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 services 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 equiped 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-taking, 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.

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AAT facilities

Instruments available at the AAT in mid-1999 are summarised in table 4.1. Further information is available in the AAO Observer's Guide, in the relevant instrument user 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 observers make their own observations with backup support from Observatory staff. However, some highly specialised but 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 FOCAP, LDSS and Taurus II. Instruments owned by other institutions are sometimes used on the telescope and may be available for collaborative projects.

Table 4.1 Instruments available on the AAT at 30 June 1999

Focus Equipment	Mode	Detector
Prime		
Two Degree Field (2dF) 400 fibre multi-object spectrograph facility	f/3.3	Two dedicated Tektronix 1K CCDs
Prime focus camera—aspheric plate, doublet and triplet correctors, sub-beam prism	direct f/3.3	Tek thinned CCD Range of types of sensitised photographic plates 254 × 254 mm
Cassegrain		
Imaging		
Auxiliary camera	f/8 or f/15	Thomson or Tek 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
3D Integral Field Spectrograph made available under agreement with MPIE	f/15	Rockwell HgCdTe array
Spectrographs		
RGO spectrograph, 25 and 82 cm cameras, spectro-polarimetry modes	f/8	Tektronix 1 K CCD, MITLL 2K × 4K CCD and other CCDs
Faint object red spectrograph (FORS), sharing slit of RGO spectrograph and optional dichroic beam splitter	f/8	GEC CCD
Wide-field imaging Fabry-Perot interferometer (Taurus II) with tunable filter (TTF), Wollaston prism polarising module	f/8 or f/15	Tektronix 1K CCD and MITLL 2K × 4K CCD
Low dispersion survey spectrograph (LDSS^{++})	f/8	Tektronix 1K CCD and MITLL 2K × 4K CCD
Auxillary focus narrow field imaging	f/8 or f/15	Tektronix 1K CCD and MITLL 2K × 4K CCD
Facilities for visitors' own equipment		
Coudé		
UCL echelle spectrograph, 70 cm camera (UCLES)	f/36	Tektronix 1K CCD and MITLL 2K × 4K CCD
Ultra-high resolution facility (UHRF)	f/36	Tektronix 1K CCD and MITLL 2K × 4K 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 with the FLAIR fibre spectroscopy system.

There are two basic photographic options at the UKST:

direct imaging of the sky in different wavebands from ultraviolet to infrared, selected by the appropriate choice of photographic emulsion and filter;

slitless low dispersion spectroscopy through thin, full-aperture objective prisms.

Photography has traditionally been carried out on glass plates. However, because of superior performance, Kodak Tech Pan film is now used for most non-survey observations. Film is available in only one spectral sensitisation, but is panchromatic and is used for U-, V-, R- or hydrogen-alpha band exposures.

The second mode of operation on the UKST is higher dispersion multi-object spectroscopy with the fibre-optic FLAIR system, which uses optical fibres to feed the light from 90 individual selected targets to a bench spectrograph and CCD camera.

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 being scheduled almost one third of the available time. Due to the increased reliability and speed of the fibre positioning system, it has proved possible to observe well over 3000 objects during a single night.

The 2dF Galaxy Redshift Survey being undertaken with the 2dF facility is now the largest of its kind (almost a factor of two larger than the Las Campanas Redshift Survey). In addition many other fields of astronomy are making dramatic use of the full capabilities of this unique facility.

While the construction of 2dF has drawn to a close, new ideas are already being generated for novel uses of the 2dF facility. In particular new techniques are being developed for sky subtraction with fibres to achieve results at faint magnitudes previously only accessible with multi-slit spectroscopy.

Taurus tunable filter

TTF continues to find widespread use on the AAT for both imaging of nebular sources and for identifying emission or absorption line objects over a wide field.

The overall throughput of Taurus is now very well calibrated. With the use of MITLL2 (blue) and MITLL3 (red) CCDs, the total system efficiency (telescope + Taurus + CCD) is 25 percent (35 percent) in *B*, 28 percent (42 percent) in *V*, 34 percent (48 percent) in *R* and 30 percent (42 percent) in *I*. The numbers in brackets reflect the expected improvement if we were to recoat the optics with sol gels applied directly to the MgF_2 layer, a proposal actively under investigation.

The blue and red 'arms' of the TTF are fully commissioned allowing for broad or narrow band imaging over the 370–1100 nm range. Low resolution (R < 300) spectroscopic imaging is possible with conventional broadband (R≈5) blocking filters (e.g. *UBVRIz*). High resolution imaging requires special blocking filters. The red TTF has a complete set of R≈20 order blockers for spectral regions free of atmospheric bandheads. This strategic choice has paid off in that a very dark sky in a narrow band benefits many science programmes. The blue TTF has a limited set of order blockers for high resolution work, although the WHT UES order-sorting filters have helped to make up this deficiency.

IRIS2

Design and construction of the AAO's next generation infrared camera and spectrograph IRIS2, continues apace. On-telescope commissioning of this instrument is expected in the second quarter of 2000, with shared risks observations for scheduled observers being possible in the third quarter of that year.

IRIS2 will replace and considerably expand the functionality of the AAO's current infrared camera and spectrograph, IRIS. In particular, it will feature a detector, 64 times larger than IRIS, with a corresponding ability to image much larger areas of the sky (7.7 × 7.7 arcminutes) at the *Z, J, H* and *K* passbands, as well as at a range of narrow passbands centered on astrophysically-interesting emission lines. It will also feature spectroscopic capabilities at a resolution of 1500, and hopefully of up to 3000.

Lastly, it will feature a limited ability to carry out multi-object spectroscopy with up to two pre-punched aperture masks.

Upgrade paths foreseen, and allowed for in the current design, of this instrument include: a jukebox for the exchange of up to ten aperture masks; integral polarimetric functions; a bare fibre and lenslet integral field unit; an upgrade to a 2048 × 2048 pixel detector; and the provision of rapid tip-tilt image correction.

6dF

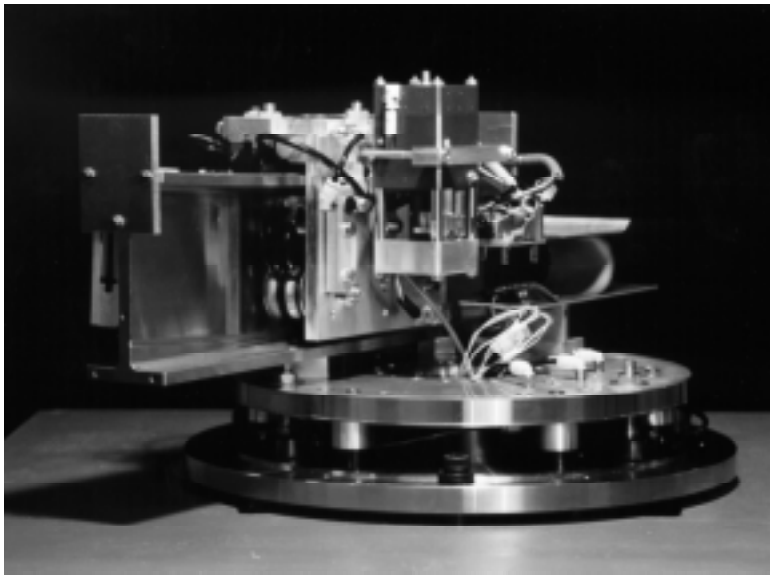
The 6dF facility for the Schmidt Telescope is a robotic fibre-positioner that will enable the existing FLAIR spectrograph to be used for multi-object spectroscopy on survey scales. It will achieve much faster fibre reconfiguration times than are possible with the current FLAIR system.

A number of milestones have been passed during the reporting year. In May 1999, critical design reviews (CDR) were held for the mechanical and electronic design of 6dF, both with satisfactory outcomes. A software CDR will follow late in 1999.

Fabrication work on the air-bearing (r, theta) and gripper mechanisms continues, and components are now being manufactured for the field-plate units. These units are specific to 6dF, and will be interchangeable between the positioner (for fibre configuration) and telescope (for observing). They contain not only the field-plates themselves, but the 154 fibre retractors and a rotation mechanism—all within the compass of a standard Schmidt plateholder.

The instrument will now only have two field-plate units, not three, because of budget pressures. This reduction will have minimal impact on survey operations. On the other hand, significant gains will be made if a proposal to replace the existing CCD chip is implemented, as recommended by ACIAAT at its last meeting. The instrument is still on track for a commissioning phase starting at the end of 2000.

The principal function of 6dF will be to carry out hemispheric galaxy redshift and peculiar velocity surveys, and an external Science Advisory Group has been set up to plan and oversee these activities.



The r, theta arm of the 6dF.

External Projects

External Projects activities at the AAO continue to grow and now clearly represent a significant fraction of the business of the Observatory.

OzPoz (Fibre positioner for the VLT)

The OzPoz project has successfully passed its Preliminary Design Review held in Garching during April. The team is now fully engaged in the final design phase with the Final Design Review scheduled for October 1999. The positioner is scheduled for delivery to the Very Large Telescope's Unit 2 telescope by mid-2001.

FMOS

The FMOS consortium (members from AAO, UNSW, Oxford, Durham, IoA and RGO) have been commisssioned to perform a Concept Design Study for a wide-field, optical/NIR multi-fibre system for Subaru's prime-focus. The AAO was originally to concentrate on just positioner issues but also took on the task of managing and refining the design of a new prime-focus corrector for Subaru for use in the 0.37 to 1.8-m range.

Given severe space constraints at Subaru's f/2 prime focus, a completely new positioner concept (the Echidna) was created. Sufficient interest was generated by the Echidna that AAO has now entered a new contract to proto-type an Echidna spine using tiny motors.

Gemini contracts

IR-MOS development study The AAO has been commissioned to produce a design study for fibre-based integral-field units for use with the next generation of Gemini infra-red spectrographs. The work is scheduled for a 15 month period beginning in May 1999.

IRIS2-g This is a proposal to build an infrared camera and spectrograph for Gemini based on the AAO's IRIS2 instrument. A Concept Design Study is being undertaken.

Enhancements to existing instruments

LDSS^{++}

The project to upgrade the performance of LDSS, originally conceived in November 1997, was completed in less than a year, and LDSS^{++} was commissioned in October. The key development was the use of charge shuffling (on the CCD) for sky subtraction. This allows the use of small apertures ('microslits') rather than long slits, resulting in a factor of ten gain in multiplex advantage (from twenty to two-three hundred or more objects) for this survey instrument. Some specialised modes offer up to 1000–2000 objects simultaneously. The upgrade also included new technology gratings — Volume Phase Holographic (VPH) gratings — which give much greater transmission efficiency.

As well, a new MITLL deep depletion CCD was commissioned, giving an increase in performance by factor of two in the red, compared with the old Tek chip.

LDSS^{++} was used to measure redshifts in the Southern Hubble Deep Field during commissioning. Redshifts for galaxies as faint as R=23.9 were secured, setting a new record for faintness for AAT galaxy redshifts.

In the last few years, LDSS has been used typically for only one or two projects per semester. The upgrade has sparked a new interest in deep high-redshift spectroscopy, and six projects will use LDSS^{++} in semester 1999B.

Charge shuffling

The AAO has continued its development of CCD charge shuffling to work with a wider range of instruments than TTF, and to operate in concert with certain telescope tasks. An important development is charge shuffling coupled to telescope nodding, to be used with Taurus, LDSS^{++} and the RGO spectrograph. Thus, it is now possible to observe two widely spaced pointings on the sky many times within a single shuffle exposure, to allow for greatly improved sky subtraction.

The telescope nods between the two pointings while separate images are built up side-by-side on the detector. Charge shuffling has been a key component of TTF observing, particularly with observations which switch between several frequencies. Charge shuffling will soon assist other actions, in particular, telescope focus, camera focus and rotating plates within a polarimeter module.

Prime Focus Upgrade/Wide Field Imager

The Prime Focus Upgrade (PFU) will provide upgraded mounting facilities at the AAT's *f*/3.3 prime focus for both AAO and visiting detectors. In particular, it will provide a large automated filter wheel and shutter capable of serving detectors of a size up to 165 × 165 mm. PFU is expected to be commissioned in the first quarter of 2000.

The size of focal plane PFU will cover has been specifically geared to that provided by the Wide Field Imager (WFI) instrument being constructed jointly by the AAO, the Research School of Astronomy & Astrophysics (RSAA) of the Australian National University, and the School of Physics of the University of Melbourne. This project will deliver a mosaic of 2048 × 4096 pixel Lincoln Laboratory CCDs in a 4 × 2 format, to provide total sky coverage of 30 × 30 arcminutes in 8192 × 8192 pixels. This will represent a dramatic increase in the imaging power of the AAT, and make possible a huge range of scientific survey projects, previously inaccessible to Australian and UK astronomers.

CCDs

The AAO has continued to commission devices from the Massachusetts Institute of Technology/Lincoln Laboratories (MITLL) CCD consortium which has been brokered by the University of Hawaii. These MITLL devices have 2048 × 4096 15 micrometre pixels. The MITLL2 device commissioned in October 1997 is now the AAO's most popular detector. In October 1998, the AAO commissioned the MITLL3 device — the first science grade detector from this consortium, and one having superior red and infrared performance.

CCDs from the EEV corporation (purchased in a partnership brokered through the now defunct Royal Greenwich Observatory) have been delivered to the AAO, and are planned for commissioning late in 1999. These devices will deliver to observers, similar sized detectors to the MITLL devices, but with significantly improved blue sensitivity.

FLAIR Interim Upgrade

Interim improvements to the FLAIR multi-fibre spectroscopy system on the Schmidt Telescope have been completed. Both fibre plateholders are now equipped with magnetic buttons, and remote control of the spectrograph has been fully implemented

MAPPIT

The MAPPIT interferometer, located in the west coudé room, is used for high-resolution imaging. A recent result was the demonstration that beta Centauri, one of the stars that form the 'pointers' to the Southern Cross, is a close binary. With a separation of 0.015 arcseconds at the time of observation, this is probably the closest binary that has been definitively resolved by any single-aperture telescope.

MAPPIT is also able to operate in two wavelength-dispersed modes, one of which gives the angular diameter of a star as a function of wavelength. The MAPPIT team is currently analysing such observations of the southern giant R Doradus; the variations with wavelength can be compared with the predictions of model atmospheres. This star has the largest apparent angular size of any known star (other than the sun), as demonstrated by previous MAPPIT observations.

The instrumentation is now being upgraded to form MAPPIT 2, which will include a wavefront sensor working in synchronism with the detector on the interferometer channel. Using special high-speed configurations, both CCDs can be read out with 10 ms periods and 100 percent duty cycle. The addition of wavefront sensor data will produce higher precision observations, and allow observation of fainter and more complex objects. The commissioning of the full system is now scheduled for January 2000.

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. During the year, after extensive consultation with users, the Observatory developed an information technology strategic plan. This plan will be in place until 2001/02.

The two main Unix systems at Siding Spring and Epping used for disk and email serving were upgraded. Faster computers with more memory and additional disk space replaced machines that were several years old. Further improvements were made to the network infrastructure at both sites.

The Observatory's presentation facilities were upgraded with the purchase of colour projection systems and colour laser printers for Siding Spring and Epping. A number of notebook computers were procured for astronomers and support staff at both sites to enhance productivity.

Software

The software group develops the specialized software needed by new instruments such as 2dF and IRIS2.

2dF has dominated the software group for some time but has now moved into the AAO's commissioned instrumentation suite. Only limited debugging and development work is ongoing. The major part of the software group effort is now directed to the software required for the IRIS2 and new CCD controller project. We have also embarked on the software for the 6dF project for the Schmidt telescope. The software for this project is being based on existing 2dF robotics software. Various smaller projects have been completed or are underway.

Additionally, the internal software group is providing support, technology transfer and some other effort for AAO external projects.

The group has recently completed year 2000 compliance tests on front-line instrumentation software and is confident that no related problems will be encountered.

The group continues to maintain the now mature DRAMA software that underpins the 2dF system and will also underpin most of our new software. 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. A DRAMA-based system using an AAO-developed DRAMA telescope control task is now being commissioned on the James Clerk Maxwell Telescope in Hawaii and is being investigated for use by the United Kingdom Infrared Telescope, also in Hawaii. 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 also charges for some of the support services provided to recover the costs involved.

Support facilities

The AAO maintains comprehensive facilities to enable visitors and staff to prepare for observations and to analyse their data. There is a plate library in the Schmidt building and chart rooms in the AAT dome and at Epping, all with facilities for the inspection, measurement and photography of sky survey and other material. A quarterly newsletter is also produced and distributed. The AAO also offers astronomers access to digitised sky survey data either in the form of CD-ROMs or from the COSMOS and APM databases available on the www.

Library

The AAO library holds one of the largest astronomical collections in Australia and, together with the libraries of MSSSO and Radiophysics Laboratory/ATNF at CSIRO, 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 at the telescope and at Epping, and are available for use by the astronomical community after a proprietary period of 2 years. An index to the archive is available via the world wide web. This index is now complete back to January 1993, with some older data still to be transferred to CD-ROM and entered in the database. The accompanying observing logs are now also available via the web. We receive regular requests for data from the archive, and in 1998 the equivalent of six months of observations were requested, significantly increasing the efficiency of the telescope. Photographic plates taken with the AAT and UKST are also archived and available on request.

Other AAO programs

Service Observing

The Anglo-Australian Observatory operates a service observing program at the Anglo-Australian Telescope (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, to look at individual targets of interest or try out new observing techniques. All service proposals are refereed by a three-member panel and are graded on the basis of scientific merit, with those accepted into the service program remaining active for one year. Full information is available on the World Wide Web and the application forms for service time are submitted electronically to the AAO.

In June 1998, 2dF was added to the suite of instruments available for service observations, and four 2dF service nights were allocated during Semesters 98B and 99A. These proved extremely successful and of the fourteen 2dF proposals accepted, six have already been completed.

During the past year, a total of 22 service nights were allocated on the AAT and 88 proposals were accepted into the service program. Of these, approximately one third were for the RGO spectrograph and one quarter have been completed. Service observations were obtained using the RGO spectrograph, Taurus II/TTF, UCLES, 2dF and CCD prime focus imaging.

Students

The AAO continues to support a vacation student program for Australian and UK undergraduate students. These schemes give students entering their final undergraduate year an opportunity to take part in a ten-week research program supervised by an AAO staff member. There were five undergraduate students employed during the year: Ziming Tu, Simon Beer, Robert Sharp, Celine Peroux and Andrew Tolley. The students visited either the radio telescopes at Narrabri or the optical telescopes at Siding Spring.

In addition, many AAO scientific staff co-supervise PhD students at other Australian Universities. Dr Brian Boyle currently supervises Michael Brown from the University of Melbourne, who is working on data obtained from the digital stacking of UK Schmidt photographic plates using SuperCosmos. Dr Karl Glazebrook supervises Kathryn Deeley from the University of New South Wales whose research involves a study of post-starburst galaxies in the 2dF redshift survey.

D H Jones (MSSSO), supervised by Dr Joss Bland-Hawthorn, has now completed his study of the TTF Field Galaxy Survey. S Cianci (Sydney), also supervised by Dr Bland-Hawthorn, has begun the design and manufacture of a new generation of interference coatings for astronomical use. Dr Bland-Hawthorn assists in the supervision of M E Putman (MSSSO) who is using Taurus II to look for H-alpha emission from high velocity clouds.