RESEARCH SCHOOL OF ASTRONOMY & ASTROPHYSICS

THE AUSTRALIAN NATIONAL UNIVERSITY

ANNUAL REPORT 2003

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Contents

2003: The Phoenix Rises

Nearly all of the Research School of Astronomy and Astrophysics (RSAA) was affected in one way or another in 2003 by a horrific event that began the year: the devastating Canberra bush fires of 18 January. The firestorm destroyed the technical and workshop building, the heritage Commonwealth Solar Observatory Building, where the library and administration staff was housed, all observing facilities, and several homes on Mount Stromlo.

Through the remarkable efforts of our colleagues across the Australian National University (ANU) most staff members were able to return to Mt Stromlo only three weeks after the fire. Some technical staff worked off-site at the Acton Campus or at Australia Defence Force Academy until temporary work accommodation could be completed later in the year. More details and a pictorial overview of the reconstruction process are given in the **Rebuilding** section. We are grateful to our many supporters in Australia and overseas who sent assistance and expressions of concern.

Despite this setback, the achievements of the RSAA remained at a very high standard throughout the year. RSAA technical and engineering staff immediately began to lay plans for the rebuild of NIFS, the Near Infrared Integral Field Spectrograph, which was nearly ready for shipping to Gemini North before its destruction in the fire. In recognition of the excellence of the instrument, the NIFS team was awarded honours by each of the Australian National University, the Australian Capital Territory, and Engineers Australia. Now well underway at Auspace, our industrial partner, NIFS II is expected to arrive in Hawaii early in 2005.

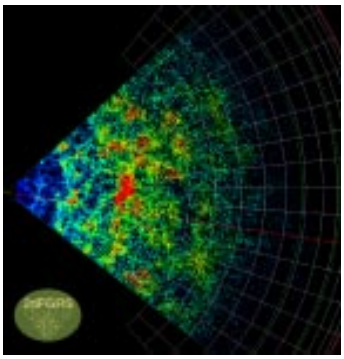
Simultaneously, we are designing and building a second instrument for the international 8m Gemini telescopes: the Gemini South Adaptive Optics Imager (GSAOI), a contract that was awarded to the School in late 2002. When completed in mid 2005, GSAOI will, together with the Adaptive Optics system on Gemini South, produce images as sharp as those from the Hubble Space Telescope. These and other technical achievements are described in the **Technology** portion of this report.

With financial assistance from the Commonwealth Government, we continued to upgrade our facilities at Siding Spring Observatory, by providing new instrumentation and thus new scientific capabilities. In the **Observing Facilities** section our telescopes and their use by all Australian astronomers for science and higher degree science training are highlighted.

We also take pride in our academic staff and students, who consistently produce results that are world-renowned in astrophysical theory, hypothesis-testing observations, rapid, accurate analysis, and large surveys conducted to answer a number of the most important questions in astronomy. This year was no exception.

RSAA astronomers developed models indicating that giant, pulsating stars develop a "midriff" bulge in old age, an explanation for previously ill-understood 800-day cyclic variations in red giant stars. Mapping an enormous volume of the early Universe, an RSAA-led team revealed a huge string of galaxies already in place at a time when the cosmos was only one-fifth its current age — generally thought to be too

early for gravity to have had time to organise such large structures. Telescopes at our Siding Spring Observatory were quickly pointed by RSAA scientists in the direction of the closest gamma ray burst yet detected, pinpointing its optical position and allowing astronomers around the world to train global resources on the transient event, discovering its nature as a ``hypernovae''.



The Two Degree Field Galaxy Redshift Survey (2dFGRS), co-led by an RSAA astronomer achieved its final milestone in July 2003, with the public release containing the positions and redshifts for nearly one-quarter million galaxies using over five years of observations with the Anglo-Australian Telescope sited on Siding Spring mountain. The survey continues to have a major impact on our understanding of cosmology, large-scale structure in the Universe, and the statistics of nearby galaxies. Details of these and many other fascinating discovers by our scientists can be found in the **Astronomical Research** section.

With achievements such as these, perhaps it is not surprising that our local, national and international communities recognised several of our staff members and students with awards in 2003. A few of the most notable are listed in **Awards and Honours**, including the sizable fraction of Australia's most highly cited scientists across all disciplines that call Mt Stromlo home.

Our graduate training program continues to grow. At the end of 2003, 12 young men and 13 young women were being trained by RSAA; nine of these hailed from overseas. In part through the active involvement of RSAA astronomers in the ANU honours program, we expect our largest intake of PhD students in over a decade to enter next year. Highlights from our student programs are described in **Students and Research Training**.

The importance that the Australian public has placed on our institution and its scientifically and historically iconic facilities is heart-warming and rewarding. We are pleased to be able to return some of that appreciation through highly popular interactions with local and national communities, as summarized in **Public Programs**. A highlight of this year was the publication of nearly 80 years of achievement and history in Stromlo: An Australian Observatory by Tom Frame & Don Faulkner. The Deputy Prime Minister, the Hon. John Anderson, officially launched the book at Stromlo in October.

The budget performance of the Research School in 2003 was characterised by consolidating our activities that have resulted in a substantial diversification of our funding base. External income accounted for more than 50% of the revenue of RSAA this year. A challenge, but important part of our strategic plan, is the maintenance of this wide base to produce more financial stability in the face of changing short-term goals and uncertain funding environments in the future.

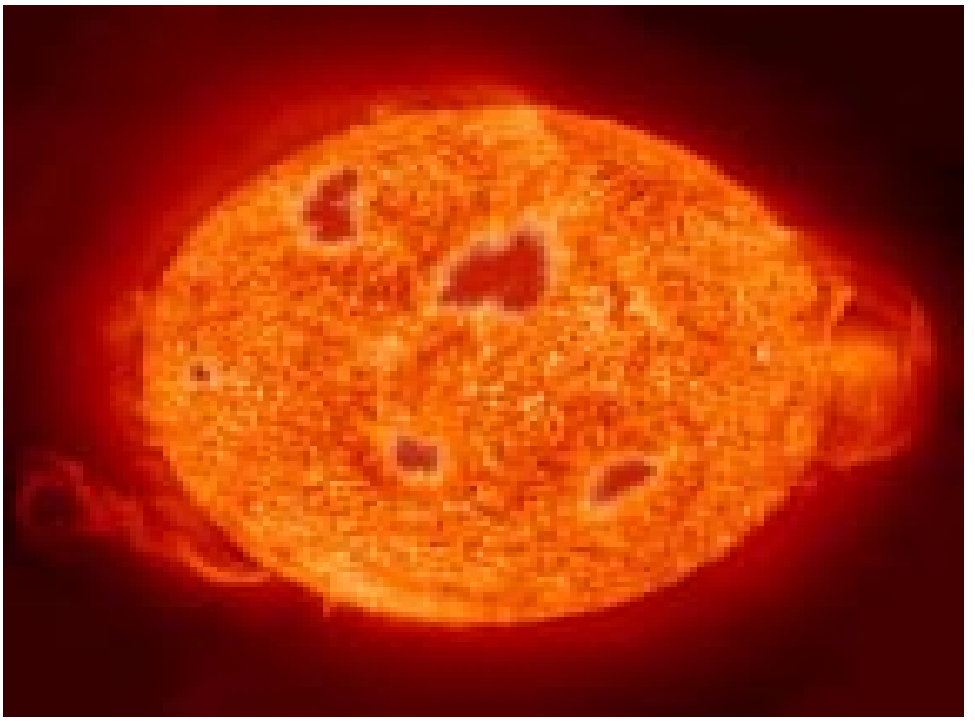
Our forward vision includes changes on both Mt Stromlo and at Siding Spring Observatory. The **New Directions** section illustrates some of this vision. Stage I of a new Advanced Instrumentation and Technology Centre (AITC) on Stromlo is being specifically designed with the future in mind, emphasizing strategic areas in astro-engineering in the next two decades: design, high-precision and adaptive optics, technical study and training, and integrated systems. We are forging links with the best teams worldwide investigating the science and technology of the Next Generation Telescopes, including optical-infrared telescopes with diameters of 20-100m The AITC will be capable of producing instruments for these mammoth eyes on the sky. Meanwhile, the new Skymapper planned for Siding Spring, a small telescope with a very large eye, will be mapping the entire Southern Skies digitally for the first time.

The year 2003 has been a challenging but exciting one. It is our hope and belief that after a tragic Januray we have now charted a course that will take the Research School of Astronomy and Astrophysics forward to contribute to scientific endeavour in the next eighty years as significantly as in the last eight decades.

Penny D. Sackett

Football-shaped red giant stars

In its old age, a star like the Sun will swell up to become a red giant of enormous size. In the Sun's case, its surface will lie near the orbit of the Earth. At this time, it will pulsate in and out with a period of about 80 days. It has recently been observed that about 25% of such red giants also show light and radial velocity variations with a much longer period of about 800 days. Associated with these long-period variations is some sort of surface activity, probably magnetic star spots, that causes a warm chromosphere to come and go. Dr Peter wood and Mr Enrico Olivier, together with Dr Steve Kawaler of Iowa State University, have tried to understand the long period variations. They concluded that the red giants most likely have large amplitude g mode oscillations, essentially large bulges that travel around the equator in about 800 days. An image of what such a red giant might look like when viewed with its bulges perpendicular to the line of sight is shown in the figure.



Nearly a Quarter Million Galaxies: the 2dF Galaxy Redshift Survey

The Two Degree Field Galaxy Redshift Survey (2dFGRS) achieved its final milestone in July 2003, with the public release of the survey database at the International Astronomical Union's General Assembly in Sydney. The 2dFGRS team, led by Drs Matthew Colless of RSAA and John Peacock of Royal Observatory Edinburgh, included Drs Bruce Peterson, Carole Jackson, Simon Driver and Roberto De Propris of RSAA, and measured the positions and redshifts for 221,000 galaxies over five years of observations with the Anglo-Australian Telescope at Siding Spring. The survey has been an outstanding success, with major impact on cosmology, large-scale structure studies and understanding of low-redshift galaxy populations.

The final database is available to astronomers worldwide on compact discs. For more information, see http://www.mso.anu.edu.au/2dFGRS/.

Gamma Ray Bursts: Fast and Steady wins this Race

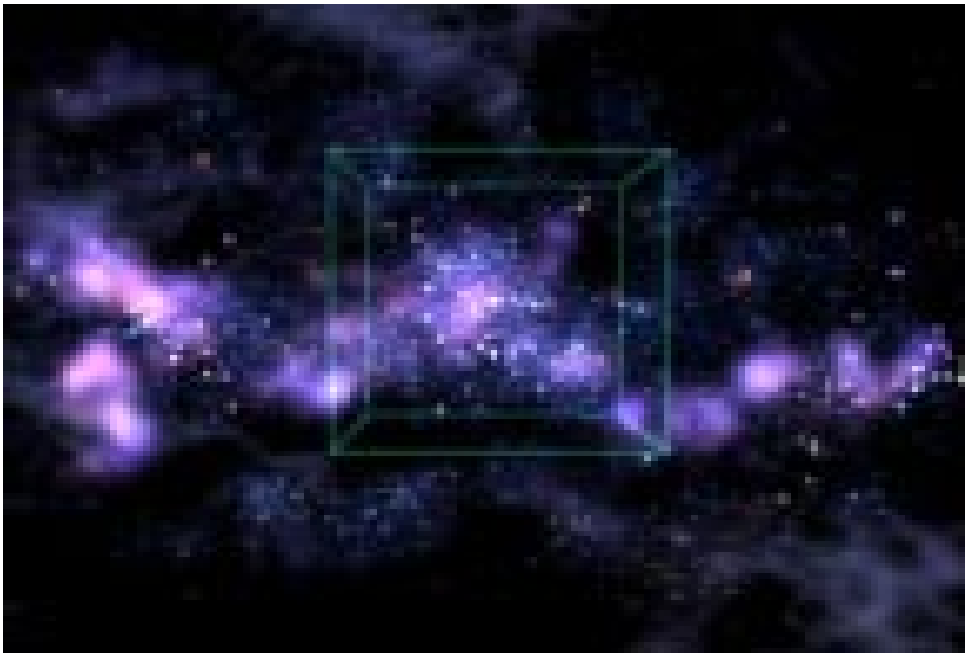
PhD student Paul Price and Dr Peterson and Prof Schmidt contributed to a major breakthrough in the understanding of gamma-ray bursts (GRBs) this year. Using telescopes at Siding Spring Observatory, they immediately identified the optical light associated with what is by far the closest (and normal) gamma ray burst yet detected. Their prompt discovery allowed unprecedented scrutiny of this object with other telescopes around the world, which showed, among other things, that this explosion was caused by a supernova, not dissimilar to a certain class of objects seen in the nearby Universe known as Type Ic hypernovae. The work was published in a March 2003 issue of Nature.

Huge String of Galaxies Discovered in the Early Universe

Dr Paul Francis of RSAA led an international team that mapped an enormous volume of the early Universe, capturing information about the Universe when it was only one-fifth the current age.

The RSAA-led team discovered a string of galaxies over 300 million light years in length. Since the observations revealed only the brightest few galaxies, what they revealed is probably far less than 1% of the total mass content in the string, most of which is invisible dark matter. This is the first time astronomers have been able to map an area in the early Universe big enough to reveal such a galaxy structure.

According to current theories, strings of galaxies this large should not have been able to form so early after the Big Bang. One explanation may be that the dark matter is not arranged in the same way as the galaxies we are seeing in the observations.



Close Encounter Garners Public Interest

On 27th August 2003, Mars passed closer to the Earth than at any point in the last 67,000 years. Public events were organised both on the ANU campus and in Coonabarabran under the auspices of RSAA, ANU Planetary Science Institute, the Canberra Astronomical Society, and the National Institute of Physical Sciences. Both events were very well attended: over 4000 people in Canberra and around 500 in Coonabarabran showed up to hear evening talks and look through telescopes. The event generated extensive media coverage, with live broadcasts from Coonabarabran on four TV channels.

Undergraduate Research at RSAA, Including Astronomical Instrument Design

Sixteen undergraduate students from the ANU's Faculty of Science, most of whom were first year students, including several PhB students, carried out research projects supervised by RSAA staff. Often their work included first-hand observations using ANU telescopes at Siding Spring. The projects included building a radio telescope receiver, searching for the origin of a supernova, taking data to help design the public outreach camera for a possible Phoenix telescope to be placed on Mt Stromlo, and pan-spectral mapping of Mars during its recent close approach.

New Grants Awarded in 2003

The success rate of RSAA applications to ARC was not as high in 2003 as in the previous two years. To what extent this can be attributed to the effects of the January bushfires, which preceded the (extended) ARC deadline by a couple of months, is difficult to determine, but it surely played a role. Nevertheless, two large awards were won by RSAA staff in 2003.

Major Prizes, Honours and Awards

RSAA staff and students continued to excel as evidenced by the honours bestowed upon them in 2003. Perhaps of greatest note is the recognition from several quarters given to the RSAA team responsible for the design and construction of the Near-infrared Integral Field Spectrograph destined for the giant Gemini telescope in Hawaii before its destruction in the bushfires, and the remarkable achievement of RSAA as one of the best organizations in all Australia for producing well-cited scientists. Shown at right is the NIFS team.

Evidence for the First Generation of Stars

Asplund has, together with collaborators Akerman, Carigi, Nissen and Pettini, determined carbon and oxygen abundances in some of the oldest stars in the Universe. These stars belong to the halo of our Galaxy. The high-quality observations were obtained with European Southern Observatory's Very Large Telescope in Chile. Surprisingly high carbon abundances were determined for the stars with the lowest oxygen and iron content. These results are unexplained by standard models of stellar nucleosynthesis combined with galactic evolution during the early times of the Galaxy. One possibility is that the high carbon abundances may be the fingerprint of the very first generation of stars formed after the Big Bang, the elusive so-called Population III stars. Observing time for follow-up studies to seek confirmation of this suggestion has already been granted.

The Origin of Sulphur and Zinc

Asplund has been involved in collaboration with Nissen, Chen and Pettini to measure the sulphur and zinc abundances in stars belonging to the Galactic halo. The aim of this study is to investigate the nucleosynthetic origins of these elements. Sulphur and zinc are of particular interest as they are among the very few elements whose abundances can be determined in galaxies in the very distant, high-redshift Universe. It was concluded that sulphur is primarily produced by massive stars and is expelled into the interstellar medium during their death throes, in a so-called supernovae type II. On the other hand, zinc originates in both supernova of type II and of type Ia, the latter arising in a white dwarf star that has accreted enough mass from a companion star that it first collapses under its own gravity and then explodes.

Extremely Metal-Deficient Stars

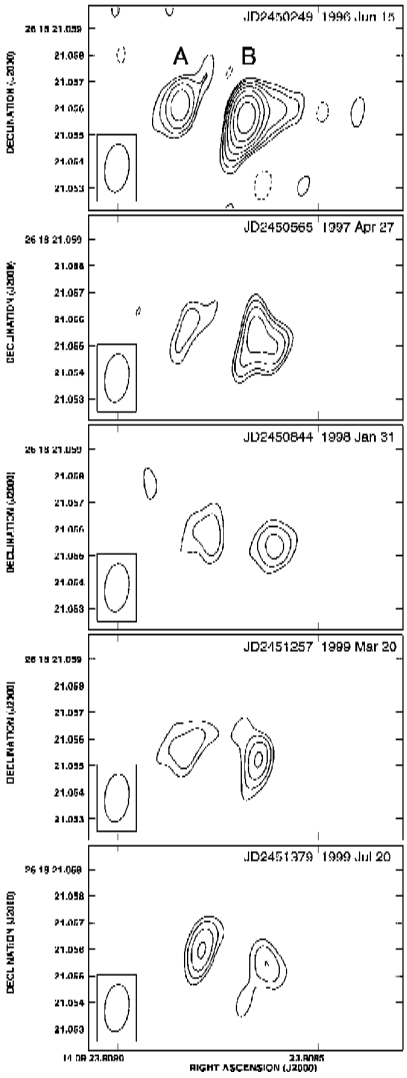
The search for extremely metal-deficient stars from the Hamburg-ESO survey by Bessell and Christlieb has continued using DBS observations on the 2.3m telescope and 6dF observations on the UK Schmidt Telescope. An analysis has been made of ultra-violet UVES spectra of HE0107-5240, discovered in November 2001 at Siding Spring Observatory, and reported in 2002 to be the most iron-deficient star known. The ratio of oxygen to iron has been determined to be a factor of 3000 higher than normal. An explanation is that HE0107-5240 formed from material expelled from a massive supernova of 20-30 solar masses.

Groups of Young Nearby Stars

Bessell, in collaboration with Zuckerman and Song, has used the 2.3m telescope at Siding Spring Observatory to survey nearby K and M dwarfs from the Hipparcos, Tycho and X-ray catalogs for the presence of lithium in their spectra. Lithium is used to identify young stars. Space-motions are then used to see whether the stars belong to any of the known groups of nearby young stars. In this way many additional members of the Beta Pictoris and TW Hydrae Associations have been discovered. Tracing back their trajectories indicates these moving groups originated in the Sco-Cen Association. The ages of these stellar groups are 8-30 million years, and their distance from Earth (less than 60pc) makes them prime targets for direct imaging searches for cooling planets and circumstellar dusty disks.

A Relativistic Jet in a Radio-Quiet Quasar

We are used to the notion of radio-loud galaxies, including quasars, being significant radio emitters because they contain jets moving at velocities close to the speed of light. These jets emit radio waves as a result of high-energy electrons spiralling around magnetic fields. The radio waves are boosted in power by the rapid motion of the plasma. It had previously been thought that so-called "radio-quiet" objects did not contain such jets. However, Blundell (University of Oxford), Beasley (Caltech) and Bicknell have discovered a radio-quiet quasar (designated PG1407+263) that is a weak radio emitter but which has jet components moving at a speed close to that of light. The latter conclusion was made possible by a thorough physical and mathematical analysis of four epochs of radio observations of this object that were carried out using the Very Large Array radio telescope in New Mexico (see figure). The observations showed that the components varied significantly of timescales of a hundred days or so. Given the sizes of the components this variability is only possible if they are moving very rapidly. The other pointer to relativistically boosted emission from the core of this object is the lack of radio emission on large scales surrounding the quasar. Blundell, Beasley and Bicknell interpret this in terms of boosted emission from the core of the quasar but with no comparable boosting from quiescent plasma well away from the core. The large-scale plasma would have been ejected at an earlier time but would have decelerated to a very low velocity as it moved out through the interstellar medium of the host galaxy.



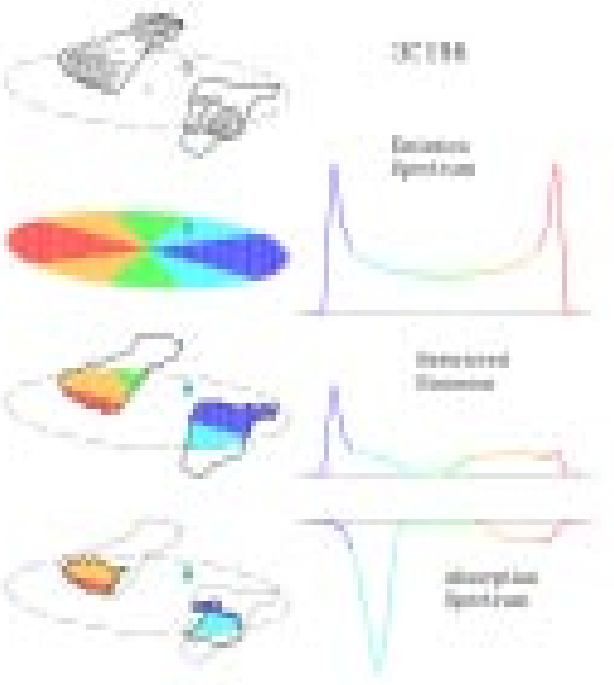
Gamma-ray Astronomy and the CANGAROO Project

The CANGAROO (Collaboration between Australia and Nippon for a Gamma-Ray Observatory in the Outback) project is a pioneering project devoted to Gamma-Ray observations of astronomical sources. The collaboration team involves a Consortium of Japanese Universities, the Australian National University and the University of Adelaide. Gamma-ray photons with energies of order a TeV are observed as a result of the optical Cerenkov flash emitted when they interact with particles in the Earth's upper atmosphere. Arrays of optical telescopes allow the source of the radiation to be accurately located through a stereo observing mode. This mode also increases the signal to noise of observations by eliminating background sources due to cosmic rays. As a result of Japanese and ARC funding, the four-telescope CANGAROO III system is almost complete. Three out of its four telescopes are now operational and can be used together in stereo mode. Some of the CANGAROO team have been working to develop camera calibration procedures, which are almost complete. Observations of some sources have been made and data reduction is in progress for them. We have been examining carefully the collaboration data analysis routines in order to eliminate spurious detections.

Surveys for 21cm Line Absorption by High Redshift Galaxies

Briggs and Little, in collaboration with Lane, Ord, Kanekar, Staveley-Smith, and Vermeulen, are using radio telescopes at Parkes and Green Bank, West Virginia to search for gas-rich galaxies that chance to lie along the line of sight to distant radio galaxies and quasars. The intervening galaxies create a distinctive pattern of absorption lines in optical, UV and radio wavelengths that are diagnostic of conditions in these proto-galactic systems as they were at early stages of their evolution. It is seldom possible to make detailed studies for the gas in galaxies because the large distances dim the signals. The radio wavelength studies of the absorption created in the 21cm line of neutral hydrogen overcome some of this difficulty, making them especially useful for determining the physical extent of the galaxies and the kinematical motions of the gas clouds in the galaxies, as shown in the figure. The radio advantage comes from the nature of radio sources, that have sizes (often tens of kiloparcs) much larger than the sub-parsec sized optical/UV light sources that sit at the nuclei of quasars; this allows the variation in the properties of an absorbing galaxy to be measured along many lines of sight, whereas the optical observations only probe a tiny pin-prick through a standard galaxy-sized disk. The team is presently surveying a large number of bright high redshift radio sources to find the absorbers. For this phase of the project, angular resolution is not needed. In order to capitalize on the full potential of the absorption against extended background sources, the next phase needs radio interferometers for use in VLBI experiments that will provide high angular resolution.

Absorption by an intervening disk galaxy against the extended background radio quasar 3C196. Top panel: Contours of radio continuum emission for the high redshift radio source; the location of the quasar nucleus seen in optical light is marked by an encircled X; an oval marks the approximate extent of a galaxy that the measurements show must fall along this line of sight. Upper middle panel: The colour-coded velocity field and 21cm line emission profile that would be observed for disk galaxy, if it were nearby. Lower middle panel: A spectrum that has been restricted to gas clouds in the regions of the intervening galaxy that lies in front of background continuum; in principle, sensitive mapping could measure the distribution and kinematics for these clouds in absorption across the face of the radio source. Bottom panel: The integral absorption spectrum obtained by observing this source in the 21cm line at redshift z=0.437 with a low angular resolution telescope, the Dutch WSRT; these are the kinds of absorption lines the Parkes and Green Bank surveys are seeking.



Radio Probe of the Epoch of Reionization

Spectral line studies of the radio sky at low radio frequencies have the potential for measuring the structure of remnant clouds of the neutral intergalactic medium, as they are ionized during the "Epoch of Reionization" (EOR) by the starlight and quasar-light from the first generation of collapse objects at redshifts greater than six. These first structures might reveal themselves in the 21cm line of neutral hydrogen, which is redshifted to meter wavelengths. Briggs has constructed a portable radio-signal recording system that can be used as a spectrometer for a small, stable, sensitive radio receiving system that detects subtle features in the background sky in the presence of radio frequency interference. Briggs and Erickson are assembling the receiving system to search for a "global signal" from the EOR. Briggs and de Bruyn are assessing the requirements for large telescope projects, such as LOFAR and SKA, whose goals include the detailed mapping of the Epoch of Reionization.

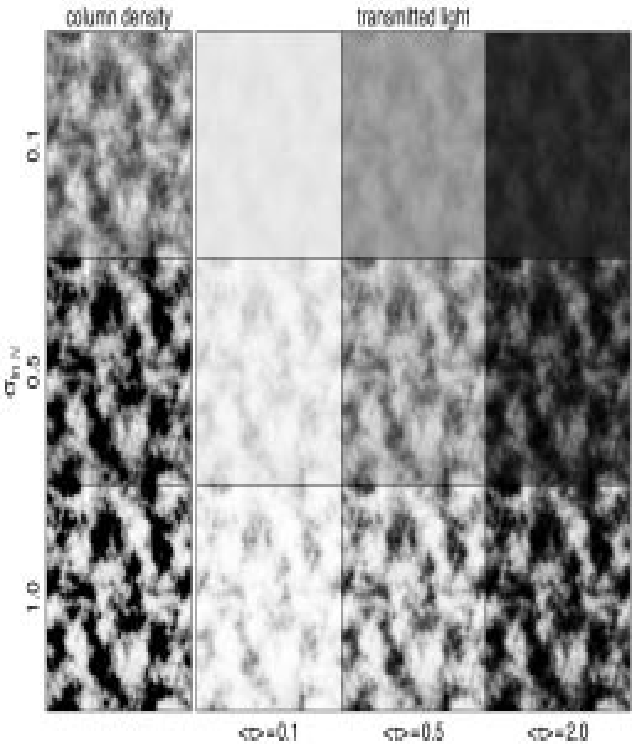
Main Sequence Star Abundance Anomlaies in the Globular Cluster 47 Tuc

The globular star clusters surrounding our Milky Way Galaxy have been known for almost three decades to show star-to-star variations in the abundances of the elements carbon, nitrogen, oxygen, sodium, aluminium and magnesium in most, if not all, clusters. These abundance anomalies lack a complete and comprehensive explanation. Two broad classes of explanations exist: that the abundance anomalies arise from internal mixing process in the stars themselves (the 'mixing' hypothesis), or that the anomalies arise from processes occurring early in the life of the clusters (the 'primordial' hypothesis). Observations of stars on the main sequence in a globular cluster can in principle distinguish between these two hypotheses since it is difficult to see how the observed abundance anomalies can be produced in a main sequence star by the mixing processes. Da Costa and Norris, in collaboration with Cannon and Croke, have analysed spectra of a large sample of main sequence stars in the globular cluster known as 47 Tuc. The observations were obtained with the 2dF multi-fibre instrument on the Anglo-Australian Telescope. The analysis confirms that anti- correlated variations in the strengths of the CN and CH bands exist among the main sequence stars in this cluster. Further, the ratio of CN-Strong to CN-weak stars on the main sequence is identical to the value for the more evolved red giant stars. The analysis also shows that the strengths of the sodium D-lines in the spectra of the main sequence stars correlate positively with the cyanogen band strength indices. These results strongly imply that mixing processes do not play a role in generating the abundance anomalies in this cluster.

The Turbulent Interstellar Medium

In order to understand how the gas and dust in the interstellar medium (ISM) interacts with electromagnetic radiation and relativistic particles, we need to understand how it is distributed. In recent years, we have begun to understand that the ISM consists of essentially four phases, a hot (~ million degree) ionised plasma heated by supernova shock waves, a warm phase - either ionised or not - with a temperature near 10,000K, a cool neutral medium with a temperature of a few hundred degrees, and a very cold molecular medium. The first three phases are in approximate pressure equilibrium, and matter is constantly exchanged between them as the medium is stirred and mixed by the violent events within it. Within the warm and cool phases, in which dust can survive, the magnetic fields are very important, and the balance between gas and magnetic pressure largely determines the distribution of local density. Fischera, Dopita and Groves & Sutherland, in collaboration with

Lazarian and Cho at the University of Wisconsin have been investigating the observational consequences of this so called magneto-hydrodynamic turbulence (MHD). These are in two major areas, the reddening function of galaxies, and the famous infrared-radio correlation. * The Reddening Function: The empirical reddening function for starburst galaxies deduced by Calzetti and her co-workers has proven very successful, and is now used widely in the observational literature. Despite its success, however, there was very little physical basis for this extinction law, or more correctly, attenuation law. Fishera and his collaborators have established that a turbulent interstellar medium provides an enormous range in the distribution of column densities (see figure). These column densities are directly related the attenuation of light, because the dust is well mixed with the gas. Extended sources seen through such a layer suffer a point-to-point wavelength-dependent stochastic. For example, dense clouds are "black" in the UV, but are translucent in the IR, this leads to a flatter wavelength-dependent attenuation law, which provides a good fit the Calzetti Law, providing for the first time the physical justification for this empirical law. This insight will enable us to provide more physically realistic models of the attenuation of light in starburst and normal galaxies, which in turn will permit us to obtain better constraints on fundamental parameters such as intrinsic luminosity, spectral energy distribution and star formation rates. * The Infrared-Radio Correlation One of the more extraordinary correlations in astronomy is that between the far infrared (FIR) and radio continuum of galaxies. This linear correlation spans some five orders of magnitude with less than 50% dispersion, making it one of the tightest correlations known in astronomy. Groves & Dopita, with their collaborators at Wisconsin, have investigated this correlation on the basis that it is produced locally through MHD turbulence. The physical basis for the correlation is that the synchrotron emissivity depends on the square of the magnetic field, while the infrared emissivity depends on the local dust (and therefore gas) density (for a given density of relativistic electrons and photons). It was found that MHD turbulence naturally produces a proportionality between density and the square of the magnetic field, and that the photon and non-thermal electron densities are both proportional to the star formation rate. Thus the conditions that are necessary for the far infrared radio correlation are met in a medium with MHD turbulence.



Attenuation through a distant turbulent screen. The left column shows the column density for various assumptions for the variance of the normal log density distribution of the column density. To the right is shown how much light is transmitted through the turbulent screen for different mean optical depths.

High-Redshift Radio Galaxies

Dopita's collaboration with van

Breugel (LLNL) on observations of high-redshift radio galaxies is beginning to bear fruit. They have studied the Lyman-Alpha haloes of four of these objects, and have shown that the star formation rates of these are certainly larger than 1000 solar masses each year! Each of these galaxies turns out to bee associated with a proto-cluster of forming galaxies that are visible as Lyman-Alpha emitting objects. As many as fifty of such objects have been identified in particular cases, and we have been awarded two nights of Keck telescope time in January 2004 to positively identify and to investigate the properties of these associated objects.

MAPPINGS-on-line

The study of the spectral properties of starburst galaxies has become increasingly important to elucidate the evolutionary history of the galaxies in the epoch of galaxy formation, from roughly one billion years after the big bang up to the present. Today, with large telescopes and space facilities, we can make observations of the stellar spectral energy distribution (SED), stellar absorption line spectroscopy, interstellar gas emission line ratios, and the interstellar gas and dust continuum SED over more than eight decades of frequency in the electromagnetic spectrum. From these observations we can, in principle, use purely theoretical modelling techniques allow us to derive the star formation rates, star formation histories, ages and chemical compositions of these objects. However, up to the present, the modelling of the stellar and the gaseous (nebular) spectra has proceeded essentially independently, and stellar and nebular results have not often been checked for consistency. In order to rectify this situation, former RSAA PhD student Lisa Kewley in collaboration with Mike Dopita, Ralph Sutherland, Brent Groves and Luc Binette, has developed a web-based interface between the MAPPINGS (shock and photoionization) modelling code developed and maintained at the RSAA, and the Starburst 99 code which is used for the stellar spectral synthesis of star-forming regions. MAPPINGS-on-line is now available at:
http://cfa-www.harvard.edu/~lkewley/Mappings/index.html

"Moon Phases" for Extrasolar Planets

The reflected light from an extrasolar planet varies periodically as the extrasolar planet orbits its host star. The amount of reflected light varies with the phase of the orbit, in much the same way as the moon phase changes for an Earth-based observer. Predicting light variations is crucial for planning and interpreting the observations of extrasolar planet light curves. Dyudina, Sackett, and Bayliss (summer scholar at RSAA) modelled the appearance of an extrasolar planet at different phases. Using the surface reflective properties of Jupiter and Saturn as observed by the Pioneer and Voyager spacecraft, they predicted how the reflected luminosity of an extrasolar planet would vary with time (a light curve) for a variety of geometries. Ringed planets and planets orbiting in eccentric orbits produce characteristic shapes and asymmetries in the light curves. These shapes, together with the orbit's characteristics obtained from the Doppler velocity measurements, provide a way to restrict a planet's masses, to detect if the planet has rings, and to learn about clouds and the atmospheric composition of the extrasolar planet.

The Rave Survey

RAVE is a very large international stellar spectroscopic survey, aimed at acquiring radial velocities and metallicities for 50 million stars in the Milky Way. It will provide a unique sample of stars to study the structure and origin of our Galaxy. The RAVE team has members from Australia, France, Germany, Italy, Netherlands, Slovenia, Switzerland, UK and USA. Freeman is the scientific coordinator for this program. The first phase of RAVE began in 2003, using the 6dF system on the UK Schmidt. This phase will be used to develop the pipelines and techniques for handling the vast amount of data from the main survey.

The High Velocity Clouds

Surveys of neutral hydrogen show clouds of gas moving at unexpectedly high velocities, mostly towards us. It is very difficult to measure the distances of these gas clouds, so there has been a long controversy over their nature. Are they small nearby clouds, maybe ejected from the disk of our Galaxy and now falling in again? Or are they much more distant and massive objects, maybe leftover debris of the galaxy formation process? With Putman, Bland-Hawthorn, Veilleux, Gibson and Maloney, Freeman made deep observations of these clouds in the light of the hydrogen-alpha spectral line. Several were detected. This suggests that their neutral hydrogen is partly ionized by radiation from the disk of our Galaxy, so the clouds are relatively nearby (nearer than 40 kpc) and they are not particularly massive.

Near-Earth Asteroids

As part of the international Spaceguard program to identify 90% of 1 km and larger Near-Earth Asteroids (NEAs) before 2008, the Uppsala Southern Schmidt has been refurbished. It will produce the first dedicated search using semi-automated techniques in the southern hemisphere, and it will be known as the Siding Spring Survey (SSS). The program is a collaborative effort between the University of Arizona (UA) and the ANU, with co-principal investigators Larson of the UA and McNaught of the ANU, assisted by Garrard. Originally a photographic telescope, the 0.5-m f/3.5 Uppsala Southern Schmidt has had the photographic mechanism replaced by a Fairchild 4Kx4K CCD. With 15 micron pixels, this gives a field of 123'x123' and an image scale of 1".8/pixel. First light was obtained in early July 2003 and the overall performance of the hardware has been good. The Minor Planet Center (MPC) has assigned the station code E12 to the SSS. A web page for the SSS is at http://msowww.anu.edu.au/~rmn/

Distant Supernovae

Schmidt is scientific coordinator for the Essence project, which in 2003 entered its 2nd year of obtaining a homogenous set of 200 Type Ia supernova at cosmological redshifts. This project, includes 20 researchers on 4 continents, and is following in the footsteps of the Schmidt-led program known as the High-Z SN Search that discovered that the Universe was accelerating in its expansion. In 2003, the Essence project discovered 35 type Ia supernovae between redshifts of 0.1 and 0.8 (or equivalent to looking back to when the Universe was 1 to 7 billion years younger than it is today). In addition, the project team was able to obtain spectra using Australian time on Gemini North and South (as well as time on Keck, VLT, and Magellan) to obtain high-quality identifying spectra of all 35

objects. This program continues with 60 half-nights per year on the Cerro Tololo Blanco 4 meter telescope until 2006, and it should provide the best measurement of properties of whatever is causing the Universe to accelerate.

Gemini South Adaptive Optics Imager

The Gemini South Adaptive Optics Imager (GSAOI) is being designed and constructed for the Gemini South 8-m diameter telescope in Chile. ANU was awarded the detailed design and construction contract before the January 2003 bushfires, but had not yet finalized contractual arrangements. The Gemini Observatory Associate Director for Instrumentation visited Mt. Stromlo Observatory after the fire and was satisfied that ANU had the capacity to continue with the project, despite the destruction of much of the RSAA facility.

Design of the instrument proceeded throughout much of 2003 and culminated in the GSAOI Critical Design Review, which was held in October 2003 and was conducted by an international panel. A number of software issues were unresolved at the time, and were deferred to a Software Critical Design Review that was held in January 2004. The Critical Design Review was successful and the instrument is now in full production in the temporary workshop facilities on Mt. Stromlo. Shipment to Gemini South is scheduled for October 2005. On-time delivery will generate 20 guaranteed nights using GSAOI and the Multi-Conjugate Adaptive Optics (MCAO) systems being developed by the Gemini Observatory.

Near-infrared Integral Field Spectrograph

The Near-infrared Integral Field Spectrograph (NIFS) had been under construction for several years at Mt. Stromlo when it was destroyed in the January 2003 bushfire. The Gemini Observatory reviewed this situation in early 2003 and decided to proceed with the reconstruction of NIFS, funded by ANU. Although delayed, NIFS is expected to be commissioned on the Gemini North 8-m diameter telescope in early 2005. This will be immediately after the laser guide star upgrade to the ALTAIR facility adaptive optics system on Gemini North, so it will allow NIFS to address the broader range of science targets that are provided by the laser guide star system. NIFS was always expected to have limited scope in its first year when it was expected to be restricted only to targets having bright nearby natural guide stars.

NIFS is being rebuilt under sub-contract by Auspace Ltd, a local aerospace company. Fortunately, the designs for the instrument were saved from the fire and several key components, such as some of the optics and the science-grade detector, were in transit at the time. NIFS-2 underwent its first cold test in December 2003 and is expected to be handed back to RSAA in its pre-fire state in August 2004.

Graduate Program

At the end of 2003, the RSAA Graduate program in Astronomy & Astrophysics was comprised of 20 on-course students, 4 students who are completing their thesis with an extension of time to submit, and 1 student who was on suspension on medical grounds.

All are studying for the PhD degree. Of this total of 25, 12 are male and 13 are female, while 8 come from overseas with the balance from Australia and New Zealand. A total of 7 students (4 from Australia and New Zealand and 3 from overseas, made up of 5 females and 2 males) commenced PhD studies in 2003. This intake is an increase of two over that for 2002. Three students completed their theses in 2003 and, at the time of writing, two have commenced post-doctoral positions, one in the Netherlands and one in Hawaii.

Our honours program, which is a joint program with the Physics Department in the Faculty of Science in which the Honours students complete courses and research projects under the supervision of RSAA faculty, continues to attract top undergraduates from ANU and from other Australian universities. A total of 7 honours students took part in the program in 2003, and 6 of these have decided to commence PhD studies at RSAA in 2004.

As usual, the first year PhD students started their program with a short research project and lectures on several areas of astrophysics, and then progressed to choose their thesis topics.

Several of our students are involved in collaborations with astronomers outside Australia, and a number of them spent time in 2003 working at institutes in Europe and the US. RSAA encourages these international activities, because they broaden the students' experience and help them to build their own network of international contacts. Further, during 2003 the XXVth International Astronomical Union General Assembly was held in Sydney and many of our graduate students were able to attend. This provided an opportunity for many students to present their work to a large international audience.

The beginning of 2003 saw the disastrous fires that devested Mt Stromlo, destroying much of the infrastructure and causing significant disruption for many of our students. Some lived on Mt Stromlo and lost essentially all of their possessions. Others depended on the Mt Stromlo telescopes for their thesis data, so their work was disrupted. Fortunately, a year later, things have returned to normal. However, we are pleased to gratefully acknowledge several sources of support in the post-fire period. These include the members of the Canberra community who provided accommodation for RSAA students after the fire, and ANU and the ACT Government who both gave substantial financial help to the students who had lost their homes

and possessions. We are also particularly grateful to the staff of the Apache Point Observatory in New Mexico and the staff of the Astronomy Department of the University of Texas, who made telescope time and data available to one of our students who was particularly disadvantaged by the loss of the 74-inch telescope.

On a final happier note, the entire Observatory was pleased when graduate student Bradley Warren was named as the 2003 ACT Young Australian of the Year.

Public Outreach

2003 saw some dramatic changes to the RSAA Outreach Programs. Due to the fires at the beginning of the year, Mt Stromlo Observatory Visitors' Centre Visitors' Services Programs were curtailed but the demand on academic staff and public outreach officers increased to meet the onslaught of public interest after the fires. Never in the history of Mt Stromlo Observatory has public respect and interest been so keenly felt.

During 2003, Prof Penny Sackett, Prof Brian Schmidt, Dr Paul Francis, Dr Ralph Sutherland, Dr Peter McGregor and Mr Vince Ford provided over 250 radio spots ranging from ten minute to one half-hour slots. Regular newspaper articles appeared both nationally and internationally featuring both Mt Stromlo Observatory and RSAA staff. In addition, numerous television interviews were conducted. Most notably was Prof Penny Sackett's 21 October 2003 appearance on the "Good Morning Australia" program.

As part of the IAU General Assembly, the work of several RSAA researchers was released to the media. Dr. Simon Driver's work providing the best estimate of the number of stars in the universe and Dr. Brad Warren's work on galaxies made of gas, both received enormous national and international media coverage.

August 15 to 24 marked the National Science Festival during which RSAA Exhibits formed part of the ANU stand at the ACTEW Amazing World of Science, Vince Ford presented a rousing comet and rockets show daily, as part of the school workshop program.

Floraide's theme for the year was "Space". RSAA capitalized on this with daily sunspot observing in the gardens and informal solar astronomy talks.

Additionally, RSAA staff held Rotary and Probus talks, were invited as question speakers to amateur astronomical societies and visited schools to entertain and educate the children.

As another positive turn, a new book about the history of Mt Stromlo Observatory was released in 2003. The book, titled Stromlo: an Australian Observatory, was written by Tom Frame and Don Faulkner and encapsulated the history of the observatory. The book's printing was delayed so that an epilogue about the 2003 fire could be included. Deputy Prime Minister John Anderson formally launched the book on the grass lawn with the fire ravaged administration building as a backdrop.

The Planetary Sciences Institute and the Canberra Astronomical Society, held a Mars extravaganza on 27 August 2003. This event, held on ANU main campus, brought together top scientist and telescopes (both smaller telescopes and live links from SSO were available) to inform the general public about Mars' close

approach to Earth. With an attendance of over 4000, the Mars event was the best-attended ANU public lecture on record.

Mt Stromlo Observatory Visitors' Centre

With plans for a major upgrade to the Mt Stromlo Observatory Visitors' Centre under way, 2003 began with a bright hope for future outreach programs. Figures for the beginning of the year where looking promising as families and tourist made MSOVC a must stop on their travel plans. However, with the bushfires of January 2003 and the destruction of the infrastructure on site, the Visitors' Centre was closed as of 18 January.

This did not stop MSOVC from hosting The National Youth Science Forum, ANU National Science Teachers Summer School, National Mathematics Summer School and Siemens Science and Technology Summer School.

MSO also hosted VIP visits to the site after the fire. Over a three-day period, the site was visited and mourned over by stakeholders, past employees and residents and families of those who had some involvement at the site.

On Canberra Day, the MSO site was opened up to bussed-in groups of the general public. These walking tours of the site were the first "in person" visits for the public. An estimated 2000 people attended this open day and the logistics of safely conducting such large crowds through the recently burned and still dangerous site was challenging. The public returned from this visit having a better understanding of the damage on site, the work done on the mountain and a hope for the future.

Siding Spring Exploratory

As the front face of Siding Spring Observatory (SSO), the Exploratory (SSE) provides public relations and outreach for the institutions located at Siding Springs. 2003 marked a much-needed upgrade to the Exploratory exhibits. Many of the MSOVC exhibits were temporarily moved and added to the SSE.

As 2003 commenced, SSE wrapped up its holiday art competition, where artwork from the local Coonabarabran schools was displayed throughout the SSE. Children participating in the program received certificates of participation as well as prizes.

Astro-camp was run with great success again in 2003. The camp is designed for year 11 and 12 students who demonstrate an interest in astronomy. The two days of activities include presentation and night observing.

On 27 August 2003, in conjunction with the Mars event held at ANU, SSE held an event at the Dramatic Club Hall in Coonabarabran for 500 guests who watched the approach of Mars from the observatory. This event was covered by three different television channels and was broadcast live by WIN TV on the evening news from the summit of Siding Spring Mountain.

October offered the opportunity for the SSO Open Day. This year's open day ran in conjunction with a Bok Lecture and Science in the Pub (run jointly with the AAO).

Director	PD Sackett
Associate Directors	MS Bessell (Associate Director of Instrument Development) JE Norris (Associate Director for Observatory Operations)
Federation Fellow	MA Dopita, MA Oxf., MSc, PhD, Manc., FAA
Professors	MS Bessell, BSc, Tas., PhD ANU FH Briggs, BS Swarthmore, MS, PhD Cornell KC Freeman, BSc, W. Aust., PhD, Camb., FAA FRS JE Norris, BSc, PhD ANU
ARC Professorial Fellow	BP Schmidt, BS, Phys, BS Astron, Az., AM, PhD, Harv.
Senior Fellows	GV Bicknell, MSc, PhD, Syd. MM Colless, BSc, Syd., PhD, Camb GS Da Costa, BSc, Monash, PhD ANU PJ McGregor, BSc, Adel., PhD ANU BA Peterson, ScB, MIT, MS, PhD, Caltech PR Wood, BSc, Qld., PhD ANU
Fellows	SP Driver, BSc, Leicester, PhD, Cardiff PJ Francis, BA, PhD, Camb (Snr. Lecturer, Physics, the Faculties)
Research Fellows	M Asplund, BSc PhD Uppsala CA Jackson, MS, PhD, Camb, FRAS (to June) H Jerjen, Dip PhD, Basel RS Sutherland, BSc, PhD ANU
Postdoctoral Fellows	P Allen, MSci Durham, PhD Oxford N Christlieb, ARC Linkage Fellow, Uppsala (to March) P De Propris, BSc, London, MSc, PhD, Victoria U Dyudina, BS MS Moscow, PhD Caltech J Fischera, Diploma CAO Kiel, PhD Heidelberg H Jones, BSc PhD ANU S Keller, BSc Syd, PhD ANU J McSaveney, PhD Canterbury

R Trampedach, Msc Arhus, PhD Mich.

Adjunct Faculty

J Bland-Hawthorn, BSc Astron, PhD, Sussex
RD Ekers, BSc, Adel., PhD, FAA, ARAS
EM Sadler, BSc, Qld., PhD ANU
CW Stubbs, BSc, Virginia, MSc, PhD, Washington

Postgraduate Students

Antoine Bouchard, BSc, MSc, Montreal
Lachlan Campbell, BSc ANU
Matthew Coleman, BSc ANU
Gayandhi De Silva, BSc, Monash
Catherine Drake, BSc, Monash
Damian Fabbian, BSc Padova
Anna Frebel, BSc Freiburg
Brent Groves, BSc, Monash
Sebastian Gurovich, BSc, UWS, Nepean
Craig Harrison, BSc, QUT, Hons ANU
Minh Huynh, BSc, UWA
Kelly Kranz, BSc UWA, Hons ANU
Brett Little, BSc Flinders
Rachel Moody, BSc ANU
Jess O'Brien, BSc, Melb
Enrico Olivier, BSc, MSc, Western Cape
Isabel Perez, MPhys, Manchester
Paul Price, BSc, U Qld.
Maria Elena Salvo, BSc Padova
Shobha Sankarankutty, BSc, MSc, UFRN
Vicky Safouris, BSc Syd
Holly Sims, BSc ANU
Laura Stanford, BSc, Flinders, Hons ANU
Christine Thurl, BSc Regensburg, MA Wesleyan
Bradley Warren, BSc, Monash
David Weldrake, BSc Herts
Eduard Westra, MSc Groningen
Mary Williams, BSC MSc Auckland
Greg Wilson, BSc ANU

Research Officer

V Ford, B App Sc. CCAE

Academic Services Officer

T Gallagher, BA Vanc

ADMINISTRATION

Business Manager	V O'Connor
Assist. Business Manager	I Sharpe
Operations Officer	D Bourne
Purchasing Officer	M Miller
Asst Purchasing Officer	S Maloney
Site Officer	G Blackman
Personal Assistant to the Director	F Aplin
Asst Site Officer	P Walsh
Asst Site Officer (Acting)	F Filardo
Gardener	H Coyle

PROJECT MANAGEMENT	J van Harmelen, Drs Delft L Waldron , BSc(Hons), PhD, MIEAust CPEng, SMIEEE, MAIP)

MECHANICAL ENGINEERING

Chief Engineer	J Hart, BE (Mech) NSW

DESIGN OFFICE

Designers	P Conroy, CME CTC M Doolan, BSc, BE(Hons), PhD G Jones, Dip MechE, Bmech, MEngSci D Stevanovic, BE(Hons), PhD

MECHANICAL WORKSHOP

Workshop Supervisor	C Vest
Instrument Makers	J Bowman A Cappuccio J DeSmet H Gebauer, CME B Miles R Tranter
Laboratory Technician	D Mitchell

OPTICAL WORKSHOP

Senior Optician	G Bloxham, DAP GIT
Optician	R Zhelem BSc, Hons, PhD

COMPUTING LABORATORY

Head	P Young, BSc
Programmers	A Czezowski, BSc Warsaw, MSc, PhD UNSW A. De Silva (casual Sep-Dec) M Jarnyk, BEng, MEng, PhD J Nielsen, BSc WA, BA Murdoch H Nyguen, BSc Griffith (until April) W H Roberts, Bsc K M Sebo, BSc WA, PhD D Smith, BSc (from February) G Wilson, BSC, PhD
Student Programmers	A Bouchard, BSc (10% from July) M Huynh, BSc WA (20% from May) R Moody, BSc (10% January) J O'Brien, BSc (20% from November)

ELECTRONICS

Engineer in Charge	M Dawson, BEng MEng
Engineers	M Downing J Griesbach G Hovey, Bsc, PhD P Oates B.A.(Hons), B.Sc (Hons),M.Sc , Ph.D
Technical Officers	A de Gans H Lawatsch M Menzies, Ass Dip EE S Owens

MT STROMLO OBSERVATORY VISITORS' CENTRE

Retail Supervisor	M Maloney, BSc (Arch)
Information Officer	N Aked
Adopt-a-Star Staff	F Neil B Smith

SIDING SPRING OBSERVATORY STAFF

OPERATIONS	
Site Officer	W Green
Assistant Site Officer	T Houghton
Operation Officer	H Davenport
Cleaner	P Nguyen
Casual Staff	R Cosgrove
	E Davenport
	T Houghton
	L Ryder
	S Watson
RESEARCH	
Research Officers	G Garradd
	R McNaught, BSc (Hons), St Andrews
Casual Staff	J Shobbrook
	R Shobbrook
TECHNICAL	
Engineer	M Harris, BEng(Elect) NSW
Technical Officers	M Callaway
	W Campbell, B App Sc, U Canb
	J Goodyear, HND BEEng, Edin.
	P Weekes
LODGE	
Lodge Supervisor	M Noy
Hospitality Staff	D Britton
	S Buckridge
	V Mathews
	S McWilliam
	R Penny
	K Ritsmitchai
	S Suckling
	J Templeman
	J Turner
	K White
SSO EXPLORATORY	
Supervisor	J Dicello-Houghton
Casual Staff	H Goodyear
	K Resch
	M Verrender

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