Research School of Astronomy and Astrophysics
The Australian National University

Annual Report 2004

Our Mission

- Advance the observational and theoretical frontiers of **astronomy** and its enabling **technologies**;
- Provide national and international astronomical **leadership**; and
- Train outstanding **scientists**.

Contents

A Foundation Year

This year has been a fundamental one for the Research School of Astronomy and Astrophysics at the Australian National University, as we re-establish and re-confirm the foundations of our mission: the frontiers of astronomy and its enabling technologies, national and international leadership, and the outstanding training of outstanding scientists.

Our astronomers helped to identify a colossal string of galaxies present at a time so early in the life of the cosmos that the formation of such large structures are not easily explained by the most favoured model.

A survey for Near Earth Objects (asteroids and comets whose orbits bring them close to the orbit of Earth) was begun at our Siding Spring Observatory, and rapidly became one of the most successful of all such searches worldwide.

Supercomputers were used by academic staff members to produce the first-ever fully three-dimensional atmosphere models for cool giant stars and three-dimensional models of the winds in galaxies undergoing massive bursts of star formation.

In collaboration with industry, a new fully-robotic telescope was designed that will map the skies faster than any other, capturing in one brief exposure a portion of sky 25 times the size of the full moon and recording objects a million times fainter than can be seen with the human eye.

In 2004, an instrument capable of delivering, when coupled to one of the world's largest ground-fixed telescopes, infrared images as sharp as the optical images delivered by the Hubble Space Telescope was designed by our astronomers and astro-engineers.

Two of our astronomers received exceptional honours this year: one topping the list of Australia's smartest scientists according to Bulletin magazine, and another recognized as a Thomson ISI
Citation Laureate for being one of the most highly-cited scientists in the world.

RSAA played leadership roles in defining a path forward for Australia's involvement in the mammoth next-generation telescopes currently being planned by international partnerships.

Our new Advanced Instrumentation and Technology Centre, scheduled for opening in 2006, is being designed specifically to provide Australian with the capability to build instrumentation for these giant new eyes-on-the-sky.

The most metal-poor star (and thus "oldest") known star in the Milky Way was discovered by an RSAA graduate student and her collaborators, as part of her PhD thesis work.

In the pages that follow, you can read more about these and other examples of how our mission was advanced in 2004. Underlying all these achievements, of course, are our people: world class scientists, engineers, technicians, administrators, educators, and students who are dedicated to excellence, team work, and productivity.

Penny D Sackett

ANU astronomer tops smart science list

ANU astronomer Professor Brian Schmidt has topped a prestigious list of Australia's top scientists for his research into the expansion of the Universe. He was number one of the nation's top ten scientists according to an expert panel brought together by The Bulletin magazine for its 2004 Smart 100 issue. Professor Schmidt led an international project called the High-Z SN Search that found the expansion of the universe was speeding up, not slowing down (the commonly held view). The project involved studying a class of exploding stars called Type Ia supernovae.

"Because the exploding star is so far away it offers the first tantalising observational evidence that gravity was once slowing down the Universe's expansion, but now has been overcome by a repulsive form of matter or 'Dark Energy'," according to Professor Schmidt. Before the research led by Professor Schmidt, it had been assumed the Universe was dominated by gravitating matter. But the High-Z SN Search indicated that only a quarter of the universe gravitates, with the other three-quarters made up of the repulsive anti-gravity.

According to The Bulletin: [Professor Schmidt] led and international astronomical survey which confirmed that a mysterious 'anti-gravity' [first proposed by Albert Einstein] force permeates the universe … and he predicts the universe will go on expanding forever". Professor Schmidt completed his PhD in astronomy at Harvard University in 1993 and in 1995 took up a postdoctoral fellowship at the Research School of Astronomy and Astrophysics, based at Mt Stromlo Observatory. He is currently an Australian Research Council Professorial Fellow at Mt Stromlo Observatory. His primary research interest is in exploding stars known as supernovae, integral to his research into the expansion of the universe, but also in the gamma ray bursts, dark matter and distant asteroids.

The 2004 Antoinette de Vaucouleurs Memorial Lecturer

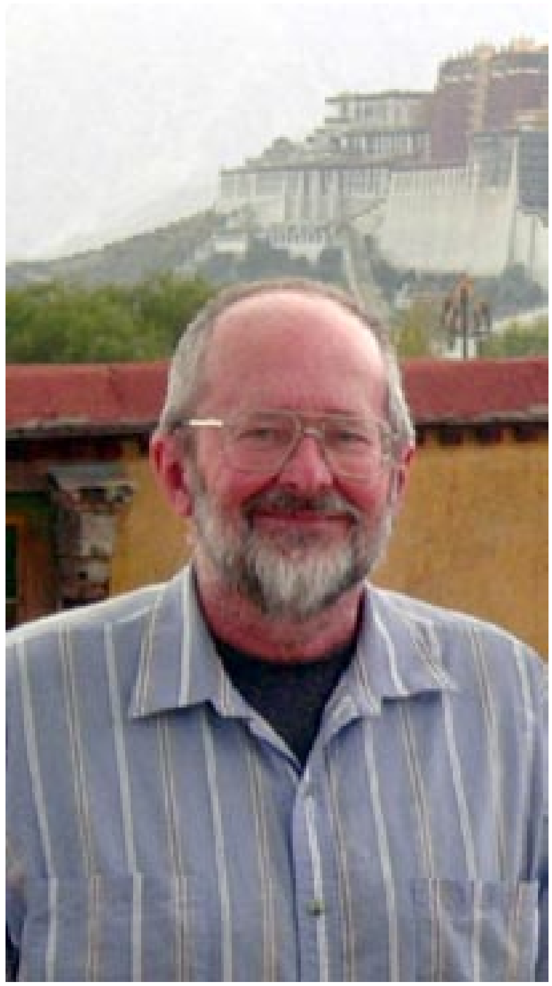
The eleventh award of the University of Texas' Antoinette de Vaucouleurs Memorial Lectureship and Medal honours the distinguished Australian astrophysicist Professor Ken Freeman of RSAA.

Professor Freeman earned a B.Sc. in Mathematics from the University of Western Australia in 1962, and a Ph.D. in theoretical astrophysics from the University of Cambridge in 1965. Following his Ph.D., he was the W.J. McDonald Postdoctoral Fellow working with Antoinette and Gérard de Vaucouleurs at The University. After a year as a Research Fellow at Trinity College, Cambridge, he returned to Australia to a long highly distinguished career at The Australian National University where he is currently the Duffield Professor in the Research School of Astronomy and Astrophysics of the Institute of Advanced Studies.

Professor Freeman's research has concentrated on the formation, dynamics, and evolution of globular clusters and galaxies, including the Milky Way galaxy. His ground-breaking work on spiral galaxies has spawned an industry trying to understand how these galaxies acquire their mass. His observational work on the components of our own Milky Way galaxy is of fundamental importance to theoretical models for its formation. He has also led significant efforts trying to measure the dark halo content in galaxies of all masses. Freeman was one of the first astronomers to point out that spiral galaxies are rich in dark matter. By synthesizing results over all galaxy types, Professor Freeman places himself in a unique position to make advances into one of the most important problems of our times: the nature of dark matter. He is clearly one of the most important figures in astronomy, advancing understanding of how galaxies form and evolve. His publications total more than 400 and are very frequently cited. The Information Sciences Institute (ISI) named him as one of Australia's most cited scientist from all surveyed sciences and includes him in their list of 250 most highly-cited researchers in the space sciences.

Professor Freeman was elected in 1981 a Fellow of the Australian Academy of Science, and in 1998 the American Astronomical Society and the American Institute of Physics awarded him the Dannie Heineman Prize for Astrophysics. He has held numerous prestigious visiting appointments and lectureships including the Aaronson Lectureship at the University of Arizona (1990), the J.H. Oort Professorship at Leiden University in The Netherlands (1994), the Beatrice Tinsley Professorship at The University of Texas at Austin (2001), Visiting Member at the Institute of Advanced Study in Princeton (1984, 1988), and appointment as Distinguished Visiting Scientist at the Space Telescope Science Institute from 1988 to the present.

2004 Citation Laureate

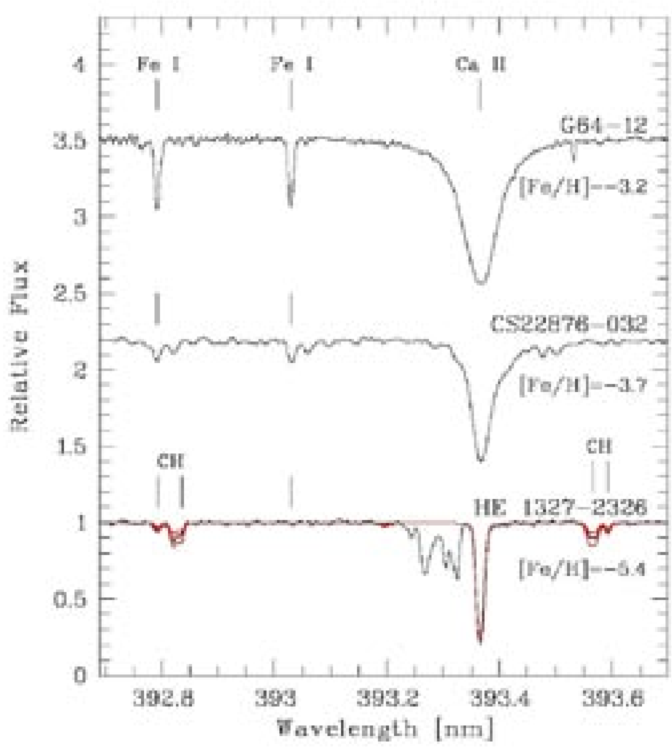


Dr Bruce A. Peterson was awarded a 2004 Thomson ISI Citation Laureate award for his outstanding contribution to Space Sciences in Australia. In the period between 1980 and 2004, Dr Peterson was one of the authors of 176 papers that were cited 11039 times, the highest of anyone in astronomy in Australia. These papers involved principally large cosmologically oriented programs, notably the Stromlo-APM Redshift Survey, the 2dF Galaxy Redshift Survey, the MACHO Gravitational Lensing Survey, an Optical QSO Survey and most recently, Gamma-ray burst identifications and High Redshift Quasar searches.

Dr Peterson is associated with the eponymous Gunn-Peterson effect used to label the predicted UV absorption of the spectra of high redshift quasars by neutral hydrogen in the early Universe.

Discovery of the most Fe-poor star

RSAA PhD student Anna Frebel has discovered the most iron-poor star yet found, from a sample of brighter stars from the Hamburg ESO Survey that she was observing with the 2.3m telescope as part of her PhD research. Analysis of subsequent SUBARU high dispersion spectra of HE1327-2326 by Frebel, Aoki (Tokyo), Christlieb (Hamburg), Asplund, Norris and others determined the extraordinarily low iron abundances [Fe/H] = -5.4 together with a huge overabundance relative to iron of carbon and nitrogen. The paper has been accepted for publication in the prestigious journal *Nature*. This star is of enormous importance because it provides observational evidence of the time when the first generations of stars formed after the Big Bang.



The figure shows the spectral region around the Ca K line in several metal-poor stars. One can see that this line and the Fe lines are weakest in the spectrum of HE1327-2326, indicating an extremely low metallicity. However, on the left side of the line one can see a complex set of Ca K absorptions caused by the interstellar gas between the star and the Earth. Only in high-resolution spectra, like shown here, it is possible to separate these absorptions from the Ca K line produced in the atmosphere of the star.

Opening of the SSO Survey for NEOs

Inhabitants of the Earth can sleep easier following the commencement of the Siding Spring Survey for Near-Earth Asteroids. After several years of development, the 0.5-m Uppsala Schmidt started regular surveying for Near-Earth Asteroids and Comets on March 16. The SSS rapidly became one of the most successful surveys in 2004 in working towards the Spaceguard goal of discovering 90% of 1-km and larger NEOs but the end of 2008.

Robert H. McNaught and Gordon J. Garradd are employed by the ANU to conduct the observations on behalf of the University of Arizona and the US National Science Foundation (NSF). On a typical night 600 squarev degrees of sky are surveyed to around magnitude 19.5 in the R band. Observations were carried out on 183 nights in 2004, during which 38 NEAs and 5 comets were discovered. The SSS discovered more mass of NEAs and NECs during 2004 that any other survey due to the fact that the southern hemisphere is largely unsurveyed. There now exist three comets Siding Spring that at discovery were "stellar" in appearance. There comets are the first to be discovered from ANU telescopes and the first to hold the name Siding Spring.

http://msowww.anu.edu.au/~rmn/index.htm

McNaught also works on meteors and the highlight of this research has been the modelling of the brightness of the Leonid meteor showers throughout history culminating in the successful prediction of the arrival time and best Earth vantage points for the 2001 event.

Surprising enormous string of galaxies discovered

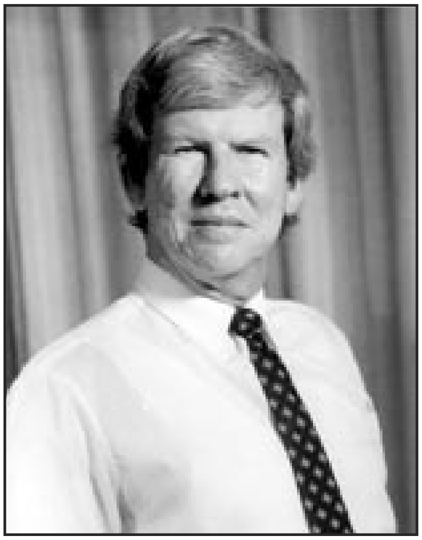
An enormous string of galaxies, 300 million light-years long, was discovered in the remote universe. Francis, together with Palunas (University of Texas), Teplitz (Spitzer Science Center), Williger (Johns Hopkins University) and Woodgate (NASA Goddard Space Flight Center) mapped a region of the universe 10.8 billion light years from Earth to find the string of galaxies. The team compared their observations to supercomputer simulations of the early Universe and found that there simply hasn't been enough time since the Big Bang for it to form structures this colossal. The HST images show only the brightest few galaxies which are probably far less than 1 per cent of all the mass, most of which is mysterious invisible dark matter. One explanation could be that the dark matter is not arranged in the same way as the visible galaxies.

Recently, evidence has accumulated for the presence of dark matter in the Universe, an invisible form of matter only detectable by the gravitational pull it exerts on ordinary matter (and light). There are many possibilities for what dark matter might be, but its true nature is currently unknown. In recent years, it had been found that in the local Universe, dark matter is distributed on large scales in very much the same way as galaxies are, rather than being more clumpy, or less. But 10 billion years ago it could be a very different story. Galaxies probably form in the centre of dark matter clouds. But in the early Universe, most galaxies had not yet formed, and most dark matter clouds will not yet contain a galaxy.

To explain the results the dark matter clouds that lie in strings must have formed galaxies, while the dark matter clouds elsewhere have not done so. This is not what is predicted by any of the current models.

Don Faulkner, 1937-2004

Don was one of the earliest PhD graduates from Mount Stromlo Observatory, and a long-time staff member. He lost his battle with cancer and passed away on 19 October 2004.



Don was initiated into the science of astronomy at the University of Queensland where he completed an MSc in 1960 before coming to the Australian National University to do a PhD degree. He spent his PhD years making observations of planetary and other gaseous nebulae. This observational experience was enough to cure Don of any desire to use a telescope again, and he subsequently turned to theory. After obtaining his PhD degree, he spent two years as a post doctoral researcher in the Physics Department at University College London, where he became acquainted with the burgeoning field of stellar evolution. Starting around this time, and after his return to Mount Stromlo in 1965, Don wrote one of the first stellar evolution codes, a code that is still used in several places around the world. This code is arguably the basis of his most important research.

Connecting with his observational past, Don initially used his evolution code to study the evolution of the central stars of Planetary Nebulae. These studies continued into the 1980s with faster and bigger computers and led to results that are highly cited and still widely used today. Another field opening up in the late 1960s was the observational study of the evolution of individual stars in Magellanic Cloud star clusters. Don and his student John Robertson developed the evolution code to model these stars, and they were able to carry out some of the earliest tests of the theory of intermediate mass star evolution.

Don was a keen painter, and took great delight in his art. Above, left: a painting of the Commonwealth Solar Observatory, inspired by view out of his office window at Mt Stromlo. Right: the Blue mountains.

While stellar evolution was making spectacular advances, the ever-present Solar Neutrino Problem was causing nagging doubts that perhaps something was fundamentally wrong with the theory of stellar evolution (the Solar Neutrino Problem arose because the Sun's neutrino flux as observed on earth did not match the model predictions). This was a deep interest of Don's, and it featured in both his professional research, in his lectures, and in the "Astronomy for Fun" courses that he gave for the general public. In the end, it turned out that the solar models were correct, and that the neutrinos emitted from the sun were oscillating to another "flavour" which was not detected by experiments on earth until very recently.

Besides his stellar evolution studies, Don had several other research interests. As part of his Planetary Nebula studies, he had an interest in how the nebulae were ejected from stars and he also wondered what happened to the ejected gas in the deep potential wells of globular star clusters. This led him to break with his purely theoretical traditions and to make radio observations with the Parkes dish to try to detect the gas. In an unrelated area, he was involved in studies of the multiperiodic beat Cepheid variables, leading to the PhD thesis of his student Sue Barrell. Finally, after his long association with Mount Stromlo, Don teamed up with Tom Frame upon his retirement and in 2003 they jointly produced a history of Mount Stromlo Observatory: "Stromlo: an Australian Observatory".

He is sorely missed.

- Peter Wood, RSAA

Cosmology

Expansion of the Universe

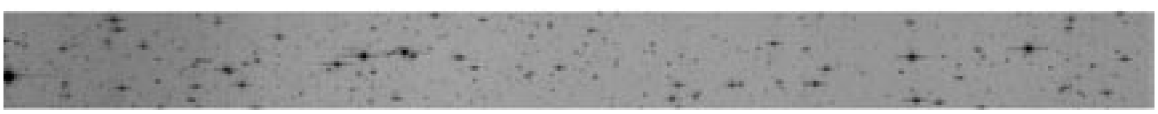
Two of RSAA's Astronomers are doing their part to clear up some common misconceptions about the expansion of the universe. Davis and Lineweaver were invited to write a feature article for Scientific American based on their 2004 paper "Expanding Confusion". In it they show that recession velocities, as they appear in Hubble's law (velocity is proportional to distance), can exceed the speed of light without violating special relativity. They also show that the redshifts of receding galaxies are not governed by the usual Doppler shift equation, that the observable universe is larger than 14 billion light years in radius (it's closer to 46 billion light years in radius), and that many galaxies within our observable universe are already beyond our cosmological event horizon so we will never be able to communicate with them. All is not as it seems!

Distant Supernovae

Schmidt is the scientific coordinator for the Essence project, a program which is tracking the accelerating Universe to high precision using Type Ia Supernovae. Essence has been awarded a swath of nearly 100 nights over 5 years on the Cerro Tololo Blanco 4 meter time to measure the properties of the Dark Energy which is ripping the Universe apart. In 2004 the Essence project identified more than 40 distant exploding stars.

Quasars

Peterson and Verner (NASA-Goddard) are studying the iron emission spectra of quasi-stellar objects. Peterson, in collaboration with Kawara and his colleagues at the University of Tokyo, has constructed a CCD camera and a new telescope control system for the AAO Schmidt Telescope at Siding Spring Observatory. This equipment is used to survey the Southern Sky in drift-scan mode at the rate of 7.5 square degrees per hour to a depth similar to that done in the North by the Sloan Digital Sky Survey. The data from this survey, along with data obtained from the Wide Field Imager on the ANU 40in telescope at Siding Spring, in collaboration with Francis, Schmidt, Keller and Bessell, is being used to search for high redshift quasi-stellar objects.



A 0.5 degree x 5.8 degree section of a 120 degree drift-scan image taken on the AAO Schmidt Telescope.

Neutral Hydrogen at High Z and the Giant Metrewave Radio Telescope

Briggs, Chengalur (National Centre for Radio Astrophysics), Colless (AAO), De Propris (University of Bristol) are collaborating in a project to measure the mass of neutral hydrogen gas in galaxies at high redshift Z. This project is using optically selected galaxies so a direct relationship between the evolution of neutral hydrogen mass, star formation and the stellar mass of galaxies can be determined for the same systems. The neutral hydrogen mass of the galaxies is being measured from the HI 21cm emission line. Previous studies have been limited to the local universe due to the difficulty in measuring HI emission from distant objects. To push the measurements to higher redshifts the HI emission from multiple galaxies is being coadded resulting in a stronger signal. This can be done because the position and redshift of the galaxies can be determined from their optical light.

The telescope being used for this project to measure the HI emission is the Giant Metrewave Radio Telescope (GMRT) which is located 80 km north of Pune, India. The GMRT has 30 radio dish antennas each of 45m in diameter. The smallest separation between the dishes is 100m with the largest separation being 26km. With its large collecting area and advantageous wavelength coverage the GMRT is the presently best telescope in the world for measuring HI 21cm emission at high redshifts.

The current status of the project is that there are GMRT observations of galaxy cluster Abell 370 and Subaru Deep Field observations of field galaxies. From the Abell 370 data preliminary HI measurements have been made (further optical observations are required). With this data the expected noise reduction using the coadding redshift techniques has been tested. Another GMRT proposal was successful for observations of galaxy cluster Cl0024+1652 and has been scheduled for January 2005.

Galaxies

Planetary Nebulae in the Coma Cluster of Galaxies

Freeman together with Gerhard (Basel), Arnaboldi (Turin) and Okamura (Tokyo), devised a technique to detect individual planetary nebulae in the Coma cluster of galaxies, which lies at a distance of about 270 million light-years. The observations were made with the Subaru telescope in Hawaii, and successfully detected many planetary nebulae in the intergalactic space between the galaxies of this very rich cluster. In the Coma cluster, about half of the starlight lies between the galaxies. These stare were probably stripped from the galaxies by the tidal field of the cluster itself. This new technique opens up the possibility to study how the stars of the intracluster medium are moving, which will allow astronomers to work out how and when the stars migrated from the galaxies into the intracluster space.

The Pan-Spectral Modelling of Collapsing and Star-forming Galaxies

A difficult problem is being tackled by Dopita, as part of his Federation Fellowship research. In the early Universe, the Epoch of galaxy formation was the most spectacular. In this epoch, the galaxies we see today were assembled, and much of the collapsing gas was converted rather violently into stars. At the same time, these galaxies grew massive black holes in their cores which shone brilliantly for a short time as luminous quasars, and ejected jets of relativistic particles which shocked the gas in their host galaxies before sweeping into the inter-galactic space. The problem of interpreting the data gathered on telescopes covering a wide range of wavelengths is that dust obscures the short wavelengths of light, but re-emits this radiation in the far infrared. To make progress, we need to build theoretical spectra of these star forming and active galaxies from the Ultraviolet through to radio wavelengths. These models would then provide the basic parameters of the star-forming proto-galaxies such as the star formation rate, the fraction of the luminosity provided by the active nucleus, the physical conditions in the gas and its chemical state.

Tackling this problem involves constructing the global spectral energy distribution (SED) by making self-consistent models of the different components of the star forming galaxy, the individual stars and their surrounding molecular clouds, clusters of stars and their surrounding molecular regions, and solving the radiative transfer problem around the active nucleus. The first part of this problem has now been solved, that of the radiative transfer for evolving HII regions around clusters of stars driven from within as mass-loss blown bubbles of gas. It was discovered that two parameters control the shape of the SED, the pressure in the interstellar medium, and the geometrical factor related to the covering fraction of dense molecular clouds. This work provides the theoretical calibration of a large number of star formation indicators, and provides a remarkably good fit to the observations of nearby violently star forming galaxies. The next stages in the problem, adding the single star component, modelling the dust emission spectrum of the active nucleus and including the older stars and the extended dust in the interstellar medium has now been commenced.

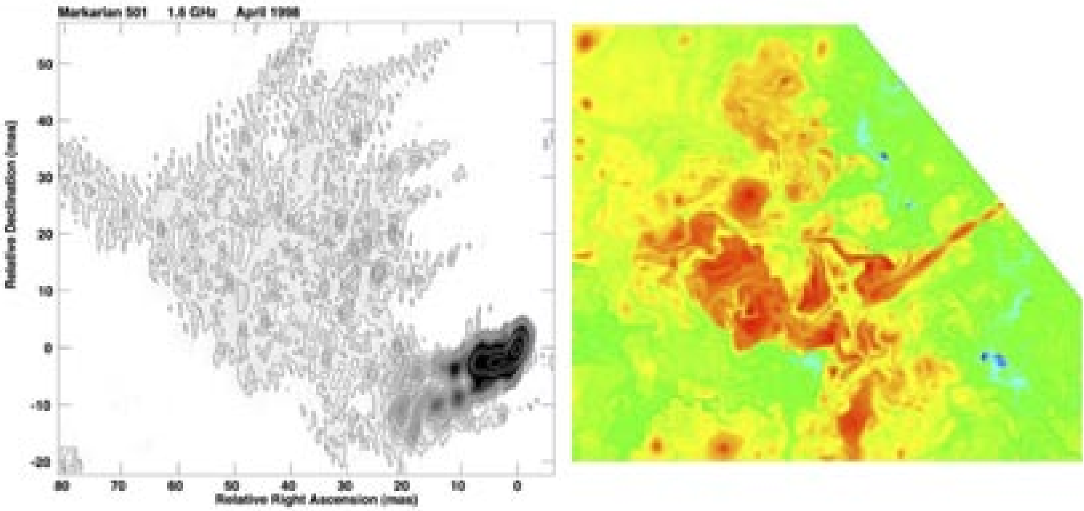
The Fate of Satellite Galaxies

Due to advances made by the Swinburne group on high-resolution particle codes to deal with the formation of structure in the Universe, it is now possible to tackle the temporal evolution of satellite galaxies and smaller sub-systems in the process of galaxy collapse. Dopita has been collaborating with this group in the investigation of such satellites to discover whether these represent the progenitors of the globular Clusters in our galaxy. In this scenario, the stars formed into a Globular originated in the dissipational collapse of baryonic matter about dark matter cusps in these halos. The dark matter, remaining gas, and a good fraction of the stars are then removed by tidal interactions with the proto-galaxy, leaving only a tightly-bound core of stars, seen today as a globular cluster. Since the number of Globular clusters seen today is about the same as the number of missing satellite galaxies predicted by LCDM models (the satellite problem). This scenario promises, at a stroke to resolve two long standing problems in modern astrophysics.

To this end the team ran models of eight galactic haloes on Swinburne supercomputer to discover what fraction of satellites are stripped by tidal interaction. This work clearly show that the evolution of the satellite system is strongly dependent upon initial conditions, and that systems which undergo a monolithic collapse lose more satellites to tidal stripping. This may provide a partial explanation of the absence of satellites in our galaxy, since it is believed that our Galaxy had (rather unusually amongst galaxies as a whole) a virtually monolithic collapse.

Deceleration of gamma-ray emitting jets

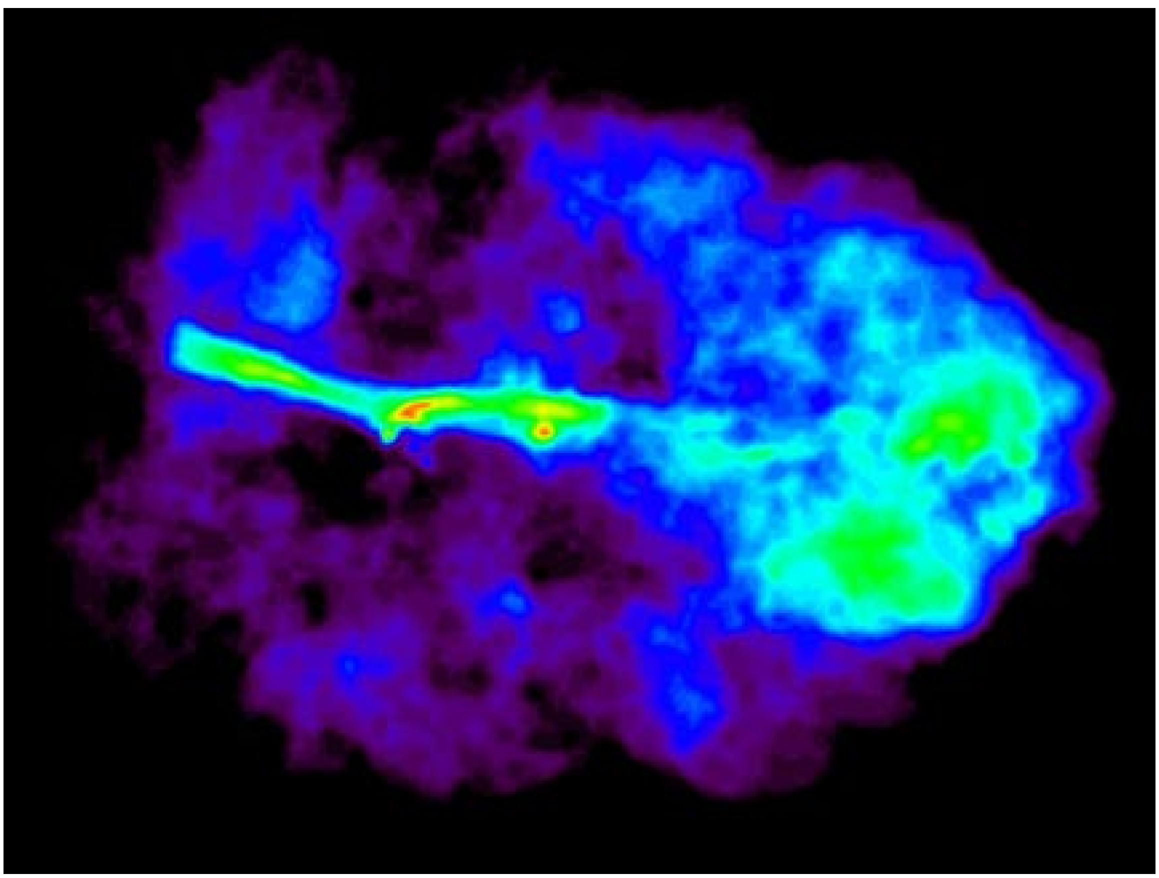
Bicknell, Sutherland, Saxton (now at Mullard Space Sciences Lab in the UK) and Midgley (ANUSF) have successfully modelled jets in two galaxies. Models for the gamma-ray emission from jets in the active galaxies MKN 501 and MKN 421 tell us that the jets are moving with speeds extraordinarily close to the speed of light. The estimates are model-dependent. However, many models place the speeds within about 0.5% of the speed of light; some recent models say that the speeds are within about 0.02% of the speed of light. The gamma-ray emission originates from a region that is of the order of about 10 light-days from the supermassive black hole that emitted the jets. However, at the present time, the inference of these velocities is indirect; we cannot make any images of these regions and measure the velocities directly. However, these so-called ultrarelativistic velocities cause a problem for radio astronomers, who can measure jet velocities at around a light year distance from the black hole. They find that the velocities of components in the jets from the black hole are subluminal, i.e. they are only moving at a small fraction of the speed of light. Bicknell has shown that these two estimates of jet velocities in different regions are consistent with a jet that decelerates as it travels away from the black hole. His theory was based in part on the similarity of supercomputer simulations of a slab jet interacting with a cloudy medium and images of the large scale structure of both MKN 501 and MKN 421 carried out in collaboration with Saxton, Sutherland and Midgley. A comparison of a snapshot from the slab jet simulation with MKN 501 is shown below. Bicknell then showed, by using the relativistic equations for conservation of jet energy and momentum, that the jet pressures and cross-sectional areas estimated from the gamma-ray and radio models and observations imply that the jets in MKN 421 and 501 must have decelerated in their travel outward from the nucleus. This theoretical work then reinforces the accumulating evidence (mainly from work at RSAA) that jet outflows in young active galaxies take place in an environment that bears the imprint of a merger that has dumped considerable amounts of gas into the centres of active galaxies.



Left panel: A VLBI radio image of the TeV gamma-ray blazar MKN 501 (Giroletti et al. 2004, ApJ, 600, 127)
Right panel: A rotated snapshot of the density (logarithmic scale) from a simulation of a slab jet interacting with a cloudy medium. In the simulation, the low density jet (shown in red) is disrupted and becomes plume-like as a result of its interaction with the inhomogeneous interstellar medium (green-blue colour). There is a strong resemblance between the simulation and the appearance of the radio source.

Three-dimensional simulations of jets in cloudy media

Following on successful two-dimensional simulations that identified relevant regions of parameter space, Bicknell, Saxton and Sutherland began a program of three dimensional simulations aimed at investigating the realistic structure of radio galaxies that are interacting with inhomogeneous interstellar media. A developing idea is that an inhomogeneous interstellar medium may result when a merger between a galaxy and a gas-rich companion dumps gas clouds into the central environment of the large galaxy, providing fuel for the black hole. The first simulation along these lines involved a fairly low luminosity jet with a power of about 10^{35} Watts. The radio emissivity from this simulation was estimated and used to construct synthetic radio images which could be concatenated to form a movie. One of these synthetic images is shown below and shows the partial disruption of the jet that is produced by the interaction of the radio emitting plasma with dense gas clouds. Some of these features are produced as a result of direct jet-cloud interactions; others are produced as a result of the interaction between the cocoon of plasma that envelops the jet as it forces its way through the interstellar medium. The power of this jet is typical of that inferred of jets in many Seyfert galaxies and the radio morphology predicted by the simulation is also typical of many radio sources observed in that particular class of active galaxy.

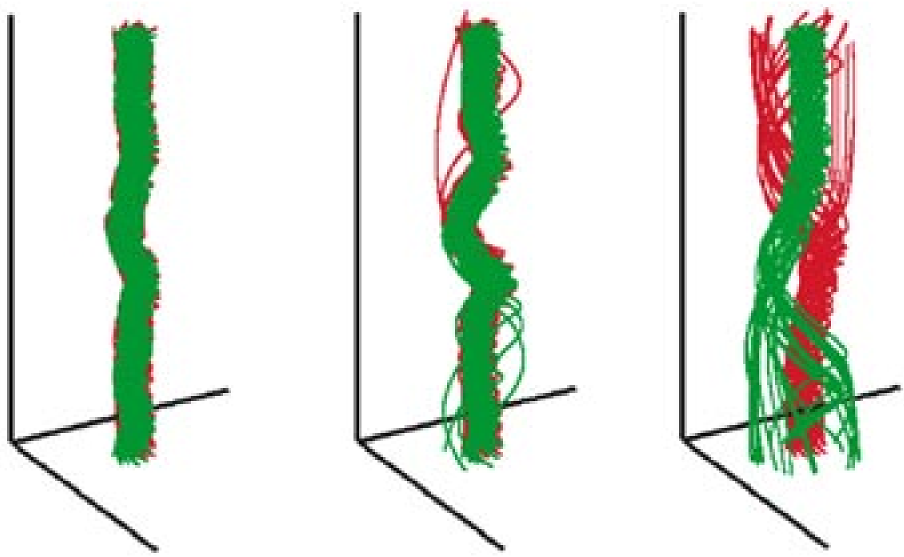


False-colour synthetic radio image of a jet being disrupted by its interaction with a cloudy medium. Whilst the jet is disrupted, it maintains some forward momentum leading to a radio source structure that is elongated but without bright hotspots at the end.

Twisted magnetic flux tubes

Sims and Bicknell have used the parallel version of the ZEUS MHD code, running on the APAC supercomputer, to simulate magnetic flux tubes twisted at their foot-points with various initial conditions. Magnetic reconnection of twisted magnetic flux tubes is an important energy conversion process in numerous astrophysical environments. The simulations confirm a theoretical scaling relationship for this process. They have also used two different initial magnetic field configurations, one with a non–zero magnetic field external to the filaments, the other with a zero external field, making useful comparisons between them.

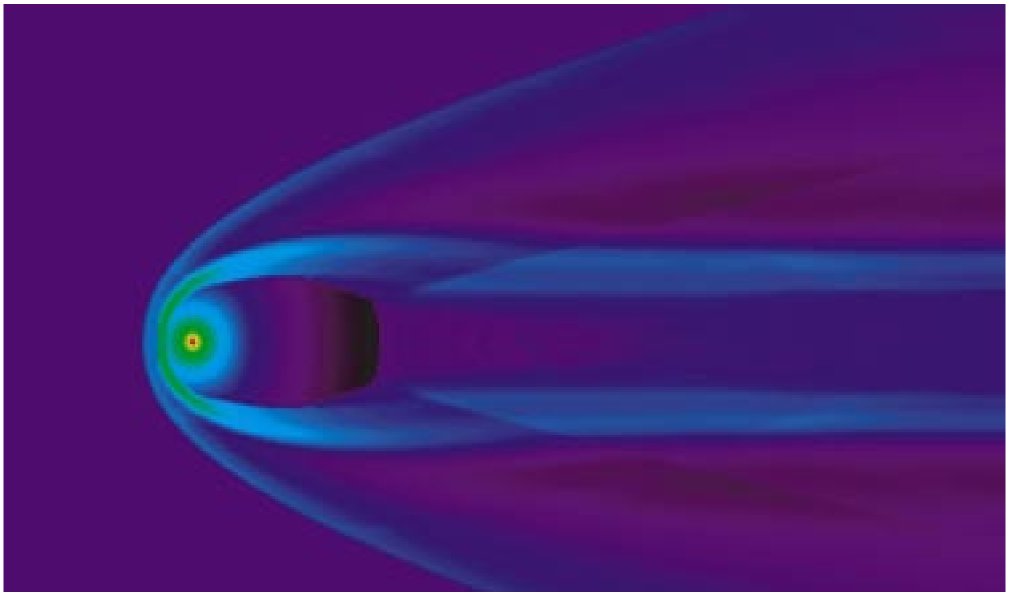
The following figure shows the evolution of a twisted magnetic flux tube succumbing to the kink instability. As the instability develops, magnetic reconnection occurs with an associated major topological change in the magnetic field. This is a repeatable process during which a significant amount of magnetic energy is converted into heat and kinetic energy.



Magnetic field lines from a twisted magnetic flux tube. Green lines were traced from the upper foot-points and red field lines were traced from the lower foot-points. These figures at increasing time intervals show the progression of the kink instability into magnetic reconnection and topological rearrangement. (The red field lines are initially obscured by the green field lines.)

Interacting winds in the Galactic Centre

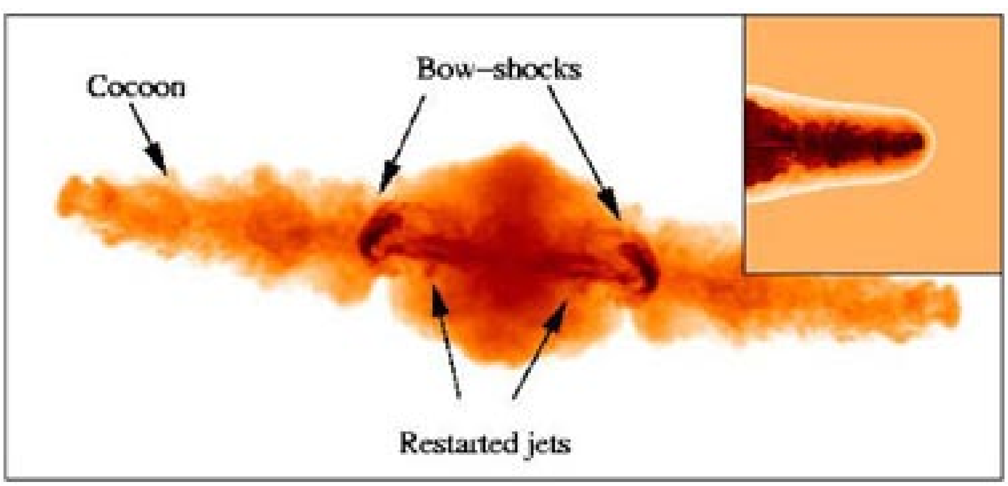
Sims and Bicknell have used the parallel version of the ZEUS MHD code to conduct 3D simulations of the interaction between a magnetised stellar wind and a non-magnetised galactic wind. They propose that this is the process creating the hitherto mysterious non-thermal filaments in the Galactic Center. Figure 3 is a slice of the logarithm of the density in the simulation through the (x,y) plane. Multiple shock structures are evident and gas from the stellar wind is drawn out in a long filament behind the star. Multiple shocks could explain the intriguing flat radio spectra emitted by the filaments. Simulations implementing the magnetic field show the field is drawn into the tail, explaining the high degree of polarization observed in the filaments. These simulations also show that the ~milli-Gauss magnetic fields inferred in the filaments have their origin in kilo-Gauss magnetic fields near the surface of the star.



This false-colour logarithmic density image shows the wind from a star (located near the red dot) interacting with another high temperature supersonic wind flowing from left to right. A bow shock is produced and further oblique shocks are produced downstream in the mixing region between the two winds. There is also a tail shock where the stellar wind merges into the long filament that is produced by this process.

Restarting Radio Galaxies

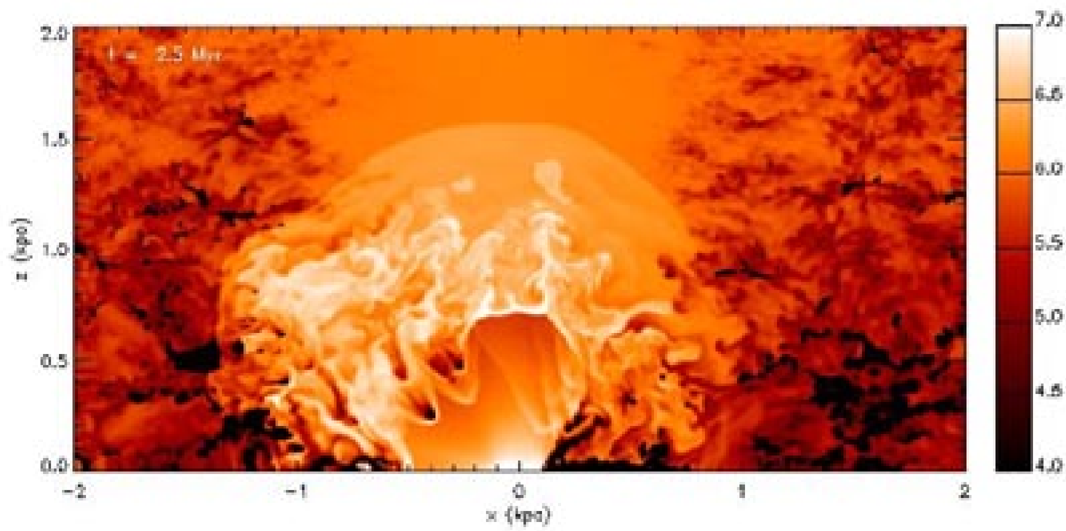
High quality images of powerful radio galaxies show jets from the central engine that have been caught in the act of restarting. Safouris, Bicknell and Sutherland have performed a 3D simulation of a hypersonic (Mach 30) restarting jet propagating into a uniform medium, 100 times denser than the jet. Figure 4 is a synthetic radio image, which shows a snap-shot of the newly restarted jet propagating through the light cocoon inflated by the old jet. The inset shows the computed gas density. The synthetic radio image indicates that, at early stages, the restarted jet propagates almost ballistically through the cocoon of the old jet. Curved bow-shock features are excited ahead of the restarted jet in the cocoon. This synthetic radio image is consistent with recent high–resolution radio observations of restarting radio galaxies. The resolution of this simulation was 512x512x512 cells and took 80 hours to complete on 64 processors of the Compaq Alpha-server.



Synthetic radio image of a restarting jet. Two new jets propagate almost ballistically through the pre-existing radio-emitting plasma. Inset: The computed density structure.

Starburst-driven galactic winds

Copper, Bicknell and Sutherland have been conducting three-dimensional hydrodynamic simulations, in order to study the evolution and morphology of winds in star-burst galaxies. These winds are formed when the energy from massive stars in the centre of a starburst galaxy drive out a bubble of very hot gas into the surrounding interstellar medium (ISM). After the bubble has reached a certain size it fragments and 'blows-out' to form a galactic wind. The main feature of their simulations is the introduction on an inhomogeneous ISM. The figure below shows the temperature distribution of a slice through the central plane of one of the data cubes. At 2.5 million years we can see that the wind is tilted (expanding more in one direction than in the other) and we can see the formation of filaments created by clouds that have been drawn into the wind. Both of these features are seen in observations of galaxies with starburst winds. Future work will be done to improve the initial set-up of the inhomogeneous ISM to increase the realism of these simulations.



The temperature structure in the central slice of a three dimensional simulation of a starburst wind. The wind is tilted as a result of the inhomogeneous structure of the interstellar medium and fragments of interstellar material are lifted up by the energetic wind.

Action in Galaxy Cores

Graham has made a new analysis of Hubble Space Telescope data that has solved a long-standing problem in the merger of galaxies.

The collisional construction of galaxies from the merger of lesser galaxies is thought to be a common occurrence in the Universe. Coupled with the presence of a supermassive black hole (SMBH) at the heart of most galaxies, dissipationless mergers have been proposed to explain the damaged nuclei in giant elliptical galaxies. Although some galaxy "core-depletion" is due to the SMBH(s) dining on stars that venture to close, it is primarily from the gravitational slingshot effect that the coalescing SMBHs - from the pre-merged galaxies - have on stars while they themselves sink to the bottom of the potential well of the newly-wed galaxy. Graham's work has quantified the extent of damage caused by these cosmic wrecking balls.

Theory predicts that the orbital decay of two such SMBHs should eject a core mass roughly equal to the combined black hole masses. However, past measurements of the central stellar deficit were an order of magnitude larger than the central SMBH mass, suggesting that most elliptical galaxies had undergone multiple (8-10) major-mergers. This result, however, is at odds with popular models of hierarchial structure formation, which predict an average of only 1 (dissipationless) major-merger event for luminous elliptical galaxies.

Figure credit: Debra Meloy Elmegreen (Vassar College) et al., & the Hubble Heritage Team (AURA/ STScI/ NASA)

The new analysis by Graham not only explains why the past measurements were so high, but yields flux deficits around 0.1% of the total galaxy light, and mass deficits equal to a galaxy's central supermassive black hole mass. These results imply that the galactic merger history (of luminous elliptical galaxies) is some ten times less violent than previous observations had suggested.

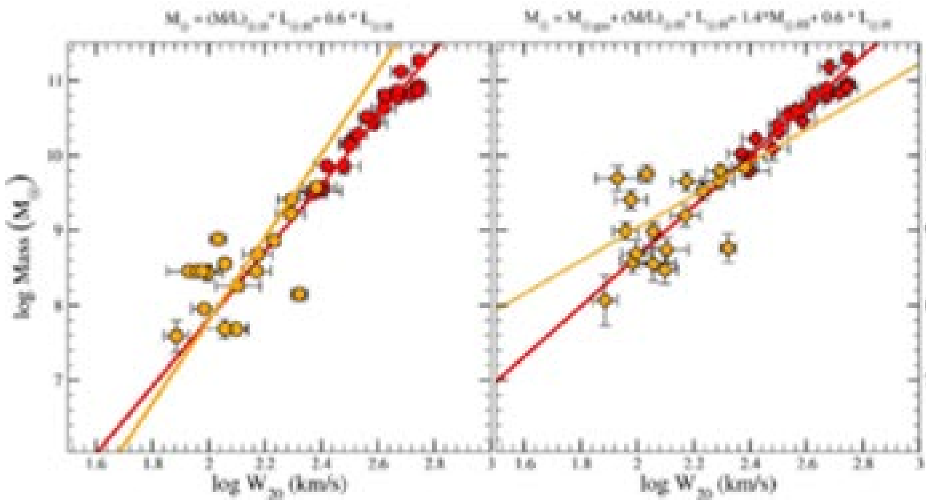
Low Surface Brightness Galaxies and Dark Matter

After his arrival at Mount Stromlo in late October, de Blok continued his research in the shapes of the dark matter halos of Dwarf and Low Surface Brightness galaxies. Comparisons with predictions derived from computer simulations of galaxies seem to indicate that the dark matter density in the centers of galaxies is 100 to 1000 times lower than predicted. De Blok analysed further observations of the rotation curves of galaxies, which will be used to further constrain the inner shape of dark matter halos.

Nearby Faint Disk Galaxies and the Tully-Fisher Relation

Gurovich was the lead author of a paper that showed an important sample of massive disk galaxies to lie more closely to the Baryonic Tully-Fisher (BTF) relation than the Tully-Fisher (TF) relation. The classical TF formulation relates the mass of the stars in the galaxy to the disk rotational velocity, whereas the BTF formulation includes the mass of gas (mostly neutral hydrogen) as well as the stars.

This study focused on the gas-rich faint end of the population of nearby disk galaxies. Interestingly, it found that for this sample at the faint end, the TF and BTF relations are not simple. This research is relevant in understanding the process of formation and evolution of galaxies in the context of the paradigm of hierarchical structure formation in which large galaxies are built up from merging of smaller galaxies.



Tully-Fisher plot (left panel) and Baryonic Tully-Fisher plot (right panel) plots for the H-band data of the HI selected galaxies from Gurovich's thesis sample and, for the adapted Sakai et al (2000) H-band calibrator data. Stellar baryon masses are represented by circles. "Total" baryon masses, which include the stellar plus gas components, are represented by diamonds. The stellar and "total" mass bi-variate weighted fits are shown. It is clear that the slopes of the BTF fits are flatter, but the simple TF and BTF relations break down for the fainter (HI-selected) sample.

Faint Galaxy Luminosity Function

Jerjen with collaborators Tully, Trentham and Dunn was awarded 80 orbits with the Hubble Space Telescope to obtain deep images for a large number of faint dwarf galaxies in the nearby galaxy group NGC1407 and to measure adequate distances to all of them via the surface brightness fluctuation method. This resulted in the best definition ever of the galaxy luminosity function in a specific environment.

Wide field imaging surveys with large ground-based telescopes now provide the capability to identify dwarf galaxy candidates to very faint levels. However, until this work by Jergen was done, the faint end of the luminosity function (the number of galaxies within different luminosity bins) was poorly known due to the omnipresent problem of group membership uncertainties resulting from poor distance derivations for the faint galaxies.

The luminosity function is of great interest because the history of the formation of galaxies must leave an imprint in the properties of the mass function of collapsed objects and hence in the observed galaxy luminosity function. Accurate knowledge of the luminosity function over the full range of galaxy clustering scales provides serious constraints on both initial cosmological conditions and modulating astrophysical processes.

Dwarf Spheroidal Galaxies

The recent results of Coleman, Da Costa, Bland-Hawthorn and Freeman for the Fornax dwarf Spheroidal have come as a surprise. These authors have used the Wide Field Imager on the 1m telescope at Siding Spring Observatory to survey an unprecendently large area of sky around the Fornax dSph.

Our Milky Way galaxy is surrounded by a system of approximately a dozen satellites, most of which are of the dwarf Spheroidal (dSph) type. These low luminosity galaxies are generally believed to be the 'survivors' of an originally much larger population of dSph-like objects that went through a merger and accretion process at early time resulting in the formation of the Milky Way. This merger and accretion process continues to the present day: for example, the Sagittarius dwarf spheroidal galaxy (dSph) is currently being disrupted by the gravitational field of the Galaxy and will be completely absorbed into the Galatic halo in a few billion years. The surviving Galactic satellite dSph galaxies, however, are not expected to show any signs of past interactions. This is not what was found.

The authors used two filters in the observations to facilitate the discrimination between foreground and background stars and Fornax members by allowing regions of the colour-magnitude diagram dominated by Fornax stars to be isolated. The observations revealed a large shell-like structure centered on the minor axis of the dSph and elongated parallel to the major axis which lies substantially beyond the tidal radius of the dwarf. The feature is on the opposite side of Fornax from the previously reported small inner shell-like feature that also lies on the minor axis just outside the Fornax core radius. Shell features are relatively common in more luminous elliptical galaxies but this is the first time such features have been observed in dSph galaxy. Further analysis of the Fornax stellar distribution beyond the tidal radius revealed an extensive lobe-like structure aligned with the minor axis in which the shells are embedded. Together these features provide strong evidence that Fornax has experienced a merger event in the relatively recent past. Further observations are planned to investigate the characteristics of the merger event and to try to gain information on the now-merged companion system.

In other research on an apparent dwarf galaxy, Bouchard, Da Costa and Jerjen have used neutral hydrogen gas observations obtained at the Australia Telescope Compact Array (ATCA), and optical observations obtained from the Hubble Space Telescope (HST) Science Archive, to clarify the nature of the galaxy known as CFC97 Cen 05, which has in the past been considered a gas-rich low-luminosity (dwarf) system in the nearby group of galaxies centered on the unusual elliptical galaxy Centaurus A.

The ATCA observations reveal that the gas previously thought to be associated with the galaxy is instead a so-called 'High Velocity Cloud' in the halo of the Milky Way located well away from the optical position of CFC97 Cen 05. The detected gas is therefore unrelated to CFC97 Cen 05. At the optical location of CFC97 Cen 05, no gas was detected. The HST images then further reveal that CFC97 Cen 05 is in fact not a dwarf galaxy at all, instead, it is an almost face-on spiral galaxy that is considerably more distant than the Centaurus A group. While mistaken identifications of this type are presumably not common, it is a salutary lesson that group membership of apparently low luminosity small galaxies needs confirmation via a number of techniques in order to have a reasonable degree of certainty.

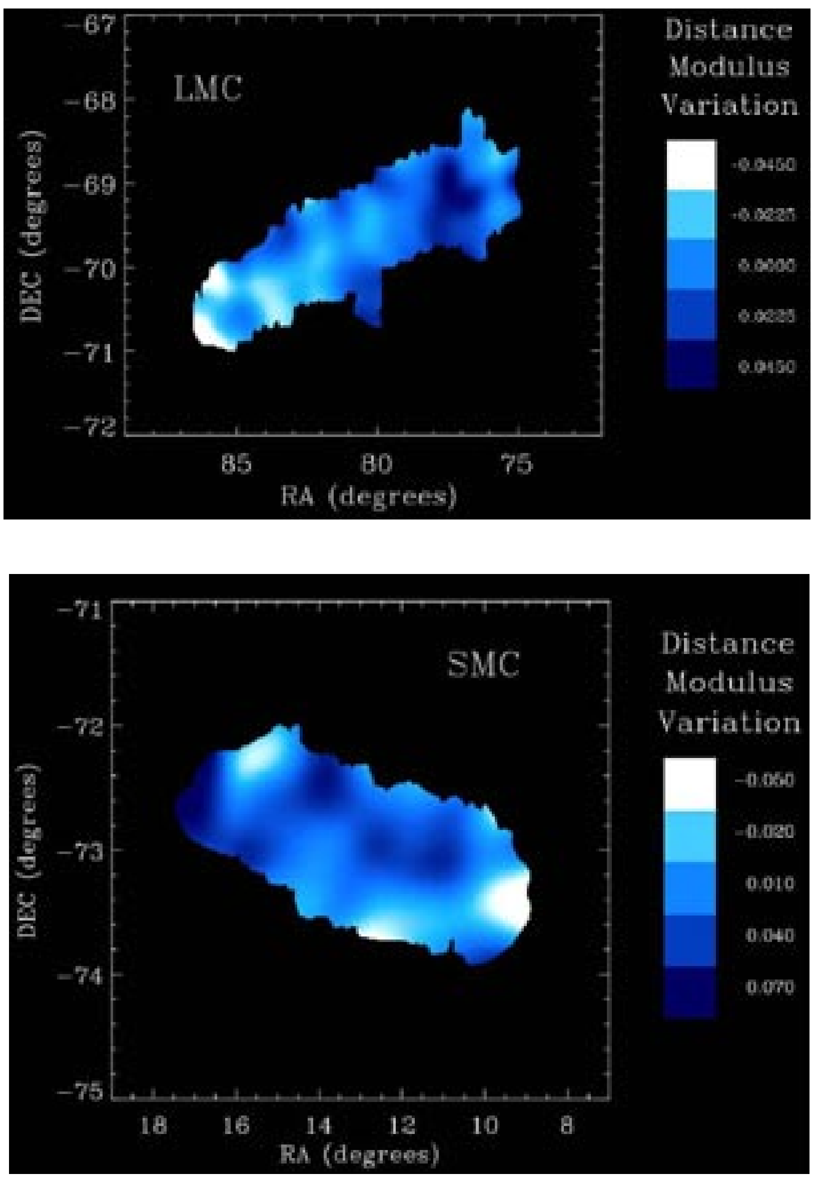
3D Structure of the Magellanic Clouds

Wood, Kiss (University of Sydney) and Bedding (University of Sydney) have analysed the period-luminosity relations for Red Giant Variables in the Magellanic Clouds. This work was begun during a Summer

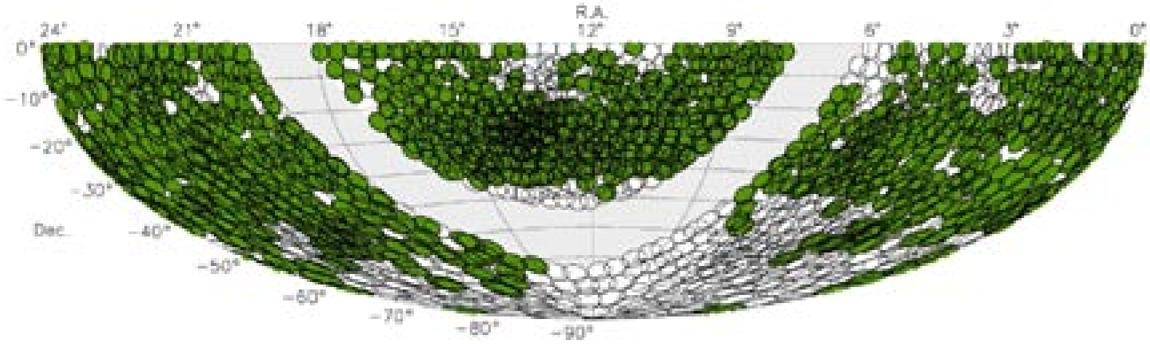
Scholarship at the Sydney University and completed at the ANU. These stars have periods of variation ranging from 10 to 1000 days. They lie on a series of period-luminosity relations discovered by Wood from the MACHO survey conducted using the 50 inch telescope at Mt. Stromlo in the Large and Small Magellanic Clouds (satellite galaxies of our own Galaxy). In this work the deviations from the mean period-luminosity relations were interpreted as distance variations in the structure of the Large and Small Magellanic Clouds. This allowed for an examination of the 3 dimensional structure of these galaxies. Data from periods derived from OGLE-II (another Magellanic Cloud photometric survey program) data and magnitudes from the 2MASS (whole sky) infrared survey. The maximum variation observed was LMC is 2.35 kpc and SMC is 3.2 kpc. The distance variations were consistent with previous work thus demonstrating the use of red giant variables as distance indicators.

The 6dF Galaxy Survey (6dFGS)

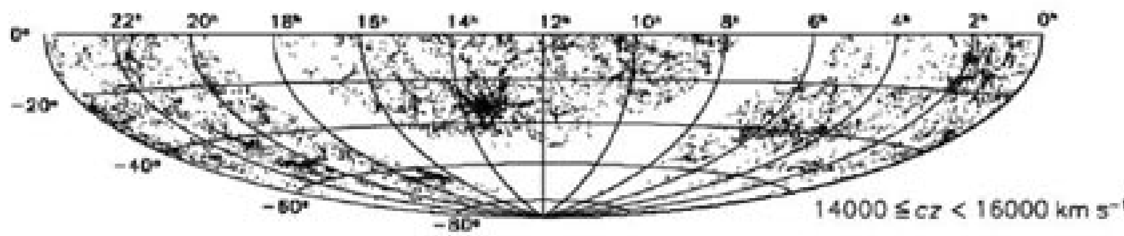
In 2004, Jones, Peterson, Colless (now AAO), Saunders (AAO) and the 6-Degree Field Galaxy Survey (6dFGS) Team continued this survey which aims to measure around 150000 redshifts and 15000 peculiar velocities from galaxies over the southern sky, at Galactic latitudes beyond 10 degrees. When complete, it will be the largest survey of its kind by more than an order of magnitude. The 6dFGS data are made public at approximately yearly intervals, with Early and First Data Releases (DR1) having taken place in December 2002 and March 2004 respectively. Most recently, the Second Data Release (DR2) spans observations during the period January 2002 to October 2004, including and superceding DR1. It contains 89211 spectra that have yielded 83014 unique galaxy redshifts over roughly two-thirds of the southern sky. A total of 71627 sources now have their spectra, redshifts, near-infrared and optical photometry available online and searchable through an SQL database at http://www-wfau.roe.ac.uk/6dFGS/. DR2 takes its data from 936 fields.



A 3D representation of the LMC and SMC. The lighter regions are closer to us and the darker regions are further away from us (i.e. negative distance modulus are closer to us). The black regions are where there is no data coverage by the OGLE-II data.



This figure shows that their distribution is true to observing strategy adopted by 6dFGS from the outset: mid-latitude fields were tackled first, followed by those nearest the equator and finished with the polar targets. In terms of sky coverage, the 6dF Galaxy Survey will ultimately cover 8 times the area of 2dF Galaxy Redshift Survey (2dFGRS) and twice that of Sloan Digital Sky Survey (SDSS). In terms of sample size, the 6dFGS will yield two-thirds as many galaxy redshifts as 2dFGRS and one-fifth as many as SDSS.



This figure shows the distribution of DR2 redshifts on the sky for a small fraction of the total sample in the redshift slice indicated. Many local large-scale structures (such as the Shapley Supercluster) are apparent in what is the most detailed and comprehensive view of the southern local universe to date. Observing for the 6dFGS will nominally finish on 31 July 2005, although some clean-up observations may occur after that date. A third and final data release will be made sometime in 2006.

Finding the first Galaxies

A team of collaborators led by Westra and Jones from the Wide Field Imager Lyman Alpha Search (WFILAS), a narrowband survey designed to find line emitting galaxies, have found a galaxy at a time when the Universe was a mere 1 billion years old. Using the FORS2 spectrograph on the ESO 8m telescope (VLT) the team confirmed that one of their candidate Lyman Alpha emitting galaxies is indeed a very small star-forming galaxy at this era. It was found to be one of the brightest in its category.

The Rave Survey

Freeman is the scientific coordinator for the international Radial Velocity Experiment (RAVE) survey http://astronomy.swin.edu.au/rave/. This large spectroscopic survey involves astronomers from 9 countries. It has now been running for about 18 months and has already acquired spectra of more than 50,000 stars. It is already the largest stellar radial velocity survey ever made. The stars are all brighter than 12th magnitude and lie in the southern hemisphere more than 30 degrees from the plane of the Galaxy. They have no other selection criteria, so will provide a very comprehensive sample of stars within a few thousand light-years of the Sun. A major goal of the survey is to identify kinematic substructure among the stars of the nearby galactic disk. 6dF on the AAT Schmidt at SSO is the instrument used. (http://www.aao.gov.au/ukst/6df.html)

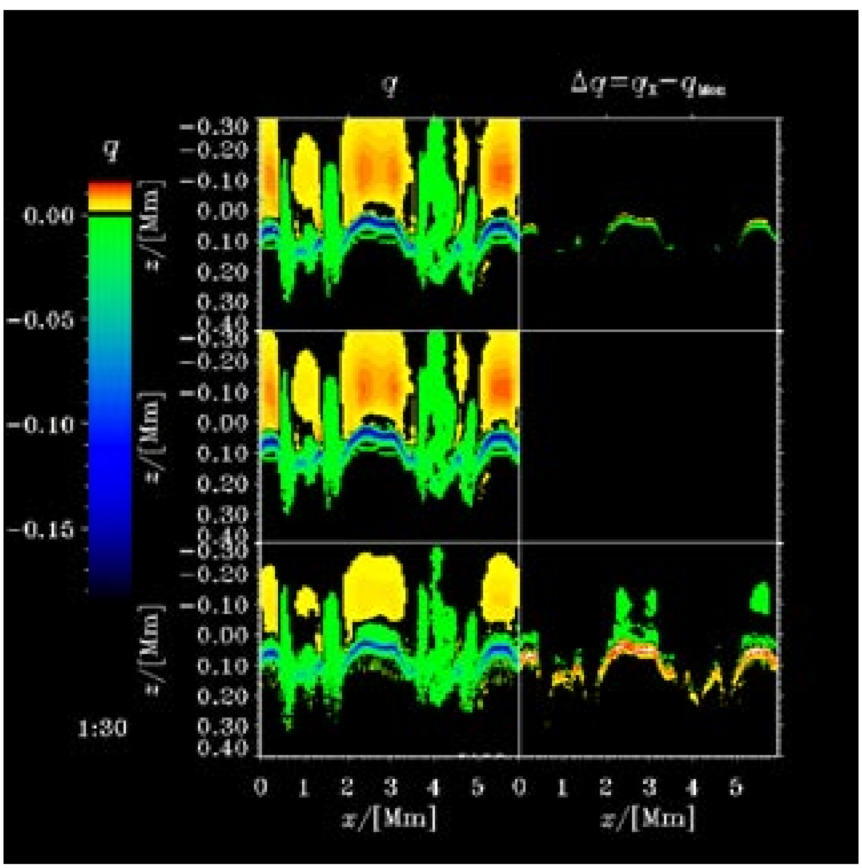
Stars

Stellar surface convection

Asplund, Trampedach and PhD student Collet (Uppsala) have continued their work on developing realistic, hydrodynamical simulations of the atmospheres of late-type stars, the major part of which is detailing the surface convection. Work is proceeding to extend the atmospheres to giant stars and to improve the handling of the atmosphere opacities.

Opacity Sampling in Convection Simulations

The interplay between convection and radiation (light) in the surface layers of stars is very complicated, and so far impossible to address with 1-dimensional (1D) models. The most fruitful method is 3-dimensional (3D) simulations of the fundamental equations of hydrodynamics, coupled with accurate atomic physics (equation of state and opacities). Since the 3D, time-dependent problem easily involves 10,000 times more computations than a 1D model, simplifications are necessary. It is obviously important that the simplifications have a minimal impact on the results. In 1D models the transfer of light through the atmosphere is solved for hundreds of thousands of wavelengths, and is an obvious candidate for simplifications. Presently this is done by grouping the wavelengths together, according to the strength of the opacity (absorption of light at that wavelength), and solving the radiative transfer for the groups - we use four opacity-groups. This method turns out to have systematic effects on the simulations, and the goal of this project, is a better alternative to the opacity grouping.



Radiative heating (yellow-red) and cooling (green-blue) in a snapshot of a convection simulation of the Sun. This is a vertical cut, and the photosphere (surface) can be seen as the blue curved lines. The top row is for the new method, the middle is the full solution and the bottom is for the opacity grouping. The left column is the actual heating and the right column is the difference between each of the cases and the full solution (that is why the middle right panel is zero). The differences between the new method and the full solution are imperceptible and can only be picked out in the difference plot to the right. The opacity grouping method, on the other hand, gives too little cooling at the surface, and too little heating above.

Trampedach is pursuing a modified opacity sampling method, where the radiative transfer is solved for, say, 50 wavelengths, carefully chosen so that they reproduce the result of the full solution involving hundreds of thousands of wavelengths. Preliminary tests are very encouraging and about 75% of the programming of this method has been done. The first simulations with the new radiative transfer should be running in May 2005. The improved radiative transfer will affect the abundance analysis of stars, and the Sun in particular. Asplund et al., have performed abundance analysis based on a Solar convection simulation, and found lower abundances of most elements (with respect to hydrogen) compared to previous 1D analysis. The lower abundances are in gross conflict the very precise 'measurements' of the Solar interior by means of helioseismology - the study of the Solar interior based on sound-waves on the surface. The new radiative transfer scheme, should give us increased confidence in the simulation results.

3D models of Red Giants

Asplund, Trampedach and Collet have computed the first ever 3D hydrodynamical model atmospheres of red giant stars with chemical compositions corresponding to both very old and young stellar populations. The simulations show much more vigorous convection than encountered in solar-type stars due to the lower densities in the atmospheres. These models are a significant step beyond classical 1D hydrostatic model atmospheres and should lead to more reliable results when interpreting observed stellar spectra in terms of the stellar properties like temperature and elemental abundances. In addition, the simulations provide insight to the poorly understood nature of stellar convection. In particular, at low metallicity the 3D models are very different than 1D models with much lower surface temperatures, which in turn have a great impact on the emergent stellar spectrum. This type of modelling which combines hydrodynamics with detailed radiative transfer and state-of-the-art input physics (opacity, equation-of-state etc) is very computationally demanding and is done with supercomputers in Australia (ANUSF) and Sweden.

1D non-LTE spectral line formation in late-type stars

Fabbian and his collaborators Asplund (RSAA) and Carlsson (University of Oslo) have studied the 1D non-Local Thermodynamic Equilibrium (non-LTE) effects for neutral carbon. The processes affect the spectral line formation, as seen for the late-type stars analysed in a grid of varying effective temperature, gravity and metallicity. The calculations show large negative non-LTE corrections for a range of stellar atmospheric parameters: when collisions with H are considered unimportant, the carbon abundance for these stars will typically be lower by ~0.4 dex than when the LTE assumption is adopted. In particular, for metal-poor halo stars, which are shown to be still affected by large non-LTE corrections, these improved calculations have important consequences on studies of nucleosynthesis processes and on Galactic chemical evolution models, enabling us to understand if the standard chemical evolution model is adequate (with no need to invoke signatures by the first generation of stars in the form of carbon yields at low metallicity), underlining the possible errors intrinsic in LTE stellar abundance analyses.

Globular Clusters

Norris investigated recent Hubble Space Telescope colour-magnitude diagrams reported by Bedin and co-workers of individual stars in the massive Galactic globular cluster omega Centauri, which clearly show three sequences in the region of the main sequence turnoff together with a double lower main sequence. (These diagrams essentially plot the luminosity of stars as a function of their temperatures.) He showed that the observations are explainable in terms of three distinct populations of stars having different heavy element abundances (iron less abundant than found in the sun by factors of order 50, 15 and 4, respectively), reasonable proportions and ages, but with surprising helium abundances. In particular, with the assumption that the earliest population has a helium abundance similar to that of the Sun (a percentage by mass, Y, of 0.23), the morphology of the colour-magnitude diagrams is very well-explained by stellar evolution models that require the second population to have a helium abundance higher by some 50% (Y ~ 0.35). This is dramatically larger than canonical models for the expected production of helium in normal stars and is currently not understood.

The result has potentially important implications for the understanding of elliptical galaxies. If such large helium variations exist in the relatively nearby Omega Cen (where one deduces such a remarkable range in helium by studies of individual stars) the question that begs to be addressed is whether such variations also exist in the more distant elliptical galaxies in which the individual stars are not resolved and for which one can study only light integrated over many objects.

Extremely Metal-Poor Stars

Bessell, Frebel and Norris have continued to take medium dispersion spectra of EMP candidate stars from the Hamburg ESO Survey provided by Christlieb (Hamburg). The spectra have been measured and those stars with the weakest lines are being followed up on large telescopes around the world. One of the brighter sample, HE1327-2326 has been found by Frebel, Aoki (Tokyo), Christlieb (Hamburg), Asplund, Norris and others to have the lowest Fe abundance of any star ever found, [Fe/H] = -5.4. (see Highlights).

HE1327-2326 has in addition huge overabundances of carbon and nitrogen, relative to iron. The only neutron-capture element detected, Sr, is also overabundant. The lower limit for the Sr/Ba ratio indicates that the abundance pattern observed at the surface of HE1327-2326 is associated with the rapid neutron absorption process that occurs in supernovae exposions. Hence, the abundance pattern of HE1327-2326 could most likely be explained with a first generation supernova which polluted the gas cloud from with HE1327-2326 formed. Longer term radial velocity monitoring is needed to explore the possibility of the star being in a close binary system which could help explain the non-detection of Li, which is unexpected for a little evolved single star of its temperature

Nearby Young Low Mass Stars

Bessell has continued taking 2.3m DBS spectra of stars identified by Zuckerman and Song as being possible nearby KM dwarfs. The spectra are examined for strong Li lines and emission activity indicative of youth. Echelle spectra are also obtained of likely moving group members to determine precise radial velocities to tie down precise UVW motions. The closest of the young low mass stars discovered are being followed up using Keck, HST and the VLT looking for nearby brown dwarf/planetary companions and protoplanetary disks. Zuckerman and Song have published an Annual Review article summarising the newly discovered members of the Beta Pic, TW Hya, Tuc/Horologium, and AB Dor moving groups and the h Cha cluster, all of which originated in the Sco-Cen Association.

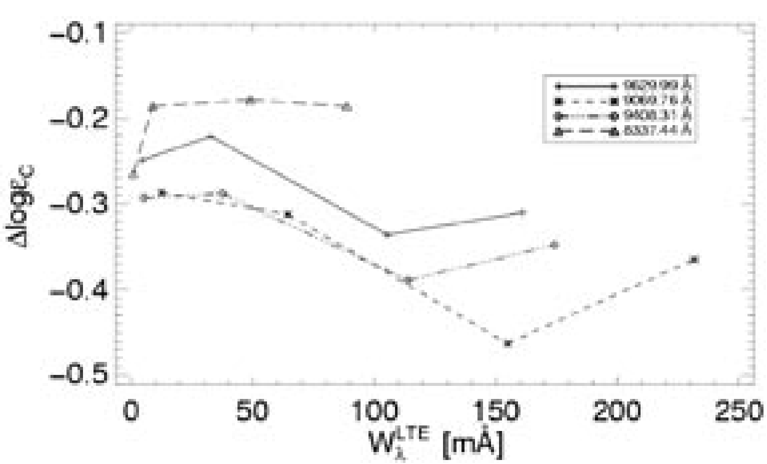


Figure. The non-LTE abundance corrections for the model with a temperature value of 6000 K, a gravity of log g=4.0 and standard [C/Fe] content. For each line, the non-LTE corrections at different metallicities (Fe/H=-3,-2,-1 and 0 respectively) were connected to underline the effect of the metallicity change. The four absorption lines considered are specified in the legend and are of interest because they are still detectable in metal-poor stars

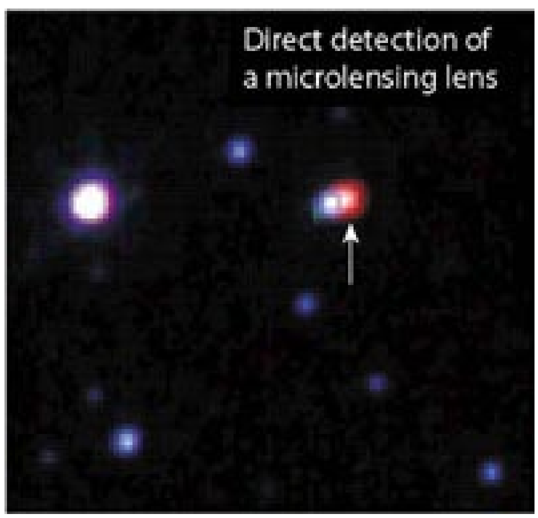
The Realisation of the Stromgren System

Bessell has started to obtain low dispersion spectrophotometry of metal-poor stars and Stromgren standards in order to synthesize magnitudes and colors in the Stromgren system. This is in collaboration with Gustafsson (Uppsala) and is being undertaken to enable accurate Stromgren photometric calibrations to be derived from the Uppsala MARCS model atmosphere fluxes.

AGB stars

McSaveney is working with pulsational models from Wood and dynamic atmosphere models from Scholz (Heidelberg) to model the spectra of Asymptotic Giant Branch (AGB) stars and thus derive abundances for a selection of such stars in the Large and Small Magellanic Clouds. These have been observed in the near infrared using the Phoenix spectrograph on Gemini South. Nucleosynthesis in stars is usually a well hidden process, the products of which do not show at the surface studied. Dredge up events in AGB stars give a window into these processes, making their abundances of particular interest. However, these cool large stars are complicated by large pulsations and hence abundance analysis is a non-trivial task.

First Detection of a Microlensing Lens

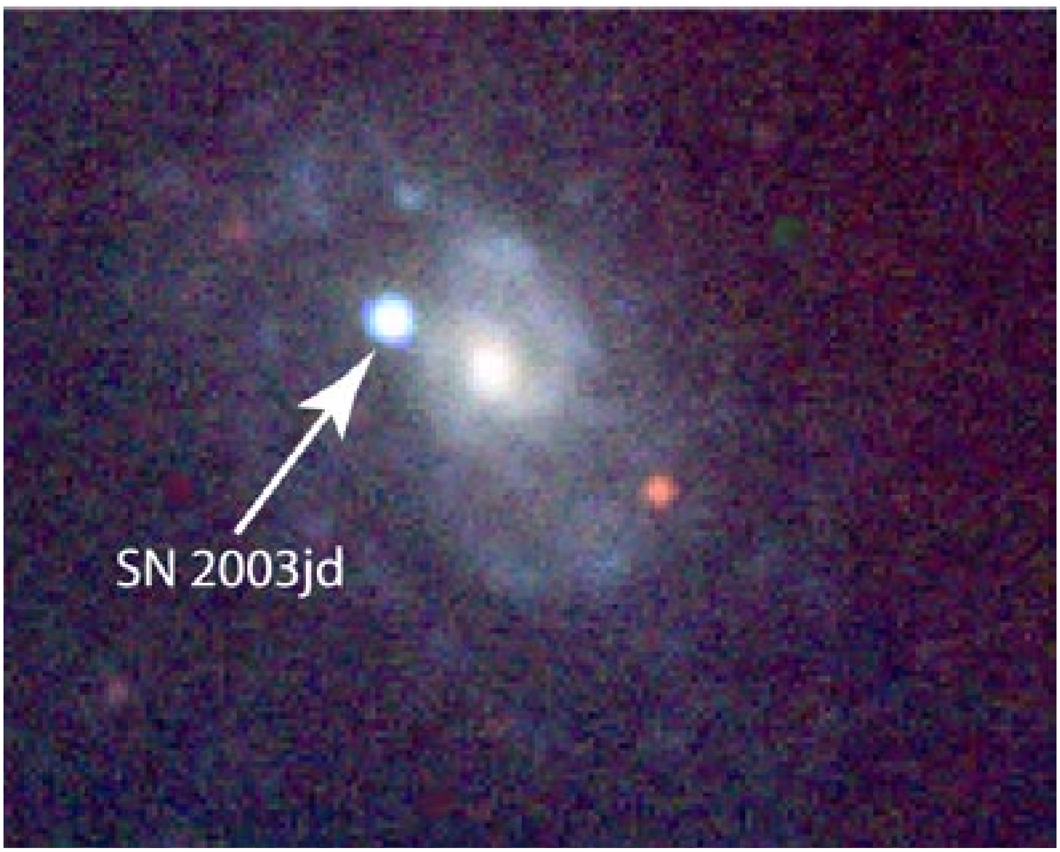


Keller together with Drake (LL Labs) and Cook (LL Labs) used the Advanced Camera for Surveys High Resolution Camera on-board the Hubble Space Telescope to revisit the site of a microlensing event in the Large Magellanic Cloud. The microlensing event occurred six years ago and was detected by the MACHO project at RSAA. Previous imaging revealed a faint red star very close to the position of the background microlensed source star (see image Alcock et al. 2001). Other characteristics of the microlensing event made it likely that the red object was the lens object. Their recent Hubble Space Telescope observations sought to confirm this by defining the red star's motion. Extrapolation of the red star's motion backwards places it extraordinarily close to the source star at the time of microlensing. This object is the first ever direct detection of a microlensing lens. The red star turns out to be a star of around a tenth of the Sun's mass and 1900 light years distant within the Galactic disk.

Supernovae

Several of the current hot topics in astrophysics are related in some way to supernovae. These objects represent some of the physically most extreme events in the Universe, they energise the interstellar medium, and are responsible for much of the chemical enrichment in the Cosmos. Currently, our understanding of their physics is the major systematic uncertainty of the use of distant type Ia supernovae as distance indicators.

Salvo and Schmidt have continued their supernova monitoring campaign at the 2.3m telescope, one of the only instruments in the southern hemisphere able to obtain optical spectra of these exploding stars. Their observations will help trace their evolution and provide insight in the physics of both thermonuclear and core-collapse supernovae, in collaboration with the European Research and Training Network for the Study of Type Ia Supernovae and the Caltech Core-Collapse Program.



Supernova 2003jd as observed with the ANU 2.3m telescope. This exploding star had an unusually high energy and appears to be related to Gamma Ray Bursts, a rare class of objects which are so bright that they can be seen back to the dawning of the formation of stars and galaxies, 13 billion years ago.

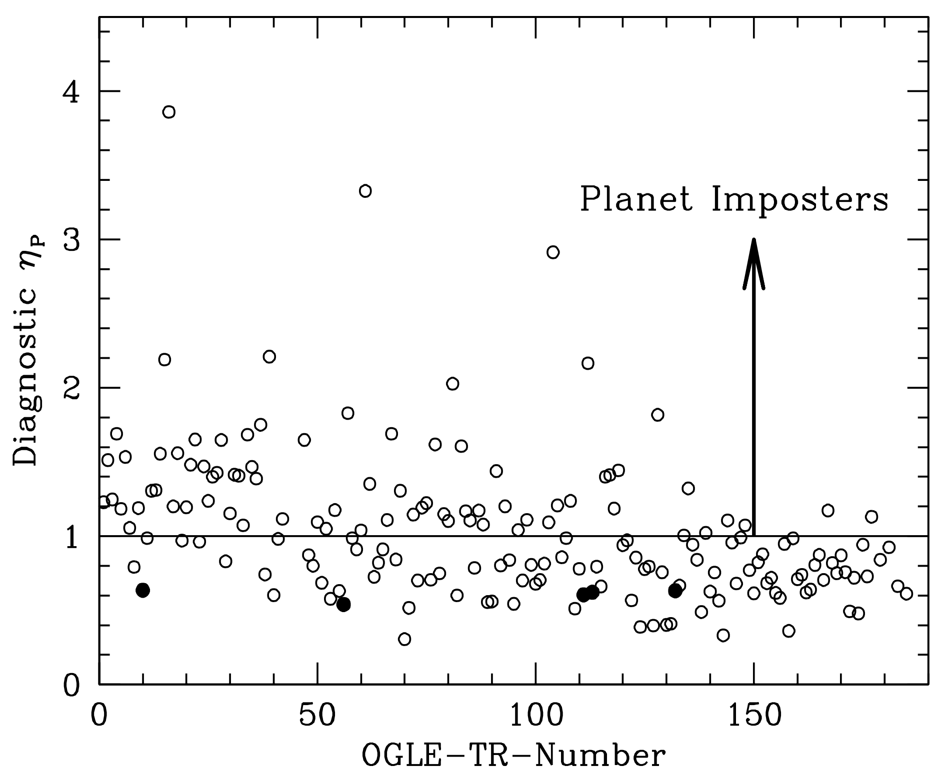
Planetary Science

A New Diagnostic for Selecting Exoplanet Candidates

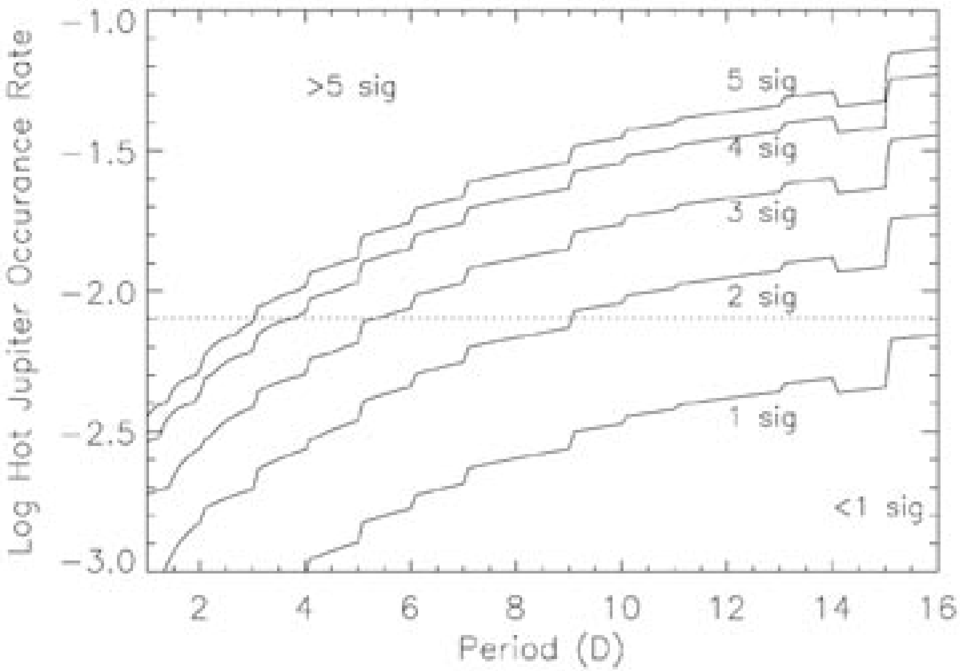
Tingley and Sackett have developed a new photometric diagnostic to aid in the identification of transiting Extrasolar Planets. One of the obstacles in the search for exoplanets via transits is the large number of candidates that must be followed up, few of which ultimately prove to be exoplanets. Any method that can make this process more efficient by identifying the best candidates and eliminating the worst is therefore very useful.

Although it is possible to separate between blends and exoplanets using only the photometric characteristics of the transits, the techniques are critically dependent on the shape of the transit light curve. Characterization of this curve requires very high precision photometry of a sort that is atypical for candidates identified from transit searches. The new method relies only on transit duration, depth, and period, which require much less precise photometry to determine accurately.

The derived numerical tool, the Exoplanet Diagnostic, is intended to identify the subset of candidates from a transit search that is most likely to contain exoplanets and is most worthy of subsequent follow-up studies. The effectiveness of the diagnostic has been demonstrated by its success in separating modelled exoplanetary transits and interlopers and by applying it to actual OGLE transit candidates. The work has been submitted to the Astrophysical Journal.



The value of the Exoplanet Diagnostic is shown for candidates detected by the OGLS team. As the diagnostic would predict, those confirmed as transiting planets lie at the bottom of the diagram.



The significance of the null detection by "hot Jupiters" in 47 Tuc is expressed as a function of the period of putative planets and their abundance. For example, the hypothesis that 1 in 100 stars in the globular has a Jupiter-sized planet in a 6 day orbit is ruled out at a 3 Omega level, that is with 99.7% confidence.

A Method for the Detection of Planetary Transits in Large Time Series Data Sets

Weldrake and Sackett have developed a fast, efficient, and easy-to-apply computational method for the detection of planetary transits in large photometric data sets. The code was specifically produced to analyse an ensemble of 21,950 stars in the globular cluster 47 Tuc for the signature indicative of a transiting hot Jupiter planet.

Using cross-correlation techniques and Monte Carlo tested detection criteria, each photometric time series is compared with a database of transit models of appropriate depth and duration. The algorithm recovers transit signatures with high efficiency while maintaining a low false-detection probability, even in rather noisy data. The code has been optimised, and with a 3 GHz machine is capable of analysing and producing candidate transits for 10,000 stars in 24 hr. The code is easily adaptable and is currently designed to accept time series data produced using difference imaging analysis.

No Hot Jupiter Planets in 47 Tucanae, but many new Variable Stars: Results of a Wide-Field Transit Search

Weldrake, Sackett, and Freeman, and Bridges (AAO) have completed a comprehensive wide-field search for transiting "hot Jupiter" planets (gas giant planets with an orbital period in the range 1 to 16 days) in the globular cluster 47 Tuc. Motivated by the discovery of many hot Jupiters in the solar neighbourhood and the apparent lack of planetary detections in the core of 47 Tuc by Hubble Space Telescope observers, this search aimed to detect giant planets in 47 Tuc by observing from the ground a 52 × 52 arc-minute field centred on the cluster. It used the Mount Stromlo 40 inch (1 m) telescope at Siding Spring Observatory and a combined V + R filter.

The search was most sensitive in the uncrowded outer regions, where the stellar densities are significantly lower than in the core. It concentrated on 21,920 main-sequence stars within 2.5 mag of the cluster turnoff (hence approaching the solar value in mass). It is the largest ground-based transit search of a globular cluster to date, incorporating a 33-night time series that gave excellent sensitivity to detect hot Jupiter planets. Despite this, a detailed search utilising a matched filter algorithm, developed specifically for this project, found no transit events. Detailed Monte Carlo simulations incorporating the actual temporal sampling and photometric precision of the data predicted that seven planets with orbital periods in the range 1 to 16 days should be present in the data set if 47 Tuc has the same planetary frequency as that observed in the solar neighbourhood.

The result indicates that system metallicity rather than crowding is the dominant effect inhibiting hot Jupiter formation in this environment.

The 33-night data set used for this result also led to the detection of 100 variable stars, including 69 new discoveries. These include 28 eclipsing binaries (21 contact binaries and 7 detached systems), 45 RR Lyrae stars (41 of which belong to the Small Magellanic Cloud and 4 seemingly to the Galactic halo), and 20 K-giant long-period variables (LPVs). Four Delta Scuti stars, one type I Cepheid, and one type II Cepheid were also detected. One variable appears to be a possible dust-enshrouded SMC star with a short-period pulsation.

The eclipsing binary sample indicates a clear radial segregation in period and includes two binaries that are seemingly orbited by low-luminosity stellar companions. One RR Lyrae star shows a Blazhko effect with remarkable regularity.

Distance moduli of 18.93 ± 0.24 for the Small Magellanic Cloud and 13.14 ± 0.25 for 47 Tuc were estimated from the sample. These are in agreement with values previously published. The total database contains V and I photometry for 43,067 47 Tuc field stars ($13.0 < V < 21.0$), along with 33 night V + R light curves and astrometry for 109,866 stars ($14.5 < V < 22.5$).

The Siding Spring Near Earth Asteroid and Comet Survey

Following several years of development, the 0.5-m Uppsala Schmidt started regular surveying for Near-Earth Asteroids and Comets on March 16. McNaught and Garradd conduct all observations. Most of the hardware installation and software development was done from the University of Arizona by Larson, Beshore and Christensen who are also responsible for the sister programs of the Catalina Sky Survey and the Mt. Lemmon Survey.

As the year progressed and the software became better optimised for detections, the SSS became one of the most successful surveys in 2004 in working towards the Spaceguard goal of discovering 90% of 1-km and larger NEOs by the end of 2008.

NEAs are defined as asteroids that approach the Sun to within 1.3 AU (the Earth's mean distance from the Sun being 1 AU or ~150 million km). Periodic comets approaching within this distance are designated NECs. A subset of the NEAs are objects larger than ~100m that can approach the Earth's orbit to within 0.05AU and these are called PHAs (Potentially Hazardous Asteroids). Over the course of thousands of years, these orbits can evolve, through the gravitational attraction of the planets, into having close encounters or possibly a collision with the Earth.

During 2004 a 4x4K un-thinned CCD was used giving a 2x2 deg field at 1.8"/pixel. The survey method is of 4 visits to a sequence of fields over an hour, image lists for each field are created by automatic extraction of all stellar positions and examination of these lists for objects displaying a uniform motion. On a typical night 600 deg2 of sky were surveyed to around mag 19.5R. Observations were carried out on 183 nights in 2004. 38 NEAs and 5 comets were discovered.

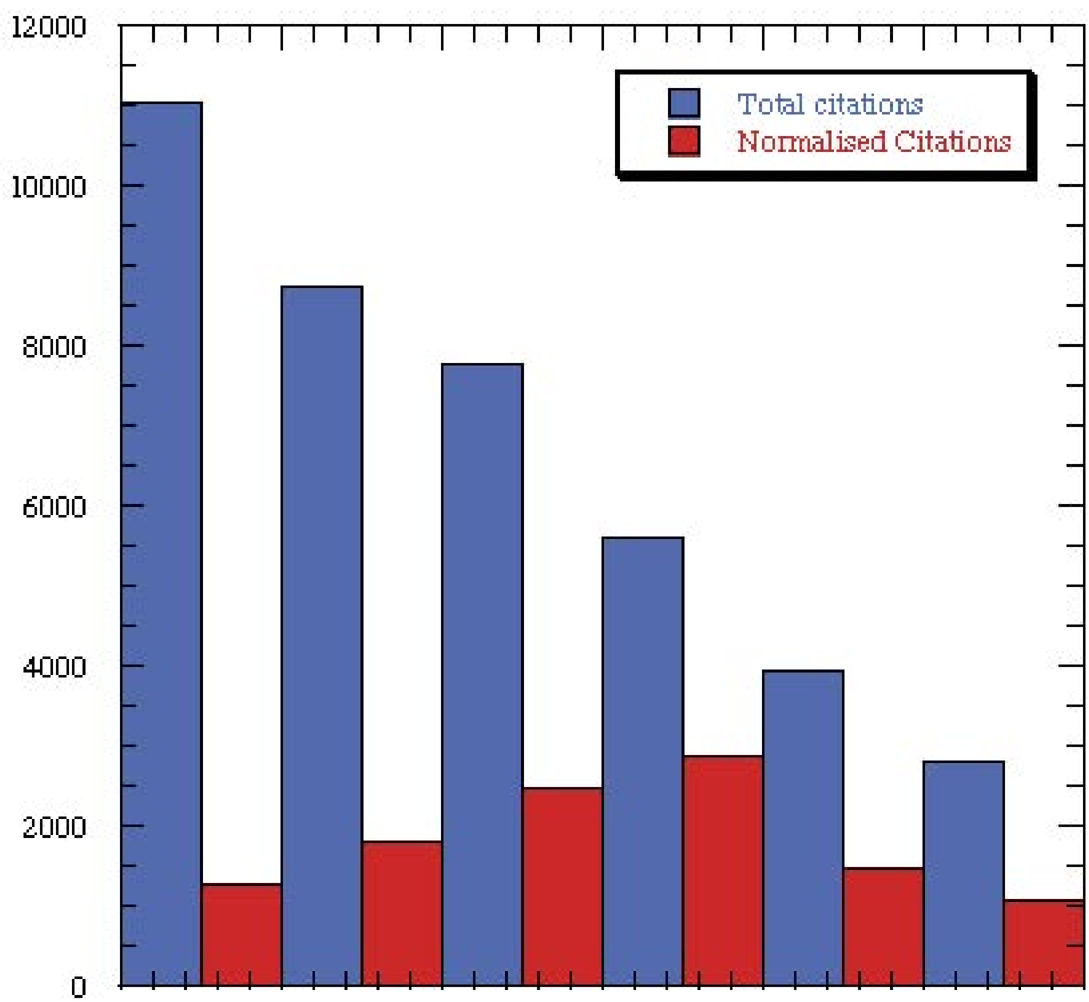
Although the Uppsala telescope is of modest size for NEO searches, the advantage of searching the southern skies, which have been largely unsurveyed in the past, means they expect to find many large objects. This was borne out with the SSS discovering more mass of NEAs and NECs during 2004 that any other survey! This was due mostly to two unusually large objects, 2004 QY2 at ~5km diameter and P/2004 TU12 (Siding Spring) initially thought to be an asteroid, but which later developing a weak tail and was reclassified as a comet of ~5-10km diameter!

Nine of these NEAs were estimated to be larger than 1km and nine are PHAs. Of the five comets, four are periodic with periods between 5 and 20 years and two of these (P/2004 K1 and P/2004 TU12) are NECs. Comets recognized as such by the observer are named after then, whereas those found to be comets at some later date are named for the project. Thus there now exist three comets Siding Spring that at discovery were "stellar" in appearance. There comets are the first to be discovered from ANU telescopes and the first to hold the name Siding Spring.

Other discoveries include 18 asteroids in unusual orbits. Two of the most highly unusual are 2004 NN8 (Orbital period~1000years, inclination = 165 deg, diameter ~4km) and 2004 YH32 (P~25 years, inc=79 deg, diam~10km). Such orbits are typical of comets, but so far neither object has shown any cometary activity. The inclination of the orbit is its tilt relative to the Earth's orbit, so an inclination greater than 90 deg indicates an orbit that revolved around the Sun in the opposite direction to the Earth and other planets.

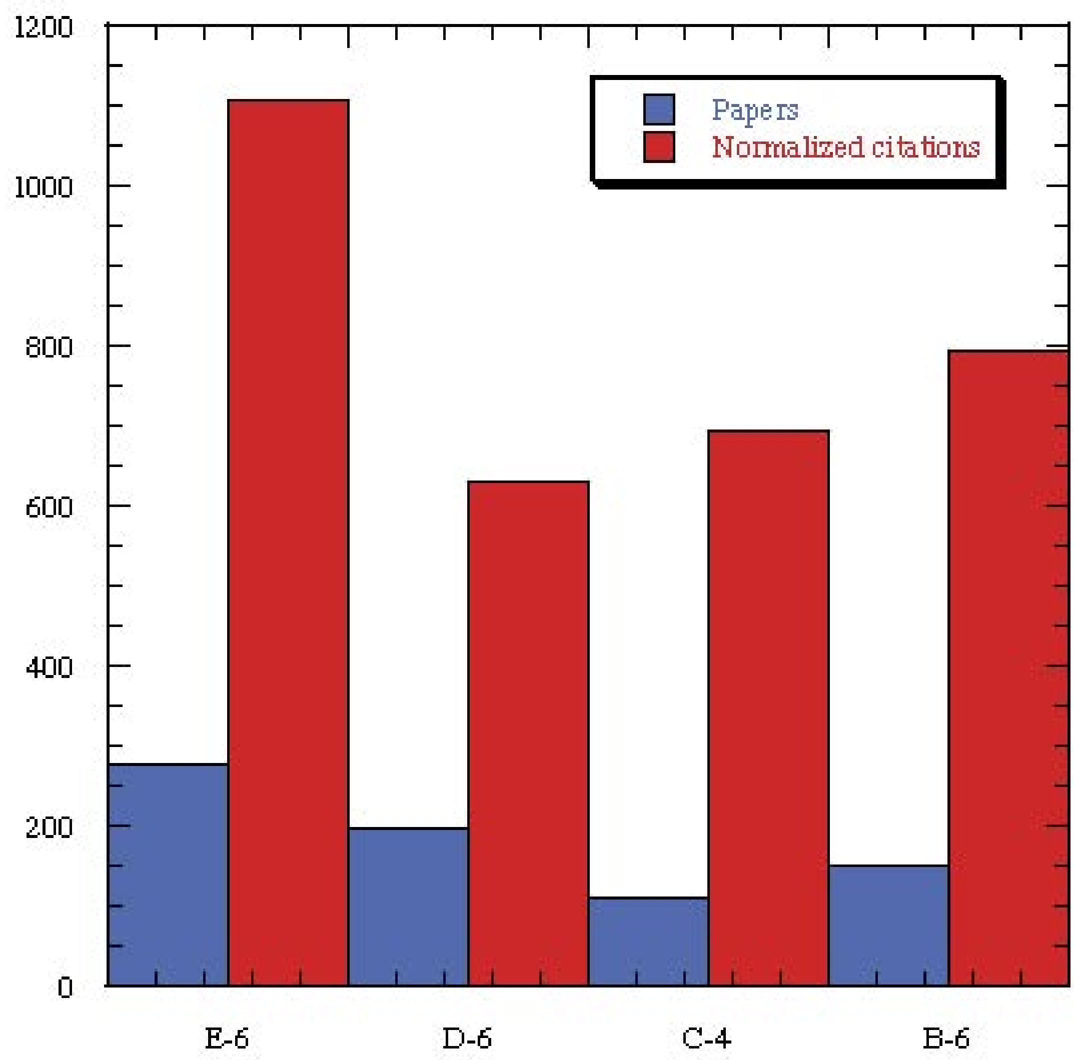
Research Impact

The research conducted by astronomers from the RSAA is highly valued by the astronomical community. Four of the staff, Peterson (see Highlights), Freeman, Dopita and Bessell are amongst the 7 Australians listed as ISI Highly Cited Researchers in Space Science for total citations between the years 1980 and 2004. The data for the 6 highest cited astronomers at the RSAA over this period are plotted below. All Highly Cited scientists are placed in the top 0.1 percent of their fields globally. Citations are only one way to measure the usefulness and impact of research done at the RSAA. Although total citations can exaggerate the impact of an individual, the normalized citation index can underestimate the impact and effort of an individual in a multi-author paper, such as a large scale survey, that often involves more than 10 people. It is useful then to consider all three parameters, the number of papers, the total citations and the normalized citations.



Total citations are the number of times a paper is cited by other researchers summed over all papers in which the person is a co-author. Normalized citations are the summation of the normalized citation for each paper (the number of citations divided by the number of authors). Citations of the most highly-cited RSAA astronomers are shown here.

The ISI Highly Cited Researcher list is calculated over a 25 year period and is therefore biased against younger researchers whose work only covers part of that period. Many of the younger staff at the RSAA are amongst the most highly cited researchers in the world. This is made clear when one examines the citations over the last 6 years. In the second figure, the number of papers and normalized citations between 1999 and 2004 are shown for staff grouped by level. Level B are the 6 younger post-doctoral fellows, level C and D are the 4 fellow and 6 senior fellows and level E are the 6 professors. The younger researchers are publishing a significant number of well cited paper in comparison to the more senior staff.

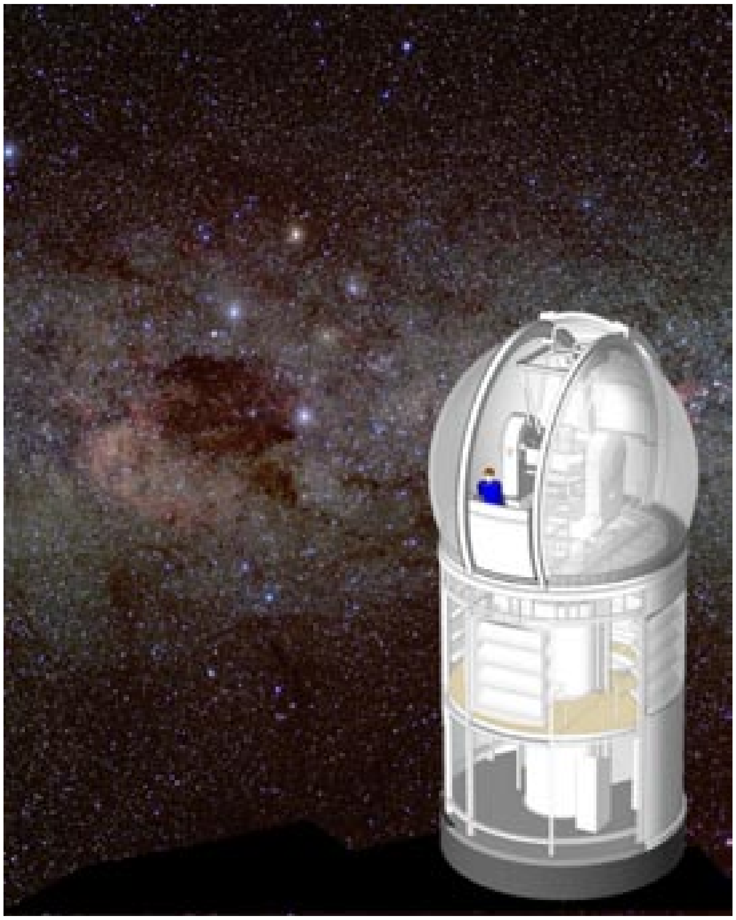


In 2004 a list of the 1000 most cited astrophysics research papers was published, and ANU astronomers past and present are very well represented. Citations are one measure of the significance and usefulness of a research paper. The list was compiled by Dr Frazer Pearce of the University of Nottingham, UK. He used the digitized NASA Astrophysics Data System to compare the citations of some 500,000 papers dating from the 1950s to the present.

The most-cited papers are a mix of reports of discoveries, controversial theories, new techniques, and large databases. RSAA is represented in all categories. Twenty-eight papers reporting research by ANU astronomers and students make it into the top 1000. Twelve are in the top 500, 3 in the top 100 and 2 in the top 50. A further 14 papers by ex-Stromlo students, reporting their research done at other observatories, also make it into the top 1000 list.

Highest ranked of the RSAA papers is one by Prof Brian Schmidt and his international Hi-Z Supernova Search Team, “Observational Evidence from Supernovae for an Accelerating Universe and a Cosmological Constant”. This came in at position 23 and is arguably one of the most significant research papers of all time, one which fundamentally changed our view of the universe.
The rating of 23, which may seem low for such a historic paper, is due to the fact that it has only been in print for 6 years!
Other papers with RSAA authors come in at positions 47, 83, 137, 260, 279, 289, 290, 313, 368, 420, 448, 519, 613, 665, 726, 731, 743, 813, 839, 843, 885, 899, 902, 906, 973, 974 and 985. They include classic papers in galactic structure and dynamics, stellar evolution, interstellar polarization, and the structure and evolution of the Universe. Ten of the authors are current RSAA staff members.
The combined number of astronomers and students at the RSAA is usually around 50, less than 0.3% of the world's astronomers. Contributing 2.7% of the top 1000 papers, 9 times better than the average citation rate, is a credit to the hard work and talent of the exceptional staff at RSAA.

Skymapper



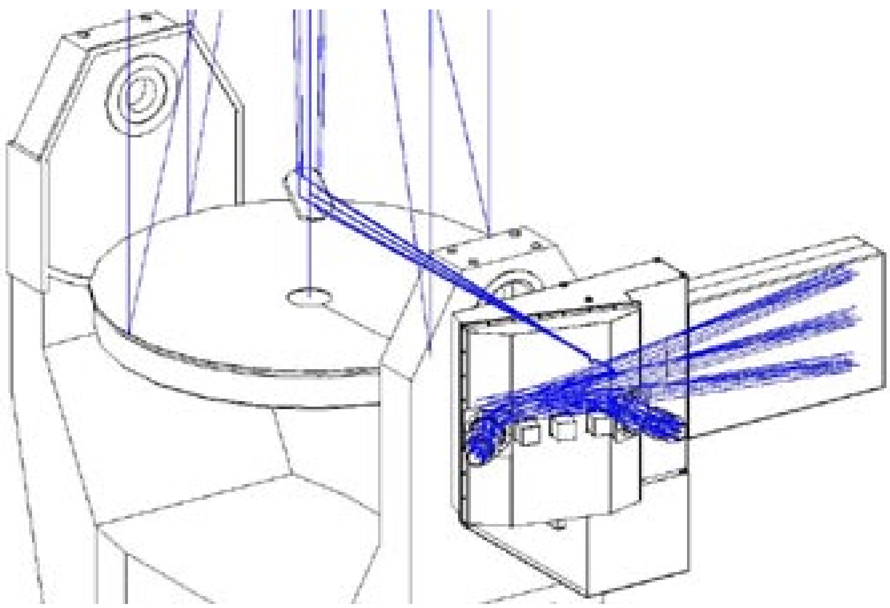
Schmidt, Francis, Bessell, Keller are leading efforts to build the SkyMapper Telescope, a replacement for the Great Melbourne Telescope that was destroyed in the bushfires of 2003. It is being designed jointly by the research team at the University's Mt Stromlo Observatory and the Queanbeyan company Electro Optic Systems Pty Ltd. This fully automated $11 million telescope will have a world-leading ability to map the sky, and it will be used to create the world's largest astronomical database and provide the most complete map of the southern sky.

Members of the Computer Section are currently preparing the software design for the SkyMapper camera. This software will use the TAROS and CICADA packages as a basis but extra work is required to handle the complexity of the instrument and the high volume of data expected.

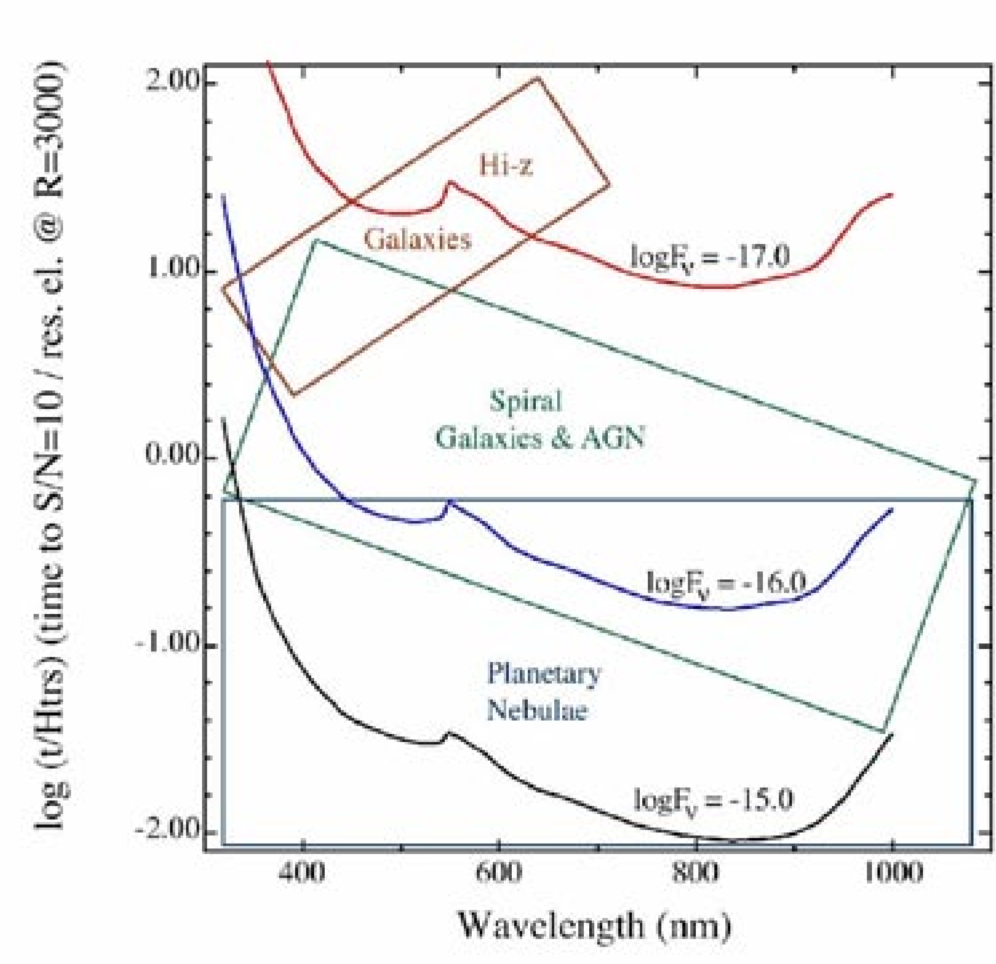
Scheduled for first light in Sep 2006, this new 1.3m telescope will be located at Siding Spring Observatory. Each minute, SkyMapper will be able observe a piece of sky 25 times the size of the full moon to a level a million times fainter than can be seen by the human eye. This telescope will provide an unprecedented census of a billion stars in our galaxy, and it will enable discoveries of the largest asteroids in our own solar system to the most distant quasars in the universe. Additional information can be found on the SkyMapper website: http://www.mso.anu.edu.au/skymapper/

The WiFeS Instrument

Dopita is the project scientist of the WIde FiEld Spectrograph (WiFeS) . During 2004, with the aid of funding provided by the Federal Government's Systemic Infrastructure Initiative Program, the detailed design was developed by RSAA engineers for the WiFeS instrument to be mounted at the Nasmyth focus of the ANU 2.3m telescope at Siding Spring Observatory. The concept of the proposed instrument is to obtain as many simultaneous spectra as possible, with full sky coverage over the instrument's field of view. This instrument is now approaching its Critical Design Review (CDR), see figure below. The WiFes spectrograph will deliver an integral field of 25 x 31 arc seconds on the sky, and each spatial element maps to a specific column on the CCD detector. The instrument provides "interleaved nod-and-shuffle capability" in accumulating the spectra on the detector. This allows the accumulation of a set of sky-subtracted sub-spectra that are limited in their signal-to-noise ratio only by sky noise.



A line drawing of the WiFeS instrument mounted at the Nasmyth A focus of the SSO 2.3m telescope. The intricate light paths from sky to the two cameras are shown.



The time taken to reach S/N=10 per resolution element- for the WiFeS (in its R=3000 mode) as a function of surface brightness of the object (erg cm-2 s-1 arc sec-2 Å-1). Likely ranges for representative science targets are shown as boxes in this figure.

The WiFeS instrument will be an exceedingly powerful device, in terms of spectral coverage from the ultraviolet cut-off of the atmosphere (up to nearly one micron in the infra-red), with excellent wavelength resolution, field of view and overall efficiency. It can operate at up to 30 times faster than existing spectrographs in a whole host of science applications. In single-star studies, the limiting sensitivity, defined in terms of the time needed to reach S/N=10 per resolution element in the presence of the intrinsic sky noise is of order V = 22 mag. In terms of a practical sensitivity limit, this is of order F ~ 10-17 erg s-1 arc sec-2 Å-1.

The ability to do quantitative spectrophotometry over a wide spectral range and spatial field, makes it unique in the world amongst the class of integral field spectrographs. With such extraordinary capabilities, the science mission of the WiFeS spectrograph is correspondingly broad.

Major components of this will include:

* Studies of the internal dynamics of galaxies.
* Studies of abundance gradients in galaxies.
* Studies of starburst galaxies and circum-nuclear star-forming regions.
* Studies of anomalous gas kinematics around the active nuclei of galaxies.
* Measurement of the dynamics of high-redshift radio galaxies.
* The detection of Lyman-break galaxies over a wide redshift range in blind searches.
* Studies of interstellar and inter-galactic absorption features in GRB sources.
* Radial velocity surveys of the cores of rich clusters of galaxies.
* Investigation of the internal structure, excitation and dynamics of Planetary Nebulae.
* Mapping the dynamics and heavy element content of supernova remnants.
* Measurements of the abundances in stars in Globular Clusters.

TAROS

The Telescope Automation and Remote Observing System (TAROS) is a project to develop software to control RSAA telescopes at Siding Spring remotely and in an unattended automatic fashion. It aims to present data acquisition, telescope control, guiding and data archiving in a uniform interface running on the user's desktop. As well as the user interface, TAROS requires the development of software for the communications backbone, data acquisition, telescope control, data archiving, observation control and guiding. Wherever possible, existing software is being used. The basic skeleton of this system was demonstrated in early 2003 and it aims to be on the telescope in late 2006.

MSOTCS

A new telescope control system called MSOTCS is being written to support the remote control and automation functionality of TAROS. MSOTCS will replace the existing 1980's VMS-based TCS which runs on an aging micro-VAX. MSOTCS aims to provide the same functionality and command set of the existing TCS though users will not interact with it directly but, rather, control the telescope through the TAROS graphical user interface. MSOTCS is scheduled for commissioning in late 2006.

Gemini Instruments

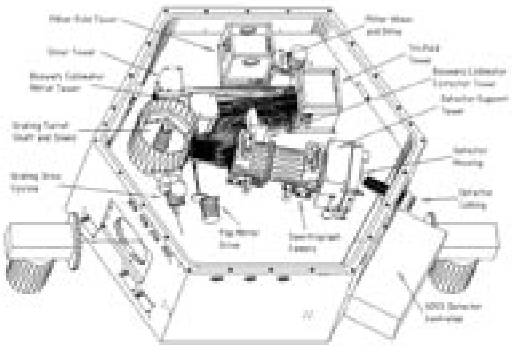
The Gemini Observatory is a seven-nation international partnership to build and operate two 8.1-metre telescopes, Gemini North and Gemini South located in Hawaii and Chile, respectively. Australian involvement in this partnership is supported by the Australian Research Council. Under the leadership of Project Scientist Peter McGregor, Gemini has contracted RSAA to design and construct two complex instruments, the Gemini Near-infrared Integral Field Spectrograph (NIFS) for Gemini North and the Gemini South Adaptive Optics Imager (GSOAI) for Gemini South.

Gemini North, Hawaii

The original NIFS was destroyed in the Canberra 2003 bushfires shortly before scheduled delivery to Gemini. In 2004, the RSAA team, together with Canberra-based aerospace company Auspace Limited, had rebuilt NIFS to near-completion on track for an early to mid 2005 delivery to Gemini North.
Significant progress was also made on the construction of GSAOI.

Gemini Near Infrared Integral-Field Spectrograph (NIFS)

The Gemini Near-infrared Integral-Field Spectrograph (NIFS) represents one of the world's most advanced and innovative astronomy instruments and Australia's first instrument to be delivered to the 8.1m Gemini North. NIFS is also an exceptional feat of engineering excellence as scientific performance requirements mandate a complex optical-mechatronic system of exacting tolerances that must perform near diffraction-limited imaging spectroscopy within the harsh environment of cryogenic temperatures (4 to 65 [K]) and vacuum.



NIFS spectrograph modules and towers mounted on the cold work surface plate with baffling and the spectrograph cover and skirt removed.

The NIFS control software is nearing completion. This software runs on the VxWorks platform and uses the Gemini EPICS control software as a basis. A switch to the Hawaii 2RG infrared detector has necessitated late changes to the data acquisition portion of the software.

By combining the superb image quality of the Gemini telescope and its adaptive optics system, ALTAIR, with the high spatial and spectral resolution achievable with NIFS, astronomers will be able to study the infrared structure of astronomical objects at resolutions on par with those achieved with the Hubble Space Telescope in the optical. The instrument is to target velocity measurements in galaxies to study the demographics of black holes in galactic nuclei and the evolution of structural properties in high redshift galaxies. The primary science drivers for NIFS are the study of the demographics of massive black holes in the nuclei of galaxies, and the study of the excitation of the inner narrow-line regions of Seyfert galaxies. Other goals include the study of the dynamical evolution of galaxies at high redshift and a diverse range of other science.

In 2004, the NIFS cryostat assembly was completed. Procurement of components, including exotic optics, was completed, the components control system was delivered, and the image slicer assembly was received back from precision diamond machining at LFM, Bremen, Germany. NIFS successfully completed several cool-downs during which internal mechanisms were tested and verified and preliminary optical alignment was achieved. The On Instrument Wave Front Sensor (OIWFS) was also completed and the decision was made by Gemini to upgrade to a new generation Rockwell "Hawaii 2RG" detector.

Delivery of the NIFS cryostat and the complete assembly

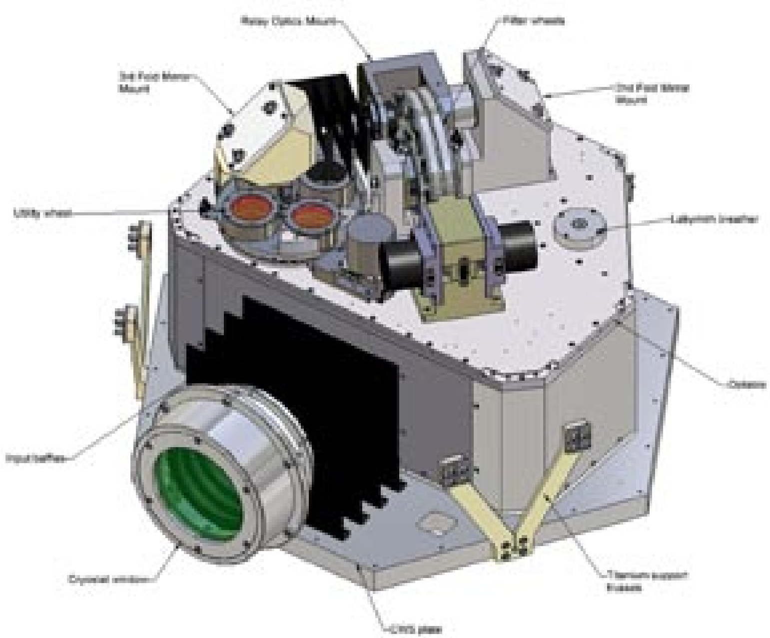
NIFS undergoing integration frame fit test at the Auspace Facility

A major spin-off of national benefit will be the guaranteed observing time for the Australian team using the NIFS instrument in Gemini. This means that the first frontier scientific discoveries made by NIFS are likely to be made by Australian astronomers. Already, NIFS has been recognized as exemplary within the Gemini consortium, a showcase of Australia's scientific research and advanced engineering design capabilities. This has both enhanced and secured Australia's international reputation and capability for delivering innovative, state-of-the-art instrumentation.

Furthermore, NIFS design concepts have been extended to the state-of-the-art Wide Integral Field Spectrograph (WiFeS) (see page 40). This will ensure that national instrumentation remains at cutting edge of technology for the next 10 years, with enhanced research and research training outcomes.

Gemini South Adaptive Optics Imager (GSOAI)

The Gemini South Adaptive Optics Imager (GSAOI) is the workhorse science camera and commissioning instrument for the Multi-Conjugate Adaptive Optics (MCAO) system on the Gemini South telescope. GSAOI will deliver diffraction-limited performance at near-infrared wavelengths over an 85"×85" field of view and due for delivery to Gemini South in Q1-2006, commensurate with MCAO delivery. GSAOI is founded on a high throughput, all-refractive optical design and a mosaic of four HAWAII-2RG detectors to form an imager focal plane of 4080x4080 pixels with a fixed scale of 0.02"/pixel. The On-Detector Guide Window (ODGW) capability of the HAWAII-2RG detectors will be used for flexure monitoring and as near-infrared substitutes for MCAO natural guide star wave front sensors.



The GSAOI Mechanical Layout

GSAOI will address the following science that requires extremely deep near-infrared photometric imaging of extended regions, including:

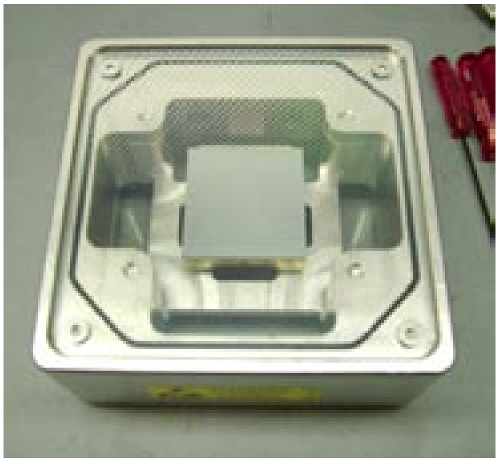
- Low mass stellar and substellar mass functions in young star-forming regions such as the Orion Nebula Cluster
- Stellar population variations in star-forming regions
- Mass functions in nearby globular clusters over a range of metallicities
- Stellar populations of super-star cluster analogs in the Galaxy and Magellanic Clouds
- Stellar populations in starburst regions of nearby galaxies
- Evolution of dwarf irregular versus elliptical galaxies in different environments
- Stellar populations in dwarf galaxies

- The formation of the disks of disk galaxies
- Exploring dark energy via high redshift supernovae

As the GSAOI software is modelled on the NIFS software, work done for NIFS automatically progresses the software for GSAOI. A specific difference is the use of on-detector guide windows from each of the four Hawaii 2RG detectors of the GSAOI focal-plane. This is a quite demanding requirement for our software developers as guide star information needs to be passed to the Gemini adaptive optics system at a rate of 800 hertz.

In 2004, the GSAOI cryostat assembly was completed with internal radiation shields and cold work surface. Procurement of components was also completed, including optics and most filters. The manufacture of optical mounts was completed in preparation for optical assembly. GSAOI underwent cool-downs for thermal verification and successful testing and verification of internal mechanism functionality. Rockwell Hawaii-2RG Detector system testing re-commenced in combination with the NIFS programme. GSAOI is on track for delivery to Gemini South in late Q4 2005.

GSAOI cryostat being transported in its partially filled integration frame after fit check



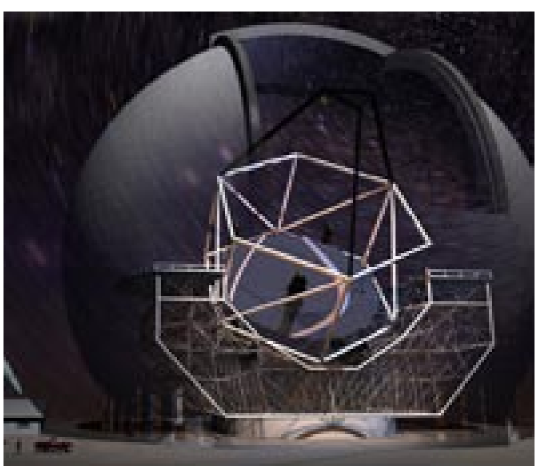
H2RG Multiplexer in shipping package (left) and installation (right)

Extremely Large Telescopes (ELTs)

Under the leadership of Jenkins and McGregor, the RSAA has launched a programme of research and development on Extremely Large Telescopes, commencing with the characterization of thin membrane deformable mirrors and the characterization of atmospheric boundary layers at Siding Spring. This activity is in accordance with the portfolio of An Extremely Large Telescope Working Group (ELTWG) which was established in 2003 by the National Committee for Astronomy of the Australian Academy of Sciences with the following terms of reference:

- Explore opportunities for Australian participation in projects to build an extremely large opti cal/infrared ground-based telescope (an ELT);
- Develop the scientific and technical case for an ELT;
- Liaise with the astronomical community to provide information about ELT projects and receive feed back on community responses;
- Explore and develop the funding opportunities and industry partnerships for an ELT.

Extremely Large Telescopes (ELTs) are key future facilities for optical and infrared astronomy. Their enormous main mirrors will collect from 10 to 100 times as much light as the world's largest existing telescopes, and will produce images far sharper than those of the Hubble Space Telescope. They will be able to see the first stars forming in the universe billions of years ago and search out Earth-like planets around nearby stars for signs of life (see the ELT Roadmap http://www.aao.gov.au/instrum/ELT/ELTroadmap040917.pdf).



Artist's impressions of ELTs, representing the future horizon for optical and infrared astronomy. Left: the proposed Thirty Metre telescope courtesy of the Thirty Meter Telescope Project, California Institute of Technology and Todd Mason, Mason Productions. Right: the Great Magellan Telescope courtesy of the GMT Consortium.

Advanced Instrumentation and Technology Centre (AITC)

Australia's astronomical instrumentation programme is built on a long and proud history at the cutting edge of design and manufacture. The continued vibrancy of this programme within the international astronomy arena depends on the ability of Australian astronomers and specialist engineers to showcase innovative, state-of-the-art instrumentation for both present and future generations of extremely large telescopes (ELTs– telescopes with main mirrors 20 to 100 metres across). In turn, this will provide opportunity for greater access for Australian astronomers to these frontier facilities, collaborations and technologies.

The RSAA's Advanced Instrumentation and Technology Centre (AITC) is Australia's premier university centre for astronomical instrumentation. Here, a dedicated team of specialist design engineers devise innovative solutions to complex engineering challenges. This team of specialist engineers comprises opto-mechanical engineers, electronics engineers, software engineers, systems engineers, and technical project managers who work in concert with instrument scientists. Capitalising on a growing international reputation for engineering design expertise in this highly specialized field of instrumentation, RSAA, industry partners and wider astronomy-industry community are actively seeking funding to develop innovative design and manufacturing technologies which would ensure their access to this multi-billion dollar hi-tech niche market. This strategic goal (http://www.mso.anu.edu.au/technology/index.php) of the RSAA technology programme is in accordance with the mission statement of the AITC (http://www.mso.anu.edu.au/technology/mission.php).

Nationally, the RSAA manages its Siding Spring Observatory (SSO), the national astronomical research and training facility. The RSAA is enhancing this facility with new instrumentation to ensure that it remains at the cutting edge of technology for the next 10 years, to make operations more efficient and cost effective, and to provide better service and support to state university users, thereby ensuring enhanced research and research training outcomes.

The RSAA's 2.3m telescope facility at Siding Spring, NSW

Graduate Program

The RSAA Graduate Program is growing strongly, with 10 new PhD students starting in 2004. The student population (at the end of 2004) is 25, including 9 international students. Our very successful astrophysics honours program continues to attract top students from ANU and from other Australian universities, and many of the honours students choose to stay at RSAA for their graduate work. This year four honours students were enrolled. One of them, Patrick Scott, received the 2004 ASA Bok Prize for best honours thesis in astronomy. Patrick was supervised by Martin Asplund (RSAA).

As usual, the first year graduate 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 2004 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.

Some of these visits were supported by the Alex Rodgers Travelling Scholarships, which are available to students for international trips related to their PhD thesis (e.g. conference attendance or working with overseas collaborators). Recipients in 2004 were Damian Fabbian and Anna Frebel.

Each year, the incoming student with the best grades is offered the Duffield scholarship. This is a stipend top-up scholarship, funded from a generous benefaction by Miss Joan Duffield, daughter of the first director of Mt Stromlo Observatory. The 2004 Duffield Scholar is Philip Lah from ANU. Philip is researching the relationship between star formation and gas content in galaxies as a function of redshift. His
thesis will involve observations at telescopes in India and Australia. Philip's main supervisor is Frank Briggs of RSAA/Australia Telescope National Facility.

2004 Duffield Scholar Philip Lah

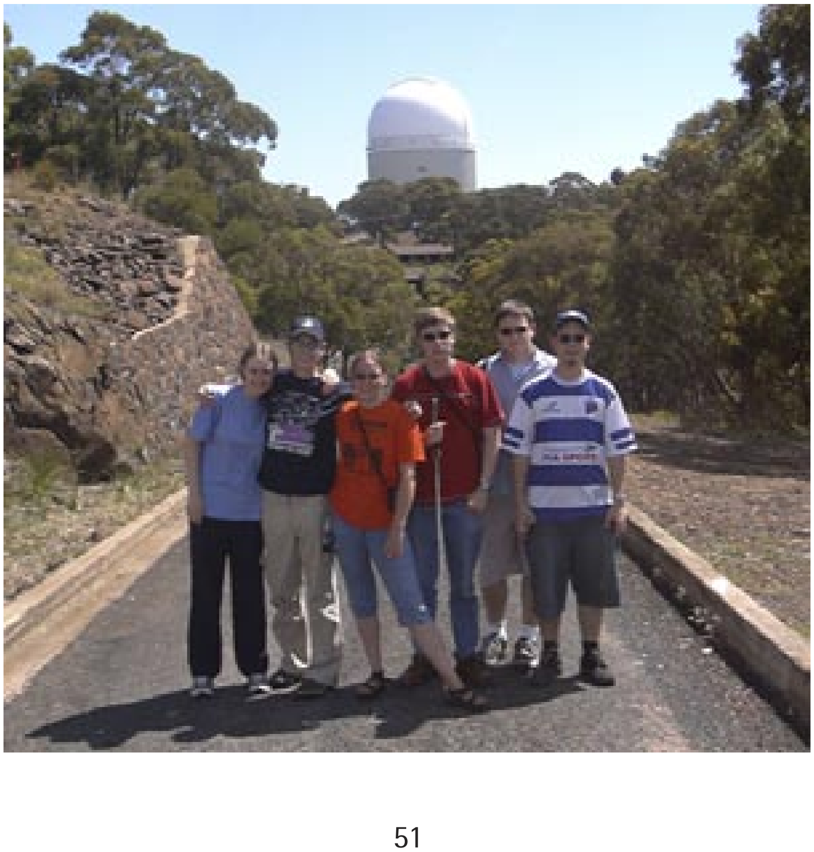
Honours Programme 2004

The 2004 academic year saw four students presenting honours theses in the Astrophysics programme. The Bok Scholar for 2004 was Lydia Philpott, who wrote a thesis "Singularity Constructions for Space-time" with the advice of Susan Scott of the Faculty of Science. Alan Payne studied "The Bivariate Brightness Distribution for the Local Sphere of Influence" with advisors Simon Driver and Helmut Jerjen (RSAA). Patrick Scott received the University Medal for his thesis on "CO Spectral Line Formation in the Sun: Convective Simulation, Line Profiles and Isotopic Abundance Measures," written under the guidance of Martin Asplund (RSAA). Christopher Weekes performed an "Analysis of Comet-Hunting Strategies using the Skymapper Telescope" with advisor Paul Francis (RSAA).

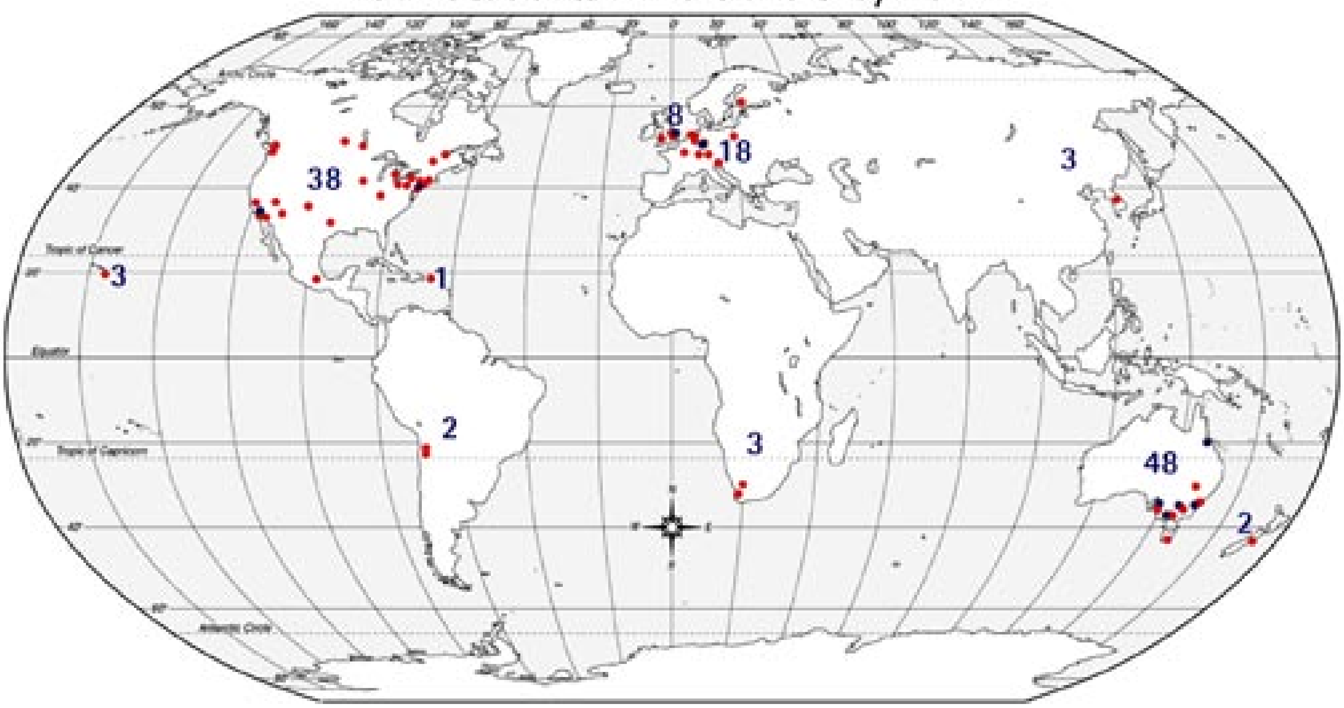
Summer Scholars Program

In 2004, RSAA hosted seven summer scholar students from Australia and New Zealand. The students (Elizabeth Adams, Gemma Anderson, Nicolas Bonne, Berian James, Karen Lewis, Simon Murphy and Giles Reid) conducted 8-12 week projects on diverse topics from Gamma Ray Bursts, to Young Stellar Objects, Interstellar Comets, QSOs and low surface brightness galaxies. Two of the students continued onto the Honours program.

The highlight of the students' visit was as usual the Observatory tour which included visits to the Parkes Radio Telescope, the Anglo Australian Observatory, the Australia Telescope National Facility, and Siding Spring Observatory (pictured). The scholars also enjoyed a lively lecture series given by the academic staff at Mt Stromlo Observatory.

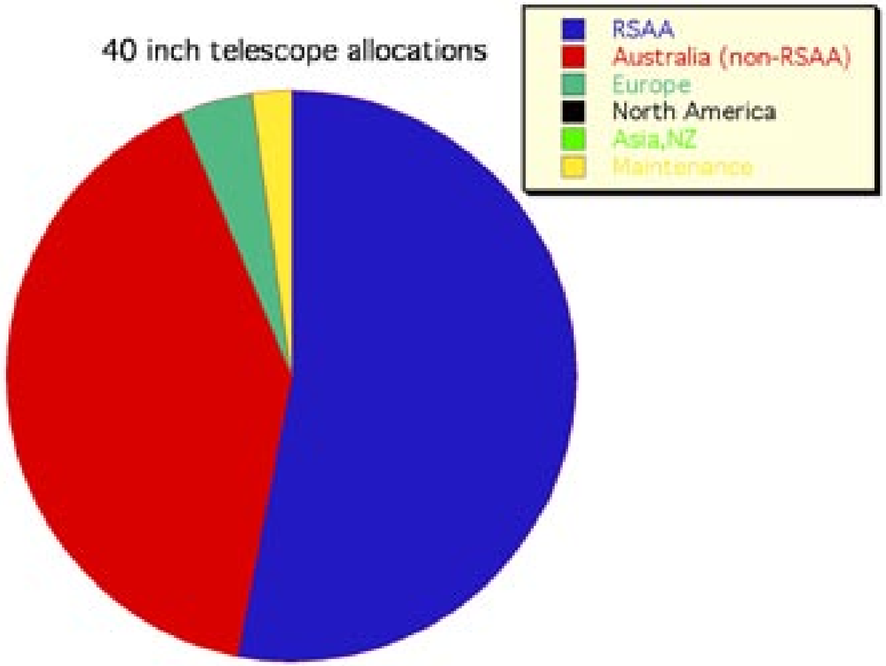


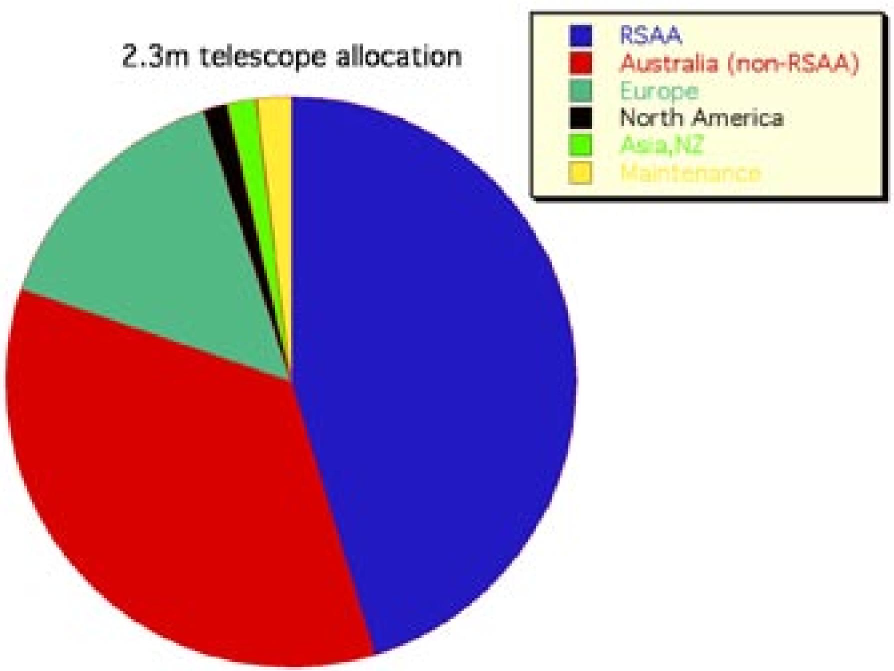
Our Students: where are they now?



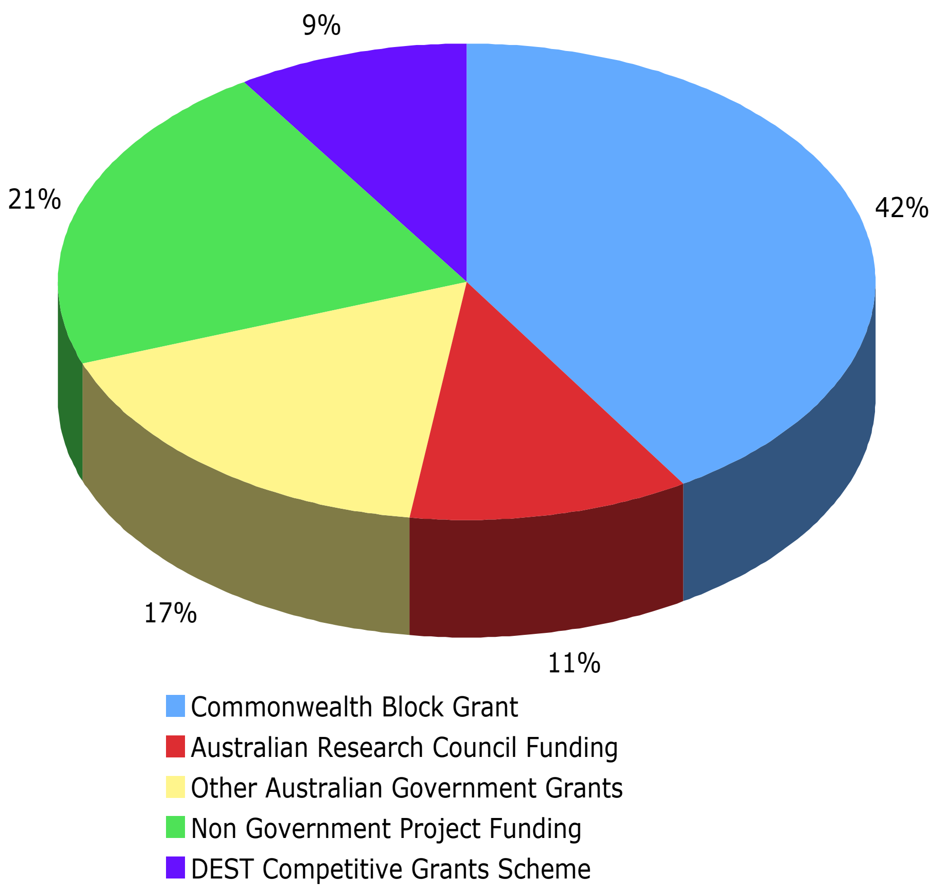
The red dots show the locations of RSAA graduates currently involved in astronomy and space sciences. Numbers at each location are shown. There are concentrations of graduates in the UK and east-coast USA locations.

The 40 inch and 2.3m telescopes at Siding Spring Observatory were fully scheduled in 2004. The following pie-diagrams indicate the geographic breakdown of users. This understates the international interest in the telescopes as many of the RSAA and other Australian users were working on collaborative programs with overseas astronomers.





Research School of Astronomy and Astrophysics
Sources of funds 2002-2004



ARC Discovery Grants	Amount to be awarded in 2004	Amount awarded for life of grant	Ongoing or starting 2004	Chief Investigator/ Lead Researcher
The 6dF Galaxy Survey: Mass and Motions in the Nearby Universe	$69,000	$279,000	Ongoing in 2004	Bruce Peterson
Interstellar Physics at the Epoch of Galaxy Formation	$107,000	$400,000	Ongoing in 2004	Mike Dopita
Taking Measure of The Universe with Exploding Stars	$75,000	$230,000	2004 Final Year	Brian Schmidt
The Evolution of Dwarf Elliptical Galaxies: Nature or Nurture?	$55,240	$165,719	Ongoing in 2004	Gary Da Costa
The Structural and Physical Properties of Galaxies over the past 10 G Years	$95,000	$275,000	Ongoing in 2004	Simon Driver
Galactic Nuclei: How Old, How Massive and How Active.	$85,000	$255,000	Ongoing in 2004	Peter McGregor
The First Stars and the Chemical Enrichment of the Universe	$100,000	$375,000	Ongoing in 2004	John Norris
The Southern Sky Survey	$200,260	$1,061,300	Ongoing in 2004	Brian Schmidt
Dying Stars, Mass Loss and the Creation of the Elements	$90,000	$270,000	Ongoing in 2004	Peter Wood
Atomic Hydrogen Through Cosmic Time: Steps to the Square Kilometre Array	$46,190	$106,190	Ended in 2004	Frank Briggs
The First Near Infrared Study of the Nearby Galaxy Population	$100,000	$300,000	Started 2004	Simon Driver
Galactic Archaeology: A Radial Velocity Experiment to Unveil the History of the Milky Way	$300,000	$730,000	Started 2004	Ken Freeman
Astrophysics with the CANGAROO III Gamma-ray Telescope	$25,000	$79,000	Ongoing in 2004	Geoff Bicknell
Calibrating Cosmology: The Near-Field Approach to Galaxy Formation	$6,000	$18,000	Ongoing in 2004	Gary Da Costa
Total:	$1,353,690	$4,544,209		

2004 was an eventful year for RSAA's public outreach program. We were often in the news, with staff giving over 500 media interviews and putting out four major press releases.

It was a year of birthdays. To celebrate Mt Stromlo's 80th birthday, an Open Day and a series of public lectures were run in October, attracting over 2000 people.

Siding Spring Anniversary

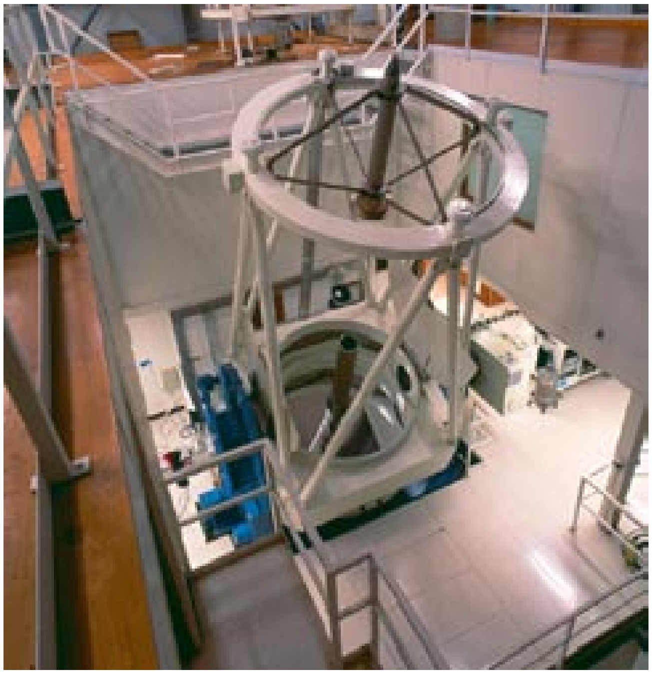
Celebrating 40 years as Australia's Finest Optical Observatory

Forty years ago the first telescope began operation at the Australian National University's Siding Spring Observatory, near Coonabarabran, NSW. Today this telescope, the 40″ reflector, is RSAA's main imaging telescope. During the 1960's two other telescopes joined the 40″, a 16″ designed for photometry and a 24″ designed for polarimetry. Photometry measures the brightness and colour of stars and polarimetry measures the magnetic fields in space.

Above: The first telescopes on Siding Spring

Siding Spring Observatory celebrated its 40th birthday with an Open Day and Open Night, the latter attracting 150 people up the mountain for a rare chance to see the telescopes in use at night. Around 15,000 people passed through the Siding Spring Exploratory during the year. Many exhibits from the Mt Stromlo Visitor Centre were moved to Siding Spring to replace the older exhibits there. In August, Siding Spring ran a three-day AstroCamp for high-school students. They were treated to curriculum-specific lectures during the day, and observing up on the mountain at night.

Back in Canberra, the Visitor Centre was refurbished, and it partially re-opened in October. Since then, it's been attracting over 1500 visitors a month. The visitors watch plasma-screen displays about RSAA research and facilities, eat in a temporary cafe and do a tour of the site. We also began regular Saturday night public viewing sessions, using the small telescopes that survived the fire. These have been blessed with unusually good weather, and have been attracting around 50 people per night.



"Birthday Beauties": the magnificent 4m Anglo-Australian Telescope (30 years old) and 2.3m Advanced Technology Telescope (20 years old)

To celebrate this 40/30/20th anniversary, RSAA hosted an Open Night on May 28, an Open Day on May 29, and an Anniversary Dinner on the evening of May 29.

Just before sunset on Open Night, two busloads of visitors gathered at the summit of Siding Spring. After being greeted by RSAA director Penny Sackett, they were split into groups and visited the 40", 2.3m, UNSW Automated Patrol Telescope, the AAT and the Faulkes South telescopes. Astronomers at each telescope explained their programs and showed the telescopes in operation and recently-collected data. Members of the Astronomical Society of Coonabarabran showed visitors the Moon, Jupiter and star clusters through smaller telescopes. Several hundred visitors from Coonabarabran and the surrounding region attended Open Day and were shown every instrument at the observatory.

Open day at Mt Stromlo Observatory allowed the public onto the site for the first time since just after the fires and marked the beginning of the new outreach program there. The public was invited into the new temporary workshops (above) and into the domes of the former research instruments.

The delicate removal of the historic Farnham Telescope (right). This is the only former research instrument to survive the 2003 Fires. Removed from the Commonwealth Solar Observatory, it is slated to become a public observation instrument in 2005.

Director	PD Sackett
Associate Directors	GS Da Costa (Associate Director for Academic Affairs) PJ McGregor (Associate Director for Instrumentation and Technology)
Federation Fellow	MA Dopita, MA *Oxf*, MSc PhD *Manc*, FAA
Professors	MS Bessell, BSc *Tas*, PhD *ANU* FH Briggs, BS *Swarthmore*, MS PhD *Cornell* GS Da Costa, BSc *Mon*, PhD *ANU* KC Freeman, BSc *WA*, PhD *Camb*, FAA FRS JE Norris, BSc PhD *ANU* PD Sackett, BS *Nebr*, MS PhD *Pitts*
ARC Professorial Fellow	BP Schmidt, BS *Ariz*, AM PhD *Harv*
Senior Fellows	GV Bicknell, MSc PhD *Syd* C Jenkins, BSc *Witwatersrand*, PhD *Camb* (from September) C Lineweaver, BSc *Mun*, MA PhD *Berk* (joint RSES) (from September) PJ McGregor, BSc *Adel*, PhD *ANU* BA Peterson, SB *MIT*, MS PhD *Caltech*, FRAS PR Wood, BSc *Qld*, PhD *ANU*
Fellows	M Asplund, BSc PhD *Uppsala* E de Blok, BSc PhD *Groningen* (from October) SP Driver, BSc *Leics*, PhD *Cardiff* PJ Francis, BA PhD *Camb* H Jerjen, Dip PhD *Basel* RS Sutherland, BSc PhD *ANU*
Research Fellows	T Davis, BA BSc PhD *UNSW* A Graham, BSc *Mon*, PhD *ANU* (from August)
Postdoctoral Fellows	P Allen, MSci *Durham*, PhD *Oxf* R De Propris, BSc *London*, MSc PhD *Vic* (to October) U Dyudina, BS MS *Mosc*, PhD *Caltech* (to September) 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*

Staff

Adjunct Faculty	J Bland-Hawthorn, BSc PhD *ANU* RD Ekers, BSc *Adel*, PhD, FAA, ARAS EM Sadler, BSc *Qld*, PhD *ANU* CW Stubbs, BSc *Virginia*, MSc PhD *Washington*
Postgraduate Students	A Bouchard, BSc MSc *Montreal* E Cameron, BSc *ANU* (from February) L Campbell, BSc *ANU* M Coleman, BSc *ANU* J Cooper, BSc *La Trobe*, Hons *ANU* (from February) G De Silva, BSc *Mon* C Drake, BSc *Mon* (to February) L Dunn, BSc *La Trobe*, Hons *ANU* (from January) D Fabbian, BSc *Padova* A Frebel, BSc *Freiburg* L Godfrey, BSc *Tas* (from March) M Goodwin, BEng *UWA* (from March) B Groves, BSc *Mon* (to May) S Gurovich, BSc *UWS Nepean* C Harrison, BSc *QUT*, Hons *ANU* M Huynh, BSc *UWA* P Lah, BSc *ANU* (from March) R Moody, BSc *ANU* (to April) J O'Brien, BSc *Melb* E Olivier, BSc MSc *Western Cape* (to May) S Prior, BSc BA *Qld,* Hons *ANU* (from February) J Rich, BInfoTech BSc *Central Qld*, Hons *ANU* (from February) J-A Robles-Martinez, BPhys *UDLA* (from February) M E Salvo, BSc *Padova* S Sankarankutty, BSc MSc *UFRN* V Safouris, BSc *Syd* H Sims, BSc *ANU* L Stanford, BSc *Flinders*, Hons *ANU* C Thurl, BSc *Regensburg*, MA *Wesleyan* B Tingley, BA *Virginia*, MS *Mass* (from March) B Warren, BSc *Mon* D Weldrake, BSc *Herts* E Westra, MSc *Groningen* M Williams, BSC MSc *Auck*
Research Officer	V Ford, B App Sc. *CCAE*
Academic Services Officer	T Gallagher, BA *Vanc*

ADMINISTRATION

Business Manager	V O'Connor
Executive Officer	S Chong
Assist. Business Manager	I Sharpe
Operations Officer	D Bourne
Purchasing Officer	M Miller
Asst Purchasing Officer	S Maloney
Site Officer	G Blackman
Executive Assistant to the Director	F Aplin
Asst Site Officer	P Walshe
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) *UNSW*
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
	R 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 (10% from July) M Huynh (20% from May) R Moody (10% January) J O'Brien (20% from November)

ELECTRONICS

Engineer in Charge	M Dawson, BEng MEng
Engineers	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

SIDING SPRING OBSERVATORY STAFF

OPERATIONS

Site Officer	W Green
Assistant Site Officer	T Houghton

Operations Officer	H Davenport
Cleaner	P Nguyen
Casual Staff	R Cosgrove
	E Davenport
	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) *UNSW*
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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The view of a poet from Mt Stromlo

The Swedish novelist and poet Harry Martinson (1904-1978) shared the Nobel prize for Literature in 1978. The citation was: *For an authorship that catches the drop of dew and reflects the Universe.*

Harry Martinson visited Australia and Mt Stromlo in 1962 and wrote the following poem, translated by B Gustafsson and P Barklem.

The star day

A spherical cluster full of shining suns
Seen clearly in the constellation of Centarurs
From the mountain Stromlo, Terra Australis.
May be what poets have sought after
When they have tried to locate paradise.

Surely a hundred thousand suns there are in the bunch,
And all the suns wander so tightly aligned
There is less than a light year between them,
Within the swarm they form together.

Thus, the light that flows
Towards the planets bound therein
Gives constant star day and illuminates
All the voids with radiation, as bright
As the light from a thousand midnight suns.

I asked the star man on Mount Stromlo
If this should be called eternal day.
The answer was: I guess we can assume
That space seems bright in such a place.

If blue skies exist, that may be questioned.
More likely the heavens appear
As a coloured vault, tightly speckled
With light from a thousand suns in concert.

Difficult to imagine, yet,
Such space, rich with suns, seems ideal
A paradise and a place for apparitions,
Perhaps souls who have attained peace,
Perhaps those blessed who made it home.

http://www.kirjasto.sci.fi/harrymar.htm
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The fascinating globular cluster Omega Centauri continues to be the focus of research for many RSAA astronomers. The search for planets in Omega Centauri has been undertaken at Mt Stromlo as part of the PhD thesis work of David Weldrake.

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