselov, D.D., Rucinski, S.M.
Formaldehyde mapping of Rho Ophiuchi B1: the densest cold prestellar core.
1990, Astrophys. J., 351, 578.

Smith, P.A., Brand, P.W., Puxley, P.J., Mountain, C.M., Nakai, N.
A 450-μm continuum map of M82: Comparison with the CO emission.
1990, M.N.R.A.S., 243, 97.

Williams, P.M., van der Hucht, K.A., Sandell, G., Thé, P.S.
Millimetre and infrared observations of the wind from the Wolf-Rayet star γ Velorum.
1990, M.N.R.A.S., 244, 101.

Woodsworth, A.W., Kwok, S., Chan, S.J.
CO observations of proto-planetary nebulae exhibiting the unidentified feature at 21 microns.
1990, Astron. & Astrophys., 228, 503.

New Results

JCMT and UKIRT observations of star formation in NGC1333

(The Best of both Worlds)

The search for the youngest stars in our galaxy, protostars, has attracted the attention of astronomers world-wide for many years. The true protostar is nevertheless as ellusive as ever. To date, every candidate object has been found to contain a fully fledged star, albeit in many cases a young pre-main sequence object. We have focussed our attention recently on the remarkable region to the south of the NGC1333 optical reflection nebula. Here there exists considerable 'stellar' activity including molecular outflows, embedded near- and far- IR objects, shock-excited gas emission, reflection nebulae and both bright optical and IRAS sources. Our aim is to characterize the number, morphology and nature of the sources in this region primarily in a 12' by 12' area centred on the well known IR source SSV13, itself the driving force behind the Herbig-Haro 'jet' HH7-11. We have utilized both the JCMT (in sub-mm and mm continuum passbands) and UKIRT (in the near-IR) to aid us in the quest for a detailed understanding of the processes occurring here and to attempt to answer important questions such as: How many young stars are there in this region? What evolutionary state are they in and are they coeval? Are there any true protostars here, and if so, what are their characteristics and how do their measured parameters compare with existing theories of star formation and evolution? In this article we hope to whet the appetite of both observationalists and theoreticians alike in the same way as this region has inspired us to probe further the mysteries of the dusty world of star formation.

The region of current interest contains 7 IRAS sources which are shown overlaid on an optical Palomar plate in Jennings et. al. (1987) Plate 1. Most of the IRAS sources have associated optical or near-IR objects (IRAS 3, 5, 6 and 7) except IRAS 2 and IRAS 4 which have no obvious optical/near-IR counterparts, although IRAS 4 does have associated water masers. The IRAS fluxes indicate that all sources are of relatively low luminosity (14 to 46 L_{sun}) and have dust temperatures of 33 to 48K. This implies that the stellar sources heating these objects are probably low mass. The nature of IRAS 4 indicates that it might be the youngest source in this region. It is also the coldest of the IRAS sources. Our new observations show this is true. In fact, we suggest that IRAS 4 is the youngest star yet found! At least 5 sources (including IRAS 4) have been found to exhibit CO molecular outflows (Knee 1991) and there is some indication that the axes of these outflows are aligned perpendicular to a large low density cavity seen in CS J=2-1 by Sandell and Takano (unpublished). Four of the outflows lie on a ridge of dense gas surrounding this cavity with the red shifted part of the outflows all pointing towards the cavity wall. The fact that so many of the sources are in a CO outflow stage together with the alignment of the outflows and the similarity in IRAS fluxes suggests that maybe these sources are coeval and may in fact be the result of triggered star formation where, for example, an expanding supernova shell impacted on the region and triggered the star formation process.

Results

Some of our new observations of the region are shown on the front cover. Here is shown a UKIRT 2.2μm (K) image of the region (containing 81 separate IRCAM images) to a limiting 'stellar' magnitude of K=18, overlaid by JCMT 800μm maps of IRAS 4, SSV13 and HH12. In addition to these data we have also obtained 350μm, 450μm, 1.1mm, 1.3mm and 2mm photometry of some of the IRAS sources together with J and H mosaics of the region and L images of the bright IRAS/near-IR objects.

1 Global Properties of the Region

The K mosaic shows numerous (~100) point-like sources in the region. Many of these sources are not seen at J and are therefore either part of an embedded stellar population or background stars. The general 'clustering' of sources around the center of the image suggests that we are, in general, looking at an embedded cluster of stars. In addition to the point-like sources, there are numerous nebulous objects including at least 6 linear features, 2 associated with HH6, 2 isolated to the south of SSV13, one extending from HH12 and one to the south west of IRAS 2. Some of the isolated features have previously been seen in S(1) v=1-0 molecular hydrogen images (Garden et. al. 1990). The most likely explanation of these linear features is that they are HH 'jets' i.e. highly collimated material flowing out from a central source. Since two of the areas in which we see these are known optical HH objects, this seems plausible. Another intriguing feature is the apparent cavity directly south of HH12. The HH 'jet' from HH12 forms the eastern wall of the cavity while a ridge of near-IR diffuse emission forms the western wall. This absence of near-IR emission coincides with the northern parts of the low density cavity seen in CS J=2-1.

A detailed analysis of the near-IR data is currently in progress and it is hoped that photometric colour information on all the sources will reveal the embedded population and allow us to make direct comparisons with current theoretical pre-main sequence tracks and hence estimate masses, ages and evolutionary states.

2 IRAS 4

The JCMT sub-mm/mm maps of IRAS 4 show immediately that this source is double with a separation of ~30". No near-IR counterpart is seen; the region surrounding IRAS 4 is void of all near-IR emission. Both IRAS 4A (NW) and IRAS 4B (SE) are extremely bright in the sub-mm/mm wavebands; at 800μm they have fluxes of 10.75±0.2 and 5.76±0.08 Janskys respectively. These are the brightest proto-stellar candidates known, given the distance of 350pc. Combining the JCMT photometry of IRAS 4A and IRAS 4B (from 350μm to 2mm) with the IRAS fluxes gives an energy distribution of the sources that appears optically thick below 1mm. IRAS 4A has a spectral index of ~2 from 350mm to 1.1mm which steepens to 2.5 at 2mm. The two sources, 4A and 4B, seem to be associated with the known water masers and are joined by a faint bar of emission seen at both 450μm and 800μm. Modelling of the spectrum of IRAS 4A with the disk model of Weintraub, Sandell and Duncan (1991) reveals a lower limit to the mass of 10 M_{sun}. This is by far the largest dust mass yet seen around a young star, implying that this is the youngest star yet found since it is of low mass/luminosity and has not yet had time to accrete the dust disk/cocoon enshrouding it. The fact that it is already associated with a CO outflow and water masers could be interpreted as evidence that a star has already formed. The source however, has no detectable free-free emission and it is quite possible that the outflow phase starts much earlier than previously thought and that here we see disk driven outflow rather than one driven by a star. Such a scenario could also be the driving force behind the known water masering. We therefore suggest that IRAS 4 contains at least one (possibly two, a binary) true protostar(s) with energy from the accretion processes driving the outflow and heating the surrounding gas and dust.

3 IRAS 5

This source seems to be faint in the sub-mm/mm making it different from the other 4 IRAS sources observed with JCMT. In the near-IR IRAS 5 is resolved into at least two components (7A and 7B) separated by ~7". Extending from these stars are 3 curving filaments of nebulosity which are all seen to ~30" from the central sources. These filaments are seen at J, H and K (and to a lesser extent in the optical) and appear to be the result of scattering. Since these two sources have infrared excesses and most likely have (hot) circumstellar material around them, it is possible that we are seeing the result of tidal interactions between circumstellar disks/shells around the 2 stars which form tidal tails as in interacting galaxies; the morphology of the tails is remarkably similar to those seen in galaxies and also in the models of tails (Toomre and Toomre 1972). An alternative to the interaction model is that the filaments represent the cavity walls of mass outflow from the central stars although no CO outflow has been detected associated with IRAS 5.

4 Other Sources

SSV13, HH12, HH6 and IRAS 2 have either been mapped or have been observed photometrically with JCMT in the sub-mm/mm wavebands. All 4 sources are bright at these wavelengths and some show extended emission, particularly SSV13 where knots of dust emission are seen extending along the HH7-11 'jet'. Near-IR images of IRAS 1, HH12 and some of the southern HH objects have also been acquired and are currently under analysis.

Conclusions

NGC1333 is a highly active and complex region of star formation. We have observed a 10'x10' region centred on SSV13 in the near-IR at J, H and K and selected regions including the IRAS sources at L. Preliminary investigation of the data suggests that there is an embedded population of stars, possibly forming a cluster, centred approximately on SSV13. A detailed analysis of the near-IR photometry of the ~100 stars in the area is in progress and will be presented in Aspin, Sandell and Russell (1991). The peculiar source IRAS 5 may well be the first known example of tidal interaction forming tidal tails (as in interacting galaxies) in stars.

interaction forming tidal tails (as in interacting galaxies) in stars.

The JCMT photometry and mapping of the IRAS sources has revealed that IRAS 4 is an extremely young double source containing a large dust mass possibly upwards of 10 M_{sun}. This source is proposed as the youngest stellar source yet found due to the large dust mass around the source and we suggest it can be classed as a true protostar. Papers on IRAS 4 (Sandell, Aspin, Russell, Robson 1991) and the JCMT results on the other NGC1333 IRAS sources (Sandell et. al. 1991) are in preparation.

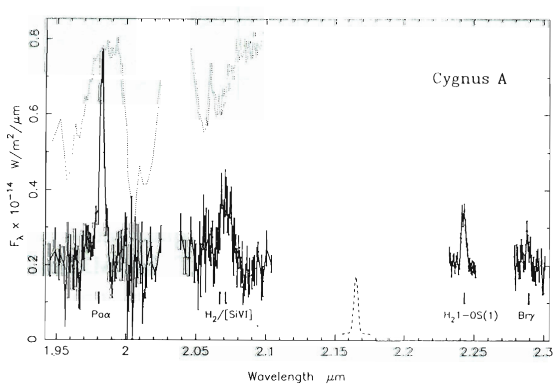
Acknowledgements

We acknowledge assistance from David Weintraub in modelling the spectrum of IRAS 4A. We also wish to thank Tom Geballe for allocating UKIRT discretionary time in which parts of this project were performed.

Colin Aspin and Goeran Sandell
Joint Astronomy Centre

References

Aspin C, Sandell G, Russell, A.P.G; 1991 in prep.
Garden, R., Russell, A.P.G., Burton, M.R.; 1990, Ap.J. **354**, 232
Jennings, R.E., Cameron, D.M.H., Cudlip, W., Hirst, C.J.; 1987, M.N.R.A.S., **226**, 461
Knee, L.B.G.; 1991, in preparation
Toomre, A. and Toomre, J.; 1972, Ap.J. **178**, 623
Weintraub, D.A., Sandell, G., Duncan, W.; 1991, in preparation



Near-infrared spectroscopy of Cygnus A

Cygnus A (z=0.057) is by far the brightest of the powerful Narrow Line Radio Galaxies and has been a subject of intense study for observers right across the electromagnetic spectrum. At X-ray and optical frequencies there is evidence for substantial amounts of extinction towards its nucleus, which is thought to contain a "buried quasar" obscured from direct view by a large column of gas and dust. From the lack of detectable broad wings on the Paschen α line we see that the radiation from the Broad Line Region is extinguished even at 2 μm.

However, near-infrared spectroscopy still enables us to penetrate moderate amounts of extranuclear dust and observe the response of three important phases of the interstellar medium to the presence of the hidden active nucleus:

1. Classical Narrow Line Region gas - Paschen α 1.875 μm and Brackett γ 2.166 μm.

2. Excited molecular gas - H_2 1-0 S(1) 2.122 μm and 1-0 S(3) 1.958 μm.

3. High ionization gas - [SiVI] 1.962 μm (here broad and blended with 1-0 S(3) H_2).

A full analysis of these data has been submitted as a *Letter* to *Astrohpysical Journal*. The wavelength coverage and sensitivity promised with the imminent arrival of CGS 4 will enable similar multiline studies of *complete samples* of narrow line active galaxies to be made.

Cygnus A was observed with CGS 2 on dates in August and October 1990; the final spectrum shown is the result of approximately 3 hours total integration. Compare this with Lilly & Hill's (1987) spectrum of the Paschen α line (*Ap. J Letters, 315, L103*) which was also taken with CGS2, but before the electronics upgrade made in February 1989. Also shown in the Figure are the atmospheric transmission (dotted line) and the instrumetal profile as derived from observations of planetary nebulae (dashed).

We are grateful to Tom Geballe for his invaluable assistance with these observations, and to the UKIRT Service programme for allocating time to observe the [SiVI] line.

Martin Ward, Philip Blanco, Andrew Wilson & Minoru Hishida.

Near-IR Observations of the Cartwheel Ring Galaxy

Introduction

Ring galaxies are amongst the most beautiful and remarkable of astronomical phenomena. The models of Lynds & Toomre (1976), Theys & Spiegel (1976) and Toomre (1978) suggest that rings are a natural consequence of the passage of a galaxy down the spin-axis of the (target) disk. The intruder galaxy creates a central perturbation as it plunges through the target galaxy, generating periodic oscillations within the disk. The oscillations give rise to radially expanding rings and other caustics (See Struck-Marcell 1990) which must inevitably affect the gaseous component in the disk. Indeed early observations of the Cartwheel ring galaxy by Fosbury and Hawarden (1977) indicated that dramatic star formation events are occurring in the outer ring, and a survey of the IRAS properties of ring galaxies by Appleton and Struck-Marcell (1987a) confirmed the suspicion that ring galaxies can produce large quantities of young stars which dominate the global properties of the underlying galaxy. In effect, the collisionally induced expanding rings provide an unusual environment for testing models of density wave induced star formation in colliding galaxies. We have embarked on a major multi-wavelength study of ring galaxies using the UKIRT 3.8m telescope and the KPNO 2.1m telescope to study the broad-band IR and optical colors of a sample of approximately 15 ring galaxies. This paper presents some preliminary results of the first complete near-IR (JHK) imaging of the prototype ring galaxy, A0035-324 (The Cartwheel). The IR work provides the much needed longer-wavelength baseline required to follow the evolution of young star clusters through the transient "red-flash" stage when they are dominated by supergiants (Arimoto & Yoshii 1987, Bica 1988). The radially expanding wave of star formation expected in a classical ring galaxy provides us with a form of galactic "chromatography" almost unique in astrophysics. In principal, the radial distribution of colors should allow us to monitor the time-evolution of a young cluster as it evolves from a massive star-forming knot on the outer edge of the ring, through the supergiant phase, to the longer red-giant dominated stage. The present data on the Cartwheel is complimentary to the excellent optical and HI study currently being made by by J. Higdon (U. of Texas, Private Communication).

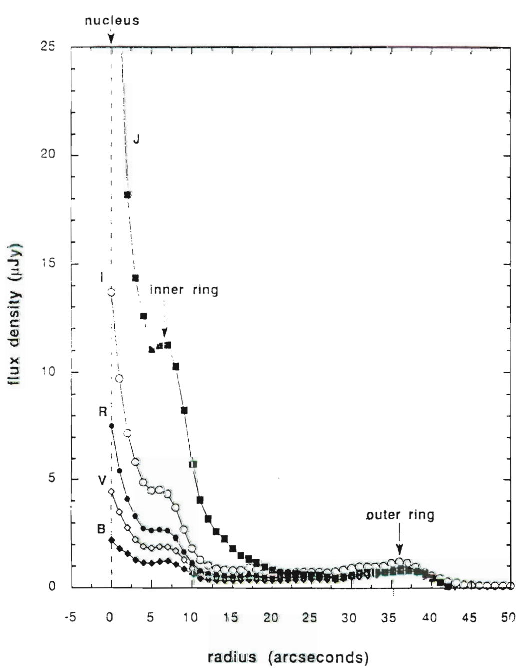


Figure 1 Optical and IR radial profiles through the Cartwheel (AAT data)

Near-IR Imaging

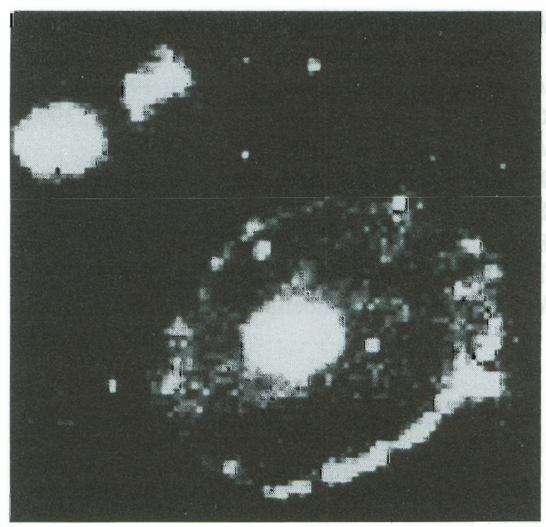


Figure 2a Cartwheel at J-band (1.25µm)

Preliminary IR imaging of the NW quadrant of the Cartwheel was made at the AAT by MJ and collaborators. Figure 1 shows radial profiles through the nucleus, inner ring and the faint NW outer ring at BVRI and J bands. The outer ring was only faintly detected at J,H and K bands in this quadrant. In Figures 2a and 2b we present new complete mapping by PNA/PMM of the Cartwheel using the IRCAM2 InSb array camera on the UKIRT 3.8m telescope on the nights of October 24 & 25, 1990. Fig.2a shows the J-band image at a

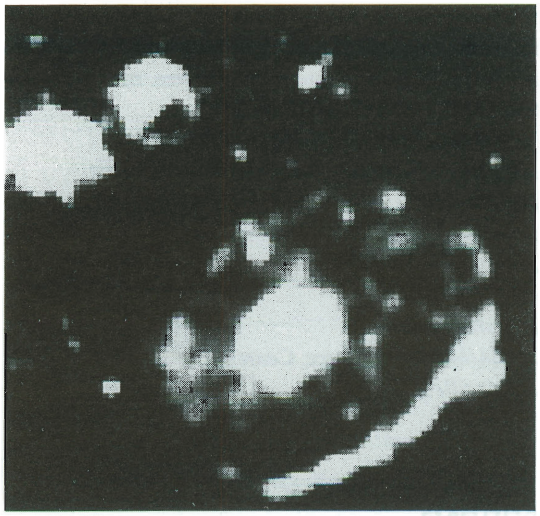


Figure 2b K-band (2.2μm) image (smoothed)

plate-scale of 1.2 arcsec/pix after co-adding frames taken from 3 different guiding centers. Fig.2b shows the K-band image, after smoothing to a resolution of 4.5 arcsec (FWHM) to enhance low surface brightness emission. Also included are the two minor-axis companion galaxies. IR data was also obtained on a more distant companion which is not shown here. The IR images show for the first time the structure of the Cartwheel in the light of the late-stellar population. In the classical Toomre picture, this light should trace the underlying stellar density wave in the old disk stars. As such, the K-band ring should be smoothly changing in intensity around the ring, as appropriate for a very mildly off-center ring wave (Toomre 1978).

Results

The images of Fig.2a,b show considerable detail, both the clumpy structure of the outer ring and much fainter emission from the region between the outer ring and the inner ring (the bright inner portion of the images). What is striking about the K-band image is its similarity to the optical images of the Cartwheel, especially in the outer ring. This one-to-one correspondence between the K-band knots and the blue optical knots, and the almost total lack of a broad underlying K-band ring component, strongly suggest that the dominant near-IR emission is from young supergiants in the blue star clusters. It may also indicate that gas dynamics play a dominant role in the appearance of ring galaxies (Appleton and Struck-Marcell 1987b, Struck-Marcell and Appleton 1987). The SW edge of the outer K-band ring is unusually bright from a position angle of 180 to 270 degrees (N th. E) and shows a rapid decline in brightness at either end of this "wave-front". This is also seen optically, and is highly suggestive of a "threshold" star formation process at work in the ring. Behind this very bright part of the ring there is an almost total lack of emission at 2.2 microns. Such a hole was predicted, although not drawn attention to, by the modeling of Toomre (1978) and explicitly discussed in the context of gas dynamics by Appleton and Struck-Marcell(1987b). The IR imaging provides the first direct evidence for the rarefaction behind the dense expanding wave.

Perhaps the most interesting differences between the IR and optical images of the Cartwheel are found in the northern and western quadrants of the disk. Here there is much inter-ring material which seems to extend inwards from the bright knots (see especially in Fig.2a). It is tempting to interpret these inwardly extending filaments as a time-sequence of stellar evolution. In this picture, the spokes are examples of the stellar "chromatography" smeared out by galactic rotation.

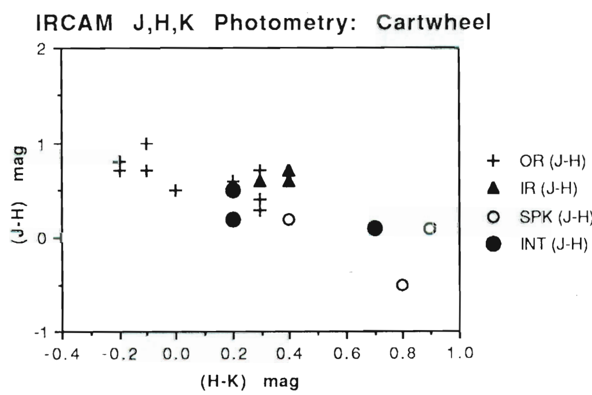


Figure 3. Infrared color-color diagram of components in the Cartwheel

In order to test this hypothesis, we present preliminary JHK colors for various features in the disk of the Cartwheel in Figure 3. The main components of the ring galaxy are found to occupy distinct positions in the J-H/H-K diagram. The outer ring (+'s) occupies a broad range of colors typical of a late-type stellar population contaminated by blue stars. The inner ring and nucleus (triangles) fall in the region typical for an evolved stellar population, having colors similar to that of an elliptical galaxy. The extended "spokes" (open circles) have very distinctive red H-K colors but are blue at J-H, pushing them to the extreme left of the diagram. Furthermore, we identify three bright K-band knots which lie interior to the outer ring (filled circles). Their colors are interesting. Two of the knots lie very close to, but interior to bright knots in the outer ring. We speculate below that they are related to the spokes. They have similar IR colors to the outer ring itself, although one of the knots is very red optically. Another knot lies closer to the inner ring and has the colors of a much more evolved stellar population.

The Sequence of Star Formation and the Origin of the Spokes?

The question of the origin of the spokes in the Cartwheel has troubled numerical modelers for some years, since multiple-armed spokes are hard to generate in a stellar N-body simulation. A careful analysis of the multi-color data from the Cartwheel is underway at present and only preliminary conclusions are now available. However, the IR data alone is very suggestive. The observations indicate that the spokes may be trails of strongly enhanced star formation in the wake of the ring as it propagates outwards through the disk. If the star formation in the ring is not smoothly varying, but occurs more strongly in overdense regions (as it seems to be from the appearance of the outer ring) then the star formation history of the knot would be smeared out and take on the appearance of a spoke, since the differential motion in the disk would "wind up" the path of the burst. Such filaments are seen perhaps most convincingly in Fig.2a, where a number of the outer knots show trails extending inwards. If this interpretation is correct, then the two inner knots previously described may also be part of the same phenomenon. A careful comparison with available UBVRI photometry (Higdon, Personal Communication) will be required to resolve this issue.

It is the relative simplicity of the colliding ring galaxies that makes them important objects of study. The fact that the expanding ring wave is expected to move through a galactic disk on a timescale not significantly larger than the lifetime of massive main sequence stars makes the study of the colors of ring galaxies a fascinating enterprise. If such color gradients are found, these rare and spectacular galaxies may yield important clues about the formation of massive stars and their subsequent evolution. Further work is underway to study a larger sample of these rare but important galaxies.

It is a pleasure to thank Colin Aspin (UKIRT) for valuable help during the observation and data reduction, and Curt Struck-Marcell for his interesting insight into the problem of how stars form.

Philip N. Appleton & Pamela M. Marcum,
Dept. of Physics and Astronomy,
Iowa State University,
Ames, Iowa.

Marshall Joy,
NASA/Marshall Space Center,
Huntsville, Alabama.

References

Appleton, P. N. & Struck-Marcell, C., 1987a. Ap.J.,312,566.
Appleton, P. N. & Struck-Marcell, C., 1987b. Ap.J.,318,103.
Arimoto,N. & Yoshii,Y.,1987.,Astr. Astrophys.,173,23.
Bica,E.,1988. Astr. Astrophys.,195,76.
Fosbury,R.A.E. & Hawarden,T.G.,1977. MNRAS 178,473.
Lynds,R. & Toomre,A., 1976. Ap.J.,209,382.
Struck-Marcell, C., 1990. AJ,99,71.
Struck-Marcell, C. & Appleton, P.N.,1987. Ap.J.,323,480.
Theys, J.C. & Spiegel,E.A., 1976., Ap.J.,208,650.
Toomre, A., 1978.,in IAU Symp. 79, The Large Scale Structure of the Universe, Ed. Einasto,J., (Dordrecht: Reidel),p109.

UKIRT discovers a Supernova

IAU Circular no. 5162 reports the discovery by Martin Shaw of an apparent supernova, designated 1989Z, in the edge-on Sbc galaxy NGC 4013 during K-band imaging observations made with UKIRT on 1990 December 30. The apparent supernova lies within the north-east spiral arm, offset 10" east and 4" north of the centre of the galaxy, and relative photometry from a single K-band frame (1200s) indicates that the supernova is 0.03 mag brighter than the galaxy nucleus.

CGS3 Observations of Proto-planetary Nebulae

Since the publication of the IRAS database, it has become apparent that there are a number of objects visible in the IR and optical which are in transition between the AGB and PN parts of the HR diagram. During the commissioning run for CGS3, UKIRT's new grating spectrometer for the 10µm and 20µm atmospheric windows, and in a PATT awarded observing run a few months later, we observed a number of such transition objects, or protoplanetary nebulae (PPNe).

Two of these objects have been known for some time - CRL2688 (the Cygnus Egg nebula), and CRL618. The former is a spectacular optical bipolar nebula, whose central star can be classified as type F5I from its spectrum seen in reflection. It is thought to have evolved off the AGB some hundreds of years ago. The latter has a much hotter central star, thought to have $T_{eff} \sim 27{,}000K$, but otherwise closely resembles CRL2688. Both have been observed in the IR many times before, and both have C_3 bands in their optical spectra and PAH features at 3.3µm (Tielens, private communication), indicating a C-rich chemistry. CRL2688 has a featureless 10µm spectrum, indicative of amorphous carbon dust grains, whilst CRL618 has variously been said to have silicate dust weakly in emission at 9.7µm and 18µm, or to have SiC in absorption at 11.3µm.

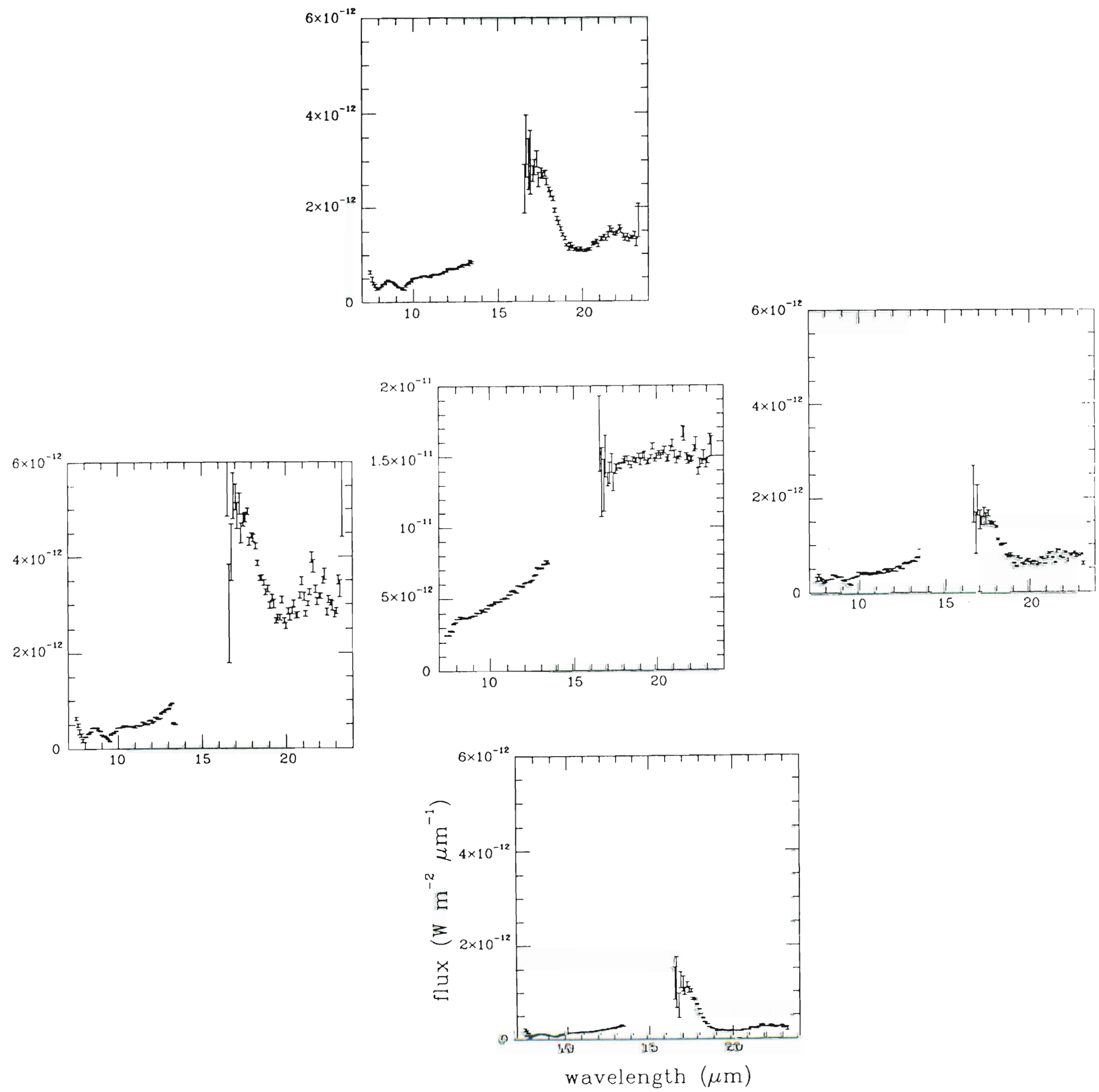


Figure 1 CGS3 spectra of CRL2688

Figure 1 shows our spectra of CRL2688, taken at the IR peak and at offsets 6 arcsec away in directions parallel with and orthogonal to the axis of the bipolar optical lobes. The central spectrum is indeed featureless, but our offset spectra reveal some spectacular new dust features at 9µm, 10.5µm, 17µm and 22µm. There are no known identifications for these features. In Figure 2 we show CGS3 spectra of CRL618; again we took one central and four offset spectra. We display just the central spectrum, compared with the IRAS

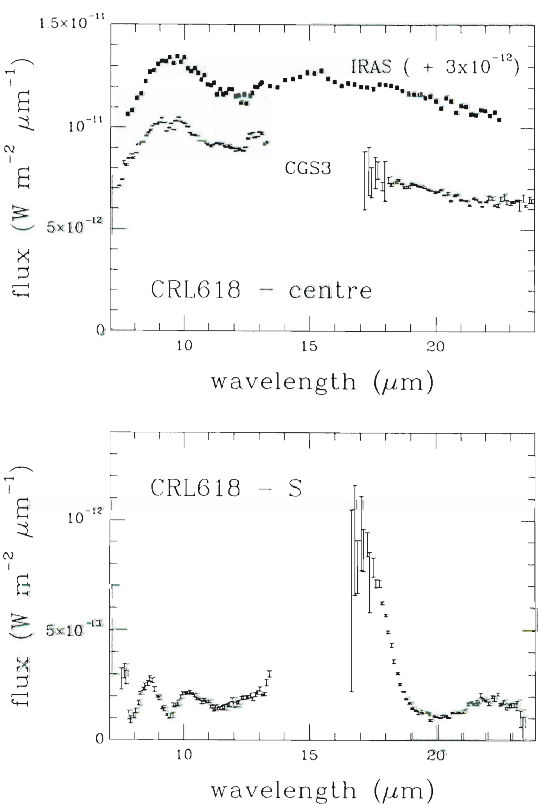


Figure 2 CGS3 spectra of CRL618

spectrum, and one offset spectrum. The same features as in CRL2688 again appear, but this time they are present in the central spectrum. This compares favourably with the IRAS spectrum, and we see that the earlier confusion over the IR spectrum of CRL618 stems from the fact that these dust features are quite new, never before seen in any other source.

Two other sources observed were SAO 34504 and IRAS 04296+3429. Both sources were originally identified by Kwok, Volk & Hrivnak (1989) from the IRAS spectral database because of their peculiar spectra. Our spectra (Figure 3) are of much higher

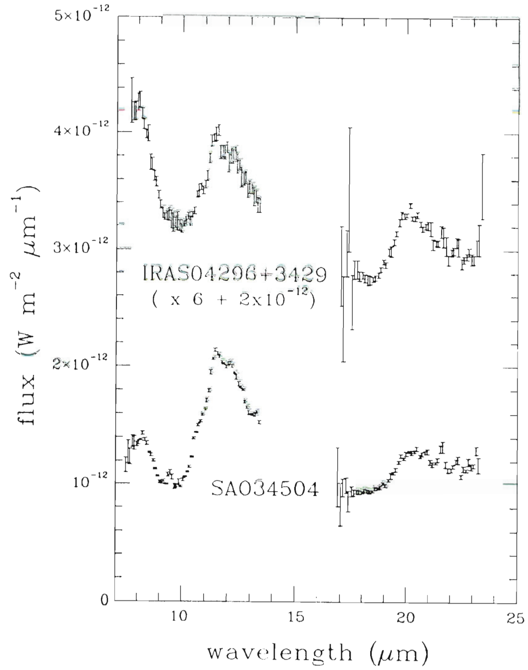


Figure 3

spectral resolution than those from IRAS, and also higher than those presented recently by Buss *et al* (1990). These objects are thought also to be PPNe, and are C-rich (they have C_3 bands in optical spectra). They have broad emission bands in the 6-9µm, 10-14µm, and the 19-23µm regions, which are believed (Buss *et al*) to be due to clusters of PAH molecules or perhaps hydrogenated amorphous carbon (HAC). For the first time we are able to see, in the low-resolution CGS3 spectra, the more usual narrow 11.3µm PAH feature on top of the broad 10-14µm emission band. CGS3 high-resolution spectra of IRAS 04296+3429 show that the emission bands do not resolve out into narrow bands, and reveal no further detail than the low-resolution spectra. Comparing this with the near-IR bands observed by Buss *et al*, we can investigate the excitation of the bands in these objects.

In four PPNe we have now observed two completely different sets of dust emission features, none of which are observed in any other type of object. In the case of CRL2688 and CRL618, it is not clear what the source of the dust bands is - 17µm is close to the expected wavelength for emission from various metal oxides, and indeed Fe_3O_4 (magnetite) has strong bands close to our 17µm and 22µm emission bands. On the other hand, PAH clusters or HAC have a number of out-of-plane ring-bending transitions in the 20μm region (Allamandola *et al*, 1989). However no carbonaceous bands have yet been reported in lab spectra or predicted which could correspond with the group of bands seen in these two PPNe, and oxides remain the most likely explanation. This would suggest that we were observing emission from O-rich material ejected from the red giant - progenitors long ago, before the stars became C-rich. In any case, PPNe seem to provide magnificent astronomical laboratories for the processing and investigation of circumstellar dust.

C. J. Skinner, Jodrell Bank
M. J. Barlow, K. Justtanont, W. M. Glencross, W. A. Towlson, T. M. Hunt, University College London
A. C. H. Glasse, J. F. Lightfoot, Royal Observatory Edinburgh

REFERENCES

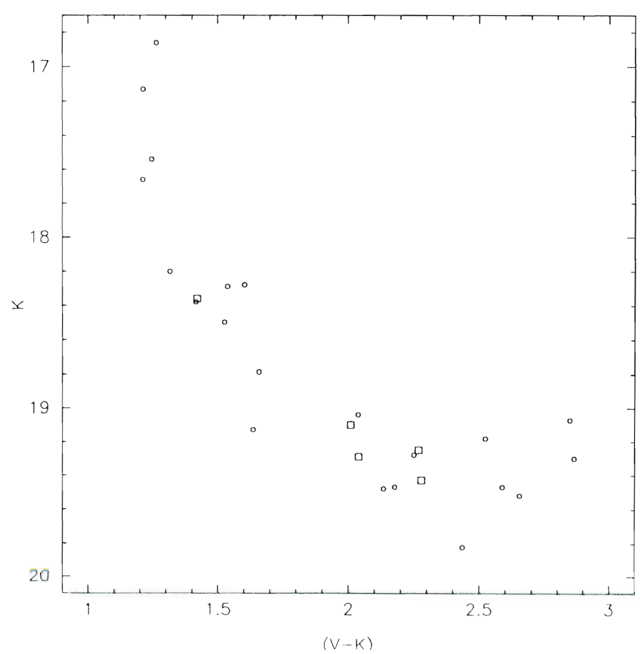
Allamandola, L. J. *et al*. 1989, Ap. J. Suppl. Ser., **71**, 733.
Buss, R. H. *et al*. 1990, Ap.J **365**, L23
Kwok, S. *et al*. 1989, Ap.J **345**, L51

Photometry of Main Sequence Globular Cluster Stars with IRCAM.

We have produced deep IRCAM K band images of an area in the globular cluster M13 by combining many individual 'jittered' IRCAM frames with fractional pixel offsets. Photometry was performed on these mosaics using the DAOPHOT point spread function software package, and the K magnitudes combined with published optical data to obtain the colour magnitude diagram (CMD) shown; note the well defined lower main sequence and main sequence turn-off. Five dwarf stars with accurate parallax estimates and metallicities similar to that of M13 are shown as squares.

A best fit by eye of the main sequence to the dwarfs gives a distance modulus of 14.35 magnitudes (a figure which agrees closely with published distance modulii for the cluster). The combination of optical and infrared information makes main sequence fitting of standard parallax stars in this way a potentially powerful means of distance determination, especially where reddening errors may be present. This will be a particular advantage in studies of clusters of higher reddening; in purely optical work errors of 0.03 mags in E[B-V] can lead to an uncertainty in the distance modulus of roughly 0.15 mags! Although at the moment the number of dwarfs with both accurate parallax estimates and of the right metallicity range for globular cluster studies is still small, the sample size should soon be greatly enhanced by HIPPARCOS data.

David R V Buckley & Andy Longmore,
University of Edinburgh & ROE



De-reddened colour magnitude diagram showing M13 main sequence

Points of Contact

Joint Astronomy Centre
665 Komohana Street
Hilo
Hawaii 96720
USA

Telephone numbers:
Prefix from outside Hawaii 1 808
Prefix from UK 010 1 808

JAC
Phone: 961 3756
935 4332 (answerphone)
Telex: 633135 on WUI
Fax: 961 6516
e-mail: PSS: 315280809053
JANET: CBS%JACH
Internet: JACH.HAWAII.EDU
(from Janet
CBS%NSFNET-RELAY::EDU.HAWAII.JACH)

Mauna Kea

JAC Offices at Hale Pohaku 935 9911
JCMT Carousel: 935 0852
UKIRT dome: 961 6091
Fax in JCMT carousel: 935 5493

Royal Observatory Edinburgh
Blackford Hill
Edinburgh EH9 3HJ
UK

Telephone:
From outside UK, omit 0 & prefix by 44
ROE has a telephone system which allows extension numbers to be dialled by the caller.

Switchboard: 031 668 8100

JCMT Section:
Dorothy Skedd 031 668 8306

UKIRT Section:
Maureen McLean 031 668 8309
(and answerphone after hours)

Fax: 031 668 8264
e-mail: UK.AC.ROE.STAR
Starlink: REVAD

Starlink Directories:
JCMT: REVAD::DISK$USER3:[JCMT]
UKIRT Vaxnotes on RESTAR::UKIRT
or UKIRT INFORM

The Newsletter is distributed in Canada by the HIA, Ottawa. Readers in Canada wishing to be placed on the mailing list should contact:

Dr John McLeod
Herzberg Institute of Astrophysics
100 Sussex Drive
Ottawa
Ontario K1A 0R6
Canada

Editor of Newsletter:

Liz Sim 031 668 8315
MES on REVAD

Please send material for the next edition of this Newsletter to the Editor by June 12 1991 - earlier if possible, please.

ISSN xxxx-xxxx