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This report covers the period from 1998 April 01 through 1999 March 31, while the publications are for the calendar year 1998. The James Clerk Maxwell Telescope (JCMT) Group of the Herzberg Institute of Astrophysics (HIA) supports the JCMT by posting staff members to the Joint Astronomy Centre (JAC) in Hilo, Hawaii to help operate and maintain the telescope, by providing services, advice, and liaison to Canadian university astronomers, by building advanced receiver systems, and by serving on pertinent committees. Canada has a 25% share in the telescope, while the UK has 55% and the Netherlands has 20%. The three partner countries have access to 90% of the net observing time, according to their share in the telescope, and the University of Hawaii has 10%. About 1/5 of the 90% is allocated to the international community.

1. PERSONNEL

The JCMT Group staff includes L.W. Avery, S. M. X. Claude, C.T. Cunningham, P.A. Feldman, H.E. Matthews (JAC), A. Mirza, G. Moriarty-Schieven (since August 1998), R.O. Redman, and K.K. Yeung. M.B. Bell, and T.H. Legg are Guest Workers. In addition, three staff positions at the Joint Astronomy Centre are supported by financial contributions from HIA. Lorna Slater and Mary Anne Kelly, Coop students from the University of British Columbia and University of Victoria, respectively, worked with Keith Yeung. J.M. MacLeod retired in October 1998. L.W. Avery returned to HIA from a three-year JCMT posting and took over as Group Leader.

2. SCIENTIFIC RESEARCH

2.1 Solar System

Redman, Feldman and Matthews completed and published the analysis of their existing JCMT measurements of the thermal continuum emission from asteroids. Preliminary analysis of new observations of the bright asteroids Ceres and Vesta suggests that the amplitudes of the submm light curves are larger than the amplitudes of the visible light curves. A new data reduction technique is under development that should simplify point-source photometry using jiggle maps from the SCUBA 450/850 arrays. The final reduction of the Ceres and Vesta data using this technique will yield light curves of these asteroids at 0.45, 0.85 and mm wavelengths. A long-term project to study how the brightness of Pallas varies with the asteroidal latitude of the sub-solar point is about half complete. When done, this should permit measurement of the emissivity of Pallas' regolith, and estimation of its thermal inertia more reliably than can be done using only data in the thermal IR. Observations of the Trojan asteroids Hektor and Nestor were carried out by Mat-

thews and Jewitt (IfA) in an attempt to detect outgassing, and hence check whether some of these asteroids might, in fact, be comets. The results of the limited work to date are negative.

In collaboration with Marten (Meudon), Owen (IfA) and Moreno (IRAM), Matthews continued a [4] long-standing program to investigate the after-effects of the collision of comet Shoemaker-Levy 9 with Jupiter's atmosphere. In addition to studying the latitudinal spreading of trace constituents such as HCN and CS through the Jovian stratosphere, attempts to determine the C, N, and S isotopic abundances were a focus of recent work. Additional observations are planned during the next Jovian opposition. Together with Meier and Owen (IfA) and Marten (Meudon) observations were made of Neptune in the high-frequency CO 4-3 line and also HCN 4-3 to establish the precise line profile. These data are being used to refine models of the stratosphere of Neptune.

2.2 Interstellar and Circumstellar Matter

Bell continued his work with Feldman on long carbon chain molecules in the interstellar medium. They completed a study with J.K.G. Watson (NRC-SIMS) of the excitation temperatures of these molecules as a function of their size. Bell, with Avery and Vallée, also continued the analysis of impact broadening in high Δn recombination lines of hydrogen. These data demonstrate that the simplest explanation for observed line width variations in high Δn lines is due to baseline removal errors rather than source structure. Bell and Feldman, together with Watson, and CFA/Harvard U. colleagues M. McCarthy, M. Travers, C. Gottlieb, and P. Thaddeus, detected two transitions of C₈H in the molecule-rich, cold, dark cloud TMC-1. They also obtained a sensitive upper limit for C₇H towards this source. They found that the abundance ratios of the longer C_nH chains decline much more rapidly than the ratios of the longer HC_nN chains. The observed decrease in fractional abundance with increasing chain length from C₄H to C₈H is reasonably well reproduced by the gas-phase models of Herbst and Terzieva, (private comm.), but C₈H is observationally somewhat underabundant compared to these calculations. Using these and other data, they also estimated the (unidentified) line density near 20 GHz in TMC-1 to be approximately 0.9 lines per MHz at an antenna temperature level of 1 mK.

Feldman and Redman, together with S. Carey (Boston College/AFRL) and M. Egan (AFRL), used the JCMT in 1998 August to make SCUBA observations of Infrared-Dark Clouds (IRDCs) detected by the MSX satellite (Egan *et al.* 1998, ApJ, 494, L199). The IRDCs appear to be very large (1-10 pc diameter), molecular cores with gas densities $\sim 10^6$ cm⁻³ and temperatures about 10 K. All 9 clouds observed were detected as strong submillimeter sources with peak flux

densities of ~ 1 Jy/beam at $850 \mu\text{m}$. In general, the submillimeter continuum emission follows the mid-infrared extinction and the line emission morphology (Carey *et al.* 1998, ApJ, 508, 721). The submillimeter data reveal substructure in the IRDCs including bright knots. The observed H_2CO line profiles are non-Gaussian suggesting the presence of molecular outflows in some of the IRDCs. It is likely that the $850 \mu\text{m}$ emission peaks are either Class 0 protostars or pre-protostellar objects. Observing time on the JCMT has been granted in 1999 for further SCUBA and heterodyne studies of these and other IRDCs.

Feldman and Redman, together with D. Balam (UVic) and S. Carey (Boston College/AFRL), used the [4] 1.8-m Plaskett telescope at the DAO to search for shock-excited molecular hydrogen associated with the compact submillimeter sources found to be embedded in MSX IRDCs. Brief observations at 2.122 m, made with the newly commissioned Veronica infrared camera, yielded two apparent Herbig-Haro jets emanating from $850\text{-}\mu\text{m}$ continuum sources in the SCUBA map of G79.27+0.38.

With van der Veen (Columbia U.) and Groenewegen (MPI-Garching) Matthews made a series of observations of the dust distribution around late-type stars using SCUBA at 850 and $450 \mu\text{m}$. These data are being analysed to determine the azimuthal distribution of dust around the objects to obtain information about outgassing rates. Together with Davis (JAC), Dent (ATC) and Ray (Dublin), Matthews obtained observations of the star-forming core in Serpens using SCUBA at 850 and $450 \mu\text{m}$. The resulting map has been used to compare earlier CO 2-1 and infrared images to investigate the energetics of the multiple outflows from the cluster, the nature of the young protostellar cores at the center of the region, and the relationship of the latter with new Herbig-Haro objects surrounding the cloud. A paper has been submitted to MNRAS.

Matthews and McCutcheon (UBC) have obtained dramatic SCUBA images at 850 and $450 \mu\text{m}$ of the entire chain of star-forming regions connected with the galactic nebula NGC 6334. The five well-known dense ionised hydrogen/IR cores are seen to be connected with a bright curved and essentially unresolved filament of dust emission which, it is speculated, may be associated physically with the formation of the young stellar clusters. Work continues on these data; already it is clear that the filament, which is associated with CO emission, is a single feature with a narrow range of velocities.

Purton (DRAO) and Matthews continued their analysis of the complex data cubes obtained from a DRAO synthesis observation of the NGC 7129 star-forming core in the 21-cm neutral hydrogen line. A new (and only the second) dissociating star has been recovered from these data; this object has a dynamical age of only 103 years.

Avery, Matthews and Moriarty-Schieven are part of the Canadian team studying a number of star-forming regions with the help of images of dust emission and associated molecular material using the JCMT. The goal is to obtain extended, sensitive sub-mm images with high dynamic-range to conduct comparative studies of regions exhibiting different star-forming properties. The team has recently published

its first results, regarding the Rho Oph molecular core, which contains a number of very young, apparently pre-stellar objects and two extensive linear features of unknown origin. Work has continued most recently with observations of the Orion B and Taurus Molecular Cloud fields. Moriarty-Schieven also worked on the modelling of circumstellar disks around young protostars in Taurus (with H. Butner (SMTO) and J. Powers (UHH)), and on oxygen isotopic variations within molecular clouds (with P. Wannier (Caltech) & G. Narayanan (FCRAO)). Claude has begun a study of the sulphur chemistry in the proto-planetary source, OH231.8. Using the JCMT he has observed a number of transitions of SO and SO₂ in this source and is carrying out an excitation analysis to determine abundances and temperatures.

2.3 Extragalactic Astrophysics

Moriarty-Schieven, Redman, Feldman and Oke, together with J. Bloom (Caltech), D. Frail (NRAO) and eleven others, studied the radio, infrared, and optical transient that followed the X-ray transient afterglow of GRB980703. After the optical transient faded, a bright ($R = 22.6$) underlying galaxy was observed where the transient had been. The multiwavelength data could be interpreted within the framework of the standard fireball model. Submillimeter observations on the JCMT with SCUBA did not succeed in detecting the synchrotron emission of the fireball, but these data were important in constraining the parameters of the model fit. For details, see Bloom *et al.* 1998, ApJ 508, L21.

Using SCUBA, images were obtained at 850 and $450 \mu\text{m}$ of the dust distribution over the central 10 arcmin of the active galaxy Centaurus A by Matthews, with Eckart and Tacconi (MPI-Garching), and Hawarden (JAC-UKIRT). These data show very clearly the twisted disk at the core of this famous object. Analysis is under way to produce a model of the galaxy incorporating these new data.

2.4 Scientific Meetings

Matthews attended the Naramata meeting on the interstellar medium and presented a talk on the impact of the SCUBA mm/submm receiver on this field.

Moriarty-Schieven attended the Protostars & Planets IV meeting in Santa Barbara, CA in June, where he presented a poster on the evolution of radial dust distributions around protostars. Another poster on which he was a co-investigator ('A dusty disk surrounding a nearby young main-sequence star') was featured in a press release which was picked up by major North American newspapers and television networks, including CNN.

3. INSTRUMENT DEVELOPMENT

3.1 Mixer Development and JCMT Receiver Upgrades

Cunningham designed a mixer for an 850 GHz receiver but unfortunately this was not tested due to cancellation of the project by the JCMT. A new mixer design was developed to upgrade the devices currently in receiver B3 centered on 345 GHz. The objective was to eliminate the need for a

mechanically tunable backshort while retaining the low-noise and wide-band performance. This will improve the reliability of the receiver and speed up the tuning procedure. The mixer chips were fabricated at the University of Groningen and laboratory tests have shown that they yield excellent performance. The first mixer will be installed in May 1999. Claude assembled and tested a new tunerless mixer block for use in the 215-270 GHz band. This work was a major part of the Receiver A3 upgrade program at the JCMT and involved a close collaboration with the NRAO receiver team using junctions made at the University of Virginia. Redman provided the microcomputer control program and high-level control task for A3, while Matthews and Feldman were project scientists. The receiver was commissioned in Hawaii in November 1998 by a team from the JCMT Group and the Joint Astronomy Centre.

3.2 Spare Electronics Modules for Receiver B3

The 345 GHz JCMT receiver known as B3 was commissioned in 1996 without a set of tested spare electronics modules. Yeung has carried out extensive laboratory testing, repair and documentation of the majority of the spare electronics modules and subsequently tested them on the JCMT in September 1998. A set of updated documentation of the electronics modules was delivered to the JCMT support staff in the fall of 1998.

3.3 345 GHz Heterodyne Array Receiver (HARP-B)

The JCMT's Heterodyne Array Receiver Programme (HARP) has started the design of a 16-detector 345 GHz B-band array receiver for the JCMT, with the possibility of an 8-detector D-band array for 690 GHz to be added later. Redman is acting as the lead for the software design and development in the project. Redman and Yeung participated in the successful Conceptual Design Review in the U.K. Yeung is responsible for the design and implementation of the control computer.

3.4 The JCMT ACSIS Correlator

Yeung is working in collaboration with Bill Dent of the UKATC and Brian Force of JAC, to develop the IF Section for the new ACSIS Correlator for use with the new array receivers. The ACSIS IF Section subdivides and down converts each IF input from the B-band Array into two separate 0-1.0 GHz base-band signals. The base-band signals are then fed into the Correlator section to produce the normalized auto-correlation results. A preliminary design of the IF Section was presented at the Preliminary Design Review (PDR) of the ACSIS Correlator in April 1998. A detailed design of the IF hardware and software systems is currently being prepared.

3.5 Water Vapour Monitors

Interferometric observations at frequencies above 200 GHz require that the measured phase be corrected for the effects of fluctuations in the column density of water vapor along the line-of-sight. This would increase the coherence

times, allowing the measurement of much weaker sources. Two different approaches to a practical solution of this problem are being investigated. The goal is to apply one of these techniques to interferometer observations combining the JCMT with the CSO and the Smithsonian Sub-Millimeter Array (SMA), and for possible use by ALMA in Chile. Feldman and Redman are collaborating with Naylor's group at the University of Lethbridge on a project to use measurements of atmospheric infrared emission lines to monitor changes in the column density of water vapor along the line-of-sight. A test water vapor monitor is being constructed at Lethbridge using fast HgCdTe photoconductive detectors to measure telluric water lines in the mid-infrared region. These lines were chosen to provide reliable estimates of the column density of water under conditions of good atmospheric transmission, using a detailed model of the atmosphere above Mauna Kea. Modelling of the performance of the system suggests that it should work at least as well as other techniques being considered while being easier and cheaper to implement on a large array of telescopes. Cunningham is collaborating with P. Dewdney (HIA), C. Wilson (McMaster U.) and R. Taylor (U. Calgary) in the construction of a 183 GHz radiometer after the MRAO design. Components are being acquired to begin construction shortly.

3.6 Planar Array

Legg and Bell are continuing work on a heterodyne planar array. They have produced beam maps with dynamic ranges close to 30 dB using their design for a mm-wavelength, focal-plane array.

4. FUTURE OF CANADIAN RADIO ASTRONOMY

4.1 Atacama Large Millimetre Array (ALMA)

Cunningham and Claude are working in close collaboration with NRAO to investigate the design of balanced and sideband-separating waveguide mixers for operation at short submillimetre wavelengths. Cunningham is looking into the use of MMIC technology in the production of low-noise ultra-wide-band mixers and in W-band power amplifiers. He has commissioned a new laboratory Fourier transform spectrometer for testing the properties of materials used in submillimetre receiver design.

4.2 Square Kilometre Array (SKA)

Legg is continuing to work on concepts for the design of a Large Adaptive Reflector as a component of the SKA. He is investigating the use of a spherical subreflector as a means of correcting for balloon displacements. Redman presented a paper at the SKA Science Meeting, at the University of Calgary in July 1998, on possible uses of the SKA to study the smaller bodies of the solar system such as asteroids, comets and Kuiper belt objects (KBOs). Although it will be a useful tool in the study of all these objects, the SKA would be especially valuable for the detection and imaging of the larger KBOs. This would be particularly true in the outer

regions of the Kuiper Belt where the intensity of sunlight is so low that optical detections of these objects will be extremely difficult.

5. JCMT SUPPORT

5.1 JCMT Advisory Panel

Redman is serving as one of the two Canadian representatives on the JCMT Advisory Panel.

5.2 Canadian Service Observing (CANSERV)

A total of 14 Canadian projects received data from the JCMT CANSERV program. Canadian JCMT support scientists (Avery, Matthews, and Moriarty-Schieven) and experienced astronomers from the Group in Victoria carry out short observing programs on the JCMT for Canadian astronomers so that they do not have to travel to the telescope to acquire small amounts of data (generally four hours or less). Such observations are useful in responding rapidly to new astronomical discoveries, accommodating important short observations, monitoring variable objects, completing nearly finished projects, or providing pilot or speculative observations prior to a full application for observing time. CANSERV observations were performed for the following projects during JCMT Semesters 98A and 98B (1998 February 1 to 1999 January 31):

- A Possible H I Bipolar Outflow (Fich, U. Waterloo; Wallace, HIA; Routledge, U. Alberta)
- A Search for the Missing Interstellar Medium of NGC 147 (Welch, St. Mary's U.)
- H13CN J= 3-2, 4-3 Emission from NGC253 (Zhu, Seaquist, Frayer, Golla, all U. Toronto)
- Submm Mapping with SCUBA of the Evolving H II Region KR 140 (Martin, Kerton, Johnstone, all U. Toronto)
- Thermal Emission from CB58: Is There Dust at $z=2.7$? (Sawicki, Clarke, both U. Toronto)
- CO and HCN in the Molecular Envelopes of 21-micron Sources (Kwok, U. Calgary; Hrivnak, Valparaiso U.)
- Submillimetre Observations of a Recently Identified Ultraluminous Quasar (Lewis, U. Victoria; Ibata, ESO; Irwin, RGO)
- The Extended Envelope Structure of the Class 0 Protostar VLA 1623 (B. Matthews, Wilson, both McMaster U.)
- Molecular Ions in Young Planetary Nebula NGC7027 (Hasegawa, Kwok, Volk, all U. Calgary)
- Dusty Cluster Galaxies at $z=1.5$? (Hall, Evans, both U. Toronto)
- SCUBA Photometry Follow-up to Source(s) Discovered in a Rich Cluster Survey (Chapman, Fahlman, Scott, all UBC)
- CO observations of the Ultraluminous Galaxy APM 08279+5255 (Lewis, U. Victoria; Chapman, UBC; Ibata, ESO; Irwin, RGO; Totten, U. Keele)
- The Blue-bulge Signature of Infall of the Class 0 Source L1251B (Moriarty-Schieven, HIA; Butner, U. Arizona; Naranayan, U. Mass.)
- HCN(4-3) at Selected Points in M82 (Seaquist, Frayer, both U. Toronto)

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L. Avery

6.1 MANUALS AND REPORTS

