THE UNITED KINGDOM INFRARED TELESCOPE
ANNUAL REPORT
1997

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Introduction

M.J. Ward, Chairman, UKIRT Board

It has become something of a cliche to claim that a telescope or satellite contributes to astronomy from comets to cosmology, but this is indisputably the case for UKIRT.

During the period covered by this report observations made using UKIRT include the following notable achievements. Within our solar system the sizes and albedos of a number of asteroids have been measured, using combined observations by UKIRT and ISO. Nitrogen rich organic molecules have been detected in one of Saturn's moons. Our understanding of stellar evolution has been increased by the discovery of 20 new brown dwarfs. At greater distances the host galaxies of quasars have been imaged with spatial resolutions at K-band of around 0.4 arcseconds, made possible by the excellent performance of the fast guide tip-tilt system. The power of the CGS4 spectrograph has been magnificently demonstrated by observations between the OH sky lines, of H beta and [OIII] emission lines in galaxies at redshifts greater than 3, at line fluxes many times weaker than previously achieved. These and other discoveries have resulted in a record number of 84 refereed publications which included UKIRT data, in a single year.

There have been some delays associated with the provision of new instruments, but we look forward to the imminent arrival of the Fast-Track Imager UFTI, designed to exploit the improved image quality of UKIRT, and later to the commissioning of MICHELLE, which is the mid-infrared imager spectrometer to be shared between UKIRT and Gemini.

Looking towards the future, work commenced on the new near-infrared imager spectrometer UIST, which will eventually become the workhorse instrument for this spectral range. Still in the planning stage the concept of a UKIRT wide-field instrument has been gaining momentum, and a census of the UKIRT user community suggested that there would be majority support for such a camera, provided that a significant fraction of the time remained to be allocated for programmes using non-survey instruments.

In current forward-look plans, the UK's telescope suite is increasingly seen in a global context, with operational modes and the delivery of specific science objectives, often important factors in the setting of priorities. UKIRT measures up well under these criteria. The focus of its programme remains aimed at optimization in the infrared, by providing a choice of instruments designed especially for imaging and spectroscopy at near and mid-infrared wavelengths. A challenge for the future will be to determine the best balance between the previously highly successful and scientifically productive mode of community access, and the delivery of possible future programmes based for example on data from a new dedicated instrument, such as a wide-field camera.
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1. The United Kingdom Infrared Telescope

The world's largest telescope dedicated solely to infrared astronomy, the United Kingdom Infrared Telescope (UKIRT) is sited in Hawaii near the summit of Mauna Kea at an altitude of 4194m above sea level. UKIRT is owned by the United Kingdom Particle Physics and Astronomy Research Council (PPARC) and operated along with the James Clerk Maxwell Telescope by the staff of the Joint Astronomy Centre, located in Hilo. In 1997 the operation and development of UKIRT were overseen by the UKIRT Board.

The mission of the United Kingdom Infrared Telescope is "to support high quality, fundamental research in astronomy by operating, maintaining, and developing the United Kingdom Infrared Telescope and its facilities in Hawai'i." In fulfilling this mission UKIRT provides wide-ranging opportunities for state-of-the-art astronomical observations at ground-based infrared wavelengths (roughly 1-25 microns), both by arranging that new observing instruments are built in the U.K. for use at the telescope and by enhancing the capabilities of existing instruments wherever possible. In addition, the UKIRT Upgrades Programme, a comprehensive project to improve the image quality of the telescope, involving contributions by the Royal Observatories in the U.K., the Max Planck Institute for Astronomy in Heidelberg, and the Joint Astronomy Centre, was nearing completion in 1997.

During 1997 the UKIRT operation had a staff equivalent to approximately 30 full-time employees in Hawaii and one in the U.K. Awards of U.K.-controlled observing time on UKIRT, 85% of the total available observing time, are decided by the Panel for the Allocation of Telescope Time (PATT). The University of Hawaii's Institute for Astronomy allocates 15% of the time to its scientists. Scientists at the Max Planck Institute for Astronomy in Heidelberg, Germany have used roughly four weeks of PPARC time during Semesters 97A and 97B in exchange for some of the Institute's effort and expenditure in the UKIRT Upgrades Programme.
2. Scientific Highlights from 1997

This section briefly presents highlights of observations made during Semesters 97A and 97B.

2.1. Galaxies and Quasars

Dr. Lance Miller and collaborators used UKIRT's excellent image quality to study the dependency of quasar luminosity on the mass of a quasar's host galaxy, and succeeded in obtaining resolutions of 0.4-0.7 arcseconds in images requiring many hours of integration. An example is shown in Figure 1. They have found that a massive host galaxy appears to be required for the formation of any luminous quasar, but that there does not appear to be a straightforward dependence of quasar luminosity on the host luminosity.

Figure 1: The host galaxy of the redshift 0.384 quasar PG00 43+039, observed on UKIRT with tip/tilt to obtain a K-band image FWHM of about 0.4 arcseconds. A point-source contribution due to the quasar has been subtracted. Contours are plotted at equal logarithmic intervals at 0.8, 2, 5, 13, 32 and 80% of the peak signal. The galaxy accounts for 18% of the light from the quasar and has an absolute K magnitude of -26.0. The inset shows an image of a nearby star used to determine the psf, shown to the same scale with contours plotted at the same fixed multiples of the peak signal.

Dr. Max Pettini continued to exploit CGS4's as yet unequalled sensitivity between OH lines in the short
wavelength infrared, by measuring the strengths of Hβ and O III emission lines in "Lyman break" galaxies at redshifts of 3 and greater. Emission lines have now been detected at levels about 10 times weaker than the limits reached in previous searches. The rates of star formation in these early-universe galaxies are found to be 20-300 solar masses per year. The velocity dispersions combined with sizes measured from Hubble Space Telescope images, implies masses of about $10^{10}$ solar masses, comparable to the mass of the Milky Way bulge. These results support the view that Lyman break galaxies are the progenitors of today's massive galaxies.
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2.2. Star Formation, the Interstellar Medium, and Stellar Evolution

UKIRT continues to make significant contributions to the study of brown dwarfs. Based on JHK photometry Prof. Richard Jameson and co-workers identified approximately 20 new brown dwarfs in nearby open clusters, more than doubling the number of known brown dwarfs. Dr Keith Noll and collaborators detected carbon monoxide in the 5 μm spectrum of the cool (T ≈ 1200 K) brown dwarf Gl229B; Dr. Maria Teresa Ruiz and her team's IR spectrum of the T ≈ 2000 K lithium-confirmed brown dwarf Kelu-1 demonstrated that dust grains must be present in the atmospheres of this, and probably other, brown dwarfs.

The molecular ion H₃⁺, which in 1996 was detected for the first time in the dense interstellar medium, was found by Dr. Thomas Geballe and co-workers in the diffuse interstellar medium along the line-of-sight to the galactic centre and to Cygnus OB2 No. 12. The surprisingly large column densities of H₃⁺ imply that either it exists over unexpectedly long path lengths, the ionization rate of H₂ by cosmic rays is considerably higher than expected, or the rate of destruction of H₃⁺ is considerably less than current predictions.
2.3. Solar System

Dr. Dale Cruikshank and co-workers obtained the best 3-4 \( \mu m \) spectrum of Iapetus' dark side (which is five times less reflecting than its bright hemisphere) ever recorded, detecting an absorption feature near 3.3 \( \mu m \) due to nitrogen rich organic molecules. Observations are continuing in 1998 to better define this band and an unidentified band detected at 3.85 \( \mu m \), both on the dark and bright sides of this enigmatic moon of Saturn.

Dr. Alan Harris and collaborators obtained spectrophotometry in the 10 \( \mu m \) band of two near-Earth asteroids. In combination with measurements at longer infrared wavelengths from the Infrared Space Observatory, the UKIRT measurements allowed the sizes (\( \sim 1 \) km) and albedos (0.35 at 10 \( \mu m \)) to be determined. These values have important theoretical implications for the formation and nature of near-Earth asteroids which in turn increases our understanding of the role played by such objects in the development and evolution of the inner planets of the solar system.
3. Report on Operations

3.1. Summary

- High efficiency observing with both of UKIRT's major instruments, CGS4 and IRCAM3, was a nearly constant feature of the UKIRT operation in 1997.

- CGS4's slit wheel operated nearly flawlessly after its repair early in the year and the instrument was converted to a pixel scale of 0.6 arcseconds/pixel, more appropriate for the improved image quality of the telescope.

- The tip/tilt fast guide system operated successfully in its first full year of use.

- The performances of already installed Upgrades systems (including tip/tilt, focus, and primary mirror figure), were refined and optimized, with a resultant significant improvement in image quality.

- Progress toward bringing the final Upgrades components into regular operation slowed considerably, largely due to high staff turnover, especially on the engineering and technical side, and the time lag in replacing them and training the new staff. However, by the end of the year UKIRT was close to being fully staffed once again and Upgrades effort had been ramped up.

- The software group and some PPARC staff at ROE began a major project to replace much of the current diverse instrument control and data reduction software by comprehensive and modular Observatory Reduction and Control (ORAC) software for preparing and sequencing observations, controlling instruments, and reducing data. Parts of the ORAC project were drawing the interest of other observatories, including Gemini and the JCMT. There is scope for collaboration with both.

- Demand for UKIRT reached an all-time high in 1997 with 135 proposals being submitted for semester 98A. There were 84 refereed publications including UKIRT data in 1997, the most ever in one year.
3.2. Telescope Usage

The following table summarizes the telescope usage for the two semesters 97A and 97B, which cover the period February 1, 1997 to January 31, 1998.

<table>
<thead>
<tr>
<th>Semester</th>
<th>97A</th>
<th>97B</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total number of nights</td>
<td>181.0</td>
<td>184.0</td>
</tr>
<tr>
<td>Eng. and Commissioning Time</td>
<td>38.5</td>
<td>31.5</td>
</tr>
<tr>
<td>Nights available for observing</td>
<td>142.5</td>
<td>152.5</td>
</tr>
<tr>
<td>Nights observed</td>
<td>68.5%</td>
<td>80.9%</td>
</tr>
<tr>
<td>Nights lost due to faults</td>
<td>3.6%</td>
<td>5.7%</td>
</tr>
<tr>
<td>Nights lost due to bad weather</td>
<td>27.9%</td>
<td>13.4%</td>
</tr>
</tbody>
</table>

The percentage of nights observed during Semester 97B was the highest ever recorded during a semester at UKIRT, and was due in part to the beneficial (for Mauna Kea) effects of El Niño during the second half of the semester. The higher than normal percentage loss of time due to faults in semester 97B was due in large part to problems encountered by a visitor instrument.
3.3. Telescope Performance

Absolute pointing accuracy, which had improved dramatically in 1996, maintained its outstanding performance at $\approx 1.5$ arcsec rms. Three significant improvements to existing Upgrades systems were made: (1) The performance of the tip/tilt and fast guide systems were enhanced; (2) auto-focus tracking (adjusting for changes in temperature of the telescope and telescope elevation) was successfully installed; and (3) primary mirror figure as a function of telescope position was adjusted using an empirically-based look-up table. The result was significant further improvement in image quality. At the start of the year sub-arcsecond images of point sources in the K band were the norm. By the second half of the year stellar images were often below 0.5 arcseconds (FWHM) and occasionally below 0.3 arcseconds. Toward the end of the year the controls for the new dome ventilation were installed and the use of the system began; the extent of its effect on the image quality was not yet determined at year's end.
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3.4. Instruments

3.4.1. CGS3 (10 and 20 μm 32-channel low resolution spectrometer)

CGS3 was used successfully on approximately 24 nights during the year. Despite the successful demonstration of MICS at UKIRT (see below), some demand for CGS3 remains because of its 20μm capability, which MICS does not possess. There has been no further development work on CGS3 and none is envisaged before its retirement, which is anticipated to be at the end of 1998.

3.4.2. CGS4 (1-5 μm multiple resolution spectrometer with 256×256 array)

Apart from the first part of the year and a brief period in December 1997, CGS4 operated highly successfully in all modes and continued to be the subject of considerable praise by a number of visiting astronomers. The slit rotation mechanism, which had hampered observations during the latter part of 1996 and continued to inconvenience or limit some kinds of observations in early 1997, was fixed in April 1997 and has operated very well since then. For the most part other faults with the instrument were minor and were addressed quickly. However in late 1997 a period of intermittently unstable array performance culminated in a failure of one of the four readout channels in December. An emergency warm-up of the dewar was required to repair the fault, which turned out to be a broken resistor on the array circuit board. The schedule was rearranged so that no visitors lost observing time. Semester 97B saw the first use of the long camera, which provides a pixel scale better suited for UKIRT's improved image quality, and a 40 l/mm grating (replacing the workhorse 75 l/mm grating) that allows moderate resolution and wide wavelength coverage with the new pixel scale.

3.4.3. IRCAM3 (1-5 μm camera with 256×256 array)

IRCAM3 operated remarkably smoothly, with no major faults occurring during the year and the performance of the instrument benefited from the improved image quality delivered by the telescope, but the coarse pixel scale (0.28 arcseconds/pixel) of the instrument led to increasing use of the 2X magnifier by the end of the year. The various instrument accessories, and the unusual data acquisition mode snapshot, were employed successfully during the year. The total amount of time lost during 1997 was approximately 10 hours and was due mostly to communications breakdowns between the instrument and the VAX data acquisition software. Two observing programmes which used the snapshot mode with the 5X magnifier suffered from lower than expected sensitivity. This was later determined to be a feature of the magnifier, which originally was intended for image quality tests and which does not decrease the background per pixel when installed. Correct
information concerning this is now on the IRCAM3 web pages.

Design work began on a modification to IRCAM3 to convert its plate scale to a smaller one that is more appropriate for imaging in the thermal infrared. Thermal IR imaging is expected to become the primary function of IRCAM3 once the new 1024×1024 UKIRT Fast Track Imager (UFTI) is delivered in 1998.

3.4.4. Accessories

Both the K band Fabry-Perot (FP) interferometer and IRPOL2 were used several times during 1997 and both performed excellently. Improved software was installed to considerably speed up the FP alignment process. The polarimetry data reduction software was enhanced in several respects.

3.4.5. Visitor Instruments

An integral field unit (IFU) for the J and H bands, designed and built at the University of Durham, was commissioned at UKIRT with CGS4 in Semester 97A. The unit has 72 fibres and reformats a 4×6 patch of sky onto the slit of CGS4. Poor weather prohibited accurate information from being obtained but the performance of the IFU was promising. Additional commissioning time for the instrument has been scheduled early in Semester 98A.

The MPIA thermal IR camera, MAX, had two very successful one-week runs at UKIRT, a third in which poor weather resulted in the observers using CGS4 instead, and another during which a number of technical problems led to considerable lost time. MIRAS, an Australian mid-infrared camera equipped with a polarimeter had a moderately successful observing run in July 1997, although electronic pickup noticeably reduced its sensitivity.

An agreement was reached whereby MICS, a Japanese prototype camera/spectrometer for 8-13 μm, is to be offered to UKIRT observers with minimal restrictions in exchange for the opportunity for Japanese astronomers to gain experience in observing at thermal IR wavelengths. Tests of MICS were performed in engineering time at UKIRT in March and September 1997. In March the performance of the instrument was poor and it was judged unsuitable for scientific use at UKIRT. The September test showed that most of the problems with the instrument had been addressed and that its performance was much better. The instrument was to be made available to the community beginning in Semester 98A.

Commissioning and science time for COHSI, a revolutionary fibre-optic J and H band spectrometer built at Cambridge University, which rejects OH line emission, was rescheduled for semester 98A.
3.5. Computing

During 1997 the main software developments have been as follows.

- characterising and improving the tip/tilt system
- improving the telescope imaging performance by implementing active focus and primary mirror control and computer control of the dome ventilation system
- ramping up the Observatory Reduction and Control (ORAC) project (discussed in the summary)
- development of low level software for UFTI, the 1024 square array camera for UKIRT being built in the U.K.
3.6. Other Developments

3.6.1. Service Observing

The Service programme continues to be popular with 81 proposals submitted in 1997 in addition to the significant backlog of proposals remaining due to poor weather during the previous year. Sixty proposals were completed within the year. Twenty-five percent of proposals were completed within six months of submission. At least 14 publications in refereed journals included Service data, which was 17% of UKIRT's total number of publications; the number roughly matches the output during 1996. In 1997 S. Ridgway of Oxford University retired as a referee and was replaced by G. Wright of ROE. The other referees are T. Geballe, T. Moore and T. Naylor.

3.6.2. Reactive Scheduling

This programme of making additional time available to the most highly rated science projects if these were adversely affected by poor weather or technical problems was continued, although because of the large allocation of engineering nights no dedicated time for it was allocated by PATT. However, some time for reactive scheduling became available because of the postponement or cancellation of some engineering work and this was put to good use in completing programmes for Drs Meaburn, Pettini, Rawlings, and Mobasher.

3.6.3. Newsletter

The first edition of the UKIRT Newsletter was published on the worldwide web in June and mailed to astronomical libraries in the U.K.. In the future the Newsletter will be published twice per year, shortly before each PATT deadline.
4. Approved Programme

4.1. Completion of the UKIRT Upgrades Programme

The core elements of the programme which were brought into operation in 1996 have continued to function with gratifyingly little trouble (especially considering that the Upgrades tripled the complexity of the telescope systems). The tip/tilt system is used at all times except on the rare occasions when no guide star can be found. The Dome Ventilation System came into routine operation in late 1997, and has been shown to have a significant and beneficial effect on dome air temperatures. Sub-arcsecond images are routinely delivered. ¹

4.1.1. Telescope Optical Performance

Roughly once a month since late 1996 measurements of the telescope optical properties are secured at around 60 points over the sky using the wavefront curvature sensor. The results have been used to set up a lookup table by which the active optical control system of the primary mirror can correct for astigmatism, low-order (r3) trefoil and spherical aberration, while the five-axis precision positioning system of the secondary (the hexapod) eliminates misalignment coma.

As it turns out, constant corrections suffice to remove all aberrations except astigmatism, which is removed by a simple hour-angle dependent correction. The stability of the alignment of the secondary and primary mirrors, in particular, is a major tribute to the excellence of the basic mechanical-optical design of the telescope by Dunford Hadfields and Grubb Parsons. As a result, the main use to which the telescope's powerful active optical capability (to insert and remove aberrations with a range of amplitudes) has so far been put, has been to test the operation of the Gemini Prime Focus wavefront sensor, which was calibrated in parallel observations with the UKIRT WFS on December 1997 and January 1998. This was done by providing aberrations of known amplitude for it to measure.

UKIRT's overall wavefront error is now typically around 300 nm rms over 95% of the optical diameter. This is mostly contributed by the secondary mirror, which as noted last year suffers from print-through of the lightweighting pattern from the rear surface to the figured front surface (up to about 200 nm peak-to-peak), a significant turned-down edge (reducing the effective diameter by 5%) and distortion by thermal effects in its mountings, which injects low- and higher-order (r5) trefoil (the latter uncorrectable by the active-optical system) and spherical aberrations. The aggregation of these exceeds the ability of the primary mirror force actuators to correct them and so a compromise setting is currently adopted, which eliminates all astigmatism and most of the low-order trefoil but only a part of the spherical aberration.

In late 1997 agreement was reached with the MPIA for the provision of a new mirror, to be correctly figured right
out to the edge, stress-relieved by rear-surface etching after lightweighting to reduce or eliminate printhrough, and equipped with athermal mounts. The procurement process proposed by the MPIA was verified to be both likely to succeed and very cost-effective. At the time of writing manufacture is well underway, and we are hoping for delivery of the new mirror in early 1999. If the new mirror measures up to expectations, the wavefront error is expected to be reduced to well below 100 nm peak-to-peak, substantially better than the goal of the upgrades programme of diffraction limited performance at 2 microns.

After the new mirror is checked out and installed, the present mirror may in turn be etched for stress relief. This, with athermal mounts, would leave it suffering only from the turned down edge. With a good-quality backup mirror available we can plan to employ advanced (low-emissivity) coatings, even if this requires the mirror to be sent away for quite long periods.

4.1.2. Focus Stabilisation

An automatic routine for maintaining telescope focus has been in operation since mid-1997. This applies corrections for the temperature of the steel trusses of which the telescope is built and for elastic deformations due to gravity (the telescope is longest when pointed at the zenith). The routine has performed remarkably well considering its simplicity. Users have sometimes to be reminded that focus checks (using semi-automatic routines now provided for both CGS4 and IRCAM) are still necessary if the best images are to be exploited, since defocus is still typically the largest degrading factor affecting imaging performance.

4.1.3. Dome Ventilation System

This critical but demanding system (which must function well if it is to be employed at all!) came into operation by stages in the second half of 1997 and early 1998. At the time of writing three of the 16 apertures await correction of mechanical problems, but use of the rest is routine and their control reliable. The DVS produces an obvious and dramatic increase in the flow of air through the dome; the vents have to be closed to reduce wind-shake in winds above 25 mph.

4.1.4. Dome Floor Insulation

The proposal to insulate the dome floor, to prevent heat from the 8-inch concrete slab - with its long thermal time constant - being transferred to the dome air at night, has been complicated by safety issues. Tests at Keck after the disastrous Subaru fire revealed that all flammable materials tested caught fire much more easily on Mauna Kea than at sea level. (This is because, while there is still plenty of oxygen for combustion of most materials, there is only half as much air to cool the igniting object, making the process easier.) A serious fire at the CTIO 4m telescope occurred in an ethylene glycol gel in insulating material, which had formed after spilled coolant solution lost water by evaporation. Since we plan to cool the UKIRT primary using ethylene glycol solution, the combination with the proposed foam floor insulation caused uneasiness.

Neutral advice from a consultant, the above considerations and others of general engineering practicability led us, early in 1998, to abandon the overfloor insulation project. We will substitute partial underfloor insulation to isolate the warm crew room and may use surplus cooling power from the primary mirror system to cool critical areas of the dome.

4.1.5. Primary Mirror Cooling

Staffing shortages have been affecting the programme since late 1996. One of the main consequences has been a complete lack of progress during 1997 towards completion of the mirror cooling system. Work on this system has recommenced in 1998 and it is expected to be under test by the end of the year.
4.2. Instrumentation Development

All elements of the programme outlined in the last Report have made progress, albeit with delivery slippages in two of the three instruments.

4.2.1. UKIRT Fast-Track Imager

The Fast-track imager, UFTI, will use a large-format (1024×1024) HgCdTe array sensitive from 0.85 to 2.5 microns to provide imaging through J,H,K and narrowband filters over a 92 arcsec field of view with high spatial resolution (0.09 arcsec pixels), to exploit the markedly sharper images of the upgraded telescope. The imager has been under development at Oxford University but suffered several setbacks towards the end of the year. Problems with fabrication of large vacuum components caused a programme slippage in October. At the end of the year the late delivery of detector arrays and, in early 1998, of the array controller, all conspired to move the anticipated time of first light from 1 April 1998, the target date at the time of the first UKIRT Board meeting in May 1997, to late June by the end of the year.

4.2.2. Michelle

Michelle, the largest and most complex instrument yet destined for UKIRT, also had its problems in 1997. This powerful imager-spectrometer is one of the most ambitious astronomical instruments ever built. As set out in more detail in the last report, Michelle will provide diffraction-limited imaging through broad- and narrow-band filters, and spectroscopy at spectral resolutions between 250 and 30,000, in the atmospheric windows between 7 and 25 microns wavelengths. It will employ an array of 320×240 arsenic-doped silicon (Si:As) blocked-impurity-band (BIB) detectors, operating at temperatures around 5 K, which will be achieved by a Joule-Thompson refrigerator. Michelle will be shared with Gemini.

In 1997 Michelle had a number of successes as well as several problems. Early in the year staff shortages at ROE caused some slippage, while the detailed opto-mechanical design of the large aluminium mirrors proved more complex than expected. Throughout 1997 there was concern about the availability and capabilities of the Santa Barbara Corporation (now Raytheon) 320×240 Si:As arrays. The project developed two levels of fallback options, a 256×256 option from Rockwell, and a 128-square array which was tested by lending the engineering version to a collaborating group to use for astronomy.
A second cliff-hanger was provided by the central portion of the vacuum vessel, the largest of three sections. At the commencement of the project no supplier was known who could fabricate such a large vacuum-tight structure in aluminium (stainless steel, the more common material on these scales, would have been much too heavy for Michelle). Manufacture by casting was therefore proposed, a supplier identified and an order placed. However the component was too large for processing to eliminate the porosity frequently encountered with cast aluminium, and the outcome was uncertain. Suspect areas of the casting were repaired by welding, but concerns were still acute. Since a company capable of fabricating the unit in aluminium had by then been identified, an order for a fabricated backup unit was placed in November 1997. Early in 1998 the cast unit failed its vacuum test and the fabricated version was adopted.5

4.2.3. The UKIRT Imager Spectrometer UIST

The project formally commenced at the beginning of the 1997/98 financial year, although considerable preparatory work had been undertaken before that stage. The overall design of the instrument took form rapidly, and a successful preliminary design review was held in December 1997. The design is based on the 1024×1024 InSb ALADDIN arrays recently developed at SBRC. To curtail cost and development time it deliberately concentrates on exploiting the accumulated expertise and experience at ROE. Filter wheels, focus units, etc. utilise pre-existing designs to a maximum degree. The design is all-transmissive, using grisms as dispersing elements in spectroscopic mode. It will be delivered with a pixel scale of 0.12 arcseconds per pixel and upgraded thereafter by the installation of a lens exchange wheel to provide 0.06 per pixel for adequate sampling of the better images. The focus mechanism has used a design for another cryostat and has already been manufactured. Array procurement has required to be accelerated in order not to delay delivery; fortunately it has proved possible to obtain the requisite movement of funds forward in the project.

In its spectroscopic modes UIST will be a highly versatile instrument offering suites of grisms to provide:

- Long-slit (120) spectroscopy with 1-, 2-, 3- and 4-pixel-wide slits at resolutions R (for a 2-pixel-wide slit) of ≈1600, when a whole atmospheric band is covered at once, and ≈4000, covering about half a band but with high enough resolution to minimise the impact of OH lines in the J, H and K bands. Grisms providing resolutions of 2000-3000 will offer excellent sensitivity in the longer-wavelength bands.
- A short-slit (≈20) cross-dispersed mode using the lower-dispersion (R≈1600) grisms to cover two atmospheric bands (I+J, H+K, K+L) at once.
- A low-resolution mode using the cross-disperser to provide long-slit (120) spectra in the perpendicular direction on the array. These will extending across the I, J, H and K windows at once at a spectral resolution R≈200 (with a 2-pixel slit).

4.2.4. University of Hawaii Adaptive-Optics system (UH-AO)

The possible installation of the University of Hawaii Adaptive Optics system on UKIRT next year, and its delay because of secondary mirror print-through, was discussed in the last report. This system is now intended to go on Gemini in 1999 as a near-first-light facility and it is unlikely to be available on UKIRT until well into 2000.
5. Longer-Term Plans

Part of the longer term programme endorsed by the Williams Panel was a move towards developing UKIRT as a wide-field telescope. We have begun to pursue this option in more detail and a number of designs intended to deliver high-quality imaging over a 30 arcmin square FOV have been examined. This is not easy to implement in the IR on a 4m telescope like UKIRT; in particular the requirements on the one hand for image stabilisation to remove telescope micro-vibrations and hence a large bandwidth (which is facilitated by a small and agile secondary mirror), and on the other for a wide field of view (which calls for a fast f/ratio and hence a large secondary mirror), are challenging to reconcile.

At the time of writing several options are under study, including a Cassegrain focus folded ahead of the primary, and a "forward Cassegrain" focus above the primary, operating at f/9 or thereabouts. A proposal for a wide-field option has been strongly endorsed by the PPARC Astronomy Committee but further progress awaits decisions by the Ground-Based Facilities Committee. In the more distant future a multi-object spectroscopic capability is a popular goal.

In the longer term the main working f/ratio of UKIRT will probably be altered to f/16 to facilitate compatibility with Gemini instrumentation. We plan to explore further the possibility of making the new secondary an adaptive system, able to provide low-order corrections over small fields of view to all instruments on UKIRT.
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6. Financial Statement

The total expenditure on UKIRT in the 1997/98 financial year (April 1997 to March 1998) was £ 3548.3 k, of which £ 2075.4 k was for operations and £ 1472.9 k was for the development programme (Upgrades and new instruments). Details of the expenditures are given below.
<table>
<thead>
<tr>
<th>1. Mauna Kea Observatory</th>
<th>1997/98 Outturn</th>
<th>£(k)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.1. Office machinery and furniture</td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>1.2. Telephone</td>
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<td>5</td>
</tr>
<tr>
<td>1.3. Utilities</td>
<td></td>
<td>51</td>
</tr>
<tr>
<td>1.4. Mechanical</td>
<td></td>
<td>15</td>
</tr>
<tr>
<td>1.5. Electrical</td>
<td></td>
<td>40</td>
</tr>
<tr>
<td>1.6. Building maintenance and development</td>
<td></td>
<td>26</td>
</tr>
<tr>
<td>1.7. Road maintenance and snow clearance</td>
<td></td>
<td>19</td>
</tr>
<tr>
<td>1.8. Cryogens, vacuum and related equipment</td>
<td></td>
<td>37</td>
</tr>
<tr>
<td>1.9. Instrument maintenance and improvements</td>
<td></td>
<td>55</td>
</tr>
<tr>
<td>1.10. Computer systems</td>
<td></td>
<td>16</td>
</tr>
<tr>
<td><strong>Sub total (1)</strong></td>
<td></td>
<td><strong>265</strong></td>
</tr>
</tbody>
</table>

| 2. Mid level (Hale Pohaku)                      |                |      |
| 2.1. Accommodations charges                     |                | 42   |
| 2.2. Mauna Kea Support Services                 |                | 12   |
| 2.3. Computer systems                           |                | 0    |
| **Sub total (2)**                               |                | **54** |

| 3. Joint Astronomy Centre (Hilo)                |                |      |
| 3.1. Office supplies and equipment              |                | 10   |
| 3.2. Telecommunications and postage             |                | 9    |
| 3.3. Utilities                                  |                | 20   |
| 3.4. Misc. admin, publicity, hospitality        |                | 4    |
| 3.5. Safety, first aid                          |                | 4    |
| 3.6. Workshop equipment                         |                | 6    |
| 3.7. Library                                    |                | 6    |
| 3.8. Building maintenance and improvements      |                | 48   |
| 3.9. Vehicle Purchases and maintenance          |                | 38   |
| **Sub total (3)**                               |                | **140** |
### Outturn

<table>
<thead>
<tr>
<th>Description</th>
<th>£(k)</th>
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<tbody>
<tr>
<td>3.10. JAC Computer systems</td>
<td>59</td>
</tr>
<tr>
<td>3.11. Computer networks</td>
<td>19</td>
</tr>
<tr>
<td><strong>Sub total (3)</strong></td>
<td><strong>223</strong></td>
</tr>
<tr>
<td>4. Local Staff (incl. recruit., research)</td>
<td>611</td>
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<tr>
<td><strong>Sub total (4)</strong></td>
<td><strong>611</strong></td>
</tr>
<tr>
<td>5. PPARC Staff (Hawaii and UK)</td>
<td>813</td>
</tr>
<tr>
<td><strong>Sub total (5)</strong></td>
<td><strong>813</strong></td>
</tr>
<tr>
<td>6. Travel, training, conferences, publications</td>
<td></td>
</tr>
<tr>
<td>6.1. Conferences, observing, publications</td>
<td>37</td>
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<tr>
<td>6.2. Training</td>
<td>8</td>
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<td>6.3. Management travel</td>
<td>27</td>
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<tr>
<td><strong>Sub total (6)</strong></td>
<td><strong>72</strong></td>
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<tr>
<td>7. ORAC requisitions</td>
<td>18</td>
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<tr>
<td><strong>Sub total (7)</strong></td>
<td><strong>18</strong></td>
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<tr>
<td>8. Development Prog Management</td>
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<tr>
<td><strong>Sub Total (8)</strong></td>
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### DEVELOPMENT

<table>
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<th>Description</th>
<th>£(k)</th>
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<tbody>
<tr>
<td>1. Upgrades</td>
<td>21</td>
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<tr>
<td>2. Michelle</td>
<td>1080</td>
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<tr>
<td>3. UFTI</td>
<td>213</td>
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<td>4. UIST</td>
<td>159</td>
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</table>
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Appendix A: List of Publications

A total of 84 refereed journal publications acknowledging UKIRT data were published in 1997. This constitutes a new record for UKIRT, exceeding the previous record of 82 publications in 1996. Some papers contain data contributed by more than one instrument on UKIRT. In such cases the contributions of the instruments are taken as equal in the first table.

**PUBLICATIONS BY INSTRUMENT**

<table>
<thead>
<tr>
<th>Instrument</th>
<th>Number</th>
<th>%</th>
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<tbody>
<tr>
<td>CGS4</td>
<td>34.5</td>
<td>41</td>
</tr>
<tr>
<td>CGS3</td>
<td>7.5</td>
<td>9</td>
</tr>
<tr>
<td>CGS2</td>
<td>0.5</td>
<td>1</td>
</tr>
<tr>
<td>IRCAM(2&amp;3)</td>
<td>34.0</td>
<td>40</td>
</tr>
<tr>
<td>UKT</td>
<td>2.5</td>
<td>3</td>
</tr>
<tr>
<td>Visitor</td>
<td>5.0</td>
<td>6</td>
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</table>

**PUBLICATIONS BY SCIENTIFIC CATEGORY**

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<thead>
<tr>
<th>Subject</th>
<th>Number</th>
<th>%</th>
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</thead>
<tbody>
<tr>
<td>Extragalactic</td>
<td>23</td>
<td>27</td>
</tr>
<tr>
<td>Galactic</td>
<td>52</td>
<td>62</td>
</tr>
<tr>
<td>Solar System</td>
<td>9</td>
<td>11</td>
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</tbody>
</table>

Refereed publications in 1997


127, 379 A baseline spectroscopic study of the infrared auroras of Jupiter


Bergeron, P., Ruiz, M.T. & Leggett, S.K., APJSS, 108, 339 The chemical evolution of cool white dwarfs and the age of the local Galactic disk


Chen, W.P. & Simon, M., AJ, 113, 752 Infrared point sources identified by lunar occultation observations


Davies, J.K., McBride, N. & Green, S.F., 1997, Icarus, 125, 61 Optical and infrared photometry of Kuiper Belt object 1993SC


Jackson, N. & Rawlings, S., MNRAS, 286, 241 *[O III] 500.7 spectroscopy of 3C galaxies and quasars at redshift z>1*

Jenson, E.L.N. & Mathieu, R.D., AJ, 114, 301 *Evidence for cleared regions in the disks around pre-main-sequence spectroscopic binaries*


Miller, S., Achilleos, N., Ballester, G.E., An Lam, H., Tennyson, J., Geballe, T.R. & Trafton, L.M., Icarus, 130, 57 *Mid-to-low latitude Hα+ emission from Jupiter*


**Mottola, S.** et al., AJ, 114, 1234 *Physical model of near-Earth asteroid 6489 Golevka (1991 JX) from optical and infrared observations*


**Pravec, P.**, Wolf, M., Sarounova, L., Harris, A.W. & Davies, J.K., Icarus, 127, 441 *Spin vector, shape, and size of the Amor asteroid (6053) 1993 BW3*


Variations in the 3 micron spectrum across the Orion Bar: polycyclic aromatic hydrocarbons and related molecules


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Appendix B: Time Allocations

UKIRT PATT time continued to be oversubscribed by more than a factor of three. In the following list of successful applications only the principal investigator is given, although in nearly every case the projects are collaborative efforts. The grouping by instrument and scientific category of the telescope time awarded was as follows. Where a proposal requested more than one instrument these have been given equal weight in the first table.

<table>
<thead>
<tr>
<th>Instrument</th>
<th>97A Number</th>
<th>97A %</th>
<th>97B Number</th>
<th>97B %</th>
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</thead>
<tbody>
<tr>
<td>CGS4</td>
<td>35.0</td>
<td>61</td>
<td>25.0</td>
<td>53</td>
</tr>
<tr>
<td>CGS3</td>
<td>1.0</td>
<td>2</td>
<td>2.5</td>
<td>5</td>
</tr>
<tr>
<td>IRCAM3</td>
<td>19.0</td>
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<td>17.5</td>
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<tr>
<td>Visitor</td>
<td>2.0</td>
<td>4</td>
<td>2.0</td>
<td>5</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Subject</th>
<th>97A Number</th>
<th>97A %</th>
<th>97B Number</th>
<th>97B %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Extragalactic</td>
<td>24</td>
<td>42</td>
<td>24</td>
<td>51</td>
</tr>
<tr>
<td>Galactic</td>
<td>29</td>
<td>51</td>
<td>18</td>
<td>38</td>
</tr>
<tr>
<td>Solar System</td>
<td>4</td>
<td>7</td>
<td>5</td>
<td>11</td>
</tr>
</tbody>
</table>

Awards 1997A
Almaini
IofA Cambridge
The nature of X-ray luminous galaxies
Carswell
MgII absorption at high redshifts
Charles
Oxford Univ
Spectroscopy of cool binaries in X-ray binaries
Collins
Liverpool John Moores
The brightest cluster galaxies in ROSAT clusters
Davies
JAC Hawaii
Davies
Spectral diversity amongst distant planetesimals
Davis
Gas excitation in molecular bow shocks
Dublin IofAS
Dhillon
A search for brown dwarf secondaries in CVs
Dunlop
Univ of Edinburgh
Investigating quasar hosts
Univ of Edinburgh
Dunlop
The redshift distribution of mJy radio galaxies
Eyres
Koell Univ
Sukarai’s object: IR spectroscopy
Geballe
JAC Hawaii
Follow-up to discovery of H₃⁺ in interstellar space
Haniff
MORO Cambridge
Morphologies of Seyfert nuclei
Harris
DLR IofP Berlin
Near-Earth asteroids
Hatchell
Univ Manchester IST
The excitation of H₃ in a jet driven outflow
Hodgkin
Leicester Univ
Search for companions to Lalande 21185
Hough
Univ of Hertfordshire
Imaging polarimetry of Cygnus A and 3C321
Hough
Univ of Hertfordshire
Interstellar polarisation between 1 and 5μm and the 3.4μm feature
Lebofsky
LPL U of AZ
3μm spectra of hydrated asteroids
Leggett
JAC Hawaii
The lowest mass Halo and Disk stars

Awards 1997A, continued
Lumsden: Cometary compact HII regions —
AAO Australia: bow—shocks or blisters
Marscher: Simultaneous multifrequency observations
Boston Univ: of the Blazar OJ287
Maxted: The eclipsing binary CM Drae —
Univ of Southampton: determining the metallicity
McHardy: Imaging of the faintest
Univ of Southampton: ROSAT X—ray sources
McHardy: Spectroscopy of red stellar objects
Univ of Southampton: in blank ROSAT errorboxes
McMahon: Spectroscopy of low—ionisation
IofA Cambridge: BALQSOs
McMahon: Evolution of radio loud quasars
IofA Cambridge: between z=2 and z=6
Meaburn: Nuclear molecular tori and rings
Univ of Manchester: in nearby active galaxies
Moore: 20μm polarimetry and magnetic fields in
Liverpool John Moores: bipolar outflow sources
Naylor: Irradiation of secondary stars
Kedc Univ: in old novac
Noll: SO2 on Europa
STScI: CO in the brown dwarf Gl229B
STScI: Emission line constraints on
Univ of Leicester: AGN ultra—soft X—ray continuum
Peacock: Spectra of the oldest
ROE, UK: galaxies at z>1
Puxley: Molecular hydrogen excitation in
gemini Tucson: dwarf galaxies
Ramsay—Howat: Polarisation of radiatively
ROE UK: excited H2 lines
Rawlings: EROs: dusty galaxies or old
Oxford Univ: high redshift ellipticals
Ridgway: Polarimetry in aligned components
Oxford Univ: in z~1 quasars
Roche: High excitation cores of
Oxford Univ: NGC 6302 and NGC 6537

Awards 1997A, continued
Serjeant  Optical lines in z~2 radioquasars
Imperial College London
Shabaz  Search for Thorne–Zytkow objects
Oxford Univ
Shanks  Reddening towards galactic open clusters
Univ of Durham containing cepheids
Skinner  Imaging of Galactic Centre
Univ of Birmingham gamma-ray source fields
Snow  Solid state CO absorption
Univ of Colorado towards M17
Strauss  Spectropolarimetry of ultraluminous
Princeton Univ IRAS galaxies
Sylvester  Mid-IR imaging of discs around
Univ College London Vega-excess systems
Walker  The spectrum of τ Boo B
UBC Canada
Ward  Nuclear activity of FR1
Univ of Leicester radio galaxies
Whittet  Spectroscopy of ices in molecular
Rensselaer PI, NY clouds towards the GC
Young  Polarimetry of Seyfert galaxies
Univ of Hertfordshire with emission line cones

University of Hawaii
Chambers  Distant faint red radio galaxies
Hodapp  Outflows from class O sources
Knopp  Polarimetry of radio galaxies
Eisloffel  The rotation of embedded YSOs
Owen  CGS4 spectra of Uranus and Jupiter
Stockton  Imaging of QSOs and radio galaxies
Vacca  Spectroscopy of starburst and WR galaxies
Vacca  Cyg X-3: a test of models

Awards 1997B
The Stephenson early type stars:
3.4\mu m spectroscopy
Spectroscopy of X-ray luminous galaxies
The SiC enrichment rate of the galaxy by extreme carbon stars
The composition of carbon rich mantles in molecular clouds
High spatial resolution imaging polarimetry of circumstellar discs
The circumstellar environment of Herbig Ae/Be stars
Galaxies at 1<z<2; high-z arcs
Galactic rotation curve from distant molecular cloud complexes
10\mu m spectroscopy of SP comets
Resolving the two conflicting pictures for galactic evolution
Star formation in z\sim 2.5
damped Lyman-\alpha galaxies
Thermal studies of near-Earth asteroids
Speckle imaging of luminous YSOs
Spectropolarimetry of the 4.67\mu m CO feature in Elias 16
Star formation in galaxy disks from the CO feature
Spectroscopy of brown dwarfs in the Pleiades
The luminosity and mass functions in the Pleiades and Praesepe clusters
Constraining disk inclinations in young binary systems
The pressure in extended line emission around z>2 quasars

Awards 1997B, continued
Lacy
Oxford Univ
Leggett
JAC Hawaii
Longmore
ROE UK
McHardy
Univ of Southampton
Miller
Oxford Univ
Mobasher
Imperial College London
Penny
RAL UK
Pettini
RGO Cambridge
Ramsay-Howat
ROE UK
Rawlings
Oxford Univ
Rawlings
Oxford Univ
Ridgway
Oxford Univ
Shahbaz
Oxford Univ
Simpson
JPL CA
Simpson
JPL CA
Strauss
Princeton Univ
Ward
Univ of Leicester
Ward
Univ of Leicester
Warren
Imperial College London

Long-slit spectroscopy of z~1 luminous radio galaxies The lowest mass Halo and Disk stars New methods to discover brown dwarfs Imaging of BL Lac host galaxies The dependence of quasar luminosity on host galaxy mass The luminosity function of galaxies in z~0.2 clusters The 51 Pég planet atmosphere — and a search in υ And The mass and reddening of z>3 galaxies Do dense clumps control PDR structure? EROs: dusty galaxies or old high redshift ellipticals A gravitationally-lensed 3-arcmin quasar pair? Polarimetry of aligned components in z~1 radio sources The mass of the black hole in A0620-00 Gas and dust in the obscuring tori of Seyfert galaxies How many high-redshift radio galaxies are quasars? Spectropolarimetry of ultraluminous IRAS galaxies Nuclear activity in FR.1 radio galaxies The collimating structures in the nuclei of Seyferts II Imaging of the first optical Einstein ring

Awards 1997B, continued
Young
Univ of Hertfordshire

Imaging polarimetry of NGC 1068

Tests of the unified field theory of type 1 and 2 active galaxies

University of Hawaii

Cowie
Hα spectroscopy of high-z star-forming galaxies

Hodapp
Mid-IR imaging of embedded outflows

Hu
Spectroscopy of 2<z<4.6 galaxies in quasar fields

Kobayashi
Substellar candidates in NGC 2024

Meech
Spectroscopy of Phaethon

Owen
Iapetus, Titan and the satellites of Saturn

Tholen
Physical Properties of trans-Neptunian Objects

Tokunaga
Brown dwarf candidates in the Taurus dark cloud
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Appendix C: Committee Membership

I. UKIRT BOARD

Prof. M.J. Ward
(chair)
University of Leicester

Prof. Dr. S. Beckwith
Max-Planck Institute fur Astronomic

Dr. R. McLaren
University of Hawaii

Dr. M. Griffin
Queen Mary & Westfield College

Dr. S.J. Warren
Imperial College

Dr. A. Adamson
University of Central Lancashire

Dr. M. Coe
University of Southampton

Dr. S. Fales
University of Wales

Mr. C.G. Brooks
Astronomy Division, PPARC

II. UKIRT PATT TIME ALLOCATION GROUP

Dr S.J. Warren
(Chair)
Imperial College

Dr. T.M. Gledhill
University of Hertfordshire

Dr. G. Fuller
University of Manchester

Dr. R.M. Johnstone
Cambridge University

Dr. T. Moore
Liverpool John Moores University

Dr. G.S. Wright
Royal Observatory Edinburgh

Dr. J.K. Davies
Joint Astronomy Centre

(technical secretary)
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Appendix D: UKIRT Staff

<table>
<thead>
<tr>
<th>Name</th>
<th>Position</th>
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</thead>
<tbody>
<tr>
<td>S.L. Arakaki</td>
<td>Senior Instrument Engineer</td>
</tr>
<tr>
<td>T. Brown</td>
<td>Accounts Assistant</td>
</tr>
<tr>
<td>T. Carroll</td>
<td>Telescope Systems Specialist</td>
</tr>
<tr>
<td>A.C. Chrysostomou</td>
<td>Support Astronomer</td>
</tr>
<tr>
<td>T.C. Chufer</td>
<td>Telescope Technical Manager</td>
</tr>
<tr>
<td>Dr. J.K. Davies</td>
<td>Support Astronomer</td>
</tr>
<tr>
<td>Dr. C.J. Davis</td>
<td>Research Associate / Telescope Systems Specialist</td>
</tr>
<tr>
<td>V. DeMatos</td>
<td>Mechanical Technician Supervisor</td>
</tr>
<tr>
<td>M. Dougherty</td>
<td>Engineering Secretary</td>
</tr>
<tr>
<td>F. Economou</td>
<td>Software Engineer</td>
</tr>
<tr>
<td>D.A. Fudieier</td>
<td>Computer Systems Administrator</td>
</tr>
<tr>
<td>Dr. T.R. Geballe</td>
<td>Head of UKIRT Operations</td>
</tr>
<tr>
<td>Dr. J. Greaves</td>
<td>Librarian</td>
</tr>
<tr>
<td>J. Greenhalgh</td>
<td>J.A.C. Chief Engineer</td>
</tr>
<tr>
<td>J.L. Griffin</td>
<td>Electronics Engineer</td>
</tr>
<tr>
<td>M. Hauschildt-Purves</td>
<td>Software Engineer</td>
</tr>
<tr>
<td>Dr. T.G. Hawarden</td>
<td>Head of UKIRT Development</td>
</tr>
<tr>
<td>M. Horita</td>
<td>Mechanical Technician</td>
</tr>
<tr>
<td>C. Jennings</td>
<td>Receptionist/Clerk</td>
</tr>
<tr>
<td>Dr T.H. Kerr</td>
<td>Support Astronomer</td>
</tr>
<tr>
<td>N. Kobayashi</td>
<td>Mechanical Technician</td>
</tr>
<tr>
<td>Dr. S.K. Leggett</td>
<td>Support Astronomer</td>
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<tr>
<td>B.M. Leite</td>
<td>Human Resources Assistant</td>
</tr>
<tr>
<td>A.M. Lucas</td>
<td>UKIRT Secretary</td>
</tr>
<tr>
<td>D.R. McCall</td>
<td>Head Of Administration</td>
</tr>
<tr>
<td>J. Moguro</td>
<td>Mechanical Design Engineer</td>
</tr>
<tr>
<td>I.L. Midson</td>
<td>Finance Officer</td>
</tr>
<tr>
<td>D. Milar-Okinaka</td>
<td>Administration Clerk</td>
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<tr>
<td>R. Myers</td>
<td>Accounts Clerk</td>
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<tr>
<td>K. O’Connell</td>
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<tr>
<td>L. Pain</td>
<td>Mechanical Engineer</td>
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<tr>
<td>D. Reed</td>
<td>Observatory Electrician</td>
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<tr>
<td>N.P. Rees</td>
<td>Head of UKIRT Software</td>
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<tr>
<td>Prof. E.J. Robson</td>
<td>Director JAC</td>
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<tr>
<td>Name</td>
<td>Position</td>
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<td>-----------------</td>
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<tr>
<td>Dr. S.D. Ryder</td>
<td>Research Associate / Telescope System Specialist</td>
</tr>
<tr>
<td>E. Sison</td>
<td>Mechanical Engineer</td>
</tr>
<tr>
<td>E. Stacman</td>
<td>Electronics Engineer</td>
</tr>
<tr>
<td>H.P. Stilmaek</td>
<td>Computer Systems Administrator</td>
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<tr>
<td>J.H. Tsutsumi</td>
<td>Site Supervisor</td>
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<tr>
<td>M. Wagner</td>
<td>Electronics Technician</td>
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<tr>
<td>D.M. Walther</td>
<td>Telescope Systems Specialist</td>
</tr>
<tr>
<td>T. Wold</td>
<td>Telescope Systems Specialist</td>
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## Appendix E: Addresses

<table>
<thead>
<tr>
<th>Addresses</th>
<th>Telephones/Faxes</th>
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<tbody>
<tr>
<td>Joint Astronomy Centre</td>
<td>JAC telephone (day)</td>
</tr>
<tr>
<td>660 N. A’ohoku Place</td>
<td>JAC telephone (night)</td>
</tr>
<tr>
<td>University Park</td>
<td>JAC Senior Magmt Fax</td>
</tr>
<tr>
<td>Hilo</td>
<td>JAC General Fax</td>
</tr>
<tr>
<td>Hawaii 96720</td>
<td>Hale Pohaku JAC Office</td>
</tr>
<tr>
<td>USA</td>
<td>Hale Pohaku JAC Fax</td>
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<tr>
<td></td>
<td>UKIRT Fax</td>
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<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

email: user@jach.hawaii.edu
UKIRT home page: http://www.jach.hawaii.edu/UKIRT/home.html