

Scientific highlights

A clue to the origin of life

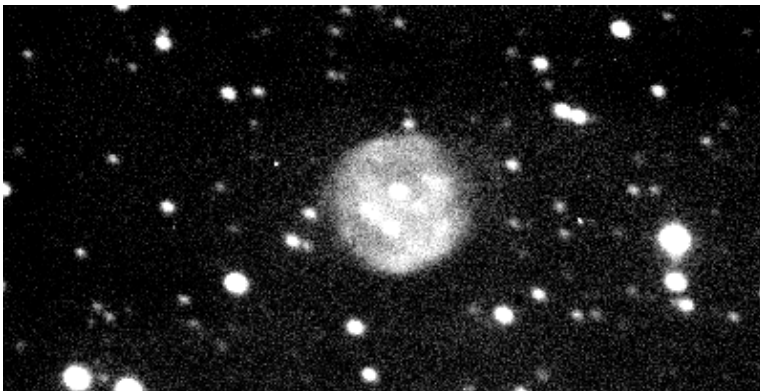
The AAT was used to produce a possible explanation for why life on earth almost exclusively uses left-handed amino acids and right-handed sugars as the building blocks of proteins and nucleic acids — a mystery that has puzzled scientists for 150 years. As a result of these novel observations, it is now believed the asymmetry was imprinted in organic molecules in interstellar space before the formation of the Solar System. These molecules then found their way onto the Earth via the impacts of comets and meteorites and provided one the starting materials for the origin of life.

The origin of the X-ray background

Observations using the LDSS instrument at the AAT have identified an obscured quasar in a sample of objects detected with the ASCA X-ray satellite. Quasars hidden at visible wavelengths have previously been proposed as a major component on the enigmatic X-ray background. The X-ray background was first discovered in 1962 and its nature is one of the longest-standing cosmological puzzles. This discovery provides direct observational evidence that obscured active galactic nuclei are present in deep X-ray samples and may be responsible for the bulk of the X-ray background.

New planetary nebulae discovered

The UK Schmidt Telescope is undertaking a major new survey of the southern sky in hydrogen-alpha (H-alpha) light. In the past year, more than one quarter of the survey has been completed. Over 300 new planetary nebulae have already been discovered from the survey. Planetary nebulae represent the phase towards the end of a star's life when it throws off its outer envelope of gas after exhausting the nuclear fuel in its core. The final survey should more than double the known number of planetary nebulae in the southern hemisphere, providing further information on how stars like our Sun will eventually die.



One of 300 planetary nebulae discovered in the UKST H-alpha survey. Planetary nebulae have nothing to do with planets, but were so named because of their resemblance to the disc shape of very faint planets.

Other highlights

The ESO/Australia Workshop

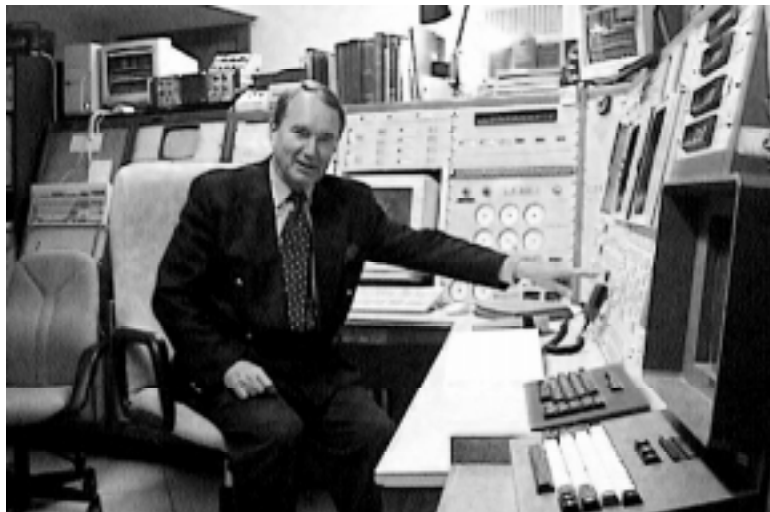
In December 1997, the AAO was one of the co-organisers of the ESO/Australia Workshop on 'Looking Deep in the Southern Sky.' Over 150 participants attended the workshop held at the State Library of NSW. Every major southern hemisphere observatory or group was represented and the workshop provided an extremely stimulating forum to discuss scientific and technical issues. Major surveys such as those undertaken with the AAT's 2dF instrument, the Parkes multibeam and the ESO imaging survey featured prominently in the topics for discussion.

Minister's visit

The Australian Minister for Science, John Moore, MP, visited the Anglo-Australian Telescope in May 1998. His visit was part of a tour of Australian astronomy facilities which included the Mount Stromlo and Siding Spring telescopes and the Paul Wild Observatory at Narrabri. He was present during a 2dF observing run for the new galaxy and quasar redshift surveys currently underway at the AAT.

'Nightskies' exhibition around the world

The British Council celebrated 50 years of presence in Australia during 1997 with program of events 'newIMAGES.' Part of this program involved the use of AAO photographs — the 'Nightskies' exhibition. This exhibition continued to tour Australia and the UK. As well, complete sets of the exhibition have been bought by several British and European museums. The exhibition also opened at the National Academy of Science in Washington DC, and a smaller version opened at a commercial gallery in New York. There has also been interest from South Africa, Korea and China.



The Australian Minister for Industry, Science and Tourism, John Moore, MP, visited the Anglo-Australian Telescope in May.

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 to ensure the best possible science. It also takes a leading role in the formulation of long-term plans and strategies for astronomy in both countries and, through its research and development of new instrumentation, to the advance of astronomy internationally.

History and governing legislation

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

The Board's facilities consist of the 3.9-metre Anglo-Australian Telescope (AAT) and the 1.2-metre UK Schmidt Telescope (UKST) on Siding Spring Mountain, outside Coonabarabran, NSW, and a laboratory in the Sydney suburb of Epping. Collectively, these are known as the Anglo-Australian Observatory (AAO). 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. Two are highlighted here, and details of scientific programs are given in Chapter 3.

Hubble Deep Field South

Archive survey material from the UKST and 2dF observations from the AAT were used to identify a high redshift quasar suitable for the Hubble Deep Field South (HDFS) project. The HDFS is a follow-up to the successful Hubble Space Telescope's (HST) Deep Field project which produced the deepest ever image of the Universe in late 1995. The HDFS will be observed by the HST for 2 weeks in October 1998.

A clue to the origin of life

The AAT was used to detect circularly polarised light in a star forming region of the Great Nebula in Orion. This type of radiation is known to influence the 'right- or left-handedness' of molecules. This handedness is present in molecules of living organisms. Scientists postulate that this asymmetry was imprinted in organic molecules in interstellar space and found their way to Earth via the impacts of comets and meteorites.

A suite of instruments that best meets the needs of the astronomical community

The AAO spends a large portion of its budget on instrumentation. Full details of instrumentation projects are included in Chapter 4.

2dF The Two-degree Field (2dF) facility for the AAT is now fully operational and in regular use. Using many optical fibres, and a robotic fibre-positioner, the 2dF enables scientists to observe and analyse 400 objects simultaneously. The 2dF galaxy redshift survey and the associated quasar redshift survey have been particularly successful. More than 2000 objects are regularly being observed and analysed on each clear allocated night.

6dF The development of the Six-degree Field (6dF) facility for the UKST was approved during the year. Though smaller and less complex than the similar 2dF, the 6dF will ensure that the UKST remains very productive into the next century. The 6dF will allow the UKST to undertake the first truly all-sky spectroscopic survey in either hemisphere.

Most efficient use of AAO resources

The Corporate Plan sets out Key Result Areas, Key Outcomes and Performance Indicators. The plan was reviewed during the year, and the revised Corporate Plan will come into operation on 1 July 1998. 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
1993-94 to 1997-98**

Source of Rev. \$k, (%)	1993-94	1994-95	1995-96	1996-97	1997-98
UK contribution	3203 (47)	3043 (45)	3119 (46)	3287 (47)	3459 (46)
Aust contribution	3063 (45)	3043 (45)	3164 (47)	3281 (47)	3462 (46)
Royalties & image sales	91 (1)	113 (2)	98 (1)	136 (2)	193 (3)
Space Telesc. Science Inst.	81 (1)	94 (1)	99 (1)	26	22
Other	339 (5)	301 (4)	267 (5)	257 (4)	335 (4)
2dF grants	42	0	0	0	0
Total	6819	6594	6747	6961	7471

Ministers responsible

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

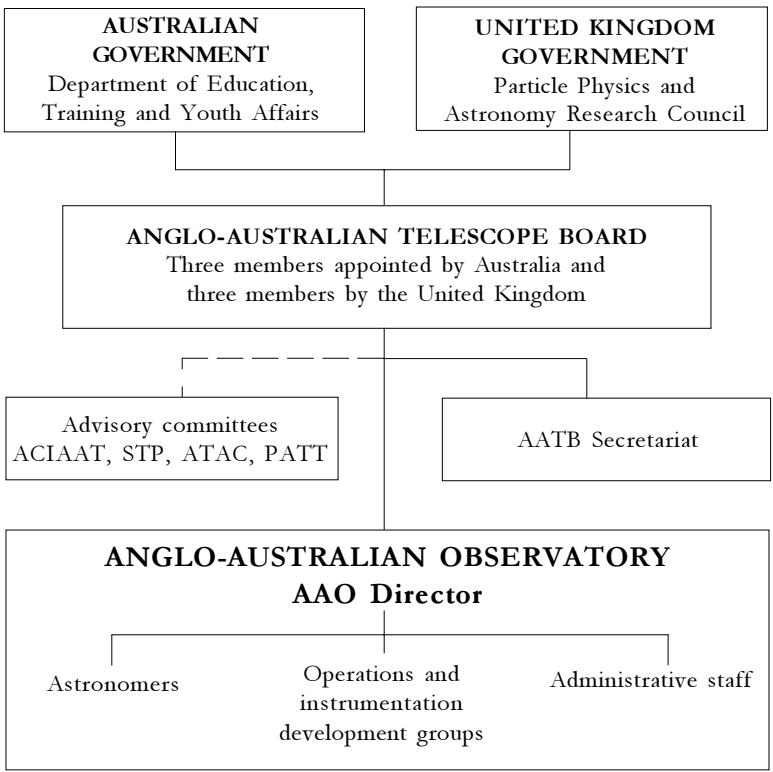
Designated agencies

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

Structure of the AAO

The AAT Board oversees the operations of the Anglo-Australian Observatory, as Figure 1.1 shows. Apart from an active research group, the Observatory has internationally recognised optical, mechanical and electronics engineering groups and a specialised software group. These five groups are critical to the maintenance and the day-to-day

Figure 1.1 General structure of the AAT Board and the AAO



operations of both the telescopes and to the development of state-of-the-art instrumentation. Additional staff were hired during the year to work on specific projects including the external contract to build the OzPoz fibre positioner for the European Southern Observatory. A small administration group contributes significantly to the effective operation of the Observatory. Details of the internal structure of the AAO are given in Appendix G.

Board members

The AAT Board has six members, three appointed by each country, and the role of Chair alternates between the two countries. Professor R L Davies took over as Chair on 1 July 1997 and Professor J R Mould was elected Deputy Chair. Professor R D Ekers was appointed on 1 July 1997 on the retirement from the Board of Professor L E Cram, after seven and a half years. Professor M H Brennan retired on 30 December 1997 after seven years service. The Board extended sincere thanks to both Professor Cram and Professor Brennan for their valuable contributions during their terms. Professor V R Sara replaced Professor Brennan as Chair of the ARC and became the Australian Designated Member. At 30 June 1998 the Board members were:

United Kingdom

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

Professor J A Peacock, Professor of Cosmology, University of Edinburgh (appointed until 30 June 2000)

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

Australia

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

Professor R D Ekers, Director, Australia Telescope National Facility (appointed until 30 June 2000)

Professor V R Sara, Chair, Australian Research Council (appointed until 31 December 2000)

Special responsibilities

Professor Sara and Dr Corbett have been nominated by the Designated Agencies, DETYA and PPARC respectively, to represent that agency on all matters in relation to the operation of the Agreement. Professor Peacock 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 Board members attended both meetings in 1997–98.

In September 1997, the meeting was hosted by the University of Durham. The scientific symposium is now held at the time of the United Kingdom National Astronomy Meeting. This year it was hosted by University of St Andrews, in April 1998. In March 1998, the Board meeting was held at both Siding Spring Observatory and the Epping Laboratory in Sydney. The associated symposium was held jointly with the Australia Telescope National Facility (ATNF), and was hosted by Mount Stromlo Observatory in Canberra. 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 C.

AAO Director

The AAO Director, Dr B J Boyle, 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 1998 the five ACIAAT members were:

Australia	Dr M Colless (MSSSO), Chair A/Prof. W J Couch (NSW)
United Kingdom	Prof. M J Barlow (UCL) Dr S Phillipps (Bristol)
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 1998 the seven STP members were:

Australia	Dr R W Hunstead (Sydney), Chair Dr M S Bessell (MSSSO)
United Kingdom	Dr J I Davies (Cardiff) Dr R G McMahon (IoA)

Astronomer-in-Charge, AAO	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 national committees—the Australian Time Assignment Committee (ATAC) and the UK Panel for the Allocation of Telescope Time (PATT)—which allocate time on the AAT on the basis of the scientific merit of proposals submitted by astronomers, including AAO staff. PATT also allocates time for projects for the UKST. At 30 June 1998, membership of the two committees was:

ATAC

Dr R Webster (Melbourne) Chair	Dr J Hawthorn (AAO)
A/Prof. W Couch (NSW)	Dr C Heisler (MSSSO)
Dr G Da Costa (MSSSO)	Dr J Caswell (ATNF)
Dr T Bedding (Sydney)	

PATT (AAT TAG)

Dr I Howarth (UCL) Chair	Dr R McMahon (IoA)
Dr M Hoare (Leeds)	Dr S Phillipps (Bristol)

AAO staff

Staff numbers

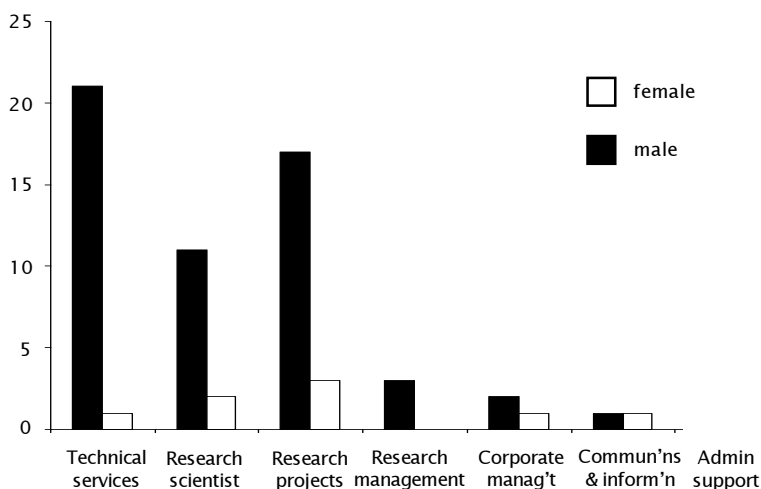
The AAO employs research scientists, technical staff, computer programmers, electronics engineers, optical and mechanical engineers, administrative and library staff. There are nine fixed-term research astronomers, three of them part-time, and sixteen other fixed-term staff members, including the Director. 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 1998 the staff positions were:

	Full time	Part time
Director	1	
Fixed term research	6	1 (0.56 FTE)
Other fixed-term	12	3 (1.82 FTE)
AAO Fellow	0	2 (1.1 FTE)
Indefinite appointment	44	2 (1.05 FTE)

Figure 1.2 Staff numbers by functional area and gender



Staff turnover

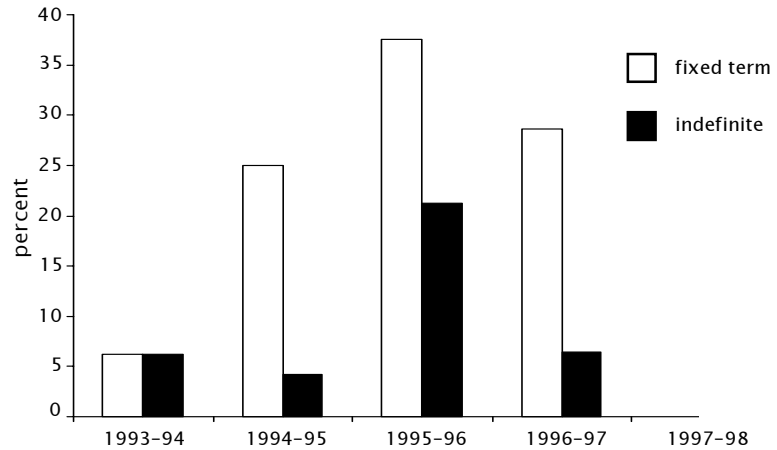
Table 1.3 shows the turnover rates for the year 1997–98, and figure 1.3 the trends. This year there was no turnover in fixed term staff but the number of fixed term staff almost doubled. This was because of appointments to projects including IRIS 2, OzPoz and 6dF. Turnover among fixed term staff, who normally have terms of about five years, can be expected to be about 20 percent a year.

Excluding the peak in 1995–96, the turnover of staff with indefinite appointments was slightly higher than average. Such an increase could be a cause for concern, however there was one medical retirement during the year, and those who resigned during 1997–98 did so for personal reasons.

Table 1.3 Staff turnover 1997–98

	Fixed term			Indefinite			Grand Total
	Female	Male	Total	Female	Male	Total	
Staff at 1 July 97	3	10	13	11	36	47	60
Staff at 30 June 98	3	22	25	11	35	46	71
Resignations	0	0	0	2	2	4	4
Retirements	0	0	0	0	1	1	1
Total departures	0	0	0	2	3	5	5
Turnover rate for year (%)	0	0	0	18.2	8.3	10.6	8.3
Appointments	0	10	10	2	1	3	13

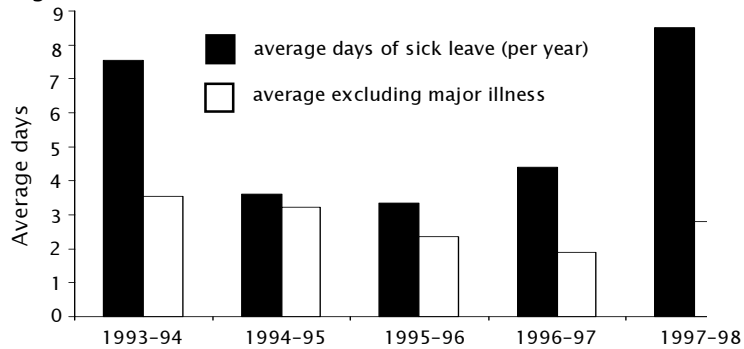
Figure 1.3 Trends in staff turnover



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 peaks in 1993-94 and 1997-98 were due to major illnesses of one or two people. During 1997-98, 2.81 percent of usual working hours were lost due to sickness, and a further 0.3 percent to personal leave. This is slightly above reported averages for Australia as a whole, where 2.4 percent of usual working hours are lost due to unscheduled absences (from *Managing Absenteeism*, Dept. of Industrial Relations, 1995).

Figure 1.4 Trends in sick leave



Enterprise Agreement

The Anglo-Australian Telescope Board's Enterprise Agreement was to run until July 1997. In the event, it ran until 7 July 1998, when a new Agreement was certified.

A working group, representative of all sections and levels of the observatory, developed a series of proposals to be incorporated in the new Agreement. Among the proposals were productivity improvements including a new shift allowance scheme and overtime

into an annualised salary, scope to use sick leave for personal leave, and two weeks paid 'new baby leave.' A pay rise of two percent was backdated to February 1997, with a further three percent upon certification, two percent in June 1999 and three percent in June 2000.

Equal employment opportunity (EEO)

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

As Figure 1.2 reveals, only a quarter of the Observatory's staff are female and, of those, half are administrative staff.

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.

There was more recruitment than usual in 1997–98. Most of the positions were for engineers, and the proportion of female applicants was disappointingly low; only one female engineer was appointed. Of the 13 appointments, three were to people of non English-speaking background.

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 1998 the Board's premium to Comcare was \$27 543, compared with \$31 431 in the previous year. There were no new compensation claims during 1997–98. Nor were there any 'dangerous occurrences' that required notification to Comcare in 1997–98. These are pleasing results, reflecting the Observatory's continuing commitment to occupational health and safety.

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

The intellectual challenge of astronomical research attracts some of the finest scientific minds. Astronomy is both 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 remains one of the world's most scientifically productive telescopes. The UKST is the most productive survey telescope in operation anywhere. Both telescopes were state-of-the-art when observing commenced in the early 1970s. 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 and are often asked to provide advice to other organisations building instruments for telescopes.

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

The 2dF facility, now in regular use, 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 smaller system, 6dF, was approved for development for the UKST during the year. The 2dF and 6dF 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 1994, after consultation with its advisory committees and with the user communities in both countries, the Board



Chris McCowage, Electronics Engineer at Siding Spring, making adjustments to one of the 2dF spectrographs.

recommended that funding should continue at a level sufficient to maintain the AAO as a well-instrumented, front-line observatory. As a consequence 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: external users do most of the research. The AAO nevertheless makes a significant contribution to the quality of the results in the following ways:

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

Second, by ensuring that the best mix of instrument and software development is undertaken, the Board, the 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.

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 communications

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

Key result area: telescope operations

Key outcome: satisfied users and good data

Strategies

An important strategy is to listen carefully to the astronomy community, especially the users of the AAO's telescopes, to assess and anticipate their needs. Several avenues are available for this. The

time assignment panels, the 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 1997–30 June 1998 is shown in Table 2.1. This year there were 3265 night hours available. In addition, a further 392 hours of twilight and 27 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 1997–98, this was 2.9 percent, a little higher than previous years due mainly to the inclusion of 2dF time in the statistics for the first time. Previously, 2dF nights were identified as commissioning time. However, this still met the Corporate Plan performance target of less than three percent.

Table 2.1 Use of observing time on the AAT

	1994–95	1995–96	1996–97	1997–98
	Percentage of total night-time hours			
Observing (incl. commissioning)	65.4	59.5	62.8	56.1
Loss due to weather	31.9	37.6	35.0	39.5
Loss due to AAT equip. failure	2.1	1.6	1.6	2.9
Loss due to other factors	0.6	1.3	0.6	1.5

User feedback

Another constructive way to assess user satisfaction is to ask users how well they regard the level of service offered. Observers at the AAT and UKST complete a form on the worldwide web in which



Greta Simms, Personnel Officer, in her Epping office.

they provide detailed comments on any areas of concern, and fill in a questionnaire which ranks their level of satisfaction with observing support, instrumentation, technical manuals, administration and web pages. These are ranked on a scale of 1 (poor) to 4 (excellent).

During the period 1 July 1997 – 30 June 1998, a total of 61 user feedback forms were completed for the AAT. This represents about half of all 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 are extremely useful for showing where improvements may be needed. In particular, the user feedback comments have strongly emphasised the need for a more stable computer environment at the Coonabarabran site.

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

The Corporate Plan sets a goal of at least 3 in all categories. This was achieved in all but one categories, and corresponding improvements are underway.

Table 2.2 User feedback at the AAT

	Average rank (maximum 4)	
	1996–1997	1997–1998
Night Assistant support	3.8	3.9
Staff astronomer support before observations	3.4	3.5
Staff astronomer support during observations	3.7	3.7
Other technical support	3.7	3.7
Instrumentation and related software	3.2	3.1
Working environment	3.1	3.2
Travel and admin support	3.3	3.6
Data reduction software	3.0	3.0
Instrument manuals	2.6	2.9
AAO Web pages	3.1	3.3

UK Schmidt Telescope organisational statistics

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

Table 2.2: Comparison of photographic imaging and total FLAIR exposures

	1993–94	1994–95	1995–96	1996–97	1997–98
Plates and films	549	507	465	485	431
FLAIR hours	309	345	203	272	263

Totals of 143 plates and 288 films were obtained during the year, including test exposures. FLAIR observations were made on 73 nights. On 28 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 263 hours of science data was obtained using FLAIR, which corresponds to about 34 percent of all the observing time used on the UKST.

Table 2.2 shows the annual totals of photographic exposures and hours of FLAIR observation. Observing conditions in 1997–98 were much the same as in the previous year, and the hours of FLAIR observation are very similar. The fall in the number of photographic exposures during the year is because almost 20 percent of them were long-exposure H-alpha films.

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



Paul Lindner, Senior Mechanic, at his lathe in the AAT workshop.

UKST Performance Indicators

The use of scheduled observing time on the UK Schmidt Telescope from 1 July 1997 to 30 June 1998, and in the previous three years is shown in Table 2.3. During the second half of the reporting year, observations were carried out at the beginning and end of some bright-of-moon periods to maximise use 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 Schmidt Telescope programs are more vulnerable to the prevailing weather, requiring photometric conditions and good seeing to carry out photographic observations.

Table 2.3 Use of observing time on the UKST, 1 July 1994 to 30 June 1998

	1994-95	1995-96	1996-97	1997-98
	Percentage of total night-time hours			
Used for observing	49.8	43.5	48.8	47.8
Lost due to poor observing conditions	50.0	56.1	49.4	50.7
Lost due to equipment faults	0.2	0.4	1.8	1.5

Table 2.3 shows that the overall weather statistics of the previous year were maintained, although in both years there was a noticeable seasonal pattern with exceptionally good conditions being experienced in late summer. In 1997-98 this was followed by an unusually wet winter. Equipment faults included a failure of the sidereal drive and problems with the plateholder elevator and the dome drive. The time lost due to equipment faults met the Corporate Plan performance measure of less than two percent.

Table 2.4 shows that progress with the surveys continues. A milestone achieved during the year is that both the ER and SES surveys were completed to B-grade. All the outstanding A-grade fields for these surveys are in the RA range 22 h - 6 h. Progress with the near-infrared I survey has been slow because of competition in grey/bright time from the H-alpha surveys (details of which are included in the non-survey statistics).

Table 2.4 Current glass-plate survey status

Survey	Plates taken 1996-97		Plates taken 1997-98		Total for survey		
	Total	A-grade	Total	A-grade	Obtained	Requ'd	Total
ER	10	8	11	7	271	17	288
I	60	39	10	4	705	189	894
R(SES)	66	47	34	22	577	29	606

Key result area: research

Key outcome: good science

Strategies

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

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

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

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

Organisational statistics

There were 15 research astronomers on the staff of the AAO in 1997–98. Nine 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 nine 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, the Astronomical Photographer and two other staff. The full time equivalent research effort is about six people.

Appendix B lists research papers published from AAT and UKST data during the period 1 July 1997 – 30 June 1998 as well as other papers published by AAO staff. Appendix D presents the AAT observing programs from 1 August 1997 to 31 July 1998. 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
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
1997–98	17	30	35	22	104	31

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
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
1997–98	15	16	44	25	100

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
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
1997–98	8	4	24	19	55

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*
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
1997–98	29	18	43	90

** 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.

Table 2.9 gives the number of AAO publications produced by staff, students and visitors. AAO staff consistently produce a large number of high quality publications. This year was the number of papers was the highest ever, 90. Of these, approximately 80 percent are in refereed journals. The average annual number of publications per research staff member is now approximately six.

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 six year period from 1992 to 1998, the average number of papers per program is 0.84.

Table 2.10 Publications per AAT observing program

Publications per AAT observing program	
1992–93	0.73
1993–94	0.68
1994–95	0.73
1995–96	0.96
1996–97	0.99
1997–98	0.96
Average 1992–98	0.84

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

Table 2.11 Publications in refereed journals using data from British telescopes (Non AAT data supplied by Royal Greenwich Observatory and Royal Observatory, Edinburgh)

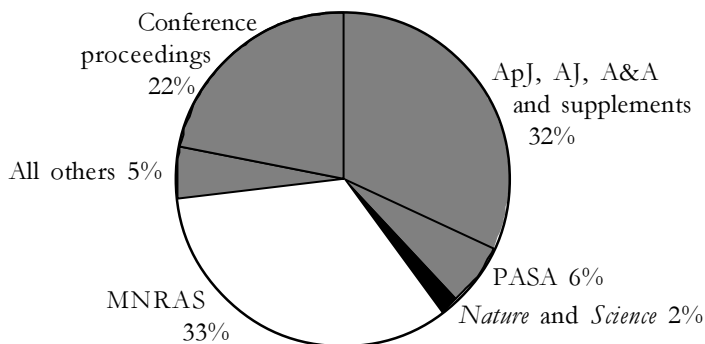
	AAT*	UKST	WHT	INT	JKT	UKIRT	JCMT
1992	71	71	42	56	25	63	33
1993	57	82	55	70	30	72	42
1994	62	66	78	63	44	77	64
1995	89	99	90	81	29	64	67
1996	86	100	100	84	52	82	52
1997	88	125	113	77	35	Not available	

* AAT data is shown for financial years, ie 1992–93 etc.

AAO publications by journal submission

Figure 2.1 shows the distribution of AAO publications for the three-year period from July 1994 to June 1997. Approximately one-third of AAO publications which include AAT data are published in the primary British journal, the *Monthly Notices of the Royal Astronomical Society* (MNRAS). Another one-third are published in the major American and European journals, while approximately one quarter of papers are published as conference proceedings. A small number of papers are published in the highly prestigious journals, *Nature* and *Science*, and in the *Publications of the Astronomical Society of Australia*. The remaining papers are published in a variety of journals of astronomy, geophysics, engineering and technical papers.

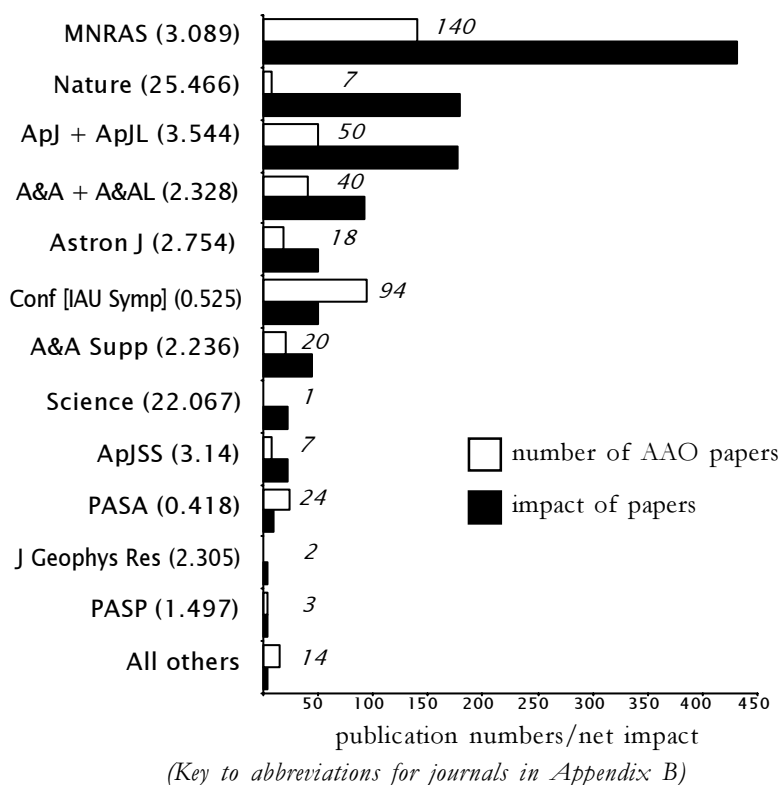
Figure 2.1 AAO Publications by Journal Submission:
July 1994 to June 1997



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. One method used to study citation rates is to use journal *impact parameters* given in the Science Citation Index (SCI). The impact parameter for a journal in a given year is the average number of citations per publication determined from all papers published in the previous two years.

Figure 2.2 shows the net impact for AAO publications between July 1994 and June 1997. The SCI impact parameters (1994 values) are given next to the journal names. For each journal the black bar shows the net impact, calculated from the total number of papers published over the three year interval multiplied by the impact parameter. During 1994–1997, the largest AAO impact was for papers published in the MNRAS and in the *American Astrophysical Journal* (ApJ). Note also the relatively large impact for the small number of papers published in *Nature* and *Science*.

Figure 2.2 AAO Publication numbers and Net Impacts:
July 1994 to June 1997



External Citation Studies

Citation analyses based on impact parameters are useful for seeing the relative effectiveness of the different journals and for looking at the overall impact of an organisation. However, such analyses do not take into account the large variations in citation rates between different papers published in the same journal. Several external analyses, based on *actual* citation rates, provide further insight into the AAT's citation record. Here we briefly review some of these studies.

In a citation survey published in *Science Watch* (the journal of the US Institute of Scientific Information) in June 1993, Mitton found that of the 20 papers with the highest number of citations during 1992, five 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' by Trimble (1995, PASP, **107**, 977), examined citations for papers published in the American journals: the *Astrophysical Journal*, the *Astronomical Journal* and the Publications of the Astronomical Society of the Pacific. The citations per paper (cpp) index from papers with AAT data was 4.96, the fourth highest

citation rate in the survey. This is a surprisingly strong result as AAT data published in Australian or British journals were not considered.

In a third study, 'The Cost Effectiveness of Observational Astronomical Facilities since 1958,' Leverington (1996, QJRAS, **31**, 643) analysed citation rates for the 15 percent most cited papers for the two primary American and British journals, the *Astrophysical Journal* and the *Monthly Notices of the Royal Astronomical Society*. This study found that for the years 1978 to 1994, the highest averaged and cumulative citation rates for any ground- or space-based observatory were obtained for papers based on AAT data.

In a more recent Australian study, the 'CSIRO Profile of Basic Research' (1997, Research Evaluation and Policy Project, ANU), Butler, Bourke and Biglia give publication and citation rates for CSIRO and for other government and university research institutions. Their report shows that Australian astronomy is extremely competitive on a world-wide basis. For all groups, the ccp rates for astronomy were higher than the Science Citation Index (SCI) 'world-average.' For the five year period from 1991 to 1995, the cpp value for the Anglo-Australian Observatory of 5.3, was somewhat higher than for the Australia Telescope National Facility (4.7) or the Australian universities (4.4).



John Stevenson, Senior Technical Officer, at work at the AAT.

Key result area: instrumentation

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

Strategies

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 recently created and filled the position of AAO Project Manager. As well, project management training continued to be provided for 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. This year, the Two-degree Field (2dF) facility was regularly scheduled for the first time. It was allocated a large share of observing time, and is now the most requested and most scheduled instrument. Demand for the UCLES spectrograph has been the highest in four years. The introduction of the Taurus Tunable Filter has also considerably increased the usage of the Taurus II imager. This has resulted in decreased usage of the RGO spectrograph, though its use for polarimetric applications continues at a steady level.

The infrared 3D integral field spectrograph was offered to users in 1997–98, under an agreement reached with the Max Planck Institut für Extraterrestrische Physik. This has resulted in decreased use of the IRIS instrument, though the combined use of infrared instruments has remained approximately constant.

Detector use in recent years is outlined in Table 2.13. Charge coupled devices (CCDs) remain the astronomical detector of choice. Several

new CCD systems were brought into regular use during the year, alongside the Tek2 CCD which has served the Observatory so well over the last 5 years. In particular, use of the dedicated CCDs built into 2dF, and the first of the large format (2048 × 4096 pixel) CCDs to come from the Massachusetts Institute of Technology, Lincoln Laboratory (MIT/LL) development program are shown in the table. The MIT/LL2 device has been extremely popular, and its use now almost equals that of the Tek2.

Table 2.12 Use of AAT instruments for the last four years

Instrument	Percentage of nights allocated			
	1994–95	1995–96	1996–97	1997–98
2dF	-	-	-	22.2‡
RGO Spectrograph (including FORS)	28.5	24.3	23.6	7.3
RGO Spectrograph with polarimeter	6.8	6.9	6.5	7.0
AUTOFIB	3.7	0.0	0.0†	0.0†
FOCAP	0.0	0.9	0.0†	0.0†
Low dispersion survey spectrograph (LDSS)	1.1	5.8	2.7	1.0
UCL coudé echelle spectrograph (UCLES)	10.8	12.7	12.9	18.7
Ultra high resolution facility (UHRF)	8.5	3.1	6.5	3.2
Taurus II	4.6	5.8	13.3	17.5
Infrared imager/spectrograph (IRIS)	17.9	21.7*	22.4	7.3
Infrared photometer-spectrometer (IRPS)	0.0	} 2.2	0.0†	0.0†
Hatfield photometer	0.0		0.0†	0.0†
Auxiliary photometer	0.6	0.2	0.0†	0.0†
Prime focus imaging with CCD	2.6	8.9	5.3	2.5
f/1 focal reducer	2.3	0.0	0.0	0.0
Prime focus photography	2.3	1.2	1.5	0.0
3D	-	-	-	13.3
Instruments supplied by users	10.3	6.4	5.3	1.9

‡ 2dF regularly scheduled for the first time in 1997–98

* Includes UNSWTRF 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			
	1994–95	1995–96	1996–97	1997–98
CCDs Tek2	73.5	67.5	72.6	31.1
2dF	-	-	-	22.2
MIT/LL2	-	-	-	26.1
IPCS	0.0	0.6	0.0†	0.0†
Infrared IRIS	18.8	23.8	22.4	7.3
3D	-	-	-	13.3
Photometer	0.6	0.2	0.0†	0.0†
Photographic plates	2.3	1.2	1.2	0.0
Detectors supplied by users	4.8	6.7	6.7	0.0

† 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, this information is compiled from the user feedback survey responses. The level of user satisfaction with instrumentation and related software (a mean rank of 3.1 for this year) shows that the AAO is meeting its performance indicators as outlined in the corporate plan.

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. A new Corporate Plan was developed and approved during the year, and a new Enterprise Agreement was drawn up. A cross-section of staff was actively involved in the development of these important documents.

The Observatory is committed to equal employment opportunity and up-to-date occupational health and safety practices as a way of meeting



Coral Cooksley, Public Relations Assistant, looks after the sale and copyright of AAO images.

its objective of stimulated, productive, creative and focused staff working in an environment in which they feel secure. Training in these concepts and practices is a well-established part of AAO life.

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 and Chapter 1 outline the AAO's financial position.

Performance indicators (Financial)

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

Key result area: external communication

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

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

Public Relations

Photographic exhibitions

The success of the two parallel 'Night skies' exhibitions in the UK and Australia continued during the year. These exhibitions of 40 AAO photographs are in great demand and are still touring. Several museums in Europe have bought their own sets of the pictures. 'Night skies' opened at the US National Academy of Science in April and a smaller exhibition of prints opened at a commercial gallery in New York in May. There has also been interest from South Africa, Korea and China.

Talks and lectures

Many AAO staff frequently give talks and lectures, not only directed to the science community, but also to schools and general audiences. The number of popular talks doubled during the year reflecting the Observatory's keenness to tell the general community about the work of the AAO. The Annual Bok Lecture is part of an education program

for towns near Siding Spring Observatory. Dr Rachel Webster (Melbourne) gave the lecture 'Gravitational lensing.' The annual AAO/Questacon—National Science and Technology Centre Lecture was given by Dr Fred Watson, his topic was 'The future of Australian optical astronomy.' This year there was large increase in the number of public talks given by staff (see table 2.14). 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.

Dark skies

One of the main reasons that Siding Spring site was chosen as a location for an observatory was because of its dark skies. Astronomers need skies unpolluted by artificial light to observe the faintest objects. The maintenance of dark skies requires a local awareness and commitment to the concept of well planned lighting. Councillors from Coonabarabran and surrounding Shires were invited to Siding Spring for dinner, and a tour of the AAT, to remind them about the importance of well planned lighting, and their responsibilities under the Orana Regional Environmental Plan. The Observatory, together with MSSSO contracted a lighting consultant to assist with lighting issues and hopes to develop a strategic plan to further raise awareness of the importance of dark skies.

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 there was an increase in press releases and many items appeared in the press, on TV and on radio. This was reflected in the number of media interviews given over the year (see table 2.14). Fred Watson's weekly spot on ABC radio continues to be extremely popular and brings astronomical ideas to new audiences.

General inquiries

AAO staff respond to thousands of telephone and e-mail inquiries each year. These responses are an important way of publicising the Observatory's work.

Use of AAO images

The demand for the use of AAO images in all traditional forms of media continues to show a steady rise, with queries for combined book, magazine TV and movie uses increasing about ten percent over last year. Revenue from these sources is up slightly. Much more dramatic has been the growth in queries requiring digital images, either for CD-ROMs, worldwide web pages or direct supply of images for publication in digital form, for use as computer 'wallpaper,' educational overheads or Web-based teaching packages. Many of these uses are non-profit and/or educational, so revenue from these sources is small but growing. The most dramatic increase in activity (and income) has been print sales, sparked in part by the very successful 'Night Skies' exhibitions, but mainly by the sale of prints in the 'fine art' market in

the USA. Many publication and other queries for images originate from the Observatory's WWW presence.

World Wide Web

The WWW is by far our most public face. The AAO maintains an excellent record of WWW access for the complete year and can monitor usage (see <http://www.aao.gov.au/stats/www1998/index.html>). The AAO's Australian site averaged 250 000 hits per month, with a maximum of over 400 000 hits per month in March and April 1998. The average hit rate for the calendar year 1997 (the first time detailed records were kept) was about 175 000, peaking at 21 000 hits a day. The mirrored pages hosted at Cambridge attract typically just over 30 000 hits a month, while about three percent (12 000) are from UK sources direct to the Australian pages.

This suggests about ten percent of our hits are from the UK, while 20 percent were from Australian sources. Seventeen percent of hits appeared to be from 'USA commercial sources,' and, while it was not possible to determine the country of origin of the remaining hits, a large proportion of them are also likely to be from the USA. About three-quarters of the hits were attracted by the images pages. The publicly available web pages have recently been redesigned, with a more modern interface and reorganised sections for easier navigation around an increasingly complex site.

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.

Publications

The Observatory circulates a quarterly newsletter which gives updates on the latest scientific, instrumentation and staff news to recipients worldwide. Last year, the newsletter was redesigned and this has proved so popular with contributors that the number of pages has been increased from 20 to 24 to cope with the increased submissions. The newsletter is also available on the WWW. A new brochure for the general public about the AAO was produced during the year.

Table 2.14 External communication organisational statistics

	1996–97	1997–98
'Popular' Talks	48	95
Media Interviews	52	83
Revenue from sales of images	\$136 000	\$193 000
Science/Technical Colloquia	111	72
Review panels	20	20
Organising committees	8	12

3. Scientific research

Introduction

This chapter highlights some of the research programmes carried out using the 3.9-metre Anglo-Australian Telescope (AAT) and the 1.2-metre UK Schmidt telescope (UKST) during the period from July 1997 to June 1998. A summary of research activities of AAO staff is given in Appendix F.

The AAT is a powerful and versatile telescope which is equipped with a 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 C lists the projects allocated AAT time during the year. Each year, approximately one hundred different observing programs are awarded time on the AAT.

A major highlight at the AAT was the first year of scheduled scientific observations with the 2-degree Field (2dF) facility. This unique instrument is used to obtain spectra simultaneously for up to 400 objects. After six years of development work, the first scheduled astronomical observations with 2dF began in 1997. During the year 2dF was allocated about 20 percent of the available telescope time and data were taken for many different research programs. As described later in this chapter, considerable progress was made for the 2dF Galaxy Redshift Survey which aims to obtain redshifts for 250 000 galaxies, and for the 2dF Quasar Redshift Survey which will provide a catalog of redshifts for over 25 000 quasars.

Appendix E gives a breakdown of the time allocated to the UKST. The UKST is used for several systematic surveys of the southern sky. These include 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 all close to completion. The resulting atlases and their

digitised versions, produced using plate scanning machines, provide one of the fundamental tools in astronomy. In July 1997, the UKST began a major new survey for ionized hydrogen emission in our Galaxy and the Magellanic clouds. More than a quarter of this survey was completed during the year, with many new discoveries.

Appendix A gives a list of publications for 1997–1998. Tables giving publication and proposal statistics are given in Chapter 3. Typically 90 percent of all projects involve Australian or British astronomers, while 45 percent involved collaborations with astronomers from many other countries. On average, each observing program at the AAT results in about one publication.

Stars and the interstellar medium

Circular polarization and the origin of life

Observations with the Anglo-Australian Telescope may have provided the solution to a mystery which has puzzled scientists for 150 years. Living organisms use almost exclusively left-handed amino acids and right-handed sugars as the building blocks of their proteins and nucleic acids. When and how did this fundamental asymmetry arise? Bailey (AAO), Chrysostomou, Hough, Gledhill, Clark, McCall (Herts), Menard (Grenoble) and Tamura (NAO, Tokyo) propose that a preferred handedness was imprinted in organic molecules in interstellar space before the formation of the solar system, by the action of circularly polarized light. These molecules then found their way onto the Earth via the impacts of comets and meteorites providing some of the starting material for the origin of life.

In 1848, Louis Pasteur discovered that some molecules are asymmetric, such that they exist in two distinct mirror-image forms, either left-handed or right-handed. When these molecules are synthesized in the laboratory an equal mixture of left- and right-handed forms is generated. However, when such molecules occur in living organisms they are invariably of only one handedness. Thus amino acids, the building blocks of proteins, are always left-handed, whereas sugars, including deoxyribose, an important component of DNA, are always right-handed.

Pasteur speculated that we might be seeing the result of some ‘cosmic asymmetry,’ and that understanding the asymmetry might provide a key to understanding life. But he was unable to find any way of introducing a preferred handedness into molecules of non-biological origin. In 1930, it was discovered that the action of circularly polarized light could preferentially destroy molecules of one handedness, but no source of circularly polarized light is known that could have been important on the early Earth at the time that life forms originated.



Last year however, scientists at Arizona State University, reported the discovery of an excess of left-handed amino acids in the famous Murchison meteorite. This meteorite fell in 1969 near the small town of Murchison in the Goulburn Valley of Victoria, Australia and has been found to contain an extraordinary variety of organic molecules. This remarkable discovery showed that a preferred handedness already existed in organic molecules before life began on Earth. Such an asymmetry may well have been present in the material from which the solar system formed.

New infrared observations taken by Bailey and his collaborators at the Anglo-Australian Telescope with the IRIS infrared camera and a polarimetry system show how the asymmetry might have been generated. They show the presence of circularly polarized infrared light in a region of the Great nebula in Orion called the Orion Molecular Cloud 1 (OMC-1). This is a region in which new stars are being formed, and in which organic molecules are known to be present. It may well be similar to the region in which our own solar system formed. The polarization seen in the infrared is attributed to the scattering of light by dust particles which are aligned by a magnetic field. Calculations show that this process can produce circular polarization at all wavelengths from infrared to ultraviolet. Circularly polarized light at ultra-violet wavelengths in such a region could imprint a preferred handedness on organic molecules in the region, including those in a cloud beginning to collapse to form a star and its planets. Unfortunately, the thick dust clouds in front of OMC-1 prevent it being observed directly in the ultraviolet. However the detection of circularly polarized infrared emission shows that similarly polarized ultraviolet light must also be present.

Many scientists have argued that a preferred handedness in molecules must have been present in order for the origin of life to have been possible. These results therefore suggest that the suitability of our planet for life may be as much a consequence of the environment in which our solar system formed as of the local conditions on the early Earth.

The UKST hydrogen-alpha survey

The Balmer hydrogen-alpha (H-alpha) emission line provides an excellent tool for studying the ionized gas content of our Galaxy and of other galaxies.

The UKST H-alpha survey is a large-scale photographic survey of H-alpha emission in our Galaxy and in the neighbouring Magellanic Clouds. The survey images are taken using the Schmidt telescope with a purpose-built interference filter, tuned to the deep red wavelength of H-alpha emission. Images are recorded onto high resolution Tech

Pan film using exposure times of three hours per field. Each film covers a standard UKST field size of six by six degrees, while to ensure a full sky coverage, the survey field centres are separated by four degrees. The survey provides high resolution, deep H-alpha images which are particularly well suited for the detection of extended low-surface brightness objects. Such objects have proved difficult to detect in other surveys taken with poorer sensitivity or with poorer sky coverage.

One of the first results of the H-alpha survey is the discovery by Parker and Hartley (AAO) of more than 300 previously unknown planetary nebulae. During the later stages of stellar evolution, stars develop strong stellar winds in which gas is blown away from the stellar atmospheres. In this critical evolutionary phase, stars typically lose between 40 and 90 percent of their initial masses. The strong stellar winds initially form dense circumstellar envelopes around the central stars. The envelopes absorb the stellar radiation and the stars themselves become optically invisible. At a later stage, the mass-loss slows down and the circumstellar envelopes are swept up into shell-like regions. Radiation from the central stars ionize the shells which are seen as planetary nebulae.

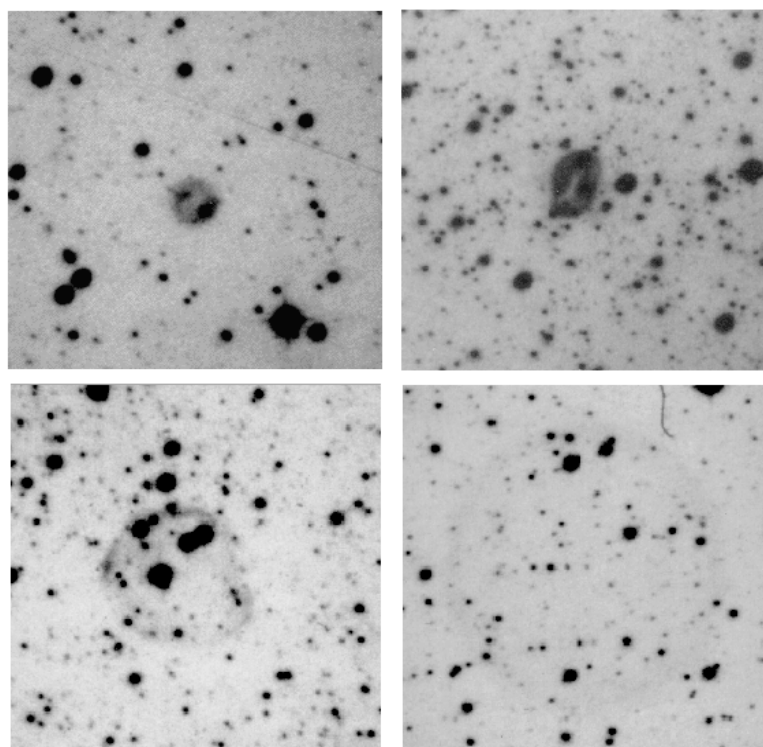


Figure 3.1 Images of four planetary nebulae discovered in the UKST H-alpha survey. Each image shows a region of approximately 3 by 3 arcminutes. The circular planetary nebula shown in the bottom right-hand panel is one of the faintest and most extended planetary nebulae ever discovered, with a diameter of 2.2 arcminutes. So far 300 planetary nebulae have been discovered in the survey.

The planetary nebulae discovered in the H-alpha survey were identified from visual scanning of the H-alpha films. Most of the new detections are invisible on standard UKST R- or J-band photographic plates, but are easily seen on the Tech Pan H-alpha films. Figure 3.1 shows images for four of the newly detected planetary nebulae. Each print shows a region of size 2.6×2.6 arcminutes, taken from part of a survey film. The detection of such faint and extended objects highlights the strengths of the H-alpha survey.

The newly discovered nebulae have much larger angular diameters than most of the known planetary nebulae. As planetary nebulae age, their shells expand, gradually dispersing into the interstellar medium. The large sizes of the newly discovered nebulae show that they are in a very advanced stage of evolution. The detection of such planetary nebulae provides new insights into how stars, including our own Sun, will eventually die.

H-alpha emission is also used to study regions of recent and ongoing star-formation activity. The emission nebulae in such regions can show a variety of structures occurring over a large range of scale sizes. As an example, Figure 3.2 shows the complex distribution of H-alpha emission in part of the Orion region. From visual scans of this survey image, Mashedier (Bristol), Mader, Zealey (Wollongong) and Parker (AAO) have identified a large number of emission-line features such as Herbig-Haro (HH) objects, filamentary features, collimated outflows and arc-shaped structures, many of which were previously unknown. HH objects are compact regions which are formed when an outflow powered by a young stellar object impacts with the surrounding interstellar medium. Prior to 1994, it was believed that such outflows extend to around one-third of a parsec from the central source. More recently however a number of 'giant' outflows have been discovered with collimated jet-like emission extending over much larger regions. In Figure 3.2, two such giant HH outflow regions are evident. The strong gas outflows in regions such as these alter both the chemical composition and gas motions within the parental molecular clouds. Indeed, the giant outflows associated with HH objects may provide a self-regulating mechanism for star-formation activity within molecular clouds.

Chemical abundances in carbon-rich metal-poor stars

Beers (Michigan), Norris (MSSSO) and Ryan (RGO) are investigating some of the most metal-poor stars in the Galaxy. These objects contain only 1/100 to 1/10 000 of the heavy elements (per unit mass) contained in the Sun. They are the oldest stars in the Galaxy and contain clues as to the manner in which it formed, and the way in which the first chemical elements were synthesized in the early Universe. They also permit, through studies of their lithium content, insight into conditions which existed during the Big Bang.

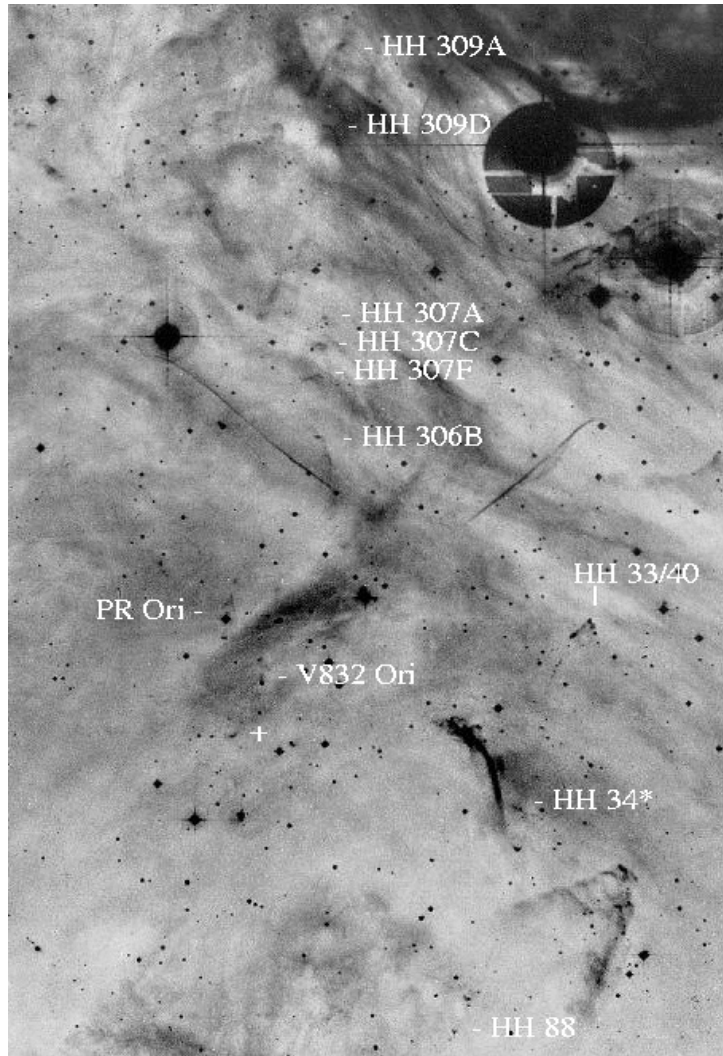


Figure 3.2 UKST H-alpha image of part of the Orion region. The image size is 35×50 arcmin. The northern Herbig-Haro objects HH 306B to HH 309A are located within a 'giant' outflow from an embedded cluster of objects known as L1641-N which is indicated by the cross. The two Herbig-Haro objects HH 33/40 and HH 88 are at opposite ends of a second outflow from the central source HH 34.

Among these objects there is an important subset which contains surprising over-abundances of carbon: about 10 percent of objects which have metallicities less than $1/300$ that of the Sun have carbon enhancements, relative to iron, of factors 10–100 times the solar value. An understanding of the origin of these carbon over-abundances will give insight into the production of carbon at the earliest times and the first objects to produce this element.

From the limited existing studies it seems that at least three sub-classes

of carbon-rich metal-poor stars exist. The first, and probably major, class shows large over-abundances of the so-called heavy neutron-capture elements such as strontium, barium and europium, in a ‘s-process’ distribution. The s-process occurs when elements heavier than iron are built up by the slow bombardment of neutrons onto iron nuclei. This process probably occurs in binary systems in which there has been a transfer of mass from an evolved star onto the other star. The clue that such a process has occurred is that much more barium has been produced than europium. The second class has its heavy neutron-capture elements in an ‘r-process’ distribution. Here the heavy elements are built up by neutron bombardment of iron on a very short timescale. It is almost universally accepted that the r-process occurs when massive stars explode as supernovae and neutron stars are formed. For this class of stars, europium is much more abundant relative to barium than in the first group. In the one well-studied case

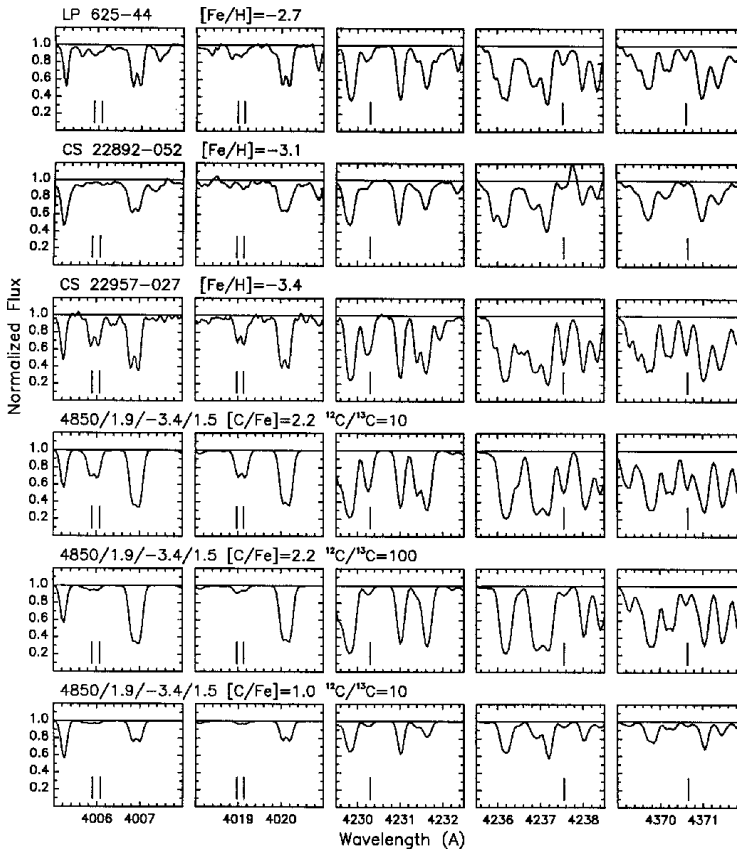


Figure 3.3 UCLES spectra taken at the AAT for three carbon-rich stars, CS 22957-027, CS 22892-052, and LP 625-44, are shown in the top three panels. The spectra cover wavelength ranges which include strong ^{13}CH features, indicated by the vertical lines. Note the unusual strength of the ^{13}CH features in CS 22957-027 evident near 4006 Angstroms. The lower three panels show synthetic spectra for different carbon/iron and carbon isotope ratios calculated using stellar atmospheric parameters appropriate for CS 2295-7027.

of this type of star (CS 22892–052, by Sneden and co-workers) the enrichment is so large that the abundances of not only europium but also of thorium can be accurately determined. From the thorium/europium ratio and the known decay rate of thorium, the age of the star and hence of the halo of the Galaxy has been determined to be 17 ± 4 billion years. The third class of carbon-rich objects appears to have no enhancement of the heavy neutron-capture elements at all, despite the large carbon abundances, and is not well understood.

Using the AAT high resolution echelle spectrograph (UCLES), Beers, Norris and Ryan have performed detailed abundance analysis of several carbon-rich metal-poor stars in the Galaxy. Figure 3.3 shows UCLES spectra obtained for three sources. During these investigations they analyzed the carbon-rich 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. This is one of the most metal-poor stars known, and its combination of carbon enrichment but no heavy element enhancement makes it unique. Furthermore, for CS 22957–027, the carbon isotope ratio of $^{12}\text{C}/^{13}\text{C}$ of about 10 is very low, in comparison with the solar value of 90. The origin of these abundance patterns is not fully understood, but one interesting possibility is that they result from internal mixing processes which occurred within the star itself when helium first began to burn in its core. Such an effect has been predicted by detailed theoretical calculations for stars which contain no heavy elements at all.

Perhaps of equal interest was the discovery that the lines of ^{13}CH are so strong, and the other metal lines so weak in CS22957–027, that there are ^{13}CH features which are almost coincident in wavelength with the thorium line which was used to determine the age of 17 ± 4 billion years for CS 22892–052 mentioned above. This raises the question as to whether ^{13}CH contamination would significantly affect the age which has been determined for this star. The sense of the effect would be to increase the age estimate. Clearly this should be taken into account in future age determinations using carbon-rich objects and the thorium chronometer.

The origin of high velocity clouds

The nature and origin of the high velocity clouds associated with our Galaxy is highly controversial. The high velocity clouds are concentrations of neutral hydrogen with velocities which do not conform to a simple model of galactic rotation. Although the clouds cover at least a third of the sky, few, if any, have reliable distance determinations. The lack of known distances has encouraged wide ranging speculation as to their origin. Explanations for the origins of the high velocity clouds have included local supernovae remnants, large-scale expanding motions in nearby spiral arms, condensations in the



local Galactic halo, structures in the Galactic warp, tidal disruptions of the Magellanic Clouds and intergalactic gas. These various hypotheses cover an enormous range of assumed distances. A further hypothesis has been proposed recently (by Blitz and Spergel) that some high velocity clouds are the remnants of galaxy formation throughout the Local Group of galaxies. If this is correct then such clouds may be present to distances of around one million parsecs.

Bland-Hawthorn (AAO) has used the Taurus facility at the AAT to investigate the origin of the high velocity clouds. He has developed observational techniques for detecting extremely faint levels of optical line emission for sources which extend over several arcminutes or more. This Fabry-Perot ‘staring’ technique has been used to observe high-velocity clouds and the Magellanic stream of gas which extends between the Magellanic clouds and our Galaxy. Surprisingly, all high-velocity clouds observed to date are detected, suggesting that their outer surfaces are illuminated by ionizing photons.

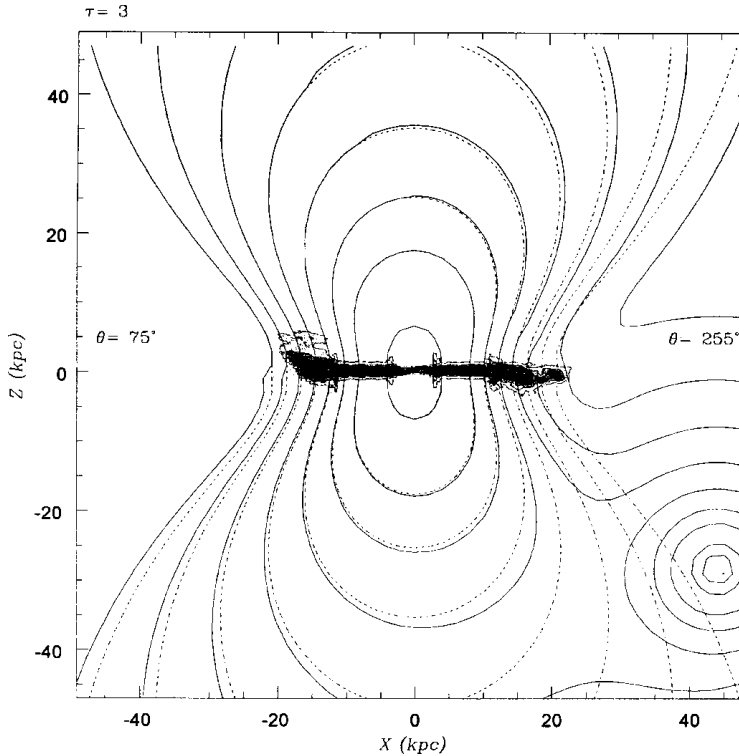


Figure 3.4 A model for the Galactic halo ionizing field arising from the young stellar disk. The coordinates are with respect to a plane perpendicular to the Galactic disk (with the Galactic Centre at the origin) at a constant angle measured in the plane of the disk passing through the Large Magellanic Cloud (LMC). The dotted lines show cross-sections through surfaces of constant ionizing flux in the halo of our Galaxy; the solid lines include the contribution from the LMC. The opacity of the neutral hydrogen disk (shown in grey scale) has been included. Note that the neutral hydrogen warp on the side nearest to the LMC (right) is less severe than the warp on the opposite side. This may be due to the ionizing influence of the LMC (contours at lower right).

Bland-Hawthorn has also developed models for the ionization field in the halo of our Galaxy and throughout the Local Group of galaxies. Figure 3.4 shows the model for the ionization field of the Galactic halo. This model includes ionizing photons from young stars in the disk of the Galaxy and from hot and warm plasmas which surround the Galaxy. One application of the ionization models is to estimate distances to the high velocity clouds. If the radiation field is known then the distance to a cloud can be estimated from the strength of observed emission features. The ionization model for the Local Group indicates that high velocity clouds could be detectable in hydrogen-alpha emission within 200 thousand parsecs of the Galaxy and near the large spiral galaxies M31 and M33.

In an early test of these predictions, Bland-Hawthorn has observed a high velocity cloud known as the Smith cloud. Using Taurus it was possible, for the first time, to observe two different elements, hydrogen and nitrogen, simultaneously at two distinct positions within the cloud. The analysis of the data reveals that the distance to the Smith cloud is at least 20 thousand parsecs from the Galaxy. Such a large distance is required to explain the faintness of the hydrogen-alpha emission, the observed emission line ratios and the non-detection of oxygen.

Extragalactic Astronomy

Dwarf galaxies

The number and nature of faint galaxies in the Universe has important implications both for the mean mass density of the Universe and for the process of galaxy formation. As part of a joint UK–Australian program, Phillipps, Jones (Bristol), Driver, Couch (NSW) and Smith (Cardiff) have been carrying out a deep CCD imaging program on the AAT of moderate redshift clusters, at $z \sim 0.2$, in order to measure the space density of faint dwarf galaxies in these clusters.

They have discovered a clear environmental dependence in the numbers of dwarf galaxies. Regardless of their total richness, lower density clusters have a higher proportion of dwarf galaxies than dense clusters. Similarly, in individual clusters, the ratio of dwarf galaxies to giants increases outwards as the number-density of galaxies decreases. Together, these results seem to imply that there is a dwarf galaxy population-cluster density relation, akin to the well-established morphology-density relation for ‘normal’ galaxies.

The origin of the new relation may also be similar to that of the standard morphology-density relation, in that it arises out of the different merger histories, in hierarchical clustering, in different density regions.

A new population of X-ray sources?

The X-ray background, discovered in 1962, is finally beginning to give up clues as to its origin. As part of an ongoing program to obtain optical identifications for faint X-ray sources, Boyle (AAO), Almaini (Edinburgh), Georgantopoulos (Athens), Griffiths (Pittsburgh), Shanks (Durham) and Stewart (Leicester) have been using the LDSS spectrograph at the AAT to obtain spectroscopy of faint X-ray sources detected by the ASCA satellite. The ASCA mission is capable of imaging the X-ray sky at higher X-ray energies than previously (2 to 10 thousand electron volts, corresponding to a wavelength range from 6.2 to 1.2 Angstroms), and much closer to the 0.5 Angstrom region in the X-ray spectrum where the bulk of the X-ray background originates.

By investigating this largely unexplored region of the X-ray spectrum, astronomers have proposed that a new class of astronomical source responsible for the observed X-ray background may emerge. Such a source would be undetectable at lower X-ray energies.

One source observed by Boyle and his colleagues appeared to fit the criteria for just such an object. Although easily detected by the ASCA satellite, it is barely visible in deep images obtained with the ROSAT mission, an X-ray satellite sensitive to lower X-ray energies below 2 thousand electron volts. The optical spectrum of the closest optical counterpart to this X-ray source (AXJ0341.4–4453) was obtained with LDSS on the AAT, and is consistent with a Seyfert 2 galaxy at a high redshift of $z = 0.67$. This is only the second Seyfert 2 galaxy to be identified at cosmological redshifts. The previous object was also initially detected from ASCA observations.

High redshift Seyfert 2 galaxies have long been predicted to exist. Their existence would provide one of the missing links in the unified classification for active galactic nuclei (AGN) which links Seyfert galaxies with quasars. Such objects, referred to as Type 2 AGN, are believed to be ‘obscured’ quasars, where dust and gas blocks out much of the light from the central active region.

Such obscuration is consistent with the large amounts of hydrogen absorption inferred from the X-ray spectrum of AXJ0341.4–4453. Theoretical models invoking obscured AGN with varying amounts of dust have previously been used to explain the origin of the X-ray background. The confirmation that such objects do exist and are detectable from their high energy X-ray emission provides further evidence that Type 2 AGN may indeed be responsible for the bulk of the extra-galactic X-ray background

Gamma ray bursts and SN1998b

The last year has been a watershed in the study of the gamma-ray burst (GRB) phenomena. After twenty-five years of study with little insight into the nature of these extreme but short-lived events, optical counterparts to gamma-rays bursts were finally detected. This breakthrough has been made possible by the Italian/Dutch BeppoSAX satellite which provides positions for the gamma-ray bursts which are accurate to approximately 1 arcminute, within a few hours of the event.

The optical images of the gamma-ray bursts confirm that they are located in distant galaxies. In two cases, redshifts measured for the host galaxy, of $z=0.8$ and $z=3.4$, imply that, if the radiation was emitted uniformly, these gamma-ray bursts yielded at least 10^{46} Joules of energy, making the GRB phenomenon by far the most energetic event in the Universe. However, in no case had it been possible to obtain a spectrum for the GRB event itself.

This changed dramatically with the GRB event GRB980425. Initial CCD images revealed that the GRB was most likely associated with a supernova event, SN1998bw, in which a star exploded in the nearby galaxy ESO184-G82. An AAT image of the galaxy, taken after the event is shown in Figure 3.5. Inspection of pre-explosion UKST Sky Survey photographs shows that the supernova probably lies within a giant HII region in one of the spiral areas of the galaxy. A 2dF spectrum of the supernova/galaxy taken by Cannon and Stathakis (AAO) confirmed a distance to the galaxy of 30 million parsecs and a



Figure 3.5 An AAT prime focus CCD image taken by Tinney (AAO) and Abraham (IoA) for the galaxy ESO184-G82. The object SN1998bw, seen in the image as a bright stellar-like object, near the centre of the picture, has been identified as the likely source of the gamma ray burst event which occurred in April 1998. This object may be the first known hypernova where the core of a massive star has collapsed to form a black hole.

classification of type Ic for the supernova. Further spectra taken by Stathakis (AAO) and James (St Andrews) with the RGO spectrograph revealed expansion velocities of 20 000 to 30 000 kilometres per second. High resolution spectra taken by Drew and Gatti (ICSTM) with UCLES confirm the presence of sodium absorption lines in the supernova spectrum, verifying that the supernova must be at least as distant as ESO184-G82, and making it highly likely that it is indeed associated with the galaxy. This placed the GRB much closer than the two previous GRBs with measured redshifts, and thus up to a million times less energetic. Even so, GRB980425 emitted more energy in a 30 second burst than the combined energy output from the Sun in five million years.

The AAT observations, in particular the likely association of SN1998bw with a GRB event, indicate that this object is perhaps the first example of a 'hypernova' to be reliably identified. Like supernovae, hypernovae occur when the core of a massive star implodes after it has run out of nuclear fuel. However, unlike supernovae whose cores collapse to neutron stars, in hypernovae the centre of the parent star is sufficiently massive to collapse to form a black hole. Such hypernovae events have previously been postulated as a potential source for gamma ray bursts. Beaming of gamma-ray emission, required to explain the high energies, is also predicted by these models. Irrespective of whether it is a unique or typical GRB, SN1998bw is clearly a remarkable object. The spectroscopic monitoring campaign of SN1998bw will continue at both the Anglo-Australian telescope and the UK Schmidt telescope until at least the end of 1998.

The Hubble Deep Field South

During the past year the AAT and the UKST have played a major part in the ground-based support observations of the proposed Southern Hubble Deep Field (HDFS). The HDFS follows on from the success of the first Hubble Deep Field (HDF) observed by the Hubble Space Telescope (HST) in December 1995. The HDF yielded the deepest ever images of the Universe and provided information about the faintest and most distant galaxies in the Universe.

The HDFS differs in two significant ways from the original HDF. First, it will be located in the southern sky, and thus within the reach of southern hemisphere telescopes. Second, it contains a distant quasar, which can be used to light up the otherwise invisible clouds of intergalactic gas along the line of sight to this distant object. The HDFS will therefore provide unique information on both the faintest galaxies we can see directly and perhaps even the gas systems from which they formed.

When plans to observe the HDFS were first announced, there was no known quasar in the areas initially selected as suitable for the HDFS. These areas were chosen to contain no bright stars, have low galactic extinction and be in one of the Hubble's Continuous Viewing Zones.

Fortunately a suitable area was located in a UK Schmidt field which had an archival IIIaJ objective prism plate (UJ9697P). Irwin (RGO) used the Automated Plate Measuring Machine in the Cambridge to digitise this plate and the prism spectra of objects were analysed by Hewett (IoA) using his Prism Reduction Software. One outstanding candidate was identified, a bright ($B=17.5$ mag) object with an estimated redshift of $z=2.25$. The J2000 co-ordinates of the object are right ascension = 22h 33m 37.6s, declination = $-60^{\circ} 33' 29''$. A spectrum obtained with 2dF by Lewis and Bland-Hawthorn (AAO) subsequently confirmed this object to be a quasar with a redshift of $z=2.245$.

Based on these observations, the Space Telescope Science Institute decided in October 1997 to use this quasar to define the location of the Hubble Deep Field South. Observations of the HDFS will be carried out in October 1998. The quasar will be positioned at the centre of the field-of-view of the Space Telescope Imaging Spectrograph (STIS), one the three HST instruments that will be gathering data simultaneously on the HDFS area. The other two are the wide field/planetary camera (WFPC) and the infra-red camera (NICMOS).

The HDFS has already spawned intense activity in the provision of suitable support observations. These include infrared and X-ray space-based observations and ground-based observations—in which the AAO is playing a leading role.

High-resolution spectroscopy of the quasar has been carried out with UCLES at the AAT. UCLES is currently the only spectrograph in the Southern Hemisphere which enables observations with high spectral resolution ($R=50\,000$) to be carried out with high efficiency at short wavelengths, below 4500 Angstroms. Observations in this part of the quasar's spectrum provide key information on the 'Lyman alpha forest,' the multitude of absorption lines arising from the intergalactic hydrogen gas clouds lying in front of the quasar. The UCLES data obtained so far has been made publically available via the AAO's World Wide Web page. In the true spirit of the HDF, further observations will continue to be made available to the community as quickly as possible.

Science with the 2dF

The 2dF and the large-scale redshift surveys

The past year saw the 2dF instrument fully commissioned, with two spectrographs and two full sets of 400 fibres. The time required for the positioner robot to reconfigure a field fell from almost three hours to just over one hour. The precision and reliability of the instrument were also improved substantially during the year. These developments meant that real progress could be made with the very large redshift surveys which had been the main motivation for building 2dF, as well as with many other projects in both stellar and extra-galactic astronomy. By the end of the year, the capability of the 2dF instrument



for obtaining over 3000 spectra in a single night had been clearly demonstrated, although adverse weather conditions mean that the highest scores to date are about 1150 galaxies plus 250 quasars, achieved on those nights when four full 2dF fields were observed.

The highest-priority 2dF projects are a pair of linked redshift surveys, both designed to produce an order-of-magnitude increase in the size of the basic databases for observational cosmology. One of these, the AAT 2dF Galaxy Redshift Survey, is a bi-national project to map out the 3-dimensional structure of the relatively local Universe; this will involve obtaining spectra for a sample of a quarter of a million galaxies. The second will probe the Universe at much larger distances and hence at earlier times, by obtaining redshifts for about 25 000 quasars. These two projects are being carried out in parallel, since this affords the most efficient way of maximising the numbers of targets in a given amount of observing time.

The Galaxy Redshift Survey

A consortium of two dozen mainly British and Australian astronomers, headed by Ellis (IoA) and Colless (MSSSO), is using 2dF to obtain spectra for a total of 250 000 galaxies spread over two regions of sky. The larger region is in the South Galactic Cap which passes overhead at Siding Spring, and the other is in a strip of the North Galactic Cap lying along the Celestial Equator. A diagram showing the distribution of target fields was included in the 1996–97 Annual Report, together with a representative sample of early spectra. Candidate galaxies have been selected from the catalogue of Maddox (IoA) and colleagues, generated by measuring the UK Schmidt Telescope Southern Sky Survey photographs in the APM machine in Cambridge. The intention is to obtain spectra for all galaxies (to better than 95 per cent completeness) brighter than blue (B_r) magnitude 18.5, which corresponds to a median redshift of about 0.1.

As well as yielding redshifts, and hence distances, the spectra are of sufficiently high quality that galaxy types can be derived for most of the sample. Thus it will be possible to investigate such questions as the effect of environment (i.e. space density and degree of clustering) on the formation and evolution of galaxies, as well as deriving the basic three-dimensional distribution of a far larger sample of galaxies than any observed previously. The sample should be large enough to determine the true topological structure of the local Universe, i.e. whether the distribution of galaxies should be thought of as hierarchical clustering, as a cosmic bubble bath consisting mainly of voids, as a connected sponge-like structure, or in some other way.

The redshift survey will also be used to investigate the redshift space distortions caused by the gravitational infall effects of very large concentrations of galaxies (leading to an apparent flattening along the line of sight). The well-known opposite effect, whereby rich clusters of galaxies have a high internal velocity dispersion, producing apparent

'fingers of God' in plots of redshift against position on the sky, will also be measured. These studies will determine to what extent the visible galaxies map out the underlying mass distribution in the Universe, and set limits on the amount of dark matter present.

Progress with the Galaxy Redshift Survey during the year can be judged from the 'cone diagram' shown in Figure 3.6. This shows the distribution of galaxies within a large, flat slice of the Universe. The

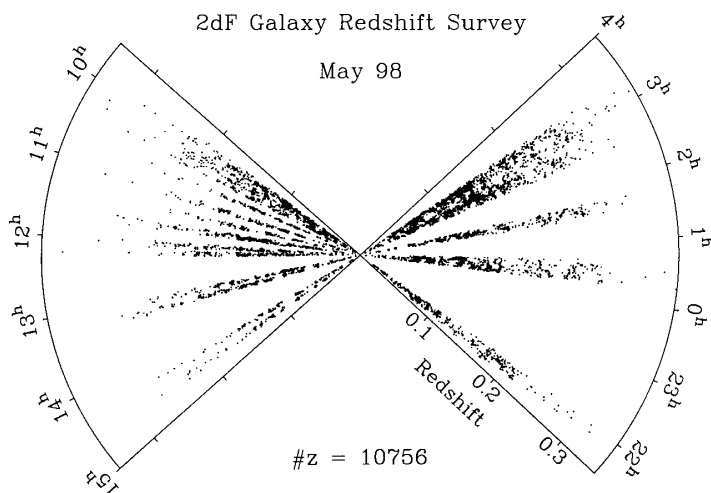


Figure 3.6 This 'cone' diagram shows the progress with the Galaxy Redshift Survey. Each 'ray' represents the galaxies seen along one particular line of sight (i.e. within a single 2dF field). The Milky Way Galaxy is at the centre; radial distance on the plot corresponds to the redshift, which is proportional to the true distance to each galaxy. This diagram is thus an incomplete map of all the galaxies in one slice of the Universe.

2dF survey works rather like a radar scanner; each field that is observed corresponds to looking in one very narrow beam in the sky and determining the distances to all the galaxies along that line of sight. As the survey progresses along a strip in the sky, different directions in space are observed and a picture of the 3-dimensional structure gradually emerges. Although the picture is still very incomplete, it is clear that the distribution of galaxies in space is highly structured and there are tantalising hints of large-scale structures spanning several adjacent 2dF fields.

By the end of July 1998 over 10 000 galaxies had been observed, making the 2dF survey already one of the largest homogeneous redshift databases. This is sufficiently large to give a good determination of the overall galaxy luminosity function, as shown in Figure 3.7. This sample represents only a few percent of the intended quarter of a million galaxies; clearly the full sample will provide a wonderful database for exploring subtle changes in the luminosity function with position on the sky, and for correlating these with other readily-measured properties of the galaxies.

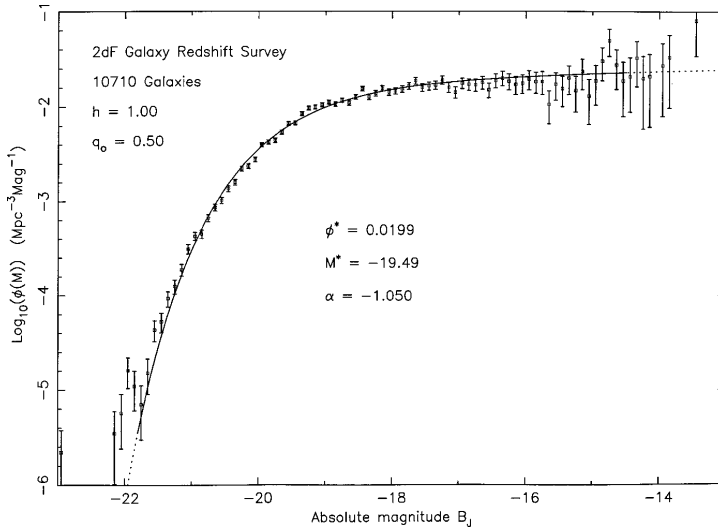


Figure 3.7 2dF galaxy luminosity function (data points). Model fits to the luminosity function (i.e. the space density of galaxies as a function of their true luminosity) are shown by the lines. This has been calculated using ‘Schecter functions’ with the parameters indicated in the figure.

The 2dF QSO Redshift Survey

The parallel 2dF survey, to explore the Universe at much higher redshifts (i.e. much greater distances and much earlier times), is a quasar survey being carried out by a consortium of mainly UK astronomers, headed by Boyle (AAO) and involving Croom and Shanks (Durham), Smith (MSSSO) and Miller and Loaring (Oxford). Quasi-stellar objects (QSOs, or quasars) are, by definition, indistinguishable from stars on single images. However, they have very unusual colours and so can be discovered by measuring a set of photographs in different filter bands (e.g. ultraviolet, blue and red) and looking for point-like objects which are well separated from the majority of Galactic stars in colour-colour plots.

The QSO Survey involves two thin strips of sky, 75 degrees long by five degrees wide, one each in the northern and southern Galactic caps. Because there are only about 150 quasar candidates in each two degree field, use of precious observing time is optimised by combining this with galaxy survey described previously, with the quasar strips being embedded in the larger areas of the galaxy redshift survey. The 2dF quasar survey is estimated to be 93 percent complete for quasars with $18.25 < B_j < 20.85$ and redshifts in the range $0.3 < z < 2.2$, and also finds a significant fraction of all quasars out to a redshift of 3.

As with the galaxy survey, only a few percent of the quasar survey has been completed so far. Nevertheless, the 2dF sample of over 1000 quasars, augmented by some brighter objects observed with FLAIR on the UK Schmidt Telescope and some close pairs observed on the AAT and ANU 2.3-m Telescope, is the largest single systematic sample

of quasars. One key objective is to evaluate the degree of quasar clustering in 3-dimensional space; already some clustering is detectable statistically, although coverage of a larger contiguous area on the sky is needed to identify specific clusters. Another objective is a search for close pairs of quasars with the same redshift, which may be gravitationally lensed images of one object; one good candidate has already been found. This is shown in Figure 3.8.

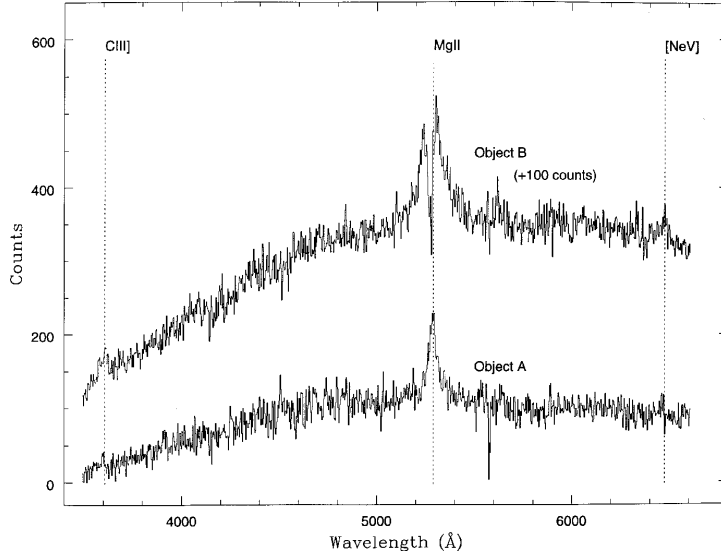


Figure 3.8 2dF spectra of a close pair of quasars (17 arcsec separation) which may be gravitationally lensed images of the same object.

Other extra-Galactic astronomy with 2dF

Many smaller-scale projects are also exploiting the unique capabilities of 2dF on the AAT. One such is a detailed investigation of the radio sources in a single two-degree field which has been very carefully mapped by the Molonglo Observatory Synthesis Telescope, as the Phoenix Deep Survey of Cram and colleagues (Sydney).

The data from the 2dF observations made in semester 1997B have been added to the results compiled in the PhD thesis of Andrew Hopkins (Sydney). From the 2dF observations made so far, about 250 redshifts have been obtained. This comprises 50 percent of the known optical counterparts, to a magnitude limit of $R=22$, for the radio sources brighter than 0.1 milli-Jansky identified in the 'Phoenix Deep Survey.'

An example of an interesting source from the survey is shown in Figure 3.9. The source PDF J011426.4-455224 is presented as an optical image with radio contours at a frequency of 1.4 gigahertz overlaid. The contour levels are 0.12 and 0.20 milli-Jansky. This source is particularly interesting by virtue of a prodigious burst of star formation. Its 2dF

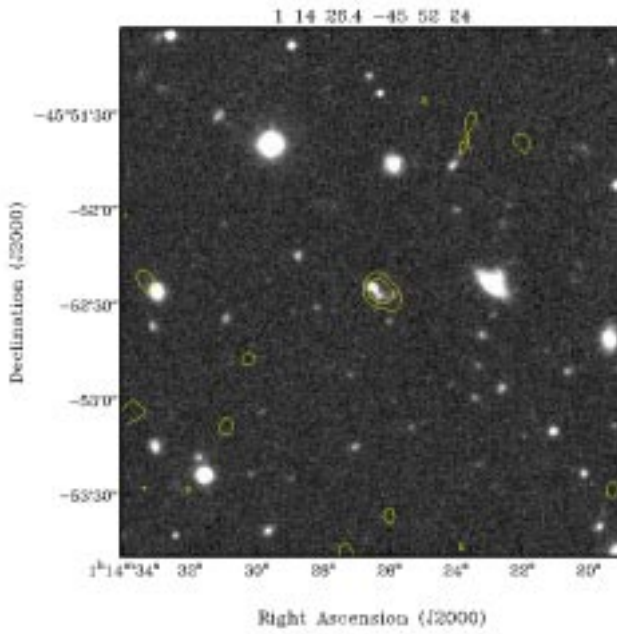


Figure 3.9 A radio contour map of the source PDF J011426.4-455224, overlaid on an R-band optical image of the field taken with a CCD at the prime focus of the AAT.

spectrum, seen in Figure 3.10, indicates that the radio emission is dominated by star formation processes, while the redshift of the source, $z=0.459$, along with the 1.4 gigahertz flux density, gives this source a radio luminosity greater than $10^{23.5}$ watts per hertz. Such a luminosity, if wholly derived from star formation processes, is quite extreme, and is probably related to the apparent merger of the galaxies visible in the image.

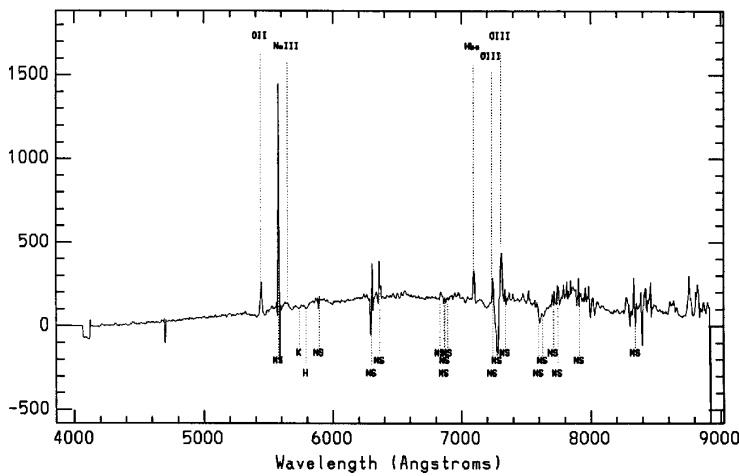


Figure 3.10 A 2dF spectrum of the vigorous star-forming radio galaxy PDF J011426.4-455224.

Galactic and stellar astronomy with 2dF

2dF also has many applications in stellar astronomy, especially where large samples are needed for studies of kinematics or chemical composition distributions. These range from large scale studies of the content and structure of the entire Milky Way Galaxy, and of its companions the Large and Small Magellanic Clouds, to detailed studies of samples of stars in particular star clusters. With their emphasis on accurate stellar velocities and abundances of the elements, such studies often involve working at higher spectral resolution and higher signal-to-noise ratio than the redshift surveys described above. 2dF has already shown itself to be a uniquely powerful instrument for this type of work.

One example is the major Anglo-Australian Old Stellar Populations Survey of Gilmore (IoA), Wyse (JHU), Norris and Freeman (MSSSO). This project aims to obtain spectra for several thousand faint stars in several carefully-chosen fields around the Milky Way, in order to sort out the star formation and chemical evolution histories of the different populations of stars in the disc, bulge and halo of our Galaxy. The velocity distribution function (Figure 3.11) shows that the sample selection is extremely efficient at isolating thick disk stars with velocities between about 40 and 120 kilometres per second and halo (higher velocities) stars, without serious swamping by stars in the old disk. It is clear that the project will provide several interesting results in addition to the primary aim of defining the joint abundance-kinematics distribution function, and so map the early evolution of the oldest stellar populations.

The survey will be able to identify sub-systems arising from any small galaxies accreted by the Milky Way Galaxy, and to set limits on the dissolution timescale for star-forming regions.

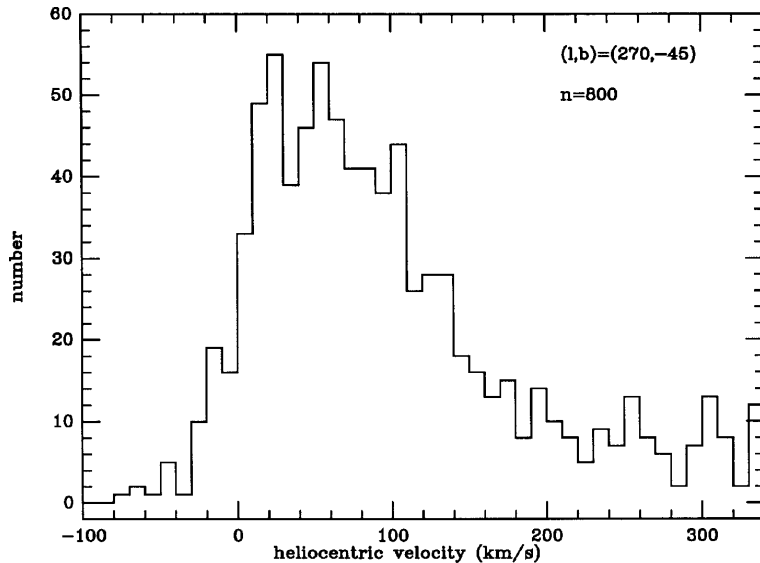


Figure 3.11 A histogram showing the distribution of velocities for 800 stars in one field of the Old Stellar Populations Survey, using combined 2dF and Autofib data.

A somewhat smaller project which aims to understand the history of our nearest neighbours is a survey of carbon stars in the Magellanic Clouds by Cannon (AAO), Hatzidimitriou and Croke (Crete) and Morgan (ROE). Carbon stars form good tracers of the older stellar populations in a galaxy because they are very easily identified (from UKST objective prism plates) and are known to come from progenitor stars in a well-defined mass range. They thus probe populations of stars that were born a few billion years ago. A sample of some 700 spectra of LMC stars was obtained in two part-nights in January 1998 and these are yielding radial velocities with a high internal accuracy of about 2.5 kilometres per second, more than adequate to distinguish between populations from different star-forming episodes. The spectra are of very high quality and can be used to do much more than determine radial velocities. By applying a Principal Components Analysis technique, originally developed by Glazebrook, Offer and Deeley (AAO) to determine redshifts and types for galaxies in the 2dF Redshift Survey, it seems that it will be a relatively straightforward matter to to classify the LMC carbon star spectra automatically and objectively. For example, the 'J-type' carbon stars, with a high $^{13}\text{C}/^{12}\text{C}$ isotope abundance ratio, are readily identified. With these data, it will be possible to separate out stellar populations with different origins and ages.

4. AAO facilities

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

The AAT and UKST are the heart of the AAO. To maintain its position as a leading-edge research organisation, it is essential 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.

The Two-degree Field (2dF) facility for the AAT is now fully operational and in regular use, and this year was offered for research for both semesters. The development of a similar instrument for the UKST—the Six-degree Field facility (6dF)—was approved during the year.

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

AAT facilities

Instruments available at the AAT in mid-1998 are summarised in Table 4.1. Further information is available in the AAO Observer's Guide, in the relevant instrument user manuals, in the AAO newsletters and on the AAO www pages.

Table 4.1 Instruments available on the AAT at 30 June 1998

Focus Equipment	Mode	Detector
Prime		
Two Degree Field (2dF) 400 fibre multi-object spectrograph facility	f/3.3	Two dedicated Tektronix 1K CCDs
Prime focus camera— aspheric plate, doublet and triplet correctors, sub-beam prism	direct f/3.3	Tek thinned CCD Range of types of sensitised photographic plates 254 × 254 mm
Focal reducer	f/1	Thomson CCD
Cassegrain		
<i>Imaging</i>		
Auxiliary camera	f/8 or f/15	Thomson or Tek CCD
<i>Infrared equipment</i>		
IRIS 128 × 128 format infrared camera and low-resolution spectrometer, with imaging, spectroscopic and polarimetry modes	f/15 or f/36	Rockwell HgCdTe array
3D Integral Field Spectrograph made available under agreement with MPIE	f/15	Rockwell HgCdTe array
<i>Spectrographs</i>		
RGO spectrograph, 25 and 82 cm cameras, FOCAP multi-object fibre optic coupler, spectro- polarimetry modes	f/8	Tektronix 1 K CCD, MIT/LL 2K × 4K CCD and other CCDs
Faint object red spectrograph (FORS), sharing slit of RGO spectrograph and optional dichroic beam splitter	f/8	GEC CCD
Wide-field imaging Fabry-Perot interferometer (Taurus II) with tunable filter (TTF) and charge shuffling. Wollaston prism polarising module	f/8 or f/15	Tektronix 1K CCD and MIT/LL 2K × 4K CCD
Low dispersion survey spectrograph (LDSS II)	f/8	Tektronix 1K CCD and MIT/LL 2K × 4K CCD
Facilities for visitors' own equipment		
Coudé		
UCL echelle spectrograph, 70 cm camera (UCLES)	f/36	Tektronix 1K CCD and MIT/LL 2K × 4K CCD
Ultra-high resolution facility (UHRF)	f/36	Tektronix 1K CCD and MIT/LL 2K × 4K CCD
Facilities for visitors' own equipment		

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

UKST facilities

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

There are two basic photographic options at the UKST:

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

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

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

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

The 2dF

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

This year the 2dF was regularly scheduled for both semesters, and several scientific projects made significant advances. During the June 2dF run scientists configured 8 fields during the course of one cloudy night. This effectively meant the observation of 3200 objects on one night.

Although the June nights are obviously longer, this has doubled the

number of fields able to be observed in one night. This has been brought about by the reduction in configuration time for each field from approximately 2 hours to 1 hour 20 minutes (8.5 seconds per fibre).

Taurus tunable filter

The TAURUS Tunable Filter (TTF) is producing 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. Now that the blue TTF has been successfully commissioned, the instrument allows for wide-field (4.5 – 9 arcminutes) narrowband imaging over 370 – 1000 nanometres, where the bandpass can be set anywhere in the range 0.5 – 8 nanometres full-width half-maximum.

The associated development of CCD charge shuffling has been highly successful and has played a crucial role in about half the TTF projects to date. During the year, TAURUS II secured 17.5 per cent of the total number of nights.

The reflectance phase (which arises when the plate spacing is comparable to the coating thickness) can now be calibrated rapidly with a Hartmann test based on charge shuffling, and therefore resolving powers of order 100 can now be reached with the TTF.

IRIS 2

IRIS 2 is the current major ongoing instrumentation project at the AAO. Work commenced last year, and on-telescope commissioning is expected to start early in 2000.

IRIS 2 is designed to replace all the functions of the original IRIS, which is shortly to be decommissioned. The design is based around a 1024×1024 Rockwell HgCdTe Hawaii array, though provision has been made to upgrade this in future to a 2048×2048 device, if funds are available. The array used, limits the instrument to wavelengths below 2.5 microns.

In particular, IRIS 2 will provide a wide field imaging capability (7.7 arcmin \times 7.7 arcmin) with 0.45 arcsec/pixel (providing Nyquist sampling of the typical seeing). It will also provide JHK spectroscopy with a resolution of at least 1000, and, if technology allows, 3000. IRIS 2 will also provide an integral polarimetry capability.

Currently, the major design work is being completed, manufacture is expected to begin before the end of 1998.

6dF

The development of the Six-degree Field facility (6dF) for the USKT was approved during the year. 6dF is a multifibre spectroscopy system similar but smaller and less complex than the 2dF. Three interchangeable fibre plateholders will be constructed, each having 150 self-retracting fibres arranged in a circle around the 6-degree field.



Fibre positioning will take place on the curved focal surface and a fully robotic positioner will be used. The positioner will make extensive use of air-bearings, and the fibre gripper will be pneumatically controlled and driven. The target set-up time for the 150 fibres is one hour.

The 6dF will allow the UKST to undertake the first truly whole-hemisphere spectroscopic survey, ensuring that the UKST remains very productive into the next century.

Hydrogen-alpha filter

The high-specification, hydrogen-alpha interference filter came into regular use on the UKST during the year. At 356×356 mm (14×14 inches), this is one of the largest optical interference filters ever made for astronomy.

Excellent progress was made with the hydrogen-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. As reported in Chapter 3, one significant advance has been the discovery of 300 previously unknown planetary nebulae.

External Projects

The AAO's expertise in fibre optics technology for astronomy was recognised in May 1998 when it was awarded the contract (together with Mount Stromlo Observatory and the University of NSW) to build a fibre positioner for the European Southern Observatory's Very Large Telescope (VLT) in Chile. The positioner, known as OzPoz, is due for completion by 2003. Some project staff have been employed and initial design work has commenced. A preliminary design review will take place in March 1999.

As well, the AAO is involved in smaller design studies for optical fibre-based projects. These include other work for the VLT and an optical/near-infrared fibre facility for the National Observatory of Japan's Subaru telescope atop Mauna Kea, Hawaii.

The AAO is committed to making sure that these external projects will not compromise our current level of service provided to Australian and British astronomers.

Enhancements to existing instruments

CCDs

In October 1997, the AAO began to commission its first large format CCD, an engineering grade device from the AAO's membership of the Massachusetts Institute of Technology, Lincoln Laboratories (MIT/LL) CCD Consortium. This device MIT/LL2 has 15 micrometre sized

pixels in a 2048×4096 format. It is a thinned detector, but has an anti-reflection coating optimised in the infrared, producing superior performance in the red, but relatively poor performance in the blue. It has excellent read noise performance, acceptable cosmetics, and less fringing in the red than the AAO's workhorse Tek detector. This device was made available to observers from Semester 1998A onwards, and has proved extremely popular with all observers working longwards of about 500 nanometres. In particular, TTF observers have used almost nothing else since its introduction.

The AAO also plans to commission its first science grade device from this consortium run (MIT/LL3). This device has an unusual 'deep depletion' construction, which should optimise its performance in the red, and further reduce fringing. It will be commissioned in the forthcoming LDSS⁺⁺ run in October 1998, and is expected to be well matched to the LDSS⁺⁺ red optimised performance goals.

Prime focus upgrade

The AAO is upgrading the prime focus imaging facility of the AAT. This will involve the construction of a new CCD camera head to replace the existing camera head (which will be retained for photographic purposes). The new camera head will be remotely controlled, eliminating the need for an observer to ride in the prime focus cage. It is expected that the new facility will be commissioned in mid-1999.

Wide Field Imager (WFI)

The AAO and MSSSO are constructing 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. This instrument was described in detail in the 1996/97 Annual Report. WFI is expected to be commissioned in the second half of 1999.

LDSS⁺⁺

The AAO is planning to upgrade the LDSS. The upgrade, LDSS⁺⁺, will yield an increase in performance by up to a factor of three in the throughput of LDSS. This will be achieved by the use of the new high-resistivity MIT/LL CCD, volume phase holographic gratings and a telescope-nod/CCD charge shuffling mode. The latter development will permit the use of small apertures rather than slits, resulting in a factor of ten gain in multiplex advantage (from thirty to three hundred objects) for this survey instrument. It is planned to commission LDSS⁺⁺ in October 1998 with spectroscopic observations of faint galaxies in the Hubble Deep Field-South.



Iodine cell for UCLES

During the year, the Lick Observatory backup iodine absorption cell was installed for use with the UCLES spectrograph. The iodine cell is used to provide a fiducial wavelength scale for making precise Doppler velocity measurements. Velocity precision of 5 metres per second has been attained with this instrument, although this level of precision requires active modelling of the observed spectrum and of the instrumental point-spread-function. The iodine cell is being used in the extra-solar planet survey.

FLAIR Interim Upgrade

Several important developments have occurred which have significantly improved the way that FLAIR operates.

The most important of these is the commissioning of an interim magnetic-button type fibre-positioning system. Currently one plateholder has been converted to magnetic buttons and was successfully commissioned on the telescope during May 1998. It has since been used to monitor the Gamma ray burst event (GRB980425). Once some minor additional modifications are performed, and barring any unforeseen problems, a second plateholder will be converted in the second half of 1998.

Both plateholders should be available in their new magnetic button format by Semester 1999A. Coupled with the changes to the fiberizing process, several significant improvements to the spectrograph have been implemented. As well, there is now remote control of spectrograph focus, Hartmann shutter, grating rotation, RA dec. fine motion and FLAIR plateholder rotation. All these operations can now be performed from the FLAIR console control area in the UKST common room.

MAPPIT

MAPPIT is an interferometer installed at the coudé focus of the AAT and dedicated to high resolution imaging. It uses the principle of Non-Redundant Masking, and is able to reach the diffraction limit of the telescope (0.03 arcsec) for observations of bright stars.

A new system, MAPPIT2, is being developed which will combine the existing interferometer with a Shack-Hartmann wavefront sensor, providing information on the instantaneous wavefront distortions. This will permit more detailed analysis of the data, allowing observations of fainter and more complex objects.

The new wavefront sensor was successfully commissioned in June, together with a 10 ms read-out time for a 523×1 window on the Tek CCD. The system, with the wavefront sensor and the interferometer working together, is due for commissioning in early 1999.

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

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

Four of the main Unix systems used for data processing and instrument control were upgraded at the AAT and Epping. Memory and disk space resources on these systems were significantly improved. New, high-capacity tape devices were installed at each site for backing-up disk systems.

A program to upgrade the computer data-cabling infrastructure at both sites began. The Epping laboratory has been recabled with Category 5 network cable and, at the AAT, a start has been made on installing fibre optic and Category 5 cable throughout the telescope building.

Software

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

For the first time in some years, the year's software workload was not completely dominated by 2dF. Although 2dF still requires work to bring it to final completion, this now comprises only maintenance work and occasional enhancement. This has allowed work to begin on IRIS 2 and the new CCD controllers. The IRIS 2 design process is now well underway, heading towards a critical design review in October 1998.

The software group continues to maintain the DRAMA software that underpins the 2dF system. It also provides occasional support for other observatories such as those on La Palma and Hawaii that are using



DRAMA itself, and for Gemini, which is using some of the DRAMA sub-systems. DRAMA has recently been ported to Linux and to Windows NT, providing two different options for using it in systems built around PC hardware.

The SUN workstations that form the backbone of the AAO computing systems have now moved almost completely from the older SunOS operating system to the newer Solaris system. This should allow the systems staff to concentrate on providing the best available facilities on the one system rather than having their effort diluted by the need to support multiple systems.

Support facilities

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

Library

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. New shelving was installed this year in the Observatory publications area of the library, providing more space for the journals collection and room for its expansion for some years to come.

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.

An index to the data archive is now available on the world wide web but the full archive is not yet complete. All observations using standard AAT instrumentation taken since mid-1994 have been indexed. As well, indexes to most of the data taken with the IPCS detector since 1976, and all photographic plates taken at the AAT since 1974 are available on line.

Other AAO programs

Service observing

The service observing program at the AAT was relaunched in July 1997. Applications forms and full information on the service system are now available on the world wide web and all service proposals are submitted electronically.

The service program was extended to include programs that require up to three hours of observations. Service time is normally used for programs that require a small amount of data to complete a project, to look at individual targets of interest, or to try out new observing techniques. All service proposals are refereed by a three-member panel and are graded on a basis of scientific merit. During the year an exceptionally large number of 80 service proposals were received. Of these, approximately one-half were for the RGO spectrograph. Service observations were taken with the RGO and also with the CCD prime focus imaging, Taurus II/TTF, RGO, UCLES and UHRF facilities.

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 a policy of employing undergraduate students of astronomy as assistant during vacations. In total, six student from the UK and Australia were employed during the year. AAO staff were responsible for the joint supervision of the PhD research students. These were Robert Smith (IoA), Michael Brown (Melbourne), Heath Jones (MSSSO), Kathryn Deeley (NSW) and Andrew Walker (Wollongong).

F. Staff research

This section describes the research activities of staff at the Anglo-Australian Observatory, where not already covered in Chapter 3. In addition to providing support for the Observatory, the scientific staff pursue their own research programs. Staff make extensive use of the Anglo-Australian Telescope (AAT) and UK Schmidt (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.

The Keck, Lick, and Anglo–Australian Extrasolar Planet Surveys

Within the last three years, planets have been discovered around 12 nearby Sun-like stars. All of these planets have been revealed by small periodic Doppler variations in the spectra of their host stars. The planets detected to date have profoundly challenged the theories of planet formation, with the discoveries of Jupiter-mass planets in very small (four-day) orbits, and Jupiter-mass planets in extremely eccentric orbits. Only the 47 Ursae Majoris system, with a Jupiter-mass companion in a circular orbit with a period of several years, reminds us of the Solar System.

Now that planets have been detected, we would like to know what fraction of stars have planets, what fraction of planetary systems are similar to the Solar System, and how many other types of planetary systems exist. Toward this goal, Butler and Tinney (AAO), and their collaborators are carrying out surveys of all 800 of the nearest, brightest Sun-like stars using the Lick 3-m (California), Keck 10-m (Hawaii), and the Anglo-Australian 4-m telescopes. The precision of their velocity measurements, of 3 metres per second, is sufficient to detect Saturn-mass planets within five astronomical units, and Neptune-mass planets within one astronomical unit. During the year, three further planets were detected, bringing the total discovered in this program to nine.

This research project was awarded the International Astronomical Union Bioastronomy Medal.

Studies of Brown Dwarfs and very low mass stars

Tinney (AAO), Forveille and Delfosse (Grenoble), have continued their study of brown dwarf candidates from the DEep Near Infrared Survey (DENIS) being carried out at La Silla, Chile. Using the AAT, they have obtained optical and infrared spectra of a sample of brown dwarf candidates from the first one per cent of the DENIS data. They have not only used this data to discover the first isolated field brown dwarfs, but have shown that an entirely new spectral class needs to be created for the faintest objects found in this survey. These objects — the L dwarfs — fit into none of the canonical OBAFGKM spectral types usually used. Their atmospheres are dominated by the production of perovskite (CaTiO_3) and vanadium oxide dust, leaving only caesium and chromium hydride features behind in their spectra. This means that the material which is responsible for the features usually seen in cool stars is being depleted into dust. Consequently, radically different spectra of a type never seen before are produced.

Tinney (AAO), Reid (Palomar) and Hawthorn (AAO) have continued using the AAO's Taurus Tunable Filter (TTF) facility 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 Balmer hydrogen-alpha line. This line is present in young stars and brown dwarfs, but not in the majority of field stars. So the TTF selects only the members of interest in the cluster. Two nearby clusters (IC 2391 and IC 2602) have now been surveyed in this way, producing a list of possible brown dwarf members. The next step in this program is to use the two-degree field

facility (2dF), to confirm the success of this new selection technique. Successful confirmation with 2dF would give enough confidence in the new selection process to do away with the need for follow-up spectroscopy.

Tinney (AAO) and Reid (Caltech) have completed a study of the kinematics of the lowest mass stars. They were trying to see if they could confirm the suggestion by numerous authors that there exists a population of young brown dwarfs near the sun, which are masquerading as M-dwarfs. They found no kinematic difference between the population of the lowest mass stars, and more massive M-dwarfs. In the course of this study, they acquired a set of quality high-resolution spectra for the lowest mass stars near the sun. They were able to analyse this data to produce two interesting results. First they found that the 'star' LP944-20, previously thought to be an ordinary M-dwarf, is in fact a brown dwarf with a mass of 0.060 ± 0.004 solar masses, and age about 560 ± 90 million years. Secondly, they found that the same object shows an extremely rapid rate of rotation. This makes it the second of a growing class of objects at, or below, the bottom of the hydrogen burning main sequence which show very rapid rotation, and very little signature of dynamo activity.

Tinney (AAO) has begun a study of brown dwarfs, almost of all of which are now known to be quite rapidly rotating. To date, rotation signatures have been based on the observed broadening of spectra. However, this only tells us how rapidly the star is spinning to within an unknown inclination factor — the so-called $v \sin i$ factor, where v is the rotation velocity and i is the unknown inclination angle. A photometric study looking for signatures of rotation offers the possibility of measuring the period, and deriving $\sin i$. Tinney has therefore pioneered using the TTF in a time-series mode to seek the signatures of cool patches (either dust clouds or star spots) traversing the disk of several nearby brown dwarfs. As dust clouds are now known to play an important role in brown dwarf atmospheres, this offers the tantalising prospect of the study of 'weather' on other stars.

Magnetic White Dwarfs

Ferrario, Vennes, Wickramasinghe (ANUATC), Bailey (AAO) and Christian (Berkeley) have obtained spectropolarimetric observations for the source EUVE J0317-855. This is a rapidly rotating white dwarf with a strong magnetic field which was first detected as an extreme ultra-violet source by the EUVE and ROSAT satellites. A strongly structured, circular polarization spectrum with polarizations of up to about 8 percent is observed. The data can be modeled as the result of a dipole field of strength 450 million Gauss displaced from the center of the star by 35 percent of the stellar radius. The high mass and rapid rotation suggest that this star may be the result of a double degenerate merger.

Ferrario, Wickramasinghe (ANUATC), Bailey (AAO) and Buckley (SAAO) have continued to work on magnetic cataclysmic variable stars found by the X-ray satellite ROSAT. Spectropolarimetry of the intermediate polar RX J1712-2414 shows circular polarization of several percent and was taken with sufficient time resolution to study variations during the white dwarf rotation period of 927 seconds. Polarimetry of the eclipsing polar RX J0929.1-2404 has been used to derive a model for the emission regions on two poles, and determine a magnetic field of 20 million Gauss.

Pre-main-sequence stars

Bailey (AAO) has continued his program of studying pre-main-sequence stars using the technique of spectro-astrometry as a way of detecting close binaries and studying the outflows around these sources. The method has shown itself capable of detecting close binary systems with separations larger than around 100 milli-arcsec. This is the resolution limit of infrared speckle interferometry which has been the technique most widely used to resolve close binary systems in the past. Using spectro-astrometry, Bailey should be capable of detecting even closer binaries. The pre-main-sequence star T CrA has been confirmed as a new binary and may have a short enough period for orbital motion to be detected. A program of radial velocity measurements has been started to provide further observation on binaries discovered using this technique.

Chemistry in molecular outflows

Bourke (AAO/ATNF), in collaboration with Garay (Chile), Bergin (SAO) and Caselli (Arcetri), has begun an intensive study of the chemistry within the molecular outflow from the low mass protostellar source IRAS 11590–6452 using the SEST telescope. This outflow is one of only a few to show significant abundance enhancements of SiO and CH₃OH. These are due to the destruction of dust grain mantles and the wearing away of grain cores through shock activity. The ongoing study includes observing a large number of molecular species and transitions at millimetre wavelengths to determine abundances, temperatures and densities within the outflow, and the development of shock chemistry models to explain the observations.

Bourke, with McGregor (MSSSO), Robinson (ADFA), Hyland (SCU), have imaged the full length of the molecular outflow from the source IRAS 11590–6452 in the 1–0 S(1) and 2–1 S(1) molecular hydrogen transitions at 2 microns with CASPIR (MSSSO) and IRIS at the AAT, to determine if this emission is in fact solely due to shocks and to investigate whether the excitation conditions vary throughout the outflow. This data, together with previous H and K spectroscopic data obtained with IRIS, will also be used to investigate temperature variations at the shock locations. Modelling of these data will allow the group to determine whether C- or J-type shocks, or some combination of the two, are present.

Magnetic field strengths in molecular clouds

The extent to which magnetic fields play a part in the evolution of molecular clouds and star formation is possibly the greatest outstanding question in star formation studies. Observationally, the difficulty is measuring magnetic field strengths in the dense molecular cloud cores in regions of direct interest to star formation studies. So far a few molecular clouds have been studied in detail with the VLA (e.g. W3(OH), S106, Orion) and their magnetic field strengths imply that they are in an approximate critical balance between gravity and magnetic energies. However, there is a sufficient number of upper limit measurements to imply that the magnetic fields are not important in the support against gravity in many, if not most, molecular clouds.

Bourke, with Myers (SAO), Robinson (ADFA) and Hyland (SCU) have undertaken a program to measure the large scale magnetic field strengths in a sample of southern and northern molecular clouds with the Parkes radio telescope and the NRAO 140-foot telescope. By measuring the Zeeman effect in the thermal-ground state OH transitions at 1.6 GHz, the magnetic field strength in the molecular gas can be determined. For a sample of about 20 clouds, they have detected the Zeeman effect in only 1 or 2 sources. The upper limits for the remaining sources imply that the magnetic fields certainly do not dominate the cloud physics, and in some cases cannot be important in long term cloud support. Follow-up observations with the ATCA and VLA are planned to examine the small-scale field structure within the sample.

Asteroseismology

The analysis of stellar oscillations provides a powerful method for studying stellar interiors. Stars are gaseous spheres which, in some circumstances, may be excited into many different radial and non-radial oscillation modes. Asteroseismology uses the analysis of stellar oscillations to provide information on stellar interiors, such as their composition, mixing properties, ages and internal rotation. Medupe, Kurtz (SAAO), Chapman (AAO/ATNF), Bedding and Baldry (Sydney) have begun a program in which the AAT high resolution echelle spectrograph (UCLES) has been used to observe two rapidly oscillating A-type (roAp) stars, HR3831 and α Circinus, which have pulsation periods of approximately 10 minutes. Several thousand high signal-to-noise UCLES spectra were obtained at the AAT. These data are being analysed to look for radial velocity and line profile variations in the stellar absorption lines. Line profile variations have not previously been detected

from rapidly oscillating stars. Their detection would not only enable pulsation mode identification, but would also provide information on the stellar magnetic fields and the interaction between the magnetic fields and the stellar pulsations.

Mass-loss from evolved stars

Chapman (AAO/ATNF), Cohen (Jodrell Bank), Habing and Bouter (Leiden) have used the Australia Telescope Compact Array (ATCA) to search for OH maser emission in 40 fields in the Galactic bulge. Each field covered a region of 15×15 arcminutes. A total of 30 maser sources were detected above a threshold of 0.25 Jy. All the maser sources are identified as evolved stars with strong circumstellar winds. The data have been used to study the detection statistics for OH maser emission from evolved stars. A long-standing issue has been to explain the low detection rates for OH masers from highly evolved stars which have infrared colours that indicate high mass-loss rates. For the bulge sample, the sources detected in OH have redder infrared colours and stronger far-infrared flux densities than the non-detections. The OH masers are pumped by far-infrared photons emitted by dust grains. Chapman et al. find that the efficiency of the pumping process varies over a large range and this is the likely reason for the low detection rates of stellar masers.

Chapman (AAO/ATNF), Leitherer (STScI), Bouter (Leiden), Koribalski (ATNF) and Storey (RCfTA) are studying the stellar winds from Wolf-Rayet stars. They have used the ATCA to measure the radio continuum flux densities at 3, 6, 13 and 20 cm from a sample of 36 southern Wolf-Rayet stars within three thousand parsecs of the Sun. A key result from this study is that at least 40 percent of Wolf-Rayet stars have non-thermal radio continuum emission. Comparison of the radio data with recent high resolution HST images show that 80 percent of the non-thermal sources have an identified massive binary companion star which also has a strong stellar wind. In most, if not all cases, the non-thermal emission arises from an interaction zone where the winds from the two stars collide with each other, producing high temperature shocked gas and synchrotron radio emission. The non-thermal emission may be variable and partially absorbed as it passes back through the ionised stellar wind of the nearer star. Wind-wind interactions appear to occur for binary systems with a large range of separations. Indeed, the strength of the non-thermal emission appears to be largely independent of the separation of the two stars.

X-ray emission from stars

Johnston (AAO), Fender (Amsterdam) and Wu (Sydney) observed the bizarre X-ray binary Cir X-1 at optical and infrared wavelengths. This binary system contains a neutron star in a highly eccentric 16-day orbit, the longest known orbital period for a low-mass X-ray binary. Both the infrared and optical spectra show complex emission lines, with several components which originate in different parts of the binary. They have determined the best position for the optical counterpart of Cir X-1, using HST images and SuperCOSMOS scans of UK Schmidt plates.

Johnston (AAO) and Verbunt (Utrecht) have used the High-Resolution Imager of the ROSAT X-ray satellite to study several globular clusters known to contain faint X-ray sources. The nature of these faint sources is unclear, in contrast to the bright sources, whose identification as low-mass X-ray binaries is fairly secure. The X-ray observations put further constraints on the number, luminosity, and X-ray spectral shape of these sources.

Supernova studies

Cannon and Stathakis (AAO) continued the long-term spectroscopic monitoring of SN 1987A. No time was allocated this year for observations with the RGO Cassegrain spectrograph, but an opportunity arose to obtain data during commissioning tests of the prototype SPIRAL fibre-feed imaging spectrograph. With Kenworthy (IoA/Cambridge), Lee and Taylor (AAO), spectra were

taken of a field a few arcseconds in diameter around the supernova. In good seeing, it was immediately apparent that there were significant differences between the spectra from adjacent half-arcsecond pixels. These differences presumably correspond to different proportions of light coming from the central supernova remnant, the circumstellar ring, hot ambient interstellar gas in the Large Magellanic Cloud and two nearby, relatively bright stars. Similar data were subsequently obtained in the near-infrared spectral region, using the 3-D instrument from the MPIE (Munich) in collaboration with Meikle and Fassia (ICSTM), again in sub-arcsecond seeing.

Considerable effort has gone into trying to monitor the spectroscopic development of SN 1998bw, a bright Type Ic supernova first discovered because it appears to be the origin of a burst of γ -rays detected on 25 April 1998. In addition to the monitoring observations, Cannon, Malin and Tinney (AAO), in collaboration with Hambly and MacGillivray (ROE), obtained an accurate optical position for SN 1998bw by combining SuperCOSMOS measurements of a Schmidt Sky Survey photograph of the field with some recent CCD images of the supernova. The resultant position agreed with that of the radio source, measured at the ATNF, to within 0.2 arcseconds. Inspection of the UKST photographs shows that SN 1998bw is located within an HII region lying on one of the spiral arms of its parent galaxy.

Abundances of globular cluster stars

Cannon (AAO), with Da Costa, Norris and Gibson (MSSSO) and Croke (Crete), used 2dF to obtain spectra for a sample of upper main-sequence stars in the giant globular cluster ω Centauri. This cluster is unique in that its evolved red giants display a large spread in iron-group abundances, in addition to the CNO variations seen in the evolved stars in many clusters. The objective is to determine to what extent the abundance spread seen in ω Cen is primordial, or perhaps due to a self-enrichment process early in the life of the cluster, and how much can be attributed to internal processes of stellar evolution.

Astrometry from Schmidt plates

Continuing a project begun last year, Cannon (AAO) is working with Hambly and MacGillivray (ROE), and other members of the UKST and SuperCOSMOS teams at Siding Spring and in Edinburgh, to improve the accuracy of astrometry obtainable from UKST photographs. Steps taken so far include the use of a better reference catalogue (the ACT, made by the US Naval Observatory by combining Tycho-Hipparcos positions with proper motions derived from the old Astrographic Catalogue); the use of an empirical 'mask' to remove the distortions caused by the curvature of the photographs in the Schmidt Telescope; and some improvements to the data analysis code. The result is that positions accurate to better than 0.25 arcsec can now be derived over entire Schmidt plates.

Advanced imaging

Bland-Hawthorn (AAO) continues to develop new methods for advanced imaging. He has investigated the possibility of a double cavity scanned with a synchronised capacitance bridge in order to 'square off' the Lorentzian profile of the etalon cavity. He has also performed simulations to demonstrate the feasibility of a tunable filter with curved plates and graded index coatings. The technology has important applications for removing phase effects over a wide field, and achieving a monochromatic field in fast beams, for example at the AAT f/3.3 prime focus.

As well, Bland-Hawthorn and PhD student Cianci are investigating Rugate beam splitters to identify specific classes of sources, including brown dwarfs at different temperatures and quasars beyond the redshift of reionization.

Bland-Hawthorn (AAO) and MacKenzie (Sydney), are producing a simple optical Rugate filter in preparation for more sophisticated OH suppressing filters in the near infrared, designed in collaboration with Offer (AAO).

Sky subtraction with fibre systems

Watson, Offer, Lewis, Bailey and Glazebrook (AAO) have reviewed the techniques used for sky subtraction with multi-fibre spectroscopy systems. The concern is that sky subtraction with fibres does not in general compare favourably with that using multi-slits for the faintest classes of objects. While it is true that fibres demand much greater care in sky subtraction, there is no fundamental reason why the two techniques should not produce similar results. With the 2dF facility, high-quality sky subtraction must be carried out on a routine basis, and techniques for further improving the existing performance are being explored. Examples include improved profile-fitting for extraction of the spectra, and elimination of optical effects causing occasional fibre-to-fibre spectral transmission differences. In designing new fibre instruments, it is possible to incorporate novel methods of sky subtraction, and one such technique using the optical properties of fibres is being investigated. For this method, the same fibre is used to transmit both the object signal and a local sky sample, and may approximate better to slit sky subtraction than conventional fibre techniques.

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 will exploit the excellent astrometric properties of CCDs, and the excellent seeing of the ESO site to obtain positions of these galaxies (relative to quasars discovered by Tinney and collaborators) to a precision of one milli-arcsecond per epoch. This should produce a firm detection of the proper motions of these galaxies within five years.

Gas in nearby galaxies

Bland-Hawthorn (AAO), Veilleux (KPNO), Carignan (Montreal) and Freeman (MSSSO) have continued to study ionized gas in nearby galaxies. They have measured the hydrogen-alpha rotation curves beyond the extent of the neutral hydrogen disk, for a further four galaxies. Dark haloes extend considerably further than the hydrogen disks in most cases. A continuing puzzle is the source of the outer warm gas, since the cosmic ionizing flux appears to be too weak by an order of magnitude. Since all spirals have warped outer disks, they are presently investigating a model in which the central blue disk irradiates the gas exposed to the inner disk. An early indication is that warps in spirals may be far more severe than observed in HI surveys.

Galaxy clusters

Bland-Hawthorn and Malin (AAO) have continued their work to understand very extended, extremely faint, diffuse structures in rich clusters identified in stacked photographic plates. In collaboration with Weil (Columbia), they have shown that in the Virgo cluster, the galaxy M87 exhibits a stellar fan-like structure which arises from a dwarf galaxy that has been scattered by the compact stellar core of M87. As much as half the mass of the interloper is retained by M87's core, and this may explain the counter-rotation observed there. In collaboration with Moore (Durham), Calcanéo-Roldan (Durham) and Sadler (Sydney), they have studied extraordinary linear features in the Centaurus and Coma clusters. These features appear to require a low-surface brightness galaxy to have been disrupted along its orbit more than two billion years ago. In support of this picture, they identify a standing wave at the point of closest approach to the cluster centre. The observed features have broadband colours which are consistent with two billion years of stellar ageing.

Bland-Hawthorn and Jones (MSSSO) have made extensive progress with the TTF in measuring variations in star formation rate density between galaxy clusters and the field over the redshift interval $z = 0.2$ to 0.6 . Using the TTF, a hundred emission-line sources can be identified in a rich cluster over

a 10 arcminute field, in a time of around four hours, considerably quicker than with more traditional observing techniques. A powerful demonstration of the technique was recently made in conjunction with Zaritsky (UCSC). His group identify compact clusters from surface brightness fluctuations in drift scan surveys. From only three hours of observation, Bland-Hawthorn and his collaborators have identified a peak in the number of emission-line objects at a slightly higher cluster redshift, compared to the number of objects seen at a lower cluster redshift or in the surrounding field population.

Phillipps (Bristol), Parker (AAO) and Jones (Bristol) are continuing a study of the Virgo and Fornax galaxy clusters which involves digitally stacking multiple exposures on Tech Pan film of the clusters. The high sensitivity of Tech Pan film, together with the addition of multiple exposures makes the survey well suited to the detection of low surface brightness objects. A new catalogue of the low surface brightness galaxies in the two clusters is in preparation. The search has led to the detection of many thousands of previously unknown low surface brightness galaxies within a region of nine square degrees within the Virgo cluster. These have been used to study the luminosity function for galaxies within the Virgo cluster.

Drinkwater (NSW), Phillipps (Bristol), Gregg (LLNL), Jones (Bristol), Smith (Cardiff), Parker (AAO), and Sadler (Sydney) are using the 2dF facility to obtain redshifts for 14 000 objects within the Fornax galaxy cluster. They aim to obtain redshifts for all objects within the cluster with blue magnitudes brighter than $B = 19.7$. The redshifts obtained so far have revealed a population of unresolved compact emission-line galaxies. These galaxies are missing from existing galaxy catalogues but may amount to one to two percent of all galaxies. From their hydrogen-alpha emission lines it is evident that the galaxies have high star-formation rates.

FLAIR redshift surveys

Shanks (Durham), Parker (AAO), Fong and Metcalfe (Durham) have continued with the extension of a large redshift survey for galaxies included in the Edinburgh/Durham Southern Galaxy Catalogue. The redshift survey has been extended to cover an additional 90 UK Schmidt fields. The large homogeneous survey will result in a powerful cosmological resource for detailed statistical analyses of galaxy clustering on large spatial scales.

Wakamatsu (Gifu), Malkan (UCLA), Parker (AAO) and Hasegawa (Gifu) have finished obtaining redshifts for heavily-obscured galaxies in crowded fields between the Ophiucus and Hercules clusters of galaxies. The data have been taken to look for a possible connection between the two clusters. Evidence was found for a wall-like structure that links the two galaxy clusters, and for a possible additional galaxy cluster located in the constellation of Libra, between the Ophiucus and Hercules clusters. The observed wall of galaxies appears to be extremely large, extending over 70 degrees on the sky, with a linear size estimated to be up to one million parsecs.

Colless (MSSSO), Parker (AAO), Hola (MSSSO) and Raychaudhury (IUCAA) have started a project in which FLAIR is used to measure integrated linewidths for galaxies for which redshifts were previously obtained in a magnitude-limited redshift survey by Colless and Hola. The linewidths will be used to investigate the dependence of the Tully-Fisher relationship on galaxy properties and to provide a low redshift comparison sample for studies of the evolution of the Tully-Fisher relationship.

Proust (Meudon), Parker (AAO) and Drinkwater (NSW) are continuing a programme to obtain redshifts for galaxies in four relatively nearby, rich X-ray galaxy clusters. These will be used to analyse the structure, dynamical evolution and sub-clustering properties of the clusters and to investigate correlations between the optical and X-ray properties of the clusters. This may shed new light on the current discrepancy that exists between X-ray and optical estimates for the mass of galaxy clusters.

Gamma Ray Burst follow-up

Tinney (AAO), Galama (Amsterdam) and Palazzi (BeppoSAX) have been co-ordinating a program of follow-up over-ride observations on the AAT for over 12 months now. This program has shown some success, with the AAT being able to contribute to the identification of at least two (GRB 980326 and GRB 980425) Gamma Ray Burst optical counterparts within the last 12 months.

Infrared emission from active galactic nuclei

Wolstencroft (ROE), Parker (AAO) and Lonsdale (Caltech) are using FLAIR and the ATCA to study several hundred sources included in the IRAS far-infrared catalogue which show a peak of emission at 25 μm . They have found that spectroscopic observations of IRAS sources, selected to have strongest emission at 25 μm , provide an efficient method for identifying active galactic nuclei where the far-infrared emission occurs from dust grains that are heated by a central source. The far-infrared properties are being used to test recent models in which the dusty material is located within a toroidal shaped region which absorbs and reddens light from the central regions. The study has led to the identification of three highly reddened quasars. Approximately one-quarter of the selected IRAS sources have been identified as active galactic nuclei.

Quasar studies

With Shanks, Croom (Durham), Smith (MSSSO), Miller and Loaring (Oxford), Boyle has continued to obtain redshifts for the 2dF QSO Redshift Survey. The overall aim of the survey is to obtain 25 000 quasar redshifts with which to measure large-scale structure in the Universe. So far, over 1200 redshifts have been obtained, making it already the largest single quasar redshift survey in existence. Initial results indicate a mean clustering scale length of quasars close to 4 million parsecs (for a Hubble constant = 100).

Together with Brotherton and van Breugel (IGPP/LLNL), the quasar redshift survey team have created a unique catalogue of radio-selected active galactic nuclei by cross-correlating the NVSS VLA radio catalogue with the 2dF quasar survey input catalogue. Over 100 of the 600 radio sources have been spectroscopically identified with the Keck telescope, resulting in the discovery of a new class of radio-loud broad absorption-line quasars. Other interesting rare objects have also been found as part of the survey, including a unique starburst-AGN.

Boyle (AAO), Aretxaga (ESO) and Terlevich (RGO) have also continued to work on the imaging of luminous quasars at high redshifts. This includes the first unambiguous detection in the near-infrared K-band of a host galaxy around a normal radio-quiet quasar at $z = 2$. The host galaxy comprises some 35 percent of the light of the system, corresponding to a galaxy five magnitudes brighter than a passively-evolved elliptical galaxy at $z = 2$.

Boyle and Terlevich (RGO) have also shown that the luminosity evolution of quasars closely mirrors the evolution of the star formation rate in the Universe recently derived from deep galaxy redshift surveys and the Hubble Deep Field data. They argue that this provides circumstantial evidence that star formation and the quasar phenomenon must be closely linked.

With Smith (MSSSO), Boyle has been working on the environments of intermediate redshift ($0.3 < z < 0.7$) radio-quiet quasars. They find that the redshift evolution in the environment of radio-quiet quasars is consistent with that of field galaxies over the same range in redshift. This is in marked contrast to the cluster galaxy environments observed for radio-loud quasars over these redshifts.

Research Papers

The following list includes research papers published from AAT and UKST data, 1 July 1997–30 June 1998, 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.

ALLEN L E (UNSW), ASHLEY M C B (UNSW), RYDER S D (UNSW), ET AL
IR Fabry-Perot imaging of NGC 3132. IAU Symp. 180: Planetary nebulae, p.205, 1998 (A)

ALMAINI O (CAMBRIDGE), SHANKS T (DURHAM), GRIFFITHS R E (PITTSBURGH),
BOYLE B J (AAO), ET AL
A deep ROSAT survey - XIV. X-ray emission from faint galaxies. Mon Not R astr Soc, 291:372, 1997 (A)

ALMAINI O (CAMBRIDGE), SHANKS T (DURHAM), GUNN K F (DURHAM), BOYLE B J (AAO), ET AL
Faint galaxies and the X-ray background. Astron. Nachr., 319:95, 1997 (A)

ARAGON-SALAMANCA A (CAMBRIDGE), BAUGH C M (DURHAM), KAUFFMANN G (MPA)
The K-band Hubble diagram for the brightest cluster galaxies: a test of hierarchical galaxy formation models. Mon Not R astr Soc, 297:427, 1998 (A)

ARETXAGA I (MPA), TERLEVICH R J (RGO), BOYLE B J (AAO)
Multicolour imaging of $z = 2$ QSO hosts. Mon Not R astr Soc, 296:643, 1998 (O)

BAILEY J (AAO)
Eclipsing AM Herculis binaries. ASP Conference series vol. 130:279, 1997 (A)

BAILEY J (AAO), PRESTAGE R (HAWAII)
The portable telescope control system project. SPIE Proc vol 3112: Telescope Control Systems II, p.124, 1997

BAILEY J A (AAO)
Eclipsing AM Herculis binaries. ASP Conf series 121, IAU Coll.163: Accretion phenomena and related outflows, p.391, 1997 (A)

BARDELLI S (TRIESTE), ZUCCA E (BOLOGNA), ZAMORANI G (BOLOGNA), ET AL
A study of the core of the Shapley Concentration: III. Properties of the clusters in the

A3558 complex. Mon Not R astr Soc, 296:599, 1998 (S)

BEERS T C (MICHIGAN), ROSSI S (MICHIGAN), NORRIS J E (MSSSO), RYAN S G (RGO), ET AL

The low metallicity tail of the halo metallicity distribution function. Primordial Nuclei and their Galactic Evolution, ISSI Workshop, p.?, 1998 (A)

BLAIR A (DURHAM), STEWART G C (LEICESTER), GEORGANTOPOULOS I (DURHAM), BOYLE B J (AAO), ET AL

QSO X-ray spectral evolution. Astron. Nach., 319:25, 1997 (O)

BLAND-HAWTHORN J (AAO), FREEMAN K C (MSSSO), QUINN P J (MSSSO)

Where do the disks of spiral galaxies end? Astrophys. J., 490:143, 1997 (A)

BLAND-HAWTHORN J (AAO), GALLIMORE J F (MPE), TACCONI L J (MPE), ET AL

The Ringberg standards for NGC 1068. Astrophysics & Space Science, 248:9, 1997 (O)

BLAND-HAWTHORN J (AAO), JONES D H (MSSSO)

Taurus Tunable Filter: a flexible approach to narrowband imaging. Publ Astron Soc Australia, 15:44, 1998 (A)

BLAND-HAWTHORN J (AAO), JONES D H (MSSSO)

The TTF survey of galaxy populations. 37th Herstmonceux Conference, p.121, World Scientific, 1997 (A)

BLAND-HAWTHORN J (AAO), LUMSDEN S L (AAO), VOIT G M (JHU), ET AL

Strict limits on the ionizing luminosity in NGC 1068 from jet-axis molecular clouds. Astrophysics & Space Science, 248:177, 1997 (O)

BOUMIS P (MANCHESTER), MEABURN J (MANCHESTER), BRYCE M (MANCHESTER), LOPEZ J A (MEXICO)

The H alpha echoes of Eta Carinae from 1985 to 1997. Mon Not R astr Soc, 294:61, 1998 (A,S)

BOWEN D V (ROE), PETTINI M (RGO), BOYLE B J (AAO)

Ly alpha absorption in the nearby universe: the sightline to Q1821+643. Mon Not R astr Soc, 297:239, 1998 (O)

BOYLE B J (AAO), GEORGANTOPOULOS I (LEICESTER), BLAIR A J (LEICESTER), ET AL

ASCA observations of deep ROSAT fields - II. The 2-10 keV AGN luminosity function Mon Not R astr Soc, 296:1, 1998 (A)

BOYLE B J (AAO), TERLEVICH R J (RGO)

The cosmological evolution of the QSO luminosity density and of the star formation rate. Mon Not R astr Soc, 293:L49, 1998 (O)

BRANSFORD M A (IOWA), APPLETON P N (IOWA), HEISLER C A (MSSSO), ET AL

Radio-luminous southern Seyfert galaxies. I. Radio images and selected optical/near-infrared spectroscopy. Astrophys. J., 497:133, 1998 (A)

BRATSOLIS E (ATHENS)

A simple automatic method of determining the positions of spectra on objective-prism images. Wide-field spectroscopy, p.119, Kluwer, 1997 (S)

BRINCHMANN J (CAMBRIDGE), ABRAHAM R (CAMBRIDGE), SCHADE D (DAO), TRESSE L (CAMBRIDGE), ELLIS R S (CAMBRIDGE), LILLY S (CAMBRIDGE), LE FEVRE O (MARSEILLE), GLAZEBROOK K (AAO), ET AL

Hubble Space Telescope imaging of the CFRS and LDSS redshift surveys. I. Morphological properties. Astrophys. J., 499:112, 1998 (O)

BRYCE M (MANCHESTER), LOPEZ J A (MEXICO), HOLLOWAY A J (MANCHESTER), MEABURN J (MANCHESTER)

A bipolar, knotty outflow with velocities of 500 kilometers per second or above from the engraved hourglass planetary nebula MyCn 18. Astrophys Jnl Letters, 487:L161, 1997 (A)

BUCKLEY D A H (SAAO), FERRARIO L (ANU), WICKRAMASINGHE D T (ANU), BAILEY J A (AAO)

Polarimetry of the eclipsing polar RX J0929.1 - 2404. Mon Not R astr Soc, 295:899, 1998 (A)

BURKE D J (DURHAM), COLLINS C A (LIVERPOOL), SHARPLES R M (DURHAM), ET AL

The Southern SHARC survey: the $z = 0.3 - 0.7$ cluster X-ray luminosity function. Astrophys Jnl Letters, 488:L83, 1997 (A)

BURTON M G (UNSW)

Inside the bullets of Orion. ASP Conf series 121: Accretion phenomena and related outflows, p.571, 1997 (A)

BUTLER R P (AAO)

A precision velocity study of photometrically stable stars in the Cepheid instability strip. Astrophys. J., 494:342, 1998 (O)

CANNON R (AAO)

2dF: the two-degree field facility on the AAT. Wide-field spectroscopy conf, Athens p.33, Kluwer, 1997 (A)

CANNON R (AAO)

Conference summary (Wide-field spectroscopy, Athens, 1996). Proc Wide field spectroscopy conf, Athens, 1996, p.395, Kluwer, 1997

CANNON R (AAO)

High density requirements. IAU Highlights, Kyoto, 1997

CANNON R (AAO)

Fringing - a user's perspective. Optical detectors for astronomy, p.209, Kluwer, 1998

CANNON R (AAO), BARTON J (AAO)

AAO detectors - present status and future plans. Optical detectors for astronomy, p.65, Kluwer, 1998 (A)

CANNON R (AAO), WHITELOCK P (SAAO) (EDITORS)

General discussion - IAU Symposium vol.192. IAU Symposium 192: The stellar content of Local Group galaxies, p.508

CARTER D (LIVERPOOL), THOMSON R C (HERTFORDSHIRE), HAU G K T (CAMBRIDGE)

Minor axis rotation and the intrinsic shape of the shell elliptical NGC 3923. Mon Not R astr Soc, 294:182, 1998 (A)

CHAKRABARTY D (MIT), ROCHE P (SUSSEX)

The symbiotic neutron star binary GX 1+4/V2116 Ophiuchi. Astrophys. J., 489:254, 1997 (S)

CHEN H W (SUNY), LANZETTA K M (SUNY), WEBB J K (UNSW), BARCONS X (SPAIN)

The gaseous extent of galaxies and the origin of Ly alpha absorption systems. III. Hubble Space Telescope imaging of Ly alpha-absorbing galaxies at z less than 1. Astrophys. J., 498:77, 1998 (A)

CHRYSTOSTOMOU A (HERTFORDSHIRE), BURTON M G (UNSW), AXON D J (STSI), BRAND P W J L (EDINBURGH), HOUGH J H (HERTFORDSHIRE), BLAND-HAWTHORN J (AAO), GEBALLE T R (HAWAII)

Velocity resolved Fabry-Perot imaging of molecular hydrogen emission in OMC-1. Mon Not R astr Soc, 289:605, 1997 (O)

CLOCCHIATTI A (CTIO), WHEELER J C (TEXAS), PHILLIPS M M (CTIO), ET AL
SN 1983V in NGC 1365 and the nature of stripped envelope core-collapse supernovae. Astrophys. J., 483:675, 1997 (A)

COCHRAN W D (TEXAS), HATZES A P (TEXAS), BUTLER R P (SAN FRANCISCO, AAO), MARCY G W (SAN FRANCISCO)

The discovery of a planetary companion to 16 Cygni B. Astrophys. J., 483:457, 1997 (O)

COE M J (SOUTHAMPTON), BUCKLEY D A H (SAAO), CHARLES P A (OXFORD), ET AL

The identification of the optical/IR counterpart to the ROSAT SMC X-ray transient RX J0117.6 - 7330. Mon Not R astr Soc, 293:43, 1998 (A)

COLLESS M (MSSSO)

Wide field spectroscopy and the universe. Wide-field spectroscopy, p.227, Kluwer, 1997 (A)

COUCH W J (UNSW), BARGER A J (HAWAII), SMAIL I (DURHAM), ELLIS R S (CAMBRIDGE), SHARPLES R M (DURHAM)

Morphological studies of the galaxy populations in distant "Butcher-Oemler" clusters with HST. II. AC 103, AC 118, and AC 114 at z=0.31. Astrophys. J., 497:188, 1998 (A)

CRAWFORD I A (UCL)

Ultra-high-resolution observations of interstellar C2, CH and CN towards Zeta Ophiuchi and HD 169454. Mon Not R astr Soc , 290:41, 1997 (A)

CRAWFORD I A (UCL), BEUST H (GRENOBLE), LAGRANGE A M (GRENOBLE)

Detection of a strong transient blueshifted absorption component in the Beta Pictoris disc. Mon Not R astr Soc, 294:L31, 1998 (A)

CRAWFORD I A (UCL), WILLIAMS D A (UCL)

Detection of interstellar NH towards Zeta Ophiuchi by means of ultra-high-resolution spectroscopy. Mon Not R astr Soc , 291:L53, 1997 (A)

CROFT R A C (OXFORD), DALTON G B (OXFORD), EFSTATHIOU G (OXFORD), ET AL

The richness dependence of galaxy cluster correlations: results from a redshift survey of rich APM clusters. Mon Not R astr Soc, 291:305, 1997 (S)

CROWTHER P A (UCL), DE MARCO O (UCL), BARLOW M J (UCL)

Quantitative classification of WC and WO stars. Mon Not R astr Soc, 296:367, 1998 (A)

DA COSTA G S (MSSSO), HATZIDIMITRIOU D (CRETE)

Ca II triplet spectroscopy of giants in Small Magellanic Cloud star clusters: abundances, velocities, and the age-metallicity relation. Astronom Jnl, 115:1934, 1998 (A)

DAVIES R I (OXFORD), FORBES D A (BIRMINGHAM), RYDER S (UNSW), ET AL

Near-infrared line and radio continuum imaging of the Circinus Galaxy. Mon Not R astr Soc, 293:189, 1998 (A)

DE MARCO O (UCL), BARLOW M J (UCL), STOREY P J (UCL)

The WC10 central stars CPD-56 8032 and He 2-113 - I. Distances and nebular parameters. Mon Not R astr Soc, 292:86, 1997 (A)

DE MARCO O (UCL), CROWTHER P A (UCL)

The WC10 central stars CPD - 56 deg 8032 and He 2-113 - II. Model analysis and comparison with nebular properties. Mon Not R astr Soc, 296:419, 1998 (A)

DEHNEN W (OXFORD), BLAND-HAWTHORN J (AAO), QUIRRENBACH A (MPE), CECIL G N (NORTH CAROLINA)

Kinematics and mass modelling of NGC 1068. Astrophysics & Space Science, 248:33, 1997 (O)

DELFOSSSE X, FORVEILLE T, TINNEY C G (AAO), EPCHTEIN N

The DENIS Sky survey: first results on very low mass stars and substellar objects. ASP Conf series vol.134: Brown Dwarfs and Extrasolar Planets, p.67, 1998 (A)

DELFOSSSE X (GRENOBLE), TINNEY C G (AAO), FORVEILLE T (GRENOBLE), ET AL

Field brown dwarfs found by DENIS. Astronomy & Astrophysics, 327:L25,1997 (A)

DERMER C D (NAVAL RESEARCH LAB), BLAND-HAWTHORN J (AAO), CHIANG J

(NAVAL RESEARCH LAB), MCNARON-BROWN K (NAVAL RESEARCH LAB)
OSSE observations of the ultraluminous infrared galaxies ARP 220, Markarian 273, and Markarian 231. *Astrophys Jnl Letters*, 484:L121, 1997 (O)

DONATI J F (OMP), COLLIER CAMERON A (ST ANDREWS)
Differential rotation and magnetic polarity patterns on AB Doradus. *Mon Not R astr Soc*, 291:1, 1997 (A)

DONATI J F (OMP), SEMEL M (PARIS), CARTER B D (USQ), ET AL
Spectropolarimetric observations of active stars. *Mon Not R astr Soc*, 291:658, 1997 (A)

DOPITA M A (MSSSO), HEISLER C (MSSSO), LUMSDEN S (AAO), BAILEY J (AAO)
Probing the dusty accretion torus of Seyfert galaxies. *Astrophys. J.*, 498:570, 1998 (O)

DRINKWATER M J (NSW), GREGG M D (CALIFORNIA)
High surface brightness dwarf galaxies in the Fornax cluster. *Mon Not R astr Soc*, 296:L15, 1998 (S)

DUNCAN D K (CHICAGO), PRIMAS F (CHICAGO), REBULL L M (CHICAGO), RYAN S G (AAO), ET AL
The evolution of galactic boron and the production site of the light elements. *Astrophys. J.*, 488:338, 1997 (O)

DUNCAN D K (CHICAGO), REBULL L M (CHICAGO), PRIMAS F (CHICAGO),
BOESGAARD A M (HAWAII), DELIYANNIS C P (YALE), HOBBS L M (YERKES), KING J R (STSI), RYAN S G (RGO)
Boron in the very metal-poor star BD - 13 3442. *Astronomy & Astrophysics*, 332:1017, 1998 (O)

DUNKIN S K (LONDON), BARLOW M J (LONDON), RYAN S G (AAO)
High-resolution spectroscopy of Vega-like stars - II: Age indicators, activity, and circumstellar gas. *Mon Not R astr Soc*, 290:165, 1997 (A)

DWORETSKY M M (UCL), JOMARON C M (UCL), SMITH C A (UCL)
The gallium problem in HgMn stars. *Astronomy & Astrophysics*, 333:665, 1998 (A)

ELMOUTTIE M (QUEENSLAND), KORIBALSKI B (ATNF), GORDON S (QUEENSLAND), TAYLOR K (AAO), HOUGHTON S (UNSW, AAO), ET AL
The kinematics of the ionized gas in the Circinus galaxy. *Mon Not R astr Soc*, 297:49, 1998 (A)

FERRARIO L (ANU), VENNES S (ANU), WICKRAMASINGHE D T (ANU), BAILEY J A (AAO), CHRISTIAN D J (CALIFORNIA)
EUVE J0317 - 855: a rapidly rotating, high-field magnetic white dwarf. *Mon Not R astr Soc*, 292:205, 1997 (A)

FRANCIS P J (MSSSO), WOODGATE B E (NASA), DANKS A C (NASA)
Galaxy clusters and large scale structure at high redshifts. *ASP Conf series vol.146: The young universe*, p.496, 1998 (A)

FUJIYOSHI T (UNSW), SMITH C H (UNSW), MOORE T J T (UNSW), ET AL
12 micron fine-structure emission line and continuum images of G333.6-0.2. Mon Not R
astr Soc, 296:225, 1998 (A)

GATTI A A (ICL), DREW J E (ICL), LUMSDEN S (AAO), ET AL
A radial velocity study of the companion to the central star of Abell 35. Mon Not R astr
Soc, 291:773, 1997 (A)

GEORGANTOPOULOS I (LEICESTER), STEWART G C (LEICESTER), BLAIR A J
(LEICESTER), SHANKS T (DURHAM), GRIFFITHS R E (PITTSBURGH), BOYLE B J
(AAO), ALMAINI O (CAMBRIDGE), ROCHE N (JHU)
ASCA observations of deep ROSAT fields I. The nature of the X-ray source populations.
Mon Not R astr Soc, 291:203, 1997 (A)

GIZIS J E (PALOMAR), SCHOLZ R D (POTSDAM), IRWIN M (RGO), JAHREISS H
(HEIDELBERG)
APMPM J1523-0245: a new high proper motion cool subdwarf. Mon Not R astr Soc,
292:L41, 1997 (S)

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

GLAZEBROOK K (AAO), ECONOMOU F (HAWAII)
Detection of H alpha in a $z=1$ star-forming spiral galaxy. 37th Herstmonceux Confer-
ence, p.139, World Scientific, 1997 (O)

GLAZEBROOK K (AAO), OFFER A R (AAO), DEELEY K (AAO)
Automatic redshift determination by use of principal component analysis - I: fundamen-
tals. Astrophys. J. 492:98, 1998 (A)

GOLDHABER G (CALIFORNIA), DEUSTUA S (CALIFORNIA),...BOYLE B J (RGO,
AAO), GLAZEBROOK K (AAO), ET AL
Observation of cosmological time dilation using Type Ia supernovae as clocks. The
Supernova Cosmology Project: III Thermonuclear supernovae, p.777, Kluwer, 1997 (O)

GOLDSCHMIDT P (ICL), MILLER L (OXFORD)
The UVX quasar optical luminosity function and its evolution. Mon Not R astr Soc,
293:107, 1998 (S)

GREEN S F (KENT), McBRIDE N (KENT), CEALLAIGH D P O (BELFAST), ET AL
Surface reflectance properties of distant Solar system bodies. Mon Not R astr Soc,
290:186, 1997 (A)

GRIFFITHS R E (PITTSBURGH), BOYLE B J (AAO), GEORGANTOPOULOS I (ATH-
ENS), ET AL
The AGN content of ROSAT and ASCA deep surveys. Astron. Nachr., 319:55, 1997 (O)

GROENEWEGEN M A T (MPA), WHITELOCK P A (SAAO), SMITH C H (ADFA),
KERSCHBAUM F (WIEN)

Dust shells around carbon Mira variables. Mon Not R astr Soc, 293:18, 1998 (A)

HAIGH A J (SYDNEY), ROBERTSON J G (SYDNEY), HUNSTEAD R W (SYDNEY)
Optical identification strategies for the Molonglo Cluster Survey. Publ Astron Soc Australia, 14:221, 1997 (S)

HAMBLY N C (ROE), SMARTT S J (LA PALMA), HODGKIN S T (LEICESTER)
WD 0346+246: a very low luminosity, cool degenerate in Taurus. Astrophys. J., 489:L157, 1997 (S)

HARRISON P M (ST ANDREWS), JEFFERY C S (ST ANDREWS)
A spectral analysis of the hydrogen-deficient star HD 144941. Astronomy & Astrophysics, 323:177, 1997 (A)

HAWKINS M R S (ROE), CLEMENTS D (ESO), FRIED J W (MPIA), ET AL
The double quasar Q2138-431: lensing by a dark galaxy? Mon Not R astr Soc, 291:811, 1997 (S)

HAWKINS M R S (ROE), DUCOURANT C (BORDEAUX), JONES H R A (LIVERPOOL), RAPAPORT M (BORDEAUX)
A new population of brown dwarfs. Mon Not R astr Soc, 294:505, 1998 (A,S)

HEWETT P C (CAMBRIDGE), FOLTZ C B (ARIZONA), HARDING M E (CAMBRIDGE), LEWIS G F (SUNY)
Two close separation quasar-quasar pairs in the Large Bright Quasar Survey. Astronom Jnl, 115:383, 1998 (A)

HUNSTEAD R W (SYDNEY), WU K (SYDNEY), CAMPBELL-WILSON D (SYDNEY)
New radio and optical data for GRO J1655-40. ASP Conf series vol.121, IAU Coll.163: Accretion phenomena and related outflows, p.63, 1997 (A)

IWASAWA K (CAMBRIDGE), FABIAN A C (CAMBRIDGE), BRANDT W N (PENNSYLVANIA), ET AL
Detection of an X-ray periodicity in the Seyfert galaxy IRAS 18325-5926. Mon Not R astr Soc, 295:L20, 1998 (S)

JAMES D J (BIRMINGHAM), JEFFRIES R D (KEELE)
Rotation, activity and lithium in NGC 6475. Mon Not R astr Soc, 291:252, 1997 (A)

KERR T H (NOTTINGHAM), HIBBINS R E (NOTTINGHAM), FOSSEY S J (UCL), MILES J R (NOTTINGHAM), SARRE P J (NOTTINGHAM)
Ultrafine structure in the wavelength 5797 diffuse interstellar absorption band. Astrophys. J., 495:941, 1998 (A)

KOEKEMOER A M (STSI), BICKNELL G V (ANU)
Dynamics and excitation of radio galaxy emission-line regions - I. PKS 2356-61. Astrophys. J., 497:662, 1998 (A)

KUNKEL W E (CIW), DEMERS S (MONTREAL), IRWIN M J (RGO), ALBERT L (MONTREAL)

The dynamics of the Large Magellanic Cloud periphery: mass limit and polar ring. *Astrophys Jnl Letters*, 488:L129, 1997 (S)

KUNTSCHNER H (DURHAM), DAVIES R L (DURHAM)

The ages and metallicities of early-type galaxies in the Fornax cluster. *Mon Not R astr Soc*, 295:L29, 1998 (A)

KUNTSCHNER H (DURHAM), DAVIES R L (DURHAM), BENDER R

Line-strength indices and kinematics. In *Fornax Proc. ESO-VLT Workshop: Galaxy scaling relations*, p.363, Springer-Verlag, 1998 (A)

LA FRANCA F (ROME), ANDREANI P (PADOVA), CRISTIANI S (PADOVA)

Quasar clustering: evidence for an increase with redshift and implications for the nature of active galactic nuclei. *Astrophys. J.*, 497:529, 1998 (S)

LE FEVRE O (PARIS), ELLIS R S (CAMBRIDGE), LILLY S J (CAMBRIDGE), ABRAHAM B (CAMBRIDGE), BRINCHMAN J (TORONTO), SCHADE D (TORONTO), BROADHURST T J (CALIFORNIA), COLLESS M (MSSSO), CRAMPTON D (DAO), GLAZEBROOK K (AAO), ET AL

HST observations of field galaxies to $z \approx 1$: clues to galaxy evolution. 37th Herstmonceux Conference, p.81, World Scientific, 1997 (O)

LEE S W, CANNON R D (AAO)

The photographic photometry of the globular cluster NGC 6752. *Journal of Korean Astronomical Society*, 30:135L, 1997 (O)

LILLY S (TORONTO), SCHADE D (TORONTO), ELLIS R (CAMBRIDGE), LE FEVRE L (MEUDON), BRINCHMANN J (CAMBRIDGE), GLAZEBROOK K (AAO), ET AL

Hubble Space Telescope imaging of the CFRS and LDSS redshift surveys. II. Structural parameters and the evolution of disk galaxies to $z \approx 1$. *Astrophys. J.*, 500:75, 1998 (O)

LUMSDEN S (AAO), BLAND-HAWTHORN J (AAO), MOORE T (LIVERPOOL), ET AL

Near and mid-infrared polarization of the nucleus in NGC 1068. *Astrophysics & Space Science*, 248:287, 1997 (A)

LUMSDEN S L (AAO), COLLINS C A (LIVERPOOL), NICHOL R C (PITTSBURGH), EKE V R (AAO), GUZZO L (BRERA)

The Edinburgh-Durham Southern Galaxy Catalogue - VIII: The cluster galaxy luminosity function. *Mon Not R astr Soc*, 290:119, 1997 (S)

MACGILLIVRAY H T (ROE)

Digitisation, archiving and dissemination of the 275 Gbytes of the AAO/UKST H alpha survey data. *Publ Astron Soc Australia*, 15:42, 1998 (S)

MALIN D (AAO)

Photographic enhancement of H alpha films. *Publ Astron Soc Australia*, 15:38, 1998 (S)

MANN R G (EDINBURGH), PEACOCK J A (ICL), HEAVENS A F (EDINBURGH)

Eulerian bias and the galaxy density field. *Mon Not R astr Soc*, 293:209, 1998 (S)

MARCHENKO S V (MONTREAL), MOFFAT A F J (MONTREAL), EVERSBERG T (MONTREAL), ET AL
A comprehensive variability study of the enigmatic WN8 stars: final results. Mon Not R astr Soc, 294:642, 1998 (S)

MARCY G (SAN FRANCISCO), BUTLER R P (AAO)
New worlds: the diversity of planetary systems. Sky & Telescope, v95 n3:30, 1998

MARSTON A P (DES MOINES), BRYCE M (MANCHESTER), LOPEZ J A (MEXICO), ET AL
Kinematics and origin of the ringed bipolar nebula Mz 1. Astronomy & Astrophysics, 329:683, 1998 (A)

MASHEDER M R W (BRISTOL), PHILLIPPS S (BRISTOL), PARKER Q A (AAO)
Scientific background to the UKST H alpha survey. Publ Astron Soc Australia, 15:5, 1998 (S)

MEABURN J (MANCHESTER), CLAYTON C A (RAL), BRYCE M (MANCHESTER), ET AL
The nature of the cometary knots of the Helix planetary nebula (NGC 7293). Mon Not R astr Soc, 294:201, 1998 (A)

MENGEL M W (TOOWOOMBA)
Zeeman Doppler Imaging: a technique for investigating magnetic activity on rapidly-rotating stars. Aust. J. Astr. 6:231, 1998 (A)

METCALFE N (DURHAM), RATCLIFFE A (DURHAM), SHANKS T (DURHAM), FONG R (DURHAM)
UBVRI photometry of the Durham - AAT redshift survey. Mon Not R astr Soc, 294:147, 1998 (S)

MISSELT K A (LOUISIANA), CLAYTON G C (LOUISIANA), SCHULTE-LADBECK R E (PITTSBURGH)
Polarimetry of the LMC X-ray binary A0538-66 during an "on/off" transition in 1991. Publ Astron Soc Pacific, 110:396, 1998 (A)

MITCHELL K J (MARYLAND), SAFFER R A (STSI), HOWELL S B (WYOMING), BROWN T M (JHU)
A new, complete sample of faint B stars in the Galactic halo. Mon Not R astr Soc, 295:225, 1998 (A)

MORGAN D H (ROE)
Planetary nebulae in extragalactic systems. Wide-field spectroscopy, p.161, Kluwer, 1997 (S)

MORGAN D H (ROE), PARKER Q A (AAO)
Colour equations for Tech-Pan films. IAU Symposium 179: New horizons from multi-wavelength sky surveys: 374, 1998 (S)

MORGAN D H (ROE), PARKER Q A (AAO)

FLAIR observations of planetary nebulae in the Large Magellanic Cloud. Mon Not R astr Soc, 296:921, 1998 (S)

MORGAN I (WALES), SMITH R M (WALES), PHILLIPPS S (BRISTOL)
The luminosity function around isolated spiral galaxies. Mon Not R astr Soc, 295:99, 1998 (A)

MORGANTI R (ATNF), TADHUNTER C N (SHEFFIELD), DICKSON R (SHEFFIELD),
SHAW M (SHEFFIELD)
Clues on the nature of Compact Steep Spectrum radio sources from optical spectroscopy. Astronomy & Astrophysics, 326:130, 1997 (A)

MORRISON J E (HEIDELBERG), SMART R L (TORINO), TAFFA L G (JHU)
Do we need to model plates at all? Mon Not R astr Soc, 296:66, 1998 (S)

NAKANISHI K (KYOTO), TAKATA T (TOKYO), YAMADA T (SENDAI), ET AL
Search and redshift survey for IRAS galaxies behind the Milky Way and structure of the local void. Astrophys Jnl Suppl, 112:245, 1997 (S)

NORRIS J E (MSSSO), RYAN S G (AAO), BEERS T C (MICHIGAN), DELIYANNIS C P (YALE)
Extremely-metal-poor stars. III. The Li-depleted main-sequence-turnoff dwarfs. Astrophys. J. 485:370, 1997 (A)

NORRIS J E (MSSSO), RYAN S G (AAO), BEERS T C (MICHIGAN)
Extremely metal-poor stars. IV. The carbon-rich objects. Astrophys. J, 488:350, 1997 (A)

NORRIS J E (MSSSO), RYAN S G (AAO), BEERS T C (MICHIGAN)
Extremely metal-poor stars. The carbon-rich, neutron capture element-poor object CS 22957-027. Astrophys Jnl Letters, 489:L169, 1997 (A)

ODUMAIJER R D (ICL), DREW J E (ICL), BARLOW M J (UCL), ET AL
Helium absorption and emission towards Theta 1 Ori C. Mon Not R astr Soc, 291:110, 1997 (A)

PAIN R (CALIFORNIA), HOOK I M (CALIFORNIA), GLAZEBROOK K (AAO), BOYLE B J (RGO, AAO), ET AL
The Type Ia supernova rate at $z \approx 0.4$. Thermonuclear supernovae, p.785, Kluwer, 1997 (O)

PARKER Q A (AAO)
FLAIR on the UK Schmidt telescope. Wide-field spectroscopy, p.25, Kluwer, 1997 (S)

PARKER Q A (AAO), BLAND-HAWTHORN J (AAO)
Technical aspects of the new AAO/UKST H alpha interference filter. Publ Astron Soc Australia, 15:33, 1998 (S).

PARKER Q A (AAO), COLLESS M (MSSSO), MAMON G (PARIS)
The UKST FLAIR-DENIS survey. Wide-field spectroscopy, p.303, Kluwer, 1997 (S)

PARKER Q A (AAO), HARTLEY M (AAO)

Objective-prisms on Schmidt telescopes: past activity and future prospects. Wide-field spectroscopy, p.17, Kluwer, 1997 (S)

PARKER Q A (AAO), PHILLIPPS S (BRISTOL)

An H alpha survey of the galactic plane. IAU Symposium 179: New horizons from multi-wavelength sky surveys: 179, 1998 (S)

PARKER Q A (AAO), PHILLIPPS S (BRISTOL)

Background and first results from the new AAO/UKST H alpha survey. Publ Astron Soc Australia, 15:28, 1998 (S)

PASIAN F (TRIESTE), SMAREGLIA R (TRIESTE), HANTZIOS P (ATHENS), ET AL

Automated objective prism spectral classification using neural networks. Wide-field spectroscopy, p.103, Kluwer, 1997 (S)

PASIAN F (TRIESTE), SMAREGLIA R (TRIESTE), KONTIZAS E (ATHENS)

A system for the analysis of objective-prism data. Wide-field spectroscopy, p.123, Kluwer, 1997 (S)

PERLMUTTER S (CALIFORNIA), DEUSTUA S (CALIFORNIA), BOYLE B J (RGO, AAO), GLAZEBROOK K (AAO), ET AL

Scheduled discoveries of 7+ high redshift supernovae: first cosmology results and bounds on q_0 . The Supernova Cosmology Project: I Thermonuclear supernovae, p.749, Kluwer, 1997 (O)

PERLMUTTER S (CALIFORNIA), GABI S (CALIFORNIA), BOYLE B J (RGO, AAO), GLAZEBROOK K (AAO), ET AL

Measurements of the cosmological parameters Ω and Λ from the first seven supernovae at z greater than or equal to 0.35. Astrophys. J. 483:565, 1997 (O)

PETTINI M (RGO), SMITH L J (UCL), KING D L (RGO), HUNSTEAD R W (SYDNEY)

The metallicity of high redshift galaxies: the abundance of zinc in 34 damped Lyman alpha systems from $z=0.7$ to 3.4. Astrophys. J, 486:665, 1997 (A)

PHILLIPPS S (BRISTOL)

Complete spectroscopic surveys of nearby galaxy clusters. Proc. IAU Commission 9 conf: Wide-Field Spectroscopy, Kluwer, p.281, 1997 (A)

PHILLIPPS S (BRISTOL), DRIVER S P (UNSW), COUCH W J (UNSW), SMITH R M (CARDIFF)

The luminosity distribution in galaxy clusters; a dwarf population - density relation? Astrophys Jnl Letters, 498:L119, 1998 (A)

PHILLIPPS S (BRISTOL), ET AL

Dwarf galaxies in medium redshift clusters. Astrophysics Letters & Communications, 36:161, 1997 (A)

PHILLIPPS S (BRISTOL), PARKER Q A (AAO), SCHWARTZENBERG J M (BRISTOL), JONES J B (BRISTOL)

Dwarf spheroidal galaxies in the Virgo Cluster. Astrophys. J., 493:L59, 1998 (S)

PIETSCH W (MPE), BISCHOFF K (GOTTINGEN), BOLLER T (MPE), ET AL
New active galactic nuclei detected in ROSAT All Sky Survey galaxies. *Astronomy & Astrophysics*, 333:48, 1998 (S)

PORTER J M (LIVERPOOL), DREW J E (LONDON), LUMSDEN S L (AAO)
Broad band infrared spectroscopy of massive young stellar objects. *Astronomy & Astrophysics*, 332:999, 1998 (A)

PREIBISCH T (WURZBURG), GUENTHER E (TAUTENBURG), ZINNECKER H (POTSDAM), ET AL
A lithium-survey for pre-main sequence stars in the Upper Scorpius OB association. *Astronomy & Astrophysics*, 333:619, 1998 (S)

PRESTAGE R, OLIVIERA F, BAILEY J A (AAO), ET AL
A route-finding algorithm for the optimal control of telescope slews. *SPIE Proc. 3112: Telescope Control Systems II*, p.76, 1997

PRESTAGE R M (HAWAII), OLIVEIRA F J (HAWAII), BAILEY J A (AAO), MASUDA N T (HAWAII)
The new JCMT telescope control system. *SPIE Proc. 3351: Telescope Control Systems III*, p.140, 1998

RATCLIFFE A (DURHAM), SHANKS T (DURHAM), PARKER Q A (AAO), FONG R (DURHAM)
The Durham/UKST Galaxy Redshift Survey - II. The field galaxy luminosity function. *Mon Not R astr Soc*, 293:197, 1998 (S)

RATCLIFFE A (DURHAM), SHANKS T (DURHAM), PARKER Q A (AAO), FONG R (DURHAM)
The Durham/UKST Galaxy Redshift Survey - III. Large-scale structure via the two-point correlation function. *Mon Not R astr Soc*, 296:173, 1998 (S)

RATCLIFFE A (DURHAM), SHANKS T (DURHAM), PARKER Q A (AAO), FONG R (DURHAM)
The Durham/UKST Galaxy Redshift Survey - IV. Redshift-space distortions in the two-point correlation function. *Mon Not R astr Soc*, 296:191, 1998 (S)

REID A D (SYDNEY), HUNSTEAD R W (SYDNEY), PIERRE M M (SACLAY)
Radio study of X-ray clusters of galaxies I: A3528 - a pre-merging cluster in the core of the Shapley Supercluster. *Mon Not R astr Soc*, 296:531, 1998 (S)

REID I N (CALTECH), HUGHES S M G (CALTECH), GLASS I S (SAAO)
Long-period variables in the Large Magellanic Cloud - IV. A compendium of northern variables. *Mon Not R astr Soc*. v275, 331, 1995 (S)

REYNOLDS C S (COLORADO), WARD M J (LEICESTER), FABIAN A C (CAMBRIDGE), CELOTTI A (TRIESTE)
A multiwavelength study of the Seyfert 1 galaxy MCG-6-30-15. *Mon Not R astr Soc*, 291:403, 1997 (A)

ROBERTSON J G (SYDNEY)

MAPPIT 2: second generation high-resolution imaging at the AAT. Publ Astron Soc Australia, 14:189, 1997 (A)

ROLLESTON W R J (BELFAST), HAMBL Y N C (ROE), DUFTON P L (BELFAST), ET AL

High-resolution spectroscopic observations of B-type stars from the Edinburgh-Cape survey. Mon Not R astr Soc, 290:422, 1997 (A)

ROY J -R (MONT MEGANTIC), WALSH J R (ESO)

1. The abundance gradient of NGC 1365: evidence for a recently formed bar in an archetype barred spiral galaxy. 2. The O/H distribution in the transition Magellanic Galaxy NGC 1313. Mon Not R astr Soc, 288:715 & 726, 1997 (A)

RYAN S G (RGO, AAO)

The importance of collision broadening of weak lines in stellar spectra. Astronomy & Astrophysics, 331:1051, 1998 (O)

RYAN S G (RGO, AAO), DELIYANNIS C P (YALE)

Processing of lithium in halo stars cooler than the Spite plateau. III. Observations and abundance analysis. Astrophys. J., 500:398, 1998 (A)

RYANS R S I (BELFAST), DUFTON P L (BELFAST), KEENAN F P (BELFAST), ET AL
LS 4825: a blue supergiant on the far side of the Galaxy. Astrophys. J., 490:267, 1997 (A)

RYDER S D (HAWAII), ALLEN L E (NSW), BURTON M G (NSW), ET AL

Molecular hydrogen line emission from the reflection nebula Parsamyan 18. Mon Not R astr Soc, 294:338, 1998 (A)

SAAR S H (HSCA), BUTLER R P (AAO), MARCY G W (CALIFORNIA)

Magnetic activity-related radial velocity variations in cool stars: first results from the Lick extra-solar planet survey. Astrophys Jnl Letters, 498:L153, 1998 (O)

SCHOLZ R D (POTSDAM), IRWIN M (RGO), ODENKIRCHEN M (BORDEAUX), MEUSINGER H (TAUTENBURG)

New space motion of Galactic globular cluster Palomar 5. Astronomy & Astrophysics, 333:531, 1998 (S)

SCHUECKER P (MUENSTER), OTT H A (MUENSTER), SEITTER W C (MUENSTER), ET AL

The Muenster Redshift Project. III. Observational constraints on the deceleration parameter. Astrophys. J., 496:635, 1998 (S)

SCHWARTZ R D (ST LOUIS), BURTON M G (UNSW), HERRMANN J (ST LOUIS)

Infrared imaging of HH 25/26 and HH 42/128. Astronom Jnl, 114:272, 1997 (A)

SCHWARTZENBERG, PHILLIPPS S (BRISTOL)

Low surface brightness galaxies in different environments. Astrophysics Letters & Com-

munications, 36:279, 1997 (S)

SEALEY K M (UNSW), DRINKWATER M J (UNSW), WEBB J K (UNSW)
Observations of QSO J2233-606 in the Southern Hubble Deep Field. *Astrophys. J.*, 499:L135, 1998 (S)

SERJEANT S (ICL), RAWLINGS S (OXFORD), MADDOX S J (RGO), ET AL
The radio-optical correlation in steep-spectrum quasars. *Mon Not R astr Soc*, 294:494, 1998 (S)

SEVENSTER M N (LEIDEN), CHAPMAN J M (AAO, ATNF), HABING H J (LEIDEN), ET AL
The ATCA/VLA OH 1612 MHz survey. II. Observations of the Galactic disk region. *Astronomy & Astrophysics Supplement*, 124:509, 1997 (O)

SHAHBAZ T (OXFORD), CASARES J (IAC), CHARLES P A (OXFORD)
The rotation speed of the companion star in Aquila X-1. *Astronomy & Astrophysics*, 326:L5, 1997 (A)

SHAHBAZ T (OXFORD), LIVIO M (STSI), SOUTHWELL K A (OXFORD), CHARLES P A (OXFORD)
T Pyxidis: the first short-period cataclysmic variable with a collimated jet. *Astrophys. J.* 484:L59, 1997 (A)

SHOPBELL P L (CALIFORNIA), BLAND-HAWTHORN J (AAO)
FPTOOL: a GUI for the analysis of Fabry-Perot data in IRAF. *ASP Conf series vol.101: Astronomical data analysis software and systems V*, p.116, 1996

SHOPBELL P L (RICE), BLAND-HAWTHORN J (AAO)
The asymmetric wind in M82. *Astrophys. J.* 493:129, 1998 (O)

SHORT C I (ARMAGH), DOYLE J G (ARMAGH)
Pa-beta as a chromospheric diagnostic in M dwarfs. *Astronomy & Astrophysics*, 331:L5, 1998 (A)

SMARTT S J (BELFAST), DUFTON P L (BELFAST), LENNON D J (MPA)
Metallicities of 4 blue supergiants near the Galactic centre. *Astronomy & Astrophysics*, 326:763, 1997 (A)

SMITH C H (ADFA), MOORE T J T (ADFA), AITKEN D K (ADFA), FUJIYOSHI T (ADFA)
NIMPOL: an imaging polarimeter for the mid-infrared. *Publ Astron Soc Australia*, 14:179, 1997 (A)

SMITH L J (UCL), STROUD M P (UCL), ESTEBAN C (IAC), VILCHEZ J M (IAC)
The AG Carinae nebula: abundant evidence for a red supergiant progenitor? *Mon Not R astr Soc*, 290:265, 1997 (A)

SMITH R J (CAMBRIDGE), BOYLE B J (AAO), SHANKS T (DURHAM), ET AL
Input catalogue for the 2dF QSO redshift survey. *IAU Symposium 179: New horizons from multi-wavelength sky surveys*:348, 1998 (S)

SMITH R J, HUDSON M J, LUCEY J R, SCHLEGEL D J, DAVIES R L (DURHAM),
BAGGLEY G

Streaming motions of Abell clusters within 12000 km/s. Proc. ESO-VLT Workshop:
Galaxy scaling relations, p.296, Springer-Verlag, 1998 (A)

SORIA R (MSSSO), WICKRAMASINGHE D T (ANU), HUNSTEAD R W (SYDNEY),
WU K (SYDNEY)

Measuring the motion of the black hole in GRO J1655-40. Astrophys Jnl Letters,
495:L95, 1998 (A)

STEVENS J B (SOUTHAMPTON), REIG P (SOUTHAMPTON), COE M J (SOUTH-
AMPTON), ET AL

Multiwavelength observations of the Be/X-ray binary 4U 1145-619. Mon Not R astr Soc,
288:988, 1997 (A)

TAYLOR K (AAO), CANNON R D (AAO), PARKER Q A (AAO)

The AAT's 2-degrees field project. IAU Symposium 179: New horizons from multi-wave-
length sky surveys: 135, 1998 (A)

TERNDRUP D M (OHIO), POPOWSKI P (OHIO), GOULD A (OHIO), ET AL

The proper motion of NGC 6522 in Baade's Window. Astronom Jnl, 115:1476, 1998 (A)

TINNEY C G (AAO)

The intermediate age brown dwarf LP 944-20. Mon Not R astr Soc, 296:L42, 1998 (O)

TINNEY C G (AAO)

The kinematics of the lowest mass stars. ASP Conf series vol.134: Brown Dwarfs and
Extrasolar Planets, p.75, 1998 (O)

TINNEY C G (AAO), DELFOSSE X (GRENOBLE), FORVEILLE T (GRENOBLE)

DENIS-P J1228.2-1547 - A new benchmark brown dwarf. Astrophys Jnl Letters,
490:L95, 1997 (A)

TOTTEN E J (BELFAST), IRWIN M J (RGO)

The APM survey for cool carbon stars in the galactic halo - 1. Mon Not R astr Soc,
294:1, 1998 (S)

UNAVANE M (CAMBRIDGE), GILMORE G (CAMBRIDGE), EPCHEIN N (PARIS), ET
AL

The inner Galaxy resolved at IJK using DENIS data. Mon Not R astr Soc, 295:119, 1998
(S)

UNRUH Y C (VIENNA), CAMERON A C (ST ANDREWS)

Does chromospheric emission mimic polar starspots in Doppler images? Mon Not R
astr Soc, 290:L37, 1997 (A)

VAN LOON J T (ESO), ZIJLSTRA A A (ESO), WHITELOCK P A (SAAO), ET AL

Obscured Asymptotic Giant Branch stars in the Magellanic Clouds IV. Carbon stars and
OH/IR stars. Astronomy & Astrophysics, 329:169, 1997 (O)

VETTOLANI G (BOLOGNA), ZUCCA E (BOLOGNA), MERIGHI R (BOLOGNA), ET AL
The ESO Slice Project (ESP) galaxy redshift survey: III. The sample. *Astronomy & Astrophysics Supplement*, 130:323, 1998 (S)

VILLAR-MARTIN M (SHEFFIELD), TADHUNTER C (SHEFFIELD), MORGANTI R (ATNF), ET AL
PKS 1932-464: a jet-cloud interaction in a radio galaxy? *Astronomy & Astrophysics*, 332:479, 1998 (A)

WAKAMATSU K (GIFU), MALKAN M (UCLA), PARKER Q A (AAO), KAROJI H (TOKYO)
A redshift survey of obscured galaxies. *Wide-field spectroscopy*, p.345, Kluwer, 1997 (S)

WALBORN N R (STSI), BLADES J C (STSI)
Spectral classification of the 30 Doradus stellar populations. *Astrophys Jnl Suppl*, 112:457, 1997 (A)

WEIL M L (OXFORD), BLAND-HAWTHORN J (AAO), MALIN D F (AAO)
Diffuse stellar light at 100 kpc scales in M87. *Astrophys. J.* 490:664, 1997 (S)

WEIL M L (OXFORD), BLAND-HAWTHORN J (AAO), MALIN D F (AAO)
Diffuse stellar light at 100 kpc scales in M87. *Astrophys. J.* 490:664, 1997 (S)

WILKING B A (ST LOUIS), MCCAUGHREAN M J (MPIR), BURTON M G (UNSW), ET AL
Deep infrared imaging of the R Coronae Australis cloud core. *Astronom Jnl*, 114:2029, 1997 (A)

WOODGATE B E, FRANCIS P J (MSSSO), DANKS A C
High redshift galaxies already old? The ultraviolet universe at low and high redshift: probing the process of galaxy evolution, p.297, AIP, 1997, (A)

YOSHII Y (TOKYO), KAJINO T (TOKYO), RYAN S G (AAO)
Evolution of the light elements and the cosmic ray flux in the Galaxy. *Astrophys Jnl*, 485:605, 1997 (O)

YOUNG C K (BEIJING), CURRIE M J (RAL)
The "Virgo photometry catalogue", a catalogue of 1180 galaxies in the direction of the Virgo Cluster's core. *Astronomy & Astrophysics Supplement*, 127:367, 1998 (S)

YOUNG C K (BEIJING), CURRIE M J (ROE)
Distance indicators based on the luminosity-profile shapes of early-type galaxies - a reply. *Astronomy & Astrophysics*, 333:795, 1998 (S)

YOUNG S (HERTFORDSHIRE), HOUGH J H (HERTFORDSHIRE), AXON D J (STSI), BAILEY J A (AAO)
Beaming in radio-quiet AGN. ASP Conf series 121, IAU Coll.163: Accretion phenomena and related outflows, p.837, 1997 (A)

Popular articles by AAO staff

BOYLE B J (AAO)

Hubble's deep southern view. Sky and Space, vol.10 no.4, p.24, 1997

LEE S (AAO)

Technical tips (The best colour filter for your refractor? - a colourful alternative...). Sky & Space, vol.10 no.4:56, 1997

MARCY G (SAN FRANCISCO), BUTLER R P (AAO)

New worlds: the diversity of planetary systems. Sky & Telescope, v95 n3:30,

1998MARCY G (SAN FRANCISCO), BUTLER R P (AAO)

New worlds: the diversity of planetary systems. Sky & Telescope, v95 n3:30,

1998MASSEY S (AAO)

Luna-Cam (Technical tips). Sky and Space, vol.10 no.3, p.55, 1997

REES M,...MALIN D (AAO),...WATSON F (AAO)

Happy birthday Patrick... Astronomy & Space, March 1998, p.22

VEILLEUX S, CECIL G, BLAND-HAWTHORN J (AAO)

Colossal galactic explosions. Scientific American Presents, v.9 n.1, p.74, 1998

WATSON F G (AAO)

Reflections on comet Hale-Bopp's New Year spectacular. Sky & Space, vol.11 no.2:57

WATSON F (AAO)

Reflections...on joining the 8-metre club. Sky & Space, vol.11 no.3:57, 1998

