Anglo-Australian Observatory

Annual Report

of the Anglo-Australian Telescope Board

1 July 1996 to 30 June 1997

The Right Honourable Margaret Beckett 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,
Minister for Employment, 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 1996 to 30 June 1997. 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.

R L Davies
Chair
Anglo-Australian Telescope Board
October 1997

Contents

The year's highlights	vi
1. The Anglo-Australian Observatory	
Statement of purpose	1
History and governing legislation	1
Principal objectives	1
Sources of revenue and net cost of service	2
Ministers responsible	2
Structure of the AAO	3
Board members	3
AAO Director	5
Advisory Committees	5
AAO staff	6
Equal employment opportunity	9
Occupational health and safety	10
2. The year in review	
Operational Environment	11
Strategic directions	13
Key result Area: Telescope operations	14
Key result Area: Research	19
Key result Area: Instrumentation	24
Key result Area: AAO resources	26
Key result Area: External Communication	27
3. Scientific research	
Introduction	31
Stars and the interstellar medium	32
Dwarf Galaxies	39
Redshift surveys with 2dF	43
4. AAO facilities	
AAT facilities	49
UKST Facilities	51
2dF project	51
Taurus tunable filter	52
Rugate filter	53
H-alpha filter	54
Spiral	54
Enhancements to existing instruments	54
Other facilities	57
Appendices	
A. Financial Reports	61
B. Research papers	78
C. AAO research symposia & visiting scientists	89
D. AAT time allocation	91
E. UKST time allocation	98
F. Staff research	100
G. Staff and OH&S policy	108
H. AAO early history	110
Abbreviations for institutions	112
Glossary of abbreviations	114

Anglo-Australian Telescope Board

Australia

Chair
Professor L E Cram
Professor of Physics (Astrophysics), University of Sydney

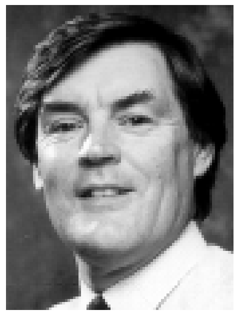
Professor J R Mould
Director, Mount Stromlo and Siding Spring Observatories

Professor M H Brennan
Chair, Australian Research Council

United Kingdom

Deputy Chair
Professor R L Davies,
Professor of Astronomy,
University of Durham

Professor J A Peacock
Royal Observatory,
Edinburgh



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

Anglo-Australian Observatory

Dr R D Cannon
AAO Director
(until September 1996)

Dr B J Boyle
AAO Director
(from September 1996)

Scientific highlights

'Brown dwarf' detected

Spectroscopic observations taken at the AAT have confirmed the first detection of an isolated brown dwarf in our Galaxy. The brown dwarfs are star-like objects which are not massive enough to burn nuclear fuel and so are extremely faint and difficult to detect. The newly discovered brown dwarf is in the constellation of Corvus and has a mass of approximately 60 Jupiter masses, making it the most massive of the small number of known brown dwarfs.

Origins of X-ray background become clearer

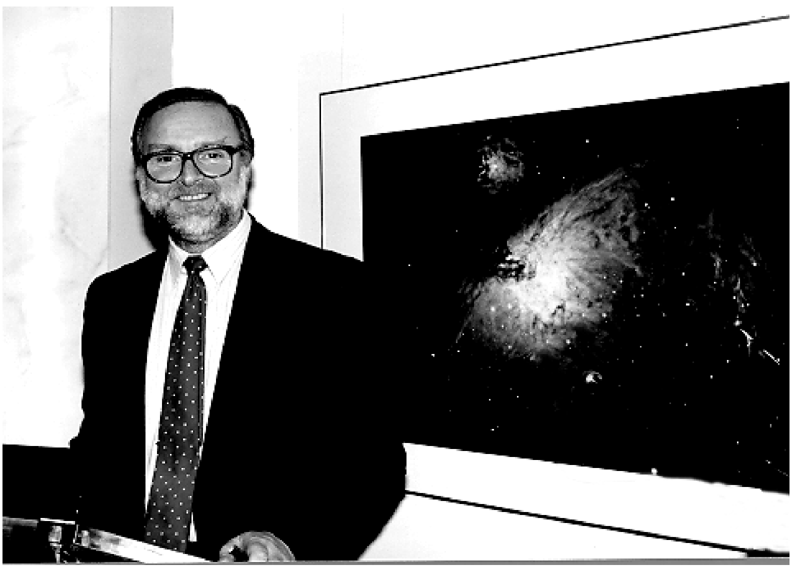
The AAT has played a key role in identifying the origin of the cosmic X-ray background which has been poorly understood until recently. AAT data taken for sources detected with the ASCA X-ray satellite have shown that the X-ray background comes from active galactic nuclei, 40 per cent from quasars and the bulk of the remainder, up to 80%, from Seyfert galaxies.

Research programs begin using 2dF

The first comprehensive scientific observations were taken with the 2-degree field facility at the AAT, with approximately 9000 spectra taken for twenty different research programs. These included the first observations for major redshift surveys of galaxies and quasars. Over 2000 galaxy spectra and 300 quasar spectra have already been obtained for the major redshift surveys.

H-alpha survey

The UK Schmidt has begun a major H-alpha survey of the southern Milky Way and Magellanic clouds, using probably the world's largest single-element optical interference filter for astronomy. A survey of unprecedented area coverage, depth and resolution should result, superior to any previous optical survey of ionized gas in the galaxy.



David Malin at the opening of the 'Night Skies' exhibition at the Victorian Arts centre in Melbourne.

Other highlights

'Night Skies' exhibition

In celebration of 50 years in Australia, the British Council has sponsored two parallel exhibitions of AAO astronomical photographs as part of its 'newIMAGES' campaign. The photographs will be on tour in Australia and the UK until mid-1998 and have attracted much favourable publicity.

Breakfast astronomy

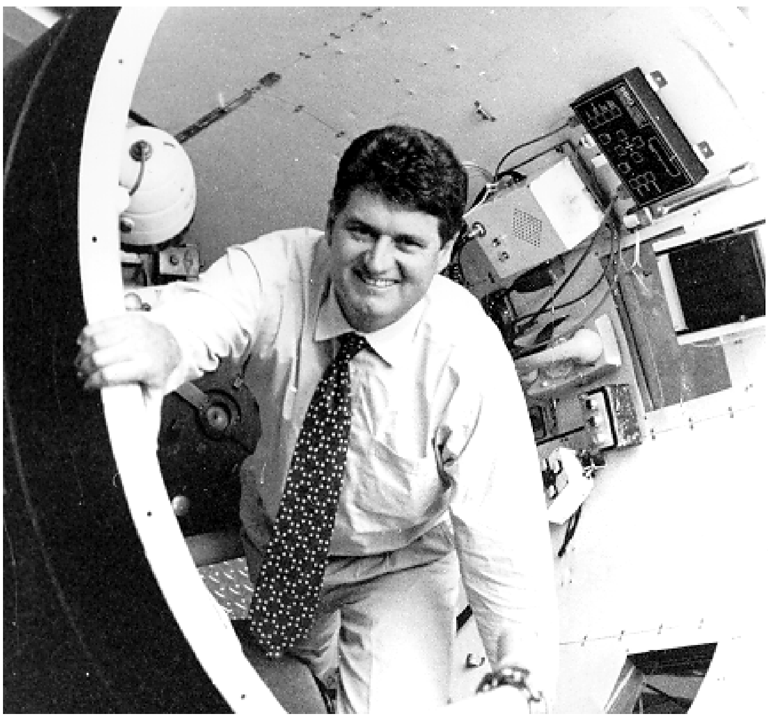
While the main point of Fred Watson's early-morning chats with Phil Clarke on Sydney's ABC Radio 2BL is to raise the profile of astronomy, the Anglo-Australian Observatory receives its fair share of publicity too. These informal astronomy interviews have been a weekly feature of the Breakfast Show since January 1997, and seem to have attracted their own select band of early-rising devotees.

H-alpha workshop

To highlight the H-alpha survey, the AAO organised a very successful three-day International Workshop in Sydney during April 1997. There were about 50 participants, and half came from overseas. Preliminary UK Schmidt survey images were presented. It became clear that the new survey would set the benchmark for wide-field high resolution imaging of our galaxy in ionized gas.

Minister visits AAT

In March 1997, the Honourable Peter McGauran, the Australian Federal Minister for Science and Technology, and Mr John Cobb, the local member for Parkes, visited the Anglo-Australian Telescope. They inspected the 2dF facility and discussed aspects of the AAO's operation with staff members. Their tour concluded with the 'uplifting' experience of a ride in the prime-focus cage.



Minister for Science and Technology, the Hon. Peter McGauran visited the AAT in March.

1. The Anglo–Australian Observatory

About the AAO

Statement of purpose

The Anglo-Australian Observatory provides world-class optical and infrared observing facilities for British and Australian astronomers. 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 an agreement, *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). A brief history of the AAO is given in Appendix H.

Principal objectives and progress towards achieving them

Good science Many excellent scientific programs were carried out at the AAO during the year. One is highlighted here, and details of a variety of programs are given in Chapter 3.

Observations at the AAT detected the presence of a 'brown dwarf' in the constellation of Corvus. Brown dwarfs are very difficult to detect because they are extremely faint. They are star-like objects not massive enough to burn nuclear fuel like the sun, and they are proposed as a source of the Universe's dark matter.

A suite of instruments that best meets the needs of the astronomical community The Two-degree Field (2dF) facility for the AAT has been under development for the past seven years. This year, the project progressed further, and as well as commissioning, a number of scientific programs were begun, and promising results were obtained. There has been a strong demand for observing time on the 2dF from both Australian and United Kingdom astronomers.

A new H-alpha filter for the UKST was acquired and put into operation. It will be used in a H-alpha survey of our own galaxy, and the nearest neighbouring galaxies, the small and large Magellanic Clouds. This survey will give more information about how stars form and die.

Most efficient use of AAO resources The Corporate Plan sets out Key Result Areas, Key Outcomes and Performance Indicators. A full report on the AAO's principal objectives and the progress made towards achieving them is given in Chapter 2. Copies of the Corporate Plan are available from the AAO on request.

Sources of revenue and net cost of service

The sources, levels and relative shares of revenue over the past five years, at current values are shown in Table 1.1.

Table 1.1 Sources, levels and relative shares of revenue 1992–93 to 1996–97

Sources of Revenue $k, *(%)*	1992–93	1993–94	1994–95	1995–96	1996-97
United Kingdom contribution	3195 *(47)*	3203 *(47)*	3043 *(45)*	3119 *(46)*	*3287 (47)*
Australian contribution	3055 *(45)*	3063 *(45)*	3043 *(45)*	3164 *(47)*	*3281 (47)*
Royalties & sales of images	94 *(1)*	91 *(1)*	113 *(2)*	98 *(1)*	*136 (2)*
Space Telesc. Science Inst.	68 *(1)*	81 *(1)*	94 *(1)*	99 *(1)*	*26*
Other	316 *(5)*	339 *(5)*	301 *(4)*	267 *(5)*	*257* (4)
2dF grants	218	42	0	0	0
Total	**6946**	**6819**	**6594**	**6747**	**6961**

Ministers responsible

The Australian Minister responsible for the Anglo-Australian Telescope Board is Senator Amanda Vanstone, Minister for Employment, Education, Training and Youth Affairs. In May 1997, the Minister responsible in the United Kingdom, The Right Honourable Ian Lang, MP, was replaced by The Right Honourable Margaret Beckett, MP, as President of the Board of Trade and Secretary of State for Trade and Industry.

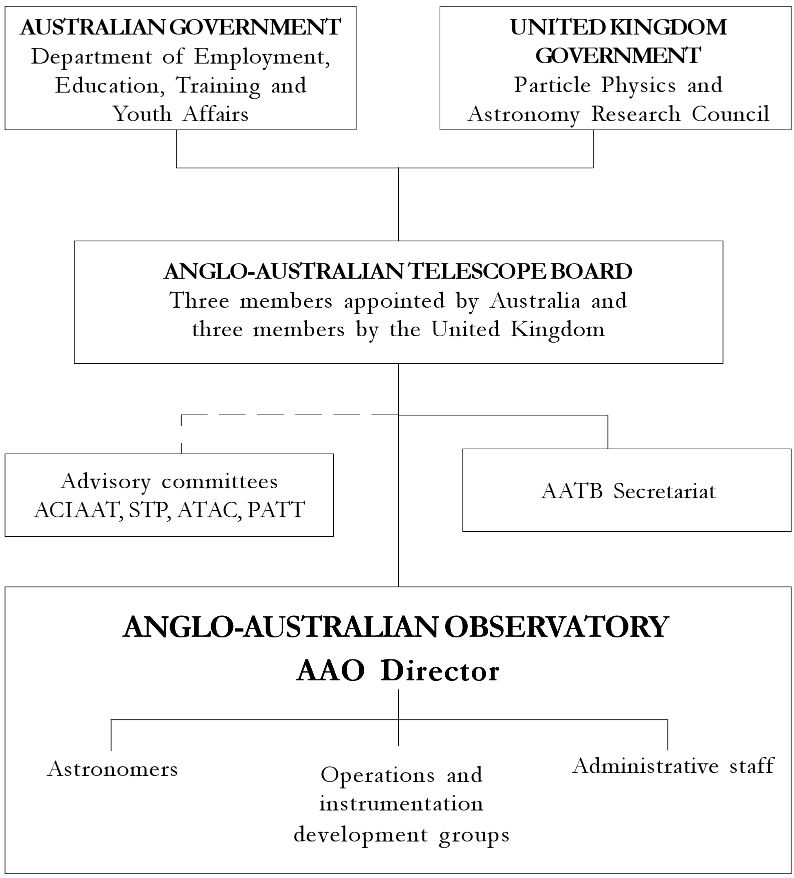
Designated agencies

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 Employment, Education, Training and Youth Affairs (DEETYA) 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.

Figure 1.1 General structure of the AAT Board and the AAO



Board members

The AAT Board has six members, three appointed by each country, and the role of Chair alternates between the two countries. Until 30 June 1997, the Board was chaired by Professor L E Cram of the University of Sydney. Professor R L Davies took over the Chair on 1 July 1997. Professor R D Ekers was appointed to the Board on 1 July 1997. At 30 June 1997 the Board members were:

Board members

Australia

Professor L E Cram (Chair), Professor of Physics (Astrophysics), University of Sydney (Appointed until 30 June 1997)

Professor J R Mould, Director, Mount Stromlo and Siding Spring Observatories (Appointed until 31 December 2000)

Professor M H Brennan, Chair, Australian Research Council (Appointed until 31 December 1997)

United Kingdom

Professor R L Davies (Deputy Chair), Professor of Astronomy, University of Durham (Appointed until 30 June 1999)

Professor J A Peacock, Royal Observatory, Edinburgh (Appointed until 30 June 1998)

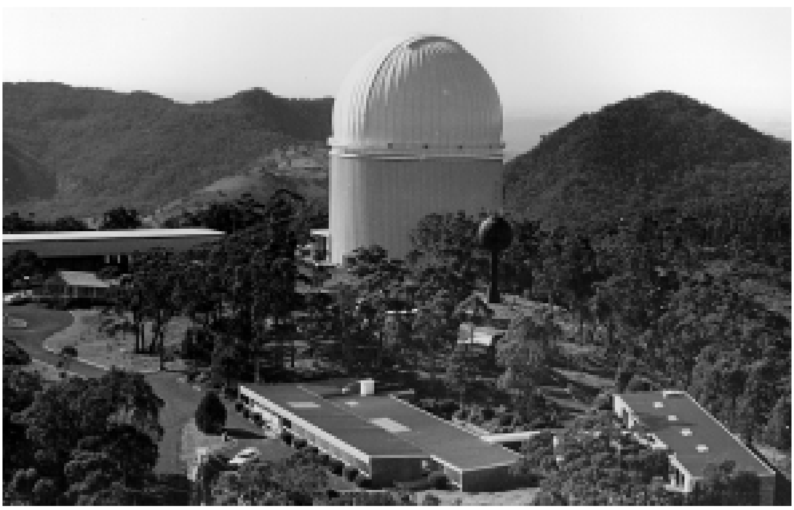
Dr I F Corbett, Director Science and Deputy Chief Executive, Particle Physics and Astronomy Research Council (Continuing appointment)

Special responsibilities

Professor Brennan and Dr Corbett have been nominated by the Designated Agencies, DEETYA and PPARC respectively, to represent that agency on all matters in relation to the operation of the Agreement. Professor Davies represents the Board on the UK Ground Based Facilities Committee, which advises the PPARC on instrumentation priorities for all the UK ground-based telescopes.

Board meetings

The AAT Board usually meets twice each year. All six Board members attended both meetings in 1996–97.



DAVID MALIN

The Australian National University lodge is in the foreground of this aerial photograph of Siding Spring Mountain, which is dominated by the dome of the AAT.

In September 1996, the meeting was hosted by University of Manchester. The associated scientific symposium, previously held immediately following the Board meeting, was held at the time of the United Kingdom National Astronomy Meeting, in April 1997. In March 1997, the Board meeting was held at both Siding Spring Observatory and the Epping Laboratory in Sydney. Once again, the symposium was held jointly with the Australia Telescope National Facility (ATNF), and was hosted this time by the School of Physics, University of New South Wales. These joint symposia help to maintain the strong links which exist between the radio and optical communities in Australia. The scientific papers presented at each symposium are listed in Appendix B.

AAO Director

The ten-year term of appointment of Dr R D Cannon, the then Director, concluded in September 1996. At that time, Dr B J Boyle, formerly of the Royal Greenwich Observatory in the UK, commenced as AAO Director. The AAO Director is responsible for the successful operation of the telescopes, for providing the best possible facilities for all telescope users and for ensuring that the Observatory maintains its high standing in the international scientific community. The Director also retains an active interest in his own scientific research.

Advisory committees

Advisory Committee on Instrumentation for the AAO

The Advisory Committee on Instrumentation for the AAO (ACIAAT) provides advice to the Board on a wide range of instrumentation matters. In consultation with the AAO Director and both user communities, it formulates plans for new instruments and other facilities, and recommends priorities to the Board. Committee members communicate regularly and meet as required. ACIAAT reports formally to the Board each September. At 30 June 1997 the five ACIAAT members were:

United Kingdom	Dr M J Barlow (UCL)
	Dr T Shanks (Durham), Chair
Australia	A/Prof W J Couch (NSW)
	Dr P J McGregor (MSSSO)
AAO Head of Instrumentation	Dr K Taylor

Schmidt Telescope Panel

The Schmidt Telescope Panel (STP) determines priorities for the scientific program of the telescope and advises the Board on future scientific possibilities. Assessments of the non-survey and FLAIR II applications are carried out by the respective national halves of the Panel. At 30 June 1997 the seven STP members were:

Australia	Dr R W Hunstead (Sydney)
	Dr J E Norris (MSSSO)
United Kingdom	Dr R McMahon (IoA),

	Dr C Collins (Liverpool J M), Chair
Astronomer-in-Charge, UKST	Dr F G Watson
Head of the UKST Unit (ROE)	Dr D H Morgan
AAO Director	Dr B J Boyle

Time allocation committees

Under Article 5 of the Anglo-Australian Telescope Agreement, observing time and use of associated facilities and services is shared equally by Australia and Britain. The Board has chosen to exercise its responsibility for the allocation of time on the AAT through arrangements made with the two Designated Agencies. Under guidelines set by the Board, each agency operates through a national committee — the Australian Time Assignment Committee (ATAC) and the UK Panel for the Allocation of Telescope Time (PATT) — which allocates time on the AAT on the basis of the scientific merit of proposals submitted by astronomers, including AAO staff. At 30 June 1997, membership of the two committees was:

ATAC	PATT (AAT TAG)
Dr R Webster (Melbourne) Chair	Dr I Howarth (UCL) Chair
Dr T Axelrod (MSSSO)	Dr M Hoare (Leeds)
Dr T Bedding (Sydney)	Dr R McMahon (IoA)
A/Prof W Couch (NSW)	Dr S Phillipps (Bristol)
Dr J Hawthorn (AAO)	
Dr C Heisler (MSSSO)	
Dr R Norris (ATNF)	

AAO staff

Staff numbers

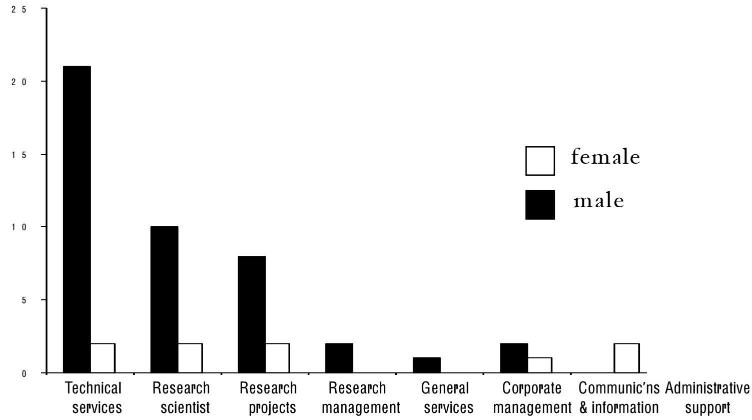
The AAO employs research scientists, technical staff, computer programmers, electronics engineers, optical and mechanical engineers, administrative and library staff. There are ten fixed-term research astronomers, one of them part-time, and three other fixed-term staff members, including the Director. The remainder of the staff are on indefinite appointment. Staff are located at both the Epping Laboratory and at Siding Spring Observatory.

Table 1.2 Staff numbers by tenure

At 30 June 1997 the staff positions were:

	Full time	Part time
Director	1	
Fixed term research	7	1 (0.5 FTE)
Other fixed-term	3	
Visiting scientific staff	1	
AAO Fellow	0	1 (0.6 FTE)
Indefinite appointment	45	2 (1.05 FTE)

Figure 1.2 Staff numbers by functional area and gender



Staff turnover

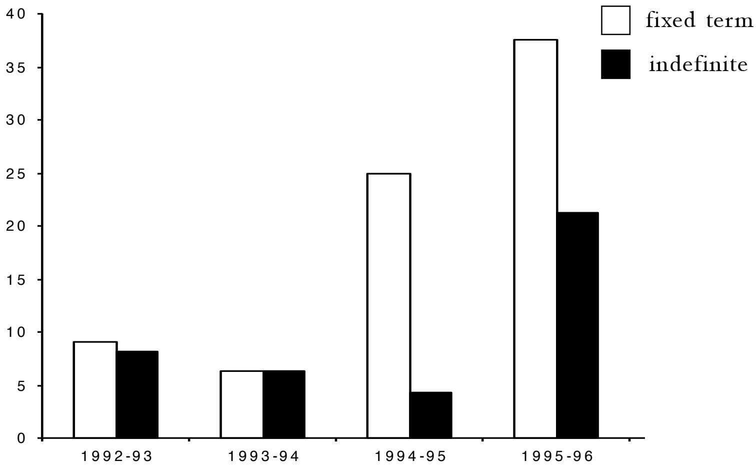
Table 1.3 shows the turnover rates for the year 1996–97, and figure 1.3 the trends. Turnover among fixed term staff, who normally have terms of about five years, can be expected to be about 20 per cent a year. The unevenness of the trends has been caused by the 2dF project which involved several fixed-term staff whose appointments came to an end as the project neared completion.

Turnover among staff with indefinite appointments had been fairly low and reasonably steady until 1995–96. A large jump in turnover could be a cause for concern. However, all but one of the people who resigned in 1995–96 did so for personal reasons. Two others had reached retirement age and, sadly, one staff member died suddenly. The turnover rate among indefinite staff returned to historic levels in 1996–97.

Table 1.3 Staff turnover 1996–97

	Fixed term			Indefinite			Grand
	Female	Male	Total	Female	Male	Total	Total
Staff at 1 July 96	4	10	14	12	35	47	61
Staff at 30 June 97	3	10	13	11	36	47	60
Resignations	1	3	4	2	0	2	7
Retirements	0	0	0	0	1	1	1
Total departures	**1**	**3**	**4**	**2**	**1**	**3**	**7**
Turnover rate for year (%)	25	30	28	17	3	6	11
Appointments	0	3	3	1	1	2	5

Figure 1.3 Trends in staff turnover



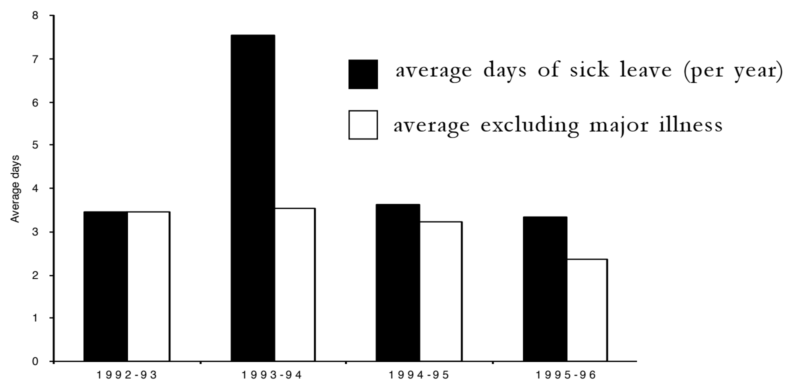
Sick leave

Figure 1.4 displays two sets of indicators for sick leave trends. One column shows the overall average rate of sick leave per person, the other with adjustment made for episodes of major illness. The peak in 1993–94 was due to major illnesses of two people. During 1996–97, 1.85 per cent of usual working hours were lost due to sickness, and a further 0.3 per cent to personal leave. This is well below reported averages for Australia as a whole, where 2.4 per cent of usual working hours are lost due to unscheduled absences (from *Managing Absenteeism*, Department of Industrial Relations, 1995).

Enterprise bargaining

The Anglo-Australian Telescope Board's first Enterprise Agreement expired at the end of March 1995. Both the AAO and the Community and Public Sector Union (CPSU) were content to let the Agreement run until March 1996, when it was replaced with a new Agreement that will run until July 1997.

Figure 1.4 Trends in sick leave



The new Agreement provided for a salary increase in three stages: 3 percent from 1 November 1995, 2 percent from 1 November 1996 and 1.5 percent from 1 April 1997. A key component of the Enterprise Agreement was to identify potential productivity improvements and it was agreed that a joint union/management working group would be established for this purpose. The outcome was a series of recommendations relating to performance planning and evaluation. The main changes recommended, and adopted, were more formal project management and a move away from individual work objectives to team-based objectives.

The CPSU and the Observatory also negotiated an Anglo-Australian Telescope Board Award to replace the Draft Interim Consent Award negotiated in May 1995.

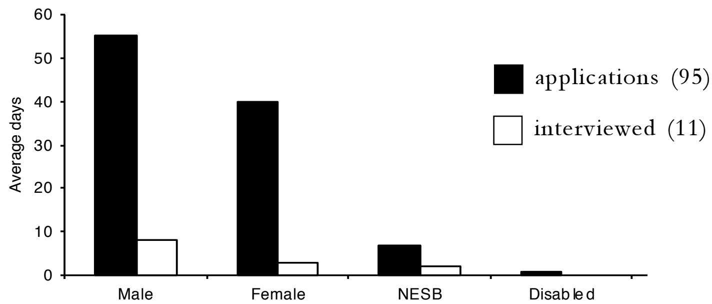
Equal employment opportunity (EEO)

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 Employment, Education, Training and Youth Affairs.

As Figure 1.2 reveals, only a quarter of the Observatory's staff are female and, of those, half are administrative staff. Only one member of staff is of non-English speaking background.

There may well be valid reasons for such an employment profile. However, the AAO is keen to ensure that bias is not present in the recruitment process, which has been overhauled in recent years. A senior member of the AAO's staff, who has extensive experience in recruitment and equal employment opportunity, is now involved in all recruitment exercises. This provides hands-on training for selection committee members as well as ensuring that selection is solely on the basis of merit. In 1996–97, for the first time, EEO information was sought from applicants on a voluntary basis. The results are summarised in figure 1.5. There were only two recruitment exercises, too few to allow robust conclusions. There is no sign of bias in either the culling process or the final selection process. What is striking is

Figure 1.5 Recruitment statistics for EEO target groups



how few applicants fall into the EEO target groups. One of the positions recruited was a technician and, perhaps not surprisingly, there were very few female applicants. A review of advertisements and advertising strategies has not revealed any reason why EEO target groups would feel reluctant to apply.

Occupational health and safety

The Anglo-Australian Telescope Board's safety policy and its agreement on health and safety with the Public Sector Union are set out in Appendix G. During the year, the Observatory continued its program of minor upgrades in the working environment in order to minimise hazards to both staff and visitors at the Epping and Siding Spring sites.

Comcare is a statutory authority established to administer the *Commonwealth Employee's Rehabilitation and Compensation Act 1988*. The Board has an extensive compensation policy for its employees. For the year ended 30 June 1997 the Board's premium to Comcare was $31 431.

There were four new compensation claims during 1996–97, one falling into each of the following Comcare categories:

Back	Strain (excluding back)
Contusion/crush	Occupational Overuse Syndrome

Payments made during the year amounted to $3578, which includes salary reimbursement. There were no rehabilitation expenses in relation to any of these cases.

In June 1996, Comcare carried out a planned investigation of the Epping site. Comcare rated the Observatory highly in many safety aspects, especially those relating to having appropriate systems in place and working well. However, two areas were highlighted as needing improvement, one of which was chemicals handling. Immediate steps were taken to engage the services of New South Wales Workcover, the State's safety body, to advise on better practices. Workcover's recommendations have now been implemented. The other area identified as needing improvement was training for supervisors. This was remedied during the year as all supervisors received training. As shown in Table 1.4, there was one 'dangerous occurrence' that required notification to Comcare in 1996–97.

Table 1.4 Dangerous occurrences reported to Comcare

1993–94	1994–95	1995–96	1996–97
3	1	1	1

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 over two decades.

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 press for the benefit of other scientists and the academic community. They are also widely publicised in more accessible places for the benefit of the general public.

The intellectual challenge of astronomical research attracts some of the finest scientific minds. Astronomy is both highly international and 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 one of the largest and most powerful in the world. 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. More than twenty 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.

By the end of the century, astronomers will have access to a new generation of telescopes with mirrors eight metres or more in diameter. 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 new facilities that exploit the unique capabilities of the AAT and the UKST. In particular, the Two-degree Field (2dF) facility for the AAT will ensure continued high international profile and scientific productivity for the telescope well into the next century.

The new 2dF facility, which has been under development at the Observatory for the last seven years, incorporates several innovative high precision technologies and is by far the largest and most complex instrument of its type to be built anywhere in the world. A similar although much smaller system, FLAIR II, has been developed for the UKST. 2dF and FLAIR II effectively exploit the unique wide-field capabilities of the AAT and UKST respectively, and use optical fibres to enable the simultaneous spectroscopic observation of many stars or galaxies. These are examples of how the AAO will maintain its international edge. Both will greatly enhance the productivity of the telescopes and ensure that scientists from both communities continue to have access to state-of-the-art equipment.

The initial 25 year period for the *Anglo-Australian Telescope Agreement* ended in February 1996. In April 1994, after consultation with its advisory committees and with the user communities in both countries, the Board prepared a paper, *Options for the Anglo-Australian Observatory into the 21st Century*. It concluded that funding should continue at a level sufficient to maintain the AAO as a well-instrumented, front-line observatory. As a consequence of the Board's positive recommendations in the Options paper, the original Agreement remains in force.

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: most research is done by external users. 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 Advisory Committee on Instrumentation for the AAO, the Schmidt Telescope Panel and AAO staff contribute very positively to the kind of science possible with AAO facilities.

DAVID MALIN

The ridges of the Warrumbungle mountains outline the distant horizon, while grass trees ornament the foreground.

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
- New instrumentation
- Use of AAO resources
- External communication

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.

Telescope Operations

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 Advisory Committee on Instrumentation for the AAO, the Schmidt Telescope Panel 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 1996 to 30 June 1997 is shown in Table 2.1. This year there were 3287 night hours available. In addition, a further 463 hours of twilight and 11 daylight hours 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 1996–97 this was 1.6 percent, similar to other years.

Table 2.1 Use of observing time on the AAT

	1993–94	1994–95	1995–96	1996–97
	Percentage of total night-time hours			
Observing (includes commissioning)	64.9	65.4	59.5	62.8
Loss due to weather	32.9	31.9	37.6	35.0
Loss due to AAT equipment failure	1.6	2.1	1.6	1.6
Loss due to other factors	0.6	0.6	1.3	0.6

User feedback

Another constructive way to assess user satisfaction is to ask users how well they regard the level of service offered. Traditionally, observers were asked to report on their experiences of the AAO. The overall feedback received was positive. However, the information collected in this way was difficult to analyse. In November 1996 a new system was established. Observers at the AAT and UKST now complete a form on the worldwide web 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, software, technical manuals, administration and web pages. These are ranked on a scale of 1 (poor) to 4 (excellent).

During the period 1 November 1996 – 30 June 1997 a total of 33 user feedback forms were completed for the AAT. This represents about two-thirds of external users. Table 2.2 summarises the information for the AAT. This table shows that the level of user satisfaction is generally very high. As well as providing a quantitative analysis, the individual forms have proved extremely useful in showing where improvements may be needed. In particular, the users responses have emphasised the need for better instrumentation manuals and a better working environment at the AAT. Both issues are being addressed.

Although the UKST is run primarily in service mode, the small number (5) of survey forms completed by visiting astronomers using the UKST FLAIR II system, indicates an overall high level of user satisfaction.

Table 2.2 User feedback at the AAT

	Average rank (maximum 4)
Night assistant support	3.8
Staff astronomer support before observations	3.4
Staff astronomer support during observations	3.7
Other technical support	3.7
Instrumentation and software	3.2
Working environment	3.1
Travel and administrative support	3.3
Data reduction software	3.0
Instrument manuals	2.6
AAO web pages	3.1

UK Schmidt Telescope organisational statistics

The 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 II multi-object spectroscopy system.

Table 2.3 Comparison of plates taken and hours of FLAIR II observations

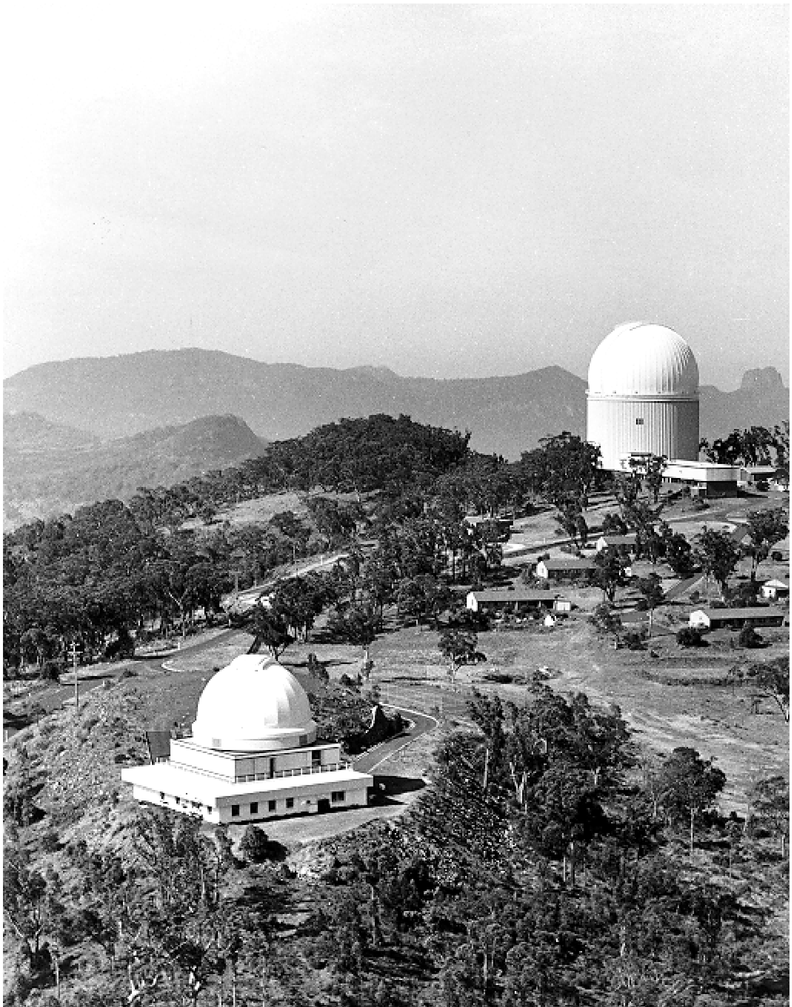
	1992–93	1993–94	1994–95	1995–96	1996-97
Plates and films	585	549	507	465	485
FLAIR II hours	282	309	345	203	272

Totals of 308 plates and 177 films were obtained during the year, including test exposures. FLAIR II observations were made on 73 nights. On 37 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 272 hours of science data was obtained using FLAIR II, which corresponds to about 36 percent of all the observing time used on the UKST.

Table 2.3 shows the annual totals of photographic exposures and hours of FLAIR II observations. The steady increase in the latter until 1994–95 resulted in a corresponding decline in the number of plates and films taken. The fall of both in 1995–96 was primarily due to poorer-than-usual weather conditions and reduced FLAIR II exposure times following the introduction of a new, more efficient CCD.

Somewhat better observing conditions during 1996–97 are reflected in an upturn in both photographic and FLAIR II exposures during this period.

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



DAVID MALIN

The UKST, in the foreground, and the AAT at Siding Spring Mountain.

UKST performance indicators

The use of scheduled observing time on the UKST from 1 July 1996 to 30 June 1997, compared to previous years, is shown in Table 2.4. Observations were also carried out on a further nine nights in bright-of-moon periods, primarily to undertake commissioning of the new H-alpha filter.

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 UKST 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

	1993–94	1994–95	1995–96	1996–97
	Percentage of total night-time hours			
Used for observing	51.4	49.8	43.5	48.8
Lost due to poor observing conditions	48.2	50.0	56.1	49.4
Lost due to equipment faults	0.4	0.2	0.4	1.8

Table 2.4 shows a return to more normal observing conditions after the previous year's poor weather. However, more time than usual was lost to equipment faults. A major failure of the sidereal drive was the principal cause of this, but problems were also experienced with the plateholder elevator and the FLAIR CCD camera.

Table 2.5 shows that steady progress has been made with the surveys. Because of pressure to complete the ER and SES surveys, plates have been attempted in more marginal conditions, resulting in a slightly higher overall rejection rate than in the previous year.

Table 2.5 Current Survey Status

	Plates 1995–96		Plates 1996–97		Total for survey		
	Total	A-grade	Total	A-grade	Obtained	Required	Total
Survey							
ER	29	16	10	8	265	23	288
I	79	56	60	39	700	194	894
R(SES)	63	51	66	47	555	51	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 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 14 research astronomers on the staff of the AAO in 1996–97. 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; two of the eight work part-time. The other six are research astronomers but have significant responsibilities not directly related to their own research. These include the Director, the Head of Instrumentation, the Astronomer in Charge of the Schmidt Telescope, the Astronomical Photographer and two other staff. The full time equivalent research effort is about 5.5 people.

Appendix B lists research papers published from AAT and UKST data during the period 1 July 1996 to 30 June 1997 as well as other papers published by AAO staff. Appendix D presents the AAT observing program from 1 August 1996 to 31 July 1997. This information, and equivalent information from previous years, is summarised in Tables 2.6 to 2.9.

Table 2.6 Numbers of 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
1991–92	20	44	36	10	110	30
1992–93	18	40	43	10	111	33
1993–94	15	36	40	13	104	35
1994–95	16	35	45	18	114	33
1995–96	17	26	38	21	102	27
1996–97	25	34	26	17	102	42

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
1991–92	20	15	27	17	79
1992–93	19	12	28	21	80
1993–94	19	20	19	18	76
1994–95	18	12	32	14	76
1995–96	17	13	45	34	109
1996–97	12	18	50	21	101

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
1991–92	9	8	32	10	59
1992–93	9	3	7	7	26
1993–94	9	3	23	14	49
1994–95	8	2	9	11	30
1995–96	17	3	22	18	60
1996–97	9	7	13	21	50

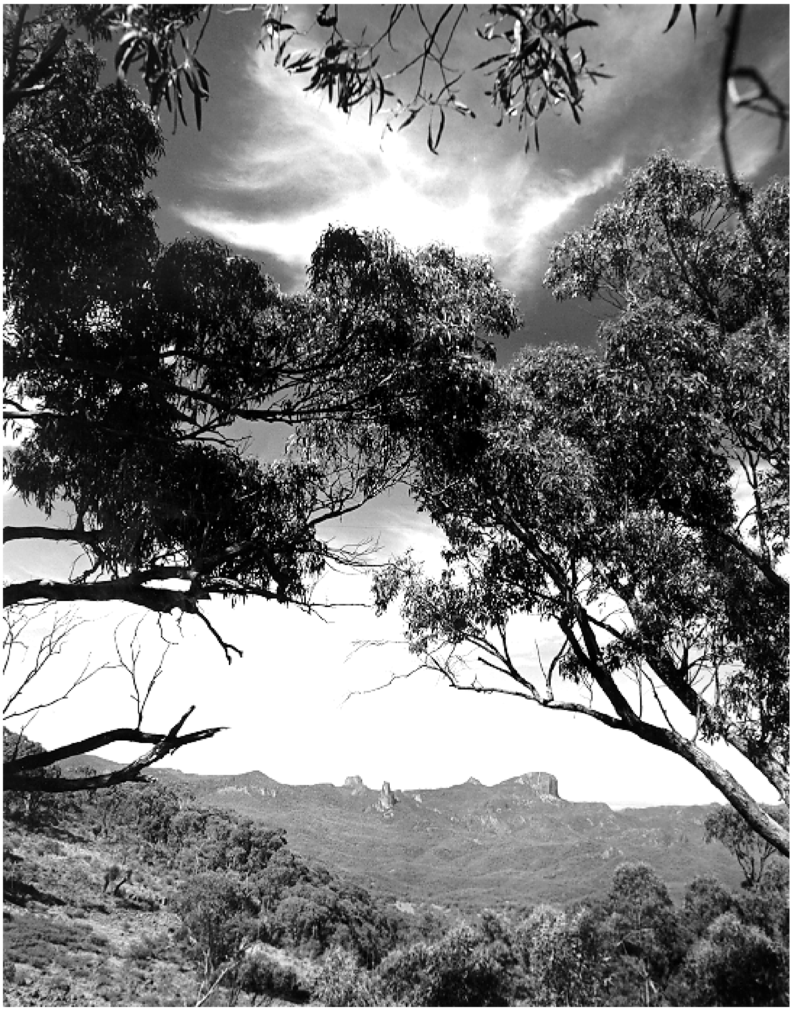
Table 2.9 Total numbers of AAO publications in refereed journals and conference proceedings (including papers published by AAO staff, students and visitors)

	AAT papers	UKST papers	Other AAO papers	Total AAO papers*
1991–92	31	17	36	84
1992–93	32	13	35	68
1993–94	37	17	23	76
1994–95	34	12	32	76
1995–96	34	24	26	84
1996–97	30	14	42	85

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

The tables reveal that AAO publication rates are fairly stable over the six year period. Each year AAO scientists are included on between 30 and 40 percent of all AAT observing programs and publications using AAT data. AAO scientists are first author in approximately 25 per cent of all AAT publications.

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. For each of the last six years the total number of AAO papers produced by AAO staff members, students and visitors has been between 68 and 85. Of these, approximately 80 per cent are in refereed journals. The average annual number of publications per research staff member is between 4 and 5.



DAVID MALIN

Curving eucalypts appear to embrace the distant view of the Warrumbungle range seen from Siding Spring Mountain

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 1992 to 1997, the average number of papers per program is about 0.8. The equivalent statistic for publications and proposals involving AAO staff is 1.1.

Table 2.10 Publications per AAT observing program

	Publications per AAT observing program	AAO publications per AAT observing program
1992–93	0.73	1.07
1993–94	0.68	1.12
1994–95	0.73	0.97
1995–96	0.96	1.03
1996–97	0.99	1.11
Average 1992–97	**0.82**	**1.06**

External Performance indicators

The evaluation of research performance is not a straightforward matter. One measure is to compare publication rates in refereed journals between telescopes, as Table 2.11 does for the British telescopes, including the two AAO telescopes. Publication numbers given for the UK Schmidt 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 Royal Greenwich Observatory and Royal Observatory, Edinburgh)

	AAT*	UKST	WHT	INT	JKT	UKIRT	JCMT
1991	67	77	39	63	19	60	36
1992	71	71	42	56	25	63	33
1993	57	82	55	70	30	72	42
1994	62	66	78	63	44	77	64
1995	89	99	90	81	29	64	67
1996	86	100	100	84	52	80	50

* *AAT data is shown for financial years, ie 1991–92 etc*

A performance measure that attempts to measure the quality, rather than just the quantity, of research output is the number of times a paper is cited in other papers. Three external analyses give some insight into the AAT's citation record. One is a citation survey carried out by Dr J Mitton and published in *Science Watch*, the journal of the US Institute of Scientific Information, in June 1993. In the 20 papers with the highest number of citations during 1992, five of them used AAT data. No other telescope ranked so highly on this basis.

A second survey, *Papers and Citations Resulting From Data Collected at Large, American Optical Telescopes*, was carried out by Dr V Trimble (1995, PASP, **107**, 977). The focus of this survey was the performance of American telescopes and the journals examined in seeking citations were the Astrophysical Journal, the Astronomical Journal and Publications of the Astronomical Society of the Pacific. Even though there were no Australian or British journals canvassed, papers based on AAT results were cited at the rate of 4.96 times per paper, the fourth highest citation rate among the 32 telescopes in the survey.

In a more recent study, *The Cost Effectiveness of Observational Astronomical Facilities since 1958*, David Leverington (1996, QJRAS, **31**, 643) analysed the citation rates for the 15 percent most cited papers published in the two primary American and British journals, the Astrophysical journal and the Monthly Notices of the Royal Astronomical Society. For this purpose, the author used citation rates for papers published in the first six months of the years 1958–1994, at four-yearly intervals. This study shows that over the period between 1978 and 1994 (when the AAT was in operation), the highest averaged and cumulative citation rates for any ground- or space-based observatory, operating in any waveband, were obtained by the AAO for papers based on AAT data. This study, although sparsely sampled, clearly highlights the extremely strong scientific output of the AAT.

Key result area: instrumentation

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

Strategies

As with the other key result areas, an important strategy in meeting the instrumentation objective is to be very much aware of developments in astronomy and instrumentation and of the needs of the astronomy community. The Advisory Committee on Instrumentation for the AAO, in which the AAO's Director and Head of Instrumentation participate, is the mechanism for reviewing the instrumentation needs of the astronomy community and advising on an appropriate development program, bearing in mind AAO staff and financial constraints.

In implementing the instrumentation development plan, two strategies are important. First, good project management is essential, and the Observatory has implemented a project management training program for project staff. Secondly, every effort is made to involve astronomers, engineers, software specialists and technicians, at both sites, in the 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 time dedicated to instrument development. The figures show that the RGO Spectrograph continues to be the single most popular instrument, followed by IRIS. Taurus II use has increased dramatically with the introduction of the powerful Taurus Tunable Filter facility. Combined demand for UCLES and UHRF had fallen slightly in recent years, but appears to have flattened out. These patterns can be expected to change substantially when the 2dF facility becomes available for general scientific use in the near future.

Detector use in recent years is outlined in Table 2.13. Charge coupled devices (CCDs) remain the most used astronomical detector. Infrared arrays (as used in IRIS) use similar technologies, though with different materials, and are in use for almost all the time when CCDs are not in use on the AAT.

Table 2.12 Use of AAT instruments for the last four years

Instrument	Percentage of nights allocated 1993–94	1994–95	1995–96	1996–97
RGO Spectrograph (including FORS)	19.0	28.5	24.3	23.6
RGO Spectrograph with polarimeter	3.4	6.8	6.9	6.5
AUTOFIB	8.3	3.7	0.0	0.0†
FOCAP	2.0	0.0	0.9	0.0
Low dispersion survey spectrograph (LDSS)	1.4	1.1	5.8	2.7
UCL coudé echelle spectrograph (UCLES)	18.8	10.8	12.7	12.9
UHRF	9.1	8.5	3.1	6.5
Taurus II	2.3	4.6	5.8	13.3
IRIS	18.5	17.9	21.7*	22.4
Infrared photometer-spectrometer (IRPS)	0.0	0.0	2.2 (IRPS and Hatfield combined)	0.0†
Hatfield photometer	1.4	0.0		0.0†
Auxiliary photometer	0.6	0.6	0.2	0.0†
Prime focus imaging with CCD	4.3	2.6	8.9	5.3
f/1 focal reducer	2.6	2.3	0.0	0.0
Prime focus photography	2.6	2.3	1.2	1.5
Instruments supplied by users	5.7	10.3	6.4	5.3

* Includes UNSWIRF in 1995–96
† Instrument decommissioned in 1996–97

Table 2.13 Use of AAT detectors for the last four years

Detector	Percentage of nights allocated 1993–94	1994–95	1995–96	1996-97
CCDs	70.6	73.5	67.5	72.6
IPCS	2.3	0.0	0.6	0.0†
Infrared	19.9	18.8	23.8	22.4
Photometer	0.6	0.6	0.2	0.0†
Photographic plates	2.6	2.3	1.2	1.2
Detectors supplied by users	4.0	4.8	6.7	6.7

† Detectors decommissioned in 1996–97

Performance indicators

The instrumentation program is largely shaped by the advice given to the AAT Board by ACIAAT and the STP. The two committees consist 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, a system has been implemented to seek this information from observers.

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 most important strategy for achieving this objective is the involvement of all staff in corporate planning and other reviews. Their involvement means that many different perspectives can be taken into account, leading to a more rounded approach. It also means that all staff understand the final outcome of such processes and feel far more commitment to, and ownership of, the results than would otherwise be the case.

The Observatory is committed to equal employment opportunity and up-to-date occupational health and safety 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 has begun and will be stepped up over the next two or three years.

Organisation statistics and performance indicators for the AAO's human resources, its people, are included in Chapter 1.

Organisational statistics (Financial)

The financial statements in Appendix A elsewhere in this report 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 was assessed comparatively poorly in 1994–95 but has markedly improved its ranking in later years.

External communication

Key result area: external communication

Key outcomes: a lively awareness of astronomy in general, and the AAO's role in particular, by all stakeholders. A leading role for the AAO in the development of long-term plans and strategies for astronomy in both countries.

The AAO is aware that good communication is a key to all its activities, and that it must always be listening to its stakeholders. These include AAO staff, the astronomy community, responsible Ministers, funding agencies, the Board and its advisory committees, the time assignment panels and the general public. The Observatory over the next few years will develop communication programs to target each group.

Public Relations

Photographic exhibitions

A major new public relations activity of the Observatory during the year has been involvement in the British Council's 'newIMAGES' campaign. The Council recognised the Observatory as an outstanding example of a successful British–Australian collaboration and chose to use its astronomical photographs as part of the celebrations of the Council's 50 years in Australia. This led to two parallel exhibitions of 40 AAO photographs touring art galleries and other venues in Australia and the UK. The UK–Australia exhibitions have been accompanied by a fine illustrated catalogue and several public lectures in Australia and the UK by David Malin. The AAO was also closely involved with producing a series of 12 'southern sky' posters intended for schools and British Council Offices around the World.

The Australian 'Nightskies' exhibition opened at the Victorian Arts Centre in Melbourne in March, and attracted 50 000 visitors until it closed at the end of May. It was at the new Parliament House in Canberra in June and will be in Sydney in July–August 1997, thereafter touring other venues in Australia, until at least May 1998. The British exhibition opened to considerable acclaim at Australia House in London in January and is currently touring Britain. It also has a full schedule well into 1998, with interest from the USA and South Africa thereafter. Other exhibitions have been held in Ravenna (Italy) and another will open in Paris in 1997–98.

The Observatory is very grateful to the British Council for sponsoring the UK–Australia exhibitions, catalogue and posters as well as other events associated with their 'newIMAGES' campaign. The Observatory also thanks Sandra Harrison, AAT Board Secretary, for her enormous contribution to the considerable success of these events.

Talks and lectures

Many AAO staff frequently give talks and lectures, not only to scientific audiences, but also to schools and general audiences. The Annual Bok lecture is part of an education program for towns near Siding Spring Observatory. This year, Fred Watson of the AAO gave a lecture about the use of optical fibres in astronomy, entitled 'High fibre astronomy.' As well, several staff members, especially in Coonabarabran, are office holders in amateur astronomy and photographic societies, and are involved in organising science events for local schools.

Organisational statistic:

Number of general interest and public lectures given by staff 48

Media relations

The AAO uses the media wherever possible to help publicise its work, and staff members are actively sought-out for interviews and opinions. During the year many items appeared in the press, on TV and on radio. Some significant items were the ABC science program 'Quantum' featured a program based on the AAO's work, and Fred Watson has a weekly spot on ABC radio 2BL, Sydney.

Organisational statistic:

Number of media interviews given by staff members 52

General inquiries

AAO staff respond to thousands of telephone and email inquiries each year. These responses are an important way of publicising the Obervatory's work.

Use of AAO images

When AAT colour pictures first became available they were mostly used in astronomy magazines and textbooks. Over the past few years they have appeared in an increasingly diverse ways, such as TV drama and comedy, CD-ROMs, web pages, commercial advertising and overseas exhibitions. They have also recently been used in two recent Warner Bros films, one of them, 'Contact', based on a Carl Sagan novel. Among the more surprising this year, was the use of the images as a source of 'styling colours' for the International Wool Secretariat's promotion of its 1997 range.

Almost 80 percent of our income from royalties and reproduction fees comes from the use of astronomical images in the contexts mentioned above and 80 percent of this income derives from overseas. This year there has been a steady increase in demand for prints both nationally and internationally together with an increasing demand for prints and display transparencies made to order for non-stock sizes, mostly from planetaria. Much of this is as a result of the 'Night Skies' exhibition.

Organisational statistic:

Revenue from sales of images	$136k

Conferences and Symposia

As an international observatory, 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.

Organisational statistics:

Number of research talks by staff	111
Number of AAO staff involved in organising major symposia	8

Publications

Apart from the Observers' Guide and the set of Instrument Manuals describing instruments used on the AAT and UKST, the Observatory circulates a quarterly newsletter which gives updates on the latest scientific, instrumentation and staff news to recipients worldwide. This is also available on the www.

3. Scientific research

Introduction

This chapter highlights some of the research programmes carried out using the 3.9-metre AAT and the 1.2-metre UKST from July 1996 to June 1997. A summary of the research activities of staff at the AAO is given in Appendix F.

The AAT is a powerful and versatile telescope which is equipped with a wide range of instrumentation for observations in the optical and near-infrared. Astronomers use the AAT to study a wide range of astronomical topics: from solar system objects to stars and the interstellar medium in our Galaxy and neighbouring galaxies, through to cosmological studies of the most distant galaxies and galaxy clusters in the Universe. Appendix D lists the projects allocated AAT time during the year. During the year 102 different observing programs were awarded time on the AAT. Most projects were allocated time for between 2 and 5 nights, with some programs requiring data to be taken over several sessions.

A major highlight at the AAT was the first year of scientific observations with the two-degree Field (2dF) facility. This unique instrument is used to obtain spectra simultaneously for up to 400 objects which are seen on the plane of the sky within a two-degree field-of-view. The first astronomical observations with the 2dF facility were obtained in June 1996. During the 1996–97 reporting year, astronomical data were taken during commissioning time for highly-ranked projects that required reasonably small amounts of observing time. The first observations were also taken for major redshift surveys of galaxies and quasars. Altogether approximately 9000 spectra were obtained using the 2dF facility, for twenty different science projects.

Appendix E gives a breakdown of the time allocated to the UKST. In 1996–97, 485 plates and films were taken; most of these were for systematic surveys of the southern hemisphere. The resulting sky atlases from the major Schmidt surveys, together with the availability of fast plate measuring machines, have provided one of the fundamental tools of modern astronomy. The Schmidt surveys in progress are a second epoch R-band (red) survey of the southern hemisphere; an extension of the ESO/UK Schmidt blue and red surveys to the equator, and a near-infrared survey of the southern sky. These surveys are nearing completion. During the year, the first observations were also taken for a new survey of hydrogen-alpha emission in our

Galaxy and the Magellanic Clouds using a monolithic, narrow-band interference filter, probably the largest of its kind in astronomy. This survey is expected to take approximately three years to complete. Several smaller surveys are also in progress. The UKST is also used for large scale spectroscopic surveys and other smaller programs with the multi-object FLAIR II facility.

Appendix B gives a list of publications for 1996–1997. Tables giving publication and proposal statistics are given in Chapter 3. Typically 90 per cent of all projects involve Australian or British astronomers, while 45 per cent involve collaborations with astronomers from other countries. On average, each observing program at the AAT results in approximately one publication. Staff astronomers at the AAO are included on approximately half of all publications and one third of all observing programs.

Stars and the interstellar medium

A three-dimensional picture of the interstellar cloud Rho Ophiuchi

Rho Ophiuchus is a hot star which belongs to an open star cluster which is embedded within an extended interstellar cloud of diffuse gas and dust. The Rho Ophiuchi region is located on the edge of a dark molecular cloud and is well known from the strong reflection nebulosity that is caused by the scattering of starlight from dust grains in the interstellar cloud (Figure 3.1).

In an innovative study, Snow (Colorado) is studying the three-dimensional structure of the Rho Ophiuchi interstellar cloud using a combination of data taken with the Hipparcos satellite and the Ultra

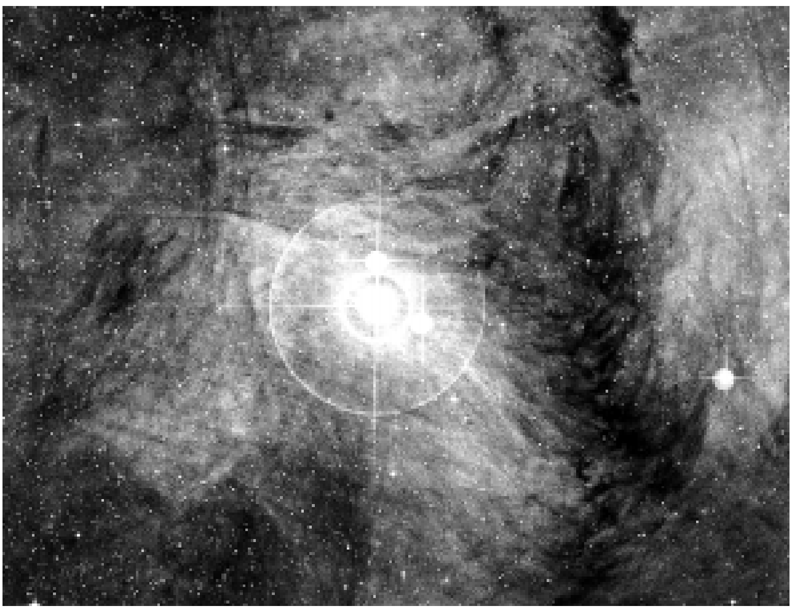


Figure 3.1 The reflection nebulosity around the close binary star Rho Ophiucus is similar to that around the better known Pleiades star cluster.

High Resolution Facility (UHRF) on the AAT. Hipparcos data were taken for the brighter stars in the cluster, through the Guest Investigator program, to determine the stellar parallaxes — the apparent motions of the stars against the distant background due to the orbital motion of the Earth around the sun. Stars with larger parallaxes are closer to us and so the parallax measurements provide a measure of the stellar distances. At the distance of the Rho Ophiuchi cloud, of approximately 400 light-years, the absolute values of the stellar parallaxes have large uncertainties. However the relative distances to the stars are more certain and it is possible to distinguish between the nearer stars in the cluster from the more distant stars.

The UHRF spectra were taken for the same set of stars that were observed with Hipparcos. The UHRF has a uniquely high spectral resolution and so allows for fine spectral details to be studied. The UHRF spectra were taken at a wavelength selected to show absorption by sodium atoms in the gas clouds which lie in front of the stars. Light from a star passing through an interstellar cloud is partially absorbed by the gas in the cloud. The extent of the absorption increases with the amount of material that the light has to pass through — much as sunlight is dimmed by clouds in our atmosphere. Such absorption features provide a means of probing the structure of the interstellar medium. In particular, by observing several stars which are located along almost the same line-of-sight in the plane of the sky, it is possible to separate out different cloud components and their locations relative to the stars in the cluster.

Results from this technique are illustrated in Fig. 3.2 which shows UHRF spectra obtained for three stars which are located along almost

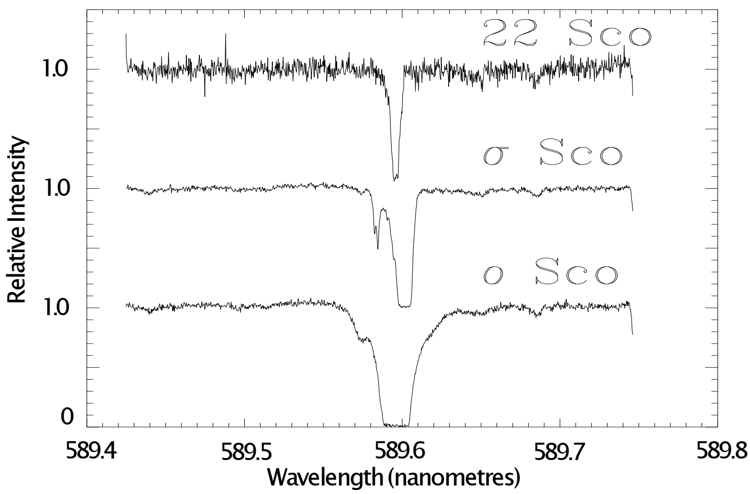


Figure 3.2 Spectra taken with the Ultra High Resolution Facility at the AAT towards three stars in the Rho Ophiuchus star cluster which is embedded in an interstellar cloud. The stars are located along almost the same line–of–sight as seen in the plane of the sky but are plotted in order of increasing distance. The UHRF spectra show absorption by sodium atoms in the interstellar cloud and clearly reveal an increase in the number of discrete absorption components with greater depth through the interstellar cloud.

the same line-of-sight as seen in the plane of the sky. From the stellar parallaxes it is known that of the three stars, 22 Sco is located closest to us while *o* Sco is located furthest away. The sodium absorption features at wavelengths near 598 nanometres, clearly show an increasing number of absorption components and stronger absorption with greater depth through the gas clouds. Similar sequences are also seen for other groups of stars lying along similar lines-of-sight in the cluster.

From data such as these, Snow is able to build up an accurate picture of the relative positions of the stars in the Rho Ophiuchi region and the relative numbers of cloud components in front of each star. To do this requires detailed line profile analysis. The spectral profiles obtained from sodium (and other elements) provide considerable information on the physical conditions in the absorbing regions and these provide valuable input for models of interstellar shocks and other mechanisms thought to be responsible for the formation of the gas clouds.

The technique of using stellar parallaxes together with high resolution optical spectroscopy provides a powerful new tool for probing three-dimensional structure within the interstellar medium. Previous high resolution studies have been confined to measurements in the plane of the sky and have been hampered by the lack of information on distances to the background stars used to probe interstellar absorption line profiles.

Discovery of a Brown Dwarf

For almost 20 years, astronomers have known that most of the matter in the Universe is not directly visible. Indeed, one of the major challenges in astronomy of our time is to determine the nature of this so-called 'dark matter.' One of the prime contenders is a class of objects which are not quite stars, but also not quite planets. Known as 'brown dwarfs,' they have been predicted to exist for many years, but not detected until recently.

Stars like our sun are bright because they transform hydrogen into helium by nuclear fusion and generate large amounts of energy in their inner cores. In contrast, the solar system planets do not burn nuclear fuel and are intrinsically much fainter. The largest planet in our solar system, Jupiter, has a mass of 1/1000th that of the sun, but an intrinsic brightness billions of times fainter. Brown dwarfs, like stars, are formed by the collapse of interstellar gas clouds due to their own gravity. Unlike stars however, their masses are too small for nuclear fusion to occur and so these objects remain intrinsically faint and extraordinarily difficult to detect. After 20 years of searching, the first confirmed detections of brown dwarfs were made in 1994, when two young brown dwarfs were found in the well-known open cluster, the Pleiades, and a third brown dwarf was found as the companion to the nearby star Gliese 229.

However, these detections failed to resolve many outstanding questions. Because they are young, the Pleiades brown dwarfs are still quite bright. Although they are lower in mass than stars, their spectra are indistinguishable from those of stars. These sources are identified as brown dwarfs because their membership of the Pleiades makes them young. But what do old brown dwarfs look like? Gliese 229B, the brown dwarf companion to Gliese 229, gives us some answers to this. It is very faint and has an *extremely* unusual spectrum, which shows that its mass is far below the transition mass which marks the boundary between stars and brown dwarfs.

What does an object near the transition mass look like? It is important to understand such sources so that brown dwarf candidates can be properly identified. To estimate the total number of brown dwarfs in our Galaxy and to attempt to answer questions on dark matter and missing mass, we also need to find 'free floating' isolated brown dwarfs which are not associated with a star.

The surface temperatures of brown dwarfs are expected to be between approximately 1000 and 2000 degrees Celcius. At these temperatures, most of their energy is emitted at near-infrared wavelengths. Using a dedicated telescope on the isolated mountain of Cerro La Silla in Chile, members of the European DEep Near Infrared Southern Sky Survey team (DENIS) are imaging the entire southern sky at near-infrared wavelengths. The DENIS observations are uniquely suited

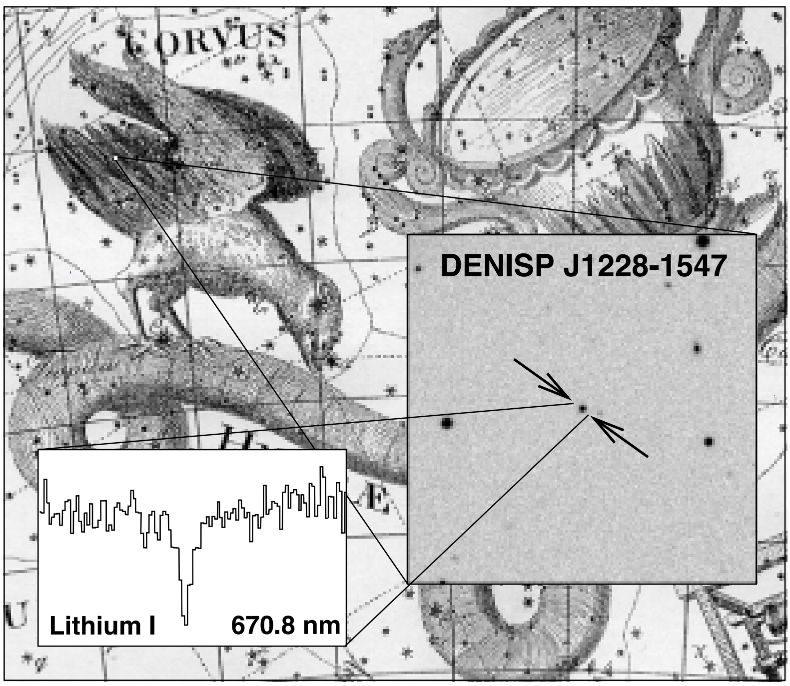


Figure 3.3 The image shows the region of the sky around the newly discovered brown dwarf, DENISP J1228–1547, in the constellation of Corvus (arrowed). Also shown is an AAT spectrum with the characteristic 'dip' due to the presence of lithium. This proves the object is a brown dwarf since lithium is not seen in more massive stars.

to the detection of brown dwarfs as they will cover half the sky, providing many thousands of near-infrared detections of faint objects.

In order to exploit the DENIS data, Tinney (AAO), Forveille and Delfosse (Grenoble) have been using the AAT to study possible brown dwarf objects detected in the survey. Using infrared spectroscopy taken with IRIS at the AAT, they have so far identified three excellent brown dwarf candidates in the first 230 square degrees of the survey. Follow-up optical observations of these three objects, taken with the RGO spectrograph, have revealed the presence of lithium in one of the three. This fragile element is destroyed in the hot centers of stars, but is preserved in the cooler interiors of brown dwarfs. The presence of lithium proves beyond doubt that the object is an old brown dwarf with a mass of approximately 60 Jupiter masses, or 1/16th that of the Sun. Gliese 229B is the only other similar old brown dwarf known. The newly detected brown dwarf, known as DENIS J1228-1547, is in the constellation of Corvus (the Crow) and at a distance of 40 light years away is at least 20 000 times fainter than the sun. The Corvus brown dwarf, shown in Figure 3.3, is of particular interest as it is the first object detected which has a mass estimated to be close to the transition boundary between stars and brown dwarfs. It is the first detection on an isolated brown dwarf in our Galaxy.

This discovery has been made using only a tiny fraction of the DENIS survey. This powerful collaboration of the light-gathering power of the 3.9-m AAT and its innovative suite of instruments, with the unique European DENIS survey, can be expected to find many more of these enigmatic objects in the years to come.

Rapid orbital motion in a stellar binary

When low mass stars like our Sun have finished burning hydrogen and helium as a nuclear fuel in their cores, they shed their outer envelopes to reveal a hot compact remnant called a white dwarf. As many stars exist in binary systems where two stars orbit around their mutual centre of gravity, it is possible that both may become white dwarfs. This produces a system known as a double degenerate (DD) binary. The first of these systems to be discovered (L870-2) was found by Saffer in 1988. In this system the individual white dwarf stars weigh about one half the mass of the Sun and orbit each other in only 1.5 days. Detailed theories have been made to describe how DD systems are formed and these theories can predict the orbital periods and masses of these binaries. As more DDs are discovered we can compare these predictions with measured values to test our understanding of binary star evolution.

WD 0957–666 is one of only 11 DD systems now known. Moran and Marsh (Southampton) observed this binary using the RGO spectrograph on the AAT. Previous spectra taken for the source had only shown features from the brighter of the two stars in the binary.

The new observations were aimed at detecting the second, much fainter white dwarf. However Moran and Marsh quickly realised that a mistake had been made in the measurement of the orbital period of the binary system. Rather than finding a 1.15 day orbital period as expected, they found that the stars in this binary complete an orbit in only 1.46 hours! This makes WD 0957–666 the shortest orbital period system of its type. Grey-scale spectra showing the orbital motions of the two stars are shown in Figure 3.4.

Both the white dwarfs in the WD 0957–666 system are about one third the mass of the Sun. The effect of the two stars moving so rapidly around each other is to produce ripples in the fabric of space. This is known as gravitational wave radiation and may soon be detectable by satellites above the Earth. As this radiation is emitted, energy is lost from the binary system and the two stars will spiral in towards each other until they eventually merge. This is a very slow process; even stars as close together as the pair in WD 0957–666 will not merge for about 200 million years. However the timescale for merging is short enough compared with the age of the universe to show that systems similar to WD 0957–666 are merging right now in galaxies throughout the Universe. This is a very significant result as merging white dwarfs are considered to be the most likely progenitors of Type Ia supernovae.

Supernovae are huge explosions which release so much energy that they are visible in many other galaxies than our own. It is well accepted that one type of supernovae (Type II) occur when huge

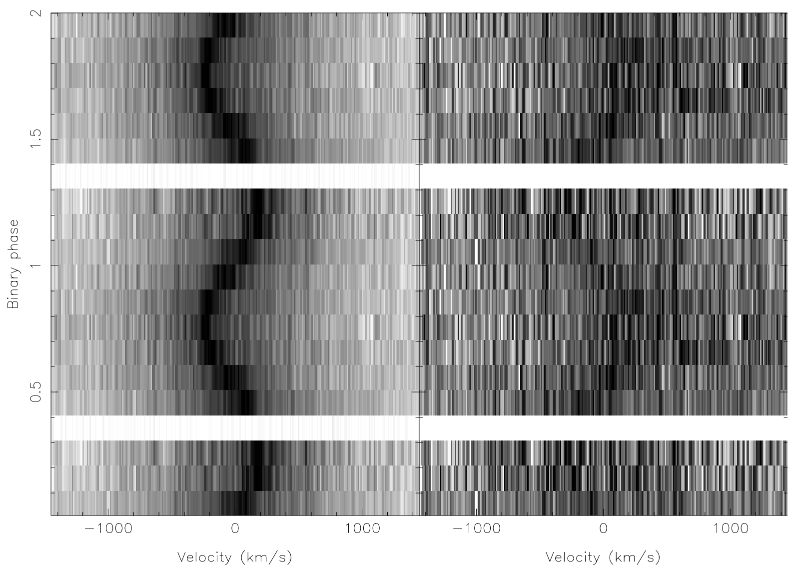


Figure 3.4 This figure shows grey scale representations of spectra obtained at the AAT for two white dwarf stars in a close binary system. The vertical axis shows the orbital phase of the system. In the left-hand panel the shift in velocity due to the orbital motion of the brighter star is clearly seen. The right-hand panel shows the residual spectra after removing a model fit to the contribution from the brighter star — the orbital motion of the much fainter star can just be made out.

stars collapse, leaving behind a neutron star or black hole. However a second type of supernovae event (Type Ia) occurs in which the material ejected in the explosion is devoid of hydrogen. This cannot be explained by the collapse of massive stars as their outer layers are almost entirely composed of hydrogen. White dwarfs however are the cores of old stars in which all the hydrogen has been burnt and so they are good candidates for Type Ia supernovae progenitors.

In order for a white dwarf to explode as a Type Ia supernova, it will most likely need to have a mass greater than the Chandrasekhar mass limit of 1.4 solar masses, above which it will be unable to support its own weight and will begin to collapse. The collapse will heat the star until it explodes. Individual white dwarfs are very rarely this massive, but a merging pair of white dwarfs could well exceed the mass limit and trigger a supernova event. This theory can be tested observationally if we identify a population of DD systems with orbital periods short enough that they will merge via the emission of gravitational radiation within the age of the Universe, and that are massive enough for the merged product to ignite. WD 0957–666 satisfies the first of these conditions but the individual white dwarfs are probably not massive enough for the merged product to explode as a Type Ia supernova. The most likely outcome for this system upon merging will be the production of a stable helium burning subdwarf star. The more we learn about the orbital periods and masses of DD systems like WD 0957–666, the more certain we can be about whether they are the source of one of the universe's most dramatic events.

The AAT observations provided the first detection of the fainter white dwarf star in WD 0957–666, aside from its inferred gravitational influence on the primary white dwarf. From the data, Moran and Marsh were able to calculate the ratio of the masses of the two white dwarf stars. This is an important parameter, as it helps to constrain the models for the evolution of DD systems. The mass ratio of this system is very close to one, as it is for the two other DDs for which it has been measured. That both white dwarfs should have very similar masses conflicts with the most popular method for DD production which should result in the first white dwarf to form being considerably more massive than the second.

So not only is WD 0957–666 an interesting system due to its very short orbital period, but also because its mass ratio suggests that our current theories for DD formation may have to be reviewed. The discovery of more of these fascinating systems will help us to better understand the evolution of a whole range of other types of binary star, as well as to ascertain whether merging DDs are the progenitors of Type Ia supernovae.

The discovery of the Antlia dwarf galaxy

Our Galaxy, the Milky Way is a member of the Local Group of galaxies which comprises over 30 members. Most of the light and mass in the Local Group is contained in the two large spiral galaxies, the Milky Way and Andromeda (Messier 31), while most of the smaller members of the Local Group are dwarf galaxies which are gravitationally bound to the large spirals. The Local Group dwarf galaxies are a particularly useful sample with which to explore questions relating to the origin and evolution of galaxies since we can study them in much greater detail than is possible for more distant dwarf galaxies.

Irwin (RGO), Whiting and Hau (IoA) have recently carried out an all-sky survey for Local Group dwarf galaxies based on visual inspection of UK Schmidt sky survey plates. Deep follow-up CCD observations on the 1.5 m telescope at CTIO revealed one of the candidates to be a previously unknown Local Group galaxy in the constellation of Antlia. Comparison with Tucana and other nearby galaxies indicates that the distance of the Antlia dwarf galaxy is approximately 3.5 million light years. It lies close to the boundary of the Local Group,

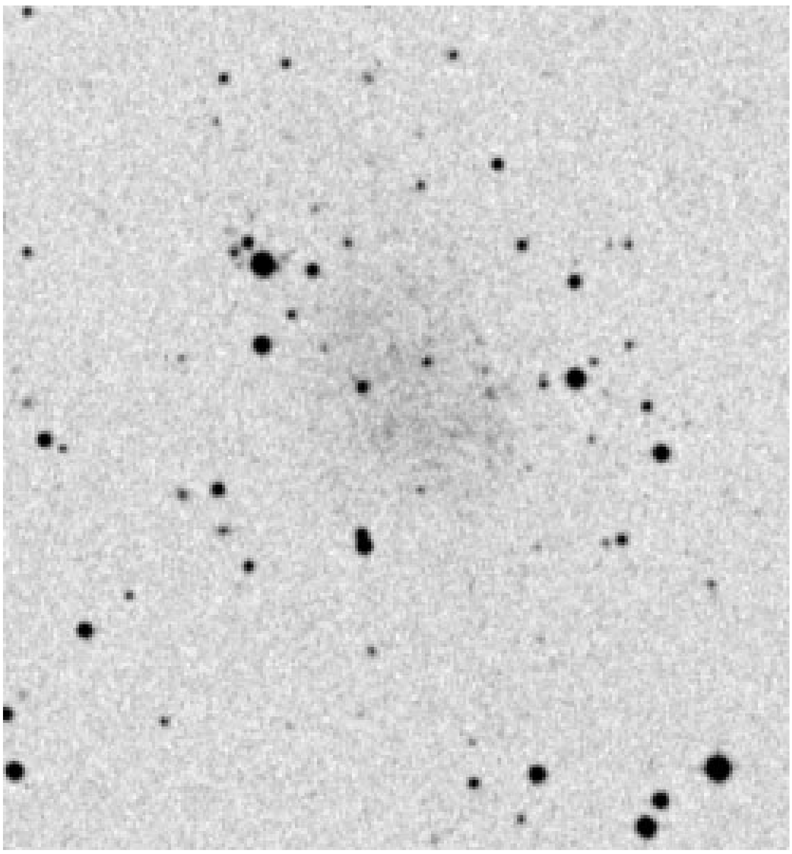


Figure 3.5 Image obtained from a photon–densitometer scan of a UK Schmidt photographic plate, showing the recently discovered Local Group dwarf galaxy which is in the constellation of Antlia. The galaxy is seen as a faint extended region towards the centre of the image.

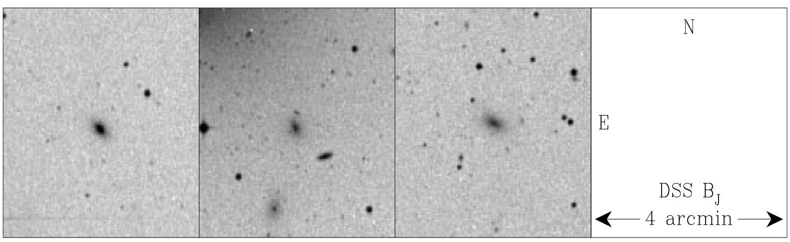
and is separated by only 1.2 degrees from the Local Group dwarf galaxy known as NGC 3109. Based on a tentative estimate of the its radial velocity from neutral hydrogen observations, the Antlia galaxy is likely to be bound to the Local Group and could possibly be a satellite of NGC 3109. The Antlia dwarf galaxy appears as a faint smudge on the sky survey plate (Figure 3.5), and although previously catalogued has never before been followed up optically. It brings the number of Local Group dwarfs identified from UK Schmidt survey plates to five, with previous identifications made for the Sagittarius, Carina, Sextans and Tucana dwarf galaxies.

Compact dwarf galaxies in the Fornax cluster

A major goal of astronomy is to understand the formation of galaxies and how they evolve with time. The smaller dwarf galaxies are particularly interesting because although they are intrinsically many times fainter than giant spiral and elliptical galaxies, they are also far more numerous. Because of their large numbers it is possible that the dwarf galaxies contribute more than the giant galaxies to the amount of matter in the Universe, although this is not known for certain.

Dwarf galaxies are rarely detected in most galaxy surveys because they are intrinsically faint and so cannot be detected at large distances. One way to find dwarf galaxies is to look at large nearby clusters of galaxies where the galaxy density is high and the dwarf galaxies in the cluster are still bright enough to be detectable. The Fornax cluster with some 300 galaxies is ideal for Australian astronomers because it is one of the nearest and it is positioned in the southern sky so it passes directly overhead.

Compact dwarf galaxies in the Fornax cluster



FCC B2144	FCC B1241	FCC 195
m_B=16.5	m_B=17.3	m_B=16.7
new member	new member (2dF)	background

Figure 3.6 UKST images showing two compact dwarf galaxies known as FCC B2144 and FCC B1241 which are members of the Fornax galaxy cluster, and a background galaxy, FCC 195, which lies in the direction of the cluster but is much more distant. Spectroscopic data taken with the 2dF facility on the AAT and the FLAIR II facility on the UKST are used to determine which galaxies are true members of the cluster.

The problem with most cluster samples is that they are compiled from images which only give two-dimensional information. From optical images of the Fornax cluster, it is hard to tell whether a galaxy that appears small is a dwarf member of the cluster or is a more distant giant galaxy which lies in the same direction but is not associated with the cluster.

Drinkwater (NSW) and Phillipps (Bristol) are leading a team that is addressing this problem by using the 2dF facility at the AAT to make the first complete spectroscopic survey of the centre of the Fornax cluster. They are measuring redshifts for all objects in the central 12 square degrees of the cluster which have blue magnitudes brighter than B=20. From the galaxy redshifts it is possible to determine the distances to the galaxies (for an adopted value of the Hubble constant) and their intrinsic brightnesses.

The first two 2dF exposures for this project were taken during commissioning time in late 1996 and resulted in the discovery of two new blue compact dwarf galaxies in the cluster. In a complementary program, a further five new detections of compact dwarf galaxies were made by Drinkwater and Gregg (California, Davis) from observations with the FLAIR II spectrograph on the UKST. Figure 3.6 shows images for two of the newly detected compact dwarf galaxies which have been confirmed as members of the Fornax cluster. Also shown is a background galaxy, FCC 195, which is seen in the direction of the Fornax cluster but is much more distant. Without the spectroscopic data it would not be possible to separate out the bright distant galaxies from the nearer fainter dwarfs.

From these new detections it has been found that dwarf galaxies are considerably more common in the Fornax cluster than was previously realised. In particular the younger, dwarf galaxies which are still in the process of forming new stars may be twice as numerous as previously thought. One of the recently detected galaxies may represent a new class of dwarf-spiral galaxies which are intrinscially much fainter than all other known galaxy types.

Measuring the motions of stars in Local Group dwarf galaxies

Irwin (RGO), Hatzidimitriou (Crete) and Da Costa (MSSSO) are using the 2dF facility at the AAT to study the motions of stars in the outer regions of the dwarf spheroidal galaxies, Carina, Fornax and Sculptor. These are small dwarf galaxies which contain mostly old or middle-aged stars with very little dust or gas. The Carina, Fornax and Sculptor dwarfs belong to a group of at least nine dwarf spheroidals which are gravitationally bound to and orbit around our own galaxy, the Milky Way. The so-called ‘extra-tidal’ stars which lie in the outer regions of the dwarf spheroidal galaxies are particularly important for understanding the disruptive effect of Galactic tidal forces and the role these play in stripping stars and other material away from the small galaxies towards the larger 'parent' galaxy.

Several outstanding questions concerning the dynamics of dwarf spheroidals are still unanswered. Are they in dynamical equilibrium? To what extent are they influenced by tidal forces and hence contribute through tidal streams to the halo of our own galaxy? What is the distribution of dark matter with respect to luminous matter in them?

Irwin and his collaborators are investigating these issues using the 2dF facility at the AAT to obtain spectra for large numbers of stars which may be members of the dwarf spheroidals. The large effective sky coverage of 2dF facilitates finding stars in the outer regions of the dwarf spheroidals and also allows for accurate measurements of their radial velocities (the velocity component which is directed along our line-of-sight).

Previous studies of stellar motions in Local Group dwarf galaxies have mostly measured velocities for stars in the inner regions of the galaxies. While it is reasonably straightforward to identify stars belonging to the core regions of the galaxies, it is much harder to distinguish stars in the outer regions from the multitude of foreground galactic stars. The 2dF facility provides an excellent tool for finding such 'golden needles' in the 'haystack' of stars by enabling velocities to be determined simultaneously for large numbers of stars. Once the velocities have been determined, the stars belonging to our own galaxy can be distinguished from stars which belong to the dwarf spheroidals.

Irwin and his collaborators have used this technique to identify much larger samples of stars in the outer regions of the Carina, Fornax and Sculptor dwarf spheroidals than has previously been possible. As an example, Figure 3.7 shows AAT spectra obtained in January 1997 for three K-giant stars in the Carina dwarf galaxy. Each of these stars shows calcium triplet absorption features. Measurements of the wavelengths of these features allow the stellar radial velocities to be determined to an accuracy of around 5 km per second and these are then used for the dynamical studies.

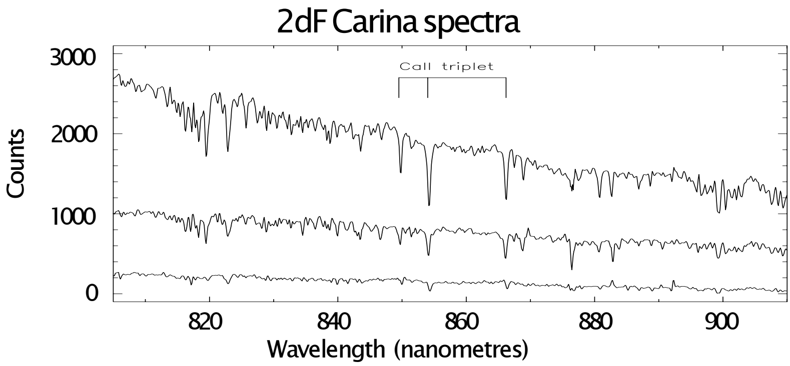


Figure 3.7 Spectra obtained with the 2dF facility at the AAT in Jan. 1997 for three stars in the Carina dwarf galaxy. From the calcium triplet absorption features it is possible to measure the radial velocities of the stars to an accuracy of five km per second

Dwarf galaxies in distant clusters

Outside of the Local Group, little is known about the relative number and distribution of dwarf galaxies compared to more luminous galaxies, yet these objects are crucial to our knowledge of galaxy formation and evolution. Surveys for dwarf galaxies belonging to a galaxy cluster have so far only been made for a small volume of space and for the three relatively nearby Coma, Virgo and Fornax galaxy clusters. These three clusters are all rich in dwarf galaxies but may be unrepresentative of the general population of galaxy clusters. At distances greater than Coma, dwarf galaxies can only be identified photometrically. Such studies of distant clusters have been limited by the sensitivity of photographic plates or the narrow field-of-view of CCD imaging systems.

Driver and Couch (UNSW) have recently used a charged-coupled device (CCD) at the prime focus of the AAT to obtain deep images for galaxy clusters. The clusters were selected to be sufficiently distant for good spatial coverage of the cluster systems to be obtained within the six arc minute field-of-view at the AAT prime focus. For this project the large field-of-view and the powerful light collecting ability of the telescope at the AAT were essential for the detection of such faint objects over extended regions.

For each of the galaxy clusters, Driver and Couch have estimated the distribution of luminosities for the galaxies in the cluster in a statistical manner, by subtracting the numbers of galaxies identified in CCD images taken ‘off’ a cluster from those taken ‘on’ the cluster. From this survey they have established that although the luminosity distribution for bright galaxies is similar for all clusters, the luminosity distribution for fainter clusters shows significant variation from cluster to cluster. Another important result is that the ratio of the number of dwarf to giant galaxies increases towards lower density environments. This indicates that giant galaxies are strongly clustered in the centres of galaxy clusters, while the dwarf galaxies are more uniformly distributed in a large halo around the cluster.

Redshift surveys with the two-degree field facility

The 2dF galaxy redshift survey

The 2dF galaxy redshift survey is a major project which aims to use the unique capabilities of the 2dF facility at the AAT to obtain spectra and redshifts for 250 000 galaxies. The full survey, which involves a large team of astronomers led by Colless (MSSSO) and Ellis (IoA), will be a factor of almost ten larger than any previous redshift survey and will be the first survey able to probe the clustering properties of galaxies on the largest scales. The survey will measure redshifts for previously identified galaxies which have blue magnitudes brighter than $B = 19.5$ and are located in two regions near the southern and northern galactic caps. The full survey covers a sky area of 1700 square degrees and will take over one hundred nights of observations at the AAT.

This survey will provide well-sampled statistical information on the distribution of galaxies at distances out to 1800 million light years. The data will be used to address fundamental cosmological questions on the formation, structure and evolution of matter in the Universe.

The first results for the galaxy redshift survey were obtained in November 1996. Since then approximately 2400 galaxy spectra have been obtained, or around one per cent of the full survey. Figure 3.8 shows the field centres observed so far. There is clearly a long way to go! However, the high quality and reliability of the early data augurs well for the project. Figure 3.9 shows a sample of spectra obtained from the 2dF observations.

To cope with the large amount of data that will be produced, Glazebrook, Offer and Deeley (AAO) have developed a new method for the automatic analysis of the galaxy spectra to obtain redshifts.

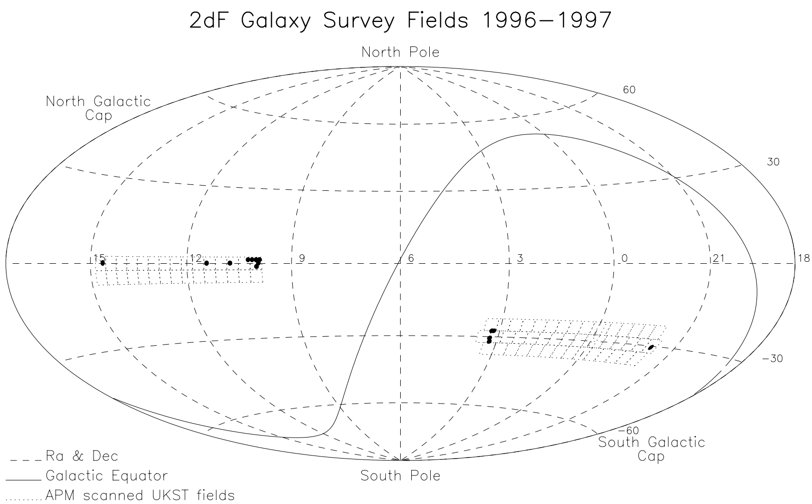


Figure. 3.8 The start of the 2dF redshift surveys. The filled circles show the survey fields which have already been observed, superimposed on dashed lines showing the two regions which will be surveyed. These two regions covers a sky area of 1700 square degrees.

Their method makes use of a technique known as Principal Components Analysis (PCA) which compares the observed spectra against 'template' spectra. Extensive tests of the new method have shown that it is not only much quicker to use than the more traditional algorithms but produces more reliable results for low signal-to-noise spectra than would otherwise be obtained.

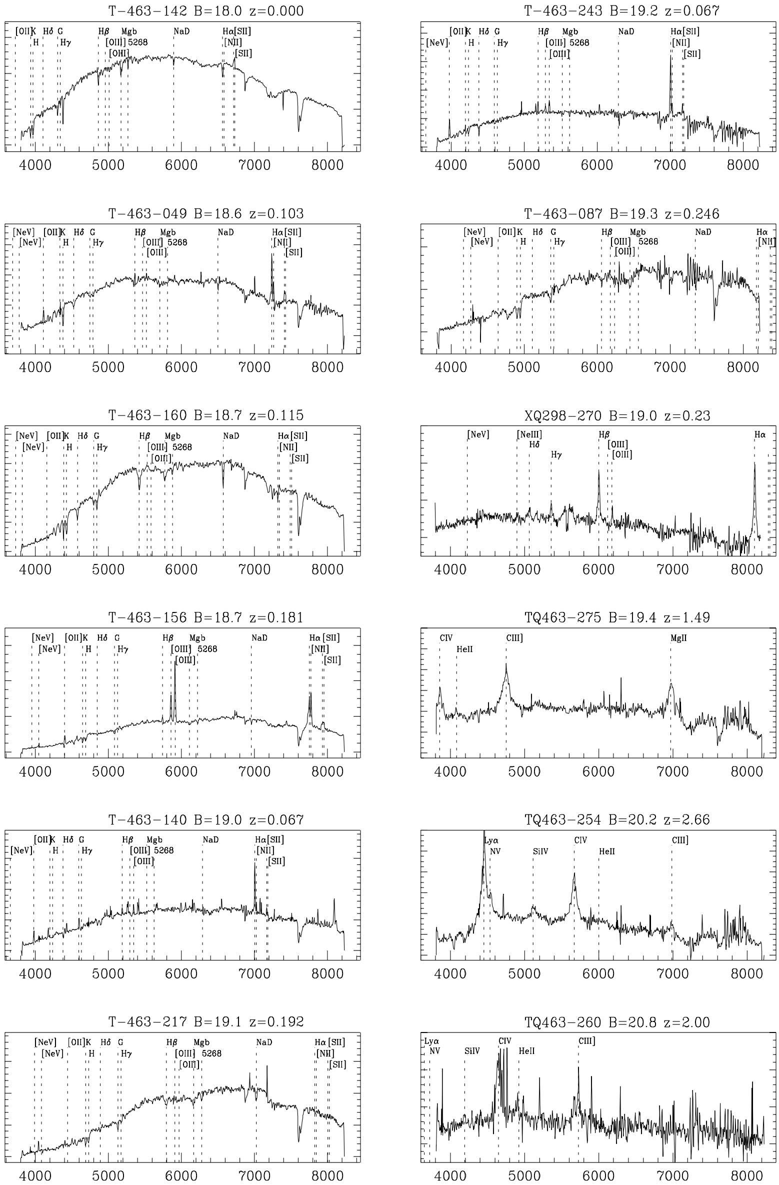


Figure 3.9 Some sample spectra taken with the 2dF facility for the galaxy and quasar redshift surveys. The figure shows spectra for twelve different extragalactic sources. The first eight panels show spectra taken for galaxies with redshifts up to z=0.25. The last four panels show spectra of quasars with redshifts between 0.2 and 2.67 obtained for the 2dF quasar redshift survey.

The bright quasar survey

The 2dF quasar redshift survey led by Boyle (AAO) and Shanks (Durham) has also benefited from data taken during the commissioning phase of 2dF. This survey will provide a catalogue of redshifts for more than 25 000 quasars with redshifts up to $z = 2.2$ and blue magnitudes of B brighter than 21. The quasars will be homogeneously sampled from 740 square degrees of sky, and the survey will be more than ten times bigger than any previous quasar survey.

The primary scientific aims of the 2dF quasar survey are to study the distribution of material in the Universe out to very large scales where normal galaxies are too faint to be readily observed and to investigate the evolutionary changes in the clustering properties and luminosities of quasars. The survey will also provide a valuable resource for a wide range of studies, including the nature of active galactic nuclei, gravitational lensing and faint foreground objects whose existence can only be inferred from their absorption of the light from more distant quasars.

At faint magnitudes, galactic stars outnumber quasars by 50 to 1, and so quasar candidates must be selected carefully. This was done using more than 100 photographic plates and films which have been taken with the UKST during the last ten years. These have been scanned to identify objects which show an excess of light at ultraviolet wavelengths, characteristic of quasars. This process has provided an input catalogue with over 46 000 possible quasar candidates. So far redshifts have been obtained, from 2dF observations, for approximately 600 of them. From these early data it appears likely that, as predicted, about half of the quasar candidates will be identified as quasars. The other sources with excess ultraviolet emission include a mixture of stars and galaxies. Already, more than 300 quasars have been identified and catalogued. By current standards this would be a large catalogue in its own right, yet this represents only one per cent of the anticipated number of quasar identifications.

The origin of the X-ray background

The extragalactic background of X-ray emission was discovered 35 years ago. Although it is now known not be a diffuse background, the nature of the sources which are responsible for most of the X-ray radiation in the Universe have, until recently, remained largely a mystery. The nature of the sources are an important issue for astrophysics; X-ray radiation provides a direct insight into some of the most energetic physical processes in the Universe. Following the launch of the ROSAT X-ray imaging satellite in 1990 and follow-up ground-based optical spectroscopy (including notable work done at the AAT with the AUTOFIB instrument) many of the 'soft' X-ray sources detected with ROSAT were identified as either quasars, or as narrow-emission-line galaxies, thought to be indicative of either hidden quasar activity or intense star formation.

The soft X-ray sources detected by ROSAT emit photons which have energies between 500 and 2000 electron-volts (eV). However, it has been known for some time that most of the energy in the X-ray background occurs from higher energy photons which have energies around 30 000 eV. The launch in 1993 of the Japanese ASCA X-ray satellite has allowed astronomers to investigate the nature of the X-ray sources with photon energies between 2000 and 10 000 eV which is much closer to the peak of the X-ray background.

Optical spectroscopic observations are essential for identifying the X-ray sources detected by ASCA. Boyle (AAO), Shanks (Durham), Griffiths (CMU), Almaini (IoA), Stewart (Leicester) and Georgantopoulos (Athens) have carried out an identification program of 26 faint ASCA sources with the Low Dispersion Survey Spectrograph (LDSS) at the AAT. Although this program is of a relatively modest size, this is currently the largest optically-identified sample of ASCA sources. This is largely because the ASCA satellite provides relatively poor positional accuracy with positions determined to within one arcminute. However, by comparing ASCA positions with weak ROSAT positions, the team were able to locate the ASCA sources to much greater accuracy of about 15 arcseconds.

Their observations showed that over 80 percent of the sources identified were quasars, with narrow-emission-line galaxies and galaxy clusters making up the remainder of the population. The narrow-emission-line galaxies are thought to belong to the class of active galactic nuclei (AGN) known as Seyfert 2 galaxies. Quasars are also AGN, but are significantly more luminous than Seyfert 2 galaxies. The quasar sample showed evidence for strong cosmological evolution, the first detection of evolution amongst an extra-galactic population of objects at these X-ray energies. Based on this evolution and the observed space–densities of quasars and emission-line galaxies, these observations show that AGN comprise the bulk of X-ray background at energies of 2000 to 10 000 eV, with quasars accounting for up to 40 percent, and less luminous Seyfert 2 galaxies comprising a further 40 percent. With these observations, the AAT has played another key role in the resolution of the origin of the X-ray background.

4. AAO facilities

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

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

Major progress was made towards final commissioning of the 2dF facility. Many scientific programs were attempted or begun, and major technical advances were made. In the next six months the full 2dF system is being offered to scheduled observers and scientific programs.

Full descriptions of progress on 2dF, as well as other AAT and UKST instrumentation projects, are given below.

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

AAT facilities

Instruments available at the AAT in mid-1997 are summarised in Table 4.1. Further information is available in the AAO Observer's Guide, in the relevant instrument user manuals, in the AAO newsletters and on the AAO www homepage.

Most instruments on the AAT are used by scientists as common-user facilities, which means that observers make their own observations with backup support from Observatory staff. However, some highly specialised but infrequently used instruments are no longer fully supported by the AAO and therefore generally require an experienced user as one of the collaborators. This group of instruments includes FOCAP, LDSS II and Taurus II. Instruments owned by other institutions are sometimes used on the telescope and may be available for collaborative projects.

Table 4.1 Instruments available on the AAT at 30 June 1997

Focus	Equipment	Mode	Detector
Prime			
	Prime focus camera — aspheric plate, doublet and triplet correctors, sub-beam prism	direct f/3.3	Tek thinned CCD. Range of types of sensitised photographic plates 254 ∞ 254 mm.
	Focal reducer	f/1	Thomson CCD
Cassegrain			
	Imaging		
	Auxiliary camera	f/8 or f/15	Thomson or Tek CCD
	Infrared equipment		
	IRIS 128 x 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, FOCAP multi-objectfibre optic coupler, spectro-polarimetry modes	f/8	Tektronix and other CCDs
	Faint object red spectrograph(FORS), sharing slit of RGO spectrograph and optional dichroic beam splitter	f/8	GEC CCD
	Wide-field imaging Fabry-Perot interferometer (Taurus II) with tunable filter (TTF) and charge shuffling. Wollaston prism polarising module	f/8 or f/15	CCD
	Low dispersion survey spectrograph (LDSS II)	f/8	CCD
	Facilities for visitors' own equipment		
Coudé			
	UCL echelle spectrograph, 70cm camera (UCLES)	f/36	CCD
	Ultra-high resolution facility (UHRF)	f/36	CCD
	Facilities for visitors' own equipment		

UKST facilities

The UKST operates in two modes; photography, for surveys and service observing, and as a common-user instrument with the FLAIR II fibre spectroscopy system.

There are two basic photographic options at the UKST:

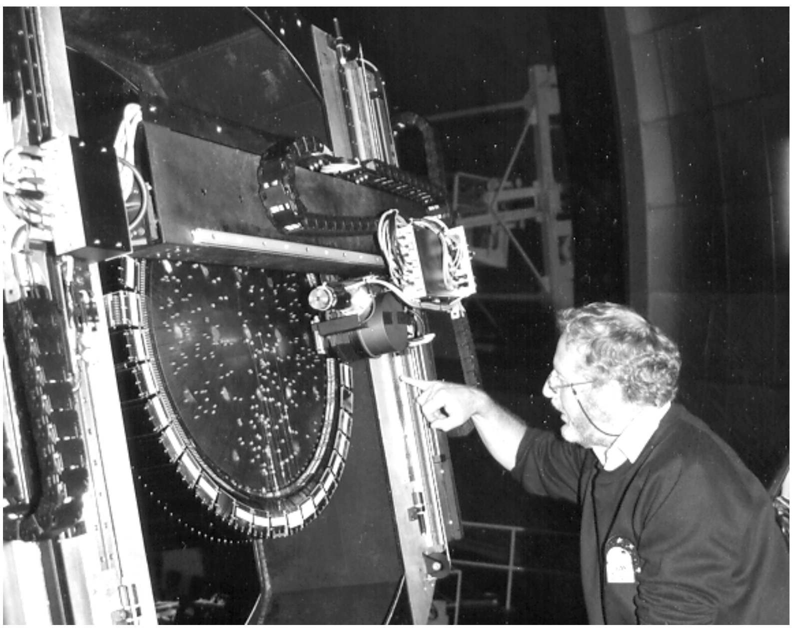
> direct imaging of the sky in different wavebands from ultraviolet to infrared, selected by the appropriate choice of photographic emulsion and filter;
>
> slitless low dispersion spectroscopy through thin, full-aperture objective prisms.

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

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

The 2dF project

The 2dF project gives the AAT an unsurpassed two-degree field-of-view at its prime focus which is equipped with 400 optical fibres for multi-object spectroscopy. The system is at the forefront of multi-object spectroscopy for large telescopes and represents one of the



The 2dF, which has been under development for the last seven years, was used for comprehensive scientific research for the first time during the year Approximately 9000 spectra were taken for 20 different research programs.

most complex astronomical instruments ever to be installed on a ground-based facility.

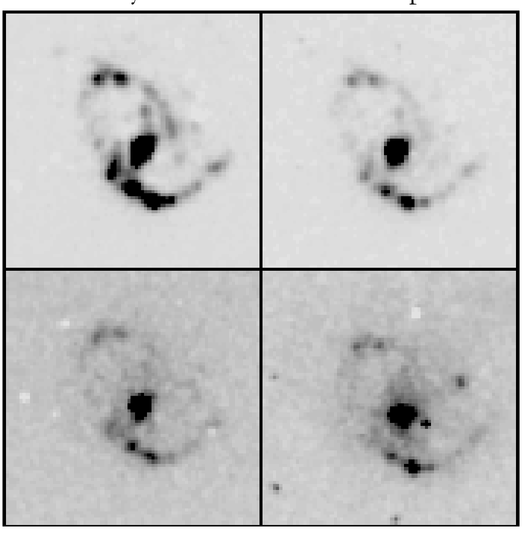
There have been numerous engineering achievements during the last year: routine positioning at progressively faster speeds of 200 fibres to 0.3 arcsecond accuracy; spectrograph focus (which necessitated some refiguring of the field flatteners); light proofing and control of back-illumination system; full electronic and software control system for the spectrographs; debugging of retractors and commissioning of full DRAMA software system (including data reduction pipeline).

The 2dF will go back on the telescope in September 1997 with a 2 ∞ 400 fibre system and two spectrographs under computer control. The current average time to position a fibre is 18 seconds, improvements should bring this down to 10–12 seconds in the short term, and ultimately to 4–5 seconds.

This year, testing continued but a significant part of 2dF time was allocated to scientific projects as well. Although the 2dF was still unable to be used by untrained observers, some high ranking projects were chosen for observations performed by AAO staff. It is estimated that 9000 spectra were collected for 20 projects.

Taurus tunable filter

The TAURUS Tunable Filter (TTF), developed by Bland-Hawthorn (AAO), has begun to produce impressive data for a diverse range of astrophysical studies. This instrument is set to revolutionize the way in which intermediate to narrowband imaging is carried out. The instrument allows for wide-field (4.5–9 arcminutes) narrowband imaging over 630–960 nanometres where the bandpass can be set anywhere in the range 0.6–6 nanometres full-width half-maximum. By the end of 1997, there will be a blue 'arm' operating in the range 370–650 nanometres which will extend the capabilities of TTF considerably. The associated development of CCD charge shuffling



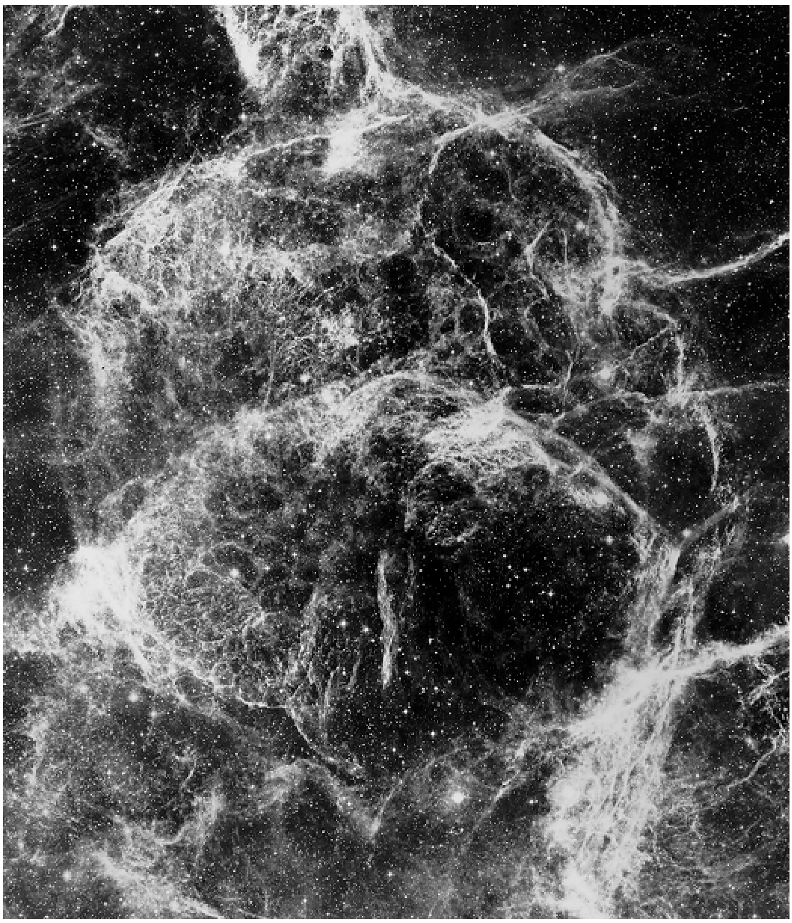
Images obtained for the luminous infrared galaxy NGC 7130, using the TTF in a charge shuffling mode. The upper two panels show emission from ionized hydrogen (left) and nitrogen (right). The lower two panels show emission from ionized sulphur at 671.7 (left) and 906.9 nanometres(right). The ionised gas reveals regions of star formation which are clearly evident along the spiral arms of the galaxy.

has been highly successful and has played a crucial role in about half the TTF projects allocated time to date. In the present semester, TAURUS II has secured 18 percent of the total number of nights. TTF is also finding limited use at the William Herschel Telescope.

H–alpha filter

A new, high-specification, H–alpha interference filter, designed by Parker and Bland-Hawthorn (AAO), has been delivered and commissioned on the UKST. Preliminary tests revealed excellent imaging, and confirm the high quality of the filter and the clear aperture of close to 12 inches. At 14 ∞ 14 inches, this is one of the largest optical interference filters ever made for astronomy.

The filter will be used to make an H-alpha survey of the southern Milky Way and the Magellanic Clouds. This survey, which began in 1997, will be vastly superior to any other optical survey of ionised gas in the galaxy, in terms of the wealth of data anticipated.



A 1.8 x 2 degree region of the Vela supernova remnant, photographed with the UK Schmidt telescope using the new H–alpha filter and Tech Pan film. The original shows an astonishing amount of detail, invisible on earlier exposures made with coarser and less advanced photographic emulsions and filters with a broader bandpass.

Rugate filter

Bland-Hawthorn and Offer (AAO) have designed filters for near-infrared imaging which suppress OH emission from the night sky. Complex thin film coatings can be made to produce several discrete passbands within a conventional broadband filter, such that the bands fall between dominant OH emission regions. Production of these multiband filters is due to start in late 1997.

SPIRAL

Taylor (AAO) and Parry (IoA) have developed a new form of fibre image slicer (SPIRAL) for intermediate-dispersion spectroscopy on the AAT. The basic concept incorporates a hexagonal array of macro lenses each feeding a small-core fibre. The lens array segments a magnified version of either the pupil or image plane of the AAT in order to gather the light from extended objects, while permitting very fine spectrograph slits and hence very compact and efficient spectrographs. This development promises to influence the design of astronomical spectrographs in fundamental ways and, in particular, will be very powerful in enhancing the light gathering capacity of the next generation of intermediate-dispersion spectrographs for the AAT. SPIRAL was successfully commissioned on the AAT in March 1997, yielding an impressive total overall system throughput (including the telescope) of 12 per cent.

Enhancements to existing instruments

Work on the 2dF facility for the AAT again dominated the instrumentation program during 1996–97. Despite this, enhancements have been made to AAT and UKST instruments.

Coudé mirror tests

The AAT coudé system used for UCLES and the UHRF consists of four mirrors in addition to the AAT primary mirror. To keep the UCLES throughput at an optimum level, it is necessary to know the reflectivities of the coudé mirrors and to re-aluminise these mirrors when their performance had degraded. In the past it has been difficult to measure the mirror reflectivities accurately and to monitor their deterioration.

To rectify this situation a TMA Microscan measurement system was purchased from Schmidt Measurement Systems. This portable system uses a laser measurement head which provides measurements of the mirror reflectivities and scatter characterizations at a wavelength of 670 nanometres. This system is now used regularly to monitor the coudé mirrors. Tests with the TMA system showed that the readings obtained have a significant temperature dependence. After calibration for the temperature effect, the mirror reflectivities can now be measured to around one percent.

As an experiment, one of three available coudé-5 mirrors was recoated using a silver and titanium-oxide coating in place of the normal aluminium coating. It was hoped that the silvered mirror would have a higher reflectivity at wavelengths above 360 nanometres. This proved not to be the case — the silvered coudé-5 mirror showed a better performance only above 420 nanometres. The silvered mirror also showed a significant drop in reflectivity and visible tarnishing within a few months of recoating. The more stable aluminium coating which provides a maximum reflectivity of 89 per cent, therefore remains the preferred option.

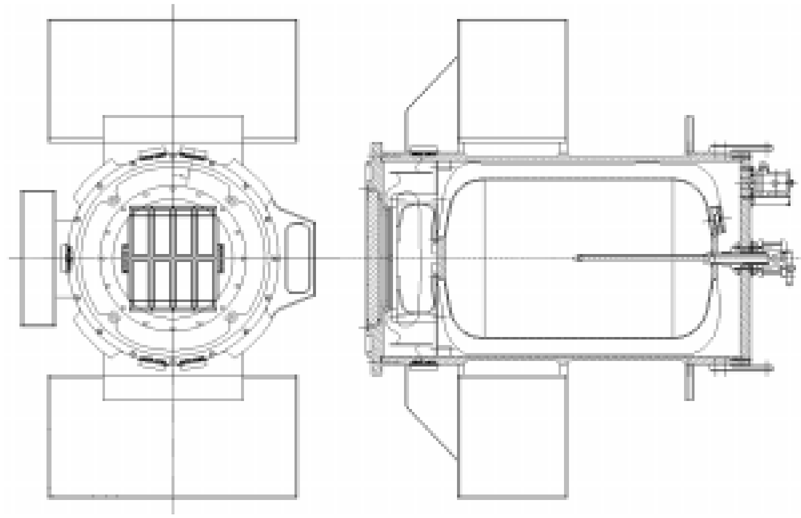
UCLES Short Camera

In 1996, the Optical Sciences Laboratory of University College London carried out a design study for a replacement camera for UCLES. They established that is was feasible to build a camera using a 4k ∞ 4k detector (based on a mosaic of two 2k ∞ 4k CCDs) that would record the entire optical spectrum from 310 to ~900 nanometres in a single exposure. This camera differs substantially from the 'short camera' proposed in the late 1980s in that it has greater (complete) wavelength coverage and higher resolution. In fact, the proposed camera would maintain the same slit width-resolution product as the existing camera, and do so with the same peak throughput, but with far greater wavelength coverage, by a factor of 4–5. The replacement camera would therefore result in more complete data being obtained in a fraction of the normal time, thus permitting more detailed study of the classes of objects currently studied, and the inclusion of objects which have previously been regarded as too faint to yield adequate data in a reasonable time. Funding is being sought to facilitate construction.

CCDs

Prime focus upgrade

The AAO is upgrading its prime focus imaging facility. This will involve constructing a new CCD camera head to replace the existing photographic camera head (which will be retained for photographic use). The new camera head will contain: an automatic six-position filter wheel, capable of carrying filters up to 165 mm square; a 165 ∞ 165 mm aperture shutter capable of exposing a CCD with a 1 percent uniformity at exposure times as short as 1 second; and an auto-guider head on an X–Y–Z stage. These will all be remotely controlled, eliminating the need for an observer to ride in the prime focus cage. It is expected that the new prime focus facility will be commissioned in June 1998.



The Wide Field Imager (WFI) is being built as a collaborative project between the AAO, MSSSO and the University of Melbourne. The figure shows two views of the proposed focal plane mosaic sitting in its vessel. The right section shows the large dewar which contains the liquid nitrogen used to hold the detectors at their working temperature of – 100·C. The left section shows the eight rectangular detectors mosaiced together to give a total detector area of 130 x 130 mm, twenty–eight times the collecting area of the AAO's present imaging detectors.

Wide Field Imager (WFI)

The AAO and MSSSO are undertaking the construction an 8192 ∞ 8192 pixel CCD mosaic for imaging use at the prime focus of the AAT and the Cassegrain focus of the MSSSO 1-m telescope. (The instrument will be allocated between the two on an 'aperture priority' basis.) WFI will give the AAT a 0.5 ∞ 0.5 degree field of view for imaging in conventional UBVRI passbands. In addition, it will be possible to use intermediate passbands which fall between strong OH emission bands from the night sky. Within these bands, the night sky is very dark, opening new research possibilities for the AAT. The WFI is expected to be commissioned on the AAT at the end of 1998.

FLAIR II

The fibre-optic multi-object spectrographic system for the UKST, FLAIR II, has undergone several minor modifications and enhancements during the last year. The most significant change has been the commissioning of film FLAIR II masks to replace the expensive glass copy plates. Preliminary tests with magnetic buttons have been encouraging and next year it is hoped to commission a basic magnetic button system. Spectrograph upgrades are underway to provide remote control of the focus, grating angle and Hartmann shutters.

Adaptive optics

In January 1997, poor weather interfered with observations to determine the altitude of turbulent layers in the atmosphere above the site. Wooder and Adcock (ICSTM) and O'Byrne (Sydney) used the SCIDAR camera system. The limited data indicate that the dominant layer is at ground level, with others around 2, 5, 8–10 and 14–16 km.

In March, the tip-tilt component of the coudé adaptive optics system was tested. Data are still being analysed but it is clear that the tip-tilt correction dramatically reduces low frequency image motion.

Consolidation project

As part of a program to upgrade observer facilities, the observing area at the AAT has been remodelled. The decommissioning of a number of instruments last year enabled the extension of the area to provide a more efficient and comfortable working environment. At the same time, a suite of software tools, to aid in the analysis of astronomical data, has been provided.

Other facilities

Computing 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. The Observatory therefore has an ongoing program of information technology upgrades to ensure that both telescopes are maintained as front-line facilities.

Two high performance Unix systems were added at the AAT and Epping, to provide additional processing power for 2dF data reduction. A number of old network terminals were upgraded to improve the user interface.

Additional disk space for storage of raw and processed data has been installed to a number of Unix systems, and tape backup facilities have been upgraded and extended, and the archiving capability was increased through the installation of a second CD-ROM mastering system.

The network link between the AAT and Schmidt telescopes was upgraded to a fibre optic cable to improve reliability and increase bandwidth.

Software

The software group maintains the general computing facilities of the observatory, and develops the specialised software needed by new instruments such as 2dF.

Although 2dF dominated the software effort again in the last year, it is now moving to a state where it needs maintenance work and occasional enhancement rather than requiring continuous development effort. This will allow work to begin on new projects such as the CCD controllers and IRIS II. The 2dF software is now taking the shape of a complete system, and work over the last year has largely involved improving reliability rather than providing the basic functionality.

Other institutions continue to be interested in the DRAMA software that underpins the 2dF system. DRAMA and some of its individual components are being used for systems developed at RGO and for Gemini telescopes. AAO staff have also been involved in work at JCMT on a new telescope control system which makes use of DRAMA.

The older SunOS operating system, used for most of the SUN workstations, is slowly being phased out in favour of the newer Solaris system. Windows NT systems are being introduced for specialised applications and for general administrative purposes such as running project management and document preparation software. The computing world changes quickly, and the systems staff have to put a great deal of effort into ensuring that these evolving systems provide the best available facilities.

Support facilities

The AAO maintains comprehensive facilities to enable visitors and staff to prepare for observations and to analyse their data. There is a plate library in the Schmidt building and chart rooms in the AAT dome and at Epping, all with facilities for the inspection, measurement and photography of sky survey and other material. The quarterly newsletter appeared in a new format during the year. This was to improve its readabilty and to make it accessible to a wider audience. The AAO also offers astronomers access to digitised sky survey data either in the form of CD-ROMs or from the COSMOS and APM databases available on the www.

Library

One of the largest astronomical collections in Australia is held at the AAO library and, together with the libraries of MSSSO and Radiophysics Laboratory/ATNF at CSIRO, provides an essential facility for the astronomical community. 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 telescopes. Most of these data are in digital electronic form on magnetic tapes. A system to archive the raw AAT data on CD-ROMs is now in place, and older data will be transferred to the new medium over the next few years. Data are available upon request after an initial proprietary period, usually two years. A project to establish an on-line database of the archive has begun. This is expected to increase useage of the stored data.

Other AAO programs

Service observing

Some scientifically important observations require only two hours or less of AAT time. For such projects observations are made by AAO staff during time allocated by the two national time assignment panels. In addition, part of the Director's discretionary time is made available for service work.

Applications for service observations are ranked according to their feasibility, timeliness and scientific merit by an AAO committee which reports to each panel. Different modes of service observation are available: photography at prime focus; direct imaging using CCD cameras; observations using the infrared camera, IRIS; and most of the options available for optical spectroscopy.

Students

The AAO continued to encourage students to use its facilities at both sites, and to work at the AAO for extended periods. There is also policy of employing undergraduate students of astronomy as assistants during vacations. In total, nine students from Australia and the UK were employed during the year. The AAO offers some short-term work experience opportunities at Siding Spring to high school students. Further, library students sometimes visit the AAO library as part of their professional development program.

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 AAT and UKST facilities and also use many other research facilities such as the radio telescopes operated by the Australia Telescope National Facility, the Hubble Space Telescope and the telescopes of the European Southern Observatory.

A search for brown dwarfs in young star clusters

Tinney (AAO), Reid (Palomar) & Hawthorn (AAO) have begun a program which aims to use the Taurus Tunable Filter facility (TTF) to search for brown dwarfs in nearby young star clusters. The TTF is ideal for selecting brown dwarf candidates in these crowded regions because it can efficiently identify stars emitting in the H-alpha line. This line is present in young stars and brown dwarfs, but not in the majority of field stars. Using this technique it should be possible to survey efficiently, large areas of these clusters for brown dwarf candidates and to determine their mass distribution.

Spectro-astrometry of pre-main-sequence stars

Spectro-astrometry is an observing technique which involves accurate measurements of the relative position of a source at different wavelengths. Bailey (AAO) has developed this technique and has demonstrated that it provides a powerful method for studying pre-main-sequence stars. Five previously known pre-main-sequence binaries have been observed using spectro-astrometry. Their binary nature is clearly seen in the data as a displacement of the H-alpha emission feature relative to the centroid position observed at other wavelengths. A survey of a sample of southern pre-main-sequence stars using spectro-astrometry has led to the discovery of several new binaries. Two of these are likely to have separations of about 50 milli-arcsec or less. This separation, which is smaller than that of binaries resolved using other techniques, implies that the binary period may be short enough for studies of the orbit to be feasible, enabling the masses of the stars to be measured. Mass determinations for pre-main sequence stars are needed to enable the observations to be compared with theoretical models for the early evolution of stars. The spectro-astrometric observations also reveal structure in the forbidden lines of sulphur and nitrogen which are formed in low density gas in outflows from the stars, or in nearby nebulosity. H-alpha structure seen in some stars may also be the result of mass outflows.

Compact HII regions

Lumsden (AAO) and Hoare (Leeds) have continued to work on compact HII regions. They have confirmed that the kinematic structure of the HII region G29.96-0.02 cannot be explained by a 'bow-shock' hypothesis. By comparing motions within the hot ionised gas directly with that in cool molecular hydrogen they were able to show that this object has all the attributes of a classic 'champagne-flow' system where the velocity structure is dominated by gas forced out by a pressure gradient.

Monitoring observations of SN 1987A

Stathakis and Cannon (AAO) are using the AAT to monitor the development of Supernova 1987A into a supernova remnant. Many such objects are known in our Galaxy and in the Magellanic Clouds; they consist of hot clouds of gas and dust, formed as the debris from the original supernova explosion expands outwards and crashes into interstellar material surrounding the star which blew up. SN 1987A has given astronomers their first opportunity to observe the formation and early development of such a nebula. In the case of SN 1987A, the star which exploded was surrounded by a complex set of rings of gas, discovered by the Hubble Space Telescope. The rings must have been created by the same star at an earlier stage of its life. The onset of the interactions has already been detected by radio and X-ray astronomers; the optical spectrum is expected to change dramatically during the next few years, as the gas surrounding SN 1987A becomes heated due to incandescence by shock waves from the fast-moving ejecta. Monitoring observations at the AAT are being taken to look for the first signs of the collisions. However, the most recent optical spectra, obtained in December 1996, remain very similar to those obtained during the preceding five years.

The cataclysmic variable V101

Johnston (AAO), Hakala, Charles (Oxford) and Verbunt (Utrecht) have detected the cataclysmic variable V101 in the globular cluster M5 in an X-ray image taken with the High Resolution Imager of ROSAT. The X-ray and optical brightness indicate that it is probably a dwarf nova. This is the first unambiguous X-ray detection of a cataclysmic variable in a globular cluster.

X-ray binary stars

Johnston (AAO), Wu (Sydney), Fender (Sussex), Tennant (NASA), Shirey and Bradt (MIT) have simultaneously obtained optical and X-ray data for the peculiar X-ray binary Circinus X-1. This binary system contains a compact object which is likely to be either a neutron star or black hole, and a companion star and has a highly eccentric, 16-day orbit. The optical spectra of Circinus X-1 show complex emission lines, with a broad component which is thought to occur from an accretion disk near the neutron star or black hole, and narrow components which probably originate from the irradiated companion star. Johnston (AAO) is also observing a sample of southern low-mass X-ray binaries to place observational constraints on models for their formation. The explosive formation of a neutron star in these systems may leave the binary with a large space velocity and a highly eccentric orbit; observations of the current state of the system can help constrain this evolutionary history.

Faint stars in the globular cluster 47 Tucanae

Cannon (AAO), Croke (Crete), Stathakis (AAO), Hesser (DAO) and Bell (Maryland) have used the FOCAP multi-object fibre optic system on the AAT to analyse spectra, taken previously in the globular cluster 47 Tucanae. More than a hundred faint stars at, and below, the main sequence turn-off were sampled. They have looked in particular at the relative strengths of the CN and CH molecular bands. Variations in CN band strength are seen among stars in all the luminosity and temperature ranges observed, while the CN and CH band strengths are anti-correlated. These differences are probably due to a relative enhancement of nitrogen and depletion of carbon in the CN-strong stars. The CN and CH data indicate that the stellar atmospheres contain material which has been processed through the CNO cycle in which hydrogen is converted to helium in the stellar cores, but not through more advanced stages of nuclear burning. In the case of the evolved red giants in the cluster, the best explanation seems to be the convective dredge-up of processed material from deep within the stars themselves. However, the faint main sequence stars do not have deep convective envelopes, and their CN variations are thought to be either primordial, or due to some sort of pollution mechanism.

Mass loss from evolved stars

Chapman (AAO/ATNF), Leitherer (STScI) and Koribalski (ATNF) have continued to study the stellar winds from massive Wolf Rayet stars. Mass-loss rates determined from radio continuum emission at 3 and 6 cm are surprisingly uniform across different Wolf Rayet spectral types and are a factor of two lower than expected from recent models of Wolf Rayet stellar evolution. A surprising result from the 3 and 6 cm data is that approximately 40 per cent of the Wolf Rayet stars detected in radio emission are non-thermal radio emitters. This is far higher than previously known. The radio survey has now been extended to include 13 and 20 cm observations of 36 southern Wolf Rayet stars within 10 000 light years of the sun. This data set is being studied with the aim of better understanding the origin of non-thermal emission from hot, massive stars.

Chapman (AAO/ATNF) has continued to study the rapid variability in the OH maser emission from the M-type supergiant star VX Sgr. The OH masers are located in an outflowing circumstellar wind and their intense emission is strongly variable with flux density changes of a factor of two or more over a period of one hour. Such rapid variability has so far not been seen in any other evolved star. Very-long-baseline observations of VX Sgr taken by Chapman and collaborators show that the masers have compact cores with sizes of a few milli-arcsec. From the observed variability timescale and the maser sizes, it is unlikely that the maser variations are a scintillation phenomenon. A more likely explanation is that the rapid variability is due to a maser propagation phenomenon which is linked to variations in the maser pump rates within the maser cores.

te Lintel Hekkert (ATNF) and Chapman (AAO/ATNF) have completed a survey for OH maser emission from 196 IRAS point sources selected to have cool far-infrared colours. The primary aim of this study was to detect OH maser emission from stars which have evolved beyond the asymptotic giant branch (AGB). OH emission and/or absorption was detected from 77 sources. Of these, 14 masers sources were found to be associated with AGB stars, post-AGB stars or young planetary nebulae.

te Lintel Hekkert (ATNF), Chapman (AAO/ATNF) and Zijlstra (ESO) have used observations taken with the Australia Telescope Compact Array to image the distributions of OH masers in the envelopes of 17 evolved stars which have unusual OH spectral profiles. Most of the selected sources are likely to be post-AGB stars which are in a short-lived stage of evolution between the AGB and planetary nebulae. The maser distributions are consistent with an interacting winds scenario in which a fast stellar wind collides with the remnant of a detached circumstellar envelope. In almost all cases the OH masers reveal a bipolar geometry.

Abundance analyses of the oldest stars in our Galaxy

Ryan (AAO/RGO) has recently left the AAO after four and a half years as research scientist.

During this time he has worked extensively with Norris (MSSSO) and Beers (Michigan) on studies of element abundances of some of the oldest stars in our Galaxy. These low mass stars were initially composed almost entirely from hydrogen and helium that was formed in the very early universe. However, they also contain extremely small abundances of heavier elements which were ejected during the first supernovae explosions of massive stars and additional heavier elements produced during nuclear fusion processes occurring within the stars themselves. Ryan and his collaborators have used UCLES at the AAT to obtain high resolution observations for over 30 extremely old stars which are located in the halo of our Galaxy. The observations have been used to determine abundance ratios for a large number of elements and these provide strong constraints on models of nucleosynthesis in stars, supernovae explosions and chemical evolution during the early stages of the Galaxy.

The major result of these investigations has been to improve our understanding of the abundance trends in the range 1/1000 to 1/10000 the metallicity of the sun. For some elements, such as the so-called a-elements (magnesium, calcium, silicon and titanium) and the iron-peak elements, the trends are fairly well defined, at least down to 1/3000 solar. Below this limit the situation is not so clear, and there is some evidence that, at a given abundance of iron, there may be a spread in the a-elements. For elements heavier than iron, however, the situation is rather chaotic. Heavy neutron-capture elements, such as strontium and barium, have a large spread in abundance at a given iron abundance which covers a range of two orders of magnitude. The simplest explanation of this phenomenon is that at these low abundances we are beginning to see stochastic variations, resulting from individual events, in the interstellar medium from which these stars formed. This has the potential to constrain more strongly the nature of the various objects responsible for the production of the first metals in the Galaxy.

The second result is that no object has been observed which has an iron abundance less that 1/10000 that of the sun. It is probably fair to say that we are approaching the point where sufficiently large numbers of stars have been surveyed to suspect that such objects do not exist, rather than as the result of small-number statistics.

A third line of investigation has been to study the group of carbon-rich metal-deficient stars. It appears that the proportion of such stars increases to ~10 per cent among objects having metallicities less than 1/300 that of the sun, and analysis shows carbon enhancements, relative to iron, of factors 10–100. An understanding of the origin of these carbon enhancements is sought to give insight into the production of carbon at the earliest times and the first objects to produce this element.

Beers, Norris and Ryan have performed detailed abundance analysis of several carbon-rich stars. Of particular interest is the object CS 22957–027 which has only 1/2500 the iron abundance of the sun, 100-fold enrichments of carbon and nitrogen, but no apparent enhancement of the heavy neutron-capture elements, strontium and barium. The origin of these abundance patterns is not fully understood. One interesting possibility is that they result from internal mixing processes induced in a helium core flash in this low metallicity object. This has been predicted by detailed theoretical calculations for stars which contain no heavy elements at all.

A UK Schmidt H-alpha survey of the southern Milky Way & Magellanic clouds

Parker (AAO) and Phillips (Bristol), together with many other collaborators in Australia and Britain, have begun work on a new H-alpha survey of the Southern Milky Way and Magellanic clouds. The UKST survey makes use of an exceptionally large (12 inches square clear aperture on a 14 inches square substrate) interference filter which was purpose built for the survey and commissioned at the UKST. Images are taken on Tech Pan film which has excellent imaging capabilities due to its small grain size and high sensitivity peak at H-alpha. The survey will initially include approximately 270 UKST four-degree field centres which cover the plane of our Galaxy and the two Magellanic clouds, and is expected to take about three years to complete.

Proper motions of the nearest galaxies

Tinney (AAO) has commenced a program of astrometric observations of the nearby satellite galaxies of the Milky Way, using the ESO 3.5 m telescope. This program exploits the excellent astrometric measurements that can be made using charge-coupled devices, and the excellent seeing conditions of the ESO site. Positions of the galaxies will be obtained relative to positions of quasars discovered earlier by Tinney and collaborators, to a precision of 1 milli-arcsecond per epoch. This should produce a firm detection of the proper motions of these galaxies within 5 years.

Gas in nearby galaxies

Bland-Hawthorn (AAO), Freeman and Quinn (MSSSO) have discovered warm ionized gas which extends beyond the neutral-hydrogen boundary of spiral galaxies. They have started to produce optical rotation curves for several nearby galaxies, including the well known spiral galaxy, NGC 253. Interestingly, the rotation curve in NGC 253 continues to rise beyond the hydrogen limit, implying an increasingly dominant role of the dark halo. The source of ionisation was predicted two decades ago to be the cosmic ionizing field. However, detailed calculations suggest that young stars in the inner disk are able to heat gas in the outer warp of the galaxy.

Bland-Hawthorn (AAO) and Veilleux (KPNO) have used TAURUS II at the AAT to observe the nearby starburst galaxy Circinus. They have detected high velocity knots in the outer reaches of the galaxy which are caused by a colossal explosion at the galaxy's nucleus. These knots lie at the ends of filaments which extend outwards from the galactic centre. One of the structures has the precise form of a Herbig-Haro optical jet, with a series of 'beads' ending in a bow-shock structure. This has never been seen before in galaxies.

Bland-Hawthorn (AAO) and Shopbell (Rice) have performed a detailed study of the large-scale wind in the starburst galaxy M82. The energetics are consistent with an outburst from a nuclear starburst, consistent with previous work. They were able to demonstrate that the wind axis is tilted with respect to the spin axis of the galaxy. There is evidence of rotation in filamentary structures. This is consistent with numerical models from N-body simulations which predict that filaments in the wind are due to gas pulled up from the disk.

Low surface brightness galaxies in the Virgo and Fornax clusters

Phillips (Bristol), Parker (AAO) and Jones (Bristol) are continuing with an extensive project to digitally stack multiple exposures on Tech Pan film of regions in the Virgo and Fornax clusters. The high sensitivity of Tech Pan film, together with the addition of multiple exposures makes this survey well suited to the detection of low surface brightness objects. Phillips and his collaborators are preparing a new catalogue of low surface brightness galaxies in the two clusters which will include surface photometry of the newly detected galaxies. So far, many thousands of detections of low surface brightness galaxies have been made for a region of 9 square degrees in the Virgo cluster.

HST imaging of low redshift active galactic nuclei

Boyle (AAO) and Schade (DAO) have been carrying out an extensive ground and space-based imaging campaign of a sample of approximately 100 X-ray-selected active galactic nuclei (AGN). This sample does not suffer from the morphological selection effects which plague optically-selected samples of AGN, and provides a more representative sample of AGN than found in radio-selected samples.

Images of over 75 AGN have been obtained with the Hubble Space Telescope in a snapshot survey. By combining these images with ground-based data taken with the 1-m Jacobus Kapteyn Telescope, all spatial scales between 300 and 3000 light years are sampled in these AGN. Initial results from the first half of the sample reveal that AGN inhabit a wide range of galaxies, with no strong correlation between host galaxy and AGN luminosity. Almost one third of these radio-quiet AGN inhabit 'bulge-only' or elliptical galaxies. This is contrary to the conventional wisdom, which suggests that most, if not all, radio-quiet AGN are in spiral galaxies. There is also little evidence for interaction between the AGN host galaxies and other galaxies, or for disrupted morphology in the AGN host galaxy. Such interaction was thought to be one of the primary mechanisms for fueling AGN. However, a significant fraction of the galaxies do exhibit a bar structure, which could play a role in supplying gas to the central AGN.

Spectro-astrometry of Seyfert I galaxies

Bailey (AAO), Robinson, Hough (Herts) and Ward (Leicester) have used the spectro-astrometry technique in observations of two Seyfert I galaxies. As expected, their data show no displacements in the central broad-line regions, but reveal displacements of 60 to 100 milli-arcsec between parts of the narrow-line emission regions relative to the galaxy nuclei and broad-line regions. The positional offsets are generally consistent with those predicted by the unified model of Seyfert galaxies.

The nature of galaxies with $0 < z < 1$

Glazebrook (AAO) and Abraham (IoA) have analysed an extensive series of spectroscopic and infrared data for galaxies in the 'Medium Deep Survey.' This is a random sample of field galaxies with redshifts of $0 < z < 1$ which have been observed with the Hubble Space Telescope. Their data have yielded constraints on how properties such as surface brightness, luminosity and stellar populations depend on the morphology of galaxies, and how they evolve over $0 < z < 1$. Working with Brinchmann (IoA) and other collaborators, they have also begun work on a similar sample which is about ten times larger.

The star formation rate at $z = 1$

Glazebrook, Bland-Hawthorn (AAO) and Abraham (IoA) have used the Taurus Tunable Filter at the William Herschel Telescope in La Palma to observe the Hubble Deep Field in a series of deep narrow-band slices which correspond to different redshifts intervals between $z = 0.89$ and $z = 1.45$. The observations are used to search for the redshifted [OII] emission line from galaxies with strong star formation. The primary motivation of this study is to look for evolution in the star formation rate as this has been predicted to show a turnover at a redshift of $z = 1.4$. The data goes several times deeper than is possible with conventional glass filters. Glazebrook and Blake (AAO summer student) are also analysing infrared spectra taken in Hawaii for $z = 1$ galaxies.

They are searching for redshifted H-alpha emission, also with the aim of studying the star formation rate in galaxies.

The 2dF facility and galaxy redshifts

Cannon (AAO) has been investigating the astrometric accuracy that can be obtained using the SuperCOSMOS measuring machine to measure the positions of stars and galaxies on UKST photographic plates. Such data are needed for 2dF input catalogues. Short-exposure UKST plates have been taken and these have been measured with SuperCOSMOS. The data will also be used to determine whether a new Short Astrometric Survey is needed to tie the Hipparcos bright star reference frame to stars of apparent magnitude $B \sim 15$; the brightest that can be well-measured on deep Sky Survey plates.

Glazebrook (AAO), Huang and Cowie (Hawaii) are conducting a 2dF spectroscopic follow-up of the Hawaii Wide K-band near-infrared survey. They aim to use the 2dF facility to obtain 4000 galaxy redshifts from objects detected in the near-infrared survey, over a sky area of 10 square degrees. This will be the biggest such survey to date. Analysis of the data will be used to determine the near-infrared luminosity function of the galaxies and will also trace the evolution of clustering in early-type galaxies out to $z = 0.3$. So far, 2dF data have been obtained for several hundred of the galaxies.

FLAIR redshift surveys

Shanks (Durham), Parker (AAO), Fong and Metcalfe (Durham), are extending a large redshift survey of galaxies included in the Edinburgh/Durham Southern Galaxy Catalogue. In the original survey, approximately 2500 galaxy redshifts were obtained using FLAIR on the UKST, for a region of 1500 square degrees in the South Galactic Pole region. This survey is now being extended to include a further six strips of constant declination with 15 UK Schmidt fields in each strip. The primary aim of the survey extension is to map a previously unsurveyed area for information on the local galaxy distribution and to improve statistical analyses of large scale galaxy clustering to larger spatial scales.

In a complementary study, Parker (AAO) has continued to work on data collected using FLAIR at the UKST for a redshift survey of 10 Schmidt fields in the South Galactic Pole region. Approximately 2000 redshifts were obtained for galaxies in a region of 300 square degrees. One extra field was observed for the survey which is now 95 per cent complete. The galaxy redshifts, classifications and cross-references are now being compiled into a systematic database.

In a separate redshift program, Wakamatsu (Gifu), Malkan (UCLA), Parker (AAO) and Hasegawa (Gifu) have continued to obtain redshifts for heavily-obscured galaxies in crowded fields between the Ophiucus and Hercules clusters of galaxies. Nearly all the data for this large redshift survey have now been taken. The FLAIR redshift surveys provide excellent databases for studies of galaxy clustering properties and luminosity distributions. Because of the wide field of view of the UKST, the FLAIR redshift surveys are highly complementary to the deeper redshift surveys underway with the 2dF facility.

Galaxy clusters

Jones (MSSSO) and Bland-Hawthorn (AAO) have begun to construct H-alpha luminosity functions for galaxies in clusters and in the field at redshift intervals from $z = 0.1$ to $z = 0.4$. For the rich cluster ACO 3665 (AC 106), they have identified more than 30 galaxies with H-alpha emission above a three-sigma detection threshold with many more candidates at lower threshold levels.

Lumsden (AAO), Collins (LJMU), Nichol (Carengie Mellon), Guzzo (Observatori di Brera) and Eke (AAO vacation student) have made a new analysis of the cluster galaxy luminosity function using UKST and AAT data. The results are in line with previous findings, but their analysis indicates that real differences in the luminosity function as a function of cluster type are now well within the reach of future redshift and CCD surveys.

Quasar studies

Smith (IoA, AAO) and Boyle (AAO) have used images of 100 low-to-intermediate redshift quasars ($0.3 < z < 0.7$) obtained with the Isaac Newton Telescope to place limits on the environments of optically-selected quasars at these redshifts. They find that the environments of these quasars are consistent with those of field galaxies at the same redshifts. There is no strong correlation with redshift or luminosity in the richness of the environments around individual quasars.

Boyle, Glazebrook and Hawthorn (AAO) have begun a program to image around high-redshift ($z > 4.5$) quasars using the Taurus Tunable Filter to search for associated galaxies either by their redshifted Lyman-alpha emission or from a Lyman continuum break in their spectra. Encouraging results have been obtained around one high redshift radio-loud quasar known as PKS 1251–407, which exhibits a significant excess in the number of galaxies around the quasar. These are evident in the narrow-band images.

With Aretxaga (ESO) and Terlevich (RGO), Boyle (AAO) has continued investigations into the nature of the extensions detected around high redshift ($z = 2$) luminous quasars. Infrared observations with the Calar Alto 3.6-m telescope indicate that these extensions are not due to scattered light or from nebular emission surrounding the quasars. The most likely origin for the extended emission is from strong star formation in luminous host galaxies.

Cannon (AAO) is analysing a sample of bright ($B < 16.5$) quasars found in the Edinburgh-Cape blue-ultraviolet survey. So far about 100 quasars have been identified, of which about half appear to be new objects not found in other surveys. This implies that the statistics for nearby low-redshift quasars are likely to be incomplete.

In a separate program, Johnston and Tinney (AAO) have carried out a search for quasars behind the globular cluster 47 Tucanae. They obtained 2dF spectra of candidate objects near the cluster, which will be used as reference objects for proper motion studies.

Research Papers

The following list includes research papers published from AAT and UKST data, 1 July 1996–30 June 1997, 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 follows.

'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.

ABRAHAM R G (CAMBRIDGE), VAN DEN BERGH S (DRAO), GLAZEBROOK K (CAMBRIDGE, AAO), ET AL
The morphologies of distant galaxies. II. Classifications from the Hubble Space Telescope Medium Deep Survey. Astrophys Jnl Suppl, v107, p1, 1996 (O)

AITKEN D (HERTFORDSHIRE), SMITH C (ADFA), MOORE T (ADFA), ROCHE P (OXFORD)
10 micron imaging polarimetry. ASP Conf series vol.102: The galactic center, p.179, 1996 (A)

AITKEN D K (HERTFORDSHIRE), SMITH C H (ADFA), MOORE T J T (ADFA), ET AL
Mid- and far-infrared polarimetric studies of the core of OMC-1: the inner field configuration. Mon Not R astr Soc, 286:85, 1997 (A)

ALMAINI O (DURHAM), SHANKS T (DURHAM), BOYLE B J (RGO), ET AL
A deep ROSAT survey - XII. The X-ray spectra of faint ROSAT sources. Mon Not R astr Soc, 282:295, 1996 (A,S)

ASHER D J (AAO), STEEL D I (AAO,ADELAIDE)
No meteor storms expected from P/Machholz 2. IAU Coll 150, Florida, 1995. PASP Conf Proc vol 104, p.129 (O)

ASHLEY M C B (NSW), BURTON M G (NSW), STOREY J W V (NSW), LLOYD J P (NSW), ET AL
South Pole observations of the near-infrared sky brightness. Publ Astron Soc Pacific, 108:721, 1996 (A)

BAKER J C (MRAO)
Origin of the viewing-angle dependence of the optical continuum emission in quasars. Mon Not R astr Soc, 286:23, 1997 (A)

BANKS T (WELLINGTON), DODD R (WELLINGTON)
The initial mass function. Aust J Astr, 6(3):91, 1996 (A)

BEDDING T R (SYDNEY), ZIJLSTRA A A (ESO), VON DER LUHE O (ESO), ROBERTSON J G (SYDNEY), MARSON R G (SYDNEY), BARTON J R (AAO), CARTER B S (SAAO)
The angular diameter of R Doradus: a nearby Mira-like star. Mon Not R astr Soc, 286:957, 1997 (A)

BEGELMAN M C (COLORADO), BLAND-HAWTHORN J (AAO)
A well-fed black hole. Nature, vol 385, p.22, 1997 (O)

BENITEZ N (SANTANDER), MARTINEZ-GONZELEZ E (SANTANDER)
Large-scale QSO-galaxy correlations for radio-loud and optically selected QSO samples Astrophys. J. 477:27, 1997 (S)

BLADES J C (STSI), SAHU M S (STSI), HE L (STSI), ET AL
Ultra high resolution observations of interstellar Na I and Ca II K toward the high galactic latitude star HD 28497. Astrophys. J. 478:648, 1997 (A)

BLAND-HAWTHORN J (AAO)
Ionised hydrogen at large galactocentric distances. Publ Astron Soc Aust, 14:64, 1997 (A)

BLAND-HAWTHORN J (AAO), MALONEY P R (COLORADO)
The Galactic halo ionizing field. Publ Astron Soc Australia, 14:59, 1997 (A)

BOYLE B J (RGO), WILKES B J (HSCA), ELVIS M (HSCA)
The Cambridge-Cambridge ROSAT Serendipity Survey - V. Catalogue and optical identifications. Mon Not R astr Soc, 285:511, 1997 (O)

BRIDGES T J (RGO), ASHMAN K M (KANSAS), ZEPF S E (CALIFORNIA), ET AL
Kinematics and metallicities of globular clusters in M104. Mon Not R astr Soc, 284:376, 1997 (A)

BYRNE P B (ARMAGH), EIBE M T (ARMAGH), ROLLESTON W R J (ARMAGH)
Cool prominences in the corona of the rapidly rotating dMe star, HK Aquarii. Astronomy & Astrophysics, 311:651, 1996 (A)

CANNON R (AAO)
2dF: the two-degree field facility on the AAT. Wide-field spectroscopy conf, Athens, 1996. pub. Kluwer

CANNON R (AAO)
Conference summary Proc Wide field spectroscopy conf, Athens, 1996. pub Kluwer

CANNON R (AAO)
Fringing - a user's perspective. ESO CCD Workshop, 1996

CANNON R (AAO), BARTON J (AAO)
AAO detectors - present status and future plans. ESO CCD Workshop, 1996

CANNON R (AAO), CROKE B (CRETE), HATZIDIMITRIOU D (CRETE), MORGAN D (ROE)
A kinematic survey of carbon stars in the Small Magellanic Cloud. IAU Symp 177 - The carbon star phenomenon, Antalya, 1996 (O)

CANNON R (AAO), TAYLOR K (AAO)
2dF on the AAT - project update and first scientific results. IAU Asian-Pacific Regional Meeting, Pusan, 1996

CARIGNAN C (MONTREAL), COTE S (ESO), FREEMAN K C (MSSSO), QUINN P J (ESO)
NGC 5084: a massive disk galaxy accreting its satellites? Astronom Jnl, 113:1585, 1997 (A)

CHAPMAN J M (AAO), REYNOLDS J, WILSON W, ET AL
Detection of compact OH mainline maser emission from the supergiant star VX Sgr. ATNF 4th Asia-Pacific Workshop, 1996 (O)

CHRYSOSTOMOU A (HERTFORDSHIRE), MENARD F (GRENOBLE), GLEDHILL T M (HERTFORDSHIRE), ET AL
Polarimetry of young stellar objects II: circular polarization of GSS 30. Mon Not R astr Soc, 285: 750, 1997 (A)

CILIEGI P (HSCA), ELVIS M (HSCA), WILKES B J (HSCA), BOYLE B J (RGO), MCMAHON R G (CAMBRIDGE)
The Cambridge-Cambridge ROSAT Serendipity Survey - IV. The X-ray properties. Mon Not R astr Soc, 284:401, 1997 (O)

CILIEGI P (HSCA), ELVIS M (HSCA), WILKES B J (HSCA), BOYLE B J (CAMBRIDGE) ET AL
VLA observations of the Cambridge-Cambridge ROSAT survey. IAU Symp 175: Extra-galactic radio sources, p.543, 1996 (O)

CLARK N E (SHEFFIELD), TADHUNTER C N (SHEFFIELD), MORGANTI R (BOLOGNA), ET AL
Radio, optical and X-ray observations of PKS2250-41: a jet/galaxy collision? Mon Not R astr Soc, 286: 558, 1997 (A)

COLE D M (CHICAGO), VANDEN BERK D E (CHICAGO), SEVERSON S A (CHICAGO), MILLER M C (CHICAGO), GLAZEBROOK K (AAO), ET AL
Optical/near-infrared observations of GRO J1744-28. Astrophys. J. 480:377, 1997 (O)

CORBET R H D (NASA), CHARLES P A (OXFORD), SOUTHWELL K A (OXFORD), SMALE A P (NASA)
A low-amplitude X-ray and optical outburst from the periodic transient A0538-66: accretion onto a magnetosphere? Astrophys. J. 476:833, 1997 (A)

COTERA A S (NASA), SIMPSON J P (NASA), ERICKSON E F (NASA), ET AL
Interstellar extinction in the vicinity of galactic center thermal radio emission regions ASP Conf series vol.102: The galactic center, p.122, 1996 (A)

CRAWFORD I A (LONDON), CRAIG N (CALIFORNIA), WELSH B Y (CALIFORNIA)
The velocity structure of the local interstellar medium probed by ultra-high-resolution spectroscopy. Astronomy & Astrophysics, 317:889, 1997 (A)

CRISTIANI S (PADOVA), TRENTINI S (PADOVA), LA FRANCA F (ROME), ANDREANI P (PADOVA)
The optical variability of QSOs II. The wavelength dependence. Astronomy & Astrophysics, 321:123, 1997 (S)

CROOM S M (DURHAM), SHANKS T (DURHAM)
QSO clustering - III. Clustering in the Large Bright Quasar Survey and evolution of the QSO correlation function. Mon Not R astr Soc , 281:893, 1996 (A)

CROWTHER P A (LONDON), BOHANNAN B (NOAO)
The distinction between O Iafpe and WNLha stars: a spectral analysis of HD 151804, HD 152408 and HDE 313846. Astronomy & Astrophysics, 317:532, 1997 (A)

CROWTHER P A (UCL), SMITH L J (UCL)
Fundamental parameters of Wolf-Rayet stars VI. Large Magellanic Cloud WNL stars. Astronomy & Astrophysics, 320:500, 1997 (A)

DI NELLA H (LYON), COUCH W J (UNSW), PARKER Q A (AAO), PATUREL G (LYON)
Unveiling a connection between large-scale structures behind the southern Milky Way. Mon Not R astr Soc, 287:472, 1997 (S)

DI NELLA H (MPIA), COUCH W J (UNSW), PATUREL G (LYON), PARKER Q A (AAO)
Are the Perseus-Pisces chain and the Pavo-Indus wall connected? Mon Not R astr Soc, 283:367, 1996 (S)

DOUGLAS N G (AAO)
Optical methane-band observations of Jovian Shoemaker-Levy 9 impact debris. Astronomy & Astrophysics, 313: 315, 1996 (O)

DRINKWATER M J (AAO), COMBES F (DEMIRM), WIKLIND T (ONSALA)
A search for molecular absorption in the tori of active galactic nuclei. Astronomy & Astrophysics, 312:771, 1996 (O)

DRINKWATER M J (AAO), FRANCIS P J (MELBOURNE), WEBSTER R L (MELBOURNE)
Spectral properties of Parkes flat-spectrum radio sources. ASP Conf series v.113, IAU Coll 159, p437, 1997 (O)

DRINKWATER M J (AAO), GREGG M D (CALIFORNIA), HOLMAN B A (MELBOURNE)
The nature of dwarf ellipticals in Virgo and Fornax. Proc 2nd Stromlo Symp. 1996, ASP Conf series vol 116, p.287, 1997 (S)

DRINKWATER M J (AAO), WEBSTER R L (MELBOURNE), FRANCIS P J (MELBOURNE), CONDON J J (NRAO), ELLISON S L (KENT), JAUNCEY D L (ATNF), LOVELL J (TASMANIA), PETERSON B A (MSSSO), SAVAGE A (AAO)

The Parkes half-jansky flat-spectrum sample. Mon Not R astr Soc, 284:85, 1997 (S)

DRIVER S P (NSW), PHILLIPPS S (BRISTOL)
Is the luminosity distribution of field galaxies really flat? Astrophys. J.469:529, 1996 (S)

DUNKIN S K (UCL), BARLOW M J (UCL), RYAN S G (AAO)
High-resolution spectroscopy of Vega-like stars - I. Effective temperatures, gravities and photospheric abundances. Mon Not R astr Soc, 286: 604, 1997 (A)

ELMOUTTIE M (QUEENSLAND), HAYNES R F (ATNF), JONES K L (QUEENSLAND), ET AL
The radio continuum structure of the edge-on spiral galaxy NGC 4945. Mon Not R astr Soc , 284:830, 1997 (A)

ESCALERA E (ROE), MACGILLIVRAY H T (ROE)
Detection of structures on multiple scales around the South Galactic Pole. Astronomy & Astrophysics Supplement 118, 519, 1996 (S)

FERRARIO L (ANU), BAILEY J (AAO), WICKRAMASINGHE D (ANU)
The magnetic fields of EF Eridani and BL Hydri. Mon Not R astr Soc, 282:218, 1996 (A)

FRANCIS P J (MELBOURNE)
The continuum slopes of optically selected QSOs. Publ Astron Soc Australia, 13:3, p212, 1996 (S)

FRANCIS P J (MELBOURNE), WEBSTER R L (MELBOURNE), MASCI F J (MELBOURNE), DRINKWATER M J (AAO), PETERSON B A (MSSSO)
The spectra of dusty quasars. ASP Conf series vo. 113, IAU Coll 159, p130, 1997 (A,S)

FRANCIS P J (MELBOURNE), WEBSTER R J (MELBOURNE), PETERSON B A (MSSSO), DRINKWATER M J (AAO)
Dust obscured quasars. New extragalactic perspectives in the new South Africa, p.501, 1996 (A,S)

GALLETTA G (PADOVA), SAGE L J (MARYLAND), SPARKE L S (WISCONSIN)
Molecular gas in polar-ring galaxies. Mon Not R astr Soc , 284:773, 1997 (S)

GLAZEBROOK K (AAO)
perl as an astronomer-friendly language - the pgperl experience. ASP Conf series vol.101: Astronomical data analysis software and systems V, p.307, 1996

GLAZEBROOK K (AAO)
Deep near-infrared surveys - understanding galaxy evolution at z greater than 1. Moriond 1997 Conference proceedings, review talk (A)

GLEDHILL T M (HERTFORDSHIRE), CHRYSOSTOMOU A (HERTFORDSHIRE), HOUGH J H (HERTFORDSHIRE)
Linear and circular imaging polarimetry of the Chamaeleon Infrared Nebula. Mon Not R astr Soc, 282: 1418, 1996 (A)

GRIFFITHS R E (JHU), DELLA CECA R (JHU), GEORGANTOPOULOS I (LEICESTER), BOYLE B J (CAMBRIDGE), ET AL
A deep ROSAT survey - X. X-ray-luminous narrow-emission-line galaxies. Mon Not R astr Soc , 281:71, 1996 (O)

GUENTHER E W (TAUTENBURG), EMERSON J P (LONDON)
Spectrophotometry of flares and short time scale variations in weak line, and classical T Tauri stars in Chamaeleon. Astronomy & Astrophysics, 321:803, 1997 (S)

GUNN A C (ARMAGH), DOYLE J G (ARMAGH), HOUDEBINE E R (ESA)
Environments of active close binaries II. GK Hydrae and TY Pyxidis. Astronomy & Astrophysics, 319:211, 1997 (A)

HAKALA P J (OXFORD), CHARLES P A (OXFORD), JOHNSTON H M (UTRECHT, AAO), VERBUNT F (UTRECHT)
X-ray detection of the dwarf nova V101 in M5. Mon Not R astr Soc , 285:693, 1997 (O)

HARLAFTIS E T (ST ANDREWS), CHARLES P A (OXFORD), HORNE K (ST ANDREWS)
Detection of the X-ray-heated companion of X1822-371. Mon Not R astr Soc , 285:673, 1997 (A)

HARRIES T J (ST ANDREWS)
Accretion-disk reflection of the bipolar wind of BI Crucis. Astronomy & Astrophysics, 315:499, 1996 (A)

HARRIES T J (ST ANDREWS), HOWARTH I D (LONDON)
Raman scattering in symbiotic stars. I. Spectropolarimetric observations. Astronomy & Astrophysics Supplement, V119 No.1, p61, 1996 (A)

HARRIES T J (ST ANDREWS), HOWARTH I D (LONDON)
Raman scattering in symbiotic stars. II. Numerical models. Astronomy & Astrophysics Supplement, 121:15, 1997 (A)

HATZIDIMITRIOU D (CRETE), CROKE B F (CRETE), MORGAN D H (ROE), CANNON R D (AAO)
Kinematics of carbon stars in the outer regions of the Small Magellanic Cloud. Astronomy & Astrophysics Supplement, 122:507, 1997 (S)

HAWKINS M R S (ROE), VERON P (OHP)
The space density of quasars at z greater than 4. Mon Not R astr Soc, 281:348, 1996 (S)

HEISLER C A (AAO, MSSSO), HILL T L (AAO, SYDNEY), MCCALL M L (ONTARIO), HUNSTEAD R W (SYDNEY)
The Sculptor dwarf irregular galaxy SDIG: present and past. Mon Not R astr Soc, 285:374, 1997 (A)

HEISLER C A (MSSSO), HILL T L (SYDNEY), MCCALL M L (YORK, CANADA), HUNSTEAD R W (SYDNEY)

The Sculptor dwarf irregular galaxy SDIG: a progenitor dwarf spheroidal? The Second Stromlo Symposium: The nature of elliptical galaxies, ASP Conf series, vol 116 p.300, 1997 (A)

HEISLER C A (MSSSO), LUMSDEN S L (AAO), BAILEY J A (AAO)
Visibility of scattered broad-line emission in Seyfert 2 galaxies. Nature, v.385: 700, 1997 (A)

HELD E V (PADOVA), MOULD J R (MSSSO), FREEMAN K C (MSSSO)
Internal kinematics of dwarf and low-luminosity elliptical galaxies. Second Stromlo Symposium: The nature of elliptical galaxies, ASP Conf series vol 116 p.292, 1997 (A)

HERNIUS O (UPPSALA), LAGERKVIST C I (UPPSALA), LINDGREN M (UPPSALA), ET AL
UESAC - the Uppsala-ESO survey of asteroids and comets. Astronomy & Astrophysics, 318:631, 1997 (A)

HEYL J (CAMBRIDGE), COLLESS M (MSSSO), ELLIS R S (CAMBRIDGE), BROADHURST T (JHU)
Autofib Redshift Survey - II. Evolution of the galaxy luminosity function by spectral type. Mon Not R astr Soc, 285:613, 1997 (A)

IMPEY C D (STEWARD), SPRAYBERRY D (STEWARD), IRWIN M J (RGO), BOTHUN G D (OREGON)
Low surface brightness galaxies in the local universe. I. The catalog. Astrophys Jnl Suppl, 105: 209, 1996 (S)

IOVINO A (MILANO), CLOWES R (PRESTON), SHAVER P (ESO)
A large sample of objective prism quasar candidates. Astronomy & Astrophysics Supplement, 119:265, 1996 (S)

IYENGAR K V K (BANGALORE), PARTHASARATHY M (BANGALORE)
BVRI photometry of a few ‘unidentified’ IRAS sources. Astronomy & Astrophysics Supplement, 121:45, 1997 (S)

JEFFRIES R D (KEELE), BUCKLEY D A H (SAAO), JAMES D J (BIRMINGHAM), STAUFFER J R (HSCA)
2RE J0241 - 525: a nearby post-T Tauri visual binary system. Mon Not R astr Soc,281: 1001, 1996 (A)

JOHNSTON H M (UTRECHT, AAO), VERBUNT F (UTRECHT)
The globular cluster population of low-luminosity X-ray sources. Astronomy & Astrophysics, 312: 80, 1996 (O)

JOHNSTON S (SYDNEY)
PSR B1259-63: periastron puzzles. ASP Conf series vol 105 p501, 1996 (A)

JONES D H (AAO), BLAND-HAWTHORN J (AAO), BURTON M G (UNSW)
Numerical evaluation of OH airglow suppression filters. Publ Astron Soc Pacific, 108:929, 1996 (O)

JONES H (MSSSO), BLAND-HAWTHORN J (AAO)
TTF survey of galaxy populations. Publ Astron Soc Aust, 14:8, 1997 (A)

KEMP S N (BELFAST), BATES B (BELFAST), HAMBLY N C (BELFAST)
Further optical and UV spectroscopy of stars in the direction of the Riegel & Crutcher cold cloud. Mon Not R astr Soc, 283:1089, 1996 (A)

KENDALL T R (BELFAST), DUFTON P L (BELFAST), KEENAN F P (BELFAST), ET AL
Abundance analyses of a sample of five faint blue stars in the galactic halo. Astronomy & Astrophysics, 317:82, 1997 (A)

KERR T H (NOTTINGHAM), HIBBINS R E (NOTTINGHAM), MILES J R (NOTTING-HAM), ET AL
Molecular rotational contour fitting of ultra-high-resolution profiles of diffuse interstellar bands. Mon Not R astr Soc, 283, L105, 1996 (A)

KHARCHENKO N (KIEV), SCHOLZ R D (POTSDAM), LEHMANN I (BERLIN)
Membership and structural parameters of the globular cluster M5 from Schmidt plates. Astronomy & Astrophysics Supplement, 121:439, 1997 (S)

KILKENNY D (SAAO), O'DONOGHUE D (CAPE TOWN), KOEN C (SAAO), ET AL
The Edinburgh-Cape Blue Object Survey - II. Zone 1 - the North Galactic Cap. Mon Not R astr Soc , 287:867, 1997 (A,S)

KIM A G (CALIFORNIA), GABI S (CALIFORNIA), GOLDHABER G (CALIFORNIA), GLAZEBROOK K (AAO), ET AL
Implications for the Hubble Constant from the first seven supernovae at z greater than or equal to 0.35. Astrophys. J.476:L63, 1997 (O)

KOTILAINEN J K (TURKU), FORBES D A (LICK), ET AL
Near-infrared line and continuum imaging of the nuclear starburst region of NGC 1808. Astronomy & Astrophysics, 313: 771, 1996 (A)

KRAAN-KORTEWEG R C (PARIS), FAIRALL A P (CAPE TOWN), WOUDT P A (CAPE TOWN), VAN DE STEENE G C (ESO)
Two new planetary nebulae discovered in a galaxy search in the southern Milky Way. Astronomy & Astrophysics, 315:549, 1996 (S)

KUNKEL W E (CIW), IRWIN M J (RGO), DEMERS S (MONTREAL)
Carbon stars in the halo of the Magellanic Clouds: identification and radial velocity data. Astronomy & Astrophysics Supplement,122:463, 1997 (S)

LARSON K A (RENSSELAER), WHITTET D C B (RENSSELAER), HOUGH J H (HERT-FORDSHIRE)
Interstellar extinction, polarization, and grain alignment in the high-latitude molecular cloud toward HD210121. Astrophys. J.472:755, 1996 (A)

LEHMANN I (POTSDAM), SCHOLZ R D (POTSDAM)
Tidal radii of the globular clusters M5, M12, M13, M15, M53, NGC 5053 and NGC 5466 from automated star counts. Astronomy & Astrophysics, 320:776, 1997 (S)

LEISY P (PARIS), DENNEFELD M (PARIS), ALARD C (PARIS), GUIBERT J (PARIS)
Accurate positions and finding charts of known planetary nebulae in the Large Magellanic Cloud. Astronomy & Astrophysics Supplement, 121:407, 1997 (S)

LEITHERER C (STSI), CHAPMAN J M (AAO, ATNF), KORIBALSKI B (ATNF)
Radio continuum measurements of southern early-type stars. II. A distance limited sample of Wolf-Rayet stars. Astrophys. J. 481:898, 1997 (O)

LELLOUCH E (PARIS)
Chemistry induced by the impacts: observations IAU Coll 156, The collision of Comet Shoemaker-Levy 9 and Jupiter, p.213, 1997 (A)

LEWIS I J (AAO), SHARPLES R M (DURHAM), PARRY I R, JONES L R, WATSON F G (AAO) ET AL
Autofib-2: commissioning results of a robotic multi-object fibre system for the William Herschel Telescope. SPIE Proc: Optical telescopes of today and tomorrow, 2871:1318, 1997

LIDMAN C E (ESO), PETERSON B A (MSSSO)
An optically based search for distant galaxy clusters. Astronom Jnl, V112 N6, p2454, 1996 (A)

LINDGREN M (UPPSALA), TANCREDI G (URUGUAY), LAGERKVIST C I (UPPSALA), HERNIUS O (UPPSALA)
Searching for comets encountering Jupiter. Second campaign observations and further constraints on the size of the Jupiter family population. Astronomy & Astrophysics Supplement, 118:293, 1996 (S)

LUMSDEN S (AAO), PUXLEY P (ROE)
Near infrared spectroscopy of the ultracompact H II region G45.12+0.13. Mon Not R astr Soc, 281, 493, 1996 (A)

MADDOX S J (RGO), EFSTATHIOU G (OXFORD), SUTHERLAND W J (OXFORD)
The APM Galaxy Survey - III. An analysis of systematic errors in the angular correlation function and cosmological implications. Mon Not R astr Soc, 283, 1227, 1996 (S)

MALIN D (AAO), HADLEY B (ROE)
HI in shell galaxies and other merger remnants. Publ Astron Soc Aust, 14:52, 1997 (S)

MALIN D F (AAO), HADLEY B (ROE)
Faint features of bright ellipticals. Proc Second Stromlo Symp: The nature of elliptical galaxies, 1996. ASP Conf series vol 116, p.460, 1997 (S)

MATARRESE S (PADOVA), COLES P (LONDON), LUCCHIN F (PADOVA), MOSCARDINI L (PADOVA)
Redshift evolution of clustering. Mon Not R astr Soc , 286:115, 1997 (A)

MEABURN J (MANCHESTER), BOUMIS P (MANCHESTER), WALSH J R (ESO), ET AL

Highly supersonic motions within the outer features of the Eta Carinae nebulosity. Mon Not R astr Soc, 282:1313, 1996 (A,S)

MEABURN J (MANCHESTER), CLAYTON C A (OXFORD), BRYCE M (MANCHESTER), WALSH J R (ESO)
The global motions of the cometary knots in the Helix planetary nebula (NGC 7293). Mon Not R astr Soc, 281: L57, 1996 (A)

MEIKLE W P S (LONDON), CUMMING R J (STOCKHOLM), GEBALLE T R (HAWAII), ET AL
An early-time infrared and optical study of the Type Ia supernovae SN 1994D and 1991T. Mon Not R astr Soc, 281:263, 1996 (A)

MINNITI D (CALIFORNIA), MEYLAN G (ESO), PRYOR C (RUTGERS), PHINNEY E S (CALTECH), SAMS B (MPE), TINNEY C G (AAO)
An unusual brightening of the eclipsing binary star AKO 9 in the globular cluster 47 Tucanae observed with HST. Astrophys Jnl Letters, 474:L27, 1997 (O)

NORRIS J (MSSSO), RYAN S G (AAO), BEERS T C (MICHIGAN)
Extremely-metal-poor stars I. Spectroscopic data. Astrophys Jnl Suppl, v107, p391, 1996 (A)

OOSTERLOO T (ATNF), DA COSTA G S (MSSSO), STAVELEY-SMITH L (ATNF)
HI observations of the Tucana dwarf elliptical galaxy. Astronom Jnl V112, No 5, p1969, 1996 (A)

OUDMAIJER R D (ICL), DREW J E (ICL)
An H alpha outburst in the B emission line star HD 76534. Astronomy & Astrophysics, 318:198, 1997 (A)

PACKHAM C (HERTFORDSHIRE), YOUNG S(HERTFORDSHIRE), HOUGH J H (HERTFORDSHIRE), AXON D J (JODRELL), BAILEY J A (AAO)
Near-infrared imaging polarimetry of NGC 1068. Mon Not R astr Soc, 288:375, 1997 (A)

PAIN R (CALIFORNIA), HOOK I M (CALIFORNIA),GLAZEBROOK K (AAO), BOYLE B J (RGO), ET AL
The Type Ia supernova rate at z approx 0.4. Astrophys. J. 473:356, 1996 (O)

PANAGI P M (READING), O'DELL M A (SUSSEX)
Spectroscopy of the open cluster Blanco 1. II. H alpha emission as an indicator of relative age. Astronomy & Astrophysics Supplement, 121:213, 1997 (A)

PARKER Q (AAO), PHILLIPPS Q S (BRISTOL)
A UKST H alpha survey of the Galactic plane. Publ Astron Soc Australia, 14:123, 1997 (S)

PARKER Q A (AAO), COLLESS M (MSSSO), MAMON G (PARIS)
The FLAIR-DENIS redshift survey. Publ Astron Soc Australia, 14:125, 1997 (S)

PATTEN B M (HAWAII), SIMON T (HAWAII)

The evolution of rotation and activity in young open clusters: IC 2391. Astrophys Jnl Suppl,v106, p489, 1996 (S)

PETTINI M (RGO), KING D L (RGO), SMITH L J (UCL), HUNSTEAD R W (SYDNEY)
Dust in high redshift galaxies. Astrophys. J. 478:536, 1997 (A)

PETTINI M (RGO), KING D L (RGO), SMITH L J (LONDON), HUNSTEAD R W (SYDNEY)
Dust in high redshift galaxies. Astrophys. J. 478:536, 1997 (A)

POTTER S B (MULLARD), CROPPER M (MULLARD), MASON K O (MULLARD), HOUGH J H (HERTFORDSHIRE), BAILEY J A (AAO)
Simultaneous UBVRIJK photometric and polarimetric observations of PQ Gem. Mon Not R astr Soc , 285:82, 1997 (O)

POTTER S B (MULLARD), MASON K O (MULLARD), CROPPER M S (MULLARD), BAILEY J A (AAO), HOUGH J H (HERTFORDSHIRE)
Simultaneous UBVRIJK photometric and polarimetric observations of PQ Gem. Cataclysmic variables and related objects, p.181, 1996 (O)

QUINN D E (ADFA), MOORE T J T (ADFA), SMITH R G (ADFA), ET AL
10-micro metre imaging of the bipolar protoplanetary nebula Mz-3. Mon Not R astr Soc, 283:1379, 1996 (A)

RAMSAY G (UTRECHT), CROPPER M (MULLARD), WU K (SYDNEY), POTTER S (MULLARD)
Optical polarisation and X-ray data on the AM Her star RE J1844-74. Mon Not R astr Soc, 282: 726, 1996 (A)

RATCLIFFE A (DURHAM), SHANKS T (DURHAM), BROADBENT A (DURHAM), PARKER Q A (AAO), WATSON F G (AAO), ET AL
The Durham/UKST Galaxy Redshift Survey - I. Large-scale structure in the Universe. Mon Not R astr Soc, 281:L47, 1996 (S)

RAWSON D M (MSSSO), BAILEY J (AAO), FRANCIS P J (MELBOURNE)
Neural networks and the classification of active galactic nucleus spectra. Publ Astron Soc Australia, 13, 207, 1996 (O)

REID A H N (LONDON), HOWARTH I D (LONDON)
Optical time-series spectroscopy of the O4 supergiant Zeta Puppis. Astronomy & Astrophysics, 311:616, 1996 (A)

RIX H-W (MPA), GUHATHAKURTA P (LICK), COLLESS M (MSSSO), ING K (LICK)
Internal kinematics of distant field galaxies: I. Emission linewidths for a complete sample of faint blue galaxies at z approx 0.25. Mon Not R astr Soc, 285:779, 1997 (A)

ROCHE N (JHU), GRIFFITHS R E (JHU), DELLA CECA R (JHU), SHANKS T (DURHAM), BOYLE B J (CAMBRIDGE), ET AL
A deep ROSAT survey - XI. Enhanced X-ray emission from faint galaxies. Mon Not R astr Soc, 282:820, 1996 (A)

ROLLESTON W R J (ARMAGH), BROWN P J F (BELFAST), DUFTON P L (BELFAST), HOWARTH I D (LONDON)
The chemical compositions of three main-sequence B-type stars in the Large Magellanic Cloud. Astronomy & Astrophysics, 315:95, 1996 (A)

RYAN S G (AAO), NORRIS J E (MSSSO), BEERS T C (MICHIGAN)
Extremely-metal-poor stars II. Elemental abundances and the early chemical enrichment of the galaxy. Astrophys. J. 471, 254, 1996 (A)

RYANS R S I (BELFAST), SEMBACH K R (MIT), KEENAN F P (BELFAST)
UHRF observations of the interstellar medium towards two stars in the Galactic Halo. Astronomy & Astrophysics, 314: 609, 1996 (A)

SADLER E M (SYDNEY), RICH R M (NEW YORK), TERNDRUP D M (OHIO)
K giants in Baade's Window. II. The abundance. distribution. Astronom Jnl, 112:171, 1996 (A)

SAGAR R (BANGALORE), CANNON R D (AAO)
Multicolour deep CCD photometric study of the moderately young southern open star clusters NGC 3228, NGC 4103, NGC 5662 and NGC 6087. Astronomy & Astrophysics Supplement, 122:9, 1997 (O)

SEVENSTER M N (LEIDEN), CHAPMAN J M (AAO), HABING H J (LEIDEN), KILLEEN N E B (ATNF), LINDQVIST M (LEIDEN)
The ATCA/VLA OH 1612 MHz survey I. Observations of the galactic bulge region. Astronomy & Astrophysics Supplement, 122:79, 1997 (O)

SHAHBAZ T (OXFORD), NAYLOR T (KEELE), CHARLES P A (OXFORD)
Infrared photometry of Nova Muscae 1991 (=GS1124-68). Mon Not R astr Soc, 285:607, 1997 (A)

SHAVER P A (ESO), WALL J V (RGO), KELLERMANN K I (NRAO), ET AL
Decrease in the space density of quasars at high redshift. Nature, 384:439, 1996 (S)

SIMPSON C (OXFORD), WARD M (OXFORD), ET AL
Emission line ratios in a radio-selected sample of AGN. Mon Not R astr Soc, 281: 509, 1996 (A)

SIMPSON C (OXFORD), WARD M (OXFORD), ET AL
Emission line ratios in a radio-selected sample of AGN. Mon Not R astr Soc, 281: 509, 1996 (A)

SIMPSON C (OXFORD), WARD M (OXFORD), CLEMENTS D L (OXFORD), RAWLINGS S (OXFORD)
Emission line ratios in a radio-selected sample of AGN. Mon Not R astr Soc, 281: 509, 1996 (A)

SMITH R M (CARDIFF), DRIVER S P (UNSW), PHILLIPPS S (BRISTOL)
Luminosity distributions within rich clusters - I: A ubiquitous dwarf-rich luminosity func-

tion? Mon Not R astr Soc, 287:415, 1997 (A)

SMITH R M (WALES), DRIVER S P (UNSW), PHILLIPPS S (BRISTOL)
Luminosity distributions within rich clusters - I: a ubiquitous dwarf-rich luminosity function? Mon Not R astr Soc, 287:415, 1997 (A)

SMOKER J V (JODRELL), DAVIES R D (JODRELL), AXON D J (JODRELL)
H I and optical observations of the NGC 428 field. Mon Not R astr Soc, 281:393, 1996 (S)

SOUTHWELL K A (OXFORD), CHARLES P A (OXFORD)
The optical counterpart of the supersoft small Magellanic Cloud transient pulsar RX J0059.2-7138. Mon Not R astr Soc, 281:L63, 1996 (A)

SOUTHWELL K A (OXFORD), LIVIO M (STSI), ET AL
The nature of the supersoft X-ray source RX J0513-69. Astrophys. J. 470:1065, 1996 (A)

SPYROMILIO J (ESO), LEIBUNDGUT B (ESO)
Carbon monoxide in supernova 1995ad. Mon Not R astr Soc, 283, L89, 1996 (A)

STAPPERS B W (MSSSO), BESSELL M S (MSSSO), BAILES M (MELBOURNE)
Detection of an irradiated pulsar companion. Astrophys Jnl Letters, 473:L119, 1996 (A)

STEEL D I (ADELAIDE, AAO), ASHER D J (AAO)
On the origin of Comet Encke. Mon Not R astr Soc , 281:937, 1996 (O)

STOBIE R S (SAAO), KILKENNY D (SAAO), O'DONOGHUE D (CAPE TOWN), ET AL
The Edinburgh-Cape Blue Object Survey - I. Description of the survey. Mon Not R astr Soc, 287:848, 1997 (S)

STORRIE-LOMBARDI L J (CAMBRIDGE), IRWIN M J (RGO), MCMAHON R G (CAMBRIDGE)
APM z greater than 4 survey: distribution and evolution of high column density H1 absorbers. Mon Not R astr Soc , 282:1330, 1996 (A)

TAMURA M (TOKYO), HOUGH J H (HERTFORDSHIRE), CHRYSOSTOMOU A (HERTFORDSHIRE), ITOH Y (TOKYO), MURAKAWA K (TOKYO), BAILEY J A (AAO)
Identification of the exciting source of Herbig-Haro objects 135 and 136. Mon Not R astr Soc, 287:894, 1997 (A)

TAYLOR K (AAO), BAILEY J (AAO), WILKINS T (DURHAM), SHORTRIDGE K (AAO), GLAZEBROOK K (AAO)
Design-led software strategy for the 2dF survey spectrograph. ASP Conf series vol.101: Astronomical data analysis software and systems V, p.195, 1996 (A)

TAYLOR K (AAO), CANNON R D (AAO), WATSON F G (AAO)
The Anglo-Australian Telescope's 2dF facility. SPIE Proc: Optical telescopes of today and tomorrow, 2871:145, 1997 (A)

TE LINKEL HEKKERT P (ATNF), CHAPMAN J M (AAO)
A search for OH maser emission from post-asymptotic giant branch stars. Astronomy & Astrophysics Supplement, 119:459, 1996 (O)

THACKRAH A (EDINBURGH), JONES H (LIVERPOOL), HAWKINS M (ROE)
Lithium detection in a field brown dwarf candidate. Mon Not R astr Soc, 284:507, 1997 (A)

TINNEY C G (AA0), DA COSTA G S (MSSSO), ZINNECKER H (POTSDAM)
QSOs behind the nearest Milky Way satellite galaxies. Mon Not R astr Soc, 285:111, 1997 A,(S)

TINNEY C G (AAO)
CCD astrometry of southern very low-mass stars. Mon Not R astr Soc, 281, 644, 1996 (O)

VAN DEN BERGH S (DAO), ABRAHAM R G (CAMBRIDGE), ELLIS R S (CAMBRIDGE), TANVIR N R (CAMBRIDGE), SANTIAGO B X (CAMBRIDGE), GLAZEBROOK K G (AAO)
A morphological catalog of galaxies in the Hubble Deep Field. Astronom Jnl, 112:359, 1996 (O)

VAN OJIK R (LEIDEN), ROTTGERING H J A (LEIDEN), MILEY G K (LEIDEN), HUNSTEAD R W (SYDNEY)
The gaseous environments of radio galaxies in the early Universe: kinematics of the Lyman alpha emission and spatially resolved HI absorption. Astronomy & Astrophysics, 317:358, 1997 (A)

VEILLEUX S (MARYLAND), BLAND-HAWTHORN J (AAO)
Artillery shells over Circinus. Astrophys Jnl Letters, 479:105, 1997 (A)

VENTURI T (BOLOGNA), BARDELLI S (TRIESTE), MORGANTI R (BOLOGNA), HUNSTEAD R W (SYDNEY)
Radio properties of the Shapley Concentration I. The Abell Cluster A3556. Mon Not R astr Soc, 285:898, 1997 (S)

VERBUNT F (UTRECHT), JOHNSTON H M (UTRECHT), DE BRUYN A G (DWINGELOO), VAN DER KLIS M (AMSTERDAM)
X-ray observations of PSR J0218+4232 and of PSR B1937+21. ASP Conf series, vol 105, p.353, 1996 (O)

VERBUNT F (UTRECHT), KUIPER L (UTRECHT), BELLONI T (ANTON PANNEKOEK), JOHNSTON H M (AAO), ET AL
High-energy observations of the millisecond pulsar PSR J0218+4232. Astronomy & Astrophysics, 311:L9, 1996 (O)

WAKAMATSU K (GIFU, JAPAN), MALKAN M (CALIFORNIA), PARKER Q A (AAO), KAROJI H (TOKYO)
An obscured galaxy redshift survey with FLAIR. Publ Astron Soc Australia, 14:126, 1997 (S)

WALSH W (UNSW), STAVELEY-SMITH L (ATNF), OOSTERLOO T (ATNF)
The giant, gas-rich, low-surface-brightness galaxy NGC 289. Astronom Jnl, 113:1591, 1997 (A)

WATSON F G (AAO)
Waveguide spectrographs for astronomy. SPIE Proc: Optical telescopes of today and tomorrow, 2871:1373, 1997

WEBSTER R L (MELBOURNE), DRINKWATER M J (AAO), FRANCIS P J (MELBOURNE), ET AL
Dust and the search for high redshift quasars. The early universe with the VLT, p.340, 1997 (A,S)

WELTY D E (CHICAGO) (AAO), MORTON D C (VICTORIA), HOBBS L M (CHICAGO)
A high-resolution survey of interstellar Ca II absorption. Astrophys Jnl Suppl, 106:533, 1996 (A)

WILSON G (DURHAM), SMAIL I (DURHAM), ELLIS R S (CAMBRIDGE), COUCH W J (UNSW)
The faint end of the galaxy luminosity function in moderate-redshift clusters. Mon Not R astr Soc , 284:915, 1997 (A)

WRIGHT A E (CSIRO), TASKER N J (MACQUARIE, CSIRO), SAVAGE A (UKST), VAUGHAN A E (MACQUARIE)
The Parkes-MIT-NRAO radio surveys. IAU Symp 175, Extragalactic radio sources, p.507, 1996 (O)

YOUNG S (HERTFORDSHIRE), HOUGH J H (HERTFORDSHIRE), EFSTATHIOU A (HERTFORDSHIRE), WILLS B J (TEXAS), BAILEY J A (AAO), WARD M J (OXFORD), AXON D J (STSI)
Polarimetry and modelling of narrow line active galaxies. Mon Not R astr Soc, 281, 1206, 1996 (A)

ZARITSKY D (LICK), SMITH R (CARDIFF), FRENK C S (DURHAM), WHITE S D M (MPA)
More satellites of spiral galaxies. Astrophys. J.478:39, 1997 (A)

ZARITSKY D (LICK), SMITH R (WALES), FRENK C S (DURHAM), WHITE S D M (MPA)
More satellites of spiral galaxies. Astrophys. J. 478:39, 1997 (A)

Popular articles by AAO staff

LEE S (AAO)
Build your own 20cm Newtonian telescope project part 1. Sky & Space, vol.9 no.2, p51, 1996

LEE S (AAO)
Technical tips (finder 'scope). Sky & Space, vol.9 no.2 p.60, 1996

LEE S (AAO)
Build your own 20cm Newtonian telescope project part 2. Sky & Space, vol.9 no.3, p.59, 1996

LEE S (AAO)
Build your own 20cm Newtonian telescope project part 3. Sky & Space, vol.9 no.4, p.59, 1996

MALIN D F (AAO)
Images - Bok globules in IC 2944. Sky & Telescope, 92:20, 1996 (A)

MALIN D F (AAO)
Images - The Triffid Nebula. Sky & Telescope, 92:20, 1996 (A)

MALIN D F (AAO)
Images - NGC 300. Sky & Telescope, 93:26, 1997

MALIN D F (AAO)
A la rencontre des galaxies a coquilles. Ciel et Espace, 315:66, 1996

MALIN D F (AAO)
Peculiar galaxies. Astronomy Now, 11:51, 1997

SEARGENT D A J
Comets. Sky & Space, vol 9 no 2 p.44-45, 1996

STEEL D I (AAO)
Meteoroids from interstellar space? Yearbook of Astronomy 1996. Ed. P. Moore

WATSON F G (AAO)
Surplus to requirements... New Scientist, v152 n2061/2, p77, 1996

WATSON F G (AAO)
Taxi ride: the observatories on La Palma. 1997 Yearbook of astronomy (ed Patrick Moore),p.257, 1996

WATSON F G (AAO)
De jacht op informatie - van Galilei tot 2dF (The hunt for information - from Galileo to 2dF) Zenit, 24:108, 1997