RESEARCH SCHOOL OF ASTRONOMY & ASTROPHYSICS

ANNUAL REPORT
1999

The Institute of Advanced Studies
The Australian National University

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Institute of Advanced Studies
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Front Cover:
This image by Dr Matthew Colless shows the effect of the mass distribution of galaxies in distorting the large-scale structure of space.

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RESEARCH SCHOOL OF ASTRONOMY & ASTROPHYSICS

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SCIENTIFIC HIGHLIGHTS

THE HUBBLE CONSTANT

Seventy five years ago, when the Observatory was established at Mount Stromlo, the standard model of the Universe, the expanding Universe, was in its infancy. Yet in the 20th century that model has been as important a development as the Copernican model was in the 16th century, and as important for our knowledge of our place in the Universe too. Most of us are very comfortable with the Copernican system. Indeed, our children laugh at us when we use a figure of speech and say that the sun rises in the east and sets in the west. However, we are not so comfortable with the expanding Universe. We should be, because it is a simple model, and it was the major discovery of 20th century astronomy.

Hubble's evidence for the expanding Universe was a basic graph of the recession velocity of galaxies (how fast they are travelling away from us) versus his estimates of their distances. It was presented to the U.S. National Academy of Sciences in 1929. Through a noisier distribution of points than the current data, he was bold enough to pass a straight line. Astronomers have never lacked this boldness. Recession velocity increased linearly with distance from the observer. Uniform expansion of the Universe is the only model compatible with these observations.

The velocities on Hubble's graph presented no great measurement difficulty, and they present even less difficulty to us today. We are very familiar with the concept of redshift through the operation of police radar. The returned radar pulse from the moving vehicle is of longer wavelength than the emitted pulse, and the velocity of the vehicle is readily calculated.

Distances, however, were, and are, difficult to measure in the Universe. The closest stars to the Sun can actually be triangulated using the baseline of the earth-sun distance. But typical distances of stars within our own Galaxy, the Milky Way, are at the limit of what we can measure by this technique. We needed more resolution, and that was provided by the Hubble Space Telescope. Measuring galaxy distances with HST was designated a Key Project for the telescope in 1984. Specifically, the goal was an accuracy in the slope of Hubble's Law, which is known as the Hubble Constant, of 10%.

To measure distances of galaxies, Hubble and others before him and since used the method of standard candles. Cepheid variable stars are good standard candles. A Cepheid which varies in brightness with a certain period, say 20 days, has a fixed power output, like a 100 watt light globe. If we measure how bright such a star appears in a distant galaxy, we are able to measure the distance of that galaxy. If a 20 day Cepheid appears 100,000 times (10^5) fainter in the Virgo galaxy M100 than it is in the Large Magellanic Cloud, our nearest galaxy, then M100 is $10^{2.5}$ times further away than the LMC.

That is how the Hubble Space Telescope Key Project team has measured the value of the Hubble Constant, the ratio of galaxies' recession velocities to their distances. The velocities were known; the distances have been measured by finding Cepheids in galaxies to the limit of HST's resolution, which is ten times what can be achieved from the ground. Perhaps one should say *could* be achieved, because the Gemini telescope opened this year has started to out-resolve Hubble in the infrared.

Measuring Cepheid distances is not the end of the story in the Key Project, however. They only take us to roughly 25 megaparsecs (75 million light years), before one strikes the limit of what HST can do. So Cepheid distances have been used to calibrate four other standard candles which are measureable to much larger distances.

The first of these more powerful standard candles is a dynamical relation for spiral galaxies, called the Tully-Fisher relation. Spiral galaxies, like our own, support themselves against their own gravitational forces by rotation. Larger galaxies rotate faster. A galaxy with a rotation speed of, say, 200 km/sec (similar to the rate the sun is moving around the centre of the Milky Way) is a standard candle. The HST project has told us the total power of this standard candle by measuring the distances of some of them. Henceforward, wherever we see such galaxies, we know their distances. The way the rotation speed of galaxies is measured is from the 21 cm emission line of hydrogen gas, which is abundant in galaxies. The Tully Fisher relation, calibrated by Cepheid distances measured with HST, allows one to measure the distance of galaxies up to 150 megaparsecs away, the limit of the Arecibo radio telescope.

A second standard candle, now calibrated in a basically similar way, is the equivalent dynamical relation for elliptical galaxies, which support themselves in their gravitational "well" by the random motions of their stars. Ellipticals have no Cepheid variable stars, and their distances had to be based on association with spiral galaxies in clusters, like the well-known Fornax cluster, the closest big cluster of galaxies in the South.

Supernovae are the third standard candle calibrated by Cepheid distances. These stellar explosions are visible to immense distances across the Universe, as Brian Schmidt of this School showed last year. In this part of the project there has been competition from a second team, but the Key Project team found results from supernovae consistent with the other three standard candles. "Other *three*" standard candles is correct, because we have also calibrated a third standard candle, which is a measurement of the resolvability of elliptical galaxies.

Combining the constraints on the Hubble Constant from these four distance indicators, one obtains a slope for the velocity/distance relation of 71 +/- 6 km/sec/megaparsec. That's the bottom line. Or almost the bottom line. One can ask whether Cepheids are simple standard candles, whose power is dependent on period alone, or whether perhaps Cepheids with chemical composition different from those in the Large Magellanic Cloud might have slightly different luminosities. There is a hint that there is such an effect, a weak one, which should be corrected for. When that is done, H_0 = 68 +/- 6 km/sec/Mpc is the result.

Of course, what people are more interested in than the expansion rate of the Universe is the age of the Universe. To know that, we have to know the history of the expansion. If we make the simplest of all assumptions about the expansion, that it has always proceeded at the rate we observe today, then 14.3 billion years (+/- 10%) have elapsed since the Big Bang.

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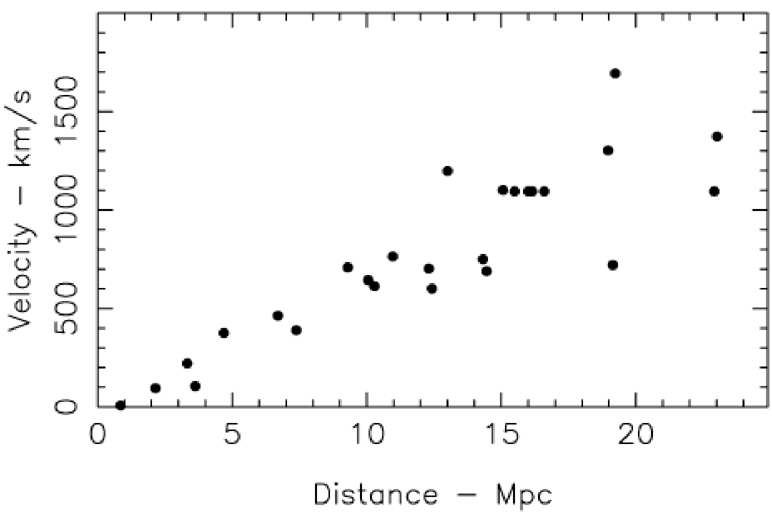
But there are other assumptions that we could make instead. One is that the expansion is decelerating due to the gravitational attraction of the galaxies. The most elegant of these models supposes that the expansion will come to a dead stop if we wait an infinite time. This is the Einstein de Sitter Universe. Another is that the Universe is accelerating. Observations of distant supernovae suggest this. We could call this model the Schmidt Perlmutter model after the astronomers who have led this supernova research.

One alternative is to make none of these assumptions, but to find the age of the Universe another way. The ages of the oldest stars in the Milky Way have been measured to 10% accuracy. Australian astronomers have been very prominent in this line of research too, thanks to an effort begun in the 1970s by Dr. Don Faulker of the RSAA. If we multiply the Hubble Constant, which has dimensions of reciprocal time, by the age of the oldest stars, we get a dimensionless number (1.0 +/- 0.3 with 95% confidence), which is a guide to the correct model of the Universe. The Einstein de Sitter model predicts that that number should be two-thirds. The Schmidt Perlmutter model, if that is what we are going to call it, comes out about right. Of course, this work has to be sharpened up. More accurate distances and more accurate ages are needed. We can expect these in the next decade from space missions currently being planned.

The Hubble Space Telescope Key Project on the Extragalactic Distance Scale has been a 10 year team project supported by NASA's Space Telescope Science Institute. Partial support for Jeremy Mould's participation at the ANU as one of the co-Principal Investigators was provided by the International Science & Technology program of DISR.



The recession velocities of each of the galaxies studied in the Hubble Space Telescope Key Project is plotted against its distance measured using Cepheid variable stars. The Hubble Constant is the slope of the velocity-distance relation. Using secondary distance indicators Mould and collaborators, extended their measurements beyond 100 Mpc, where the noise in the Hubble flow, which is visible in this graph, is negligible relative to the overall expansion.

THE SECOND CORAL SEA COSMOLOGY CONFERENCE, DUNK ISLAND, QUEENSLAND]

The 'Coral Sea Cosmology Conferences' are an occasional series of small international meetings on cosmology-related topics sponsored by RSAA. The first meeting was held on Heron Island in 1995, on the topic "Peculiar Velocities in the Universe". The second meeting in the series was held on Dunk Island from 24 to 28 August 1999, with 33 participants (6 from RSAA, 8 from other Australian institutions, and 19 from overseas) invited to discuss "Redshift Surveys and Cosmology".

The meeting was motivated by the massive new redshift surveys that are currently mapping the local Universe in unprecedented detail, and by the advent of the large 8-metre telescopes which are opening up the distant, early Universe to similar study. Highlights of the meeting included nine presentations based on early results from the 2dF Galaxy and QSO Redshift Surveys, marking the impact these major programs are having on the study of large-scale structure and the galaxy population. Other major international surveys, such as the Sloan Digital Sky Survey, the 2-Micron All-Sky Survey and the HI Parkes All-Sky Survey, were also represented. Exciting results were also reported from studies of galaxies at early epochs in the history of the Universe, particularly those using 8-metre class telescopes and the new technology of submillimetre imaging. The conference concluded with a look to the future, including the development of powerful new observing techniques for redshift surveys of faint objects and the extraordinary potential of the Next Generation Space Telescope. A detailed summary of the meeting will appear in Publications of the Astronomical Society of Australia http:www.atnf.csiro.au/pasa/ or http://www.mso.anu.edu.au/DunkIsland/

SCIENCE WITH THE WIDE FIELD IMAGER WORKSHOP

The Wide Field Imager (WFI) is a new CCD mosaic camera being developed by the RSAA for use on either the ANU 1m telescope or on the 3.9m Anglo-Australian Telescope at Siding Spring Observatory. WFI will image much larger areas of sky than is possible with the single CCD cameras currently available on these telescopes. Consequently, WFI will permit a whole new class of imaging science programs to be carried out with both these telescopes. The particular scientific opportunities WFI will generate were the subject of a 1.5 day workshop held in October 1999 at Mt Stromlo Observatory. The workshop was organized by Da Costa, RSAA WFI Project Scientist, together with Dr. C. Tinney (AAO) and Dr. M. Drinkwater (UMelb). A total of approximately 25 astronomers and students attended with workshop participants coming not only from the RSAA but also from the Anglo-Australian Observatory and from the Universities of Melbourne, New South Wales and Sydney. Two astronomers

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from the United Kingdom also took part and they discussed UK imaging survey plans. The workshop featured descriptions of WFI's capabilities on both the 1m and Anglo-Australian telescopes and key speakers reviewed the prospects for progress in selected scientific areas with WFI. The workshop culminated in the formation of a WFI Survey Working Group whose role is to foster the development of bi-national (Australia and UK) imaging science survey programs for the Wide Field Imager on the AAT.

AUSTRALIAN GEMINI OFFICE

The International Gemini Project is a multi-national partnership to build and operate two telescopes whose primary mirrors are approximately 8.5m in diameter. This makes them amongst the largest single-primary-mirror telescopes in the world. One telescope (Gemini-N) is sited at Mauna Kea Observatory in Hawaii while the other (Gemini-S) is located on Cerro Pachon in Chile. Australia is a 4.76% share partner in the International Gemini Project (the other partners are the USA, the UK, Canada, Chile, Argentina and Brazil) and this participation provides the only guaranteed access to telescopes of this class that Australian astronomers have. Oversight of Australia's participation in Gemini is provided by a Steering Committee and a Science Advisory Committee, both of which have members drawn from Australian astronomical institutions, including the RSAA. The "day-to-day" interaction between the Australian astronomical community and Gemini, however, occurs through the Australian Gemini Office, which is hosted by the RSAA, and through the Australian Gemini Scientist, Dr. Gary S. Da Costa of the RSAA. Da Costa is the Australian representative on the Gemini Science Committee, the Gemini Instrument Forum and is currently Chair of the Committee of Gemini Offices. During 1999 the RSAA funded the operation of the Australian Gemini Office whose activities included the creation of a local (i.e. Australian) mirror of the Gemini web site for rapid community access to relevant Gemini information and the generation of local publicity for the dedication of the Gemini-N telescope.

The year 2000 will be a significant one for the Gemini Project and astronomers in the partner countries as it will see the commencement of science operations on the Gemini-N telescope (science operations on Gemini-S will commence in 2001). The Australian Gemini Office will be responsible for handling Australian proposals for Gemini telescope time, for interacting with the Australian Time Allocation Committee and for conveying the successful proposals to Gemini. It will also be responsible for handling all proposal related enquiries from the Australian astronomy community and for supporting related software tools such as the Phase-I proposal tool, integration time calculators and the Phase-II observing tool. In recognition of these enhanced activities, the ARC recently awarded to the RSAA, in conjunction with USyd and UNSW, $90,000 under the RIEF program to support the operation of the Australian Gemini Office at the RSAA in 2000.

ASSOCIATION OF UNIVERSITIES FOR RESEARCH IN ASTRONOMY

AURA is a consortium of "educational and other non-profit institutions" to operate world-class astronomical observatories that we term "AURA Centres". AURA's members are 29 US universities and 5 international affiliates. AURA views itself as acting on behalf of the science communities that are served by its centres, and as trustee and advocate for the centres' missions.

AURA was founded in 1957, with the encouragement of the National Science Foundation (NSF), by a group of US universities with a common interest, to create astronomical observing facilities that would be available for use by all qualified researchers from US institutions on the basis of scientific merit. Over the years, the founding group was joined by other US and international universities, and other educational and non-profit institutions with similar goals.

Under cooperative agreements with the National Science Foundation, AURA operates the National Optical Astronomy Observatories (NOAO), including nighttime and solar facilities and the Gemini Observatory. NOAO operates ground-based observatories for nighttime astronomy at Kitt Peak National Observatory near Tucson, Arizona and at Cerro Tololo Inter-American Observatory near La Serena, Chile. The National Solar Observatory conducts solar research at Sacramento Peak in New Mexico and at Kitt Peak.

Gemini is a joint project among the United States, the United Kingdom, Canada, Australia, Chile, Brazil and Argentina to provide two 8-metre telescopes – the first in Hawaii on Mauna Kea, and the second in Chile on Cerro Pachon. AURA is the managing organisation under the auspices of the International Gemini Board and the NSF as executive agency.

Under contract with NASA, AURA operates the Space Telescope Science Institute (STScI). It carries out the scientific mission and operations of the Hubble Space Telescope – the most powerful optical/ultraviolet observatory in space. From Baltimore, Maryland, STScI serves astronomers everywhere who observe the Universe with Hubble. In 1998, NASA assigned the scientific mission and development for the Next Generation Space Telescope to STScI.

In 1999 the Australian National University joined AURA as an international affiliate and the Vice-Chancellor appointed Professor Mould as the ANU member of the Board of Member Representatives.

AURA's vision is: To learn all we can about the Universe and to share knowledge and insights with colleagues and lay audiences.

AURA's mission is: To advance astronomy and related sciences, to articulate policy and respond to the priorities of the astronomical community, and to enhance the public understanding of science. AURA shall develop and operate national and international centres that enable merit-based research by members of the astronomical community.
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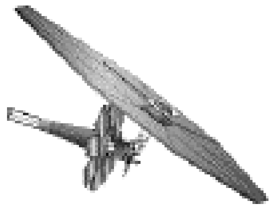
AURA's goals are: To excel in providing research opportunities at world-class facilities and to grant access based on the scientific merits of proposed work.



Artists concept of the Next Generation Space Telescope. The NGST will deploy a large sunshade and ultra-lightweight 8-metre diameter mirror on its three-month journey to a Sun-centred orbit (L2) about 1.5 million kilometres from Earth. The sunshade shields the telescope, cooled to deep space temperatures (30-50K), from the bright light and heat of the Sun, Earth and Moon.

OTHER HIGHLIGHTS

75TH ANNIVERSARY OF MOUNT STROMLO OBSERVATORY

Canberra was in its infancy in 1924 when the Commonwealth Solar Observatory was established on Mount Stromlo. For the first three years the Observatory's administrative offices were situated in the Hotel Canberra on Commonwealth Avenue. It was fitting, therefore, that the gala ball for the 75th anniversary was held at the Hyatt Hotel Canberra with its splendid period décor, and doubly fitting that the Australian National University announced the establishment of the Duffield Chair of Astronomy to commemorate Mount Stromlo Observatory's founding director, Professor W. Geoffrey Duffield. The Chair is a gift from his daughter, Miss Joan Duffield, to the ANU Endowment for Excellence. In thanking Miss Duffield, Pro-Vice-Chancellor Robin Stanton drew attention to the University's plans for increasing self-reliance and the ability that endowed chairs conferred on Schools and Faculties to retain the nation's top research academics.

The gala ball on November 12 was also a fundraising event for the Stromlo Exploratory. Master-of-Ceremonies John Doyle auctioned a number of desirable packages, such as the Warrumbungles Weekend at Siding Spring Observatory and Qantas's generous gift, a trip for two to New Zealand, in his inimitable way, making the anniversary celebration memorable for at least the next 75 years.

The second event in the anniversary commemoration was a visit by the Minister for Industry, Science & Resources, Senator Nick Minchin. The senator opened a special exhibition at the Stromlo Exploratory, *Astronomy and Innovation*. In congratulating Stromlo on its anniversary, the Minister spoke of the importance of innovation to the nation and of the special role of scientists in stimulating the culture of innovation. Two companies with their roots in Mount Stromlo Observatory, Electro Optic Systems and Auspace, exhibited their work alongside the School's instrumentation section.

Media coverage of the School's origins and anniversary included a photo-opportunity at the first Commonwealth building, the Oddie telescope, and discussion in radio and television interviews of the Observatory's landmark discoveries. The University's Public Affairs Division and our 75th Anniversary Committee deserve the School's thanks for hard work well done.

Further reading: *A pictorial history of Mount Stromlo Observatory* by Dr. Don Faulkner, available at *Star Wares,* the Stromlo Exploratory.

INAUGURAL MT. STROMLO ASTRONOMY SUMMER SCHOOL

The inaugural Mt Stromlo Astronomy Summer School participants outside the Duffield Build, Mt Stromlo

From December 12 - 17, 1999, the Research School of Astronomy and Astrophysics and the Stromlo Exploratory were host to 16 year 10 students who were participants in the inaugural Mt. Stromlo Astronomy Summer School. This School was funded by a grant from Perpetual Trustees and the students (8 boys and 8 girls) were selected nationally on the basis of their written applications and references from their teachers. The convenor of the School was Geoff Bicknell who was ably assisted by RSAA administrative staff Gay Kennedy, Ian Sharpe and Denise Bourne.

The students were treated to a varied and stimulating program. At the beginning of the School, the students were officially welcomed by the Director and the Vice-Chancellor. The formal part of the program included lectures from RSAA astrophysicists on *Making*

Maps and Exploring the Universe (Mathew Colless), *Hubble Space - the Final Frontier* (Mike Dopita), *The Big Bang and our Expanding Universe* (Jeremy Mould), *Colour in Astronomy* (Ralph Sutherland), *The Life, Birth and Death of Stars* (Don Faulkner), and *Crash - Bang Whoosh: Black Holes and Jets* (Carole Jackson).

In planning for this School, we were intent on encouraging students to actually participate in astronomy, so that we organised a series of three nights observing on the 74 inch telescope. This was probably the most popular and eagerly anticipated part of the Summer School program and fortunately we enjoyed good weather for two of the nights. Students formulated their own projects in consultation with Brian Schmidt, Robert Smith and Geoff Bicknell. Robert led the observing sessions, assisted by Michelle Buxton and Marc Metchnik and reduced the data for the students. One group undertook to determine the heights of mountains on the moon from the shadows they cast; another group made colour images of a well known Seyfert galaxy NGC 1365; a third group made colour images of the Horsehead Nebula in Orion and a fourth group made a light curve of an eclipsing Cataclysmic Variable and determined some of the parameters of the system. The teacher assisting the school, Ms Helen Baldry, from Merici College, also took on a project to produce a colour magnitude diagram of the globular cluster 47 Tucanae. All of these groups gave presentations on their projects at the conclusion of the School. It is apposite to note that this observational portion of the program would not have been successful had it not been for the expertise and dedication of Robert Smith. We were also grateful to Ms Baldry for her professional assistance in managing the students in their various activities and for supervising their stay at Burgmann College.

While the 74 inch observing was in progress, Geoff Bicknell conducted astrophotography sessions, and Carole Jackson and her husband Paul Akhurst used a six inch Newtonian telescope to show students the delights of planets, binary stars, star clusters, the Orion nebula and so on. These evenings were good fun and contributed to the camaraderie of the School as did the barbecue on the first evening and the excellent catering of the Red Belly Black Café.

Ralph Sutherland's lecture on Colour in Astronomy was put into practice by all of the students, who used Macintosh computers, loaned to us by the Teaching and Learning Technology Support Unit of the ANU, to assemble colour images from monochrome images made through various filters. Some of the students, of course, used these techniques in their projects. During the time the students were working on their projects they were assisted by a number of astronomers (including Michelle Buxton, Carole Jackson, Marc Metchnik and Ralph Sutherland) who circulated amongst the group, providing advice and discussing astronomy.

There were two tours during the week: the first to the Deep Space Communications Complex at Tidbinbilla and the second to the Molonglo Observatory Synthesis Telescope. In the Tidbinbilla visit, the students came to appreciate the nature of planetary exploration and radio astronomy. At Molonglo, Duncan Campbell-Wilson gave a comprehensive presentation incorporating aperture synthesis and image-making in radio astronomy, talked about some of the research programs at Molonglo and even "turned on" a pulsar for us. Both of these visits were appreciated by the students and exposed them to different aspects of astronomy.

On the fourth day of the school, Paul Francis led the students in a role-playing exercise to determine the nature of a mystery object that had been “observed” by astronomers in the US. This was one of the highlights of the week and Paul had the students in a state of excitement as they converged on the answer, a 10^5 solar mass black hole in a binary orbit in the Galactic halo.

In order to assess objectively the outcome of this school, Ms Anne Paul, from the ACT Department of Education, conducted exit interviews on the last day. The overwhelming conclusion from these interviews, which reinforced the informal comments received during the week, was that the School had been a great success. We have also received feedback from a number of parents who have told us that their children have “not stopped talking about the school” since returning home.

The success of this School was due in part to the variety of expertise and scientific knowledge that one can call upon in the RSAA and the varied program which the organising committee was consequently able to assemble. It was also due to the students being able to interact with other students of similar abilities and interests. One of the stated objectives was to interest top-level students in Science as a career. There seems to be no doubt that we reinforced the view of the participants that Science presents an interesting and rewarding career path. A number of the students have expressed interest in applying for the National Undergraduate Scholarships that were mentioned by the Vice-Chancellor at the beginning of the week. Those of us directly involved in the School enjoyed the opportunity of working with an exceptional group of very bright, enthusiastic and motivated students.

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DIRECTOR'S VIEW

In Mount Stromlo Observatory's seventy-fifth year we can and should celebrate its uniqueness as an astronomical institution. Stromlo is the Research School's astronomy campus. Like all campuses it is a meeting place. Interacting in the one location, one finds a research institute, a telescope sampling the dark matter in the Galaxy, an instrumentation engineering laboratory, a graduate program, a visitor centre, and on-campus residences. From California to Cambridge to Chile, there is nowhere which can boast more than two-thirds of these facilities. No wonder visitors consider Stromlo a little piece of paradise.

Each of these facilities, and especially the superb remote observatory at Siding Spring, plays its role in supporting the primary element of the School's mission within the ANU, to add to our knowledge about and understanding of the Universe. Each of the facilities is resourced leanly by the block grant from the Institute of Advanced Studies, with the exception of the visitor centre and residential areas, which are self-supporting. The 1995 review of the IAS found that in its fifty year history and in all its serious fields of endeavour, it had achieved international prominence. At the end of 75 years Mount Stromlo Observatory is a model for the IAS in sustaining international competitiveness.

What is the institution's secret? And what values, therefore, are the most important to retain, when everything is changing more rapidly than ever before? In common with other top academic institutions, challengingly high expectations of all members are a key part of the IAS ethos. Where else in Australian academia do you find students treated as postdocs, postdocs treated as faculty, faculty treated as research group leaders, and directors empowered to set the direction of the University? Maximising the responsibility we put in the researchers' hands is a winning strategy, but it is a course which sails very close to the strong winds of accountability that we feel in the present climate. It must be demonstrated excellent performance that sustains a School which continues to plot this course. The 1999 year has been a strong one from this perspective.

SOURCES OF REVENUE

Sources of revenue	**1997**	**1998**	**1999**
IAS block grant	5431	5276	5210
External funds	987	676	806
Ancillary activities	820	796	1027

NATIONAL FACILITIES

Number of Nights Allocated for External or Collaborative Use on MSSSO Telescopes During 1999

	2.3m		**74”**		**40”**		**24”**	
Overseas users	13	59	136	79	111	84	36	27
UNS universities	55	10	36	16	22	9		
AAO/CSIRO		6		11		7		
Other							10	
Total nights e xternal /collab. use	**143**		**278**		**233**		**73**	

The first entry of each pair is the number of nights allocated entirely for external use; the second is the number of nights allocated for collaborative projects involving MSSSO and external researchers.
AAO = Anglo-Australian Observatory.
The 24" is scheduled less regularly than the larger telescopes.

POSTDOCTORAL MOVEMENTS

Dr Brad Gibson and Dr David Bersier left us for Colorado and Chile respectively. Dr Carole Jackson and Dr Roger Fux joined the School. The number of women academic staff was unchanged over the course of the year.

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OBITUARY

Dr CHARLENE HEISLER (1961-1999)

Charlene Heisler was a very special person who touched the lives of all those around her in a very deep way. Although her life was not very long, she had far more influence on those around her than most people attain in a full lifetime.

When Charlene Heisler was about to embark on her PhD in astronomy, her doctor advised her that since she had cystic fibrosis - an incurable disease - and was unlikely to survive for more than a couple of years, she should abandon any thoughts of doing a PhD and should instead go out and have some fun. Well, Charlene did go out and have fun - she did her PhD! For her, what could be more fun than the excitement of probing the cores of galaxies and uncovering the secrets of the Universe? Her sense of fun propelled her right through her PhD, which she survived despite the doctors' warnings, and then through a further eight years during which she built a distinguished career as an internationally-renowned astronomer working at some of the world's top observatories.

In her scientific output, Charlene has contributed enormously to our understanding of active galaxies and to why some galaxies have broad-line regions and others don't. But her greatest gift to astronomy was something even rarer than that - her ability to inspire and motivate those around her. Her sheer enjoyment and excitement of astronomy livened up many a long night at the telescope and turned many a boring meeting into a stimulating experience.
She was particularly inspiring as a role model to young female students hesitating on the doorstep of the male-dominated bastions of astronomy. Charlene recounted the tale of when, as a young undergraduate, she had gone into her first physics class at Calgary to find that she was the only female in the room. Coolly, she took her accustomed place in the front row. The professor, seeing this pretty little thing in the front row who had obviously wandered into the wrong lecture, came up to her and said "Ahem, young lady, this is the physics class". Charlene froze him with a glare and said, "Yes, thankyou, I know that", and left him bumbling in confusion and embarrassment.

Thankfully, those days of blatant chauvinism have receded, and yet it is still difficult for a female to make it in the "hard" sciences. Charlene would not bow to those dark forces of chauvinism that still lurk in some corners of our institutions, nor would she adopt the outdated stereotypes that some felt were demanded of a woman in science. Instead, the only role that she ever played was that of herself. She projected her own feelings and beliefs with passion and forcefulness, but above all she projected her sense of fun and vitality. To her, astronomy was fun, and not only fun but also worthwhile, so what better could one do with one's life than that?

After taking her Honours degree at Calgary in 1985, she did her PhD at Yale under the supervision of Patricia Vader. In her PhD thesis, Charlene investigated the properties of galaxies whose spectral energy distributions peaked near 60 microns. These galaxies soon became known informally but internationally as "Charlene's Peakers". These Peakers were strong emission line galaxies with spectroscopic types ranging from starburst to Seyfert, with centrally concentrated H-alpha and radio continuum emission. The central core of her studies was to see what was driving these Peakers, and she concluded in her thesis, and in several papers resulting from it, that the Peakers represented a short-lived phase of nuclear activity, triggered by an interaction.

I first met Charlene at a conference in Santa Cruz in 1988, where she presented her Peaker work. Although she had not yet finished her PhD, she already made a strong impression on the attendees with her lively up-beat style, and her obvious enthusiasm for her subject. Her work overlapped with mine, and so we briefly discussed these galaxies at that meeting. We subsequently ran into each other at various conferences in different parts of globe over the next few years, and our common professional interest gradually turned into a friendship. Eventually, many years later, we became close friends and colleagues.

She finished her PhD in 1991, and took up a postdoctoral position with Mike de Robertis at York University, in which she continued her studies of her beloved Peakers, as well as starting to branch out into other areas. In 1993 Charlene took up a postdoc position at the Anglo-Australian Observatory, and moved to Sydney, Australia, accompanied by her husband, Doug, who selflessly put his legal career in Canada on hold. As well as her continuing studies of her Peaker galaxies, she became one of the support astronomers for IRIS and prime CCD imaging, and became the AAO liaison astronomer with the MPI 3D project. What might have been a chore for others was seized enthusiastically as an opportunity by Charlene, as a result of which she started several collaborations in other, unconnected, areas of astronomy. In 1996 she moved to Mount Stromlo Observatory, Canberra, and in 1998 she was awarded a prestigious Fellowship there.

In 1997 she addressed (with Stuart Lumsden and Jeremy Bailey) her second major area of work, after her Peakers, in what was perhaps her most significant paper. This paper tackled the question of why some Seyfert 2 galaxies have "hidden" broad line regions (HBLR), visible only in polarised light, and others don't. Charlene and her colleagues showed that there is a strong correlation between the existence of a broad line region and the infrared colour and extinction of the galaxy. They then developed a model, consistent with the "Unified model", in which Seyfert 2's with hidden HBLR's were simply those Seyfert galaxies whose symmetry axis was relatively close to the line of sight.

Her last major project started as a result of an animated late-night discussion between Charlene, Phil Appleton, and myself, over whether there was any real evidence to associate AGN activity with starburst activity. This became the COLA (Compact Low-power AGN) project. That heated discussion became one of many over the next couple of years, as we thrashed out the issues and worked out the selection effects and how to overcome them. One of Charlene's greatest assets in these discussions was her intellectual honesty. When one of us had become entranced by an idea of how to solve the problem, and was building up momentum to run with it, perhaps a little too uncritically and enthusiastically, Charlene would suddenly ask the hard question. Will it work? Do we have enough resolution? Do we have enough objects in our sample to give a statistically significant result? It was through such hard-hitting discussions that the project became honed and refined, and eventually took shape. It was just after one of our visits to Chile to take observations for this project that Charlene's illness took a turn for the worse. This was her last observing trip. However, her pivotal contributions to the COLA project still live on, and are still bearing fruit, and a number of papers bearing her name are yet to be published.

Perhaps even more significant than her contributions to science was Charlene's effect on other people. There are a number of young people in science now who would not be there were it not for Charlene's encouragement and guidance. Charlene's first PhD student was Tanya Hill, who is now herself an active force in Australian science communication, and her second was Lisa Kewley, who is now exploring the boundaries between AGN and non-AGN galaxies. To these students and others, Charlene was not just a teacher and mentor, and not at all an authority figure, but she was instead a friend and companion. As one student commented: "she was a wonderful friend, a big sister and an incredible inspiration". In short, she was one of the best role models that a young student could have, and astronomy is much poorer for her passing.

But perhaps that is too negative a view. While it is undoubtedly true that the world is a duller place since Charlene left, we should instead reflect that it is a much richer place than if Charlene had never lived - not just for her students, and other young people she inspired, but also for her professional colleagues. Charlene inspired many of us to do our science better, and at the same time not to lose sight of our inner human selves. Charlene showed us how our relationships with our professional colleagues don't have to be the sterile, formal, caricatures that many feel are demanded in a professional relationship. She showed us that it is possible to do good science, and have fun, and be warm, sincere, human beings - and all at the same time. For that, and for many other things, we will be forever grateful that Charlene entered our lives.

Sadly, despite her indomitable willpower, her disease started taking the upper hand in late 1998. She received a lung transplant in early 1999, which at first looked a success. Two days after the transplant she was on an exercise bike. A few days later she was taking ARC proposals to her hospital bed for refereeing, and a little later was concerned about the summer-student selection that she was supposed to be organising. Within a few weeks of the transplant, she started analysing data from our last spectroscopy run. Most people would take it easy after such an operation, but for Charlene, astronomy was everything, and she was determined to keep going. But, after such a transplant, which we all knew statistically had only a 50% success rate, the narrow path between rejection and infection is strewn with obstacles, and despite an excellent prognosis and all signs of a first-class recovery, in late October she suddenly deteriorated and on 28 October 1999 she passed away.

I’ve been amazed by the number of people from all over the Australian and international astronomical community who have been deeply and genuinely distressed and shocked by Charlene’s passing. She obviously made an enormous impact on all the people around her. She really was a very exceptional person, and we’re all very lucky to have known her. I keep on thinking back to something she once said, to the effect that the doctors didn’t really expect her to live beyond her eighteenth birthday, so everything beyond that was a bonus, and she intended to make the most of it. Well, she certainly did that! And in the process she had an amazing effect on everyone around her - infecting everyone with her vitality and enthusiasm. Many of her colleagues found her vivacious and energetic approach to science spurred them on when their enthusiasm might otherwise have been flagging. It’s quite overwhelming to appreciate the enormous effect she had on people around her. Charlene enriched our lives so much. We loved her dearly and she will always be part of us. Thank you, Charlene.

Ray Norris, Australia Telescope National Facility

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RESEARCH

* not a member of the University
‡ non-RSAA member of the University
# formerly a faculty member

STELLAR ASTROPHYSICS

"Forbidden" Maser Emission from a Dying Star?

Masers are the microwave equivalents of lasers and they arise when infrared photons pump OH molecules to high energy levels from which stimulated microwave emission can be produced. For the OH molecule, the stimulated emission is seen to occur in four lines between 1612 and 1720-MHz. Sevenster and Chapman* have studied a sample of 18 OH maser sources, selected because of some peculiarity of the profile of the OH maser line at 1612-MHz. The objects were observed in all four ground-state OH-maser lines, most notably in the satellite line at 1720 MHz. One object (IRAS 18043-2116), which is likely to be an evolved star in transition from the asymptotic giant branch (AGB) to the planetary nebula stage, showed emission at 1720-MHz (see Figure 1).

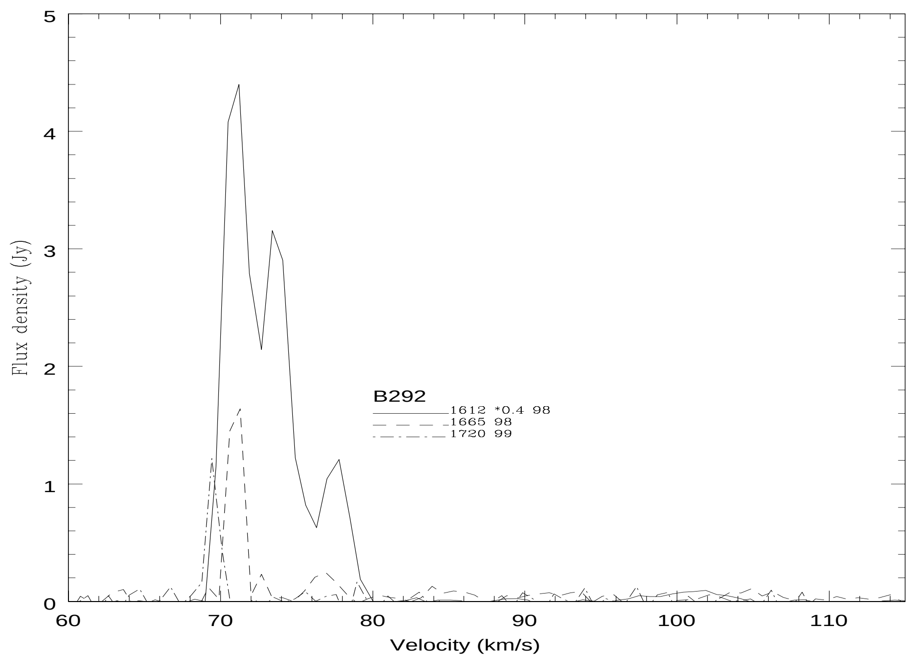

Fig. 1 The spectra of IRAS 18043-2116 at 1612-MHz (flux densities multiplied by 0.4), 1665-MHz and 1720-MHz. The source was not detected in the other main line, at 1667 MHz.

This is the first detection of the 1720-MHz maser in a post-AGB object. Based on theory, it was thought that the right environment could never be created around a post-AGB star for this fairly fussy maser. Consequently, post-AGB stars were never observed at this frequency. However, given the dramatic but poorly understood changes in the circumstellar environment that occur during the transition to the planetary-nebula stage, it is feasible that the right densities, temperatures and excitation mechanisms are provided temporarily for this maser to be switched on. Creation of the correct environment is clearly only very brief since the other 9 post-AGB stars in the total sample of 18 objects were not detected at 1720 MHz.

Evolution of Post-AGB Stars

A most intriguing challenge is to understand how Asymptotic Giant Branch (AGB) stars transform the shells of ejected mass which surround them into the variety of shapes and sizes observed in Planetary Nebulae (PNe). There are a number of theories currently being investigated. In the generalized interacting stellar wind model, a variety of axisymmetric planetary nebula shapes are produced by the interaction of a very fast, spherical central star wind with the circumstellar shell, provided the latter is denser near the equator than the poles. In this model, the fast wind can blow out of the two poles giving an hour-glass shaped nebula. An alternative theory is that the primary agent for shaping PNe is not the density contrast in the circumstellar shell, but a high speed, bipolar, collimated outflow of a few 100 km/s from the central star. In this case, it is the central collimated flow that pushes out bipolar lobes through the circumstellar shell. No consensus about the dominant physical process responsible for the shaping of PNe has emerged so far, but there is agreement that it occurs during the early AGB-to-PN transition stage. Van de Steene, Wood, and van Hoof* have been studying stars in the transition phase in order to try and tie down the shaping process. Using a combination of infrared and optical spectra, they have found evidence for fast stellar winds in a high fraction of transition objects. These winds are required for both shaping mechanisms. Detailed modelling of the spectra are required in order to determine whether the fast winds are collimated or not.

Model Atmospheres of Metal-deficient Dwarf Stars

Bessell has been studying metal-deficient dwarf stars in order to understand the systematic errors in the derivation of temperature and abundances of these stars resulting from inadequacies in current model atmospheres. Such systematic errors will affect the age determination for globular clusters and hence the age of the Galaxy, as well as the relative abundances of some elements that are critical in the understanding of element synthesis. A two pronged approach being used in this research is to obtain high resolution and high S/N spectra plus accurate photometry and to then compare the observations with theoretical model atmosphere computations.

High resolution observations have been completed for 28 Hipparcos subdwarfs using UCLES on the Anglo-Australian Telescope. Hydrogen lines have been measured and compared with theoretical line profiles computed by Castelli*. As a result, new atmospheres with less convection have been found necessary and these have been

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computed using two additional values for the mixing length to pressure scale height, 0 and 0.5 (1.2 is the original and widely adopted value). The intermediate value of 0.5 seems to best fit the Hα, Hβ, Hγ and Hδ profiles although there are still some systematic differences that are being addressed by collaborators O'Mara* and Barklem*.

The Abundance of Lithium in the Most Metal-poor Stars

Norris, with Beers* and Ryan* completed an analysis of the lithium abundances for 23 very metal-poor field main sequence stars, restricted to very narrow effective temperature and metallicity ranges, in an effort to accurately determine the dispersion of abundance at the earliest times, and hence constrain the amount of lithium (Li) which emerged from the Big Bang. Preliminary results were given in the previous annual report, where it was shown that there is very little spread in Li abundance at a given effective temperature. Further analysis of the data shows that Li abundance decreases with decreasing stellar metallicity as may be seen in the figure, which shows Li abundance as a function of overall metal abundance. The slope of the dependence is significant at the 3.3 sigma level. The implication of this result is that to determine the Li abundance which emerged from the Big Bang one must look to the most metal-poor objects.

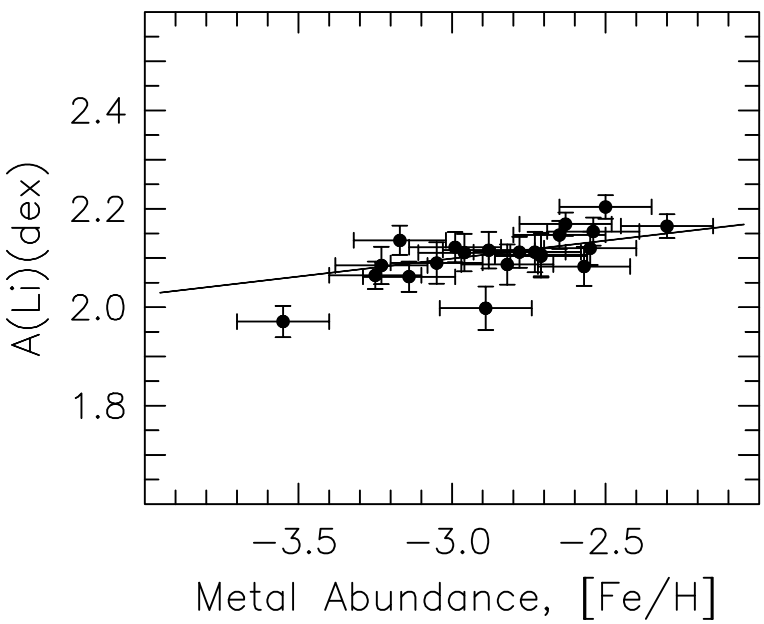


Fig. 2. The abundance of Lithium, A(Li)) (= log(N(Li) /N(H)) + 12.00), as a function of metal abundance [Fe/H], for 23 very metal-poor stars.

Norris, with Beers*, Fields*, Olive* and Ryan* investigated the decreasing trend on Li towards lower metallicity, and argued that the primordial abundance of Li of the Universe can be inferred only after allowing for nucleosynthesis processes which must have been in operation in the early history of the Galaxy. They showed that the observed Li vs Fe trend provides a strong discriminant between alternative models of Galactic Chemical Enrichment of the light elements at early epochs. A critical assessment of the current systematic uncertainties leads to the primordial Li abundance within new, much tighter limits: $(Li/H)_p = 1.23^{+0.68}_{-0.32} \times 10^{-10}$. They showed that the constraint which this places on the density of the Universe is now as much limited by uncertainties in the nuclear cross-sections used in Big Bang Nucleosynthesis calculations, as by the observed abundance itself.

CS 22876-032 – The Most Metal-poor Dwarf

Norris, with Beers* and Ryan* completed high-resolution, high-signal-to-noise, observations and model atmosphere analysis of the extremely metal-poor double-lined spectroscopic binary CS 22876-032, which is currently the most metal-poor dwarf star for which such data are available. The system has a long orbital period: P = 424.7 ±0.6 days. It comprises two main sequence stars having effective temperatures 6300 K and 5600 K, with a ratio of secondary to primary mass of 0.89 ± 0.04. The metallicity of the system is [Fe/H] = -3.71 (1/5000 the metallicity of the sun) ± 0.11 ± 0.12 (random and systematic errors) - somewhat higher than previous estimates. This result strengthens the conclusion that no star is currently known for which the heavy element abundance is less than [Fe/H] = -4.0 (1/10000 the metallicity of the sun).

They find a dependence of magnesium on iron, [Mg/Fe] = 0.50, (Mg/Fe three times its value in the sun) typical of values of less metal poor stars. The results for Si, Ca, and Ti - [Si/Fe], [Ca/Fe], and [Ti/Fe] - however, all have significantly lower values, ~0.0-0.1, (similar to the solar values) suggesting that the heavier elements might have been underproduced relative to Mg in the material from which this object formed. In the context of the hypothesis that the abundance patterns of extremely metal-poor stars are driven by individual enrichment events (pollution by supernovae), the data for CS 22876-032 are consistent with its having been enriched by a zero-metallicity supernova of mass 30 solar masses.

As the most metal-poor near-main-sequence-turnoff star currently known, the primary of the system has the potential to strongly constrain the primordial lithium abundance. The authors find A(Li) (= log (N(Li)/N(H)) + 12.00) = 2.03 ± 0.07, which is consistent with the result reported above that for stars of extremely low metallicity A(Li) is a function of [Fe/H].

A New Type of Stellar Oscillation

While seeking an explanation for oscillations with periods of about 500 days in red giant stars, Wood found a new type of stellar oscillatory mechanism. The oscillations arise because of the interaction of stellar pulsation and convective energy -

transport. The newly-discovered oscillations are unusual because they are purely thermal in origin, whereas oscillations in all other known types of regular, non-eruptive stars are dynamical. This means that acceleration plays no role in the equations of the oscillations. The physical origin of the oscillations is a phase delay in the convective energy transport relative to the change in size of the star as it oscillates. The equations lead to a family of modes analogous to the normal modes in a star (or an organ pipe). A better theory of convection is needed in order to decide with certainty if the newly-discovered thermal oscillations are actually capable of explaining the long-period oscillations observed in some red giant stars.

Studies of Young Star Clusters in the Magellanic Clouds

Star clusters are the natural testing grounds of our theoretical understanding of stellar evolution. It is through the interactive fine-tuning between observations and theory that we arrive at increasingly accurate evolutionary models. One of the most important and actively debated issues in modern stellar evolution is that of the presence of internal mixing within stars of mass 1.5 solar masses and upwards. This internal mixing is thought to arise at the boundary of the convective core - a phenomenon known as convective core overshoot (CCO).

On the theoretical front, discussion of the efficiency of CCO has been addressed by several authors with different results, ranging from negligible to substantial. In the absence of hydrodynamical models the amount of mixing is only weakly constrained by physical arguments. In order to ascertain the correct amount of CCO to apply within stellar evolutionary models we must discern the amount from that displayed in the populations within star clusters. CCO brings about a number of dramatic changes in the evolution of a star, allowing it to live longer and brighter. These changes are displayed in the colours and brightnesses we observe.

Keller, Bessell and Da Costa have targeted four young star clusters in the Magellanic Clouds in which 10-15 solar mass stars are still on the main sequence. It is in this mass range that the effects of CCO are expected to be most pronounced. Galactic clusters of this age tend to be very sparse in numbers and this make it hard to draw together a statistically meaningful sample. However, the young Magellanic Cloud clusters are a factor of 30 more populous and can be used to derive significant results.

The Hubble Space Telescope's WFPC2 camera was used for these observations. There are two important reasons that this camera was essential. Firstly, the HST was needed to provide the spatial resolving power required to image stars in these crowded clusters. From the ground, the Earth's atmosphere does not allow one to resolve the tight central portions of the clusters (see the figure). Secondly, the HST provides access to the ultraviolet which is necessary to obtain an accurate determination of the temperature of the hot stars. Analysis of the HST data has found strong evidence for amounts of CCO in excess of that normally incorporated into standard stellar evolutionary models. In addition, the amount required is a strong function of stellar mass. These results form the basis of ongoing theoretical modelling.

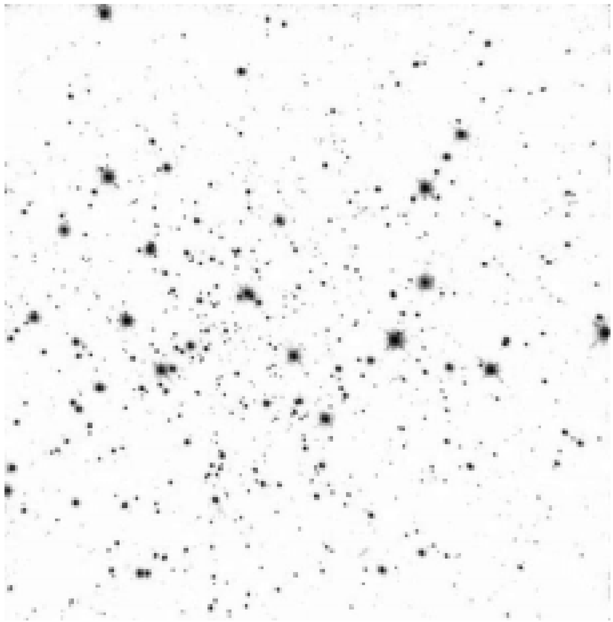


Fig. 3. The image shows the central regions of NGC 2004, a young star cluster in the Large Magellanic Cloud. The image is a composite of three exposures, F160BW (UV), F555W (V) and F656N (Hα). The hot main-sequence stars stand out as blue objects and evolved stars as bright orange and white. A large number of Be stars appear in the image. We do not yet understand why they constitute such a large fraction of the population.

The Nature of Gamma Ray Bursts

Gamma Ray Bursts (GRB's) continue to be an unsolved astronomical puzzle. Now that the optical afterglows have been detected from some GRBs, it is known that they are found at cosmological redshifts, and therefore involve enormous energies. It is also becoming clear that the GRB population is not homogeneous, and that a sub-population is likely associated with peculiar supernovae. More complete understanding will come only from observations at a wide range of wavelengths. These followup observations must be undertaken immediately after the GRB is detected by satellite, with response on timescales of minutes being desirable.

The MSO 50 inch telescope is well suited to this task, offering a nearly unique combination of field-of-view, aperture, southern hemisphere location, and automation. During 1999, Mould, Schmidt, and Axelrod used this system to followup a number of GRBs. Several optical counterparts were detected in the resulting images, with those for burst 990510 providing the earliest observations after the burst. We have strengthened our commitment to this research by joining the REACT collaboration, led by Kulkarni*. Through this, we will improve the followup effort, and have a greater participation in the theoretical development of the field.

Schmidt, Axelrod, Mould, Harrison*, Kulkarni* and Bloom* monitored gamma ray bursts, the most powerful explosions yet discovered, with the MSO 50 inch telescope. In May, the 50 inch provided the second earliest recording of a gamma ray burst. These observations suggest that gamma rays are so bright because they focus their energy into a jet of energy. If this jet is pointed towards an observer, the gamma ray burst appears to have much more energy than if oriented at random.

GALACTIC STRUCTURE

Stellar Streams in the Solar Neighbourhood

The Milky Way is a barred galaxy and the motion of the stars in the solar neighbourhood, seen in the high accuracy data collected by the HIPPARCOS satellite, splits into many distinct streams. A high resolution numerical simulation of the Galaxy has shown that star streaming must be a common feature of barred galaxies (see Figure 4) Star streaming carries valuable information about the Galaxy. For example, the stars in the stream indicated by the arrow must have spent a considerable time trapped inside the bar region which is roughly halfway between us and the galactic centre.

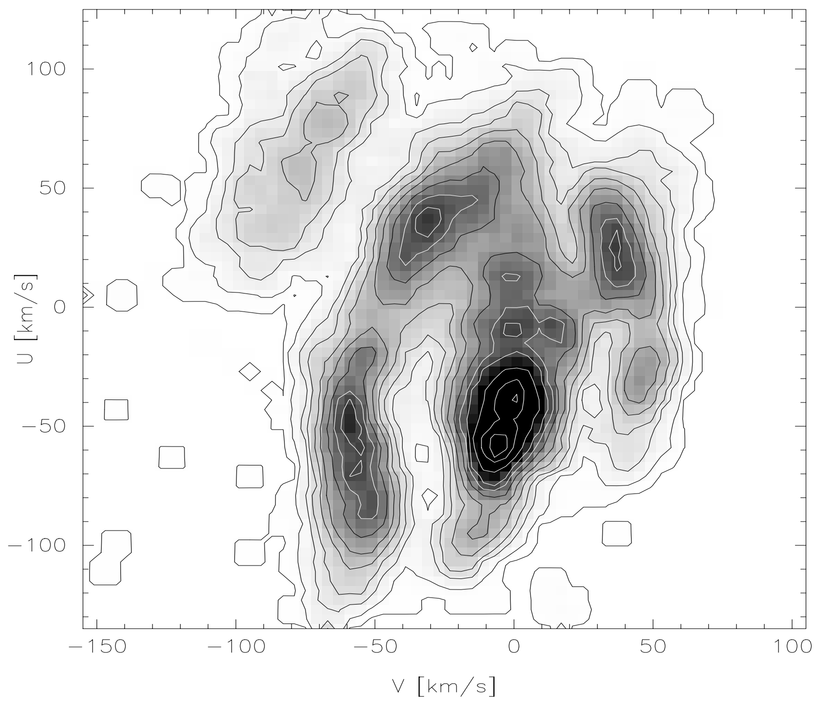
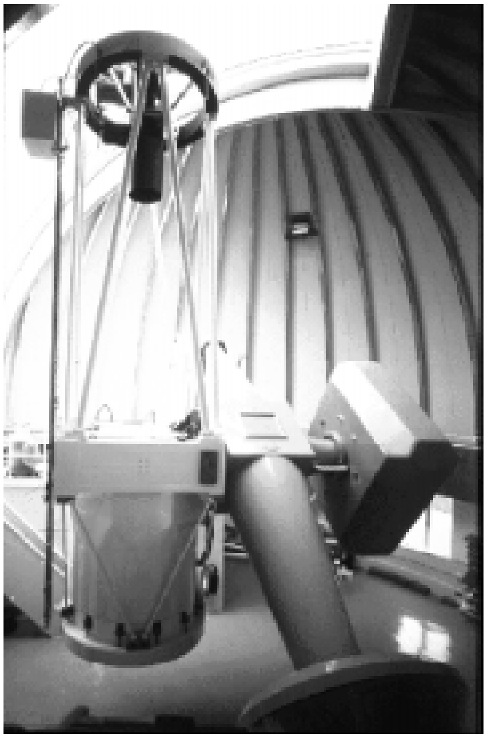


Fig. 4. Example of velocity distribution in the simulation for a realistic position of the observer relative to the bar (V and U are the velocity components towards galactic rotation and anti-centre respectively). The peaks represent individual streams.

The Galaxy

Schmidt, Mackey and Da Costa have used data taken as part of the Abell Cluster Supernova search program to monitor 1.4 million stars in our Galaxy's outer region, better known as the halo. This program uncovered 38 new RR-Lyrae stars - variable stars whose distances can be inferred from their pulsation periods. These stars are the most distant objects belonging to the Galaxy, – extending up to 300,000 light years from the centre. By measuring their velocities one will be able to determine the mass and shape of the Galaxy.

MACHO



The MACHO Project is searching for galactic dark matter by looking for its gravitational lensing effects on the light of background stars. The changing geometry of the lensing system as the lens moves relative to the background star causes the brightness of the background star to change with time. These 'microlensing' events can be detected by monitoring the brightnesses of large numbers of stars. MACHO began gathering data in 1992 using the 50 inch telescope at Mt. Stromlo, and now monitors roughly forty million stars in the Large and Small Magellanic Clouds, and in the Galactic Bulge. A large number of microlensing events have now been detected, with well over 200 along lines of sight to the Bulge, over 16 toward the LMC, and 2 toward the SMC.

During 1999 we completed analysis of the first 5.7 years of LMC data, including a careful determination of the experiment's detection efficiency. The results have been submitted for publication, and will be reported at the January, 2000 AAS meeting. In brief, the population of lensing objects detected in our first two years of data is confirmed by our new results, with smaller statistical errors. The fraction of dark matter represented by this population is still uncertain, but is roughly 20%. The mass of the individual lenses is around 0.5 solar masses, as we found before. The controversy continues over whether these objects are a galactic halo population, or are somehow associated with the LMC itself. It now appears that this controversy may soon be settled by analysis of images from the HST. Ibata et al reported this year that they detected several moving objects in the Hubble Deep Field that have velocities, colors, and brightnesses consistent with very old halo white dwarfs, the most likely candidate for the MACHO objects. If confirmed, this result will be a conclusive confirmation of the halo nature of the MACHOs. To check the Ibata et al result, a team led by Mould and containing several members of the MACHO team, was awarded a large amount of HST time to search for faint moving objects in a wider area of the sky.

The MACHO project ended its observations at the end of this year. Subsequent work will be exclusively data analysis on the very large database that has been accumulated. In addition to analyzing the entire LMC and SMC dataset, we will fully analyze the data from the Galactic Bulge, an effort which is sure to lead to some exciting insights into galactic structure.

Detection of Objects in the Outer Solar System

Axelrod is a member of the TAOS Project, an effort to detect Kuiper belt objects by observing their occultation of background stars. Occultation events will be quite brief, on the order of 100 msec, and therefore rapid sampling of the stellar intensities will be required. This will be achieved with a network of three small autonomous telescopes located in Taiwan. Axelrod's responsibility is for the photometry code, which poses unique challenges, since images will be obtained in trailed mode to achieve the rapid time sampling, and will be significantly affected by image motion. This project made substantial progress during the year, with the telescopes nearly completed, and scheduled for installation in Taiwan in early 2000.

A second project, the Southern Trans-Neptunian Object Survey, will begin using the MSO 50 inch telescope immediately on the cessation of MACHO observations. The goal of this survey is to perform a complete census of bright objects in the outer solar system located in a 20 degree wide band centred on the ecliptic. The survey will take two years, and will fill a substantial gap in our knowledge of the outer solar system.

To perform this survey in an affordable way, we are completely automating the operation of the 50 inch telescope, so that it can operate without human observers. This requires substantial effort to achieve, but will pay off handsomely in the economy of future operations.

ACTIVE GALACTIC NUCLEI

The 2dF QSO Redshift Survey

The 2dF QSO Redshift Survey is a major collaboration involving both Australian and British based astronomers (Smith, Boyle*, Shanks*, Miller*, Croom* and Loaring*) to make the first homogeneous, large-area map of the distant Universe. Quasi-Stellar Objects (often referred to by the acronym QSO and sometimes called quasars) are the brightest class of object known and offer us the most direct view of the distant, and hence early, Universe. After close to a decade of preparatory work, we are now in a period of intensive observations using the Two-Degree Field instrument on the Anglo-Australian Telescope at Siding Spring Observatory. This instrument, which has been called "arguably the World's most complex astronomical instrument", allows us to observe spectra from 400 objects simultaneously. It is this capability which allows us to undertake surveys incomparable in size to anything previously possible. About half the total number of known QSOs were discovered by this survey and so far we are only one third complete! The final catalogue will comprise more than 25000 $z<3$, $B<20.75$ QSOs, homogeneously sampled from 740 square degrees of sky, making it by more than an order of magnitude the largest QSO redshift survey ever performed. We are not simply "QSO collecting" though. More important then the sheer number of QSOs discovered is the homogeneity of our object selection and data collection. We currently cover over twenty times the sky area (about 240 square degrees or 1000 times the apparent area of the Moon) of any published surveys which went to the same faintness limits. This is comparable and highly complementary to several large-area surveys which concentrated on much brighter QSOs. It is the combination of sample size and quality which allows us to make the advances in QSO astronomy described below.

The primary scientific aims of this survey are to study the distribution of material in the Universe out to very large scales where normal galaxies are too faint to be readily observed and to investigate the evolution of QSO clustering and luminosity from redshift z=3 to the present day. Besides the original objectives for which the survey was designed, the survey will be a valuable, publicly available resource for a wide range of studies, including the nature of active galactic nuclei, gravitational lensing and faint foreground objects whose existence can only be inferred from their absorption of the more distant QSOs' light. Many collaborations involving both ANU and external astronomers have already been initiated to capitalise on this data set.

Fig. 5. We plot here a point for each QSOs so far observed, illustrating the power of this survey to probe clustering on very large scales. The thin plots on either side, show how the objects are arranged on the sky. This is all we know in our input list of QSOs to observe. The 2dF observations allow us to measure a distance to each object and the main plot therefore shows the QSOs projected out into space with us down at the centre of the plot. Each narrow stripe of points radiating from the base of the cones is one observation with the telescope. About 400 such pointings will cover the full survey area.

Ultraviolet Absorption Lines

A quasar is a special type of galaxy that shows evidence of very energetic processes going on in its central regions. The most likely cause of this is the presence of a very massive Black Hole that pulls in matter from the galaxy surrounding it. Surprisingly, there is no direct evidence that matter is flowing towards the Black Hole, but much evidence that matter is being expelled from the nuclei of quasars at very high speeds. These outflows can take two forms: very tightly collimated jets that move at close to the speed of light, and less collimated outflows in the form of winds moving at speeds ranging from a few thousand to 30,000 kilometres per second. The jets are mostly studied by their radio emission, whereas the winds are studied by their absorption lines, mainly in the ultraviolet part of the spectrum.

de Kool has been involved in several projects studying quasar winds by their UV absorption lines. The most significant result was obtained from a study of absorption lines of FeII (singly ionised iron atoms) in the quasar FBQS1044+3656, in a collaborative project with Becker* and Arav*. One outstanding problem regarding quasar winds is that we do not know very well at what distance from the active nucleus they occur, with estimates ranging from 0.01 parsec to 10 parsec depending on the theoretical model. By analysing the Fe II absorption lines caused by the outflow, it was possible to derive a relatively accurate estimate of the density in the wind, and thereby constrain the size of the outflow in which the FeII lines are formed to be larger than 100 parsec. This surprising result is in contradiction with all previous theoretical estimates, and will require a major rethinking of the physical mechanisms leading to quasar winds.

Pink Black Holes

Francis, Drake, Webster* and Whiting* used telescopes at Siding Spring Observatory to measure the colours of a very large sample of quasars in the optical and near-IR. They showed that radio emitting quasars have very different colours to the more normal quasars: many would appear a nauseous shade of purple-pink to the human eye. These colours are hard to explain. Furthermore, the colours appear to correlate with the luminosity of the quasars: this correlation could in principle be used to measure the geometry of the Universe out to unprecedented distances.

Extragalactic Radio Sources: Populations and Evolution

Extragalactic radio sources are enigmatic, highly energetic, and, for the most part, very distant objects. Jackson and Wall* are analysing the space distribution of extragalactic radio sources, using radio source counts and data at a wide range of observing frequencies (151 MHz to 10 GHz). They have determined a ‘dual-population’ unified scheme which successfully accounts for the many, apparently different, radio source types observed, as resulting from orientation and projection effects. They find that the most powerful radio sources have undergone a huge increase in space density at redshifts between 2 and 3, when they were >1000 times more common that they are at the current epoch.

Whilst distant radio sources are very powerful, local radio sources are much less so. Thus another key issue in radio source cosmology is to relate the distant, evolving, powerful objects to the nearby weaker ones. To this end, Jackson, with Sadler*, Cannon* and McIntyre* are exploiting the overlap between sensitive wide-area radio surveys and the 2dF Galaxy Redshift Survey (2dFGRS, Colless *et al*) to identify the local radio source populations. When 2dFGRS is complete, a sample of ~4000 local radio galaxies will be identified, providing the best determination of the local radio luminosity function to date.

The emission-line characteristics of a subset of 2dFGRS radio galaxies is being studied in detail by Jackson and Dopita. The key question being addressed is what proportion of the emission-line gas is created by (i) shock processes (associated with radio jets) and (ii) ionization due to young stars. This in turn has important ramifications for understanding the nature of the more powerful, high redshift radio sources.

The huge potential of the 2dFGRS radio galaxies as a rich hunting-ground for unusual objects has also been recognised. Jackson and Schilizzi* are searching for compact steep-spectrum galaxies: thought to be rare in the local Universe.

At the very distant, extremely powerful end of the radio source scale are the flat-spectrum radio quasars. Jackson, Shaver*, Wall* and Hook* have now completed a lengthly observing program to directly trace the high-redshift behaviour of these objects. Preliminary results have already been reported in *Nature*, where the group reported a clear decrease in the space density of such objects at redshift 3. The spectroscopically-complete sample is now being assembled and final analyses being performed.

Extragalactic HII Regions and Starburst Galaxies

Kewley, Sutherland and Dopita, working with Rocca-Volmerange*, have generated a large grid of theoretical HII region models. For the stellar UV continuum, these use the stellar spectral synthesis models PEGASE by Fioc* & Rocca-Volmerange, and the STARBURST 99 code by Leitherer* et al. These spectra are input into the photoionisation code, MAPPINGS 3.0, making proper allowance for dust physics and the depletion of the gas-phase abundances caused by dust. We find that the predictions made by both PEGASE and STARBURST 99 are very similar, giving confidence in the current state of spectral synthesis modelling. Furthermore, comparison of the predictions of MAPPINGS 3.0 with the photoionisation code by Ferland* (CLOUDY) for identical stellar radiation fields are also remarkably similar, showing that the HII region modelling is consistent between different codes.

Kewley *et al.* find that the extragalactic HII region sequence is reproduced remarkably well by our models, provided that the clusters which excite them are all rather young (< 2 Myr). This is an observational selection effect in that young, high surface brightness HII regions are preferentially observed. They also show that the line ratio usually used for measuring the ionisation parameter; [OIII]5007Å / [OII]3727Å, is indeed a good diagnostic of this parameter, while the [NII]6584Å / [OII]3727Å ratio gives the best diagnostic of abundance, as it is monotonic between 0.1 and over 3.0 times solar metallicity. This abundance diagnostic works because the relative abundance of nitrogen increases at high metallicity, and also because high metallicity HII regions are cool, so that the [OII] lines are not excited. For extragalactic HII regions, we find abundances 0.1 - 2.5 solar.

The photoionisation analysis has also been applied to the luminous starburst galaxies observed as part of Kewley's thesis. These are best explained as HII regions excited by stars of a wide variety of ages, in a region of continuous star formation. The relative strength of the UV ionising radiation field seems to be somewhat lower than those characterising giant extragalactic HII regions. In addition, the vast majority of these objects appear to have metallicities in excess of solar, and values as high as three times solar are inferred for some objects.

About 30% of the galaxies seem to be of mixed excitation - the combination of a nuclear HII region and an active galactic nucleus. The galaxies showing "pure" Seyfert line ratios also require that the gas has greater than solar metallicity. Objects with intermediate line ratios are composite in character, and lie on mixing lines between the AGN ionised and starlight phototoionised HII regions of the same metallicity.

Bow Shocks in the Active Jet of NGC4258

The remarkable active jet of the Seyfert Galaxy NGC 4258 (M106) has recently been studied with HST and with the VLA. These results are described a paper in press by Cecil with Dopita and others. They find clear evidence for large-scale precession of the jets over a very wide opening angle over a timescale of a few hundred thousand years. When these jets sweep through the galactic plane, they drive strong shocks into the disk at velocites of order 350 km/s, and the hot shocked gas buoyantly rises out of plane. In addition, the HST data show clear examples of strong bow-shocks being driven into individual dense clouds near the disk plane.

GALAXIES AND GALAXY EVOLUTION

Luminous Infrared Galaxies

Luminous infrared galaxies were discovered by the IRAS satellite in 1983, and emit the bulk of their radiation in the infrared. Much work has been carried out to determine the infrared source, and it is still an issue of debate. Some contain Active Galactic Nuclei (AGN), while in others the infrared source is intense star formation. It is unknown whether there is an evolutionary connection between starburst and AGN in these galaxies.

In order to study this issue, Kewley, Heisler, Dopita and Norris* have completed a large optical spectroscopic survey of their sample of 285 IRAS galaxies in order to obtain accurate optical classification of these galaxies. Theoretical modelling has been completed to compare with these galaxies and with the standard HII (ionized gas) region abundance sequence. The modelling involves the use of stellar population synthesis models (Starburst 99 and Pegase) to produce the ionising radiation field which is then utilised by our shock and photoionisation modelling code MAPPINGs vIII. They find that the photoionisation modelling using instantaneous stellar population synthesis models from either Starburst 99 or Pegase reproduces the HII region abundance sequence very well. Continuous population synthesis models are required as the radiation source to reproduce the photoionisation seen in the starburst galaxies in our sample. Both shock models and power-law models can reproduce AGN-like optical spectra, and they can now find a range of metallicity and ionisation parameters which apply to their luminous IRAS galaxies. They find that many galaxies in their sample lie on a mixing line between starburst and AGN, most likely containing both phenomena.

The goal for the coming year is to improve the dust physics in the models to compare with the infrared data available for our spectra.

Intracluster Stars in the Virgo Cluster

Astronomers have long suspected that there are stars between the galaxies in clusters of galaxies. Detecting such stars from their diffuse light is very difficult, because the light is so faint. The Virgo cluster is the nearest major cluster of galaxies, at a distance of about 15 Mpc. Recent developments have made it possible to detect individual old evolving stars at such a large distance. These stars are known as planetary nebulae: they have thrown off a shell of gas and are in a short-lived phase in which this gas shell becomes incandescent. The glowing gas emits a large amount of light in one narrow spectral line of oxygen, through which it is possible to detect these stars and measure their velocities precisely. If there are old stars between the galaxies in the Virgo cluster, then they will include some planetary nebulae, which are detectable with ground-based telescopes.

Freeman, with a group of European and US collaborators, is studying the intracluster stellar population in the Virgo cluster. An imaging survey detected large numbers of potential intracluster planetary nebulae, and it seems that about half of the starlight of the Virgo cluster comes from these stars between the galaxies. Using the 2dF fiber spectrograph on the AAT, they were able to confirm spectroscopically that most of these candidates are indeed intracluster planetary nebulae in the Virgo cluster.

The imaging survey technique is also very powerful for detecting other kinds of emission-line objects, including starburst galaxies at high redshift. About 25% of the planetary nebula candidates turned out to be starburst galaxies in the early Universe, at a redshift $z \sim 3.1$. The imaging survey detects these galaxies through the very strong Lyman alpha line of hydrogen that is associated with the burst of star formation. The upper figure shows the summed spectrum of 23 intracluster planetary nebulae in the Virgo cluster: the stronger of the two emission lines is the l5007A line of [OIII] by which these planetary nebulae were discovered. The lower figure shows the spectrum of one of the high redshift galaxies: here the strong asymmetric line is hydrogen Lyman alpha at a redshift of about 3.1.

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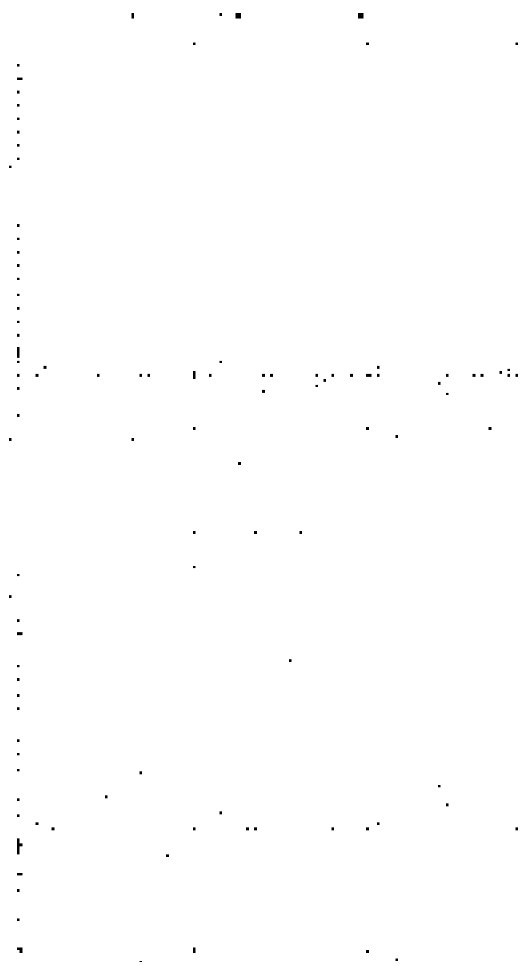

Fig. 6.: (Upper) Sum of 2dF spectra of 23 intracluster planetary nebula candidates in the Virgo cluster. The observed ratio of the two [OIII] lines indicates that 22 ± 1 of these candidates are real intracluster PN. (For each spectrum, the strong line was shifted to λ5007Å before summing). (Lower) 2dF spectrum of a high redshift starburst galaxy discovered in the deep narrowband survey for intracluster planetary nebulae. The strong asymmetric line is Lyman alpha at a redshift of 3.1 (the strong line has been shifted to λ5007Å before plotting the spectrum).

Distances to Galaxies and the Mass-to-Light Ratio

Measuring the distances to galaxies remains a difficult problem, and different techniques are needed for different kinds of galaxies. Some of these techniques depend on the dynamics of the galaxies. For spherical galaxies, the product of the projected radius r and the projected surface density distribution *m(r)* determines the structure of the galaxy. Kalnajs has shown that this product *rm(r)* is smooth enough in real galaxies so that the central line-of-sight mean-square stellar velocity s^2_0 is proportional to the maximum value of *rm(r)* (this follows from the gravitational dynamics of the individual galaxies). Thus the distance to a galaxy can be obtained by measuring the two distance-independent quantities $s^2_0$and $m(r_{max})$.

Unfortunately *m(r)* cannot be measured directly; it must be inferred from the projected surface brightness distribution *I(r)*. Hence the determination of the mass-to-light ratio $M/L = m(r) / I(r)$ in the vicinity of r_{max} is the key to measuring distances to individual galaxies. The determination of the *M/L* ratio is a spectroscopic problem. Colour measurement is the simplest form of spectroscopy.

Calibration of the Surface Brightness Fluctuation Method for Dwarf Elliptical Galaxies

One of the most precise methods available for measuring the distances of elliptical galaxies is the surface brightness fluctuation (SBF) method. This method is based on the statistical fluctuations in the numbers of individual stars that contribute to each pixel in the image of a galaxy. It requires some empirical calibration of the typical brightness of these individual stars. Such calibrations are available for the bright giant elliptical galaxies, but not for the dwarf ellipticals which have a range of metal abundances and a diverse and complex history of star formation. Jerjen *et al.(*1998) used the SBF method with great success to measure the distances to some very faint dE galaxies, but they had to rely on theoretical calibrations from synthetic models of stellar populations. An empirical calibration of the SBF method for dwarf galaxies is urgently needed.

First results on the empirical calibration for dwarf elliptical (dE) galaxies were published by Jerjen *et al*.(2000). The ideal calibrator galaxies are dE systems slightly beyond the Local Group, where the SBF method is working and where large telescopes like the VLT can make direct distance estimates from the resolved stellar population. In order to make an empirical calibration of the SBF method, Jerjen, Labhardt* & Binggeli* are running an extensive observing program with the Very Large Telescope (VLT) and the New Technology Telescope (NTT) of the European Southern Observatory (ESO). The goal is to measure accurate distances to dEs using the brightness of the brightest red giant stars. For such metal-poor stellar systems, the TRGB distance is as accurate as the distances derived from the Cepheid variable stars. To reach a statistically well-founded result, a minimum of 10 nearby dE galaxies is needed. The sample of Jerjen *et al*.(2000) is ideal for the purpose. This program is now well under way, with some data already acquired and VLT time granted in the next semester for eight more galaxies.

Distance and Depth of the Virgo Cluster

The Virgo cluster of galaxies is at the center of the Local Supercluster of galaxies. Its 3D structure and its precise distance are key issues for many many astronomical problems, like the origin of observed galaxy morphologies, cluster and supercluster formation, and the cosmological distance scale. However, these properties remain poorly known. For example, on the Virgo cluster distance, the uncertainties are illustrated by the controversial results from two HST key projects. Employing two different distance indicators, the Cepheid variable stars and the supernovae of type Ia, the mean cluster distance is measured as 16 Mpc and 25 Mpc, respectively. The reason for the discrepancy lies in the nature of spiral galaxies, which are the typical target galaxies for these HST studies. Spirals reside primarily in low density regions (i.e. in the outskirts of the cluster), so the observed distance range likely reflects the line-of-sight depth of the large spiral halo of the Virgo cluster. This shows why spirals are only of limited use to nail down the distance to the gravitational centre of the Virgo cluster.

The best kind of objects to map the 3D-structure of the Virgo cluster are the dwarf elliptical (dE) galaxies. These dwarf galaxies are concentrated to the densest inner regions of the cluster, and they are the only galaxies which are present in large numbers in the Virgo cluster core. Jerjen, Freeman, and Binggeli* are using the surface brightness fluctuation method (described in the previous item) to estimate the distances of the dE galaxies. They are using the new 8m Very Large Telescope of the European Southern Observatory to investigate the dynamics and shape of the core structure of the Virgo cluster. A first set of dwarf galaxies have already been observed with the VLT, and more observing time has been granted by the European Southern Observatory for the second half of the sample middle of 2000.

COSMOLOGY

Probing the Universe in the Time Domain

Schmidt leads a team of more than 20 astronomers on four continents who discover supernovae - stars which explode at the end of their lives with the energy of an entire galaxy. This team, known as the High-Z SN Search, mounted two search programs in 1999; one in January using telescopes in Chile, and the other in November, using telescopes in Chile and Hawaii. The first program uncovered more than 20 objects, four of which were followed by the Hubble Space Telescope. These data will help pin down the expansion of the Universe to 8 billion light years, and help to confirm or refute last year’s major result that the Universe appears to be accelerating in its expansion. In November an additional 25 objects were found, including the most distant supernova yet discovered, located some 9 billion light years away. While the simplest solution to these observations is still Einstein’s Cosmological Constant - a form of energy that pervades every piece of space in the Universe, Schmidt is continuing to use these distant supernovae to see if a simpler solution might exist to these startling observations.

The Local Universe

Schmidt, Germany, Stubbs, and Reiss* have completed a three year program using the MSO 50 inch to monitor rich clusters of galaxies, looking for the supernova explosions. This program uncovered 50 objects in total, and ongoing analysis for Germany’s thesis of these objects’ distance and velocity will allow us to measure the motion of our Galaxy in space. Reiss, in his thesis, measured the frequency at which supernovae occur in galaxies with unprecented accuracy. Supernovae are indeed rare objects, exploding in an average galaxy about 1 and a half times per millennium.

As a follow-on project, Schmidt, Stubbs and Ashley* plan to monitor the entire southern sky for bright supernovae every month. First observations show that they can find all objects within 300 million light years, and therefore this program promises to produce more than 100 objects per year for careful study. This will enable mapping of the motions of the entire nearby Universe, and comparison of observed motions to the motions these objects should have from the gravitational attraction of surrounding galaxies.

The 2dF Galaxy Redshift Survey

In 1999 this major long-term project, with Colless as co-leader of a 30-strong Australian and British team, achieved the milestone of producing the largest-ever map of the local Universe (Fig. 7). By the end of the year the survey had measured redshifts for over 80,000 galaxies, three times more than the previous largest survey. The survey will eventually map and survey the properties of 250,000 galaxies, with the primary goals of understanding the large-scale structure of the Universe and the processes affecting the formation and evolution of galaxies. Two different analyses of the galaxy population have shown that the luminosities of galaxies are a strong function of both their morphological/spectral types and their surface brightnesses.

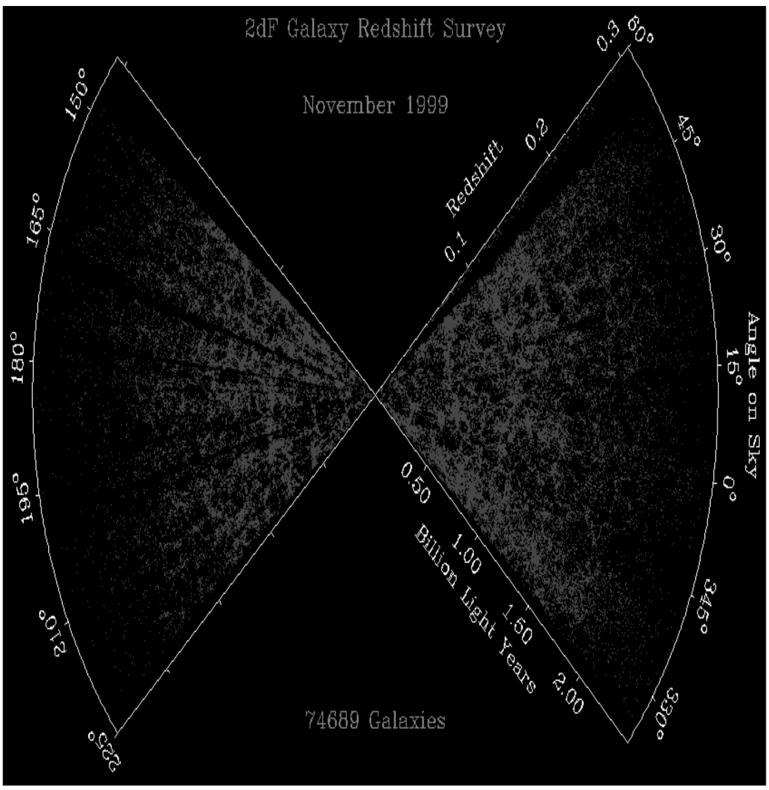

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Fig. 7. The 2dF survey map of the Local Universe

Contrary to some claims, there is no evidence for a significant contribution by low surface brightness galaxies to the total luminosity or mass density. The first analyses of the distribution of the galaxies in redshift space have clearly confirmed the theoretically-predicted effect of the mass distribution in distorting the large-scale structure (see Fig 8). At small separations on the sky, galaxies tend to have redshift differences that are larger than their true line-of-sight separations because of the high orbital velocities in clusters. At large separations on the sky, the redshift differences are smaller than the true line-of-sight separations because galaxies are falling together onto mass concentrations. This effect can be used to measure the mean mass density of the Universe. The redshift survey will continue through 2000 and finally be completed in 2001.

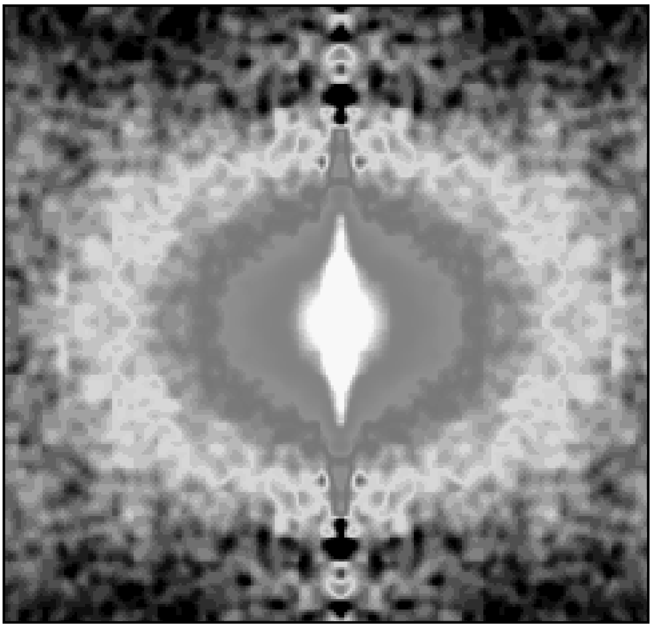

Fig. 8. This shows the effect of the mass distribution of galaxies in distorting the large-scale structure.

THEORETICAL ASTROPHYSICS

Optical Studies of X-ray Binaries

X-ray binaries are gravitationally bound systems composed of a “normal” star and a compact object (neutron star or black hole). Matter is transferred from the companion star to the compact object, and X-rays are emitted in the process. In some cases, the accreting matter may form a disk around the compact object as it spirals down. Optical observations of X-ray binaries can reveal the fundamental parameters of the binary system (binary period, mass ratio, inclination angle) as well as the nature of the companion star and the physical structure of the accretion disk. Soria, Wu*, Galloway*, Hunstead* and Johnston* have carried out optical studies of X-ray binaries in various states of activity, using the MSSSO telescopes and the Anglo-Australian Telescope.

State Transitions in Black-hole Binaries

Black-hole binary candidates (BHCs) are X-ray binaries in which the mass of the compact object exceeds the theoretical maximum mass of a neutron star (~ 3 solar masses); therefore, the compact object is thought to be a black hole. About a dozen BHCs have been found in our Galaxy so far. Most BHCs are characterised by transitions between different energy states over time-scales of a few months or years, with periods of quiescence (low accretion rate) separated by soft or hard X-ray outbursts. Soria, Wu*, Hunstead* and Johnston* have conducted optical photometric and spectroscopic studies of two optically bright BHCs (GRO J1655-40 and GX339-4). In particular, they have studied the relation between optical and X-ray spectral states, and the accretion disk structure in the various states. They have also modelled the temperature structure of an accretion disk illuminated by the X-rays emitted from the central source near the compact object, and determined when the external irradiation may create a hot, thin layer at the disk surface. Such layer (“chromosphere”) is responsible for the emission lines observed from most BHCs.

Survival and Acceleration of Dense Gas Clouds

Many low-density astrophysical plasmas have a multi-phase structure in which relatively cold dense clouds filling a small fraction of space coexist with with a much more tenuous hot gas surrounding them. Examples are the Interstellar Medium, the Intergalactic Medium, and the environment of Active Galactic Nuclei. Forces acting on the plasma such as radiation pressure, magnetic or buoyancy forces will cause differential acceleration between the clouds and the hotter intercloud medium, so that large velocity differences will develop soon. In many astrophysical contexts where such a situation is observed, the clouds appear to be much more stable against disruption due to hydrodynamical instabilities arising from the differential motion between clouds and intercloud medium than expected from simple theoretical estimates.

de Kool has started a project in collaboration with Sutherland and Bicknell to study the process of cloud disruption using multidimensional numerical hydrodynamics. The goals of this study are: a) to study to what extent the disruption timescale estimates based on linear instability growth timescales are apliccable once the non-linear development has set in; b) to study the stabilizing effect of radiative cooling on the development of the disrupting instabilities; and c) to study to what extent magnetic fields can stabilize the clouds. Initial results were obtained on problems a) and b), indicating that both non-linear effects and radiative cooling cannot be responsible for the observed cloud stability.

Supercomputer Simulations of VLT Observations of the Optical Hotspot in the Radio Galaxy Pictor A

It has been known for some time that the “hotspots” observed in powerful extragalactic radio sources represent the shock wave at the terminus of a jet as it forces its way through the relatively dense intergalactic or interstellar medium surrounding the galaxy. Indeed some of the first supercomputer simulations done in astrophysics were of light supersonic jets and these simulations revealed the general morphological structure of hot spots and the related backflow. Sometimes radio hotspots have optical counterparts and optical observations reveal more information concerning the sites of acceleration of highly relativistic particles. The Southern galaxy, Pictor A is one radio source known to have an optical counterpart to its western radio hotspot, thanks to earlier radio observations by Perley*, Roeser* and Meisenheimer* and optical imaging by Roeser* and Meisenheimer*. Recent optical images obtained by Wagner* and colleagues from one of the 8 metre telescopes of the Very Large Telescope (VLT) operated by the European Southern Observatory in Cerro Paranal, Chile, have promoted new interest in Pictor A. Their optical image of the western hotspot is shown below (Fig. 8). With the light gathering power of a large telescope in a site of excellent seeing (0.47" in this image) a more detailed and informative image could be made. One of the outstanding features of the new optical image is a clearer representation of the ridge of emission offset from the main bright hotspot. This was an unexpected feature of hotspot regions and prompted Metchnik, Sutherland and Bicknell to conduct new simulations of supersonic jets, using the ANU’s VPP300 supercomputer and a hydrodynamic code based on the Piecewise Parabolic Method of Colella* and Woodward*. What Metchnik *et al*. suspected, and found to be correct, was that the complex optical structure of the hotspot region in Pictor A, is related to complex shock wave structure produced by time-dependent flow in the jet and its “cocoon” of backflowing material. The figure below shows the pressure field produced in a VPP300 simulation of an axisymmetric Mach 5 jet with a density 0.01 times that of the surrounding medium. The cocoon surrounding the jet has an eddy structure which alternately pinches and decompresses the jet. As sideways pressure on the jet is released, a surge of material pushes forward and causes a “flange” of matter to be shocked and spread sideways. A related feature of the flow is the cycling of the shock morphology near the head of the jet between a “criss-cross” shock and a normal shock. The latter develops in response to the surge of jet material from upstream. Metchnik *et al*. propose that the squirting of material sideways is the cause of the optical ridge of emission observed in the VLT image. The model also explains a feature in the radio data, a “knot” of radio emission upstream of the main hotspot. In the view of Metchnik *et al*., this is the result of dissipation at a criss-cross shock before the normal shock mentioned earlier. This shock is also evident in the supercomputer image. In order to obtain an optimum fit to the data, a parameter study needs to be carried out. Nevertheless, this combination of large telescope and large computer research has verified, for the first time, an important feature of extragalactic jets – their time-dependence resulting from the interaction between jet and backflow. Our understanding of this interaction should lead to new ways of estimating jet parameters.

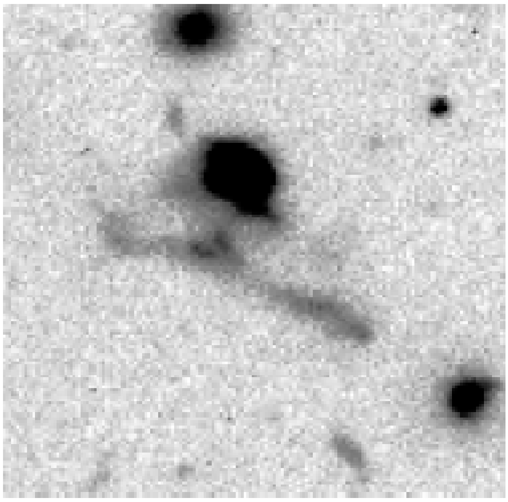

Fig. 8. VLT image of the Western hotspot of the Radio Galaxy Pictor A with 0.47 arcsecond resolution. The image is approximately 30 arcseconds square. One arcsecond corresponds to approximately 760 parsecs.

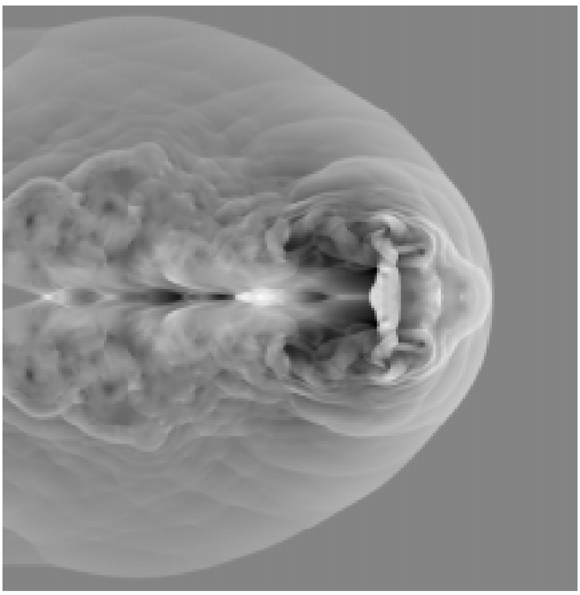

Fig. 9. Greyscale image of the pressure in a VPP300 simulation of an axisymmetric Mach 5 jet, with a density 0.01 times that of the surrounding medium. Note the ridge of high pressure (and therefore luminous) material behind the leading hotspot.

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Modelling the X-Ray and γ-ray Spectra of Markarian 501

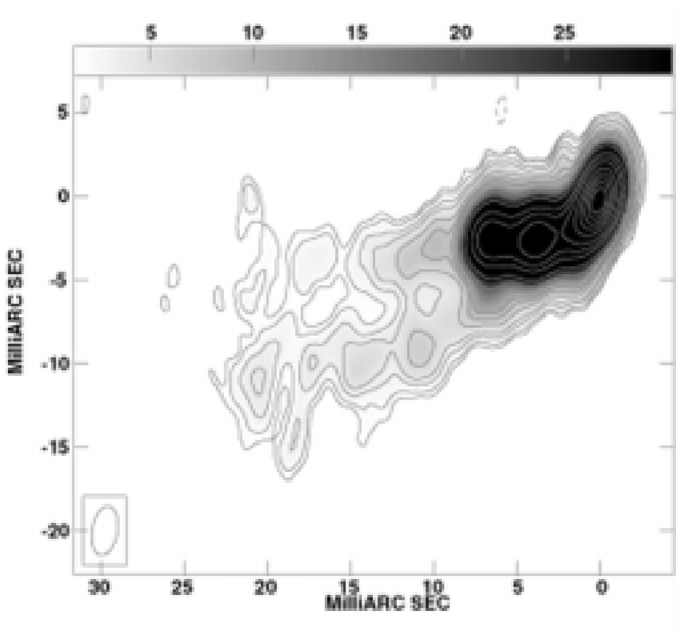

Fig. 10. Space VLBI image of the blazar Markarian 501 obtained by Giovannini and collaborators using the Japanese HALCA satellite in conjunction with ground based observatories. This is a jet observed almost pole-on. One of the radio components was determined by Giovannini et al. to have an apparent proper motion of 6.7 times the velocity of light. One milliarcsecond in this image corresponds to approximately 2.2×10^{18} cm. The X-ray and γ–ray emission comes from a region approximately 10^{16} cm in size, or about 1% of the smallest resolveable scale in this image. This region is about 100-1000 gravitational radii from the black hole in the centre of the galaxy.

Markarian 501 is a class of AGN known as a blazar. Its continuum emission is highly variable and most of the energy from this object is emitted at X-ray energies. Recent space-VLBI radio images made by Giovannini and collaborators from the University of Bologna have shown one of the radio components to have an apparent velocity of 6.7 times the speed of light. Such apparent *superluminal* speeds are characteristic of relativistic jets which are observed almost pole-on. The host galaxy for this jet is an elliptical galaxy and the mass of the black hole powering the jet is probably of order a hundred million to a billion solar masses. Jets emit radio waves through the process of synchrotron emission. However, observations of the radio emission alone do not provide enough information for us to ascertain some of the most crucially important information about the jets, principally the energy density of relativistic plasma and the strength of the magnetic field. Likewise, the X-ray emission from Markarian 501 is almost certainly synchrotron emission from the jet, albeit at a location much closer to the black hole. As with the radio emission, observations of the X-ray emission alone are insufficient to determine jet parameters. However, accompanying the X-ray emission is much higher energy emission in the form of TeV (10^{12} electron volts) γ–rays. These are produced when "soft" infrared photons are scattered by the high energy, relativistic electrons constituting the jet plasma, and thereby boosted in energy. The γ-rays from Markarian 501 were detected by a ground-based *Imaging Atmospheric Cerenkov Telescope* (the HEGRA array) located in the Canary Islands. The source of the soft photons is either the jet itself (Synchrotron Self-Compton emission) or the emission from the environs of the AGN, possibly the accretion disk surrounding the black hole (External Inverse Compton emission). An important consequence of the detection of γ–rays is that they give us a way of determining the magnetic field in the jet, especially if the emission is the result of the Synchrotron Self-Compton process.

Using a Synchrotron Self-Compton model, Bicknell and Wagner (Landessternwarte, Heidelberg) have modelled multi-epoch X-ray and g–ray spectra from a flaring state of Markarian 501 observed in 1997. The results of this fit to a particular epoch are shown in the figure below. There are a number of important implications of the modelling:

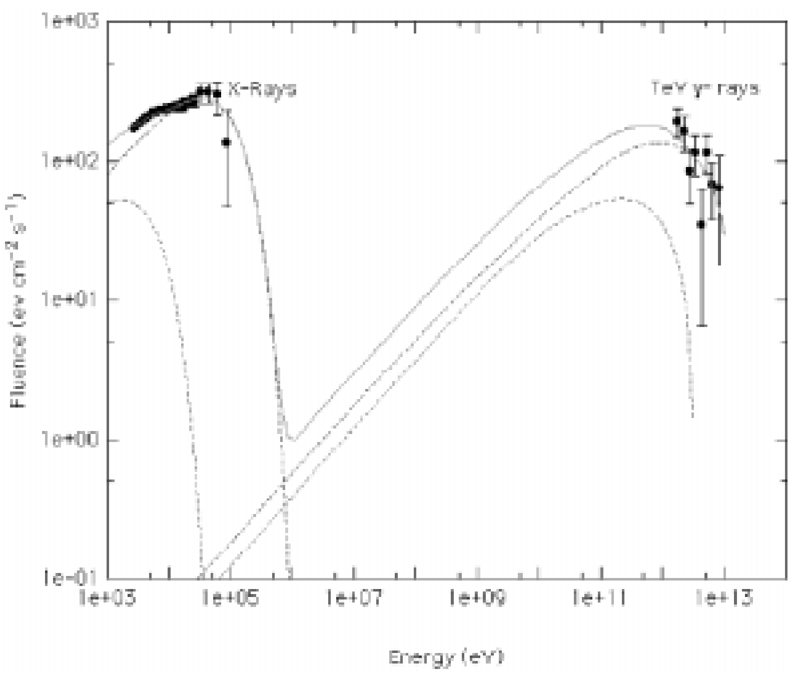

Fig. 11 A model fit to the X-ray and γ–ray spectrum of Markarian 501. This plot shows the contributions of the two components to the combined X-ray and γ–ray spectrum. The γ–rays are produced by the scattering of infrared photons by highly relativistic electrons in the jet.

- The fits require two components. For the X-ray emission there is a low energy component with a cutoff in the spectrum at about 5 keV and a component with a much higher cutoff – at around 50-100 keV. Synchrotron Self-Compton emission from the high energy component is responsible for the TeV γ–ray emission. The low energy component corresponds to emission from a decaying flare and would be responsible for γ–rays in the sub-TeV range. The high energy component corresponds to a new flare.

-

- The inferred magnetic field in both components (0.06 in the low energy component and 0.03 Gauss in the high energy component) is low – its energy density is two orders of magnitude less than that of the relativistic electrons in the jet. This in turn has implications for theories of jet production from black holes. In some theories, involving centrifugally driven flows from magnetised accretion discs, one expects comparable energy densities in magnetic field and relativistic particles.

- Jets moving at speeds close to the speed of light are often parameterised by the *Doppler factor*. (*Inter alia,* this factor determines the factor by which the emitted frequency of the moving plasma is boosted to the observed frequency.) The Doppler factor of the Markarian 501 jet, inferred from the model fitting described above, is high – about 10-20, and this is about twice that expected from the radio proper motion observations. However, Bicknell and Wagner have shown that such a Doppler factor is consistent with the X-ray and γ–ray emission being produced in weak shocks in the relativistic plasma caused by variations in the jet flow velocity.

- This result also gives us some insight into another property of the relativistic plasma in extragalactic jets. Is it composed of electrons and protons or electrons and positrons? The indication from Markarian 501 is that it is the latter. However, there are ways around this and this is a subject on which there is bound to be more speculation and theoretical work (as discussed in the following report).

Electron-Positron or Electron-Proton Jets?

Vacation scholar Brent Groves worked with Bicknell in December 1998 and January 1999, on the question of the composition of relativistic jets observed in many active galactic nuclei. A major issue in this field has been whether such jets are composed of electrons and ions (the latter being primarily protons) or electrons and positrons. It has been suggested by Blandford* and collaborators that electron-positron jets would result from the conversion of electromagnetic Poynting flux some distance from the black hole. In 1993, Celotti* and Fabian* suggested that jets are in fact electron-proton dominated. Their calculations utilised available radio and X-ray data to estimate the energy fluxes from both electron-proton and electron-positron jets. They then compared these energy fluxes to that estimated from a correlation between jet energy flux and emission line luminosity of the galaxy narrow-line region established by Rawlings* and Saunders* in 1991. A significant constraint here is that an electron-positron jet cannot have too high a density, otherwise the particles would annihilate. Celotti and Fabian concluded that in order for electron-positron jets to be energetic enough, they would be self-annihilating. The annihilation constraint can be expressed as a limit on the minimum Lorentz factor, γ_0, of the electrons and positrons, namely, $\gamma_0 > 100$. However, in order for such a jet to possess sufficient energy flux one requires $\gamma_0 \sim 1$. Nevertheless, this conclusion was based on an incorrect argument leading them to neglect the contribution of the jet internal energy density to the energy flux. When this contribution is taken into account, the situation is significantly different. Groves and Bicknell found that even when $\gamma_0 > 100$, the contribution from the internal energy of electron-positron pairs to the jet energy flux is so important that the constraint $\gamma_0 \sim 1$ is no longer necessary (see figure below). Therefore the major conclusion of this work is that electron-positron jets are indeed consistent with the energy requirements and annihilation constraints of active galactic nuclei.

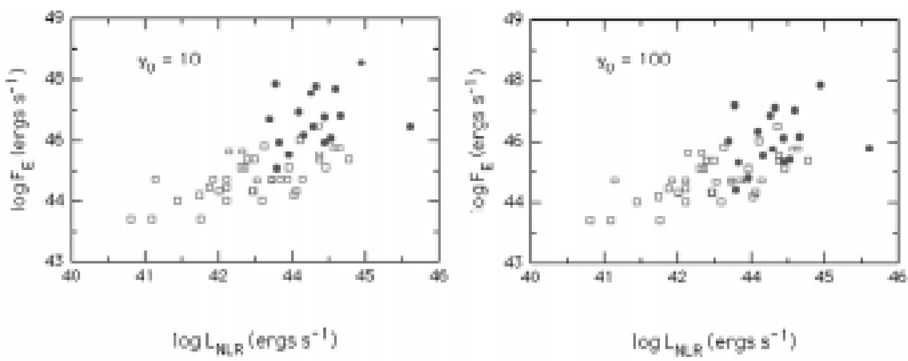

Fig. 12. The squares represent the data of Rawlings and Saunders showing the correlation between jet energy flux and emission line luminosity in a sample of powerful radio galaxies. The filled symbols represent the energy flux of parsec scale jets in 17 quasars and BL-Lac objects plotted against the emission-line luminosity of the Narrow-line region. The jet energy flux is calculated on the assumption that the jet consists of an electron-positron plasma for two values of the lower limit on the Lorentz factor of the particles, γ_0 =10 and γ_0 =100. For the latter value of γ_0, the calculated data points extend the correlation to higher luminosities.

The Galactic Snake

Over the last 15 years, radio astronomers have discovered a variety of quasi-linear, synchrotron emitting features in the Galaxy, not far from the Galactic Centre. What is remarkable about a number of these features is that they possess a radio spectrum which is very unusual for optically thin synchrotron sources. The first such object, a set of almost linear filaments about 35 parsecs from the centre of the Galaxy and perpendicular to the Galactic Plane, was discovered by US astronomers, Yusef-Zadeh*, Morris* and Chance*, in 1984. In these filaments, the radio spectral index, α, (defined by flux density $\propto$ frequency$^{-\alpha}$) is approximately zero, whereas in most synchrotron sources, such as supernova remnants and extragalactic jets, it is greater than 0.5. More recently, in 1993, Gray*, Cram*, Ekers and Goss*, using the Australia Telescope, observed an approximately linear feature, also in the vicinity of the Galactic Center, about 0.4 parsecs wide by 60 parsecs long, dubbed “the Snake”.

Images of the Snake exhibit a prominent kink which in a recent theory by Li# and Bicknell, is the key to understanding its nature. The Snake also has a curious spectrum. Near the kink, the radio synchrotron spectrum is more or less conventional but away from the kink, the spectrum flattens considerably with the spectral index going to zero as in the Galactic Center filaments. The brightness of the Snake also decreases away from the kink. In the theory proposed by Li# and Bicknell, the kink is the site of a classical magnetohydrodynamic coiling instability, produced by the winding of magnetic field by rotation of the molecular clouds in which it is embedded. This instability is similar to what happens to a twisted elastic band which eventually forms knots along its length. According to Li# and Bicknell, the coil formed by the instability brings regions of oppositely directed magnetic field together, opposing regions of magnetic field reconnect and release energy into relativistic particles at the site of the coil which relaxes into the observed kink.

The other part of their theory is that the flattening spectrum away from the kink, is the result of differential diffusion of high energy and low energy electrons. The high energy electrons diffuse the most rapidly, so that far away from the source (the kink) the synchrotron spectrum is dominated by high energy particles and therefore becomes flatter. Model fits for the 1446 MHz and 4790 MHz flux densities of the Snake, corresponding to an energy dependence of the diffusion constant for relativistic electrons proportional to energy$^{0.75}$ are shown in the figure below. This is possibly the first time that the energy dependence of electron diffusion in the Galaxy has been estimated. The Snake may be the “cleanest” example of magnetohydrodynamic processes operating in the Galactic Center region and the theory developed for this object may lead to a good physical understanding of all such features, including the original filaments discovered by Yusef-Zadeh* and coworkers.

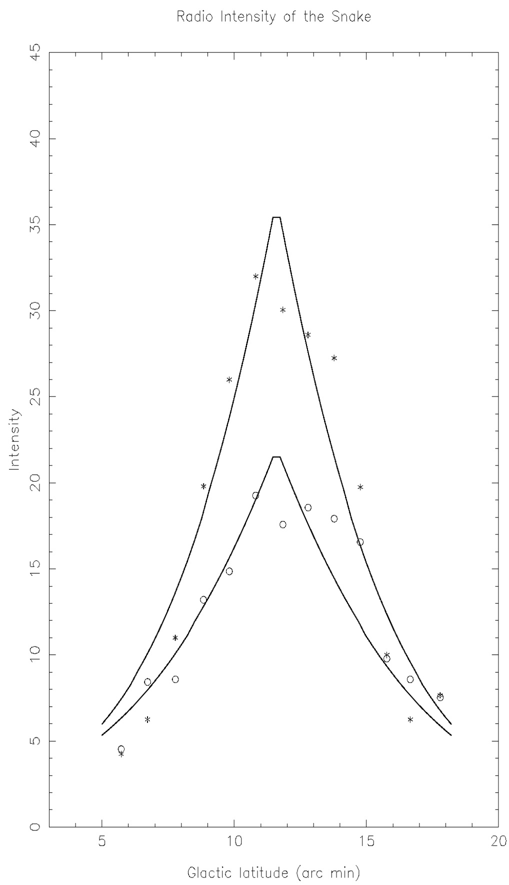

Fig. 13. Simultaneous fits to the 1446 and 4790 MHz flux densities of the Snake using the model developed by Li and Bicknell. The increasing ratio of 4790 MHz flux density to 1446 MHz flux density is the result of a diffusion coefficient for high energy electrons which is proportional to energy$^{0.7}$.The magnetic field estimated from their model is approximately 0.4 mG.

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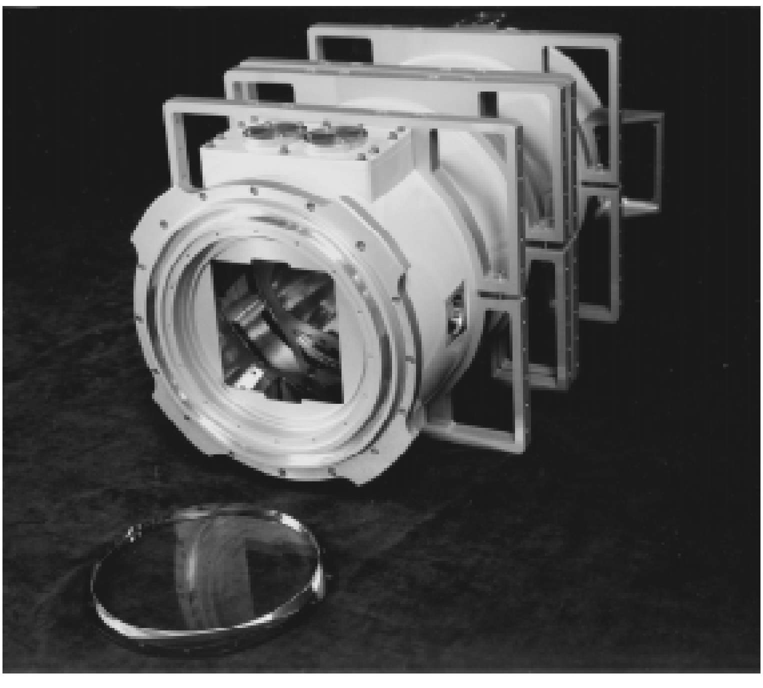
INSTRUMENTATION

Wide Field Imager

In collaboration with the Anglo-Australian Observatory, the University of Melbourne and Auspace, the RSAA is developing an instrument known as the Wide Field Imager (WFI). WFI will be used on both the SSO 1m telescope and on the 3.9m Anglo-Australian Telescope. The RSAA project scientist is Da Costa. The heart of the WFI will be a mosaic of eight 4096 x 2048 pixel CCDs, arranged to produce images 8192 x 8192 pixels in size. On the SSO 1m telescope this will allow an area of sky to be imaged that is six times larger than is currently possible with single CCDs. During the report year the fabrication of the filter wheel and shutter mechanisms, corrector lens assemblies, support structure, etc, required for the use of WFI on the SSO 1m telescope were completed. Considerable software and hardware work for both the user interface and the CCD controllers were also completed. The CCD controllers were then shipped to GL Scientific in Honolulu, Hawaii, who have been contracted to assemble and mount the CCD mosaic and perform the initial integration tests. At the present time we are awaiting delivery to Hawaii from MIT-Lincoln Labs of 3 CCDs required to complete the array - fabrication of the CCDs has proved to be a much slower process than was originally expected. Subject to the delivery of these CCDs (over which we have no control), first images with WFI should be obtained during the second quarter of 2000.



The Wide Field Imager dewar

OzPoz and ANDES

The OzPoz fibre positioner being built for the European Southern Observatory's Very Large Telescope (VLT), with Colless and Taylor* as PIs, passed both its Preliminary and Final Design Reviews during 1999. OzPoz will be deployed with the FLAMES optical spectrograph to study distant galaxies and faint stars. and will be commissioned on the second of the four 8m-class telescopes that comprise the VLT during 2001.

The Australia-Netherlands Deep Extragalactic Spectrograph (ANDES) is a near-infrared spectrograph intended to complement FLAMES. The main scientific focus of ANDES is the study of galaxies as they are formed in the early Universe. ANDES is a collaboration between Colless, Taylor*, Couch* in Australia and de Zeeuw* and Franx* in the Netherlands. ANDES received a boost during 1999, when it received major funding from an ARC RIEF program.

A CCD Camera for the UK Schmidt Telescope

A CCD camera for use with the UK Schmidt Telescope (UKST) is being built by Brown* (Apogee Instruments) for Kawara*, Nakajima* and Peterson. It will have two thinned 2k by 4k CCDs forming a 4k by 4k mosaic covering 1.1 by 1.1 degrees on the sky with 1 arcsecond square pixels. The camera fits inside a modified plateholder and is thermoelectrically cooled. The camera will work in a driftscan mode and in the usual shuttered mode using software developed by Downey* (Clear Sky Institute).

The initial filter set consists of UBVRIZ filters in a remotely controlled filter changer being built at Mt Stromlo Observatory. The VRI filters have multilayer coatings to provide a sharp cut-off at the long wavelength band edge. A set of SDSS filters for the camera is being considered by the AAO and a second filter changer is being built for an SDSS filter set.

In order to facilitate the use of the camera, Kawara, Nakajima and Peterson have commissioned Harvey* (Cornsoft) to upgrade the UKST drive system by providing digital encoders, software and digitally controlled drive amplifiers for the right ascension and declination drives. In addition to correcting in software the 2 arcsecond (peak-to-peak) periodic drive error, the drive upgrade will provide telescope position information for incorporation into the FITS headers of the camera images. Oyabu* has developed and tested Remote Procedure Call (RPC) client-server software that can allow any computer networked with the camera computer to obtain the telescope position information via an RPC.

The initial plan for the camera is a multicolour drift scan survey along the celestial equator between –3 degrees and +3 degrees declination, at galactic latitudes greater than 45 degrees.

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CICADA

Continuing effort was put into MSSSO's data acquisition software CICADA during 1999. Demonstrations of the simulation part of the acquisition software and the pipeline data reduction package were performed satisfactorily at the WFI science workshop in October. Due to delays in delivery of CCDs for the WFI, finishing up aspects of WFI support in CICADA will be completed in 2000.

Gemini Near-Infrared Integral-Field Spectrograph (NIFS) Conceptual Design Study

Australia is a member of the International Gemini Telescope Project, which is constructing two 8 m telescopes in Hawaii and Chile. This consortium provides Australian astronomers with their only assured access to 8 m class telescopes. As part of this membership, Australia has the right and the responsibility to contribute to the instrumentation program for these telescopes. RSAA proposed to the March 1999 Gemini Instrument Forum meeting to design, construct, and commission a fast-track, near-infrared, integral-field spectrograph for use with the ALTAIR adaptive optics system on Gemini North. The intention is to make a specialized instrument available to the Gemini scientific community on the shortest possible timescale by re-using much of the effort already invested by the University of Hawaii in designing the Gemini Near-Infrared Imager (NIRI). Consequently, the Near-infrared Integral-Field Spectrograph (NIFS) was proposed as a collaboration between RSAA and the Institute for Astronomy (IfA) of the University of Hawaii, where IfA is responsible for duplicating the NIRI cryostat, On-Instrument Wavefront Sensor, and control system for use in NIFS. The Gemini Instrument Forum endorsed the proposal and a Workscope to perform the Conceptual Design Study for the instrument was subsequently signed by ANU and the International Gemini Project Office in August 1999. This design study occupied much of the RSAA engineering effort during the latter half of 1999. The Conceptual Design Review for NIFS is scheduled for March 2000 with a Critical Design Review in September 2000 and commissioning on Gemini North planned for mid-2002. Fast-tracked construction of sections of the instrument is scheduled to begin in early 2000.

NIFS is designed to take advantage of the large light gathering power of the Gemini telescope and the superb image quality that will be achieved at near-infrared wavelengths by the use of a sophisticated facility adaptive optics system, ALTAIR. This system corrects image blur due to the Earth's atmosphere so that near-diffraction-limited images result. NIFS will perform near-diffraction-limited imaging spectroscopy at near-infrared wavelengths. In practice, this means NIFS will use a complex, reflective integral-field unit to measure the 1-2.5 micron spectrum of every 0.1"x0.1" spatial element in its 3"x3" field-of-view.

NIFS will be ideally suited to studying the dynamics of various dust-obscured nuclear components of nearby galaxies. Measurements of the stellar velocity dispersions in the obscured nuclear regions of late-type spiral galaxies can be made from spectra of the 2.3 micron CO first-overtone absorption bandheads. These data constrain the mass of material interior to the sampled radius, and this will allow NIFS to survey nearby galaxies for evidence of massive nuclear black holes which are the expected remnants of quasar activity during the early evolution of galaxies at redshifts of z=2-3. Measurement of the mass-to-light ratios, M/L_K, in obscured nuclear stellar populations based on NIFS spectra will provide age estimates for these populations and hence provide a unique probe the evolutionary histories of the central regions of late-type spiral galaxies and of other obscured galaxies undergoing intense starbursts. Measurements of the morphologies, kinematics, and excitation conditions of the narrow-line regions of nearby Seyfert galaxies will provide new information on how Seyfert galaxy radio jets interact with the interstellar medium of the host galaxy and how nuclear star formation and Seyfert activity are related in these objects. At redshifts of z~1, NIFS will be able to measure the strong optical H-alpha emission-line redshifted into the near-infrared. NIFS will measure spatially-complete H-alpha rotation curves for z~1 disk galaxies, and so address questions such as do disk galaxies at z~1 undergo ordered rotation like nearby spiral galaxies, are the star formation rates in z~1 disk galaxies enhanced relative to nearby galaxies, and do z~1 disk galaxies of various luminosities follow the same Tully-Fisher relation between rotational velocity and luminosity as nearby galaxies? Indications of the answers to these questions exist already. NIFS will be help find definitive answers to these and many other fundamental problems.

GRADUATE PROGRAM IN ASTRONOMY AND ASTROPHYSICS

REPORT OF THE GRADUATE PROGRAM FOR THE YEAR TO 15 DECEMBER 1999

Enrolments and Submissions

In the leadup to the 1999 academic year, we made 4 offers of APAs, two with Endowment for Excellence top ups. An outstanding student from Flinders University declined our APA with top up, deciding to stay in physics, and went to Melbourne University. A student from Wollongong declined, choosing to go for an applied physics project at his home university, while a student from Monash declined in favour of an offer from the University of Texas. One offer with top up was accepted. Marc Metchnik comes from the University of Queensland with first class honours in computer science and mathematics, a university medal (1997) and MIM Prize in computer science for the top honours student (1997). He is also our 1998 Duffield scholar. The School offered 4 ANU PhD scholarships which were accepted. Sebastian Gurovich (BSc Hons UWS), Rachel Moody (BSc Hons ANU), Jess O'Brien (BSc Hons Melbourne) and Holly Sims (BSc Hons ANU) have all commenced in 1999.

An offer of an OPRS was made to a student from Case Western Reserve University in Cleveland, but she decided to stay in the US for domestic reasons and declined in favour of the University of Arizona.

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Three students submitted theses during 1999:

Roberto Soria (August) “Accretion inflows and outflows in black-hole candidates”. Roberto has been offered a post doc position at Leicester University.

(David) Heath Jones (August) “Tunable filter surveys of star-forming galaxies”. Heath is now a postdoc with the European Southern Observatory in Santiago, Chile.

David Pfitzner (December) “The Structure of Halos in CDM Universes”.

Tavis Hamer requested and was granted suspension from the Graduate Program in October 1998 for reassessment of his career options. He was due to return from suspension in July 1999. We have been informally advised that he wishes to withdraw from the course, and continue to follow this up.

Ian Price has sought and been granted a suspension for 6 months.

Currently, there are 13 students on course in the program (* denotes an international student):

1996	1997	1998	1999
Lisa Germany	Mary Putman*	Greg Wilson	Sebastian Gurovich
Andrew Drake	Stefan Keller		Marc Metchnik
Lisa Kewley	Michelle Buxton		Rachel Moody
Oak-Kyoung Park*			Jess O’Brien
			Holly Sims

Lecture Courses

A major new development this year was the start of an Astrophysics Honours program in the Faculties. Although this program is not formally part of the Astronomy and Astrophysics Graduate Program, it is convened by Paul Francis who holds a joint appointment in the Physics Department of the Faculties and at the RSAA, and most of the lectures and honours project supervision were provided by RSAA staff. The Astrophysics Honours program started in 1999 with five very good Honours students, all from outside the ANU. Four of them have applied to our graduate program for 2000 and are likely to be accepted. A very able Graduate Diploma student from Thailand also participated in much of the program. His application for an IPRS at ANU was unfortunately not successful, but he has been offered an IPRS at Sydney University.

As in previous years, RSAA and SMS staff gave a series of lectures on core astrophysics subjects, which our graduate students must take if they have not already done so as ANU undergraduates. Most of these courses double as third year undergraduate courses in mathematics and physics, and fourth year courses for the Astrophysics Honours program. RSAA staff also give undergraduate astrophysics courses at first and second year level in the Physics department.

Summer Research Scholar Program

Another very successful Summer Research Scholarship program, convened by Dr Charlene Heisler, was run during the 1998-99 summer vacation. Eight undergraduates from Australian and New Zealand universities participated for about 8 weeks working on projects supervised by MSO staff. Also included in the program were a series of lectures and a tour of the major observatory sites in NSW. Several of the 1998-99 summer scholars decided to stay on as the first students in the Astrophysics Honours program. The 1999-00 Summer Research Scholar program has commenced, convened by Dr Robert Smith, with 7 scholars from Australian universities taking part.

Monash Collaboration

The educational collaboration between the Mathematics Department at Monash University and Mount Stromlo Observatory continued this year. As before, a group of approximately 30 third year students from Monash visit for lectures and observational experience on the 74-inch telescope. The data reduction tasks were supervised by Robert Smith and Carole Jackson. In addition, a group of five Monash Honours students, supervised by Brian Schmidt and Gary Da Costa, were taken on an observing trip to Siding Spring Observatories, and did a small observing project using data collected at the MSO 2.3m. This collaboration provides a steady source of applicants to our Graduate Program (3 highly qualified applicants for commencement in 2000).

The Harley Wood School of Astronomy and the ASA Annual Meeting

The Harley Wood School and the annual scientific meeting of the Astronomical Society of Australia were held in Sydney this year, in early July. These are important occasions for our students, and each year we send as many as we possibly can. It gives the students the opportunity to meet with graduate students and astronomers from other universities, and to take part in a focussed series of graduate-level lectures.

The Alex Rodgers Travelling Scholarship

Funds for this scholarship come from an endowment made in 1998 to the ANU's Endowment for Excellence by Mrs Ruth Rodgers, in memory of her husband the late Professor Rodgers, Director of MSSSO from 1987-92. The scholarship is to assist a currently enrolled student in the Graduate Program in Astronomy and Astrophysics to travel abroad to attend scientific meetings and/or to work with astronomers at another institution on some chosen research project of direct relevance to the thesis work being undertaken. Mary Putman is the first holder of this travelling scholarship. She is working at the Johns Hopkins University on data from the FUSE satellite, and will visit the University of Groningen to discuss a collaborative project on compact high velocity clouds.

Recruitment Activities

In addition to our Monash collaboration, the convenors went on recruitment trips to Harvard and Monash. We hope to get an occasional student out of Harvard, and a steady stream of students from Monash. We also tried to pay close attention to the many enquiries from overseas students about our graduate program during 1999, and we were able to propose five candidates for IPRS awards: two remain on the active list. Applications from Australian students were also strong, and we have nine very good candidates for APAs.

1999 Board of Studies

The current Graduate Program Convenor, Ken Freeman, operates the program with the assistance of a Co-Convenor, Brian Schmidt. The Convenor's suggestion that the position of Co-Convenor be made an ex officio member of this committee was endorsed.

Membership of the Board of Studies now comprises:
* four ex officio members (the Director, the Graduate Program Convenor and Co-Convenor, and the Convenor of the RSAA Summer Research Scholar Program),
* four elected RSAA staff including one position for an RSAA postdoc (new for 1999),
* one staff member external to the School, and
* four student members.

The membership for the Board for 1999 was:

Director, RSAA: Jeremy Mould
Convenor, Graduate Program in Astronomy & Astrophysics: Ken Freeman
Co-Convenor, Graduate Program in Astronomy & Astrophysics: Brian Schmidt
Convenor, RSAA Summer Research Scholar Program: Charlene Heisler
Elected Staff members: Tim Axelrod RSAA, Lilia Ferrario SMS, Paul Francis RSAA/Physics, Maartje Sevenster (postdoc RSAA)
Student members: Michelle Buxton, Lisa Kewley, Mary Putman, Stefan Keller

Concluding Comments

The Convenor of our Summer Research Scholar Program, Charlene Heisler, died late in 1999. Charlene was an inspirational individual and will be greatly missed.

I would like to put on record the contributions of Dr Paul Francis to the Astrophysics Honours program which began this year. Although this program is not formally part of the Astronomy and Astrophysics Graduate Program, it has already made a substantial impact on the Graduate Program in several ways: a large and lively body of students in the advanced lecture courses, a significant increase in the number of students doing research projects at RSAA, and a group of enthusiastic and well-qualified applicants for the PhD program in 2000.

It was again a pleasure to work with Co-Convenor Brian Schmidt and RSAA School Secretary Gay Kennedy: I am very grateful to Gay for all that she does in keeping our Graduate Program functioning and in making the job of the convenor and co-convenor so much easier.

Kenneth Freeman
Convener, Graduate Program in Astronomy and Astrophysics

VISITORS TO THE OBSERVATORIES AND COLLOQUIA

Visitors to Mount Stromlo Observatory

Hon. Gary Humphries, ACT Member of the Legislative Assembly
His Excellency Bernhard and Mrs Lisbeth Marfurt, Ambassador of Switzerland
Dr Jim Reilly, National Aeronautics and Space Administration

Colloquium Speakers

Jeremy Bailey (AAO)
Tim Bedding (U. Sydney)
Albert Bosma (Marseille)
Terry Bridges (AAO)
Jessica Chapman (ATNF)
Martin Cohen (UC Berkeley)
Gavin Dalton (Oxford)
Noella D'Cruz (Sydney)
Roberto de Propris (UNSW)
Vikram Dwarkadas (Sydney)
Matthias Ehle (MPE Garching)
Sara Ellison (Cambridge)
Chris Fluke (Swinburne)
Roger Fux (RSAA)
Karl Glazebrook (AAO)
David Hanes (AAO/Queen's)
Olivier Hainaut (ESO)
Martin Harwit (Washington DC/Cornell)
Andrew Hopkins (U. Sydney)
Mizuhiko Hosokawa (Tokyo/ATNF)
Trung Hua (Marseille)
Lucyna Kedziora (AAO)
John Kormendy (U. Hawaii)
Jochen Liske (UNSW)
Leon Mestel (University of Sussex)
Tadashi Nakajima (NAO Japan)
Jeremy Mould (RSAA)
Ray Norris (ATNF)
Jim Oschmann (Gemini)
Phil Puxley (International Gemini Project)
Penny Sackett (Groningen)
Martin Sperl (Vienna)
Peter Tuthill (U. Sydney)
Piet van der Kruit (Groningen)
Jasper Wall (University of Oxford)
John Webb (UNSW)
Robert Williams (STScI)
Kinwah Wu (U. Sydney)
Yuzuru Yoshii (Tokyo)

VISITING OBSERVERS ON ANU TELESCOPES

Albrow, Dr M	South African Astronomical Observatory
Balona, Dr L	South African Astronomical Observatory
Baker, Dr J	UC Berkeley
Begam, Mr M	University of Virginia
Bennett, Dr D	Notre Dame University
Bignell, Ms H	University of Adelaide
Bland-Hawthorne, Dr J	Anglo-Australian Observatory (AAO)
Boyle, Dr B	AAO
Breger, Mr M	Vienna Astronomy Institute
Bremer, Dr M	University of Bristol
Burston, Dr A	University of Leicester
Burton, Dr M	University of New South Wales (UNSW)
Butler, Dr N	Notre Dame
Butler, Dr J	Armagh University
Byun, Dr Y	National Central University, Taiwan
Cally, Dr P	Monash University
Cameron, Dr AC	University of St Andrews
Carswell, Dr R	Institute o Astronomy, Cambridge
Carter, Dr B	University of Southern Queensland
Cheng, Dr K	California State University
Chun, Dr MS	Yonsei University, Korea
Colley, Mr S	University College London (UCL)
Cook, Dr K	Lawrence Livermore Labs
Corbett, Dr E	Anglo-Australian Observatory
Couch, Dr W	University of New South Wales (UNSW)
Croom, Dr SM	ICSTM
Cropper, Dr M	University College London
Dalton, Dr G	Oxford
Davies, Dr R L	University of Durham
D'Cruz, Dr N	University of Sydney
Deeley, Ms K	UNSW
De Propris, Dr R	UNSW
De Blok, Dr E	University of Melbourne
De Silva, Dr E	Cambridge
Fernandez-Soto, Dr A	UNSW
Ferrara, Dr E	Georgia State University
Flynn, Dr C	Turku University
Fox, Dr R	Arizona State University
Frederick, Dr L	University of Virginia
Galloway, Mr D	University of Tasmania
Geha, Dr M	Lawrence Livermore Labs
Greenhill, Dr J	University of Tasmania
Glazebrook, Dr K	Anglo-Australian Observatory
Harrop-Allin, Dr K	University College London
Hua, Dr C-T	CNRS, Marseille
Hunstead, Dr R	Sydney University

Ianna, Dr PA	University of Virginia
James, Dr D J	University of St Andrews
James, Dr S	Australian Defence Force Academy
Johnston, Dr H	Anglo-Australian Observatory
Jones, Dr L	University of New South Wales
Kanbach, Dr G	Max Planck Institute
Kawanamoto, Dr S	University of Tokyo
Kedziora-Chudczer, Ms L	Australia Telescope National Facility
Kotoneva, Dr E	Turku University
Kregel, Mr M	Kapteyn Astronomical Institute
Lattanzio, Dr J	Monash University
Larson, Dr S	University of Arizona
Laws, Dr C	University of Washington
Lawson, Dr W	ADFA
Lazendic, Ms J	Sydney University
Lee, Mr J-K	UNSW
Leuftinger, Ms T	University of Vienna
Liang, Dr H	University of Bristol
Liske, Mr J	UNSW
McIntyre, Mr V	University of Sydney
Marsden, Mr S	University of Southern Queensland
Massey, Mr S	Amateur
Meurer, Dr G R	Johns Hopkins University
Miller, Dr HR	Georgia State University
Mittermayer, Mr P	University of Vienna
Mottola, Dr S	DLR, Berlin
Murphy, Mr M	UNSW
Nakada, Dr Y	University of Tokyo
Neff, Dr J	University of Charleston, SC
NHK Television	Japan
Norris, Dr R	ATNF
Oberst, Dr J	DLR, Berlin
O'Neill, Mr P	ADFA
O'Toole, Mr SJ	University of Sydney
Palunas, Dr P	NASA, Goddard Space Flight Centre
Penney, Ms N	Macquarie University
Prinja, Dr R	UCL
Prouton, Dr O	Imperial College, London
Quinn, Dr J	Notre Dame
Ramsay, Dr G	UCL
Reiss, Mr D	University of Washington
Rhie, Dr S H	Notre Dame
Sadler, Dr E M	Sydney University
Saunders, Dr E	Cambridge
Shobbrook, Dr R R	retired
Sood, Dr R	ADFA
Sperl, Dr M	Universitaet Wien, Austria
Stankov, Dr A	Vienna Astronomy Institute
Straubmeier, Dr C	Max Planck Institute

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Stubbs, Dr C	University of Washington
Sullivan, Dr D	Victoria University of Wellington, NZ
Sung, Dr EC	Korea Astronomy Observatory
Sung, Dr H	Seoul National University
Tanabe, Dr T	University of Tokyo
Ten Bummelaar, Dr T	Georgia State University
Theissen, Dr A	Armagh University
Van der Kruit, Dr PC	Kapteyn Astronomical Institute
Vaughan, Dr A	Macquarie University
Walker, Dr M	Sydney University
Ward, Dr M	University of Leicester
Warren, Dr S	Imperial College London
Webb, Dr J	UNSW
Weiss, Dr WW	University of Vienna
Whiting, Mr MT	University of Melbourne
Woodings, Mr S	University of Western Australia
Wright, Dr A	ATNF, CSIRO
Wu, Dr K	University of Sydney
Zezas, Mr A	University of Leicester

HONOURS, AWARDS AND GRANTS

Prof. M Bessell
ANSTO grant for IR observing at Sutherland, South Africa.

Dr G Bicknell
ARC Large Grant, 1999-2001.

Dr M Colless
Australian Academy of Science/Royal Society Exchange Program grant of $4,250 for collaborative research with Prof R S Ellis (Cambridge) and others on the 2dF Galaxy Redshift Survey.

ARC Research Infrastructure, Equipment and Facilities grant of $500,000 for ANDES (the Australia-Netherlands Deep Extragalactic Spectrograph) with Dr K Taylor (AAO), A.Prof W J Couch (UNSW), Prof T de Zeeuw (Leiden) and Prof M Franx (Leiden).

ANU Major Equipment Committee grant of $100,000 for ANDES.

Dr G Da Costa
Travel funds of approximately $12,000 from the ARC/USydney Gemini Travel Fund to cover costs associated with attending, as Australian Gemini Project Scientist, four International Gemini Project meetings during 1999.

Dr P Francis
Joint winner of the 1999 Fresh Science prize for Science Communication (awarded at the National Science Forum).

$3,265, Faculties Research Grant. “Galaxy Populations within High Redshift Galaxy Clusters”.

$2,874. ANSTO “Access to Major Research Facilities” grant “Galaxy Populations within High Redshift Galaxy Clusters”.

Dr R Fux
Swiss Society of Astronomy and Astrophysics travel grant - Geneva Astronomy Commission travel grant.

Dr C Jackson
IAU travel grant (Nov 1999) (US $950) to attend IAU 199 “The Universe at low radio frequencies”, held in Pune, India.

Dr H Jerjen
Research Fellow of the Swiss National Science Foundations (1997-2000).

Mr S Keller
DIST Hubble Space Telescope Research Grant: $3,850.
IAU Grant of $US 500 to attend IAU Symposium 175.
ANSTO Access to Major Facilities Grant: $3,180.

Ms L Kewley
$2,000 French Service Culturel & Scientifique, for accomodation whilst visiting l’Institute d’Astrophysique de Paris.

Prof J Mould
Danks Trust, $4,000.
Tattersalls Holdings, $17,500.
Rothschild Australia, $12,500.

Prof J Norris
John W. Cox Visiting Senior Research Fellow in Astronomy, U.Texas at Austin, May – July 1999.

Dr B Schmidt
Finalist, Eureka Prize, Outstanding Research in Australia .

Visiting Scientist award of $500 from Monash University Mathematics Dpt in August.

Japanese Society for the Promotion of Science Visiting Professorship to the University of Tokyo for $18,000.

ANSTO Access to Major Facilities: Award of $2,720 for travel to Chile in January.

DITAC International Science and Technology Program: Space Science with the Hubble Space Telescope award of $2,778 for travel to U.S.A in May/June.

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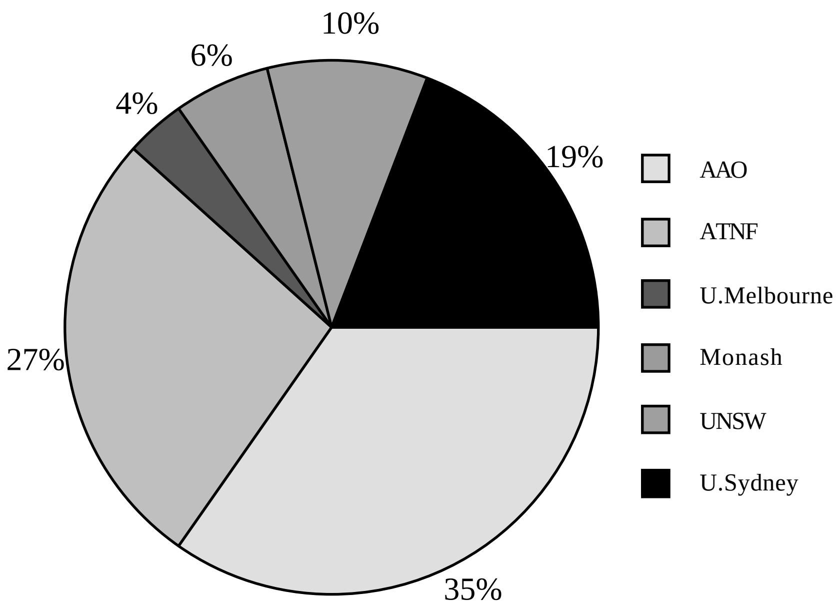
ANSTO Access to Major Facilities: Award of $2,260 for travel to Hawaii in October/ November.

Dr M Sevenster
ANSTO grant of A$3000 to observe with the IRAM 30m antenna, Granada, Spain
URSI grant of US$500 to attend the General Assembly, Toronto, Canada

Dr P Wood
$1,833 from University of Vienna to attend the 2nd Austrian ISO Workshop.

EXTERNAL COLLABORATIONS

Twenty-four RSAA astronomers took part in 114 international and Australian collaborations during 1999. Reported collaborations with Australian institutions are shown in the accompanying diagram. A full listing of external collaborations is given in the ANU Annual Report for 1999.



CONFERENCES ATTENDED

Dr T Axelrod
TAOS and Variable Star Astronomy, Academia Sinica, Taiwan, 25-26 February
Invited Paper: “Photometry for TAOS”.

Prof. M Bessell
ASA AGM and conference at University of Western Sydney, July.

Workshop on Convection Treatment in Model Atmospheres: Observatoire de Meudon, Paris, May 31 - June 2.
Paper on Problems with Hydrogen Line Profiles in Subdwarf Stars.

Workshop on Massive Star Clusters: Observatoire de Strasbourg, Strasbourg, November.
Paper (with S Keller) on “Young Populous Star Clusters in the Magellanic Clouds”.

High Dispersion Spectrograph for Subaru meeting in Tokyo, Japan, December.
Paper on “The Oxygen Problem in Halo Subdwarfs”.

Outside Studies Program at the South African Astronomical Observatories 1 September - 25 November
Lecture on Beauty and Astrophysics, University of Cape Town.
Lecture on Beauty and Astrophysics, SAAO.
Lecture on Massive Star Clusters in the Magellanic Clouds, SAAO.

Dr G Bicknell
Lifecycles of Radio Galaxies, Space Telescope Science Institute, Baltimore, Maryland, USA, July 15 – 17, 1999. Keynote Address: “Connections between Jet Physics and the Properties of Radio Loud and Radio Quiet Galaxies”.

Some Highlights in Astronomy and Astrophysics, Mt Stromlo Observatory, October 30 – September 1, 1999. Invited Talk: “The ISM of Seyfert Galaxies: Connections with Jet Physics and Radio Loud/Radio Quiet Galaxies”.

4th AGN Workshop, Mt Stromlo Observatory, December 8 – 10, 1999. Contributed Talk: “Analysis of X-Ray and TeV data on Markarian 501”.

Workshop on High Energy Astrophysics, Max Planck Institut für RadioAstronomie, Bonn, July 7, 1999: “The X-Ray and TeV emission from Markarian 501”.

Colloquia at External Institutions:
Sonderforschungbereich, Heidelberg, June 24, 1999: “Diagnostics of AGN from Shock-excited Line Emission”.
Instititute for Space and Astronautical Sciences (Nov. 30) and the Institute for Cosmic Ray Research (Dec. 2): “Analysis of X-Ray and TeV data on Markarian 501”.

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Ms M Buxton
Supernova Remnants, Pulsars and the ISM, Special Research Centre for Theoretical Astrophysics, U.Sydney, 18-19 March.

Harley Wood Winter School, Katoomba, 5 – 8 July.

Astronomical Society of Australia Annual Meeting, UWS Nepean, 9–13 July. Oral presentation, "An Optical Spectroscopic Study of the Black Hole Candidate GX 339-4", M. Buxton, S. Vennes.

Science with the Wide Field Imager, RSAA, 14-15 October.

Dr M Colless
AAO/ATNF Symposium, 24 March 1999, Sydney, Australia, Talk: "First Results from the 2dF Galaxy Redshift Survey''.

Rencontres Internationales IGRAP, Clustering at High Redshift, 29 June - 2 July 1999, Marseilles, France, Invited Review: "Clustering at Low Redshift''.

Herzberg Institute of Astrophysics, Cosmic Flows: Towards an Understanding of Large-Scale Structure, 13-17 July 1999, University of Victoria, Canada, Talk: "EFAR Peculiar Velocities and Bulk Motions''.

Second Coral Sea Cosmology Conference, Redshift Surveys and Cosmology, 24-28 August 1999, Dunk Island, Australia, Talk: "The 2dF Galaxy Redshift Survey - Overview''.

RSAA/AAO Workshop, Science with the Wide Field Imager, 14-15 October 1999, Canberra, Australia, Talk: "Surveys with WFI and 2dF''.

Dr G Da Costa
Annual Meeting, Astronomical Society of Australia, UWS-Nepean, Penrith, 12 July, Invited Presentation: "Gemini Update and the Step beyond Gemini - a ~50m Aperture Telescope?", Da Costa, G.

Science with the Wide Field Imager Workshop, Mt Stromlo, 14-15 Oct, Invited Presentation: "The Wide Field Imager and its use on the SSO 1m telescope", Da Costa, G.

Dr M de Kool
Annual Scientific Meeting of the ASA, Penrith, 9-12 July. Presentation: "Where are Intrinsic QSO Absorption Lines formed?", de Kool, M, Arav, N, Becker R.

4th Annual Stromlo AGN Workshop, Canberra, 8-10 December Presentation: "High speed clouds in Active Galactic Nuclei", de Kool, M.

Other lectures:
Colloqium at IGPP, LLNL, Livermore, USA, October.
"The Iron LoBAL FIRST 1044+3656: Implications for the scale of QSO outflows".
Colloquium at the Physics Department, UWM, Kalamazoo, USA, 1 November
"Winds from Active Galactic Nuclei".

Prof. M Dopita
14-16 April. invited speaker, Conference on Astrophysical Dynamics, Evora, Portugal. Paper given: “The Dynamics of Gas around Active Galactic Nuclei”.

3-6 August. invited speaker, conference on Assymetrical Planetary Nebulae II, Boston. Paper given: “Do the Nuclei of Elliptical Galaxies Eat Planetary Nebulae?”.

25-29 October. conference on Astrophysical Plasmas, Mexico City.
Paper Given: “Photoionisation and Shock Modelling of the HII region Abundance Sequence and of Luminous Infrared Galaxies”.

Dr P Francis
ScienceNow! National Science Forum, Melbourne 6-9th May (invited talk “Black Holes are Pink”, Francis, P J, Webster R L, Drinkwater M J).

Astronomy Education for the New Millenium, University of Western Sydney (Nepean), 11th-13th July 1999 (talk “Using Role Playing Games to Teach Undergraduate Astronomy”, Francis P J, Byrne A P).

Redshift Surveys and Cosmology, the Second Coral Sea Cosmology Conference, Dunk Island, 24-28th August.

Cosmic Evolution and Galaxy Formation, the 3rd Guillermo Haro Astrophysics Conference, Puebla Mexico, 15-19th November.

Seminars:
NASA Goddard Space Flight Center
Space Telescope Science Institute
State University of New York
Princeton University

Outreach:
Dr Paul Francis gave 4 lectures at CCE evening classes in astronomy, three talks on astronomy at various schools, and conducted one teacher in-service education session. He also wrote a popular level article on black holes for *Australasian Science* magazine, gave 8 radio interviews, 7 public lectures, and his work appeared in many newspapers including: *The Australian, The Herald Sun, The West Australian, The Sunday Times* (UK*), The Guardian* (UK), *The Sun* (UK), *Gazeta Wyborcza* (Poland), *Yomiuri Shimbum* (Japan), *La Hora* (Chile), *San Jose Mercury News* (USA), *Natur & Vetenskap* (Sweden), and other papers in Brazil, USA and France. It also appeared in many on-line news sites around the world.

Dr R Fux
15th IAP meeting, “Dynamics of Galaxies: from the Early Universe to the Present”, Paris, 9-13 July.
MSO Workshop, “Some Highlights in Astronomy and Astrophysics”, Canberra, 30 September-1 October.
Contributed talk: “Local Stellar Streams and the Global Dynamics of the Milky Way”.
Seoul and Pusan National Universities, South Korea, 7-13 September.
Invited seminars: “Dynamics of the Barred Milky Way from N-Body and SPH Simulations” and lectures: “PMDSPH: a Hybrid N-Body and SPH Code”.

Dr C Jackson
AAO-ATNF Joint Symposium, Sydney,
Poster paper:”The spectral characteristics of the 2dFGRS-NVSS Galaxies”.

Coral Sea Cosmology Conference II: Redshift Surveys & Cosmology, Aug 24-28 1999, Dunk Island, Australia.
Oral Paper: “Radio Source Cosmology with the 2dF surveys and beyond”.

IAU 199: The Universe at low radio frequencies, Nov 30 - Dec 4 1999, Pune, India.
Invited Paper: “Radio Source Evolution derived from low-frequency surveys”.

Science meets Parliament 23-24 Nov 1999, Federation of Australian Science and Technology societies, participant.

Dr H Jerjen
Invited Talk: “Cluster, Group, or Cloud? How the Surface Brightness Fluctuations can tell the Difference”, Jerjen, H, Freeman, K C, Binggeli, B, Astronomical Institute of the University of Basel.

Mr S Keller
IAU Symposium 175: The Be Phenomenon in Early-Type Stars, Alicante, Spain.
Poster paper: “Be Stars in the Magellanic Clouds”, Keller, S.C., Bessell, M. & DaCosta, G.

Ms L Kewley
Astronomical Society of Australia Scientific Meeting, University of Western Sydney.
Contributed talk: “Luminous IRAS Galaxies: Monsters or Babes? “, Kewley, L J, Heisler, C A, Dopita, M A, Sutherland, R, Norris, R P.

4th Stromlo AGN Workshop.
Contributed talk: “Shock and Photoionisation Modelling of Luminous IRAS Galaxies”, Kewley, L J, Heisler, C A, Dopita, M A, Sutherland, R, Norris, R P.

The Elizabeth and Frederic White Conference on Radio Frequence Interference Mitigation Strategies.
Contributed Talk: “Interference Excision Using the Parkes Multibeam Receiver”.

Prof J R Mould
American Astronomical Society Centennial Meeting - May 1, “Combining the Constraints on the Hubble Constant”.

Caltech Astronomy Monday Tea - April
UCLA Astronomy Colloquium - April
University of Hawaii Astronomy Colloquium - June
University of Durham, Physics & Astronomy Colloquium - September 8, “Cosmological Implications of the Key Project on the Hubble Constant”.

Astronomical Society of Australia - July .
Some Highlights in Astronomy & Astrophysics - September “H_0 t_0= 1”.

Coral Sea Cosmology Conference II - August 24, “The Hubble Constant”.

Astronomical Society of New South Wales - March 20, “The Expanding Universe”.

Space Science Update, NASA Headquarters - May 25, “Hubble Completes 8 year effort to measure Expanding Universe”.

Mensa Australia AGM – November.
Mount Stromlo Astronomy Summer School - December 14, “How Big is the Universe and how Old ?”.

Australian Institute of Physics - September 28, 31st Pawsey Memorial Lecture, “The Expanding Universe”.

Wide Field Imaging Workshop - October 15, “Identification of the Galaxy’s Missing Mass”.

Prof J Norris
Anglo-Australian Observatory/Australia Telescope National Facility Joint Symposium, Sydney, March. Paper: “The Lithium Spite Plateau: Ultra Thin but Post Primordial.”

The American Sstronomical Cociety Centennial Meeting, Chicago, June. Paper: “The Lithium Spite Plateau: Ultra Thin but Post Primordial.”

SUBARU Workshop: Stars & Galaxies: Decipherment of Cosmic History with Spectroscopy, Tokyo, December. Invited paper: “High-resultion, High-S/N Spectroscopy of Stars with [Fe/H] <-3.5”.

Colloquium, University of Texas at Austin, July, “The Enrichment of Omega Centauri”.

Dr B Schmidt
Harvard-Smithsonian OIR seminar, “SN 1997cy: A GRB in Supernova Clothing?”, April, Cambridge, Massachussetts, USA.

Space Telescope Symposium on GRB and Supernovaem “The Accelerating Universe”, May, Balitore, Maryland, USA.

National Science Week Public Talk “Measuring the Universe”, May, Canberra, ACT.

David Schramm Memorial Cosmology Symposium, “The Accelerating Universe”, May, Fermi National Lab, Batavia, Illinois, USA.

The American Astronomical Society, “The Hubble Constant with Supernovae”, June, Chicago, Illinois, USA.

The Aspen Centre for Physics, “Systematic Error in Supernovae”, Aspen, June, Colorado, USA.

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Motions in the Nearby Universe Conference, “Using Supernovae as Distance Indicators”, July, Victoria, British Columbia, Canada .

Monash University Physics Colloquium, “Measuring the Universe with Supernovae”, August, Melbourne, Victoria.

University of Tokyo Galaxy Evolution Seminar, “How many Supernovae”, September, Tokyo, Japan.

University of Tokyo Astronomy Colloquium, “Measuring the Universe with Supernovae”, September, Tokyo, Japan

National Observatory of Japan Astronomy Colloquium, “Measuring the Universe with Supernovae”, September, Mitaka, Japan

University of Sendai Astronomy Colloquium, “Measuring the Universe with Supernovae”, September, Sendai, Japan .

Kyoto University Yukawa Institute Colloquium, “Measuring the Universe with Supernovae”, October, Kyoto, Japan.

Science in the Pub, “The Age of the Universe”, November, Sydney, NSW.

Dr M Sevenster
ASA Annual Scientific Meeting, Sydney, 9-12 July, Talk: “An inner ring in the Galaxy”.

MIT Symposium, Aspherical Planetary Nebulae, Boston, August.

General Assembly, International Union of Radio Science, Toronto, 13-21 August, Invited talk: “Systematic searches for stellar spectral-line sources”.

AGN Workshop, Canberra, 8-10 December, Talk:”Global Properties of Inner-ring Barred Galaxies”.

Dr R Smith
2nd Coral Sea Cosmology Workshop, Dunk Island. Contributed talk: “The 2dF QSO Redshift Survey”.

4th Stromlo AGN Workshop, MSSSO. Contributed talk: “The 2dF QSO Redshift Survey”.

Mr R Soria
Workshop on Supernova Remnants, Pulsars and the Interstellar Medium, University of Sydney, March. Talk: “Emission Lines from Extended Atmospheres in X-ray Binaries”.

AAO/ATNF Joint Symposium, Sydney, March. Talk: “Low-Hard and High-Soft States of the Black-Hole Candidate GX339-4”.

Visit to CNR-Tesre, Bologna, December. Talk:"State Transitions in Black-Hole Candidates: the Optical-X-ray Connection".

Prof. DWN Stibbs
Workshop on Some Highlights in Astronomy and Astrophysics, held at MSO 30th September and 1st October. Invited Discourse. Prof DWN Stibbs, "Vorticity in the Velocity Field of the Galaxy: Camm's Method and the Rotation Curve ".

Mr G Wilson
ASA Harley Wood Winter School, Katoomba, 5-9th July.
Astronomical Society of Australia, Annual Scientific Meeting, Adelaide, 9-13th July.

Dr P Wood
2nd Austrian ISO Workshop: Atmospheres of M, S and C Giants: Vienna, 27-29 May. Invited Review: "Period-luminosity Laws, Angular Diameters and Pulsation Velocity Amplitudes for Red Variables: What's Wrong with Atmospheric Models?".

Asymmetrical Planetary Nebulae II, From Origins to Microstructures: MIT Cambridge, 3-6 August: Invited Talk + Poster Paper.

IAU Colloquium 176, The Impact of Large-Scale Surveys on Pulsating Star Research: Budapest, 8-12 August: Poster Paper.

Workshop on Some Highlights in Astronomy and Astrophysics, held at MSO 30th September and 1st October. Invited Talk: "Long Secondary Periods in Variable Red Giants: Investigating Single Star Solutions", Wood P and Li J.

Astronomical Society of Australia Annual Meeting, University of W. Sydney, July: Invited Talk.

National Gemini Office Training Course, Hilo, November.

Seminar, Astronomy Department, University of Vienna: "Variable Stars and Searches for Microlensing", May.

Interview on Blue Danube Radio, Vienna: Topic - " Microlensing Experiments", May.

Talk to Research Advisory Board, "MACHO Observations of Red Variables in the LMC", Canberra, October.

Talk to the Canberra Astronomical Society, "MACHO Observations of Red Variables in the LMC: Pulsating Stars and Binaries", Canberra, October.

Mr P Young
Astronomical Data Analysis Software and Systems IX, Kona, Hawaii, October.

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TEACHING/COURSES TAUGHT

Dr G Bicknell
High Energy Astrophysics (Maths 3054H) in the Department of Mathematics, Faculties.

Dr M Colless
RSAA Graduate Student lecturer, "Astrophysics from Spectra".

Dr P Francis
"Astronomy" (PHYS1009)
"Astrophysics for Physicists" (PHYS1011)
"Observational and Computational Astrophysics" (PHYS2023)
"The Big Questions" (PHYS1009)

Mt Stromlo Summer School (13-17 December)
Bicknell, Colless, Francis, Jackson, Mould and Sutherland lectured to year 10 students and helped with their evening observing sessions.

Dr P McGregor
"Observational Techniques" to Physics Honours students and RSAA First Year PhD students.

Profs. K Freeman and J Mould
C52H, Galaxies and Cosmology.

Dr B Schmidt.
"Observational Astronomy" (Physics 2023).
CCE Course "Astronomy by Astronomers".

Monash Visit
In collaboration with Schmidt, Heisler, Jackson, Smith and van der Steene, Da Costa arranged two 4 day visits (April and September) of approximately 30 Monash third year undergraduate astrophysics students. The students learnt basic observing and reduction techniques through use of the 74inch telescope. Da Costa also coordinated the visit (supervised by Schmidt) of 5 Monash fourth year (Honours) astrophysics students. The students carried out CCD observations with the 2.3m telescope to produce colour-magnitude diagrams for star clusters.

COMMITTEE SERVICE AND RELATED RESPONSIBILITIES

MEMBERSHIP OF EXTERNAL COMMITTEES

Prof. M Bessell
President, Australian Astronomical Society
Member, National Committee for Astronomy
Member, Executive, IAU Commission 29
Member, AAO Schmidt Telescope Panel
Reviewer, "New Zealand's Capability to build a spectrograph for SALT" (Nov 14-20)

Ms M Buxton
Student Rep, ASA Council (from July)
Treasurer, Postgraduate and Research Student Association
PARSA Rep. ANU Finance Committee
PARSA Rep. Postgraduate Student Loans Scheme
Member, Harley Wood Winter School Organising Committee

Dr M Colless
Chair, Scientific Organizing Committee and Local Organizing Committe, Second Coral Sea Cosmology Conference, Dunk Island, 24-28 August 1999
Chair, Advisory Committee on Instrumentation for the Anglo-Australian Telescope
Member, Australian Gemini Science Advisory Committee
Chair, 6dF Science Advisory Group

Dr G Da Costa
President, IAU Commission 37
Australian Gemini Project Scientist
Chair, Committee of Gemini Offices
Member, Gemini Instrument Forum
Member, Gemini Science Committee
Chair, Australian Gemini Science Advisory Committee
Member, Australian Time Allocation Committee
Member, Scientific Org Comm, Joint Disc 5 "Mixing and Diffusion in Stars: Theoretical Predictions and Observational Constraints", IAU Gen Assem, August 2000
Member, Scientific Organizing Committee, "Extragalactic Star Clusters", IAU Symposium proposal, Pucon, Chile, March 2001

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Prof. M Dopita
Member, NASA Science Oversight Committee for the Wide Field Camera-3
President, IAU Division VI & Commission #34 on Interstellar Matter. (1997-2000)
Chairman, IAU Executive Committee Working Group for the International Development of Antarctic Astronomy (1997-2000)
Member, Scientific Organising Committee, IAU Symposium #205, Galaxies and their Constituents at the Highest Angular Resolutions
Member, Scientific Organising Committee, IAU Joint Discussion #11, First Results of the FUSE Mission
Member, Board of Editors, Astrophysics and Space Science. (1993-1998)
Member, Visiting Committee of the Capodimonte Observatory
Member, Antarctic Astronomy Working Group (1993-)

Dr P Francis
Member, Astronomical Socity of Australia Education Sub-committee.
Consultancy: to design part of a WWW Astrophysics Course for Swinburne University

Dr R Fux
Member, IAU Commission 33, Structure & Dynamics of the Galactic System - Consultant for the National Geographic Society Millennium Map of the Milky Way

Dr H Jerjen
Coordinator, Optical follow-up program of the Parkes all-sky 21cm survey

Dr A Kalnajs
Chairman, AAS-DDA Brouwer Award Selection Committee
Member, Australia Telescope Time Allocation Committee

Dr P McGregor
Member, Editorial Board, Publications of the Astronomical Society of Australia
Member, Scientific Organising Committee, Eta Carinae and Other Mysterious Stars – The Hidden Opportunities of Emission-Line Spectroscopy, Sweden

Prof. J Mould
Chair, Anglo-Australian Telescope Board
Board Member, Association of Universities for Research in Astronomy Inc.
Member, Australian Academy of Science National Committee of Astronomy
Member, Australian Academy of Science National Committee on Space Research
Member, Australia Telescope National Facility Steering Committee
Member, National Committee for Space Science.
Member, Institute of Physics Publishing, Editorial Board *Encycl. of Astro & Astrophys*
Member, ACT Science & Technology Council
Fellow of the Australian Academy of Science

Dr M Sevenster
Member, Australia Telescope Users' Committee

MEMBERSHIP OF RSAA/ANU COMMITTEES

Faculty
All RSAA academic staff
Visiting, Adjunct and Honorary Fellows of the RSAA whose appointments are for not less than 6 months
Three student members of the RSAA elected by the RSAA graduate students [to be advised]
Under the category of "such other persons as the Faculty determines":
One member (Fellow or above) of the RSPhysSE chosen by the Faculty Board of RSPhysSE
One academic staff member of ANU not in RSPhysSE or RSAA chosen by Faculty [Dr McClelland was chosen]
The elected members of the RSAA Staff Consultative Committee

Faculty Board
Ex officio Director, RSAA: Professor JR Mould
Ex officio Associate Director(s): Professor MS Bessell, Professor JE Norris
The School's elected members of BIAS
Chair of Faculty (if not otherwise a member of the FB)

Computer Committee
Ex Officio: Head of Computer Section
Ex Officio: Head of Electronics or nominee
Reappointed to 31/3/01: Dr BP Schmidt, Dr TS Axelrod
Appointed to 31/3/01: Dr MN Sevenster
Reappointed last year, to 31/3/00: Dr P Wood (Chair), Dr A Kalnajs, Dr R Sutherland
Student Member for one year to 31/3/00: Mr G Wilson

Time Allocation Committee
Ex officio Assoc. Director for Observatory Operations (Professor JE Norris) (Chair)
Ex officio Convener, Grad Prog in Astronomy & Astrophysics (Professor Freeman)
Reappointed to 1/5/01: Dr PJ McGregor
Appointed to 1/5/01: Dr GC Van de Steene, Professor MA Dopita
Appointed last year to 1/5/00: Professor MS Bessell, Dr PR Wood
Two external members: one appointed to 1/5/01, Dr J. Bland-Hawthorn
appointed last year to 1/5/00, Dr W Couch (UNSW)
Student member for 1 year to 1/5/00 Mr IA Price
Mr V L Ford is secretary of this committee.

Instrument Committee
Ex officio: Director
Associate Director for Observatory Operations: Professor JE Norris
Heads of Design, Electronics, Computer Section (or their nominee)
Reppointed to 31/3/01: Dr MM Colless
Reappointed last year to 31/3/00: Professor MS Bessell (Chair), Dr GS Da Costa,
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Professor MA Dopita (alternate Dr RS Sutherland), Professor KC Freeman, Dr PJ McGregor, Dr PR Wood
Appointed last year to 31/3/00: Dr TS Axelrod, Dr BP Schmidt

Appointments Committee
Ex officio Director (Chair)
Reappointed to 31/3/01
Dr EM Sadler (ARC/U Sydney)
Appointed for 2 years to 31/3/01: Dr CA Heisler, Dr M de Kool
Dr D McClelland (Dept Physics & Theoretical Physics, Faculty of Science)
Appointed last year to 31/3/00: Professor JE Norris, Dr GV Bicknell
Reappointed last year to 31/3/00: Professor K C Freeman

Promotions Committee
Ex Officio Director (Chair)
Professor Richard Mark, RSBS (to 31/3/00)
Dr BR Lewis, RSPhysSE (to 31/3/01)
Appointed to 31/3/01: Professor MS Bessell

Scholarships Committee
Ex Officio Director, (Chair)
Ex Officio Convener, Graduate Program in Astronomy and Astrophysics, Professor KC Freeman
Two members from outside RSAA, reappointed to 31/3/01: Dr RA Gingold, ANUSF, Professor B Luther-Davies, Laser Physics, RSPhysSE
Reappointed last year to 31/3/00: Dr CA Heisler
Appointed for last year to 31/3/00: Dr GV Bicknell, Dr PJ Francis
Reppointed to 31/3/01: Dr BP Schmidt, Professor MS Bessell

Reappointments Committee (Tenurable Appointments)
Composition: Three to five members. Must comprise at least:
Head of School as Chair (or his nominee),
One person expert in the field, external to the School;
A person, external to the School, who is or has been a member of the BIAS Promotions
Committee and who thereby is familiar with standards on an Institute-wide basis.

This committee is required to meet this year, and the previous committee membership was reconstituted.
Ex Officio Director (Chair)
Professor KC Freeman
Professor MA Dopita
Professor R Ekers
Professor N Trudinger

The Research School of Astronomy and Astrophysics Advisory Board
Ex Officio: Director RSAA: Professor JR Mould
Dr PJ McGregor, RSAA
V-C or nominee: Professor H Bachor, Dept of Physics, The Faculties ANU
Professor E Weigold, Director, RSPhysS
Professor DNB Hall, Institute for Astronomy, University of Hawaii

Professor F Jackson, DIAS/DVC, ANU

Professor AR Hyland, DVC, Southern Cross University
Professor JJ Monaghan, Professor of Appld Mathematics, Monash University
Dr J Bland-Hawthorn (AAO) as an external member.

Library Committee
Ex Officio: The Librarian
Reappointed for 2 years to 31/3/01: Dr TS Axelrod (Chair), Professor KC Freeman, Dr AJ Kalnajs
Appointed for 2 years to 31/3/01: Dr RJ Smith , Dr RS Sutherland

Colloquium Committee
Ex officio: Convener of Feast-of Facts: Dr MN Sevenster
Reappointed to 31/3/01: Dr D Bersier
Reappointed last year to 31/3/00: Dr BP Schmidt
Appointed last year to 31/3/00: Dr PR Wood (Chair), Dr MN Sevenster
Ms M Putman to 31/3/00, student member

Visitors Program Committee
Dr M de Kool (Chair)
Dr PJ Francis
Professor JE Norris
Dr BA Peterson
Dr PR Wood
[School Secretary (in attendance)]

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PUBLICATIONS

Key: A&A = Astronomy & Astrophysics, AJ = Astronomical Journal, AJP = Australian Journal of Physics, ApJ = Astrophysical Journal, ApJS = Astrophysical Journal Supplement, BAAS = Bull American Astronomical Society, , PASA = Publications of the Astronomical Society of Australia, PASJ = Publications of the Astronomical Society of Japan, PASP = Publications of the Astronomical Society of the Pacific MNRAS = Monthly Notices of the Royal Astronomical Society, Mem Soc Astr It = Memoirs of the Astronomical Society of Italy, QRAS = Quarterly Journal of the Royal Astronomical Society, Trans.R.Soc.Lond. = Transcripts of the Royal Soceity of London.

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