Anglo-Australian Observatory

Annual Report

of the Anglo-Australian Telescope Board

1 July 1999 to 30 June 2000

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COVER: A digital image of the Antennae galaxies (NGC4038-39) made by combining three images from the Tek2 CCD on the AAT (Steve Lee and David Malin). A new wide field CCD Imager (WFI) will come into use in 2000 and will enable many more images like this to be made.

COVER DESIGN: Encore International

COMPUTER TYPESET AT THE: Anglo-Australian Observatory

The Right Honourable Stephen Byers, MP,
President of the Board of Trade and Secretary of State for Trade and Industry, Government of the United Kingdom of Great Britain and Northern Ireland

The Honourable Dr David Kemp, MP,
Minister for Education, Training and Youth Affairs
Government of the Commonwealth of Australia

In accordance with Article 8 of the Agreement between the Australian Government and the Government of the United Kingdom to provide for the establishment and operation of an optical telescope at Siding Spring Mountain in the state of New South Wales, I present herewith a report by the Anglo-Australian Telescope Board for the year from 1 July 1999 to 30 June 2000. The report summarises the operations of the Board for the period under review and includes financial statements and statements of estimated expenditure in accordance with the provisions of the Agreement.

J R Mould
Chair
Anglo-Australian Telescope Board
7 November 2000

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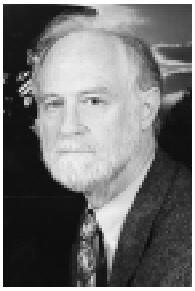
Anglo-Australian Telescope Board

Australia

Chair
Prof. J R Mould
Director, Research School of Astronomy and Astrophysics, Australian National University

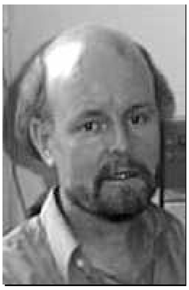


Prof. R D Ekers
Director, Australia Telescope National Facility

Prof. V R Sara
Chair, Australian Research Council

United Kingdom

Deputy Chair
Prof. J A Peacock
Professor of Cosmology, University of Edinburgh



Prof. M J Barlow
Professor of Astrophysics, University College, London

Dr I F Corbett
Director Science and Deputy Chief Executive, Particle Physics and Astronomy Research Council

Anglo-Australian Observatory

Prof. B J Boyle
Director, AAO

Scientific highlights

2dF Redshift surveys

The large galaxy and quasar redshift surveys currently being carried out with the 2-degree field both passed major milestones during the past year. The galaxy survey passed the 100000th redshift mark while the quasar survey exceeded 10000 redshifts. This makes the surveys respectively 4 times and 10 times larger than the previous largest galaxy and quasar redshift surveys. Indeed, the 2dF quasar survey has now found more quasars in 18 months than in the previous 37 years since quasars were first discovered.

Star formation in the distant Universe

LDSS++ observations of distant galaxy clusters have shown that the formation of stars is strongly suppressed in the cluster environment. Star formation rates in galaxies belonging to the cluster AC114 at a distance of 3 billion light years from our own Milky Way galaxy, are over a factor of ten lower than field galaxies at similar distances. This result has significant implications for our understanding of galaxy formation and evolution.

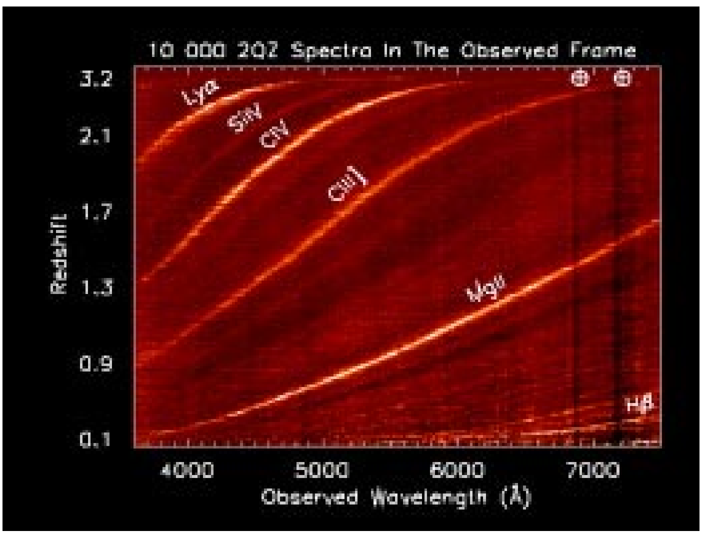


Image of 10000 QSO spectra observed to date in the 2dF redshift survey. The spectra are ordered according to increasing redshift and the effects of redshift on the bright QSO emission lines (labelled) can be clearly seen. (Courtesy: R.J.Smith and the 2QZ survey team)

Planet Search

The AAO Planet Search has successfully demonstrated its ability to measure velocities to a precision of 3 metres per second. It has now reached a stage where excellent planetary candidates are turning up; including a likely planet around a bright nearby star and possibly the first brown dwarf orbiting a star very much like our own sun.

Other highlights

A Fly-Through of the Universe

In collaboration with Swinburne University's Centre for Astrophysics and Supercomputing, the AAO released a visualisation of the 2dF Galaxy Redshift Survey: "A Flight Through the Universe". The visualisation takes the viewer on a cosmic trip through the redshift survey regions, providing a unique 3-dimensional view of the large-scale structure of the Universe as revealed by the 100000 galaxies observed to date in the 2dF galaxy redshift survey. An updated version with full commentary will soon be released to public observatories, planetaria and other organisations dedicated to scientific outreach. The visualisation is available for download from the AAO's WWW site, and from www.swin.edu.au/astronomy.

A still from *A flight through the Universe,* the movie of the 2dF galaxy redshift survey made in collaboration with Swinburne University's Department of Astrophysics and Supercomputing and the 2dF galaxy redshift survey team

AAO Instrumentation

During the year, the AAO successfully commissioned a large number of new facilities at the AAT. These include the SPIRAL integral field unit, the prime focus unit, the MAPPIT2 interferometer, oil cooling and a new CCD camera for the acquisition and guidance unit. In addition, the AAO successfully concluded a number of design studies for external clients including the OSIRIS spectrograph (Grantecan), Echidna positioner (Subaru), an integral field unit prototype (SOAR) and infrared multi-object spectrograph (Gemini).

25th Anniversary Celebrations

In October 1999, the AAO hosted a special weekend at Coonabarabran for members of the original AAT project team and those involved in the AAO throughout its illustrious 25-year history. The weekend was a tremendous success and all staff (past and present) found it a valuable opportunity to catch up with old friends and colleagues. Members of the original project team were delighted to discover that the telescope they put in so much hard work to create was still very much in the vanguard of world astronomy.

1. About the Anglo-Australian Observatory

Statement of purpose

The Anglo-Australian Observatory provides world-class optical and infrared observing facilities for British and Australian astronomers to ensure the best possible science. It also takes a leading role in the formulation of long-term plans and strategies for astronomy in both countries and, through its research and development of new instrumentation, to the advance of astronomy internationally.

History and governing legislation

The Anglo-Australian Telescope Board is an independent, bi-national authority funded equally by the Governments of Australia and the United Kingdom. The Board operates under *The Anglo-Australian Telescope Agreement* which came into operation in February 1971 for an initial period of 25 years. If either Government wishes to withdraw from the Agreement after this period it must give five years notice. So far, neither party has done so, and both have indicated their support for the AATB for the foreseeable future.

The Board's facilities consist of the 3.9-metre Anglo-Australian Telescope (AAT) and the 1.2-metre UK Schmidt Telescope (UKST) on Siding Spring Mountain, outside Coonabarabran, NSW, and a laboratory in the Sydney suburb of Epping. Collectively, these are known as the Anglo-Australian Observatory (AAO).

Ministers responsible

The Minister responsible for the AAT Board in the United Kingdom is The Right Hon. Stephen Byers, MP, as President of the Board of Trade and Secretary of State for Trade and Industry. The Minister responsible in Australia is The Hon. Dr David Kemp, MP, Minister for Education, Training and Youth Affairs.

Designated agencies

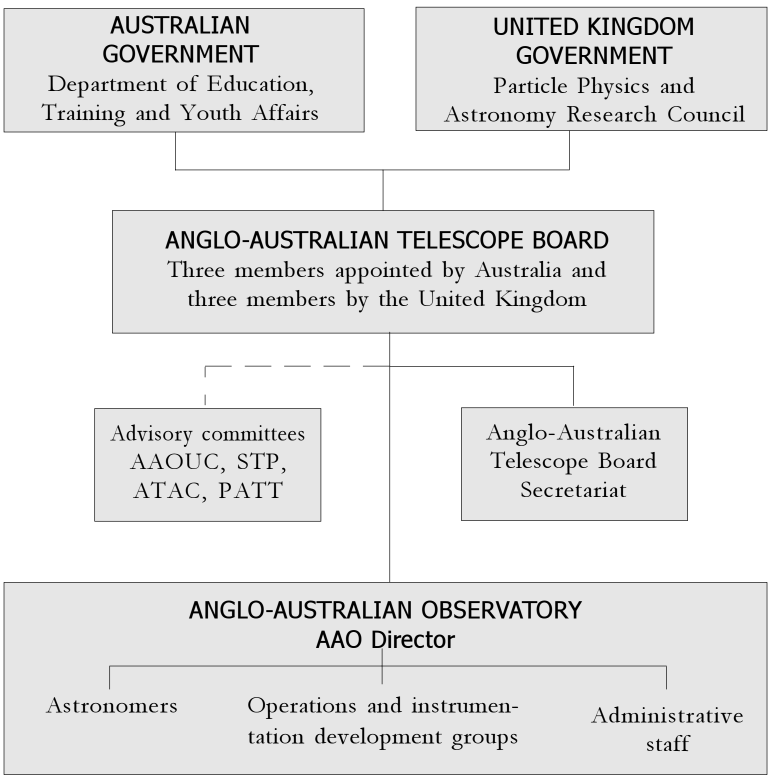
Pursuant to Article 1(2) of the Anglo-Australian Telescope Agreement, each Government acts through an agency designated for the purpose. These Designated Agencies are the Australian Department of Education, Training and Youth Affairs (DETYA) and the Particle Physics and Astronomy Research Council (PPARC) of the United Kingdom. These agencies are jointly responsible for implementing the Agreement.

Structure of the AAO

The AAT Board oversees the operations of the Anglo-Australian Observatory, as Figure 1.1 shows. Apart from an active research group, the Observatory has internationally recognised optical, mechanical and electronics engineering groups and a specialised software group. These five groups are critical to the maintenance and the day-to-day operations of both the telescopes and to the development of state-of-the-art instrumentation. A small administration group contributes significantly to the effective operation of the Observatory. Details of the internal structure of the AAO are given in Appendix G.

Board members

Figure 1.1 General structure of the AAT Board and the AAO



The AAT Board has six members, three appointed by each country, and the role of Chair alternates between the two countries. At 30 June 2000 the members were:

Australia

Professor J R Mould, (Chair), Professor R D Ekers, Professor V R Sara

United Kingdom

Professor J A Peacock (Deputy Chair), Professor M J Barlow,
Dr I F Corbett

Further details of Board members, special responsibilites and Board meetings are included in Appendix I.

Advisory committees

The Anglo-Australian Observatory User's Committee (AAOUC) advises the Board on aspects of the Observatory's operation.

Observing time on the AAT is allocated by two national committees: the Australian Time Assignment Committee (ATAC) and the UK Panel for the Allocation of Telescope Time (PATT). Observing time on the UKST is allocated by the Schmidt Telescope Panel.

Details of these committees are also included in Appendix I.

2. The year in review

Operational environment

Astronomy excites the imagination of scientist and layperson alike and, although it gives no immediate tangible return, it provides an important framework for many of the major ideas that underpin our society. The long-term nature of the scientific questions being investigated demands exceptional intellectual and scientific skills and sophisticated equipment. To be effective, astronomical research requires stable, long term funding.

The British and Australian Governments have demonstrated a substantial commitment to astronomical research by establishing the Anglo-Australian Telescope Board, which has operated the Anglo-Australian Observatory for twenty-five years.

The Observatory provides world-class optical astronomy facilities for scientists from both countries. The telescopes of the AAO have been responsible for many fundamental discoveries and continue to provide a large portion of the data used by astronomers in Australia and the UK. The results of the observing programs carried out using these facilities are published in the scientific and technical media for the benefit of other scientists and the academic community. They are also widely publicised in more accessible places for the general public.

The intellectual challenge of astronomical research attracts some of the finest scientific minds. Astronomy is both international and highly competitive. The AAO maintains strong links with other scientific organisations on astronomical and technical matters, particularly in the development of new instrumentation, and therefore plays a major role in the international astronomical community. AAO staff collaborate on a range of scientific research programs with other astronomers around the world. Through its strong links with the universities in both Australia and the United Kingdom, the Observatory also plays an active role in higher education.

The AAT is the largest optical telescope in Australia and remains one of the world's most scientifically productive telescopes. The UKST is the most productive survey telescope in operation anywhere. Both telescopes were state-of-the-art when observing commenced in the early 1970s. Twenty-five years later, as a consequence of the vision of their designers, a long period of stable funding and a continuing program of enhancements, the telescopes of the AAO remain at the leading edge of astronomical research, against considerable international competition. The Observatory's expert scientific and engineering staff have constantly upgraded the telescopes by incorporating the latest technological developments into instrument design. Staff are considered world leaders in many areas of astronomical instrumentation and are often asked to provide advice to other organisations and build instruments for their telescopes.

The new generation of telescopes with mirrors eight metres or more in diameter are beginning to come online. These telescopes will be able to carry out many of the scientific programs currently undertaken with the AAT much more efficiently. To ensure a stable future, it is important the AAO demonstrates it can compete effectively with these larger telescopes, concentrating on those programs, which the eight-metre-class telescopes will not be able to do, or which are complementary. To this end, Observatory staff have developed facilities that exploit the unique wide-field capabilities of the AAT and the UKST. The Two-degree Field (2dF) facility for the AAT and the Six-degree Field (6dF) for the UKST, are examples of this. As well, developments such as $LDSS^{++}$ and IRIS2 will ensure continued high international profile and scientific productivity for the telescopes well into the next century.

John Stevenson in the fibres lab
preparing and repairing fibres for 2dF

Strategic directions

The AAO is committed to achieving results in five key areas, with the principal aim of obtaining the best possible science for the available resources. The AAO is not exclusively responsible for the scientific results that arise from use of its facilities: external users do most of the research. The AAO nevertheless makes a significant contribution to the quality of the results in the following ways:

First, by running the telescopes efficiently and providing good support during observing runs, the likelihood of good results is maximised.

Second, by ensuring that the best mix of instrument and software development is undertaken, the Board, the AAO Users' Committee and AAO staff contribute very positively to the kind of science possible with AAO facilities.

Third, by recruiting first-class research astronomers to support visiting astronomers and encouraging and supporting the AAO astronomers in their own research, the Observatory creates a climate which facilitates the best possible scientific output from all astronomers using the AAO's telescopes.

The five key result areas are:

Telescope operations
Research
Instrumentation
Use of AAO resources
External communications

The range of strategies adopted to achieve the AAO's objectives fall into two main groups. The first group involves staying in touch with developments in astronomy, instrumentation, telescope operations and management; listening to, and anticipating, the needs of the astronomy community; and publishing and publicising the research and other outcomes achieved. The second group encompasses technical, professional and administrative excellence and an ethos of continuous improvement.

Key result area: telescope operations

Key outcome: satisfied users and good data

Strategies

An important strategy is to listen carefully to the astronomy community, especially the users of the AAO's telescopes, to assess and anticipate their needs. Several avenues are available for this. The time assignment panels, the AAO Users' Committee and the Board, all have a strong influence on the strategic directions of the AAO and are representative of the astronomy community. AAO astronomers and other staff are encouraged to observe at or visit major telescopes overseas and to provide feedback on world best practice. Informal networks and attendance at conferences, seminars and colloquia are also important ways of staying in touch.

A second strategy is to ensure that users' needs are met. This is achieved by maintaining and consolidating existing instrumentation and associated software; by developing first-rate new instrumentation; by providing good support in setting up the instruments, operating the telescope and with observing; and by soliciting users' comments.

The third strategy for achieving satisfied users is to seek ever greater efficiency in running the telescopes.

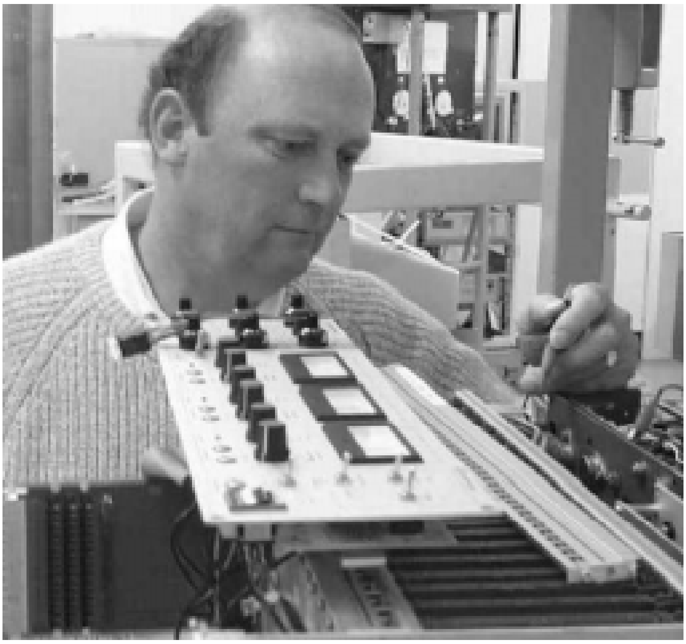
AAT organisational statistics

The high standard of the AAO's facilities and new developments in its instrumentation ensure that observing time on the AAT is always heavily over-subscribed. Appendix D shows the large number of institutions from which users compete for AAT time.

AAT performance indicators

The use of observing time for the period 1 July 1999–30 June 2000 is shown in Table 2.1. This year there were 3395 night hours available. In addition, a further 27 hours of commissioning time were used.

One measure of the extent to which users are likely to be satisfied with the levels of service provided at the AAT is the amount of available observing time lost through AAT equipment failure. In 1999–2000, this was 3.8 percent, rather more than the corporate goal of three percent. The 2dF facility accounts for just over one percent of this, while much of the remainder is due to ageing infrastructure. A single catastrophic disk crash during semester 1999B (in which 7 hours of time were lost) was a significant contributor. While the most serious faults have been resolved, there remain concerns over legacy systems such as the CCD controllers. The infrastructure review currently in progress is addressing these issues.



Ed Penny fine tuning the performance of the Taurus electronics

Table 2.1 Use of observing time on the AAT

	1996-97	1997-98	1998-99	1999-2000
	Percentage of total night time hours			
Observing (incl. commissioning)	62.8	56.1	55.2	57.4
Loss due to weather	35.0	39.5	42.0	38.4
Loss due to AAT equip failure	1.6	2.9	2.3	3.8
Loss due to other factors	0.6	1.5	0.5	0.4

User feedback

Another constructive way to assess user satisfaction is to ask users how well they regard the level of service offered. Observers at the AAT and UKST complete a form on the world wide web (WWW) in which they provide detailed comments on any areas of concern, and fill in a questionnaire which ranks their level of satisfaction with observing support, instrumentation, technical manuals, administration and web pages. These are ranked on a scale of 1 (poor) to 4 (excellent).

During the period 1 July 1999 – 30 June 2000, a total of 44 user feedback forms were completed for the AAT. This represents about 48 percent of user groups, a marked improvement over the previous year's return rate. Users are now actively encouraged to submit feedback forms at the end of their observing runs.

The average scores over the year are shown in Table 2.2, together with averages for the previous two years. The statistical error on these mean grades is ~0.2. They show that the level of user satisfaction is generally high, and fairly consistent over the three years.

The Corporate Plan sets a goal of at least 3 in all categories. This was achieved throughout except for instrument manuals, and a review of manuals is planned. Other categories in which scores are consistently close to the minimum acceptable are instrumentation/related software, general computing and working environment. All of these are being actively addressed, and significant improvements have already been made. In the working environment, for example, the principal complaint is noise in the control room, so noise-damping screens and low-noise fans are being progressively introduced. Other suggestions for improvements that have been followed up are the introduction of a bleep system for the night assistant or afternoon-shift technician, and a mimic display in the observers' tea room.

Although the UKST is run primarily in service mode, the small number of survey forms completed by visiting astronomers (two) using the FLAIR system, also indicate a high level of user satisfaction.

Table 2.2 User feedback at the AAT

	Average rank (maximum 4)		
	1997–98	1998–99	1999-2000
Night Assistant support	3.9	3.8	3.9
Staff astronomer support before observing.	3.5	3.5	3.6
Staff astronomer support during observing.	3.7	3.9	3.7
Other technical support	3.7	3.8	3.6
Instrumentation and related software	3.1	3.2	3.1
General computing	-	3.2	3.0
Working environment	3.2	3.6	3.1
Travel and admin support	3.6	3.9	3.5
Data reduction software	3.0	3.2	3.2
Instrument manuals	2.9	3.0	2.9
Library facilities	-	3.3	3.5
AAO Web pages	3.3	3.2	3.4

On 1st June 2000, a new feedback form was introduced. It differs from the old one in having a five-step scale on which observers are asked to judge how well AAO meets its obligations under its Client Service Charter. They are also asked to indicate categories they consider to be of low importance. The results from this form are not directly comparable with those from the earlier one. (The four responses received on the new form up to the end of the reporting period are not included in Table 2.2.) It is hoped, however, that they will reflect a more accurate view of observer opinion and allow the AAO to target resources into improving those areas that the users consider important.

UK Schmidt Telescope organisational statistics

The UK Schmidt Telescope (UKST) supports a large number of research projects, including long-term photographic surveys. Non-survey photographic requests are undertaken, as are research programs using the FLAIR multi-object spectroscopy system.

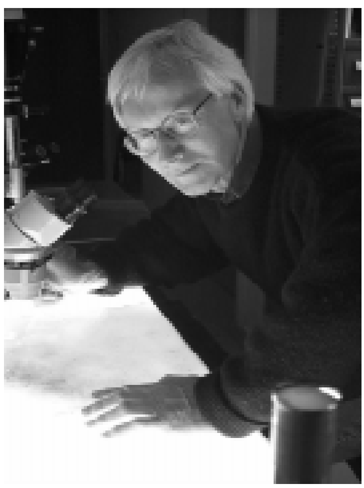
Table 2.3 Comparison of photographic imaging and total FLAIR exposures

	1995–96	1996–97	1997–98	1998–99	1999–2000
Plates and films	465	485	431	401	401
FLAIR hours	203	272	263	148	138

Totals of 103 plates and 298 films were obtained during the year, including test exposures. Film usage has expanded dramatically during the reporting year following the cessation of plate production by Kodak. During the final five lunations of the reporting year, film accounted for 91 percent of all photographic exposures.

FLAIR observations were made on 48 nights. On 18 of these, photographs were also taken as part of the flexible approach intended to help maximise the overall scientific productivity of the telescope. A total of 138 hours of science data was obtained using FLAIR, which corresponds to about 20 percent of all the observing time used on the UKST.

Table 2.3 shows the annual totals of photographic exposures and hours of FLAIR observation. (The number of exposures obtained in this



Malcolm Hartley inspects a new photographic plate taken through the new Hα filter, discovering several previously undetectable planetary nebulae reporting year is coincidentally the same as in the previous year.) The fall in both photographic exposures and FLAIR hours that took place in 1998–99 was due partly to the relatively large number of three-hour H-alpha exposures being obtained and to the introduction of the new three-observer operating model for the Schmidt Telescope (reflecting a reduction in staffing levels at the UK Schmidt by 50% between 1996 and 1999). This limited the number of nights scheduled per lunation, the number of FLAIR runs supported and also eliminated weekend processing. The figures for the present reporting year follow the same trend.

Appendix E gives details of the observations undertaken by the Schmidt Telescope during the year.

UK Schmidt Telescope Performance Indicators

The use of scheduled observing time on the UK Schmidt Telescope from 1 July 1999 to 30 June 2000 and in the previous three years is shown in Table 2.4.

It is not unusual for the percentage of night-time hours used to be 10 to 15 percent less than for the AAT, as the Schmidt Telescope is more vulnerable to the prevailing weather, requiring photometric conditions and good seeing to carry out photographic observations.

Table 2.4 Use of observing time on the UKST, 1 July 1996 to 30 June 2000

	1996-97	1997-98	1998-99	1999-2000
	Percentage of total night-time hours			
Used for observing	48.8	47.8	45.0	46.5
Lost due to weather	49.4	50.7	54.6	52.2
Lost due to equip faults	1.8	1.5	0.4	1.3

Table 2.4 shows that poor weather has again limited the amount of time available, though not quite as severely as in 1998–99. The four reporting years in the table have been characterised by a quasi-seasonal pattern, with good conditions during late summer followed by a fairly wet winter. The time lost due to faults during the period was typical of recent years, with the telescope drives, plateholder elevator and FLAIR being the main causes.

The Hα survey of the galactic plane has progressed well, with 143 of the 233 fields now covered to A-grade with Hα/short red pairs. Details are given in Appendix E. Additionally, 20 of the 40 fields of the Magellanic Clouds Hα survey (also detailed in Appendix E) are complete to A-grade with paired exposures. Both Hα surveys have been subjected to a regrading exercise.

Table 2.5 shows that the glass-plate surveys are very close to completion, with both the ER and SES red-light surveys being essentially finished. The last few A-grade exposures (approximately 10 and 20 fields respectively for the two surveys) were obtained on film due to the non-availability of glass plates of sufficient quality. One field remains to be obtained in red-light; it is the south polar field (Field 1), which currently only has a B-grade exposure. The near-infrared I survey has progressed extremely well during the reporting year, and is expected to be complete by the end of 2001.

Table 2.5 Current glass-plate survey status

	1997–98	1998–99	1999–2000	Total for survey		
	A-grade	A-grade	A-grade	Obtained	Requ'd	Total
Survey						
ER	7	3	12	288	0	288
I	4	10	53	838	56	894
R(SES)	22	9	22	605	1	606

Key result area: research

Key outcome: good science

Strategies

Most research using data from AAO telescopes is undertaken by external users. The time assignment committees, which are peer review panels independent of the AAO, are the most important factor in the achievement of the desired research outcome: their strategy is to ensure that only projects likely to result in good science are awarded time.

The AAO also has an effect on the achievement of this outcome. The first AAO strategy for achieving good science mirrors the first strategy for telescope operations: it is for the research astronomers to keep thoroughly in touch with developments in the astronomy community.

A second strategy is to publish research results and to publicise more broadly the work and achievements of the Observatory. Research astronomers spend about half of their time on research, are encouraged to publish, and have the financial costs of publication met by the Observatory.

Finally, the AAO seeks to keep its research outcomes at the forefront by inviting distinguished visiting scientists to work at the Observatory for extended periods.

Organisational statistics

There were 12 research astronomers on the staff of the AAO at 30 June 2000. Eight of them, while spending about half of their time on Observatory duties such as supporting visiting astronomers, spend the rest of their time on research. The other four are research astronomers but have significant responsibilities not directly related to their own research. These include the Director, the Astronomer in Charge and the Astronomical Photographer. The full time equivalent research effort is about five people.

Appendix B lists research papers published from AAT and UKST data during the period 1 July 1999 – 30 June 2000 as well as other papers published by AAO staff. Appendix D presents the AAT observing programs from 1 August 1999 to 31 July 2000. This information, and equivalent information from previous years, is summarised in Tables 2.6 to 2.9.

Table 2.6 Numbers of Scheduled AAT observing programs and location of Principal Investigator (PI)

	PI at AAO	PI at Aust institution (non AAO)	PI at UK institution (non AAO)	PI else-where	Total	AAO staff on program
1995–96	17	26	38	21	102	27
1996–97	25	34	26	17	102	42
1997–98	17	30	35	22	104	31
1998–99	16	24	38	15	93	29
1999-00	11	28	44	11	94	26

- The slightly lower number of total scheduled programs over the last two years (Col 6 in Table 2.6) is in part attributable to the higher number of survey programs over that period

Table 2.7 Research papers published from AAT data in refereed papers and conference proceedings

	First author at AAO	First author at Aust inst. (non AAO)	First author at UK inst. (non AAO)	First author at other inst.	Total
1995–96	17	13	45	34	109
1996–97	12	18	50	21	101
1997–98	15	16	44	25	100
1998–99	24	19	34	38	115
1999-00	6	17	51	18	92

Table 2.8 Research papers published from UK Schmidt data in refereed journals and conference proceedings (excluding papers, which make use of UK Schmidt survey data only)

	First author at AAO	First author at Aust inst. (non AAO)	First author at UK inst. (non AAO)	First author at other inst.	Total
1995–96	17	3	22	18	60
1996–97	9	7	13	21	50
1997–98	8	4	24	19	55
1998–99	9	3	13	25	50
1999-00	5	8	16	36	65

Table 2.9 Total numbers of AAO publications in refereed journals and conference proceedings (including papers published by AAO staff, students and visitors)

	AAT papers	UKST papers	Other AAO papers	Total AAO papers*
1995–96	34	24	26	84
1996–97	30	14	42	85
1997–98	29	18	43	90
1998–99	41	12	48	98
1999-00	22	13	63	96

* *Total AAO papers does not equal sum of three columns as a few papers contain both UKST and AAT data*

Table 2.8 shows an increasing trend of publications based on UK Schmidt data over the past 5 years, with the number for the current year (65) the highest yet. Table 2.7 shows that the number of research papers based on AAT data has declined slightly from a high of 115 in 1998-99 to 92 in the current year. Each year, AAO scientists are included on between 25 and 40 percent of all AAT observing programs and publications using AAT data.

Table 2.9 gives the number of AAO publications produced by staff, students and visitors. AAO staff consistently produce a large number of high quality publications. This year the number of papers was very close to last year's high of 98.

Table 2.10 shows how well AAT observing programs are converted into scientific papers. To allow for the delay between observations and publications, the statistic given here is the number of publications in a given year divided by the number of proposals in the *previous* year. Over the five year period from 1995 to 2000, the average number of papers per program is 0.93. Once again, the slight decline in publication numbers can be partly attributed to the impact of survey programs over this period.

Table 2.10 Publications per AAT observing program

	Publications per AAT observing program
1995–96	0.96
1996–97	0.99
1997–98	0.96
1998–99	1.00
1999-00	0.74
Average 1995–00**	0.93

Table 2.11 compares the publication rates in refereed journals for the AAT and UKST with other British Telescopes. Publication numbers for the UKST include survey papers as well as other papers.

Table 2.11 Publications in refereed journals using data from British telescopes (Non AAT data supplied by respective observatories)

	AAT*	UKST	WHT	INT	JKT	UKIRT	JCMT
1995	89	99	90	81	29	64	67
1996	86	100	100	84	52	82	52
1997	88	125	113	77	35	84	52
1998	93	145	118	72	38	77	72
1999	70	55	119	81	45	81	82

* *AAT data is shown for financial years, ie 1995–96 etc.*

Key result area: instrumentation

Key outcome: an integrated suite of instruments and telescope controls that best meet, in a timely fashion, the needs of the astronomical community, with the instruments working as well as they need, without being over-engineered.

Strategies

A key strategy in achieving the instrumentation objective is always to remain very much aware of developments in astronomy and instrumentation and of the needs of the astronomy community. The AAOUC's terms of reference include advising the Director on a development program which best meets the needs of the astronomy community bearing in mind AAO staff and financial constraints.

A further two strategies are vital to the implementation of the instrumentation development plan. The first is quality project management. Significant improvements in this area have been made in recent years, with the filling of two specialist project manager positions, resulting in improved monitoring and tracking for current projects, and improved procedures for the initiation, design review and tracking of future projects. This is supported by the provision of project management and risk assessment training for scientific and engineering staff to assist in their roles.

The second key implementation strategy is involvement at all stages, and at both sites, of all of the Observatory's highly innovative and world class astronomers, engineers, software specialists and technicians. This includes conception, design, construction and commissioning of instruments.

Organisational statistics

The AAO spends about 15 percent of its budget each year on new instruments and associated software and detectors. Table 2.12 summarises the use made of instruments on the AAT over the last few years. It does not include time used for aluminising the primary mirror, or Director's or Service time, or time dedicated to instrument development.

In the third full year of its operation, the Two-degree Field (2dF) facility has continued to be both highly in demand and highly allocated, with about 60% of the time allocated on 2dF going to the two major redshift survey programs. Demand for the high-resolution UCLES and UHRF spectrographs also remains high, with 15% of the time devoted to the ongoing search for extrasolar planets. The availability of charge-shuffling with both the Taurus Tunable Filter (TTF) and the Low-Dispersion Survey Spectrograph (LDSS++) continues to make these facilities more popular than ever. A resurgence in prime focus imaging is expected with the impending arrival of the 8K x 8K CCD mosaic Wide-Field Imager (WFI).

Chris McCowage makes an adjustment to the 2dF gripper

Raylee Stathakis setting up the RGO spectrograph in the AAT control room

The RGO spectrograph continues to be requested at a modest level, partly reflecting the increased competition for time from 2dF. The commissioning of the SPIRAL integral field unit in March 2000, along with its own bench-mounted spectrograph, will no doubt see a further reduction in RGO spectrograph use, although it will continue to serve an important role in spectropolarimetry and in time-series readout modes.

The infrared 3D integral field spectrograph, which had been made available to the AAO community under an agreement with the Max Planck Institut für Extraterrestrische Physik, was withdrawn in 1999-2000 on termination of the agreement. Only a small number of nights were allocated to the AAO's own infrared imager/spectrometer IRIS, almost exclusively for use with visitor auxiliary instrumentation such as the University of New South Wales Infrared Fabry-Perot (UNSWIRF) and the University of Hertfordshire's IRISPol polarimetry module. IRIS will be decommissioned once the new common-user infrared imager/ spectrometer IRIS2 is operational.

Detector use in recent years is outlined in Table 2.13. Charge coupled devices (CCDs) remain the astronomical detector of choice. The MITLL2 and MITLL3 CCDs have a significantly larger format (2048 × 4096 pixels) than the Tek2 device (1024 ×1024 pixels) and have proved extremely popular (2dF users have no choice and must use the Tek detectors mounted in the 2dF instrument). In January 2000, the MITLL2 device suffered a catastrophic hardware failure, but was able to be revived by use of an alternate readout amplifier, and is now designated "MITLL2A". An EEV 2048 × 4096 pixel device with superior sensitivity at blue wavelengths will soon be commissioned, which should allow the older Tek2 device to be retired.

Performance indicators

The instrumentation program is shaped by the advice given to the Director by the AAO Users' Committee. The committee consists of experienced representatives of the user communities who are responsible for ensuring that the agreed program does indeed meet the needs of the astronomical community. The best way to judge this after the event is to survey telescope users as to their satisfaction with the suite of instruments and the way the instruments, software and detectors perform. As mentioned above, this information is compiled from the user feedback survey responses (see Table 2.2). The level of user satisfaction with instrumentation and related software (a mean rank of 3.1 for this year) remains high, and shows that the AAO is meeting its performance indicators as outlined in the corporate plan.

Table 2.12 Use of AAT instruments for the last four years

Percentage of nights allocated

Instrument	1996-97	1997-98	1998-99	1999-00
2dF †	—	22.2	33.5	37.4
RGO Spectrograph (including FORS)	23.6	7.3	10.8	5.8
RGO Spectrograph with polarimeter	6.5	7.0	0.0	0.0
Low dispersion survey spectrograph (LDSS)	2.7	1.0	2.9	7.7
UCL coudé echelle spectrograph (UCLES)	12.9	18.7	25.5	20.9
Ultra high resolution facility (UHRF)	6.5	3.2	1.8	3.0
Taurus II & Taurus Tunable Filter (TTF) #	13.3	17.5	9.3	18.6
Infrared imager/ spectrograph(IRIS)*	22.4	7.3	2.2	3.4
Prime focus imaging with CCD	5.3	2.5	0.0	0.0
Prime focus photography	1.5	0.0	0.0	0.0
Instruments supplied by users	5.3	1.9	3.5	3.2

† 2dF regularly scheduled for the first time in 1997–98
 # Includes Faint Object Polarimeter from 1998–99 onwards
** Includes UNSWIRF and IRISPol*

Table 2.13 Use of AAT detectors for the last four years

Detector		Percentage of nights allocated 1996-97	1997-98	1998-99	1999-00
CCDs	Tek2	72.6	31.3	15.5	13.7
	2dF	-	22.2	33.5	38.1
	MITLL2/A	-	26.1	36.7	29.1
	MITLL3	-	-	0.0‡	19.7
Infrared	IRIS	22.4	7.3	2.2	3.4
Photographic plates		1.2	0.0	0.0	0.0
Detectors supplied by users		6.7	0.0	1.6	0.0

‡ *MITLL3 was commissioned and used in 1998–99 in Director's time, though no time was awarded for its use through the normal allocation process*

Key result area: AAO resources

Key outcome: AAO funds to be used optimally and to have stimulated, productive, creative and focused staff working in a safe environment.

Strategies

Perhaps the best strategy for achieving this objective is the involvement of all staff in corporate planning and other reviews. Their involvement

Don Kingston, Accountant at Epping at work on the AAO's Annual Financial Report

IRIS2 team members from left Denis Whittard, Dwight Horiuchi, Neal Schirmer and Vlad Churilov placing the IRIS 2 fore dewar shell in position on the main structural plate.

means that many different perspectives can be taken into account, leading to a more rounded approach. It also means that everyone understands the final outcome of such a process and feels more commitment to, and ownership of, the results than would otherwise be the case.

The Observatory is committed to equal employment opportunity and occupational health and safety best practices as a way of meeting its objective of stimulated, productive, creative and focused staff working in an environment in which they feel secure. Training in these concepts and practices is a well-established part of AAO life.

Organisational statistics (People)

Staff numbers

The AAO employs research scientists, technical staff, software engineers, electronics engineers, optical and mechanical engineers, administrative and library staff. There are 8 fixed-term research astronomers and 21 other fixed-term staff members, including the Director; two of these are part-time. The rest, 46 in all, are on indefinite term appointments. Staff members are located at both the Epping Laboratory and at Siding Spring Observatory. Table 2.14 shows staff numbers by tenure.

Table 2.14 Staff numbers by tenure

At 30 June 2000 the staff positions were:

	Full time	Part time
Director	1	
Fixed term research	5	
AAO/2dF Fellow	3	
Other fixed-term	21	2 (1.4 FTE)
Indefinite	46	3 (2.2FTE)
Total	76	5 (3.6 FTE)

Performance indicators (people)

Equal employment opportunity (EEO)

The *Equal Employment Opportunity (Commonwealth Authorities) Act 1987* requires the Board to develop an EEO program for each of the four designated groups identified within the Act. The Board reports annually to the Minister for Education, Training and Youth Affairs.

Only a fifth of the Observatory's staff is female. In earlier years, most of the women were in the administrative or research areas. In the past year, more women have been recruited to the technical areas. As well, there have been several recent recruits from non-English speaking backgrounds. This is an encouraging outcome to a campaign over several years to ensure that the Observatory's recruitment processes did truly offer equal opportunity to all.

Occupational health and safety

The Anglo-Australian Telescope Board's safety policy and its agreement on health and safety with the Community and Public Sector Union are set out in Appendix G. The Observatory embarked upon a more strategic approach to occupational health and safety about three years ago. The focus for 1999-00 was manual handling and safe working practices, part of a two-year rolling program to identify and fix manual handling problems; the program involves training in manual handling for all staff.

Comcare is a statutory authority established to administer the *Commonwealth Employee's Rehabilitation and Compensation Act 1988.* The premium the Board has to pay is a function of staff numbers and claims history. As table 2.15 shows, both the premium and compensation claims have fallen significantly in recent times. As well, there have been no notifications of dangerous occurrences for the last three years.

Table 2.15 Worker's compensation and dangerous occurrences

	1994-95	1995-96	1996-97	1997-98	1998-99	1999-00
Comcare premium	$27 748	$34 000	$31 431	$27 543	$28 770	$19 200
No of claims	2	4	4	0	0	3
Payments made	$66 488	$31 119	$3 578	0	0	$635
Dangerous occurrences	1	1	1	0	0	0

Organisational statistics (Financial)

The financial statements in Appendix A outline the AAO's financial position.

Performance indicators (Financial)

The Australian National Audit Office (ANAO) has audited the financial statements of the AATB and has found them to be acceptable. ANAO also assesses organisations it audits on the basis of the professionalism with which the financial statements and supporting documentation have been prepared. The AAO has markedly improved its ranking in recent years.

Key result area: external communications

Key outcomes: a lively awareness of astronomy in general, and the AAO's role in particular, by all stakeholders.

The AAO is aware that good two-way communication is central to all its activities. While it must listen to its stakeholders, it must also communicate to the wider community. The stakeholders are the AAO staff, the astronomy community, responsible Ministers, funding agencies, the Board and its advisory committees and the time assignment panels. The community includes the general public, hence the broad term 'Public Relations.'

World Wide Web and digital images

The AAO's main method of external communication, the World Wide Web, continues to attract a large audience, with a consistent hit rate over a million a month. These figures do not include the Cambridge (UK) mirror of the AAO site. Most of the Internet visitors are attracted by the images pages, which have been substantially redesigned and expanded in the last year. The pages now support a total of about 220 photographs, which is an increase of over 50 on a year ago. About 20 of the new pictures are from CCDs, but many existing plate sets, both from UKST and the AAT, have been digitally re-mastered to very high resolution files emphasising the Observatory's wide field capability. These are essentially new pictures, but digitisation has also allowed us to greatly improve the quality of the existing photographic images, all of which are now available digitally.

Public relations

A highlight of the year was the media launch of 2dF the movie, a representation of the true, three-dimensional distribution of distant galaxies on the sky. The movie was made at the Swinburne University super-computer centre in Melbourne from real 2dF data and real galaxy images from the AAO images collection. Video tapes of the dramatic 'fly through' of thousands of galaxies were widely distributed and received good coverage, including an excellent piece in the New York Times.

Science in the Outback

In May, Fred Watson and David Malin spent a week touring outback towns in eastern Australia from Broken Hill to Longreach and back as part of a travelling science and media circus organised by a group known as Science Communicators of Australia. Public talks, Science in the Pub sessions and other presentations followed in rapid succession as an elderly (but sprightly) DC3 carried an odd assortment of characters to some very remote places. For the astronomers at least, the highlight was "Starry Starry Night" where we sustained a 2 hour commentary on the twilight, its colours, perception and meaning, introducing the bright stars as they appeared. The talk was leavened by appropriate music from Ross Edwards, one of Australia's leading composers. On at least one occasion all this was done without stars being visible, so it is clearly a flexible program.

Use of AAO images

AAO images continue to be widely used despite an increasing number of alternative sources. In part this is because we offer rapid response to requests but also because the images are available as large digital files which are capable of very high quality book or magazine reproduction. They are also increasingly used for wall decoration in large sizes. A 7 x

David Mailn (left) and Fred Watson (right) plan their Science-Meets-Art session with well-known Australian composer Ross Edwards during "Science in the Pub Goes Outback". Photo courtesy of the ABC

A recent visit by Don Morton to the AAO provided a photographic opportunity to capture three AAO Directors (past and present) covering 24 years of the AAO's history. From left to right: Don Morton (AAO Director 1976-86), Brian Boyle (1996-present), Russell Cannon (1986-96).

10m outdoor mural of the well-known Horsehead nebula graced the new building of the American Association of the Advancement of Science in Washington D.C. for several months during the reporting period. They have also featured extensively in the new Rose Planetarium (successor to the Hayden) in New York. Revenue from image sales had decreased significantly, no doubt because of increased competition.

Conferences and symposia

The AAO plays a full role in organising and participating in conferences. These conferences provide the opportunity for staff to present results from the Observatory's telescopes and recent technical developments, and are essential in maintaining strong links with the international astronomical community.

Table 2.16 External communication organisational statistics

	1996–97	1997–98	1998–99	1999-00
'Popular' Talks	48	95	89	102
Media Interviews	52	83	152	97
Revenue from sales of images	$136 000	$193,000	$158,000	$105,000
Science/Technical Colloquia	111	72	77	68
Review panels	20	20	18	12
Organising committees	8	12	14	19

3. Scientific research

Introduction

This chapter highlights some of the research programs carried out using the 3.9-metre Anglo-Australian Telescope (AAT) and the 1.2-metre UK Schmidt telescope (UKST) during the period from July 1999 to June 2000. A summary of research activities of AAO staff is given in Appendix F.

The AAT is a powerful and versatile telescope which is equipped with a large suite of instrumentation for observations in the optical and near–infrared. Astronomers use the AAT to study a wide range of astronomical topics, from the search for planets around nearby stars, through to cosmological studies of the most distant galaxies and quasi-stellar objects (QSOs) in the Universe. Appendix D lists the projects allocated AAT time during the year. This year, eighty–five different observing programs were awarded time on the AAT.

Appendix E gives a breakdown of the time allocated to the UKST. The UKST is mainly used for systematic surveys of the southern sky. Red and near–infrared surveys of the southern sky are close to completion while new surveys for hot hydrogen gas in the Milky Way and the Magellanic Clouds, using a special narrow–band Hα filter, are 60 percent complete. The resulting atlases and their digitised versions, produced using plate scanning machines, provide one of the fundamental tools used by astronomers.

Appendix B gives a list of publications for 1999–2000. Tables giving publication and proposal statistics are given in Chapter 2. Typically 90 percent of all projects involve Australian or British astronomers, while 45 percent involve collaborations with astronomers from many other countries. On average, each observing program at the AAT results in about one publication.

2dF Science

The major projects carried out during the year with 2dF were the two very large cosmological studies, the galaxy redshift survey (2dFGRS) which aims to obtain redshifts for 250,000 galaxies, and the QSO redshift survey (2QZ) which will obtain spectra for 25,000 quasars. Both of these will be by far the largest surveys of their type ever carried out — already both are larger than any previous survey. They aim to map the large scale structure of our universe — the 2dFGRS will give a detailed view of our local universe, and the 2QZ will provide less detail over much larger scales, to probe the distant (and early) universe.

100,000 Redshifts and Counting

The distribution of galaxies in space has a large–scale structure that is determined by the initial conditions during the Big Bang and the subsequent growth of structures through gravitational collapse. Redshift surveys of large samples of galaxies provide 3-dimensional maps of the galaxy distribution showing arcs, filigrees and sheets of galaxies between vast dark regions, or voids. Until recently, however, redshift surveys have covered volumes containing only a few of the largest structures.

The 2dF Galaxy Redshift Survey (2dFGRS) aims to cover a large enough volume to provide a truly representative sample of the largest structures in the universe, and to sample this volume in enough detail to resolve structures ranging from small groups of galaxies to massive superclusters. The 2dFGRS has now obtained more than 100,000 galaxy redshifts, well on the way to the final target of 250,000. Although the dataset could now in principle have detected much larger–scale structure than previous surveys, no such structures have been detected. The 2dFGRS results show that there is a limit to the scale of structure in the universe.

These findings confirm a fundamental assumption of cosmology: that the universe should be smooth on extremely large scales. At the same time, the survey confirms that beneath this image of a smooth surface, the universe is punctuated on a smaller scale by the bumpiness of individual galaxies, clusters and superclusters. A major focus of the survey is understanding the formation of these objects. Preliminary comparisons show good agreement between the observed structure and computer simulations based on current models for the growth of structure by gravitational collapse and the formation of stars in high–density regions. The subtle differences between the observed and simulated maps will provide important new clues to the mechanics of galaxy formation. The 2dFGRS is a project undertaken by a large collaboration of British and Australian astronomers. Principal investigators are Colless (RSSA), Peacock (ROE) and Maddox (Cambridge).

Figure 3.1 A computer simulation of a 3-dimensional fly–through of our universe, based on the 2dFGRS and produced in collaboration with Swinburne University, can be accessed at http://www.swin.edu.au/astronomy/2dfmovie/

The 2dF QSO Redshift Survey (2QZ)

The 2dF QSO Redshift Survey (2QZ) continues to move towards its goal of 25,000 QSO redshifts, with the current total (June 2000) standing at 13,315. The fact that this number actually exceeds the total contained in all currently published catalogues ably illustrates the success and future potential of the 2dF facility.

The principal aim of the 2QZ survey is to investigate the clustering of QSOs in 3-dimensional space. Preliminary results suggest that, averaged over the entire survey, the clustering of QSOs is very similar to the clustering seen in local galaxies even though the QSOs are an order of magnitude more distant than locally observed galaxies. Studying the evolution of clustering as a function of redshift we find that QSO clustering properties are approximately constant over the entire observed redshift range. This is in disagreement with evolution driven by gravity, and suggests that the formation of QSOs plays a part in determining their clustering properties.

The survey's impact is not restricted to cosmology. The luminosity function (i.e. the abundance of a class of object as a function of their

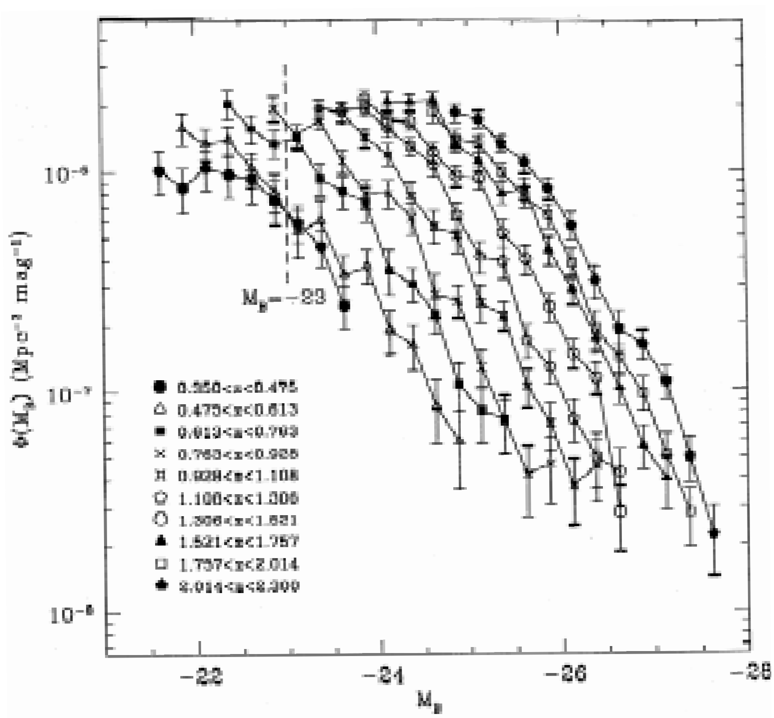


Figure 3.2 The QSO luminosity function measured in ten redshift slices derived from the first 6000 objects in the 2QZ and supplemented by almost 900 from the Large Bright Quasar Survey.

luminosity or intrinsic brightness) is an important way of analysing a population. Any model seeking to describe QSO formation and fuelling mechanisms must be able to reproduce the observed population and its evolution with redshift.

The 2QZ has allowed the measurement of QSO evolution in unprecedented detail. Figure 3.2 shows the optical luminosity function (OLF) for ten separate data subsets at increasing redshift. The form of the OLF does not vary, but is simply shifted to higher luminosity at higher redshift.

The 2QZ team are a small consortium of British and Australian astronomers headed by Boyle (AAO) and Shanks (Durham), including Croom (AAO), Loaring, Miller (Oxford) and Smith (RSAA). Results, pre-prints and updated status reports are available from the survey home page at http://msowww.anu.edu.au/~rsmith/QSO_Survey.

Hot horizontal branch stars in the Galactic bulge

Many elliptical galaxies emit far more ultraviolet light than is expected from the old, metal–rich stellar population that dominates at visible and infrared wavelengths. This 'UV–upturn' is believed to arise from old horizontal branch (HB) stars of high metallicity, i.e. stars which pass through a brief, very hot phase after they move from burning hydrogen to burning helium in their core.

Our understanding of this hot phase in stars more metal–rich than the Sun is still very incomplete, and the inner region of our Galaxy, the Galactic bulge, is the only place where we can see individual stars of this kind in sufficient numbers to work out their production rate as a function of temperature and metallicity.

Using the 2dF in service mode to study a region of the Galactic bulge, Peterson (Lick), Terndrup (Ohio), Sadler (Sydney) and Walker (CTIO) obtained spectra of 164 hot–star candidates. Twenty–three of these were confirmed as blue (i.e. hot) horizontal–branch (BHB) stars (the remainder being mainly reddened foreground disk stars). The 2dF spectra show for the first time that there are two separate populations of BHBs in the galactic bulge. Fourteen stars have low metallicity and are warm BHBs. The remaining nine stars have high metallicity, are cooler BHBs, and are distributed closer to the Galactic center.

No very hot BHBs were found in this pilot sample, but they are known to be fainter and harder to observe. A deeper survey of the Galactic bulge is now planned.

The history of bright elliptical field galaxies

The evolutionary history of bright elliptical galaxies in rich galaxy clusters has been well studied over the past ten years. The galaxies are all very similar and show little change in properties from the present day out to a redshift (z) = 1. The evolution that is detected is consistent with the aging of their stars. It can be shown that the stars were formed much earlier in the history of the universe — at redshifts $z > 2$.

In contrast, there has been little study of field elliptical galaxies which are in regions of much lower galaxy density. Competing theoretical models make very different predictions about the effect of the different environments on the evolution of elliptical galaxies. By searching UKST plates scanned by APM, and then obtaining spectra of potential targets using 2dF on the AAT, Willis (PUC), Hewett (IoA), Warren (ICSTM) and Lewis (AAO) have obtained a sample of over 500 bright elliptical field galaxies between redshifts of 0.3 and 0.6.

Willis and collaborators have found that the field galaxy spectra do resemble those of galaxies in clusters. Like cluster galaxies, there is little variation in the age of the stars and the amount of heavy elements. The results support the view that the environment of the galaxy has little effect on its early history and that the stars in the majority of elliptical galaxies were formed at a similar time and from similar materials. If this conclusion is born out by further work, more detailed results derived from studies of galaxies in rich clusters can confidently be applied to all elliptical galaxies.

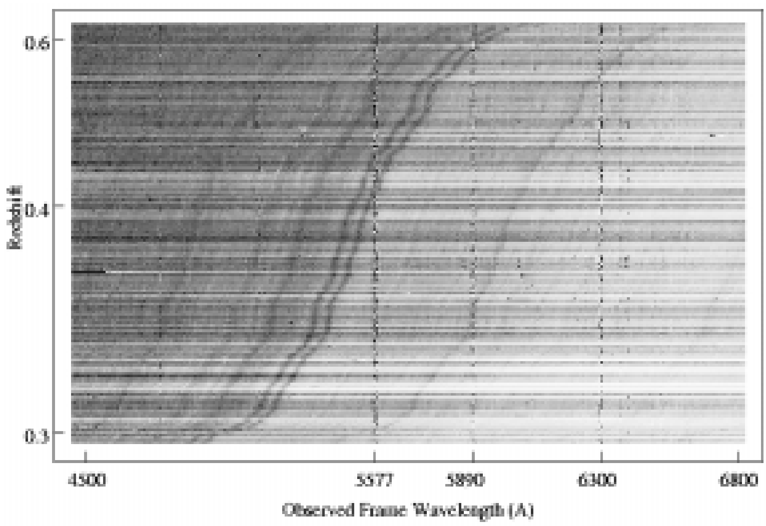


Figure 3.3 2dF spectra of 485 elliptical galaxies, in order of distance. The dark lines that appear further to the right in galaxies at higher redshift result from the stars in the individual galaxies. Vertical lines arise from features due to molecules in the Earth's atmosphere.

Extragalactic Astronomy Highlights

Discovery of a post–starburst quasar

As part of the follow up of the 2dF QSO Redshift Survey (2QZ), high quality spectra were obtained of bright QSO candidates with radio detections from the NRAO VLA Sky Survey (NVSS). The spectra were obtained using the Keck telescope in collaboration with Brotherton and Van Breugel (LLNL). These observations led to the discovery of a spectacular “post–starburst quasar” at a redshift of z = 0.63.

The spectrum is shown in Figure 3.4. The strong broad MgII emission feature and the continuum which rises sharply towards the ultraviolet are both typical features of a quasar. At the red end, the sudden rise in the spectrum (known as a Balmer break) and strong, narrow hydrogen absorption lines are typical of a galaxy which has recently undergone a major starburst.

The spectrum can be explained by a single burst of star formation which occured about 400 million years ago containing 70 billion times the mass of our sun. 50 million years after the start of star formation, the starburst would have been as bright as 6000 billion suns — the luminosity of a typical ultra–luminous infrared galaxy (ULIRG). An image of the object shows that 70% of the light is contained in a core, smaller than 0.5 arcsec, which is surrounded by a faint “fuzz”. Both the starburst and quasar emission must originate in the core.

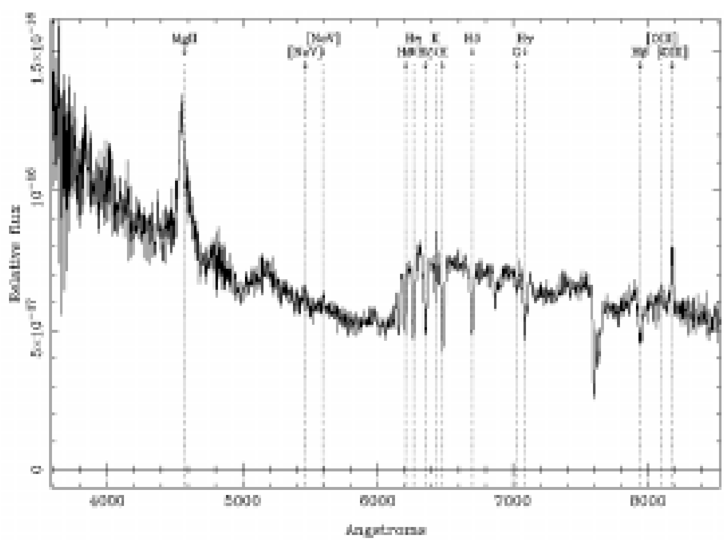


Figure 3.4 The optical spectrum of the post–starburst quasar taken at the Keck observatory. Features on the left are typical of a quasar, while the emission on the right comes from hot, young stars.

Investigation of this object is continuing — recently observations have been made using the AAO's SPIRAL integral field unit and further observations are scheduled with the HST and SCUBA on the JCMT. This exciting find could provide an evolutionary link between ULIRGs and broad emission–line active galaxies, furthering our understanding of the mechanisms behind the formation and fuelling of quasars.

Star formation in distant clustered galaxies

Galaxies in rich clusters are far more likely to have undergone strong star formation compared to galaxies in local clusters. This is evidence for a period in the past where nearby field galaxies fell into the rich galaxy clusters. In the process, star formation in the galaxies was enhanced and/or suppressed as they encountered the high density cluster environment. Some mechanisms proposed to explain these changes in star formation are: tidal interactions and merging with other galaxies, ram–pressure stripping of the gas supply as the galaxy encounters the hot intra–cluster medium, and galaxy 'harassment' which arises from high speed encounters between galaxies. Which of these mechanisms are important has been hard to determine observationally — galaxy interactions and merging are the only processes that have been observed directly, and distant cluster studies have been restricted to the central core regions where any changes due to the infall process have been erased with time.

In an attempt to overcome this problem, Couch (NSW), Bower, Balogh, Smail (Durham) and Glazebrook (JHU), have been using the recently upgraded Low Dispersion Survey Spectrograph (LDSS++) in 'nod–and–shuffle' mode to conduct a survey of Hα–emitting galaxies in distant clusters over a very large field. Hα observations provide a direct means to identify and quantify star formation within galaxies, located anywhere from the central core of the cluster to the outer regions. It is therefore easier to discriminate between the effects of the different mechanisms.

To date, one cluster — AC114 at $z = 0.32$ — has been observed, with spectra for 675 galaxies obtained in a single mask. This sample includes galaxies spanning the cluster out to a radius of 2 Mpc. The results of analysing these spectra have been quite startling. The cluster environment strongly *suppresses* (rather than stimulates) star formation almost uniformly across the cluster. Furthermore, none of the galaxies detected show a high star–formation rate. In Figure 3.5 the galaxies in AC114 (solid and dotted lines) are compared to field galaxies (dashed line) at the same epoch. The distribution of Hα luminosity is much lower for AC114 compared to the field galaxies, showing the extent that star formation has been suppressed in the cluster. This result argues that star–formation suppression occurs at large cluster radii, and is probably not due to ram–pressure stripping which would only be effective at smaller radii. More definitive conclusions will require observations of other clusters at these redshifts — the program is continuing.

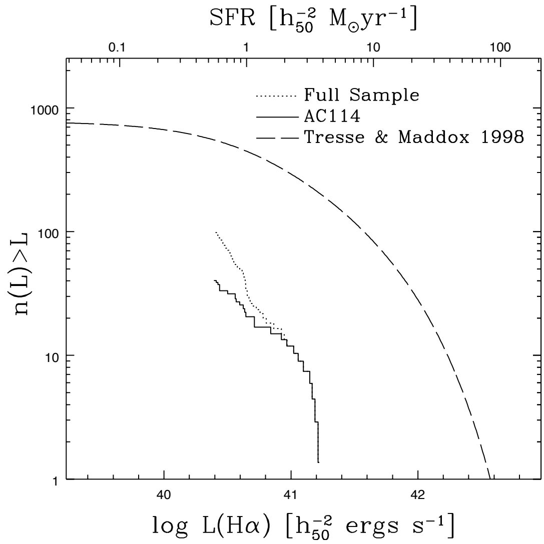


Figure 3.5 Comparison of the Hα luminosity functions for galaxies in the cluster AC114 (solid and dotted line) and field galaxies (dashed line) at a similar epoch. The lower curve shows that star formation is strongly suppressed in the cluster.

Associated absorption in radio–loud quasars

Many of the dark lines seen in the spectra of quasars are due to absorption by gas clouds between us and the distant quasar. Other absorption systems have redshifts which are so close to the emission redshift of the quasar that they are probably associated with the quasar environment itself, although their precise origin is still unknown. These associated absorbers are too common to be due to chance superpositions of field galaxies, but could mark galaxy clusters around quasars, or accelerated gas clouds close to the quasar nucleus. These features are usually found in quasars which are strong radio emitters, particularly those with steep radio spectra, suggesting that the absorption may be related to the physics of the radio sources.

To study the properties of these associated absorbers in more detail, Baker (Berkeley) and Hunstead (Sydney) have obtained a large sample of optical spectra of quasars from the (radio) Molonglo Quasar Sample. The majority of these observations were made at the AAT using the RGO spectrograph. This study shows that strong associated absorption is almost never seen towards quasars with dominant radio cores (i.e. relativistic jets beamed towards the observer), so the absorbing gas is concentrated at large angles away from the jet axis — either the jet has cleared out absorbers in its path or the absorbers are located in a dusty torus around the quasar. The second result is that amongst steep–spectrum

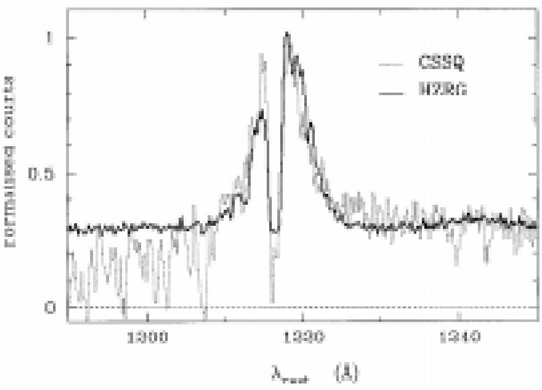


Figure 3.6 Overlaid spectra of the compact steep spectrum quasar MRC 0246–213 (dotted line) and the high–redshift radio galaxy MRC 0943–242 (solid line), both at z = 2.9, showing the striking similarity of the Lyα emission and absorption profiles.

quasars associated absorption is seen much more frequently towards *small* (<25 kpc) rather than larger radio sources. This suggests that the fraction of the source covered by absorbing material is greater when the radio sources are small, and supposedly young. These two results can be explained if the radio lobes of the quasar push aside and/or ionise the enriched clouds of neutral hydrogen as they expand into the ISM and beyond.

Interestingly, the absorption systems towards compact steep spectrum (CSS) quasars are remarkably similar to those seen towards high–redshift radio galaxies (HZRGs) (Figure 3.6). Many small HZRGs may in fact be misaligned CSS quasars with their broad–line regions hidden by a dusty torus. Again, the smaller HZRGs have the strongest absorption. A sample of closer quasars will be observed using the HST to test whether high redshift or small source size is responsible for the large number of associated absorption lines seen so far in small sources.

The Structure of the Shapely Supercluster.

The Shapely supercluster (SSC) was first discovered in 1930 and is recognised as one of the most massive concentrations of galaxies in the local universe. The SSC consists of many clusters and groups of galaxies lying about 130 Mpc behind the Hydra–Centaurus supercluster, or about 180 Mpc from us. The study of this supercluster is of importance in understanding the dynamics of the galaxies in the Local Group. The peculiar velocity of a galaxy is the velocity produced by effects other than the expansion of the universe. According to one model, the gravitational pull of the SSC may account for up to one quarter of the peculiar velocity of the Local Group. In this model the mass of the supercluster is dominated by dark matter.

Observations to date have been limited to the brightest galaxies in the supercluster. Using the multi–fibre spectrograph Flair II on the UKST, Proust (Meudon), Parker (ROE) and Drinkwater (Melbourne) are obtaining redshifts of a much larger sample of galaxies in order to get a more complete picture of the structure of the supercluster. To date, 645 velocities have been measured, a substantial improvement on previous studies. The resulting maps (Figure 3.7) show the galaxies position on the sky versus velocity at two orientations.

The results show that the SSC is even bigger than previously thought, with many detections of galaxy members outside the brighter clusters. New structure within the SSC is detected, showing that the cluster is part of a much larger structure extending uniformly in at least two sheet like structures over the whole region studied. These results also indicate that the SSC is at least 50% more massive than previously thought, with many of the new members in the closer regions to us. The SSC has thus an even more important effect on the Local Group than expected. A larger survey is now planned.

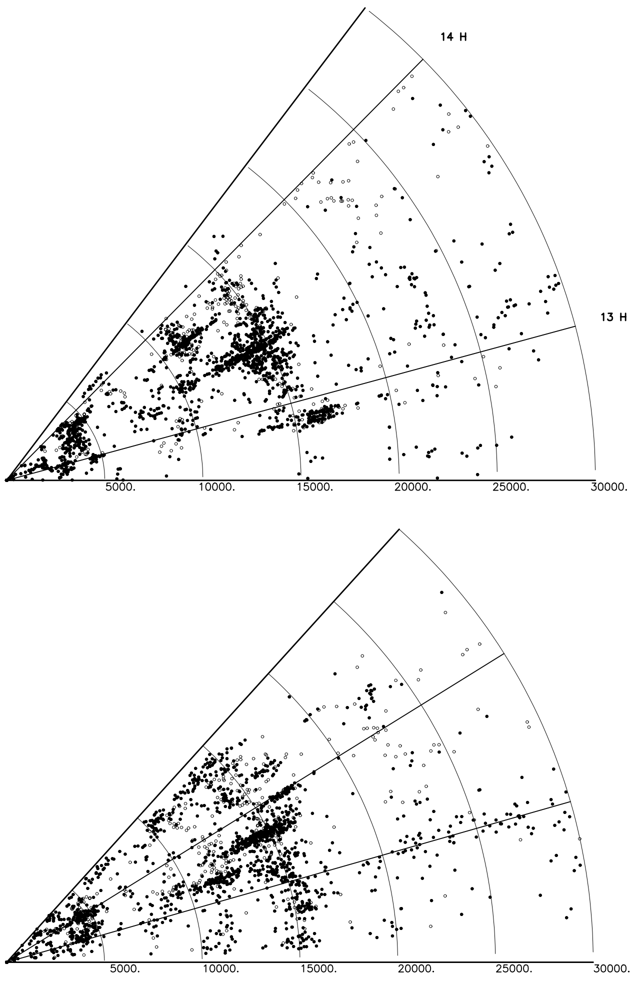


Figure 3.7 Map of the observed galaxies in the Shapely Supercluster Region, collapsed in two directions (top: Right Ascension versus velocity, bottom: Declination versus velocity).

Galactic Astronomy Highlights

Unlocking the Keyhole

The Keyhole Nebula is part of the Carina Nebula — a star–forming giant molecular cloud at a distance of 2.2 kpc. It is bathed in UV radiation from the nearby star cluster Tr16, which contains the famously massive star Eta Carina. The dark 'holes', lined by bright rims in the optical image of the Keyhole Nebula (Figure 3.8), are actually hot molecular clumps called "photodissociation regions" or PDRs. PDRs are the surface regions of molecular clouds, heated by the UV radiation from nearby stars.

Using the UNSWIRF with IRIS on the AAT, and the SPIREX telescope at the South Pole, Brooks, Burton, Rathborne, Ashley and Storey (NSW) have obtained infrared images of the Keyhole Nebula, specifically in wavelength bands sensitive to light from molecular hydrogen and from polycyclic aromatic hydrocarbon molecules (PAHs). PAHs are

Figure 3.8 The Keyhole Nebula in optical light. This image is derived from the three–colour image constructed by Malin (AAO) from AAT photographic plates. Molecular clouds show up as dark regions with bright rims known as PDRs. The main features making up the "keyhole" do not show up in molecular hydrogen (H_2) or PAH emission, suggesting that they are actually in front of the nebula.

particularly interesting as these molecules are now known to be a major component of the interstellar medium. They are believed to be formed as interstellar dust is broken down into smaller molecules, but where and when this occurs is still under dispute.

The UNSWIRF and SPIREX images show that the H_2 and PAH emission match almost exactly in seven small clumps, showing that this emission is coming from the PDR regions (Figure 3.9). By comparing the velocity and brightness of each clump of emission, it is found that the clumps moving the fastest have the faintest emission and the brightest clumps are moving most slowly. This tells us that the velocities are measuring the position of the clumps. It also shows which clumps are located on the near side, in the middle, and on the far side of the nebula. The molecular clumps of the Keyhole Nebula have been swept up from molecular gas by stellar winds from Eta Carina, whose radiation field is now heating the clumps and forming PDRs on their surfaces. The most prominent of the dark obscurations, which forms the shape of a keyhole, turns out to be foreground of the emission nebulae as it is not emitting from either molecular hydrogen or PAHs.

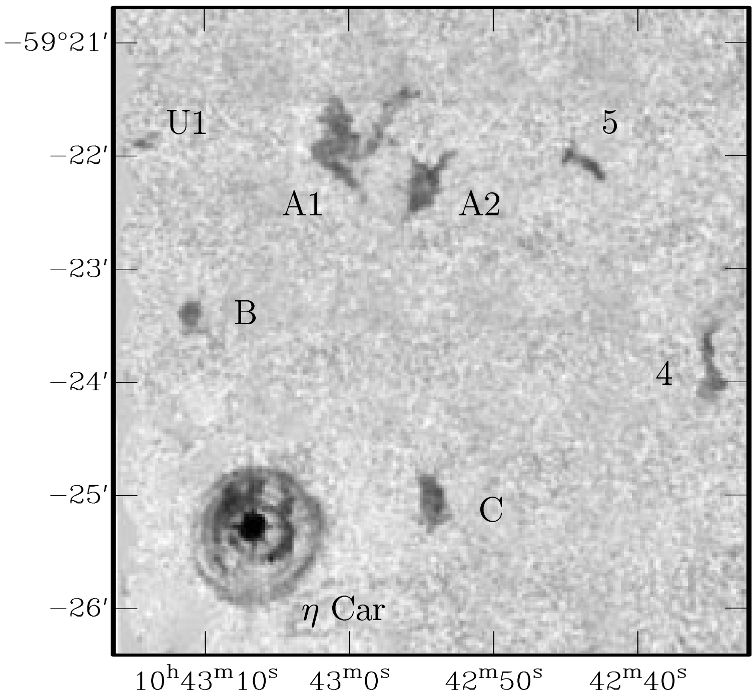


Figure 3.9 The same region as Figure 3.8 in the infrared, tracing emission from hydrogen molecules. Seven main spots are found, coinciding with PDRs. The same spots are seen in emission from PAHs. Velocity measurements show that clumps A1, A2, 4 and 5 are in the nebula, and clumps B and C are located at the far side.

Zeeman Doppler Imaging

Magnetism is the key to understanding stellar activity, but the measurement of stellar magnetic fields is very difficult. In principle, the magnetic field can be detected due to its polarisation of a star's light. However, in classical polarimetry, separate regions of opposite magnetic polarity (as is observed on the Sun) will tend to cancel when the whole star disc is observed.

Zeeman Doppler Imaging (ZDI) overcomes this problem by combining Doppler imaging with magnetic field detection. Due to the Doppler effect, opposite magnetic polarities across the stellar surface have different radial velocities producing a wavelength shift between polarisation profiles. Therefore, the polarisation signals from different parts of the star no longer cancel. ZDI provides both brightness mapping (i.e. Doppler imaging of starspots) and details of the surface structure of the star's magnetic field.

Researchers based in France, the UK, Australia and Germany have extensively used the AAT to make ZDI measurements of a number of nearby stars — a total of 41 nights have been awarded in the past three years for this project.

This project has produced the first ever surface magnetic images of stars other than the Sun, and magnetic detections for more than a dozen rapidly rotating active stars, including dwarf, pre-main sequence and evolved stars. ZDI has revealed the complex nature of magnetic fields on cool stars that feature, like the Sun, many small–scale magnetic regions of different polarities.

Interestingly, the magnetic activity cycles observed for the stars HR1099 and LQ Hydrae show that the dynamo processes of late–type rapidly rotating stars differ from the Sun — they operate throughout the whole convective envelope inside the star. Also, some stars have starspots at and near the poles, unlike our Sun whose sunspots are always in a band around the equator.

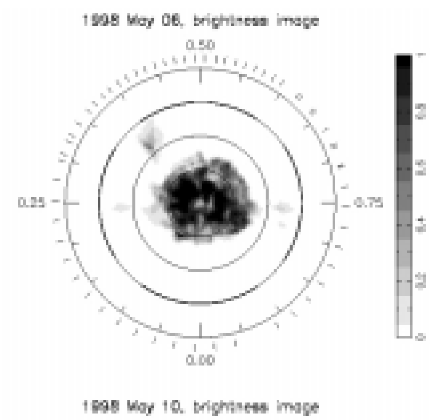


Figure 3.10 Zeeman Doppler image of the Lupus star RXJ 1508.6–4423 from observations taken in May 1998.

The search for planets outside our solar system

In 1995, the field of extra–solar planetary science was born, when the first planet outside our solar system was discovered around the star 51 Pegasi. Since late in 1997 Butler (CIW), Tinney (AAO), Penny (RAL), Jones (Liv JM) and Marcy (Berkeley) have been carrying out a search for such planets using the AAT to target 200 nearby southern hemisphere stars.

This search uses the same "Doppler Wobble" technique which has seen Butler and Marcy discover the vast majority of known extra–solar planets in the northern hemisphere. This technique relies on the fact that planets orbiting distant stars induce a small orbital motion in the parent star. By measuring the velocities of stars to extremely high precision, it is possible to detect these wobbles, and so uncover otherwise invisible planets.

The velocity changes which have to be measured, however, are tiny. For comparison, Jupiter induces a 15 m/s Doppler wobble in our Sun, with a 12 year period. In astronomical terms this is a tiny velocity — only just faster than a 100-m sprinter. However, the UCLES spectrograph has turned out to be an ideal facility for these observations, delivering velocity precisions as low as 3 m/s. The upper plots in Figure 3.10 are examples of stars with no detectable velocity variations at levels of 4.2 and 2.9 m/s respectively. The Anglo–Australian Planet Search program has been running for two years, and it has now reached the point where excellent planetary candidates are turning up — there are clearly a lot of wobbling stars amongst the Planet Search's targets. The lower panels of Figure 3.11 show two objects in which velocity variation has been detected. The first is an excellent candidate planet around an F9V star, while the second is a likely brown dwarf around a G2V star. The next twelve months are expected to reveal the first confirmed Anglo–Australian planets.

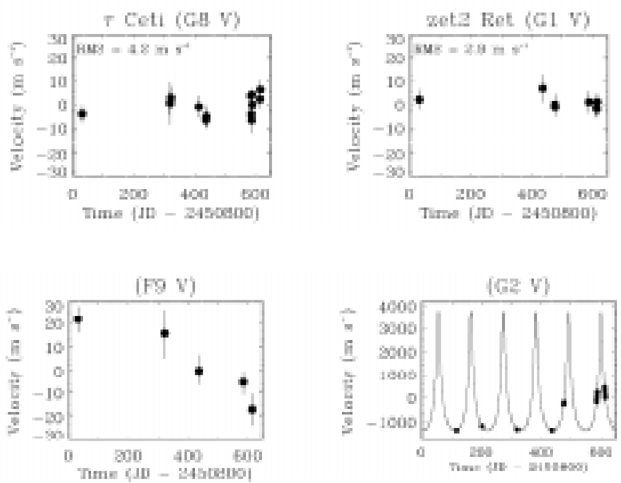


Figure 3.11 Measurement of Doppler wobble in nearby stars. The upper panels show two examples of stars with no observed variation. The lower panels are examples where variation has been detected: a planet candidate orbiting an F9 V star, and a probable brown dwarf orbiting a G2 V star.

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).

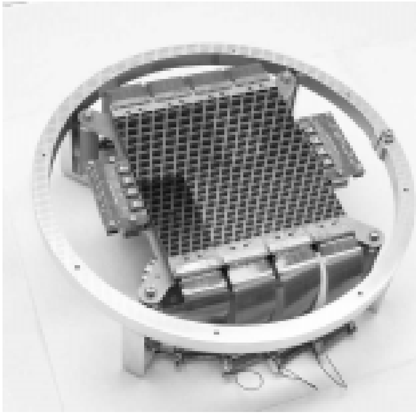
WFI is a mosaic of eight 4096 × 2048 MITLL CCDs installed in a single dewar cooled by liquid nitrogen. Together these CCDs provide a single 8192 × 8192 pixel imaging capability for the AAT, with a field of view

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.

F. Staff research

This section describes the research activities of staff at the Anglo-Australian Observatory, where not already covered in Chapter 3. In addition to providing support for the Observatory, the scientific staff pursue their own research programs. Staff make extensive use of the Anglo-Australian Telescope (AAT) and UK Schmidt Telescope (UKST) facilities and also use many other international research facilities such as the radio telescopes operated by the Australia Telescope National Facility and the Hubble Space Telescope.

A search for solar-like oscillations in Beta Hydri

In June 2000, Bedding (Sydney), Baldry (AAO) and O'Toole (Sydney) continuously monitored Beta Hydri for five nights using UCLES on the AAT. A circumpolar star, Beta Hydri was tracked for the full night and a spectrum was taken roughly every two minutes. In total, about 1200 spectra were obtained. The aim of this project (or why did it require five nights to study a third magnitude star?) was to detect solar–like oscillations. Theory predicts that Beta Hydri has a number of oscillation modes with periods of around 17 minutes and amplitudes of less than 1 m/s. Detecting these modes would allow the study of the internal structure of this star, which would otherwise be impossible, through the seismic interpretation of the frequencies and amplitudes. This technique is known as astroseismology.

In order to detect such a small motion on such a distant object, a high–resolution spectrograph is used in combination with an iodine cell to obtain Doppler shift measurements. This technique is used regularly by Paul Butler (CIW) and Chris Tinney (AAO) for their planet search program, and they have already shown that for the most stable stars, 3 m/s precision per measurement can be obtained. This precision in 1200 individual spectra should allow detection of sinusoidal amplitudes as low as 0.5 m/s using Fourier techniques. If successful, these oscillations will be the smallest motions to have been detected on a star other than our sun.

Type Ic Supernovae

Supernovae with no strong hydrogen, helium or silicon lines in their spectra are known as Type Ic. There is still no agreement on the type of star which explodes to form a Ic supernova, or what makes this event different from other supernovae. SN 1998bw was apparently a Ic supernova which also emitted a gamma-ray burst — an extremely high energy outburst not previously associated with supernovae — which can be best explained by an asymmetric explosion. As a followup to an AAO/RSAA monitoring program of SN 1998bw, Stathakis (AAO) is comparing velocity profiles from the strongest emission lines in four other Ic SNe. Line profiles can be analysed to map the velocity structure of the ejected envelope and to provide limits on the asymmetry and composition. Most of the observed lines in all four supernovae have significantly more blueshifted emission than redshifted emission. This result suggests that either Ic SNe are preferentially asymmetric towards the observer, enhancing emission travelling towards us, or more likely, emission from the far side of the supernova is being hidden by dense gas or dust.

Peculiar X-ray binary Circinus X-1

Circinus X-1 is a peculiar X-ray binary star system, whose nature has for many years defied explanation. Johnston (AAO) with Fender (Amsterdam) and Wu (Sydney, RCfTA) obtained infrared and optical spectra of the system, and discovered asymmetric emission lines. Asymmetric emission has also been detected in archival AAT spectra stretching back over 20 years. A new model suggests that the system is in a highly eccentric orbit. This group, together with Tauris and van den Heuvel (Amsterdam), suggests that the binary must be the survivor of a highly asymmetric supernova, leaving it with both a high eccentricity and a high space velocity.

Faint X-ray sources and black holes

Globular clusters contain many low–luminosity X-ray sources, whose nature is the subject of debate, because various types of objects can emit X-rays at such luminosities. Verbunt (Utrecht) and Johnston (AAO) have analysed High–Resolution Imager (HRI) data from the Rosat X-ray satellite on several clusters known to contain multiple X-ray sources in their core. Long images enable us to greatly improve the accuracy of the measured positions of the sources, to detect new sources and to measure variability in the known sources. A total of seventeen sources is detected in three clusters, several of which are well outside the core and thus may not be associated with the cluster.

Wu (Sydney, RCfTA), Soria (Sydney, MSSL) and Johnston (AAO) have been carrying out spectroscopic observations of several southern black–hole candidate binary systems. Spectra of GX 339–4, GRO J1655–40 and RXT J1550–564 reveal that the morphology and properties of the emission lines observed in these objects are different at different X-ray spectral states. The emission lines are double–peaked when the soft X-ray flux is strong. A model for this system based on an X-ray illuminated disk is successful in reproducing many features seen in the optical spectra.

The nature and origin of high–velocity clouds

The Galactic Halo is believed to have been formed by lower mass structures which were accreted and merged with the Halo. This process should still be ongoing today at a low level, and simulations predict that the Halo should have many more satellites than are actually observed. Strong candidates for the missing accreting mass are high velocity HI clouds (HVCs). These are ionized hydrogen clouds with velocities that can't be explained by simple galactic rotation. Unfortunately their distances are unknown for all but a few sources, so astronomers have not been able to test if HVCs are likely to be associated with dark matter.

Indirect measures of the distances to HVCs have resulted in wildly differing figures. Bland-Hawthorn (AAO) and Maloney (Colorado) have developed a new method to measure distances based on the Hα flux from a cloud. Using this method, HVCs fall into two populations: bright, nearby clouds; and faint clouds in the Galactic Halo, or even at greater distances. The discovery of dense clouds beyond the Halo would demonstrate for the first time that self-gravitating primordial gas clouds survive to the present day. A comparison of Hα and virial distances will be used to infer the contribution of a dark matter 'mini–halo'. Bland-Hawthorn and Lewis (AAO) intend to test the possible association of HVCs with dark matter. They will search for 'twinkling' of the starlight from a background galaxy seen through the HVC due to dark matter made of compact dark objects.

The Sagittarius Dwarf Galaxy

Lewis (AAO), working with Ibata (Heidelberg), Irwin (IoA) and Totten (Keele) have investigated the demise of the Sagittarius Dwarf Galaxy as it is torn apart by the tidal forces of the Milky Way. This study has revealed the presence of tidal material torn from the dwarf, traced by giant carbon stars, that covers a great circle on the sky. The spatial and kinematic properties of the stream offer strong constraints on the shape of the dark matter halo of the Galaxy, indicating that it is almost spherical. Such a result is at odds with theoretical models of the form and nature of dark matter in the Halo. Recent results from the Sloan Digital Sky Survey have uncovered coherent structures in their maps of the Galactic Halo which agree with our predictions of the form of the tidal debris.

Gravitational Lensing

Lewis (AAO), working with Ibata (Heidelberg), has investigated how the cosmologically distributed dark matter, in the form of compact objects, distorts our view of the distant universe. If this population exists, it will induce an observable flickering into the surface brightness of galaxies. With Wyithe (Melbourne, Princeton), Lewis and Ibata have extended these ideas to search for compact dark matter in clusters of galaxies, demonstrating that similar flickering will be seen in the surface brightness of gaint luminous arcs.

Globular clusters in spiral and elliptical galaxies

Bridges (AAO), in collaboration with a team of American, British and Canadian astronomers, is involved in several projects using multi–object spectroscopy to study globular cluster kinematics, ages and chemical composition, and the dark matter content in spiral and elliptical galaxies. In the Virgo cluster giant elliptical galaxy NGC 4472 (M49), nearly 150 globular cluster velocities have been measured, revealing significant differences between the metal–poor and metal–rich clusters: the metal–poor clusters have both a higher spread in velocity and a higher rotation. While all the clusters are old and similar in age, there is a hint that the metal–rich clusters are 0.5–1.0 Gyr younger than the metal–poor clusters. All of these results seem most consistent with a merger origin for NGC 4472, with the metal–poor clusters coming from the original spirals, and a new population of more metal–rich clusters formed later during the merger. The observed spread in cluster velocities, when compared with ROSAT X-ray observations of the hot gas around NGC 4472, supports the existence of a dark matter halo.

Bridges is also working with astronomers at Queen's University, Lick Observatory, Cambridge, and Harvard, on a major multi–fibre spectroscopic study of globular clusters in the Local Group spiral galaxy M31. The goal is to learn more about the formation and chemical enrichment history of M31 and other galaxies, and to distinguish between models for the formation of their stars and globular clusters. Velocities precise to 10–15 km/s have been measured for ~ 200 M31 clusters, a huge improvement over previous work. Chemical abundances have been derived from absorption–line features in the blue part of the spectrum. Preliminary analysis again shows significant differences between the metal–poor and metal–rich clusters: the metal–rich clusters are more spatially concentrated and have a much higher rotation. Thus, it is finally possible to identify the different cluster populations belonging to the disk, bulge, and halo of M31. The globular cluster velocities will be combined with those of M31 planetary nebulae stars to determine the mass (ie. dark matter content) of M31, and how the mass varies with distance from the galaxy center.

Circumnuclear star formation in barred galaxies

A significant fraction of barred spiral galaxies are actively forming stars in their centres, usually within a ring or tightly–wound spiral a kiloparsec or so across. Ryder (AAO), together with Knapen (ING) and Takamiya (Gemini), has used CGS4 on UKIRT to collect K-band spectra of the circumnuclear star–forming regions in NGC 4321 and NGC 2903. Using the equivalent widths of the Brγ emission and CO absorption features, they are able to date the age of the star–forming regions. The observed spread in ages suggests that star formation is triggered by the passage of a spiral density wave travelling sequentially through each region.

What fuels active galactic nuclei?

Many galaxies possess a highly luminous compact core known as an Active Galactic Nucleus (AGN) which is thought to consist of a massive black hole into which matter is falling or accreting. The host galaxies of AGN frequently show other forms of nuclear activity such as massive bursts of star formation and inner rings or bars. Corbett (AAO) is a member of the COLA Project (Compact Objects in Low–power AGN), a large multi-national collaboration which aims to determine whether these forms of activity are related to the presence of the AGN, for instance by transporting fuel to the AGN, or are purely coincidental. This should help to explain why some galaxies have AGN and others do not.

The COLA project will address this question by comparing multi–wavelength properties of galaxies with AGN to those of a matched sample of "non-active" galaxies. During the past 24 months the COLA collaboration has undertaken a major all–sky study of the multi–wavelength properties of 217 galaxies in order to identify a sample of AGN without biases such as orientation and redshift. This initial phase is close to completion and when complete, a matching control sample of non-active galaxies will be selected. The two samples will then be studied in great detail from optical to radio wavelengths and on scales ranging from a few parsecs to kiloparsecs.

Radio sources in the 2dFGRS

Powerful radio galaxies act as "beacons" which can be seen to enormous distances, so radio surveys play a key role in developing our understanding of galaxy evolution and the high–redshift universe. The limiting factor, however, has always been the difficulty of obtaining follow-up optical spectroscopy. A new generation of faint, large–area radio imaging surveys are just being completed, and 2dF on the AAT is the ideal instrument to rapidly obtain redshifts and optical spectra for these large samples of radio sources. Sadler (Sydney), Cannon (AAO), McIntyre (ATNF) and Jackson (RSAA) have undertaken a project to cross–identify galaxies in the 2dF Galaxy Redshift Survey (2dFGRS) and the radio surveys NRAO/VLA Sky Survey (NVSS) in the north and Sydney University Molonglo Sky Survey (SUMs) in the south.

As a first step in exploring the redshift distribution of the faint radio source population, galaxies in the first 20% of the 2dFGRS have been cross–identified with 1.4 GHz radio sources in the NVSS. About 1.5 – 2% of 2dFGRS galaxies are detected as radio sources in the NVSS — already a sample of over 900 candidate radio–galaxies have been identified — including both active galaxies (AGN) and star–forming galaxies. One early result is that the space density of radio–weak AGN is higher than previously measured. The completed project is expected to yield ~ 4000 radio–galaxy spectra. This sample will be a powerful tool for studying the distribution and evolution of both AGN and star–burst galaxies.

Unusual variable quasars

Kedziora–Chudczer (AAO) has been studying an unusual quasar PKS 0405–385 at the distance of 9 billion light years, which shows large and rapid changes in its radio flux density. Such variability is probably produced by scintillation which requires an extremely small and compact component of the radio source. The brightness temperature of this compact component, contained in a volume of a few Solar Systems, is higher than 10^{14} K. The presence of such a hot source in a relatively small volume questions our understanding of emission processes in active galactic nuclei. To address this question, the properties of the polarized emission from PKS 0405–385 at optical and radio wavelengths are being investigated, and its intensity is being monitored to determine the long–term evolution.

During the Australia Telescope Intraday Variability Survey of 118 extragalactic radio sources, another unusual intraday variable BL Lac object has been found — PKS 1519–273 — which shows high and variable circular polarization. Such high circular polarization cannot be produced by any obvious known process, either intrinsic to the source (synchrotron emission) or a propagation effect (the conversion of linear to circular polarization). At present Kedziora–Chudczer and collaborators are investigating the possibility of coherently–induced emission in this object.

The evolution of quasars

The QSO luminosity function measures the brightness distribution of quasars. Boyle (AAO), Shanks (Durham), Smith (RSAA), Croom (AAO), Miller and Loaring (Oxford) have analysed the first 5000 quasars identified in the 2dF QSO redshift survey by comparing the luminosity function at different redshifts. They find that the function shows strong luminosity evolution — quasars are intrinsically fainter in the present day than at large redshifts. The results indicate that the quasar luminosities evolved in the period bracketted by $0.35<z<2.3$ and $-23>M_B>-26$.

With Schade (DAO), Boyle has completed the analysis of 76 low redshift AGN/QSOs imaged with the Hubble Space Telescope. They find that 55% of these radio–quiet QSOs live in spheroid–dominant galaxies. Other than this bias towards early–type galaxies, the properties (luminosity and size) of the galaxies are consistent with a field galaxy population. Boyle and Schade find no evidence for mergers in any of the QSOs, casting doubt on the hypothesis that QSOs are largely fuelled by interactions.

Together with Londish (Sydney), Boyle and Schade have also shown that the luminosity function for these AGN/QSOs changes to a flatter slope for objects brighter than $M_B = -20$ — there are more intrinsically bright AGN/QSOs than previously thought. This has an important bearing on the evolution of the QSO luminosity function and for the local luminosity density of AGN.

A. Financial statements

As provided for in the Anglo-Australian Telescope Agreement, the accounts, records and financial transactions of the Board are audited by the Australian Auditor-General. The form of the Board's financial statements is in accord with Schedule 1 of the Commonwealth Authorities and Companies (Financial Statements 2000-2001) Orders made by the Finance Minister for the preparation of Financial Statements in relation to the financial year ending on 30 June 2001.

The Board submits detailed estimates of receipts and expenditure for approval by each Government in respect of the financial accounting period from 1 July 2000 to 30 June 2001. All estimates are expressed in Australian dollars.

Statement by the Director

In my opinion, the attached financial statements give a true and fair view of the matters required by Schedule 1 of the Commonwealth Authorities and Companies (Financial Statements 2000-2001) Orders made under the *Commonwealth Authorities and Companies Act 1997* for the year ended 30 June 2001.

M J Barlow
Chair of the Board
8 November 2001

Australian National
Audit Office

INDEPENDENT AUDIT REPORT

To the Minister for Education, Training and Youth Affairs

Scope

I have audited the financial statements of the Anglo-Australian Telescope Board for the year ended 30 June 2001. The financial statements comprise:

- Statement by Directors;
- Statement of Financial Performance;
- Statement of Financial Position;
- Statement of Cash Flows;
- Schedule of Commitments;
- Schedule of Contingencies; and
- Notes to and forming part of the Financial Statements.

The members of the Board are responsible for the preparation and presentation of the financial statements and the information they contain. I have conducted an independent audit of the financial statements in order to express an opinion on them to you.

The audit has been conducted in accordance with Australian National Audit Office Auditing Standards, which incorporate the Australian Auditing Standards, to provide reasonable assurance as to whether the financial statements are free of material misstatement. Audit procedures included examination, on a test basis, of evidence supporting the amounts and other disclosures in the financial statements, and the evaluation of accounting policies and significant accounting estimates. These procedures have been undertaken to form an opinion as to whether, in all material respects, the financial statements are presented fairly in accordance with Australian Accounting Standards, other mandatory professional reporting requirements and statutory requirements in Australia so as to present a view of the Anglo-Australian Telescope Board which is consistent with my understanding of its financial position, the results of its operations and its cash flows.

The audit opinion expressed in this report has been formed on the above basis.

PO Box A456 Sydney South NSW 1235
130 Elizabeth Street
SYDNEY NSW
Phone (02) 9367 7100 Fax (02) 9367 7102

Audit Opinion

In accordance with subsection 19(1) of the *Anglo-Australian Telescope Agreement Act 1970,* I now report that the financial statements are in agreement with the accounts and records of the Anglo-Australian Telescope Board, and in my opinion:

(i) the financial statements are based on proper accounts and records;

(ii) the financial statements show fairly, in accordance with applicable Accounting Standards and other mandatory professional reporting requirements, the financial position of the Board as at 30 June 2001 and the results of its operations and its cash flows for the year then ended;

(iii) the receipt, expenditure and investment of moneys, and the acquisition and disposal of assets, by the Board during the year have been in accordance with the *Anglo-Australian Telescope Agreement Act 1970*; and

(iv) the statements are in accordance with Schedule 1 of the Commonwealth Authorities and Companies (Financial Statements 2000-2001) Orders.

Australian National Audit Office

P Hinchey
Senior Director

Delegate of the Auditor-General

Sydney
12 November 2001

STATEMENT OF FINANCIAL PERFORMANCE
for the year ended 30 June 2001

	Notes	2001	2000
		$'000	$'000
Revenues from ordinary activities			
Revenues from Australian government	*4A*	**3725**	3670
United Kingdom government contribution	*4B*	**3450**	3400
Sales of goods & services	*4C*	**1724**	1403
Interest	*4D*	**51**	61
Proceeds from sale of assets	*5E*	**23**	109
Net foreign exchange gains	*4E*	**3**	1
Other	*4F*	**310**	676
Total revenues from ordinary activities		**9286**	9320
Expenses from ordinary activities			
Employees	*5A*	**5055**	4453
Suppliers	*5B*	**2570**	2964
Depreciation	*5C*	**2488**	2360
Write-down of assets	*5D*	**571**	454
Disposal of assets	*5E*	**46**	94
Total expenses from ordinary items		**10730**	10325
Net operating (deficit) from ordinary activities		**(1444)**	(1005)
Net credit to asset revaluation reserve		**3678**	-
Total revenues,expenses and valuation adjustments recognised directly into equity.		**3678**	**-**
Total changes in equity other than those resulting from transactions with owners as owners		**2234**	(1005)

The above statements should be read in conjunction with the accompanying notes

STATEMENT OF FINANCIAL POSITION
as at 30 June 2001

	Notes	2001	2000
		$'000	$'000
ASSETS			
Financial assets			
Cash	*6A*	**421**	1215
Receivables	*6B*	**111**	251
Total financial assets		**532**	1466
Non-financial assets			
Land and buildings	*7A*	**23192**	20325
Infrastructure, plant and equipment	*7B*	**24783**	25451
Other	*7D*	**111**	66
Total non-financial assets		**48086**	45842
Total assets		**48618**	47308
LIABILITIES			
Provisions			
Employees	*8A*	**1536**	1439
Total Provisions		**1536**	1439
Payables			
Suppliers	*8B*	**52**	92
Other	*8C*	**259**	1240
Total Payables		**311**	1332
Total liabilities		**1847**	2771
EQUITY			
Reserves	*9*	**32846**	29168
Accumulated surplus	*9*	**13925**	15369
Total equity		**46771**	44537
Current liabilities		**1051**	2051
Non-current liabilities		**796**	720
Current assets		**643**	1532
Non-current assets		**47975**	45776

The above statements should be read in conjunction with the accompanying notes

STATEMENT OF CASH FLOWS
for the year ended 30 June 2001

	Notes	2001	2000
		$'000	$'000
OPERATING ACTIVITIES			
Cash received			
Appropriations		**3725**	3670
Contributions from UK Government		**2587**	4262
Sales of goods and services		**1600**	1173
Interest		**49**	61
GST recovered from taxation authority		**267**	-
Other		**310**	-
Total cash received		**8538**	9166
Cash used			
Employees		**(4828)**	(4260)
Suppliers		**(2822)**	(3044)
Total cash used		**(7650)**	(7304)
Net cash from operating activities	*10*	**888**	1862
INVESTING ACTIVITIES			
Cash received			
Proceeds from sales of plant and equipment		**23**	109
Total cash received		**23**	109
Cash used			
Purchase of land & buildings		(16)	(34)
Purchase of plant and equipment		**(1689)**	(2414)
Total cash used		**(1705)**	(2448)
Net cash by investing activities		**(1682)**	(2339)
Net (decrease) in cash held		**(794)**	(477)
Cash at the beginning of reporting period		**1215**	1692
Cash at the end of reporting period	*6A*	**421**	1215

The above statements should be read in conjunction with the accompanying notes

SCHEDULE OF COMMITMENTS
as at 30 June 2001

	2001 $'000	2000 $'000
BY TYPE		
CAPITAL COMMITMENTS	**-**	-
OTHER COMMITMENTS		
Operating Leases	**88**	101
Total Commitments Payable	**88**	101
COMMITMENTS RECEIVABLE	-	**-**
Net commitments	**88**	101
BY MATURITY		
All net commitments		
One year or less	**67**	59
From one to two years	**21**	42
Net Commitments	**88**	101

SCHEDULE OF CONTINGENCIES
as at 30 June 2001

	2001 $'000	2000 $'000
CONTINGENT LOSSES & GAINS	-	-

The above schedule should be read in conjunction with the accompanying notes

1. Summary of Significant Accounting Policies

1.1 Basis of Accounting

The financial statements are required by section 19(1) of *The Anglo-Australian Telescope Board Act 1970* and are a general purpose financial report.

The statements have been prepared in accordance with:

- Schedule 1 of the Commonwealth Authorities and Companies (Financial Statements 2000-2001). Orders by the Finance Minister for the preparation of Financial Statements in relation to the financial years ending on 30 June 2001.
- Australian Accounting Standards and Accounting Interpretations issued by Australian Accounting Standard Boards;
- other authoritative pronouncements of the Boards; and
- Consensus Views of the Urgent Issues Group.

The statements have been prepared and have regard to:

- Statements of Accounting Concepts; and
- The Explanatory Notes to Schedule 1 issued by the Department of Finance and Administration.
- Guidance notes issued by that Department.

The Statements of Financial Performance and Financial Position have been prepared on an accrual basis and are in accordance with historical cost convention, except for certain assets, which, as noted, are at valuation. Except where stated, no allowance is made for the effect of changing prices on the results or on the financial position of the Anglo-Australian Telescope Board (Board).

1.2 Changes in Accounting Policy

The accounting policies used in the preparation of these financial statements are consistent with those used in 1999-2000.

1.3 Rounding

Amounts have been rounded to the nearest $1 000 except in relation to the following:

- remuneration of directors;
- remuneration of executive officers (other than directors); and
- remuneration of auditors.

1.3 Taxation

The Board is exempt from all forms of taxation except for the goods and services tax.

1.4 Property, Plant and Equipment

Asset Recognition Threshold

Purchases of property, plant and equipment are recognised initially at cost in the Statement of Financial Position, except for purchases costing less than $3000, which are expensed in the year of acquisition (other than where they form part of a group of similar items which are significant in total). The $3000 threshold was selected because it facilitates efficient asset management and recording without materially affecting asset values recognised.

Revaluations

Property, plant and equipment acquired free or for a nominal value are recognised initially at fair value.

Land, buildings, infrastructure, plant and equipment revalued progressively in accordance with the deprival method of valuation in successive three-year cycles, so that no asset has a value greater than three years old.

The revaluation cycle is as follows:

- land and buildings were revalued as at 1 July 2000.
- the telescopes and instrumentation were revalued as at 1 July 1998
- plant and equipment were revalued as at 1 July 1999; in the process, this class of assets was split into three separate classes, personal computers, other computers and other plant and equipment, each with a different useful life.

Assets in each class acquired after the commencement of the progressive revaluation cycle are not captured by the progressive revaluation then in progress.

In accordance with the deprival methodology, land is valued at its current market buying price. Property other than land, plant and equipment is measured at its depreciated replacement cost. Any assets that would not be replaced or are surplus to requirement are valued at their realisable value; at 30 June 2001 there were no assets in this situation.

The valuations of plant and equipment and land and buildings are independent. The valuations of the telescopes and instrumentation were developed within the Board based on historic prices and indices of inflation since then.

Recoverable Amount Test

Schedule 1 requires the application of the recoverable amount test to the Board's non-current assets in accordance with AAS *10 Recoverable Amount of Non-Current Assets*. The carrying amounts of non-current assets have been reviewed to determine whether they are in excess of their recoverable amounts. In assessing recoverable amounts, the relevant cash flows have not been discounted to their present value.

Depreciation and Amortisation

Depreciable property, plant and equipment assets are written off to their estimated residual values over their estimated useful lives to the Board using, in all cases, the straight line method of depreciation.

Depreciation rates (useful lives) and methods are reviewed at each balance date and necessary adjustments are recognised in the current, or current and future reporting periods, as appropriate. Residual values are re-estimated for a change in prices only when assets are revalued.

Depreciation rates applying to each class of depreciable assets are as follows:

	2001	2000
Buildings	**50 years**	25 years
Telescope and Ancillary Equipment	**50 years**	50 years
Telescope Instrumentation	**20 years**	20 years
Personal Computers	**3 years**	3 years
Other Computers	**5 years**	5 years
Other Plant and Equipment	**20 years**	20 years

The aggregate amount of depreciation allocated for each class of asset during the reporting period is disclosed in Note 5C.

1.5 Liability for Employee Entitlements

(a) Leave

The liability for employee entitlements includes provision for annual leave and long service leave. No provision has been made for sick leave; it is non-vesting and the average sick leave taken in future years by employees of the Board is estimated to be less than the annual entitlement for sick leave.

The liability for annual leave reflects the value of total annual leave entitlements of all employees at 30 June 2001 and is recognised at its nominal amount.

The non-current portion of the liability for long service leave is recognised and measured at the present value of the estimated future cash flows to be made in respect of all employees at 30 June 2001. In determining the present value of the liability, the Board has taken into account attrition rates and pay increases through promotion and inflation.

(b) Superannuation

Employees contribute to the Commonwealth Superannuation Scheme, the Public Sector Superannuation Scheme, the Anglo-Australian Telescope Board Staff Superannuation Scheme and to AGEST. Employer contributions amounting to $587,532 (1999-2000 - $544,810) have been expensed in these financial statements.

No liability for superannuation benefits is recognised as at 30 June as the employer contributions fully extinguish the accruing liability that is assumed by the Commonwealth.

Employer Superannuation Productivity Benefit contributions totalled $102,439 (1999-2000 $98,339).

1.6 Leases

A distinction is made between finance leases, which effectively transfer from the lessors to the lessee substantially all the risk and benefits incidental to ownership of leased assets, and operating leases, under which the lessor effectively retains all such risks and benefits. Operating lease payments are charged to expense on a basis, which is representative of the pattern of benefits derived from the leased assets. The Board has no finance leases.

1.7 Foreign Currency Transactions

The contributions from the United Kingdom are converted to Australian dollars at the selling rate quoted by the Bank of England at the time each contribution is made. All other foreign currency transactions are converted at the ruling exchange rate at the time of the transaction. Foreign currency receivables and payables are translated at the exchange rate as at balance date. Associated currency gains or losses are brought to account in the Statement of Financial Performance.

1.8 Cash

Cash means notes and coins held and any deposits held at call with a bank or financial institution.

1.9 Revenue

Australian government appropriations are recognised at the time the Board receives the revenue.

Grants are received from the Australian Research Council (ARC) and the Particle Physics and Astronomy Research Council (PPARC) of the United Kingdom (UK) for the specific purpose of employing astronomers at the Observatory. Grants are recognised as revenue on receipt.

Resources Received Free of Charge

Services received free of charge are recognised as revenues when and only when a fair value can be reliably determined and the services would have been purchased if they had not been donated.

Contributions of assets at no cost of acquisition or for nominal consideration are recognised at their fair value when the asset qualifies for recognition.

The following resources are received free of charge:

(i) Use of Land

At Siding Spring Observatory, the 3.9 metre Anglo-Australian Telescope (AAT) building and the 1.2 metre Schmidt Telescope (ST) building are on land owned by the Australian National University (ANU). At Epping, New South Wales, the Board's buildings are on the site of the Commonwealth Scientific and Industrial Research Organisation (CSIRO). The Board has entered into a permissive occupancy agreement with CSIRO covering its establishment at Epping. The value of this land is disclosed in Note 7A. The Board has also entered into a permissive occupancy agreement with the ANU for its establishment at Siding Spring, for which a "peppercorn rental" of one dollar is charged.

(ii) Use of the Schmidt Telescope

The Schmidt Telescope is owned by PPARC and operated by AAO. It was brought to account for the first time in 1996-97 based on a valuation provided by PPARC.

1.10 Agreements

Under an agreement between the Board and the PPARC, the Board is responsible for the management, care and maintenance, operation and development of the Schmidt Telescope. PPARC, the owner of the Schmidt Telescope, has entered into a lease with the ANU in respect of use of land for the Schmidt Telescope. The revenues, expenses and asset values in respect of the Schmidt Telescope form part of the financial statements.

1.11 External Projects

The Anglo-Australian Telescope Board has, in recent years, been invited to build telescope instrumentation for other Australian and international telescope bodies. Sometimes these non-profit contracts are on a time and materials basis, other times on a fixed price basis. The projects are costed to result in break-even results on completion. In the event of a surplus or over-run arising, it is the policy of the Board to absorb these.

1.12 Financial Instruments

Accounting policies in relation to financial instruments are disclosed in note 15.

1.13 Accrual Budgeting Framework

The Anglo-Australian Telescope Board is not part of the Commonwealth Government's accrual budgeting framework.

1.14 Capital Use Charge

The Anglo-Australian Telescope Board is not subject to the Commonwealth Government's capital use charge.

1.15 Comparative Figures

Where appropriate, comparative figures have been restated to conform to changes in the presentation of the financial statements.

2. Financial Reporting by Segments

The Board operates solely in Australia and in one industry by operating and maintaining research facilities for astronomy.

3. Economic Dependency

The Board is dependent upon Australian government revenue and contributions from the United Kingdom government for its continued existence and ability to carry out its normal activities.

	2001 **$'000**	2000 $'000
4. Operating revenues		
4A Australian Government Revenues		
Australian government revenue (Note 3)	**3,725**	3,670
Total	**3,725**	3,670
4B United Kingdom Government contribution		
The Board received the following contribution during the year from the United Kingdom government (Note 3)	**3,450**	3,400
4C Sale of goods and services		
Sale of goods	**1,398**	864
Rendering of services	**326**	539
Total	**1,724**	1,403
Cost of sale of goods	1,415	711
4D Interest		
Cash at Bank	**51**	61
4E Net foreign exchange gains/(losses)		
Non-speculative	**3**	1
4F Other revenues		
Rent	**7**	7
Fellowships	**69**	48
Take up of assets previously expensed	**-**	503
Other Revenue	**234**	118
Total	**310**	676

5. Operating Expenses - Goods and Services

5A Employee Expenses

	2001 $'000	2000 $'000
Basic remuneration for services provided:		
External project staff	**735**	574
All other staff	**4,320**	3,879
Total	**5,055**	4,453

The Board contributes to the Anglo-Australian Telescope Board Staff Superannuation Scheme, the Commonwealth Superannuation (CSS) and the Public Sector (PSS) superannuation schemes that provide retirement, death and disability benefits to employees. Contributions to the schemes are at rates calculated to cover existing and emerging obligations. Current contributions are 11.76% of salary (AATB Superannuation Scheme), 29.8% of salary (CSS) and 11.7% of salary (PSS). An additional amount of between 2 and 3% is contributed for employer productivity benefits.

5B Suppliers' Expenses

Supply of goods and services	**1,980**	2,531
Motor vehicle lease costs	**77**	69
External projects	**513**	364
Total	**2,570**	2,964

5C Depreciation

Property, plant and equipment	**2,488**	2,360

The aggregate amounts of depreciation expensed during the reporting period for each class of depreciable asset are:

Buildings	**829**	834
Telescope	**627**	624
Instruments	**602**	394
Plant and equipment	**430**	508
Total allocated	**2,488**	2,360

5D Write-down of assets	**2001 $'000**	2000 $'000
Non-financial assets:		
Plant and Equipment – revaluation decrement	**-**	454
Plant and Equipment – written off	**571**	-
Total	**571**	454

5E Proceeds and expense from sale of assets

Non-financial assets – plant and equipment		
Revenue (proceeds) from sale	**23**	109
Expense from sale	**46**	94
Total gain of (loss) on sale	**(23)**	15

6. Financial assets

6A Cash

Cash at bank and on hand	**421**	1,215
Balance of cash as at 30 June as shown in the Statement of Cash Flows	**421**	1,215

6B Receivables

Goods and services	**49**	225
Other debtors	**43**	26
GST Receivable	**19**	-
Total receivables	**111**	251
Receivables (gross) which are overdue are aged as follows:		
Not Overdue	**97**	208
Overdue by:		
-Less than 30 days	**4**	9
-30 to 60 days	**1**	23
-more than 60 days	**9**	11
Total	**111**	251

7A Land and buildings	**2001**	2000
	$'000	$'000
Land at 1996 valuation	**-**	14
Land - at 30 June 2001 valuation	**15**	-
Land (the use of which is free of charge)		
- at 1997 valuation	**-**	1,800
- at 30 June 2001 valuation	**2,350**	-
	2,365	1,814
Buildings - at cost	**-**	34
Buildings - at 1997 valuation	**-**	18,615
Buildings - at 30 June 2001 valuation	**41,778**	-
Less accumulated depreciation	**22,951**	2,007
	18,827	16,642
Buildings (the use of which is free of charge)		
- at 1997 valuation	**-**	2,100
- at 30 June 2001 valuation	**4,549**	-
Less accumulated depreciation	**2,549**	231
	2,000	1,869
Total land and buildings	**23,192**	20,325

7B Plant and equipment

Telescope and ancillary equipment at 1998 valuation	**31,213**	31,189
Less accumulated depreciation	**16,939**	16,312
	14,274	14,877
Telescope and ancillary equipment at cost	**31**	48
Less accumulated depreciation	**1**	1
	30	47
Telescope instrumentation at 1998 valuation	**11,255**	9,477
Less accumulated depreciation	**3,927**	3,269
	7,328	6,208
Telescope instrumentation at cost	**1,314**	1,963
Less accumulated depreciation	**33**	89
	1,281	1,874

	2001	2000
	$'000	$'000
Other plant and equipment at 1999		
Valuation	**3,046**	3,470
Less accumulated depreciation	**1,806**	1,418
	1,240	2,042
Other plant and equipment at cost	**666**	403
Less accumulated depreciation	**37**	10
	629	393
Total plant and equipment	**24,783**	25,451
Total property, plant and equipment	**47,975**	45,776

The revaluation of Land and Buildings was in accordance with the revaluation policy stated at Note 1.4 and was completed by an independent valuer, McGees, National Property Consultants, Certified Practising Valuer. Revaluation increments of $3,678,000 were credited to the Asset Revaluation Reserve.

7C. Analysis of Property, Plant and Equipment

TABLE A

Movement summary 2000-2001 for all assets irrespective of valuation basis

Item	Land '000	Buildings $'000	Total land and buildings $'000	Plant and equipment $'000	Total $'000
Gross value as at 1 July 2000	**1,814**	**20,749**	**22,563**	**46,551**	**69,114**
- Additions-purchase of assets		17	17	1,608	1,625
- Revaluations: write-ups/write-downs	551	25,561	26,112	(572)	25,540
- Disposals				(61)	(61)
Gross value as at 30 June 2001	**2,365**	**46,327**	**48,692**	**47,526**	**96,218**
Accumulated depreciation as at 1 July 2000	**-**	**2,239**	**2,239**	**21,099**	**23,338**
- Depreciation charge for year	-	829	829	1,659	2,488
- Adjustment for revaluation		22,432	22,432	-	22,432
- Adjustment for disposals				(15)	(15)
Accumulated depreciation as at 30 June 2001	**-**	**25,500**	**25,500**	**22,743**	**48,243**
Net book value as at 30 June 2001	**2,365**	**20,827**	**23,192**	**24,783**	**47,975**
Net book value as at 1 July 2000	1,814	18,510	20,324	25,452	45,776

TABLE B

Summary of balances of assets at valuation as at 30 June 2001

Item	Land $'000	Buildings $'000	Telescope $'000	Instruments $'000	Plant & equipment $'000	Total $'000
As at 30 June 2001						
Gross value	**2,365**	**46,327**	**31,213**	**11,255**	**3,046**	**94,206**
Accumulated depreciation	**-**	**25,500**	**16,939**	**3,927**	**1,806**	**48,172**
Net book value	**2,365**	**20,827**	**14,274**	**7,328**	**1,240**	**46,034**
As at 30 June 2000						
Gross value	1,814	20,715	31,189	9,477	3,470	66,665
Accumulated depreciation	-	2,237	16,312	3,269	1,418	23,236
Net book value	1,814	18,478	14,877	6,208	2,052	43,429

	2001 $'000	2000 $'000
7D. Other non-financial assets		
Prepayments for goods and services - includes insurance premiums, rentals in advance and subscriptions	**111**	66

8. Provisions

8A Employees

	2001 $'000	2000 $'000
Salaries and wages	**127**	130
Annual leave	**530**	489
Long service leave	**879**	820
Aggregate employee entitlement liability	**1,536**	1,439

8B Suppliers

	2001 $'000	2000 $'000
Trade creditors	**52**	92

	2001 $'000	2000 $'000
8C Other Liabilities		
ESO (Note 14A)	**-**	165
PNS (Note14H)	**50**	108
Non Trade creditors	**96**	104
Contributions from PPARC received in advance	**-**	863
ECHIDNA	**113**	-
Total	**259**	1,240

9. Equity

10. Cash Flow Reconciliation

Reconciliation of operating deficit to net cash provided by operating activities:

	2001 $'000	2000 $'000
Operating surplus/(deficit)	**(1,444)**	(1,005)
Depreciation and amortisation	**2,488**	2,360
(Gain) loss on sale of non-current assets	**-**	(15)
Property plant & equipment written off	**611**	(503)
Revaluation of plant and equipment	**-**	453
Changes in assets and liabilities:		
Increase/(decrease) in liabilities to employees	**97**	193
Decrease/(increase) in receivables	**224**	(153)
(Increase)/decrease in other current assets	**(45)**	1
Increase/(decrease) in creditors	**(40)**	(77)
Increase/(decrease) in other current liabilities	**(1,003)**	608
Net cash provided by operating activities	**888**	1,862

11. Related Party Disclosures and Remuneration of Directors

Members of the Board during the year were:

Dr I F Corbett, Professor M Barlow, Professor M Birkinshaw, Professor R D Ekers, Professor K Freeman (from 1 January 2001), Professor J R Mould (to 31 December 2000) Professor V Sara.

The Directors do not receive remuneration.

Professor J R Mould was also Director of the ANU Research School of Astronomy and Astrophysics (RSAA) and Professor Freeman is currently an employee of the same organisation. RSAA provides site services to the AAO at Siding Spring. Professor R D Ekers is the Director of the Australian Telescope National Facility, a Division of CSIRO; CSIRO provides site services to the AAO at Epping.

12. Remuneration of Officers

The number of Officers who receive or were due to receive total remuneration of $100,000 or more

	2001 Number	2000 Number
$110 001 - $120 000	**1**	-
$120 001 - $130 000	-	1
$130 001 - $140 000	**1**	1
$140 001 - $150 000	**1**	1
$150 001 - $160 000	-	1
$160 001 - $170 000	**1**	-

	2001 $'000	2000 $'000
Income received or due and receivable by officers		
Salary and on costs	**449,187**	327,510
Superannuation	**56,490**	44,135
Vehicle benefits	**71,916**	43,150
Total received, due and receivable	**577,593**	414,795

13. Remuneration of Auditors

	$	$
Remuneration to the Auditor-General for auditing the financial statements for the reporting period.	**25,000**	24,760

No other services were provided by the Auditor-General during the reporting period.

14. External Projects

A) In May 1999, the Observatory entered into an agreement with the European Southern Observatory (ESO) to build a positioner for the Very Large Telescope in Chile. This was a natural extension of the work the AAO had done on its own instruments and provided an opportunity for the AAO to enhance its instrumentation building skills. The instrument will be delivered to Chile by Christmas 2001.

ESO will make a series of staged payments in advance. The position at 30 June 2001 was as follows:

	2001	2000
	$000	$000
Instalments received from ESO	**835**	320
Suppliers expenses	**383**	97
Employee expenses	**520**	372
On-cost credited to Other Revenue	**146**	186
Net surplus carried forward from prior year	**165**	500
Instalments unexpended - included in other liabilities	**49**	165

B) The Observatory received in 1997-98 and 1998-99 funding from the Australian Government's Major National Research Facility fund. The funding is for a concept design study for an innovative instrument to be known as Australis. The position at 30 June 2001 was as follows:

Employee expenses	**-**	23
Net surplus carried forward from prior year	-	23
Instalments unexpended - included in other liabilities	**-**	-

C) The Japanese Telescope Subaru contracted the AAO to design and evaluate a prototype positioner, the Echidna. The contract began just before the end of the 1998-99 year and was completed in March 2001. The position at 30 June 2001 was as follows:

Instalment received	**479**	68
Suppliers' expenses	**78**	39
Employee expenses	**176**	23
On Cost credited to Other Revenue	**113**	-
Net deficit from prior years	-	2
Instalments unexpended- included in Other Liabilities	**112**	4

D) The Association of Universities for Research in Astronomy Inc (AURA) contracted the Observatory to build, in collaboration with the SOAR Telescope, an integrated field unit. The contract was on a best-efforts, time and materials basis and was very successful. The contract was completed on time and within budget. The position at 30 June 2001 was as follows:

	2001 **$000**	2000 $000
Instalment received	-	54
Suppliers' expenses	-	27
Employee expenses	-	30
Net deficit of prior years	-	4
Owing by AURA – included in receivables	-	7

E) The Instituto de Astrofisica de Canarias contracted the Observatory to do a preliminary design on some aspects of their OSIRIS project. The project was successfully completed on time and within budget. The position at 30 June 2001 was as follows:

Instalment received	-	76
Suppliers' expenses	-	12
Employee expenses	-	38
Net surplus at project completion	-	26

F) The Association of Universities for Research in Astronomy Inc (AURA) contracted the Observatory to undertake a design study for an infra-red instrument, IRIS2 G. It was a fixed price contract. The contract was delivered on time and just within budget. The position at 30 June 2001 was as follows:

Instalment received	-	180
Suppliers' expenses	-	45
Employee expenses	-	162
Owing by AURA – included in receivables	-	27

G) The Association of Universities for Research in Astronomy Inc (AURA) contracted the Observatory to undertake a design study for an instrument to be known as GIRMOS. It was a fixed price contract that began in 2000-00 and finished in 1999-2000. The position at 30 June 2001 was as follows:

Instalment received	-	23
Suppliers' expenses	-	68
Employee expenses	-	72
Net defecit on project completion	-	117

H) The Observatory is part of a consortium involved in the development of a planetary nebulae spectrograph. Overall management of the project is the responsibility of one of the consortium members. However, as most of the design and manufacturing work is being done in Australia, the Observatory is managing the financial aspects of the project. The collaborators have lodged their contributions with the Observatory and the Observatory is using those funds to pay for the work packages as they are completed. The Observatory is not itself involved in any of the manufacturing. The financial position at 30 June was as follows:

	2001	2000
	$000	$000
Instalment received	-	191
Suppliers' expenses	**100**	83
Employee expenses	-	-
Instalment unexpended prior year	**150**	**-**
Instalments unexpended - included in other liabilities	**50**	108

ANGLO-AUSTRALIAN TELESCOPE BOARD
NOTES TO AND FORMING PART OF THE FINANCIAL STATEMENTS
for the year ended 30 June 2001

15. Financial Instruments

a) Terms, conditions and accounting policies.

Financial Instruments	Notes	Accounting Policies and Methods (including recognition criteria and measurement basis.)	Nature of Underlying Ir significant terms and c amount, timing and ce
Financial Assets		Financial assets are recognised when control over future economic benefits is established and the amount of the benefit can be reliably measured.	
Cash at Bank	6A	Cash at Bank is recognised at the nominal amount. Interest is credited to revenue as it accrues.	Temporarily surplus fur have interest credited
Receivables	6B	These receivables are recognised at the nominal amount due less any provision for bad and doubtful debts. Provisions are made when collection of the debt is judged to be less rather than more likely.	Credit terms are net 3
Financial Liabilities		Financial liabilities are recognised when a present obligation to another party is entered into and the amount of the liability can be reliably measured.	
Trade Creditors	8B	Creditors and accruals are recognised at their nominal amounts, being amounts at which the liabilities will be settled. Liabilities are recognised to the extent that the goods or services have been received (and irrespective of having been invoiced)	Settlement is usually m
Other Liabilities	8C	Amounts owing to Subaru and the PNS consortium, representing unspent contributions, are recognised at their nominal amounts.	Funds will be expende June 2002.

b) Interest rate risk

Financial Instrument	Note	Floating Interest Rate **2001** **$'000**	Floating Interest Rate 2000 $'000	Non Interest Bearing **2001** **$'000**	Non Interest Bearing 2000 $'000	**Total** **2001** **$'000**	Total 2000 $'000
Financial Assets (Recognised)							
Cash at Bank	6A	387	1 184	**-**	-	**387**	1 184
Cash on Hand	6A	-	-	**34**	31	**34**	31
Receivables for Goods & Services	6B	-	-	**111**	251	**111**	251
Total Financial Assets (Recognised)		387	1 184	**145**	282	**532**	1 466
Total Assets						**48 618**	47 308
Financial Liabilities (Recognised)							
Trade Creditors	8B	-	-	52	92	**52**	92
Other Liabilities	8C	-	-	259	1 240	**259**	1 240
Total Financial Liabilities (Recognised)		-	-	311	1 332	**311**	1 332
Total Liabilities						**1 847**	2 771

The weighted average effective interest rate for Cash at Bank is 4.7% (1999-2000 4.5%)

c) Net fair value of assets and liabilities

	Note	**Total Carrying Amount 2001 $'000**	**Aggregate Net Fair Value 2001 $'000**	Total Carrying Amount 2000 $'000	Aggregate Net Fair Value 2000 $'000
Financial Assets					
Cash at Bank	6A	**387**	**387**	1 184	1 184
Cash on Hand	6A	**34**	**34**	31	31
Receivables for Goods & Services	6B	**111**	**111**	251	251
Total Financial Assets		**532**	**532**	1 466	1 466
Financial Liabilities (Recognised)					
Trade Creditors	8B	**52**	**52**	92	92

Financial Assets

The net fair value of cash assets is their carrying value as shown.

Financial Liabilities

The net fair values of trade creditors and other liabilities, all of which are short term in nature, are their carrying values as shown.

d) Credit risk exposures

The economic entity's maximum exposure to credit risk at reporting date in relation to each class of recognised financial assets is the carrying amount of those assets as indicated in the Statement of Assets and Liabilities.

The economic entity has no significant exposures to any concentration of credit risk.

Research papers

The following list includes research papers published from AAT and UKST data, 1 July 2000–30 June 2001, together with papers published by AAO staff from data obtained entirely from other telescopes. It does not include AAO contributions to the IAU circulars, which are used to make urgent announcements, nor does it include all of the papers that have made use of UKST sky survey plates and atlases.

A list of some of the popular articles published by AAO staff members is given on page 84.

Volume numbers appear in bold, followed by the page number and the year of publication. 'A' or 'S' following each entry indicates whether the paper was based on AAT data or UKST data. 'O' indicates publications by AAO staff members using data obtained from other telescopes. Abbreviations for journals are listed at the end of this appendix, and abbreviations for institutions begin on page ZZ.

ALEXANDER D M, RUIZ M , YOUNG S (HERTFORDSHIRE), HEISLER C (MSSSO), LUMSDEN S (AAO), HOUGH J H (HERTFORDSHIRE), BAILEY J (AAO) 'Near-IR polarimetry of the obscured nucleus in the Circinus galaxy' in *Active Galactic Nuclei and Related Phenomena,* Y Terzian, D Weedman & E Khachikian (eds) p75 2000 (A)

ALONSO-HERRERO A (HERTFORDSHIRE), RYDER S D (AAO), KNAPEN J H (HERTFORDSHIRE) 'Nuclear star formation in the hot-spot galaxy NGC 2903' *MNRAS* **322** 757 2001 (O)

ALONSO-HERRERO A (HERTFORDSHIRE), RYDER S (AAO), KNAPEN J H (HERTFORDSHIRE) 'Nuclear star formation in the hot-spot galaxy NGC 2903' *CFHT Information Bulletin* **42** 16 2000 (O)

ALTON P B (CARDIFF), RAND R J (NEW MEXICO), XILOURIS E M (CRETE), BEVAN S (CARDIFF), ET AL 'Dust outflows from quiescent spiral disks' *A&AS* **145** 83 2000 (A)

AMADO P J, DOYLE J G (ARMAGH), BYRNE P B, CUTISPOTO G (CATANIA), ET AL 'Rotational modulation and flares on RS CVn and BY Dra stars. XX. Photometry and spectroscopy of CC Eri in late 1989'. *A&A* **359** 159 2000 (A)

BAILEY J A (AAO) 'Astronomical sources of circularly polarized light and the origin of homochirality' *Origins of Life and Evolution of the Biosphere* **31** 167 2001 (O)

BAILEY J (AAO) 'Chirality and the origin of life' *Acta Astronautica* **46** 627 2000 (A)

BAILEY J (AAO) 'Circular polarization and the origin of biomolecular homochirality' in *A New Era in Bioastronomy,* G Lemarchand & K Meech (eds) p349 2000 (A)

BAILEY J, TAYLOR K (AAO), ROBERTSON G (SYDNEY), BARDEN S (NOAO)

'Instrumentation plans for the Anglo-Australian Observatory' *New Astronomy Reviews* **45** 41 2001 (I)

BAKER J C (CALIFORNIA), HUNSTEAD R W (SYDNEY), BREMER M N (BRISTOL), BLAND-HAWTHORN J (AAO), ET AL 'Tunable-filter imaging of quasar fields at z ~ 1. A cluster around MRC B0450-221' *AJ* **121** 1821 2001 (A)

BALDI A (MILAN), BARDELLI S, ZUCCA E (BOLOGNA) 'A study of the core of the Shapley Concentration: VI. Spectral properties of galaxies'. *MNRAS* **324** 509 2001 (S)

BALDRY I K, BLAND-HAWTHORN J (AAO) 'A Tunable Echelle Imager' *PASP* **112** 1112 2000 (I)

BALDRY I K, BLAND-HAWTHORN J (AAO) 'Optimising background-limited observing during bright-moon phases and twilight'. *MNRAS* **322** 201 2001 (I)

BALDRY I K (SYDNEY, AAO), BEDDING T R (SYDNEY) 'Time-series spectroscopy of the rapidly oscillating Ap star HR3831'. *MNRAS* **318** 341 2000 (O)

BARNES D G, STAVELEY-SMITH L, DE BLOK W J G (ATNF),...MALIN D F (AAO),...RYDER S D (AAO), ET AL 'The HI Parkes All Sky Survey: southern observations, calibration and robust imaging' *MNRAS* **322** 486 2001 (O)

BARNES J R, CAMERON A C, JAMES D J (ST ANDREWS), DONATI J -F (OMP) 'Doppler images from dual-site observations of southern rapidly rotating stars - II. Starspot patterns and differential rotation on Speedy Mic' *MNRAS* **324** 231 2001 (A)

BARRADO Y NAVASCUES D (MPIA), STAUFFER J R (HSCA), BRICENO C (VENEZUELA), ET AL 'Very low-mass stars and brown dwarfs of the young open cluster IC 2391' *ApJS* **134** 103 2001 (S)

BEASLEY M A, SHARPLES R M (DURHAM), BRIDGES T J (AAO), HANES D A (QUEENS), ET AL 'Ages and metallicities of globular clusters in NGC 4472' *MNRAS* **318** 1249 2000 (O)

BEDDING T R (SYDNEY), BUTLER R P (CIW), KJELDSEN H (AARHUS), BALDRY I K (AAO), O'TOOLE S J (SYDNEY), TINNEY C G (AAO), MARCY G W (CALIFORNIA), ET AL 'Evidence for solar-like oscillations in β Hydri' *ApJL* **549** 105 2001 (A)

BEKKI K (UNSW), COUCH W J (UNSW), DRINKWATER M J (MELBOURNE) 'Galaxy threshing and the formation of ultracompact dwarf galaxies' *ApJ* **552** 105 2001 (A,S)

BENITEZ N (CALIFORNIA), SANZ J L, MARTINEZ-GONZALEZ E (SANTANDER) 'Quasar-galaxy associations revisited' *MNRAS* **320** 241 2001 (S)

BJORNSSON G (ICELAND), HJORTH J (COPENHAGEN), JAKOBSSON P (ICELAND), CHRISTENSEN L (COPENHAGEN), HOLLAND S (NOTRE DAME) 'The jet and the supernova in GRB 990712'*ApJ* **552** 121, 2001 (A)

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Journal abbreviations

A&A	Astronomy & Astrophysics
A&AS	Astronomy & Astrophysics Supplement Series
A&SS	Astronomy and Space Science
AJ	Astronomical Journal
ApJ	Astrophysical Journal
ApJL	Astrophysical Journal Letters
ApJS	Astrophysical Journal Supplement Series
ASP Conf Ser	Astronomical Society of the Pacific, Conference Series
Aust J Astr	Australian Journal of Astronomy
IAJ	Irish Astronomical Journal
JAH^2	Journal of Astronomical History and Heritage
MNRAS	Monthly Notices of the Royal Astronomical Society
PASP	Publications of the Astronomical Society of the Pacific
Publ ASA	Publications of the Astronomical Society of Australia
SPIE Proc	Proceedings of the International Society for Optical Engineering