4. AAO facilities

This chapter summarises existing instrumentation and research facilities at the AAO, and provides details on new instruments, computer developments and enhancements to existing instruments. It also outlines service provided to the user communities, such as service observing.

The AAT and UKST are the heart of the AAO. To maintain its position as a leading-edge research organisation, it is essential that these telescopes are equipped with state-of-the-art instrumentation and that a range of facilities for visiting astronomers is provided.

The instrumentation for the telescopes involves much more than the new instruments themselves; they must be fitted with the most sensitive electronic detectors for visible light and infrared radiation, have sophisticated computer systems for both control and data acquisition, and powerful software for on- and off-line data analysis. The AAO aims to provide astronomers with a complete system for the acquisition and analysis of astronomical data.

AAT facilities

Instruments available at the AAT as of mid-2000 are summarised in Table 4.1. Further information is available in the AAO Observer's Guide, in the relevant instrument manuals, in the AAO Newsletters, and on the AAO WWW pages.

Most instruments on the AAT are used by scientists as "common-user" facilities, which means that visiting observers make their own observations with backup support from Observatory staff. However, some highly specialised or infrequently used instruments are no longer fully supported by the AAO and therefore generally require an experienced user as one of the collaborators. This group of instruments includes LDSS++, Taurus II (without TTF), and IRIS. Instruments owned by other institutions are sometimes used on the telescope (e.g. UNSWIRF, and the Semel polarimeter) and may be available for collaborative projects.

Table 4.1 Instruments available on the AAT at 30 June 2000

Focus Equipment	Mode	Detector
Prime		
Spectrographs		
Two Degree Field (2dF) 400 fibre multi-object spectrograph facility	f/3.3	Two dedicated Tektronix 1K CCDs
Imaging		
Prime focus camera—triplet corrector, filter wheel, travelling blade shutter	direct f/3.3	Tektronix 1K CCD MITLL 4K × 2K CCDs
Cassegrain		
Imaging		
Auxiliary camera	f/8 or f/15	Tektronix 1K CCD
Infrared Equipment		
IRIS 128 × 128 format infrared camera and low-resolution spectrometer, with imaging, spectroscopic and polarimetry modes	f/15 or f/36	Rockwell HgCdTe array
Spectrographs		
RGO spectrograph, 25 and 82 cm cameras, spectro-polarimetry modes	f/8	Tektronix 1K CCD MITLL 4K × 2K CCDs
Wide-field imaging Fabry-Perot interferometer (Taurus II) with Tunable Filter (TTF), Wollaston prism polarising module	f/8 or f/15	Tektronix 1K CCD MITLL 4K × 2K CCDs
Low Dispersion Survey Spectrograph (LDSS++)	f/8	MITLL 4K × 2K CCDs
SPIRAL integral field unit, bench-mounted spectrograph	f/8	MITLL 4K × 2K CCDs

Facilities for visitors' own equipment

Coudé

Spectrographs

UCL échelle spectrograph, 70 cm camera (UCLES)	f/36	Tektronix 1K CCD MITLL 4K × 2K CCDs
Ultra-high resolution facility (UHRF)	f/36	Tektronix 1K CCD MITLL 4K × 2K CCD

Facilities for visitors' own equipment

UKST Facilities

The UKST operates in two modes: photography (for surveys and service observing), and as a common-user instrument for multi-object spectroscopy.

Photography

Photographic imaging can be carried out either in direct mode (in various wavebands from ultraviolet to near-infrared) or in slitless spectroscopic mode using one or both of the telescope's two full-aperture objective prisms. With the cessation of glass-plate production at Kodak, all new photographic work will be carried out on Kodak Tech Pan film. While there is only one (panchromatic) sensitisation, filters can be used to select U, B, V, R or Hα wavebands. Tech Pan film has better resolution and sensitivity than plates, and its astrometric stability is only marginally worse.

Multi-object spectroscopy

For almost a decade, multi-object spectroscopy has been carried out at the UKST using the FLAIR fibre-optics spectroscopy system, which allows up to 90 selected targets to be observed at one time. Early in the forthcoming reporting year, FLAIR will be replaced by 6dF, a fully-robotic fibre-positioning system that will allow up to 150 targets to be observed with rapid turn-round from one configuration to the next. The new system will be available both for survey and common-user non-survey spectroscopy.

CCD Imaging

The Peterson Camera for the UKST is an externally-funded project jointly managed by the ANU and the University of Tokyo. It will provide a mosaic CCD camera giving 4K × 4K x 15 μm pixel coverage over approximately one square degree. The camera will be operable in either staring or drift-scanning mode, and an upgrade to the telescope's control

system is in progress to facilitate this. The camera will be commissioned during the forthcoming reporting year and will become available for regular use shortly thereafter.

6dF

The 6dF facility for the UKST is a robotic fibre-positioner that will enable the existing FLAIR spectrograph to be used for multi-object spectroscopy on all-sky survey scales. Much faster fibre-reconfiguration times will be achieved than are possible with the current FLAIR system. 6dF also includes an upgrade to the spectrograph's CCD detector to allow the for the increase in the number of fibres and to enhance its sensitivity.

During 1999-2000 6dF passed its mechanical, electronic and software critical design reviews, and the hardware is now almost complete. The robot is nearing completion, while the two field-plate units are finished. These units are specific to 6dF, and will be interchangeable between the

Most of the fibre retractors assembled into the first field plate unit for 6dF

positioner (for fibre configuration) and telescope (for observing). They contain not only the field-plates themselves, but the 154 fibre retractors (for 150 science fibres and 4 guide fibres) and a rotation mechanism - all within the compass of a standard UKST plateholder.

The robotic control software for the instrument is well-advanced, and the off-line fibre-configuration software is almost complete. A pipeline data reduction system, 6dFdr, will be implemented early in 2001. The instrument itself is expected to be commissioned towards the end of 2000.

The new CCD system for 6dF has at its heart a Marconi CCD47-10 device with very high DQE and low read noise. Its 1K × 1K × 13.5 μm pixels are well-matched to the spectrograph. The new system will use a SDSU controller and ANU's CICADA software package. Work on the installation has been outsourced to the Research School of Astronomy and Astrophysics at ANU.

The principal function of 6dF will be to carry out hemispheric galaxy redshift and peculiar velocity surveys. These will be managed by the 6dF Science Advisory Group, which has already put into place the strategy for carrying out the surveys. The instrument will also be available for limited non-survey work.

The 2dF facility

The 2dF facility gives the AAT an unsurpassed (for a 4 metre or larger telescope) field-of-view at its prime focus, which is equipped with a state-of-the-art optical fibre system for multi-object spectroscopy of up to 400 objects simultaneously.

During the year 2dF has remained the most popular instrument on the telescope (Table 2.12) being scheduled for over one third of the available time. During a single night it is possible to observe over 3000 objects and reduce the data in real time as observing proceeds using the dedicated data reduction software.

The 2dF Galaxy Redshift Survey and the 2dF QSO Redshift Survey remain the heaviest users of the 2dF facility and have together observed over 120,000 galaxies and QSOs. In addition many other fields of astronomy are making dramatic use of the full capabilities of this unique facility. With 2dF in routine operation, effort is still being applied to develop 2dF to improve its performance and reliability.

AAO instrument scientist David Lee carefully adjusting the output slit of the SPIRAL instrument during commissioning.

SPIRAL

At the end of March 2000, the AAO successfully commissioned the new SPIRAL spectrograph for the AAT. SPIRAL provides the AAT with a new observing mode: Integral Field Sectroscopy (IFS). This is a technique which produces a spectrum for every spatial element in an extended two-dimensional field. A sophisticated microlens array containing 512 lenses is used to feed light from the telescope into optical fibres. The fibres then transfer the light from the telescope to the spectrograph. As the spectrograph is not attached directly to the telescope, it is very stable.

The performance of SPIRAL during commissioning was excellent. The total system throughput was measured at 14% in the *R*-band. This is double the efficiency of the AAT's older RGO spectrograph. SPIRAL operates over the wavelength range 450-1000 nm and provides spectral resolutions of up to 6000.

Although only recently commissioned, SPIRAL has already generated great interest in the astronomical community. SPIRAL will now be upgraded to common-user instrument status. There are also plans to build a new spectrograph for SPIRAL which will provide greater wavelength coverage, particularly in the blue, and even higher efficiency.

IRIS2

Design of the AAO's next generation infrared camera and spectrograph is now completed, and construction is nearing its all important commissioning phase. First light on the AAT for IRIS2 is expected before the end of 2000.

IRIS2 will completely replace the functionality of the AAO's existing infrared instrument, IRIS. In particular, it will feature a detector 64′ larger, with a corresponding ability to image much larger areas of the sky (7.7×7.7 arcminutes) at wavelengths between 0.9 and 2.5 microns. It will feature full spectroscopic capabilities as well, at resolutions of 1500-2500.

Lastly, it will have the unique ability to perform wide-field multi-object spectroscopy in the infrared. That is, with the provision of suitable masks, it can observe up to 100 objects in its field of view simultaneously. This feature will be unique in international astronomy.

RGO Spectrograph

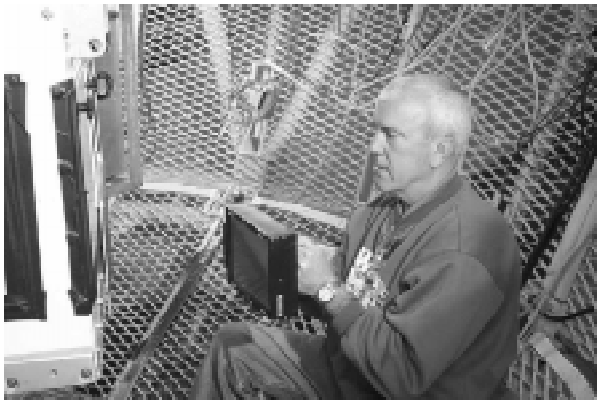
The RGO spectrograph continues to offer single and long slit spectroscopy with a range of special modes, such as time resolved observations, of rapidly varying objects and polarimetry. The use of the latest detec-

IRIS 2 shells undergoing first pump down and leak test. The fore dewar is clearly visible.

tors has once again increased the efficiency of the observations, and has enabled the decommissioning of FORS, the red spectrograph extension to the RGO. The RGO continues to be the preferred instrument for service projects, providing urgent observations, testing new proposals and completing older observing programs.

UCLES

The UCL échelle spectrograph is the most popular AAT instrument during the period of each month when the Moon is brightest. A total of 20 nights per year are set aside for a joint UK/Australian long-term program



Frank Freeman is at the Cassegrain focus of the telescope preparing the RGO spectrograph for observing, here seen changing the diffraction grating.

to search for planetary companions to nearby southern stars, by looking for the tiny, but regular perturbations induced by the motion of the planet around the parent star. Another regular program uses a special fibre-feed to UCLES and the technique of polarimetry to analyse the strength and long-term nature of magnetic fields in hot stars.

Like most AAT instruments, UCLES has benefited from the introduction of new, larger-format CCD detectors, which allows visiting observers to record virtually the entire optical spectrum of a star in just 2 exposures. The provision of an exposure time calculator on the WWW has allowed astronomers to better plan their observing runs, and work on improving and updating documentation continues.

UHRF

The Ultra-High Resolution Facility is an extension to the coudé échelle spectrograph, UCLES. It offers even higher resolution (up to one million) and is mostly used to study the gas between us and bright stars. In the past year, UHRF was found to have become misaligned, with a loss in efficiency. It has been realigned with modern techniques, and now has better throughput than when it was first commissioned in 1994. A new mode in UHRF, offering a lower intermediate resolution of 100,000 with a considerable increase in efficiency, has been fully tested and successfully used to observe detailed stellar line profiles.

LDSS++

Over recent years, upgrades have provided LDSS++ (the Low Dispersion Survey Spectrograph) with nod-and-shuffle capabilities for enhanced sky subtraction, and the use of Volume Phase Holography (VPH) gratings to improve transmission efficiency. As well as a single slit, LDSS++ can employ multi-slit masks to obtain up to 2000 spectra simultaneously. Interest in LDSS++ continues to grow and coming months will see it employed in a further search for extremely distant quasars, as well as undertake surveys of star formation in galaxy clusters and probe the kinematic properties of globular clusters in external galaxies.

External Project Activities at the AAO

Design and manufacture of instruments for other telescopes continues to represent a significant fraction of the business of the AAO. Projects currently active at the observatory are briefly discussed below.

- The OzPoz positioner contract to deliver to the European Southern Observatory (ESO) a fibre positioner for the Very Large Telescope (VLT) FLAMES facility had its Final Design Review (FDR) in October 1999. Analysis of the original exchanger design, as formulated at the Preliminary Design Review, did not satisfy ESO's stringent earthquake specifications and, as a result the mechanical de-

OzPoz Exchanger - revolver structure ready to machine

sign team produced an alternative, more robust, design which received general approval at the FDR. However the panel's conclusion was to postpone formal FDR closure until a detailed Finite Element Analysis on the new design had been completed. This together with several other issues, including a verification of the new gripper's performance, were resolved to ESO's satisfaction at a progress meeting in mid-March and formal FDR closure was subsequently announced.

- The FMOS project, a collaboration between various UK groups and the AAO, is geared to supplying a 400-fibre near-infrared spectrograph facility for the Japanese Subaru telescope's prime-focus. The conceptual design study is now complete and has involved AAO in several stages of prototyping of its Echidna positioner concept. Preparations for the next phase in the project are underway with Japan currently reviewing an AAO proposal for further design study work on the Echidna top-end to be complete by March 2001 with preliminary costings for completion of the work in early 2004.

- The large SPIRAL Integral Field Unit for the AAT was successfully commissioned in late March 2000. Assistance in the SPIRAL work was supplied by the SOAR (Southern Observatory for Astrophysical Research) consortium, with the result that a clone of SPIRAL for SOAR has now been completed.

- The GIRMOS cryogenic fibre development study has been modified recently by Gemini's development of Multi-Conjugate Adaptive Optics (MCAO) technology, and its realisation that the desire for wide-field, near-infrared multi-slit spectroscopy will be largely satisfied through the development of a classical IR-MOS spectrograph/imager. Good progress has been made in evaluating infrared fibre performance and on cryogenic fibre tests. Work is now

focussing on mechanical designs of deployment schemes for multiple Integral Field Units.

- The concept design for a fast-track infrared spectrograph for Gemini (IRIS-2Gg) was successfully completed in May 2000. Unfortunately Gemini favoured a competing design from the University of Florida (FLAMINGES II) principally on the basis of the larger field-of-view offered.

- The OSIRIS contract to develop concepts for an optical imager/TTF/spectrograph for the Spanish Gran Telescopio Canarias, was completed in December 1999.

Enhancements to existing instruments

CCDs

The AAO continues to offer to observers its large format 4096 × 2048 pixel MITLL2A and MITLL3 devices, which were devloped out of the Observatory's involvement in the Massachusetts Institute of Technology / Lincoln Laboratories CCD Consortium. A further four devices from the AAO's share of this consortium, together with four devices from the Research School of Astronomy and Astrophysics' share have been installed into the Wide Field Imager, which will be commissioned in August/September 2000.

The AAO also continues to offer its Tektronix and Thomson 1024 × 1024 pixel detectors to observers. A further large format 4096 × 2048 pixel CCD has been obtained from the EEV Corporation, offering considerably improved performance at blue wavelengths over the MITLL devices. It is hoped to commission this device for general use in late 2000/early 2001.

Prime Focus Upgrade / Wide Field Imager

Imaging facilities at the prime focus of the AAT have been considerably improved with the implementation of the Prime Focus Upgrade (PFU). This removes the requirement for prime focus imaging programs to have an observer riding in the prime focus cage, by providing an automatic filter wheel and shutter. It also provides a large mounting location for the Wide Field Imager (WFI).

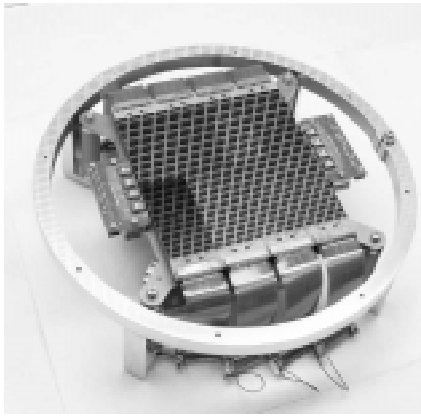
WFI is a mosaic of eight 4096 × 2048 MITLL CCDs installed in a single dewar cooled by liquid nitrogen. Together these CCDs provide a single 8192 × 8192 pixel imaging capability for the AAT, with a field of view

Neville Hopkins preparing a lathe in the mechanical workshop while working on the Prime Focus Unit

of 0.5 degrees × 0.5 degrees. Construction of WFI has been a collaboration between the AAO, the Research School of Astronomy and Astrophysics, the University of Melbourne, and Auspace. WFI will be used on both the AAT and the RSAA's 1 m telescope also located on Siding Spring (with the AAT having "aperture priority" in scheduling). It will see first operations in August and will be available to all observers thereafter.

MAPPIT

The MAPPIT instrumentation, located in the west coudé room, is used for interferometric imaging, and attains the true diffraction-limited resolution of the telescope. The highlight of the past year was the successful commissioning in January 2000 of the MAPPIT 2 mode, in which a Shack-Hartmann wavefront sensor is used in conjunction with the interferometer. Knowledge of the wavefront perturbations then enables the interferometric data to be corrected for the effects of atmospheric turbulence. Compared with the usual method of data treatment for optical interferometers, this results in enhanced sensitivity, particularly for objects which are well resolved. Both the wavefront sensor and the interferometer require a CCD detector operating with fast sampling, and the two must be exactly synchronised. The two Thomson CCD systems were used, with readout times of 10 ms and 100% duty cycle. The master/slave system for synchronised operation of the two CCDs worked perfectly during the entire run. The weather was not ideal, but sufficient data was obtained to commission the system successfully.



The eight CCD focal plane of WFI prior to its installation in the WFI dewar. These eight CCDs will provide a digital field of view 33 arcminutes on a side at the AAT prime focus.

New Cassegrain Acquisition Camera

As the first stage of an overhaul and upgrade of the Cassegrain Acquisition and Guiding (A&G) unit, the Quantex intensified TV camera used for acquiring and guiding on astronomical targets has been replaced by a commercial CCD camera made by Apogee Inc. The CCD system is based on an engineering grade SITe 1K chip which is thermoelectrically cooled to around -30 degrees C. It provides a field of 2.7 arcminutes square with pixels 0.16 arcseconds. It is usually used binned by 3 for acquisition, which provides a readout time of less than 6 seconds.

Compared to the Quantex, the CCD offers significantly higher quantum efficiency and better red response, leading to better operations in bright moonlight and an overall improvement in limiting magnitude. Future development of this system will include writing software to control the camera which will be "telescope aware", thus allowing point-to-acquire operation as well as autoguiding.

Other facilities

Computing facilities

The Observatory has a program of information technology enhancements and upgrades to keep both telescopes operating as front-line facilities. State-of-the art computing facilities for instrument control, data acquisition and data reduction, at both Siding Spring and Epping, are vital components of the infrastructure of the Observatory.

A number of old Unix systems were upgraded, including the Observatory's main Web Server and desktop systems used by astronomers. The storage capacity of the main disk server systems was increased and several old network components were replaced with faster technology. Various personal computers including servers, desktop systems, and

notebook computers were acquired and upgraded to provide all members of staff with access to the internal Web and e-mail systems.

Software

The software group develops the specialised software needed by instruments such as 2dF and IRIS2. In the past year, the major part of the software group effort has been directed to the software required for IRIS2 and the new CCD controller project. This effort is proceeding well, and most of the software data chain has been run in simulation mode. Testing of communications with the controller will commence in late 2000.

The software group has also been implementing software for the 6dF project. The software for this project is being based on existing 2dF robotics software and this project is nearing the testing stages. The software group also provides support, technology transfer and some other effort for AAO external projects.

The software group continues to maintain the now mature DRAMA software that underpins the 2dF, IRIS2 and 6dF systems. It also provides occasional support for other observatories such as those on La Palma and Hawaii that are using DRAMA itself, and for Gemini, which is using some of the DRAMA sub-systems. The use of DRAMA by outside users imposes some effort on the AAO but is rewarded by the new ideas that flow back to the AAO. The AAO charges for the support services provided to recover the costs involved.

Robert Dean debugs a new Sun workstation for use in the PFU

Library

The AAO Library holds one of the largest astronomical collections in Australia and, together with the libraries of the ANU's Research School of Astronomy and Astrophysics and CSIRO's Division of Telecommunications and Industrial Physics, provides an essential facility for the astronomical community. The monograph collection is now searchable via the library's Web page. Electronic databases and online search facilities are kept up-to-date, and ensure that the library is part of an international network of specialist astronomical libraries.

Data archive

The AAO maintains a complete archive of data obtained with the AAT. The digital data are stored on CD-ROM and are available after a 2 year proprietary period via a Web-based index database. We also maintain databases of the observing logs, fault logs and daily diary. We receive regular requests for these data, with the equivalent of months of observing requested each year, thus substantially increasing the efficiency of the telescope. Data from 2dF are being processed using the pipeline software, and are available for direct access via the Web after their proprietary period expires, ensuring the optimal use of these data.

Service Observing

The Anglo-Australian Observatory operates a service observing program at the AAT for projects that require up to three hours of observing time. Service time is normally allocated for programs that require a small amount of data to complete a project, look at individual targets of interest or try out new observing techniques. All service proposals are refereed by a 3-member panel and are graded on the basis of scientific merit, with those accepted into the service program remaining active for one year. Application forms for service time are submitted electronically to the AAO.

During 1999-00 there were some changes to the service program. Following the appointment of the UK 2dF Fellow, all PATT 2dF time is observed in service mode and 2dF service observations are directly incorporated into the PATT allocation. 2dF service nights are still allocated by ATAC. The service program has been extended to include spectropolarimetry with the RGO spectrograph.

Between June 1999 and May 2000, 61 proposals were accepted into the service program. Of these, one third were for the RGO spectrograph, which remains the most popular service instrument. A total of 19.5 nights were allocated for service observations during Semesters 99B and 00A. These nights were distributed across all the AAT instruments and observations were obtained for more than 30% of the service proposals submitted over the same period.

Students

The AAO continues to support a vacation student programme for Australian and UK undergraduate students. This scheme offers students with at least two years of undergraduate experience an opportunity to take part in a 10-12 week research programme development supervised by an AAO staff member. There were seven undergraduate students employed during the year: Blair Conn, Kevin Covey, Clive Dickinson, Catherine Heymans, Davienne Monbleau, David Nicholas and Imma Wormleaton. The student programme now caters for students who want experience in instrument development. This year, six students did astronomical research, and one student did experimental work. The students visited either the radio telescopes at Narrabri or the optical telescopes at Siding Spring.

In addition, AAO scientific staff co-supervise PhD students at other Australian universities. Dr Brian Boyle supervises two students: Michael Brown (University of Melbourne) is working on galaxy clustering in the Panoramic Deep Field; and Diana Londish (University of Sydney) is studying BL Lacs in the 2dF QSO redshift survey.

Dr Karl Glazebrook assisted in the supervision of Kathryn Deeley (University of New South Wales) whose research involves a study of post-starburst galaxies in the 2dF Redshift Survey. Dr Bland-Hawthorn supervises Sonia Cianci (University of Sydney) who has worked on the design and manufacture of multi-band interference filters for astronomical use. This technique has been used with the TTF to undertake multi-line images of spiral galaxies. Dr Bland-Hawthorn also assists in the supervision of Mary Putman (RSAA/ATNF) who is using Taurus II to look for Hα emission from high velocity clouds.

Visiting scientists

The AAO also runs a modest visiting scientist program which aims to attract scientists to work at the AAO for an extended period. A list of the scientists who visited the AAO during 1999-2000 is at Appendix C.