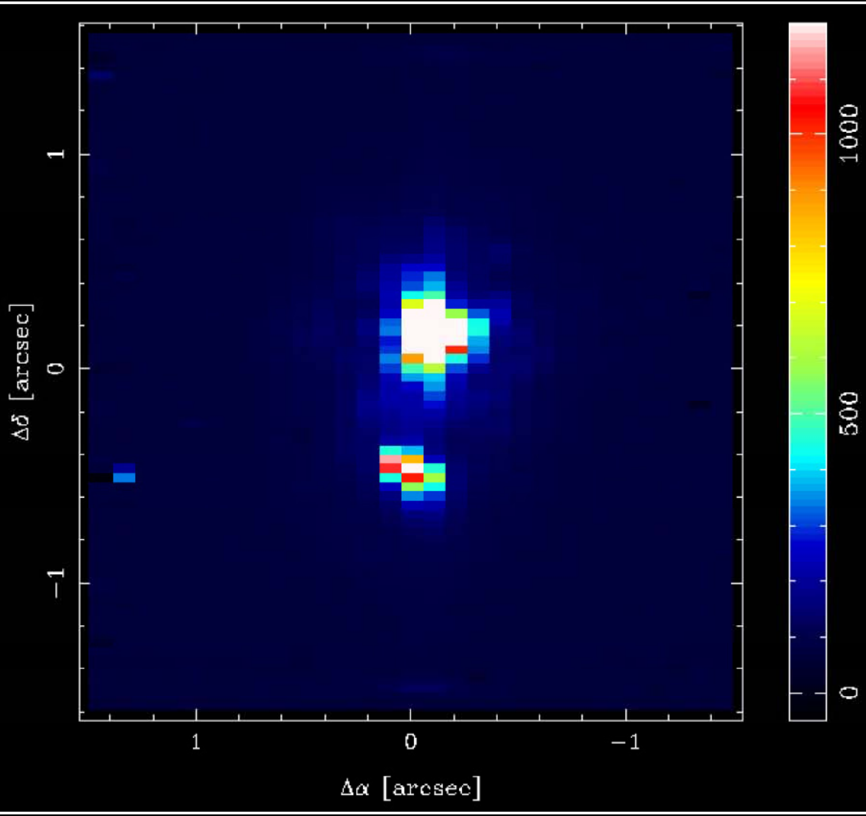
RESEARCH SCHOOL OF ASTRONOMY & ASTROPHYSICS

THE AUSTRALIAN NATIONAL UNIVERSITY



ANNUAL REPORT 2005

2005 Annual Report

Research School of Astronomy & Astrophysics

Including a development report for 2004-2005

Research School of Astronomy and Astrophysics

The Australian National University

(CRICOS # 00120C)

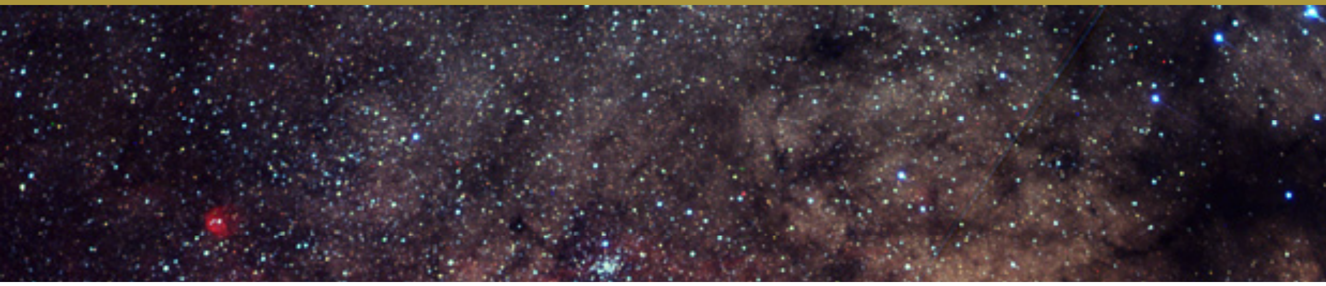
Annual Report 2005

Published : 2006

Eds: R. Sutherland, J. Norris, M Ni Mhordha, J. Balban

THE AUSTRALIAN NATIONAL UNIVERSITY

RSAA Mission Statement



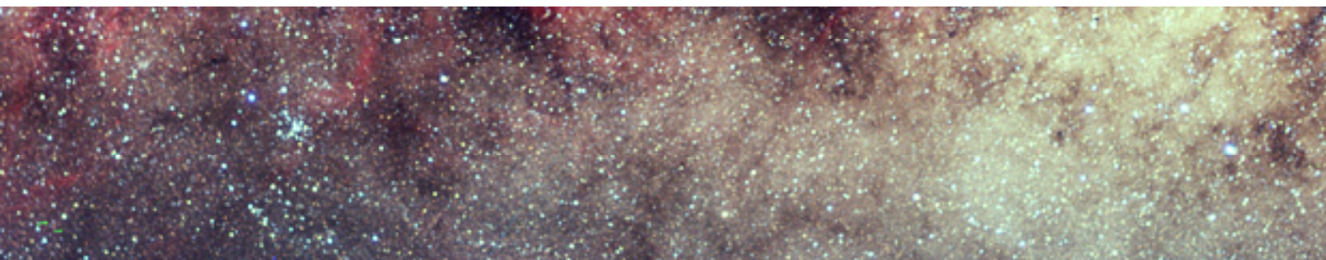
Our Mission is to:

Advance the observational and theoretical frontiers of astronomy and its enabling technologies,

Provide national and international astronomical leadership;

&,

Train outstanding scientists.



2005 Annual Report

Siding Spring Observatories, 2.3m telescope in the foreground, circa 1990.

Contact Details

Mt Stromlo Observatory
Cotter Road, Weston ACT 2611
Australia
T: +61 2 6125 0230
F: +61 2 6125 0233
www.mso.anu.edu.au

Mt Stromlo Observatory Visitors' Centre
T: +61 2 6125 0232
F: +61 2 6125 8045
www.mso.anu.edu.au/msovc

Siding Spring Observatory
Coonabarabran NSW 2057
Australia
T: +61 2 6842 6262
F: +61 2 6842 6240
www.mso.anu.edu.au/about_us/ssopage.php

Siding Spring Observatory Visitors' Centre
T: +61 2 6842 6211
F: +61 2 6842 6226
www.sidingspringexploratory.com.au

Contents

Director's Message

Excellence, Flexibility and Sustainability

In 2005, the Research School of Astronomy and Astrophysics (RSAA) at The Australian National University (ANU) underwent a program of strategic planning and restructuring in order to prepare the School for continued strong performance in an increasing varied – and variable – environment. Our watchwords throughout were excellence, flexibility, and sustainability.

The entire RSAA staff engaged in a process to define and prioritise our core and extended functions going forward, and suggest strategies for increased efficiency, resource sharing, and cost transfer to evolving second and third stream funding sources. The School Executive then prepared a strategic plan to align RSAA resources to these priorities and strategies.

Tested against fiscal modelling, the plan is driven by our internal mission while responsive to our environment, and is now being implemented in stages so as to not mortgage or under-resource our future. Features of the plan include increased emphasis on: rewarding initiative, performance, technical design and development, the highest impact ANU observing facilities, cross-skilling staff, and support for income generation and monitoring functions.

With these changes set in motion, we expect RSAA to continue to stand out as an institution of the highest international standing in astronomical research.

We set high goals for ourselves in 2005. The excellence of our individual staff members working in strong teams at ANU, across Australia, and around the world, enabled some remarkable achievements. You can read about some of them in this annual report, including: the discovery of

- the smallest known cool planet orbiting a normal star other than our Sun
- evidence that gas in the very early Universe has already been enriched by elements forged in stellar interiors

creation of

- the first three-dimensional models of red giant star atmospheres
- self-consistent models of how molecular clouds emit and absorb light

analyses indicating that

- new jets generate bow shocks in the old, hot cocoons of radio galaxies
- small satellites may collide with even smaller neighbouring galaxies

design and commissioning of

- a portable software analysis box for the prototype of a next-generation radio telescope in remote Western Australia
- an innovative spectrograph for one of the world's largest telescopes that is now measuring the mass of distant black holes.

So how did we do in 2005? You be the judge. Tell us what you decide.

Staff & Resources 2005

Academic Staff

Director

PD Sackett

Associate Directors

GS Da Costa (Associate Director for Academic Affairs) / JE Norris (Acting)
PJ McGregor (Associate Director for Instrumentation and Technology)

Federation Fellows

MA Dopita, MA Oxford, MSc PhD Manc, FAA
BP Schmidt, BS Ariz, AM PhD Harv

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, BSc Nebr, MS PhD Pitts
ARC Professorial BP Schmidt, BS Ariz, AM PhD Harv

Senior Fellows

GV Bicknell, MSc PhD Syd
C Jenkins, BSc Witwatersrand, PhD Camb
C Lineweaver, BSc Mun, MA PhD Berk (joint RSES)
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
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
M Pracy
A Graham, BSc Mon, PhD ANU

Postdoctoral Fellows

P Allen, MSci Durham, PhD Oxf
J Fischera, Diploma CAO Kiel, PhD Heidelberg
S Keller, BSc Syd, PhD ANU
J McSaveney, PhD Canterbury
R Trampedach, MSc Arhus, PhD Mich

Postgraduate Students

D Bayliss,
J Blackman, B.Sc (Hons) Adelaide
A Bouchard, BSc MSc Montreal
E Cameron, BSc ANU
L Campbell
J Cooper, BSc La Trobe, Hons ANU
G De Silva, BSc Mon
L Dunn, BSc La Trobe, Hons ANU
D Fabbian, BSc Padova
A Frebel, BSc Freiburg
L Godfrey, BSc Tas
M Goodwin, BEng UWA
S Gurovich, BSc UWS Nepean
C Harrison, BSc QUT, Hons ANU
M Huynh, BSc UWA (to July)
G Kennedy, BSc
J Kocz, BIT/BE, ANU
P Lah, BSc ANU
S-H Oh, BSc Yonsei
J O'Brien, BSc Melb
S Prior, BSc BA Qld, Hons ANU
J Rich, BInfoTech BSc Central Qld, Hons ANU
J-A Robles-Martinez, BPhys UDLA
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
L Veltz, DEA ULP
S Walsh, BSc Curtin
E Westra, MSc Groningen
M Williams, BSC MSc Auck

Project Management

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

Mechanical Engineering

Head

J Hart, BE (Mech) UNSW

Engineers

P Conroy, CME CTC
M Doolan, BSc, BE (Hons), PhD
D Stevanovic, BE (Hons), PhD
A Granlund

Mechanical Workshop

Workshop Supervisor

C Vest

Instrument Makers

J Bowman
A Cappuccio
J DeSmet
H Gebauer, CME
R Tranter

Optical Workshop

Senior Optician

G Bloxham, DAP GIT

Optician

R Zhelem BSc, Hons, PhD

Electronics

Head

M Dawson, BEng MEng

Engineers

P Oates B.A.(Hons), B.Sc (Hons), M.Sc , Ph.D
M Waterson
E Kowald

Technical Officers

B Keys
A de Gans
H Lawatsch

Computing Laboratory

Head

P Young, BSc

Programmers

A Czezowski, BSc Warsaw, MSc, PhD
A Green
G Hovey, BSc, PhD
M Jarnyk, BEng, MEng, PhD
J Nielsen, BSc WA, BA Murdoch
W H Roberts, Bsc
K M Sebo, BSc WA, PhD
D Smith, BSc
A Vaccarella

Staff 2005

G Wilson, BSC, PhD

Skymapper Project

T Martin-Jones
T Preston

Student Programmers

A Bouchard
M Huynh
J O'Brien
J Rich
M Salvo

Administration Staff

Executive Officer

S Chong

Business Officer

M McDonald, BAppSc,USyd, Dip Acc

Assistant Business Manager

Ian Sharpe

Site Manager

M Maloney, BSc

Academic Services Officer

T Gallagher, BA Vanc

Exec. Assistant to the Director (Acting)

F Filardo

Exec. Assistant to the Director

M Ni Mhordha, BBS DCU

HR Officer

R Noble

Development Officer

C Neil

Research Officer

V Ford, BSc CCAE

Information Officer

N Aked

Adopt-a-Star Staff

F Neil

Purchasing Officers

M Miller
S Maloney
Y Malmberg

Grants and Finance Officers

R Mills
L Micallef

Site Officer

G Blackman

Asst Site Officer

P Walshe

Gardening Supervisor (ANU Facilities and Services)

H Coyle

Siding Spring Observatory Staff

Operations

Manager

P Starr

Assistant Site Officer

T Houghton

Operations Officer

H Davenport

Research

Research Officers

G Garradd
R McNaught, BSc (Hons), St Andrews

Casual Staff

R Shobbrook

Technical

Engineer

M Harris, BEng 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

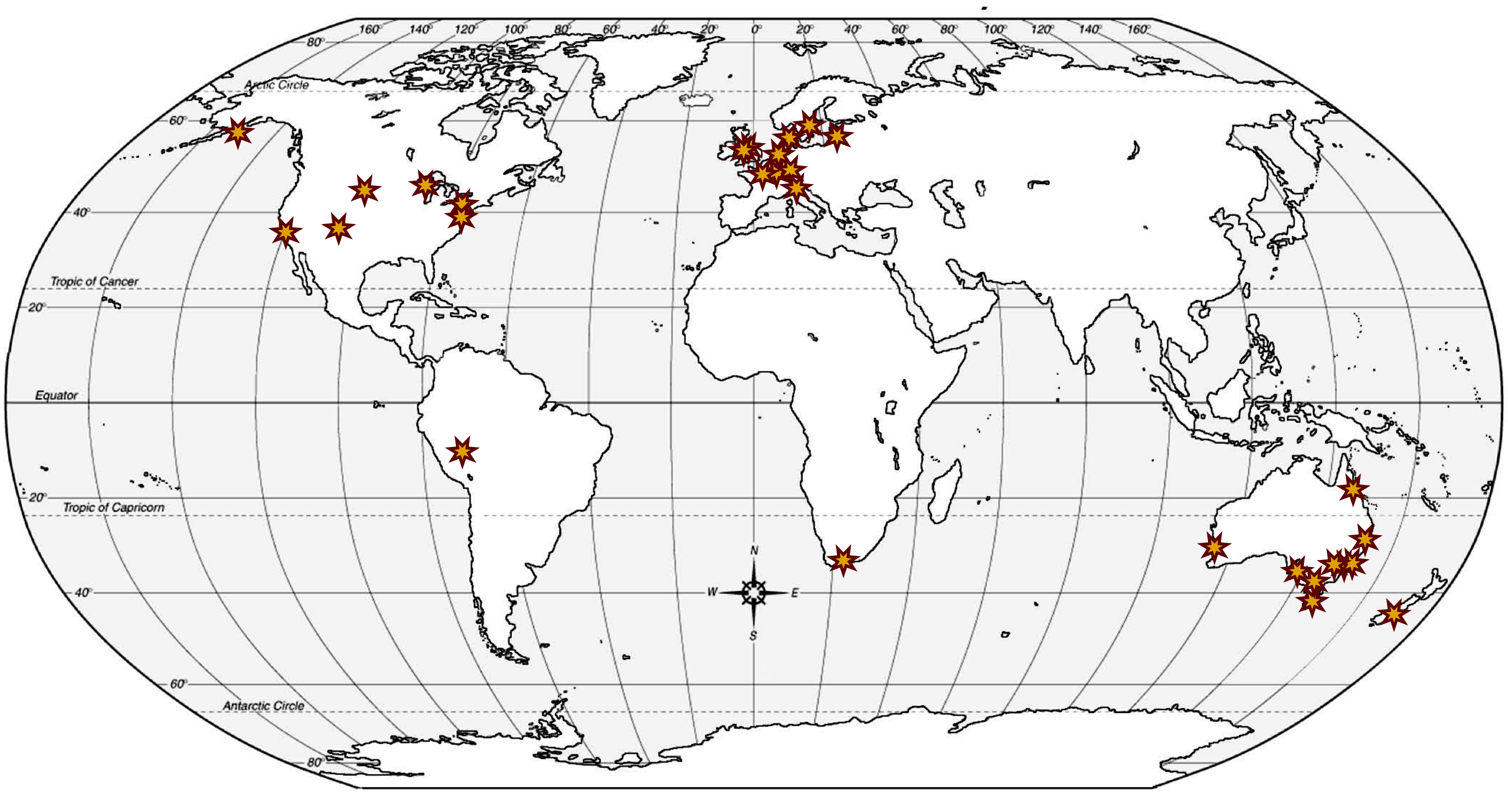
Phong Nguyen

SSO Exploratory

Supervisor

J Dicello-Houghton
M Verrender

Staff Origins 2005



The results of an informal survey of the country of origin for all 2005 RSAA staff is shown. Each star shows the geogrphic of an RSAA staff member. There is the expected clustering in Australia, Europe and the US, but also a few interesting "outliers".

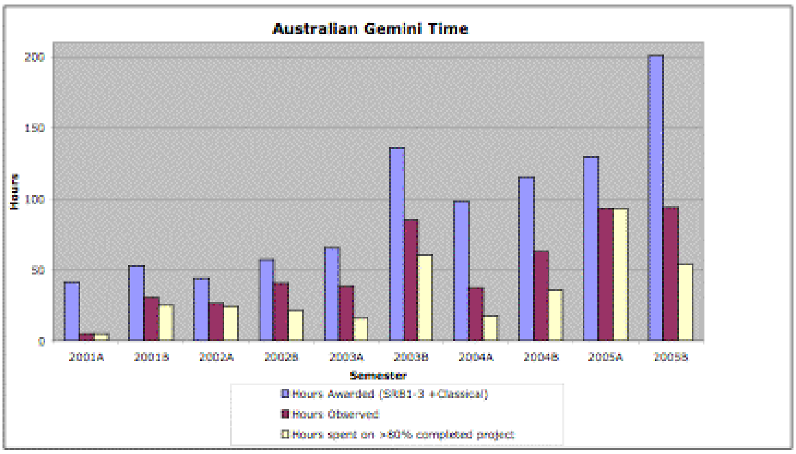
Australian Gemini Office

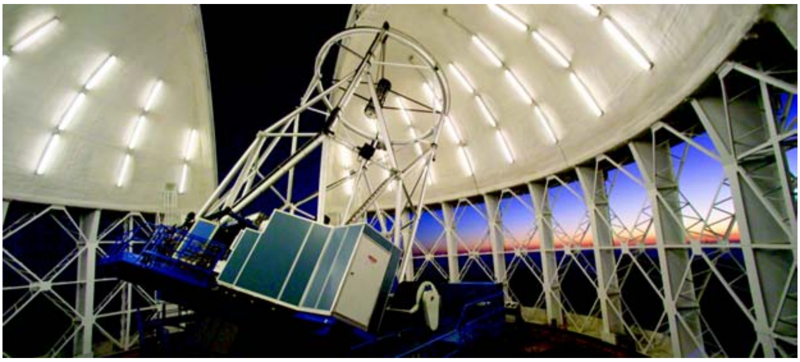
Since January 2005, RSAA has been host to the Australian Gemini Office. This office is responsible for Australian access to the twin Gemini telescopes: the largest and most powerful optical/IR observing facilities in which Australia is a partner. Dr Paul Francis took on the role of Australian Gemini Scientist. Previously the office had been based at the University of New South Wales.

The Australian Gemini Office has the following roles:

- It supports Australian users of the Gemini Telescopes. It maintains a web page, handles the proposal submission process, answers user questions, and advertises Gemini telescope capabilities to the Australian community.
- It represents the views of the Australian community on a wide range of international Gemini project committees.

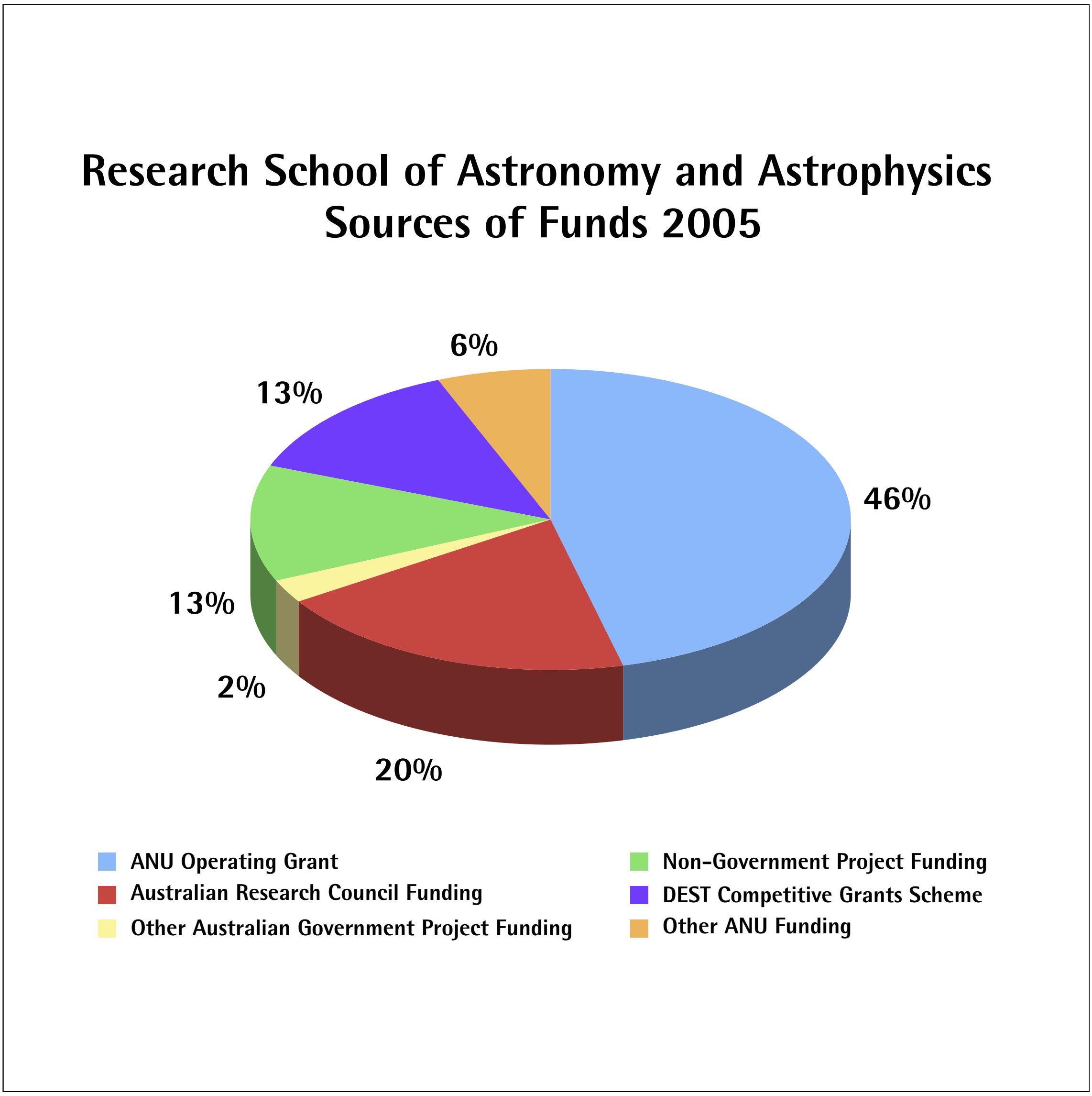
During 2005, the office handled 51 proposals to use the Gemini telescopes, dealt with over 100 user enquiries, and ran a national speaking tour informing the community about Gemini issues. The office represented the Australian community's views at five international committee meetings and innumerable telecons.





School Funding 2005

ANU Recurrent Funding is the single biggest source of RSAA income in 2005, though income received through the ARC Competitive Grants scheme is an increasingly important source of school funds. Compared with previous years, funding from other sources, both government and non-government, has decreased as special instrumentation projects near completion.



Grants

External Grant Funding

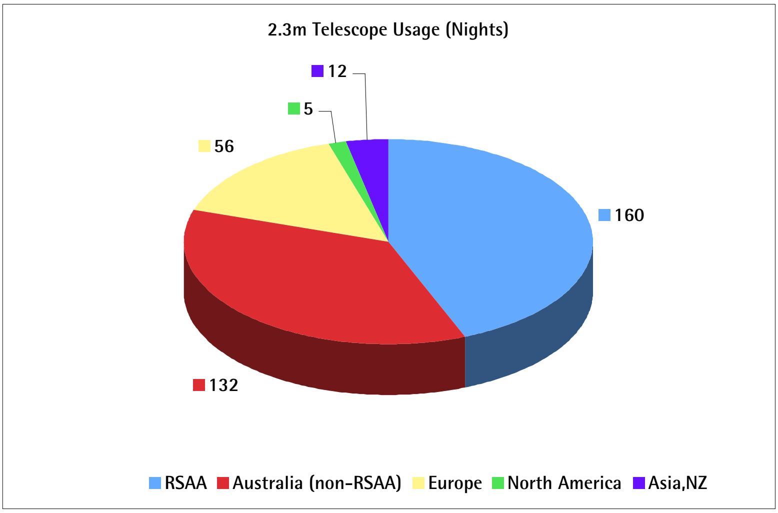
External grant funding in 2005 for the Research School of Astronomy and Astrophysics, principally ARC funding, is summarised in the table below.

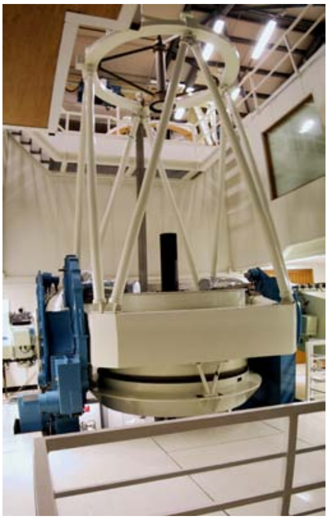
Name of Grant	Amount awarded in 2005	Amount awarded for life of grant	2005 Status	ANU Lead Researcher
The 6dF Galaxy Survey: Mass and Motions in the Nearby Universe	$69,000	$279,000	Ending in 2005	Peterson
Interstellar Physics at the Epoch of Galaxy Formation	$97,000	$400,000	Ending in 2005	Dopita
The Evolution of Dwarf Elliptical Galaxies: Nature or Nurture?	$49,102	$169,330	Ending in 2005	Da Costa
The Structural and Physical Properties of Galaxies over the past 10 G Years	$85,000	$275,000	Ending in 2005	Driver
Galactic Nuclei: How Old, How Massive and How Active?	$85,000	$255,000	Ending in 2005	McGregor
The First Stars and the Chemical Enrichment of the Universe	$100,000	$375,000	Ending in 2005	Norris
The Southern Sky Survey	$190,260	$1,061,300	Ongoing in 2005	Schmidt
Dying Stars, Mass Loss and the Creation of the Elements	$90,000	$270,000	Ending in 2005	Wood
The First Near Infrared Study of the Nearby Galaxy Population	$100,000	$300,000	Ongoing in 2005	Driver
Galactic Archaeology: A Radial Velocity Experiment to Unveil the History of the Milky Way	$250,000	$730,000	Ongoing in 2005	Freeman
Astrophysics with the CANGAROO III Gamma-ray Telescope	$25,000	$79,000	Ending in 2005	Bicknell
Calibrating Cosmology: The Near-Field Approach to Galaxy Formation	$6,000	$18,000	Ending in 2005	Da Costa
Stellar Abundances as Records of Stellar Nucleosynthesis and Galactic Evolution	$120,000	$567,000	Started 2005	Asplund
Star Formation and Gas Consumption in High Redshift Galaxies	$100,000	$260,000	Started 2005	Briggs
Probing the Universe with Exploding Stars	$110,000	$210,000	Started 2005	Schmidt
Total:	$1,476,362	$5,248,630		

Telescope Usage

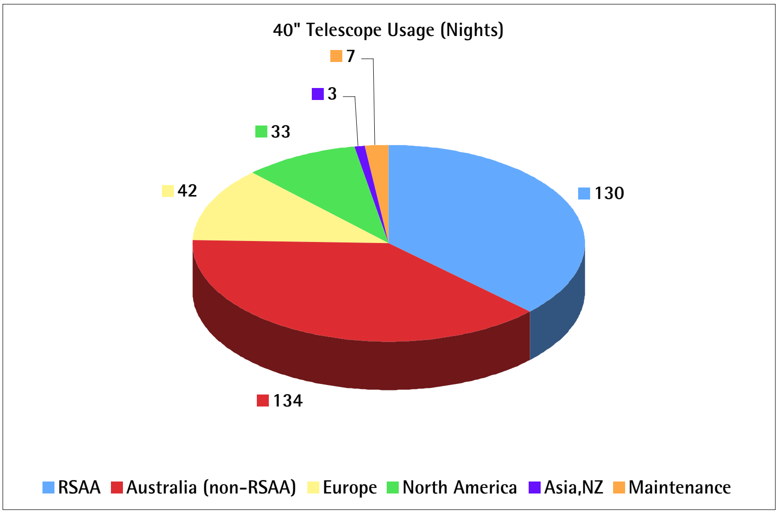
The Research School of Astronomy and Astrophysics allocates time on its telescopes through a peer review process to the national and international astronomical community. The breakdown of the observing nights allocated in 2005, by astronomer's host institution location, is shown in the pie charts below.

2.3m Telescope Nights in 2005





40 inch Telescope Nights in 2005



2005 Highlights

Federation Fellowship 2005
Professor Brian P. Schmidt

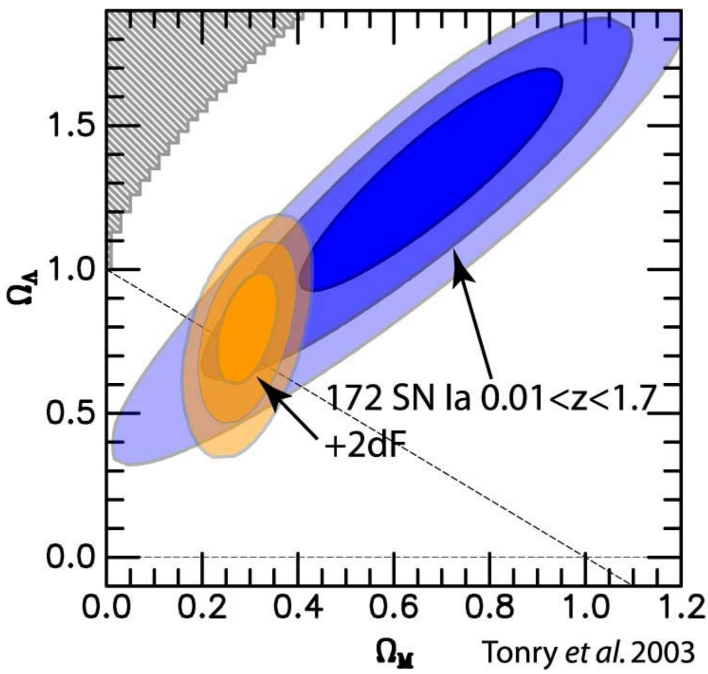
A prestigious Federation Fellowships were awarded to Professor Brian Schmidt, who will study of the evolution of the Universe.

Mt. Stromlo is now home base for two Federation Fellows. Brian joins Professor Mike Dopita, who was awarded one of the inaugural Fellowships in 2001.

The Federation Fellowship is the latest in a string of awards that Professor Schmidt has accumulated since beginning his career in astronomy. They include the 2000 Harvard Bok Prize for an outstanding astronomical thesis, the inaugural Australian Government Malcolm McIntosh Prize for physical scientist of the year (2000), the 2001 Australian Academy of Science Pawsey Medal for outstanding research in physics, and the 2002 Vainu Bappu Medal of the Astronomical Society of India. Last year (2004) he was named as Australia's top scientist by Bulletin magazine in its annual "Smart 100" listing.

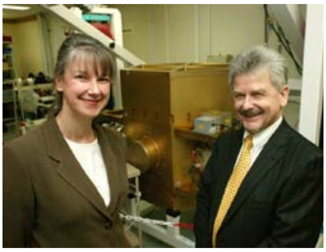
Brian's Fellowship will fund research into the formation and evolution of stars and galaxies, dark matter, and the mysterious "Dark Energy", which accounts for around 70 per cent of the Universe. Much of the research will be done with the new ultra-fast SkyMapper telescope now being built for Siding Spring Observatory.

RSAA's two Federation Fellows, left: Professor Michael Dopita, right: Professor Brian Schmidt.



Left: Measurements of the composition of the entire Universe, from the ESSENCE project. (From Tonry et. al 2003, ApJ, 594,1T) The "Dark Energy" component (Ω_Λ)of the universe is most likely to account for over 70 per cent of the Universe.

Left to right – Doug Simons (Head of Gemini Instrumentation), Helen Sims (Gemini media liason, CSIRO), Paul Francis (Australian Gemini Project Scientist, RSAA), Penny Sackett (Director, RSAA) and Peter McGregor (NIFS Project Scientist, RSAA).



NIFS with RSAA Director, Penny Sackett, and the Managing Director of Auspace, Roger Franzen. NIFS was formally handed over to Gemini on August 4 at a ceremony at Auspace Ltd.

The Near-infrared Integral-Field Spectrograph (NIFS)

NIFS shipped to Hawaii in August 2005, was attached to the Gemini North 8.1 metre telescope on 11 October. Following extensive tests, it recorded its first data on Tuesday, 18 October. First images show the instrument to be a complete success.

The data from NIFS consists of a series of 29 spectra taken across the field of view. This spectral information give details of the chemistry and velocity of the objects in the field. The spectra can also be used to construct an image of the objects.

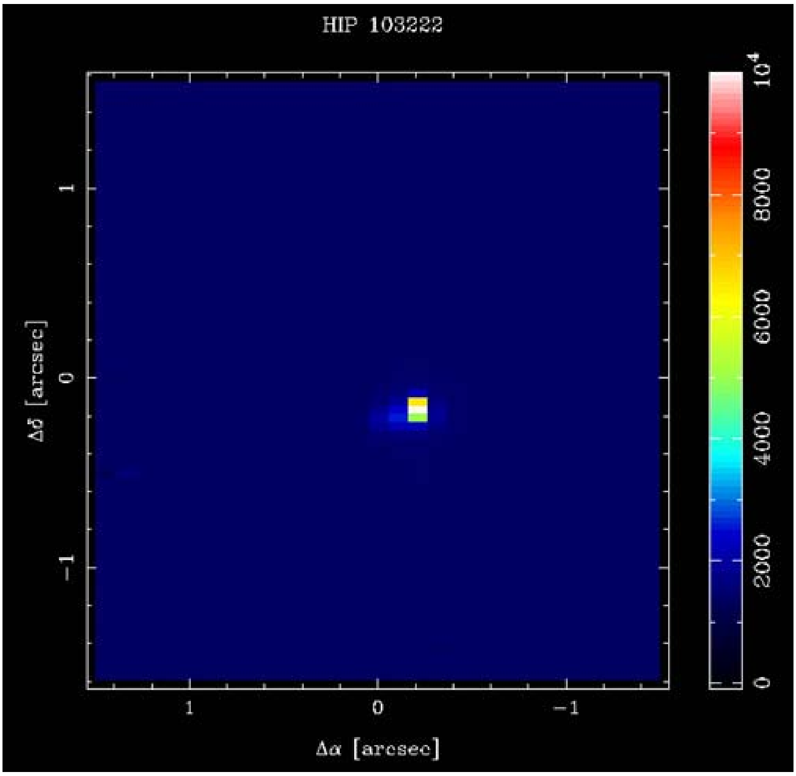
NIFS Project Manager, RSAA engineer Mr Jan van Harmelen and NIFS Project Scientist, RSAA's Dr Peter McGregor, spent a month at the Gemini North Observatory supervising the tests and initial observations with the instrument. The initial tests went flawlessly.

NIFS uses a unique optical design to analyse the light from an object allowing astronomers to study phenomena in detail, including the gravitational effects of black holes, the interactions of colliding galaxies, and the formation and death of stars. The original NIFS was destroyed in the January 2003 bushfires. NIFS-2 has been rebuilt by the Canberra-based aerospace company, Auspace Ltd, in collaboration with Mt Stromlo designers and engineers.

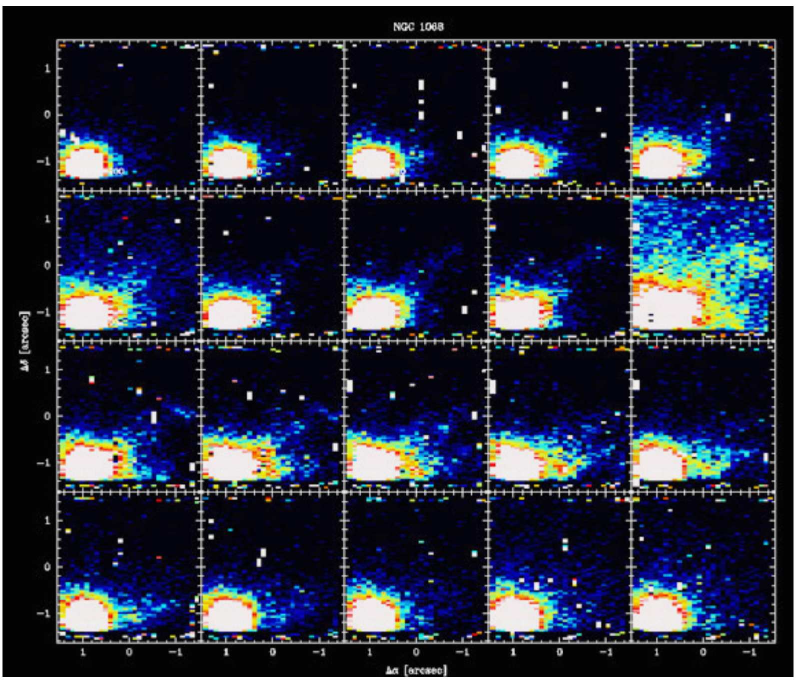
NIFS is part of the ANU contribution to the Australian Astronomy Major National Research Facility, supported in part by the Department of Education, Science and Training.

The Director, Professor Penny Sackett, said the news of NIFS' successful first observation had been a buzz for staff, and that congratulations were pouring in from around the world. "The NIFS journey has been a long one, but the fruits of that labour are now very tangible, with the successful first astronomical observation by NIFS."

RSAA staff shared in the excitement of the first images via a video link to the Gemini North control room during the start of the second night of observations. There was much discussion of the first images, technical discussion between the crew at Gemini and the NIFS team members at Stromlo, and the success of the instrument was toasted.



Left: The first light image, taken to check the pointing and alignment of the instrument. The field of view of NIFS is three arc-minutes square; the star image fell almost exactly in the centre of the fieldon the first attempt.



Left: A series of spectral images of the active galaxy NGC 1068. The images are "velocity slices", which allow the motions within the galaxy to be measured. Note the jet reaching to the right of the galaxy in several of the frames. (See also the front and back covers of this report.)

Dr Helmut Jerjen

Einstein ring gives view of early universe

[from: ESO press release 30 June 2005 and ANU press release 4 July 2005]

Astronomers are being provided a rare glimpse back to the time when galaxies were in their infancy, thanks to the work of Dr Helmut Jerjen.

The partial Einstein Ring discovered in the southern constellation of Fornax is only the fourth of its kind ever observed. The new Ring is the furthest ever found, is remarkably bright, and is almost complete.

An Einstein Ring is an optical phenomenon that occurs when two galaxies are perfectly aligned along the line of sight. The gravity of the nearer galaxy acts as a lens, distorting and magnifying the light from its distant counterpart into the shape of a circle.

It is a pure geometrical coincidence that these two galaxies are perfectly aligned with one another. This can be discovered anywhere in the sky, but it is extremely rare that the alignment and distances are right – finding them is finding like finding needles in a haystack.

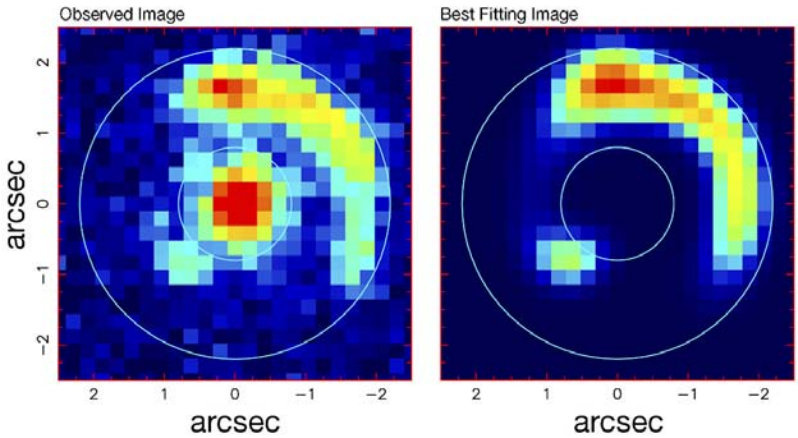
The bright red dot at the centre of the left VLT image is the massive galaxy doing the lensing. The arc around this galaxy is the Einstein Ring, the focussed and magnified light of the distant galaxy. The VLT image has been processed to highlight the structure of the ring and shows it to be about 75 per cent complete.

The closer, lensing galaxy in the new Einstein Ring is eight billion light years away. It is about 10 times larger than our Milky Way and contains mostly old stars. The distant galaxy is 12 billion light years distant, and would remain invisible if it weren't for the magnifying effect of the foreground galaxy. This galaxy is much younger and is in the early stages of its life. It has just gone through a burst of star formation and contains mostly young stars. The lensing effect is allowing a rare glimpse into the early epoch of galaxy formation in the young Universe.

We can explore the stellar composition of this distant object, which at 12 billion light years from us, is really located at the time when galaxies were just forming, and the Universe was about 12 per cent of its present age. Thanks to these magnified images, we are able to explore parts of the universe that wouldn't be accessible to us otherwise.

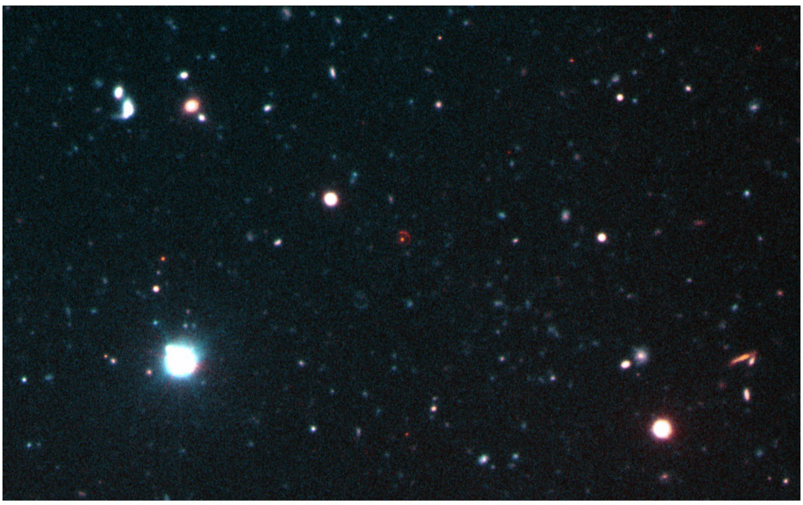
The possibility of such rings was first predicted by Einstein's general relativity theory 100 years ago. One of the predictions from the theory is that light will bend when it passes through a strong gravitational field. The results of this research have been published in Astronomy and Astrophysics.

Einstein Ring



Einstein Ring in Distant Universe
(FORS/VLT)
ESO PR Photo 20c/05 (30 June 2005)
© ESO

Left: VLT image of the Fornax Einstein Ring. **Right**: A reconstructed, modelled, image after processing.



Zoom-in on the Newly Found Einstein Ring
(FORS/VLT)
ESO PR Photo 20b/05 (30 June 2005)
© ESO

Left: The region of Fornax containing the Einstein Ring. The object is just visible in the centre of the image in this enhanced image. This image is only a small portion of a much larger area viewed in the original discovery frame.

Members of the discovery team are:

- **R. Cabanac,** Pontificia Universidad Catolica de Chile and the Canada-France-Hawaii Telescope (CFHT)
- **D Valls-Gabaud**, CFHT and Observatoire Midi-Pyrenees
- **A Jaunsen,** ESO
- **C Lidman,** ESO
- **H Jerjen**, RSAA

Chris Lidman is a Mt. Stromlo graduate, gaining his PhD in astronomy from ANU in 1995.

Professor Michael Dopita

An Intergalactic Shock in Stephan's Quintet of Galaxies.

When a team of astronomers including Professor Michael Dopita of RSAA, used NASA's Spitzer Space Telescope to observe a well-known group of galaxies called Stephan's Quintet, they were, quite literally, shocked to discover one of the biggest shock waves ever seen.

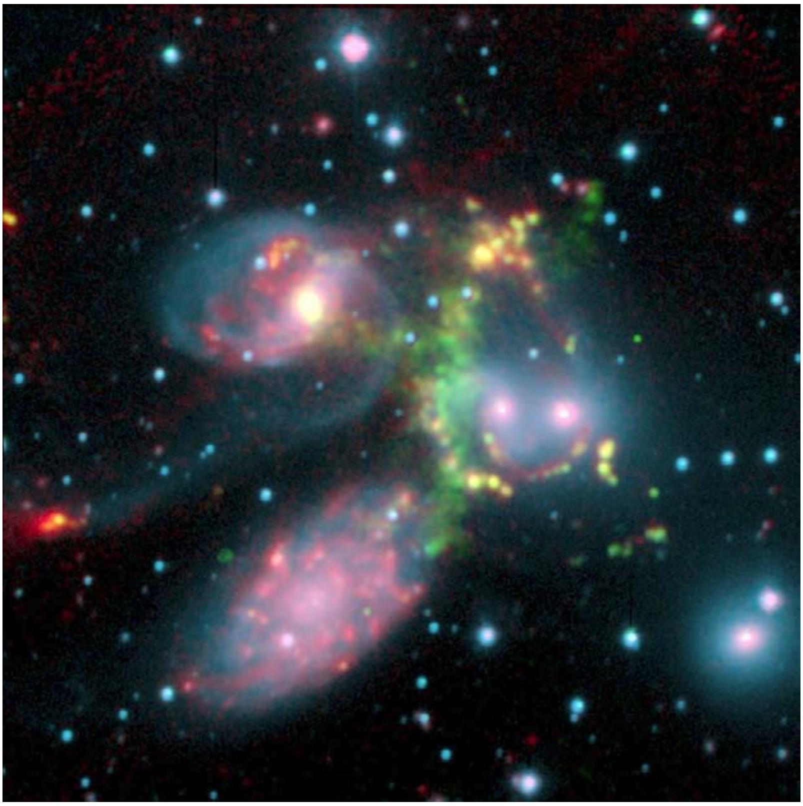
For decades, astronomers have known that the galaxies in this group, located about 300 million light years away, show evidence of multiple collisions and tidal disruption. But this, as it turns out, is only part of the drama. Recently, astronomers looked in the radio and X-rays to discover huge quantities of gas, about 100 000 million solar masses, in the space between the galaxies - more than all the gas inside the galaxies themselves.

Now, a team of scientists from four continents (RSAA/ANU, Caltech, USA, the Max Planck Institute für Kernphysik, Heidelberg, Germany, the University of Alabama, the University of Massachusetts (USA), and the Purple Mountain Observatory, China), have turned the Spitzer Space Telescope, equipped with a super-sensitive infrared spectrograph, towards the location of the group. They discovered that one of the galaxies, called NGC7318b, which is falling towards the others at nearly 1000 kilometres per second, is generating a shock wave bigger than the Milky Way as it falls into the cluster.

The shockwave is revealed by its X-rays, radio and optical emissions, and most remarkably, by the detection of strong radiation from molecular hydrogen. When hydrogen molecules are "excited" by the mechanical energy produced in the collision and transported by shock waves, they emit a distinctive type of radiation that can be detected in the infrared, and it was this radiation that was picked up by Spitzer. "The strength of the emission was a huge surprise to us." said team leader Dr. Phil Appleton. "We expected to see the spectral signature of dust grains - but instead we saw an almost pure laboratory-like spectrum of hydrogen molecules and almost nothing else. It was quite unlike anything we had seen before in a galaxy system."

Spectrometers have the ability to break light down into its component wavelengths, where the chemical signatures of the material that produced it can be seen as spectral lines. The width of these lines allows astronomers to determine the velocity of the gas, with wider lines indicating gas at a higher velocity. The hydrogen line seen by Spitzer in Stephan's Quintet is the widest ever observed for hot hydrogen molecules, corresponding to gas motions of 870 kilometres per second, equivalent to a Mach number of 100 or more.

The Spitzer observations provide a new diagnostic for studying conditions in merging and colliding galaxies, which were much more prevalent in the early universe. This group gives us a local view of the type of physics that must have occurred at the Epoch of the Formation of Galaxies about 10 billion years ago. The new results may indicate that some of the emission from the most luminous infrared galaxies seen in the very distant Universe may actually be created not by stars, but by vast shocks in the gas between the colliding galaxies.



Left: The central region of Stephan's Quintet, showing the complex web of galaxy-galaxy and galaxy-intergalactic medium interactions. The intergalactic shock wave, triggered by the 1000 km/s infall velocity of the intruder galaxy NGC7319b, is delineated by the ridge of Hydrogen emission (shown in green) which runs vertically through this image. NGC7319b is the compact blob, seen both in optical light (coded blue) and in infrared light (coded red) immediately to the right of this ridge.

Though still far in the future, it is likely that in about two billion years from now, our own Galaxy will collide with the slightly larger neighbouring Andromeda Galaxy, creating galactic-scale shocks of our own.

The observing team consisted of

Philip N. Appleton, Kevin C. Xu, William Reach & N. Lu

California Institute of Technology, Pasadena, USA:

Michael Dopita, The Australian National University:

Richard J. Tuffs and Cristina C. Popescu ,

Max Planck Institut fuer Kernphysik,

Astrophysics Department, Heidelberg, Germany:

J.W. Sulentic, University of Alabama, USA:

M.S. Yun , University of Massachusetts, USA:

Y. Gao, Purple Mountain Observatory, China:

The Astronomer Statue

The National Institute of Physical Sciences, ANU, commissioned artist Tim Wetherell to construct an outdoor sculpture from the remains of the Yale Columbia telescope, as part of the Stromlo Orrery Project.

It was envisaged that the sculpture would be located near Questacon in the

parliamentary triangle, and the 'Astronomer' was dedicated on the 13th of December 2005.

The Yale Columbia was a 26-inch refractor built by Mason lab at Yale University in 1924. It spent time in Johannesburg before being relocated to Canberra in 1952. Until its destruction, it was the fifteenth largest refractor ever built. As recently as 1998, the Yale Columbia was used in a long term project measuring stellar parallaxes to calculate distances and proper motions of nearby stars. Over its lifetime, it provided much valuable information about the structure of the southern skies.

One of the great setting circles from the Yale Columbia Telescope was used to create a large outdoor sculpture that encapsulates something of the feel of the old telescope and also preserves part of the instrument that remained essentially intact.

From an artistic standpoint, the iron man on a tall pole has overtones of the famous English contemporary sculptor Antony Gormley's work. In this way, the piece aims to find a balance between a historical monument and an artwork that sits comfortably within the broader framework of contemporary sculpture. The rusted, riveted construction also enables a seamless blend of historic and new components.

For more information about the artwork project, the National Institute of Physical Sciences and the RSPhysSE, which comissioned and oversaw this work, see **www.rsphysse.anu.edu.au/orrery/**

Artist's Background

Tim Wetherell is a Canberra based sculptor whose work has been featured in the National Gallery of Australia (2003 sculpture prize) Sculpture by the Sea (2004 show), the National Science Festival (2004) and many other venues. Tim's original background was in physics and as well as being a practicing artist, he currently works in science communication.

The Astronomer Statue

The pose and gesture of the iron figure speaks of astronomy and examining the heavens, whilst the riveted plates give strong ties to the appearance and "flavour" of the original 1920's telescope. The figure is holding part of the telescope skyward as though examining the heavens. He stands on the declination wheel which is marked in 360° divisions. The concept ties in with the primary use of the Yale Columbia which was renowned for making stellar position measurements in parallax studies.

IAU Colloquium 198

IAU Colloquium 198

RSAA's Dr Helmut Jerjen chaired the scientific organising committee for an important international conference on "Near–Field Cosmology with Dwarf Elliptical Galaxies", giving recognition of his leadership in the field around the world.

Following endorsements by IAU Commissions 28 (Galaxies) and 47 (Cosmology) as well as IAU Division VII (Galaxies and the Universe), the proposal for an IAU Colloquium entitled *Near-Field Cosmology with Dwarf Elliptical Galaxies* was approved and sponsored by the IAU Executive Committee. The overwhelming, positive response materialised in 92 astronomers from 23 countries who participated at the conference that took place in Les Diablerets, Switzerland, from 14–18 March, 2005.

IAU Colloquium No. 198 provided a forum for the presentation and discussion of the most recent results on dwarf elliptical (dE) galaxies (including dwarf spheroidals) and to highlight the importance of this research field as a provider of local benchmarks for cosmological studies, in particular of theories of structure formation. Almost all research groups working on dwarf galaxies worldwide were represented at the meeting and were joined by various international cosmology groups. As a result there was a good balance between observers and theoreticians, giving this IAU Colloquium the right mixture and density of scientists to mark current, and initiate future, progress in the field.

Research topics covered at the conference included:

- Dwarf Galaxy Surveys and the Missing Satellites Problem
- Faint-End of the Galaxy Luminosity Function: Implications for Cosmological Models
- Distance and Velocity Measurements
- Physical Nature of Morphological Substructure in dEs
- Central Nuclei and Globular Cluster Systems
- Photometric Scaling Relations for High Redshift Cosmology
- From Gas to Stars: Content of Dwarf Ellipticals
- Transformation Processes: Outflows, Winds, and the Fate of Dwarfs
- Kinematics and Dynamics
- Dark Matter Halos
- Star-Formation Histories of dEs and their Possible Contribution to Faint Galaxy Counts
- The First Galaxies.

The Conference Proceedings were published by Cambridge University Press.

Research

Low Mass Extrasolar Planet

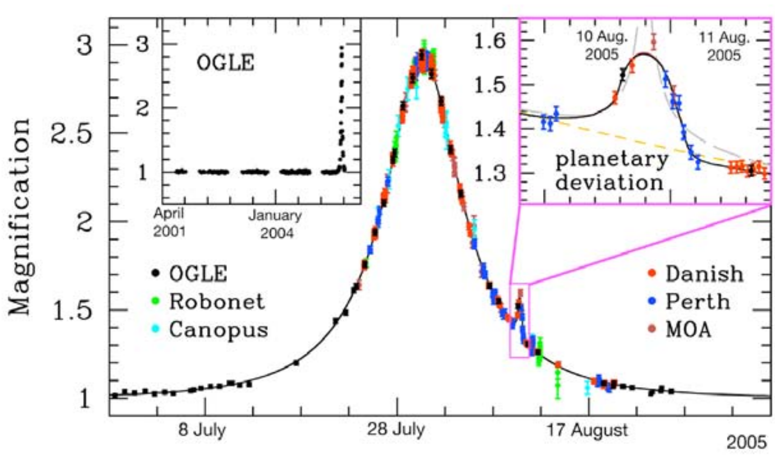
The 2005 discovery of the lowest-mass and coolest of "terrestrial" extrasolar planets known was the culmination of a decade of work undertaken by an international research team. The PLANET collaboration, co-founded by Sackett in 1995, monitors microlensing events looking for the telltale signatures of planets orbiting the microlens. PLANET began monitoring the microlensing event OGLE-2005-BLG-390 soon after it was announced by the OGLE science team, in 2005. A sharp anomaly in the light as a function of time traced by PLANET indicated that a smaller mass body was orbiting the unseen lens responsible for the microlensing brightening and dimming of the background star.

Analysis of the deviation revealed that the small perturber has about 5 times the mass of Earth, making this planet, OGLE-2005-BLG-390Lb, the least massive discovered so far. It orbits its M-dwarf parent star (the lens) at a distance 3 times the distance of Earth from the Sun (three AU), and takes 11 years for one orbit. The parent star is only 0.2 times as massive as the Sun, which means that it emits much less heat, and puts estimates of the surface temperature of the newly-discovered planet at minus 225 degrees Celsius.

The low mass and temperature of the new planet mean that it is likely made of rock and ice, quite unlike the "hot Jupiters" - large gaseous planets orbiting close to their parent star - that make up most of the extra-Solar planets discovered so far.

Current core accretion theory predicts that planets forming around such stars should be Earth-size to Neptune-size and in orbits less than 10 AU from the star. OGLE-2005-BLG-390Lb was one of the first planets detected by microlensing, despite its low mass, suggesting that low mass planets around M dwarfs may be common, consistent with core accretion models. Further, since M dwarfs are common in the Milky Way, so may be Earth-sized planets.

Right: The discovery data, showing the changing brightness of the background star as the foreground star and then the smaller planet distorted and amplified the brightness of the background star.



Light Curve of OGLE-2005-BLG-390

The colour of the atmosphere of a star changes as one scans from its edge (or limb), over its centre, and out to the limb again, due to an effect known as differential limb darkening. (This occurs because the regions emitting most of the light reaching the observer from the limb have different temperature compared with the regions nearer the centre of the stellar disk.) If astronomers understand stellar atmospheres well, these colour changes should be predictable. A planet transiting across the face of a Sun-like star, as it does in the HD 209458 system, provides a perfect probe of stellar colours as a function of position, as it blocks light first from the limb, then from the centre of the disk, and then from the limb again as it egresses.

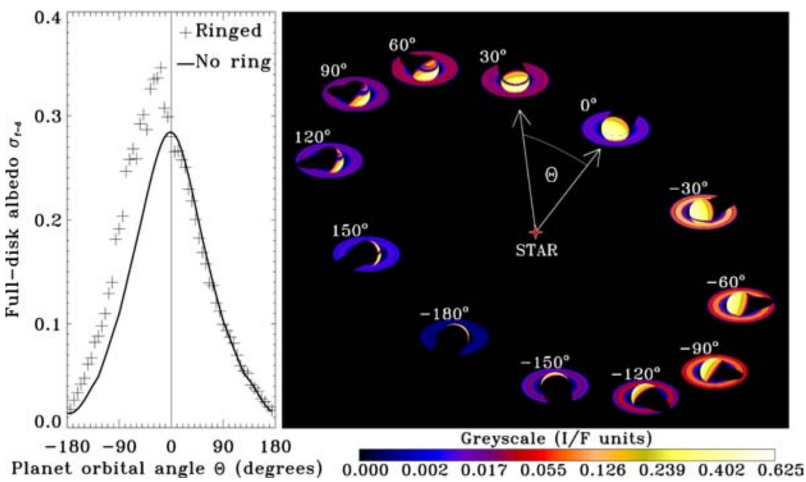
Changes in colour across the face of a Sun-like star

By analysing published data in several photometric bands for HD 209458 as its primary planet executes partial eclipses, graduate students Tingley and Thurl, working with Sackett, showed that this star's atmosphere may be more complicated than would normally be assumed. Although the colour signature displayed the correct shape at the predicted times, the size of the colour changes is larger than would be expected on the basis of stellar atmosphere models. Whether this is due to a missing element in the models, or some other complexity of HD 209458, is under investigation.

Could we observe the "phases" of Jupiters and Saturns around nearby stars?

Sackett, Dyudina (now at Caltech) and summer research scholar Bayliss, working with colleagues, showed that Extremely Large Telescopes now on the drawing board may be able to detect the change of phase (from waxing crescent to full to waning crescent) of large planets orbiting nearby stars. Starting with the actual optical scattering properties of our own Jupiter and Saturn measured by spacecraft, they used computer models to predict the change in optical brightness of similar, large, gaseous planets as they reflect the light from their own parent stars.

They found that the differences were small, especially compared to the glare of the parent star itself, but that telescopes with diameters 20-30m should be able to detect the changes, which are 1 to 100 parts per billion smaller than the light from the host star for a planet like Jupiter. Planets in tighter orbits around their host stars would be easier to detect. Monitoring how the reflected light varies with the planet's path along its orbit could reveal information about the



Left: Depending on the orientation of the observer, the light collected from the planet (left) will vary differently as a function of the planet's position along its orbit (right). Ringed planets can generate asymmetric light curves.

gas giant and its orbit, including whether the planet has rings such as those of Saturn. Such rings can be brighter in optical light than the planet itself, and their illumination changes in a characteristic manner throughout the orbit.

The Siding Spring Survey (SSS) for Near Earth Objects

The Near Earth Object (NEO) search program is operated as a collaboration between ANU and the University of Arizona and funded by a NASA grant to the latter. It utilises the ANU 0.5-m Uppsala Schmidt at Siding Spring. Hardware and software upgrades during 2005 improved the overall efficiency and sensitivity in detecting moving objects. In particular, the 4x4K CCD was removed and thinned during January.

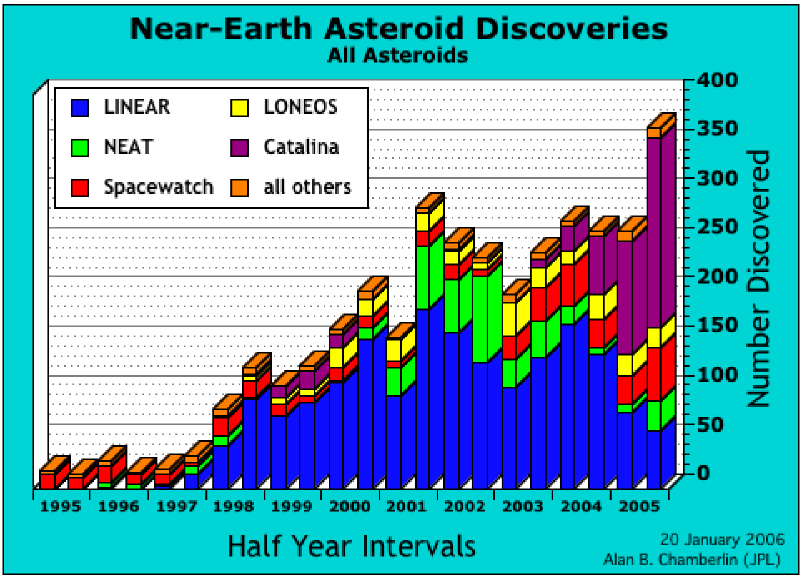
NEO Discoveries in 2005

Total Near Earth Asteroids (NEAs)	54
NEAs > 1km	4
Potentially Hazardous Asteroids (PHA)	13
Comets	9
Damocloids	3

In comparison with our first year of operation, the Siding Spring Survey (SSS) was down on the number of >1km diameter NEAs from 10 in 2004 (9 NEAs and 1 NEC, Near Earth Comet) to only 4 in 2005, but up in total numbers (54 as opposed to 35 in 2004). PHAs are potentially hazardous asteroids that can have close approaches to the Earth (within 0.05AU) and are larger than ~100m diameter; with four more discovered in 2005 than in the previous year.

The three Damocloids discoveries were a significant addition to the known population of only ~30 such objects as of the end of 2005. These are objects in comet-like orbits but not displaying any cometary activity and assumed to be inactive comet nuclei. The category is named after asteroid (5335) Damocles,

Right: In terms of the worldwide effort, the three-telescope operation of the University of Arizona group led by Steve Larson (Mt Lemmon and Catalina Sky Surveys in Arizona and Siding Spring in Australia) has been a clear leader in NEO discovery during 2005 with 49 per cent of the worldwide NEA discoveries, 37 per cent of NEAs larger than 1km and 48 per cent of PHAs.



the first such object discovered, in 1990, at the U. K. Schmidt during the AANEAS program. Two of the above Damocloids have retrograde orbits.

One of the comet discoveries, C/2005 E1, became a prominent telescopic object towards the end of the year and was widely observed by amateur astronomers

How many comets are there in our solar system?

Despite being studied for millennia, the answer to this question is still highly uncertain. Until recently, most comets were discovered in eyeball searches with hard to quantify selection biases. The number of bright comets that pass close to the Earth is not in doubt, but the number of small comets, and of comets with perihelia further from the Sun, is highly uncertain.

Francis addressed this issue, combining a Monte-Carlo simulation of the long-period comet population with published data from an automated near-Earth asteroid program. This was the first attempt to determine the demographics of long-period comets from an automated CCD survey, rather than from historical eyeball searches.

The results were unexpected: the number of faint comets was a factor of more than 100 below previous best estimates, which is hard to explain given conventional comet formation models. The number of comets per unit perihelion also does not seem to increase as one moves away from the Sun, disagreeing with theoretical expectations.

This work shows that the risk of the Earth being hit by a long-period comet (the scenario used in the movie Armageddon) is considerably less than previously estimated.

The Search for Extra-terrestrial Life

In theoretical work in collaboration with Paul Davies (Macquarie), Lineweaver showed that if life emerges readily under Earth-like conditions, the possibility arises of multiple terrestrial genesis events. They quantified the probability of this scenario using estimates of the Archean bombardment rate and the fact that life established itself fairly rapidly on Earth. They found a significant likelihood that at least one more sample of life may have emerged on Earth, and could have coexisted with known life. It is thus difficult to rule out the possibility of extant alien life.

Lineweaver challenged the assumption that we have not yet found extraterrestrial life. He argued that by redefining life in a more general way, we can legitimately conclude that we have already detected extraterrestrial life. Thermodynamic justifications for a broader definition of life are compelling and more universal than the traditional definitions of life based on DNA, "self-reproduction" and the chemical complexity of the terrestrial life most familiar to us. He also reinterpreted biogeographical and plate tectonic observations as the best evidence we currently have to evaluate the question: Is human-like intelligence a convergent feature of evolution? He found that this evidence indicates that human-like intelligence is not a convergent feature of evolution.

Brown Dwarfs around Sun-like Stars

Sun-like stars have stellar, brown dwarf and planetary companions. Relatively few brown dwarfs (compared to the number of planets and stellar companions) have been found in close orbits around Sun-like stars. Why this should be so is unknown. With graduate student Grether (UNSW), Lineweaver compiled, analysed and interpreted the world's data on exoplanet, brown dwarf and stellar companions. Their analysis confirmed that the brown dwarf desert is not a selection effect, and located the position of the driest part of the brown dwarf desert (the mass at which the fewest number of companions exist) in a mass range of M = 31 +25/-18 MJupiter. They found that approximately 16 per cent of Sun-like stars have close companions more massive than Jupiter: 11 per cent ± 3 per cent of these are stellar, <1 per cent are brown dwarf, and 5 per cent ± 2 per cent are giant planets.

Nearby Young Low Mass Stars

Bessell, Zuckerman (UCLA) and Song (Gemini) continued a program of 2.3m echelle and DBS spectroscopy of candidate members of young, nearby moving groups through measurement of their Li line strength and radial velocity. Their program has identified moving groups of nearby low-mass stars with ages ranging from 8 to 200 million years, an excellent source of stars with which to investigate the statistics and evolution of protoplanetary disks. Several of the nearby group members that were found in previous years were observed using IR imaging with Keck and VLT in 2005 searching for brown dwarf or massive planetary companions. At least two such objects were found, one with a likely mass of five Jupiter masses.

Bessell and Ngoc (IAA, Academia Sinica) have also been using the 2.3m DBS to observe very red sources from the DENIS survey. They have identified several new late-M dwarfs and L dwarfs that are helping to complete the stellar census of low-mass stars within 25 pc.

Time-dependent 3D Hydrodynamic Model Stellar Atmospheres

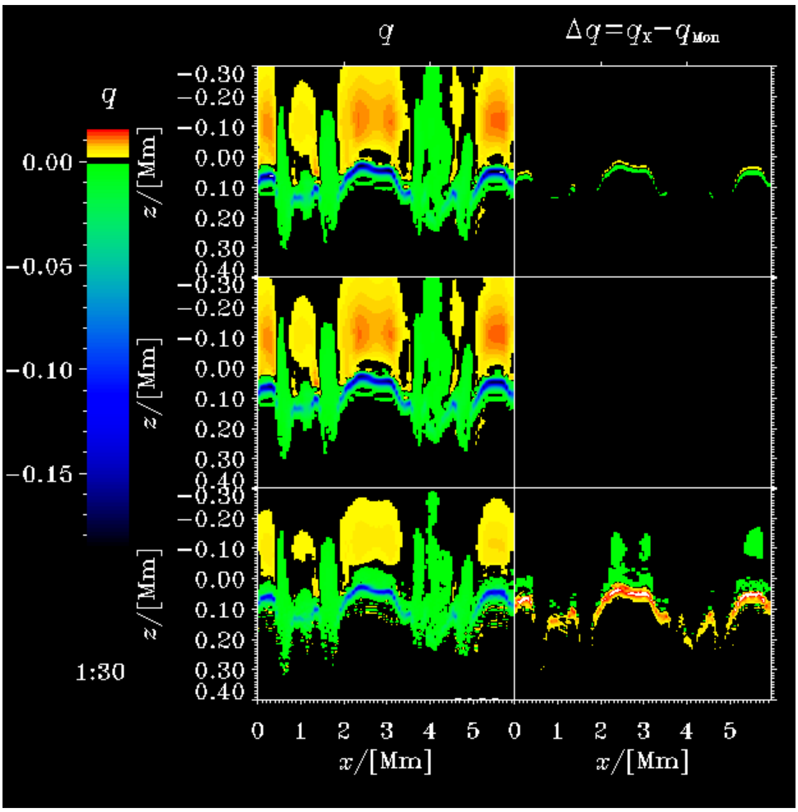
The light we see from stars escape from their surface regions - the atmosphere of the star. To correctly interpret stellar observations one therefore needs a good understanding of their atmospheres. Until now, the standard has been one dimensional (1D) models, which are homogeneous in the horizontal directions and where changes only occur with height. One knows from observations, however, that many stellar atmospheres, including the Sun, are convective. (Convection is the transport of energy by hot gas moving outwards and cool gas moving inwards, resulting in a net-transport of energy.) This is a dynamic and three-dimensional (3D) process, that increases the computational complexity of atmospheric models enormously.

Asplund and Trampedach have continued their pioneering work to produce realistic 3D models, urgently needed to provide a more complete understanding of the outer layers of the stars. In order to make the time-dependent 3D hydrodynamic atmosphere modelling tractable, they have made approximations in the treatment of the transfer of radiation in the atmosphere, a process that in fact drives the whole convection. Since the opaqueness (opacity) of the gas depends in a complicated way on the wavelength of the light, one must in principle consider hundreds of thousands of wavelength points.

Their 3D atmosphere modelling to date had made a rather drastic assumption in the way the different wavelengths are grouped together, which may lead to systematic effects on the temperature structure of the atmosphere. They have therefore devised an alternative, which they call Selective Opacity Sampling (SOS): a small number (~50) of wavelengths are carefully selected to reproduce the solution of the full calculation. The SOS method has been implemented and is now being tested using a 3D simulation of the solar atmosphere. This new 3D model atmosphere will be compared against various observational constraints to verify that the new method is indeed more realistic, and then applied to the problem of spectral line formation and elemental abundance determinations.

The First Three-Dimensional Red Giant Model Stellar Atmospheres

Asplund and Trampedach have also constructed 3D hydrodynamical model atmospheres for stellar parameters previously not investigated. In particular, they have successfully produced the first 3D models of red giant stars, which show significantly more vigorous convection than do solar-type dwarfs. A number of giant simulations of varying chemical composition has been generated. Elemental abundances deduced from comparison between observed stellar spectra and those computed for the 3D models differ significantly from those obtained when 1D models are used.



Left: 3D Radiative Transfer Modelling Tests.
Top-row: radiative heating for the new SOS method.
Middle row: full solution
Bottom: old method
Left side is for the actual heating and the right side is the difference with the full solution - hence the blank panel middle right. These diagnostic plots represent one vertical slice of one snapshot of a Solar simulation.

Nucleosynthesis in Asymptotic Giant Branch Stars

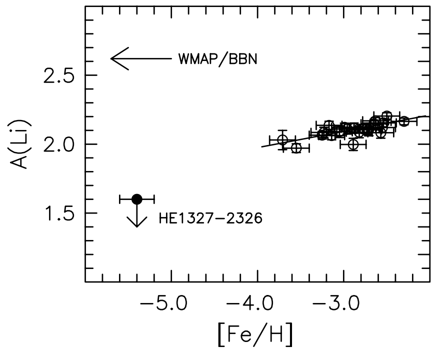
The production of the elements in stars is usually a well-hidden process, the products of which do not show at the surface studied. Dredge up events in Asymptotic Giant Branch (AGB) stars give a window into these processes, making their abundances of particular interest. These cool large stars are, however,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

HE 1327-2326 - the Most Metal-Poor Star

Graduate student Frebel, working with Asplund and Norris, has continued her investigations of the dwarf/subgiant HE 1327-2326, the star with the lowest iron abundance ([Fe/H] = -5.40) currently known. A detailed abundance analysis, made in conjunction with Aoki (Tokyo), Beers (Michigan State), Christlieb (Hamburg) and others, was completed in 2005, and confirmed large overabundances of C, N, Na, Mg, Al and Sr relative to iron, together with an enigmatic underabundance of lithium (see previous Annual Report).

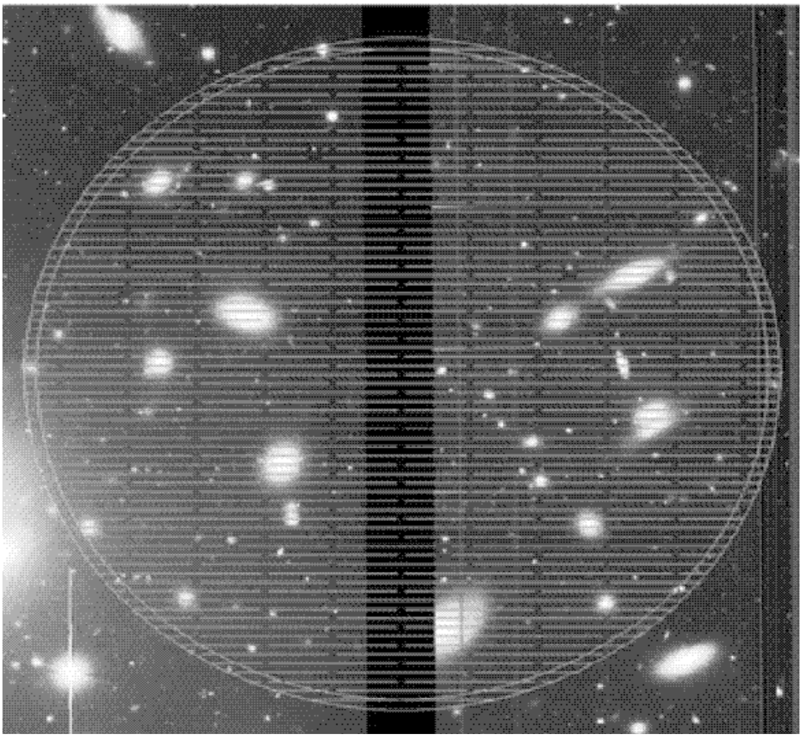
The underabundance of Li in HE 1327-2326 is shown in the attached figure, where A(Li) = log(N(Li)/N(H)) + 12.00 is plotted as a function of [Fe/H] for metal-poor dwarfs. The lithium abundance in HE 1327-2326 is lower by 0.4 dex than found in the other most metal-poor dwarfs, and ten times smaller than reported from the Wilkinson Microwave Anisotropy Probe to have existed immediately following Big Bang Nucleosynthesis. The implication of this result is that we have an incomplete understanding of the formation and/or evolution of the abundance of Li at the earliest times.

From the discovery spectrum, Frebel and others reported an upper limit for



Right: The abundance of lithium: A(Li) = log(N(Li)/N(H)) + 12.00, as a function of [Fe/H] for metal-poor dwarf stars.

the abundance of oxygen. From new VLT/UVES data, obtained in 2005, she, Asplund and Norris, together with Aoki and Christlieb, were able to measure the oxygen abundance of HE 1327-2326 - which has the surprisingly high value [O/Fe] = 2.8 (subgiant case) or [O/Fe]=2.5 (dwarf case). Knowledge of the oxygen abundance of HE 1327-2326 has implications for the interpretation of its abundance pattern. The large value reported here is in accordance with HE 1327-2326 being an early Population II star that formed from material chemically enriched by a first-generation supernova. The totality of the derived abundances do not, however, definitively exclude other possibilities, including a Population–III scenario.



Left: The multislit mask used for the Subaru observations of planetary nebulae in the Coma cluster, superposed on an image of the Coma cluster field. The diameter of the circular field is about 6 arcmin. The 70 slits are the narrow bright horizontal lines. The mask is laser cut from a very thin metal sheet, and the short dark interruptions provide improved mechanical stability of the mask.

Planetary Nebulae in the Coma Cluster of Galaxies

Freeman, working with Gerhard (Basel), Arnaboldi (Turin), Kashikawa (NAOJ), and Okamura and Yasuda (Tokyo), made the first detection of individual planetary nebulae in the Coma cluster of galaxies, which lies at a distance of about 95 Mpc. This is a very difficult observation, because at this large distance the planetary nebulae are so faint (< 2x10-18 erg cm-2 s-1).

The detection was possible by using a novel technique with the Faint Object Camera and Spectrograph on the Japanese Subaru 8m telescope in Hawaii. A very large multislit was constructed, covering the whole field of the instrument (see the figure above). This multislit suppressed the light from the night sky and made it possible to detect the emission lines from the very faint planetary nebulae that shine through the slits.

Why is this discovery important? The Coma cluster is the nearest of the rich clusters of galaxies. In this rich system, about half of the starlight comes from the intracluster light, i.e. from stars that lie in the space between the galaxies. The origin of these intracluster stars is still a mystery. To solve the problem, one needs to know how the intracluster stars are moving, but this observation seemed totally out of reach at such a large distance. The planetary nebulae have made it possible. Planetary nebulae are normal stars in a late phase of their evolution. Because much of their light is emitted in a single green spectral line of oxygen, it possible to measure their velocities accurately using the Doppler shift. It now becomes possible to study the motions of starlight between the galaxies in the Coma cluster, and so determine whether this starlight has been tidally stripped from the galaxies, as we suspect.

The Distribution and Motions of Stars in Elliptical Galaxies

Elliptical galaxies are the most common type of galaxy in the nearby Universe. Given the growing use of Sersic's model for describing the stellar distributions in galaxies, and the lack of any single reference that contains the various associated mathematical expressions, Graham and Driver prepared a review article providing a compendium of equations, numbers, and figures for ease of reference. In addition to uncovering the original, and uncited, 1963 Spanish paper by Sersic, they also present new expressions pertaining to Petrosian and Kron magnitudes that will help astronomers quantify and accurately measure the brightness of galaxies.

One of the main difficulties in measuring the total flux from a galaxy stems from the lack of a well-defined edge: the deeper one looks, the more stars one sees at the outskirts of a galaxy. To account for this "missing flux" at large radii, Graham, with co-workers, provided a simple prescription to recover this excess light using measured properties from the central stellar distribution. This is expected to be particularly advantageous for studies of cosmologically-dimmed high-redshift galaxies, and for shallow, wide field-of-view survey programs

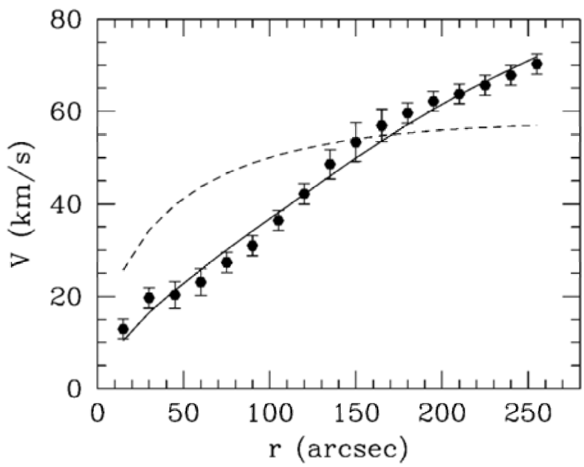
To understand the dynamics of elliptical galaxies, it is necessary to deproject the observed stellar distributions (seen on the plane of the sky) in order to reconstruct the actual 3D distribution. Graham and Terzić (Northern Illinois) developed an advanced model for describing the position and motion of stars in such galaxies. Moreover, their model is expected to help better understand the connection between supermassive black holes and their surrounding host galaxies.

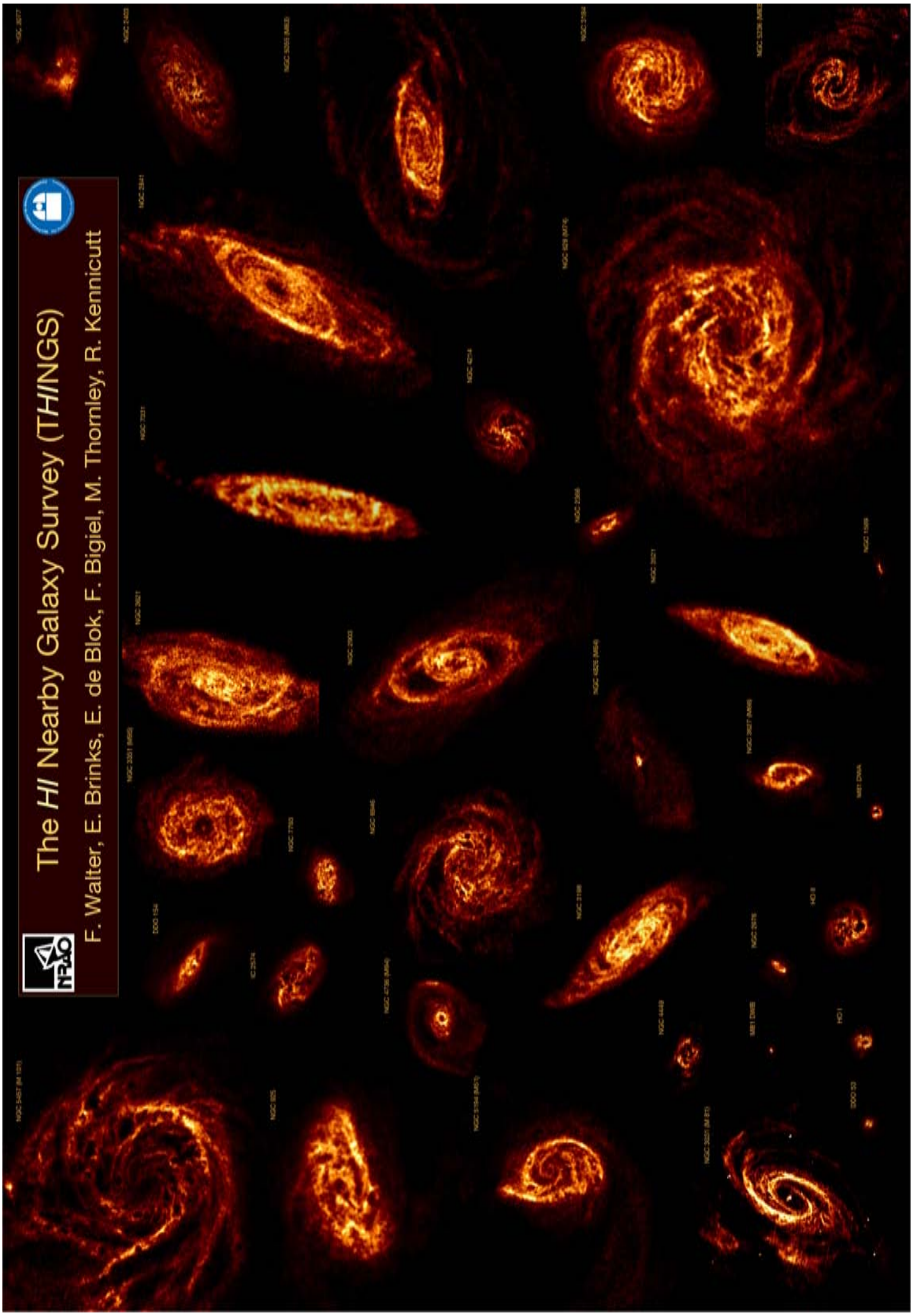
The Distribution of Dark Matter in Disk Galaxies

de Blok continued his research on dark matter. In an effort to understand the effects of star formation and random motions on the inferred dark matter mass distributions a large study was undertaken of the Local Group galaxy NGC 6822, where the dynamics can be studied at sub-kiloparsec scales.

de Blok's study of rotation curves of Low Surface Brightness galaxies was also continued. Results indicate that the conflict of these data with predictions of Cold Dark Matter simulations continue to be significant, posing interesting challenges to our understanding of cosmology and galaxy evolution.

Right: Mass models for DDO 47; the solid line is the best-fitting model with the Burkert halo, and the dashed line represents the (poor) best-fitting NFW model.





Graduate students Rich and Oh (working with de Blok) both started studies of the dynamics of disk galaxies using high-resolution neutral hydrogen observations from the THINGS survey – the largest survey of the neutral hydrogen distribution in nearby galaxies. These data will be compared with data from GALEX, Spitzer and the South African Large Telescope to improve current galaxy mass models.

Early-Type Dwarf Galaxies in Nearby Groups

Da Costa and Jerjen, together with Rejkuba (ESO), Binggeli (Basel) and other collaborators, have an on-going program to study the stellar populations of early-type dwarf galaxies in nearby groups, such as the relatively low density Sculptor Group and the more compact group centred on the unusual elliptical galaxy Cen A. The long term aim of the program is to endeavour to understand the role of environment, as measured, for example, by distance from the nearest large galaxy or local galaxy density, in determining the star formation histories of early-type dwarf galaxies. Within our Local Group there is a marked variety of star formation histories among the early-type dwarf galaxies, yet there is no clear indication of what drives that diversity.

During the report year, graduate student Bouchard, Jerjen, Da Costa and Ott (ATNF) presented the results of observations of the neutral hydrogen gas content of five early-type dwarfs in the Sculptor group obtained with the Parkes radio telescope. Generally, early-type dwarf galaxies are found to be virtually gas-free. However, four of the five Sculptor group systems were found to have measurable amounts of neutral hydrogen, with neutral gas mass to blue luminosity ratios in the range of 0.08 to 0.18 in solar units. This contrasts strongly with the early-type dwarfs in the Local Group, which have typical values of this ratio of 10-2 or less. It is likely that the low-density environment of the Sculptor group has enabled these galaxies to retain gas. The relation of gas content to star formation history in the dwarfs will be revealed via deep Hubble Space Telescope imaging observations scheduled for mid-2006.

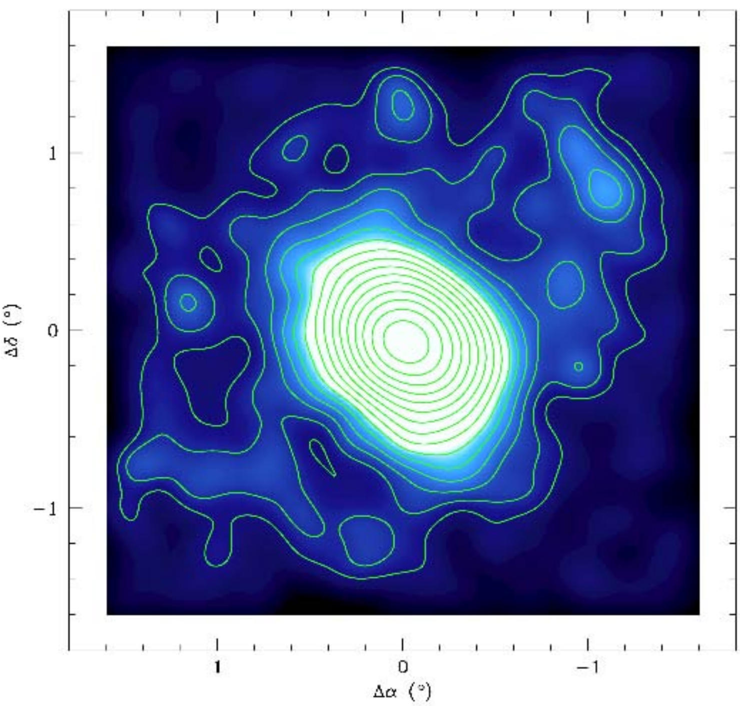
In the Cen A group, ESO VLT observations in the near-infra red have been combined with optical observations taken with the Hubble Space Telescope to study the red giant star populations of two early-type dwarfs. Both dwarfs are classified as outlying satellites of Cen A. In each galaxy, stars with luminosities above that of the red giant branch tip are clearly present. Given the metal-poor nature of the galaxies, these luminous stars are best interpreted as upper-asymptotic giant branch (AGB) stars of intermediate age (4 - 8 Gyr). The presence of such stars indicates an extended period of star formation, much like that seen in many early-type dwarfs in the Local Group. In the Cen A group dwarfs, however, the number of upper-AGB stars is considerably less than is the case for the outlying early-type dwarf satellites of the Milky Way. This result hints at stronger influence at early times on satellites for the giant elliptical Cen A compared to the Milky Way.

The Structure of the Milky Way Satellites Sculptor and Fornax

The Milky Way is surrounded by approximately a dozen low-luminosity early-type dwarf galaxies. These objects are generally thought to have very high masses compared to the number of stars in them. In other words, they are thought to contain large amounts of dark matter. This result, expressed as mass-to-light ratios exceeding 100 in solar units, is sometimes challenged by claims that the galaxies are not in dynamical equilibrium, but rather are in the process of being disrupted by the tidal field of the Milky Way. In such a situation the velocity dispersion, from which the mass is inferred under the assumption of dynamical equilibrium, would be large not because of unseen mass, but rather as a result of energy added to the galaxy in the disruption process. One way to investigate this question is to look at the structure in the outer parts of the galaxies: if they are interacting strongly with the Milky Way the stellar distribution in their outer parts should show substantial distortions. In particular, substantial numbers of stars should be present beyond the nominal outer boundary of the dwarf galaxies. This question has been investigated by graduate student Coleman, Da Costa, Bland-Hawthorn (AAO) and Freeman using data obtained with the Wide-Field Imager on the 40 inch telescope at Siding Spring Observatory.

Two systems were investigated - the Sculptor and the Fornax dwarf spheroidals. For Sculptor, the imaging observations and follow-up spectroscopy with the 2dF multi-fibre instrument at the AAT reveal that there is essentially no significant structure beyond the nominal outer radius. The results therefore support at most a mild level of interaction between this dwarf and the Galaxy. Consequently, the existing velocity dispersion measures are not strongly influenced by the tidal field of the Milky Way and the large mass estimates remain valid. For Fornax, however, the results were rather surprising.

The imaging observations showed the presence of a shell-like structure beyond the nominal outer boundary. Further analysis revealed that the stellar distribution beyond the nominal outer boundary has a double lobe structure aligned with the minor axis of the dwarf galaxy and containing the outer shell and the previously discovered inner shell. The best interpretation of these data is that they are not related to any interaction with the Milky Way, but rather reflect the disruption and merger of a smaller companion galaxy with Fornax approximately 2 Gyr ago. This would be the first known instance of a merger between two dwarf galaxies.



Left: The distribution of red giant branch stars in the Fornax dwarf spheroidal galaxy. Most of the stars are confined to the central regions (white area in the contour plot), which are aligned approximately NE-SW (upper left - lower right). There is, however, a large low-density region (shades of blue) beyond the nominal outer boundary that is aligned with the galaxy's minor axis, i.e. SE-NW. In the NW quadrant a shell-like feature aligned parallel to the Fornax major axis is also visible.

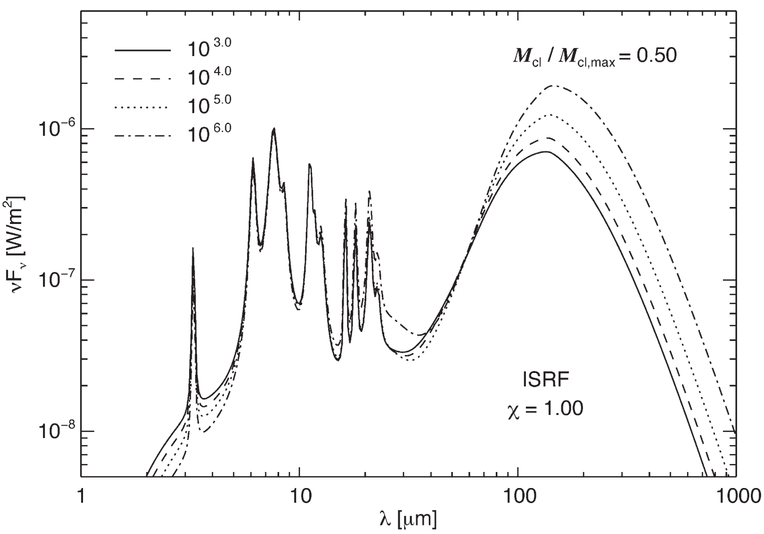
The First Pan-Spectral Galaxy Emsision Models

The problem of building a theoretical dust continuum spectrum of a starburst galaxy from the Lyman limit to radio wavelengths has now been solved in principle. This involved self-consistent radiative transfer for evolving H II regions driven from within as mass-loss blown bubbles of gas. The emission line spectrum is determined by two parameters: the chemical abundances in the ionised plasma, and the ionisation parameter. Dopita, and Sutherland discovered that the second factor is not a free variable, but is determined by the ratio of the ionising flux to the mechanical energy flux from the central star.

Models of both stellar mass and H II region diagnostics based on dusty, radiation-pressure dominated photoionisation models for compact and ultra-compact H II regions were developed and compared with observational constraints. These models, based upon the TLUSTY model stellar atmospheres, successfully reproduce the observed relationship between the density and the thickness of the ionised layer. The emission line spectrum of the ionised material is strongly dependent on chemical abundance.

The models provide a good fit to observed diagnostic plots involving ratios of infrared emission lines, all accessible with the IRS instrument of the Spitzer Space Telescope. These are excellent diagnostics for the effective temperature, or for the mass of the ionising star in the case of H II regions excited by a single star. Although somewhat sensitive to chemical abundances, they allow the effective temperature to be determined to an accuracy of about 2500K, and the stellar mass to a precision of about 30 per cent. The infra-red [S IV] line lies in the silicate absorption feature, making the [S IV]/[S III] ratio sensitive to foreground extinction as well as to stellar effective temperature or mass. From this ratio, Dopita determined that the mean extinction to observed compact H II regions is typically ~ 30 mag. Dopita used these models to re-derive the slope of the galactic abundance gradient, with the result that dlog(O/H)/dR= 0.06 dex/kpc. This brings the Galactic abundance gradient derived from compact HII regions into closer agreement with other techniques.

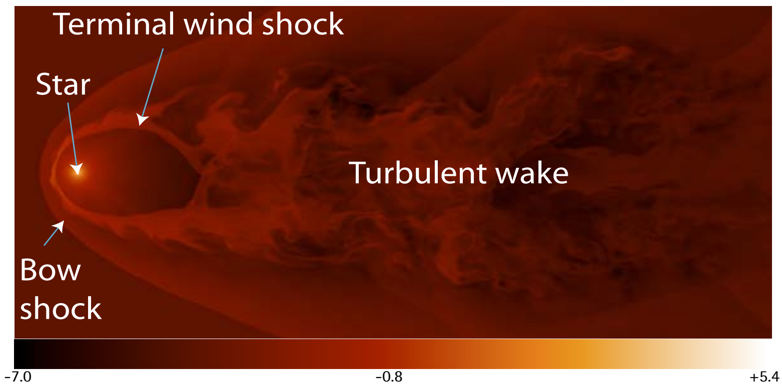
Right: IR Emission from a dusty molecular cloud model. In the cloud centre the emission from big molecules, the polycyclic aromatic hydrocarbons (PAH), and the emission from small grains is reduced as they are heated predominantly by ultraviolet and optical light which is strongly attenuated by dust.



Three-dimensional Simulations of Interacting Winds

Massive stars in the early stages of their life-cycles eject mass at a prodigious rate, losing over a solar mass of material to the ambient interstellar medium during their lifetimes. The ambient medium need not be static; energy input from supernovae and the combined effect of mass-loss from several hundred stars in a cluster can drive a galactic or cluster wind. The interaction between an individual stellar wind and an ambient wind can have interesting consequences, especially if the stellar wind is highly magnetised.

Graduate student Sims, in collaboration with Bicknell, has carried out an analytical and computational study of the interaction of a magnetised stellar wind with an ambient wind. The figure below represents the mid-plane of a three-dimensional simulation and shows the characteristics of such an interaction. The most notable feature is the turbulent wake, which is the result of the unstable interface between the ambient and stellar winds. The main motivation for this work is the curious filaments observed by radio astronomers in the centre of our own Galaxy. The interacting wind model for these filaments proposes that the filaments arise from turbulent wakes. In order to achieve the milli-Gauss magnetic fields observed in the Galactic Centre filaments, the magnetic field at the surface of the star has to be of the order of a thousand Gauss, values compatible with recent measurements..

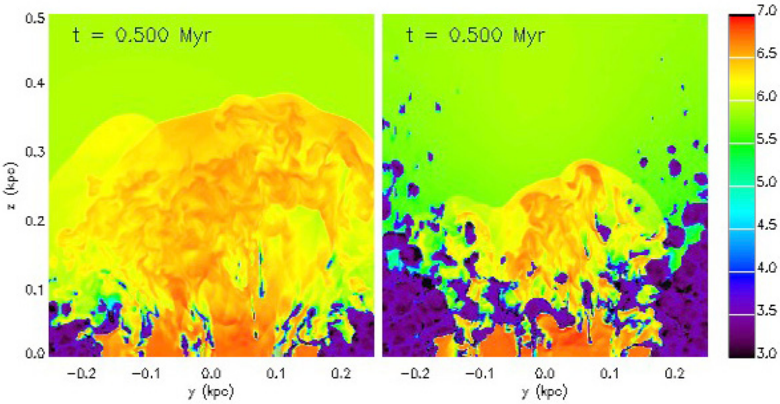


Left: Logarithmic density image of the mid-plane of a three-dimensional 1080 x 504 x 504 simulation of interacting stellar and ambient winds. The colour-bar represents the logarithm of the density.

Starburst-Driven Galactic Winds

Starburst galaxies have high star-formation rates in their central regions, resulting in the formation of massive OB stars. These stars have short lifetimes, ending in supernova explosions. The combined energy from these supernovae drives out a "bubble" of hot gas into the interstellar medium (ISM). This bubble is surrounded by a dense shell of gas, which, as the bubble expands, begins to fragment via Rayleigh-Taylor instabilities. The wind "blows-out" and expands freely into the surrounding ISM. These winds are seen in H-alpha emission as complex filamentary systems of dense gas propagating perpendicular to the galaxy disk, and exhibit other features, when observed in different wavelengths, such as X-rays. The best-studied galactic wind is the outflow in M82, which has a spectacular filamentary system that is both asymmetric and tilted.

Right: Log-temperature images of two 256 cubed simulations at 0.5 million years, demonstrating the effect of the interstellar medium on the morphology of a galactic wind. The wind mainly appears as red and yellow in these images, whereas the dense disk of the galaxy appears in blue.



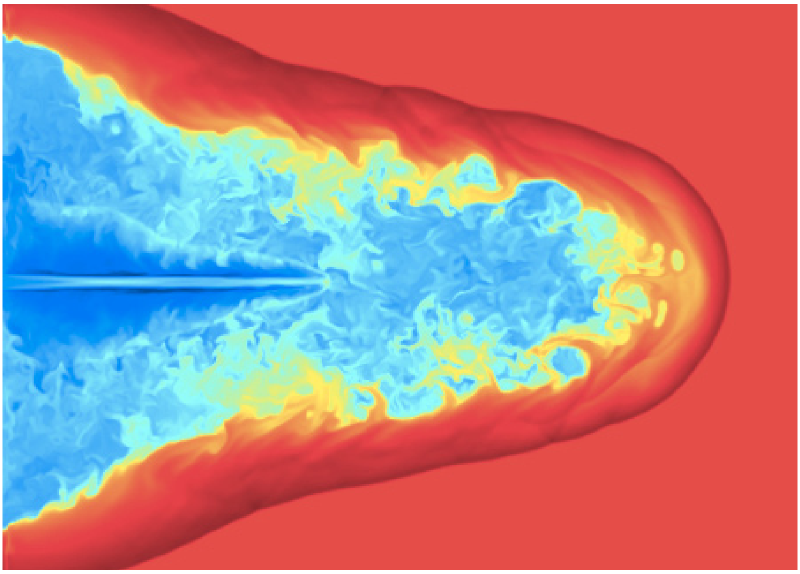
In order to better understand how these winds evolve and how the ISM in the host galaxy shapes the wind, graduate student Cooper, in collaboration with Bicknell and Sutherland, has been performing three-dimensional hydrodynamic simulations of a wind forming in a cloudy interstellar medium. The figure above represents the central plane of a three-dimensional simulation and demonstrates the effect of the interstellar medium on the wind. The wind on the right has evolved in a thicker disk than the wind on the left and as a consequence more gas covers the star-forming region, resulting in a more collimated outflow and also retarding the expansion of the wind.

Restarting Jets in Megaparsec Scale Radio Galaxies

Some giant (megaparsec scale) radio galaxies show evidence for restarting radio emitting jets. The phenomenon is not well understood. High-resolution radio imaging of these structures has revealed that the lobes and hotspots associated with the newly restarted jets are unlike those of typical jets. It appears that the evolution of restarted jets in pre-existing hot cocoons is unusual compared to the case of jets in the interstellar or intergalactic medium.

Graduate student Safouris, in collaboration with Bicknell, Sutherland and Subrahmanyan (ATNF) and Saripalli (ATNF), has carried out a series of simulations of restarting jets in radio galaxies in order to develop an understanding of how new jets evolve in the cocoons created by previous jets. The figure opposite top, shows a central density slice from a three-dimensional simulation of a Mach 23 restarting jet (equivalent to a jet with a relativistic Lorentz factor of 10). A broad cocoon is created by the passage of the initial jet through the dense external medium. The exhausted jet material, which fills the cocoon, is much hotter and lighter than the original background medium. Hence, the newly restarted jet in this image rapidly advances through the turbulent cocoon of the first jet. The supersonic advance of the near-ballistic jet excites a narrow bow-shock ahead of the new jet in the old cocoon, explaining the "bullet-like" inner structures that are observed in restarting radio galaxies.

Along with a team of American and British astronomers, graduate student

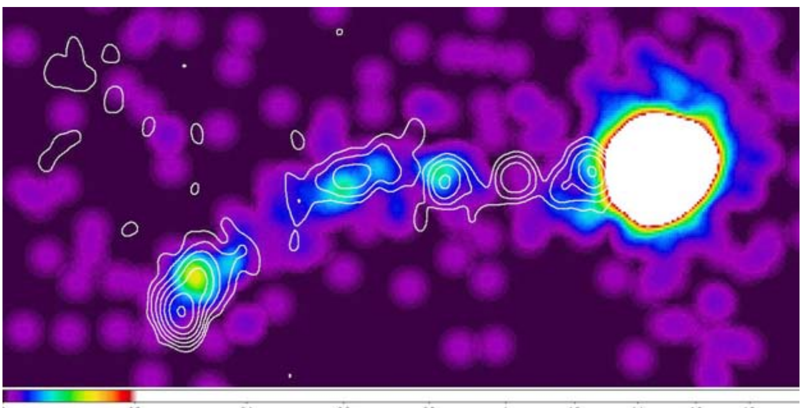


Left: Logarithmic density image of the central plane of a three dimensional simulation of a Mach 23 restarting jet. The image has been rendered with a rainbow palette with blue representing lower densities associated with the jet and cocoon and red representing higher densities associated with the ambient medium.

X-ray Studies of Relativistic Jets

Godfrey, in collaboration with Lovell (ATNF), Jauncey (ATNF) and Bicknell, is undertaking a study of some of the largest and most powerful jets, in order to better understand the properties of the plasma and the overall dynamics.

By imaging these sources at radio (Australia Telescope Compact Array), optical (Hubble Space Telescope) and X-ray (Chandra X-ray Observatory) wavelengths, they are able to determine the properties of the jet plasma and the underlying flow using analytical models. Some of their recent results, however, challenge conventional interpretations of the jet emission. The figure below shows a smoothed image of the X-ray emission (in colour) with a contour image of the radio emission overlaid. Clear offsets between the peaks in the two images can be seen, and these offsets suggest that the emission in the different bands is in fact associated with different parts of the jet, contrary to current understanding.



Left: PKS 2101-490 smoothed X-ray image (pixels), with 20GHz radio contours overlaid. The large white blob in the centre of the image is due to saturation of pixels from the bright quasar core.

Galactic Jet-Halo Interaction Models

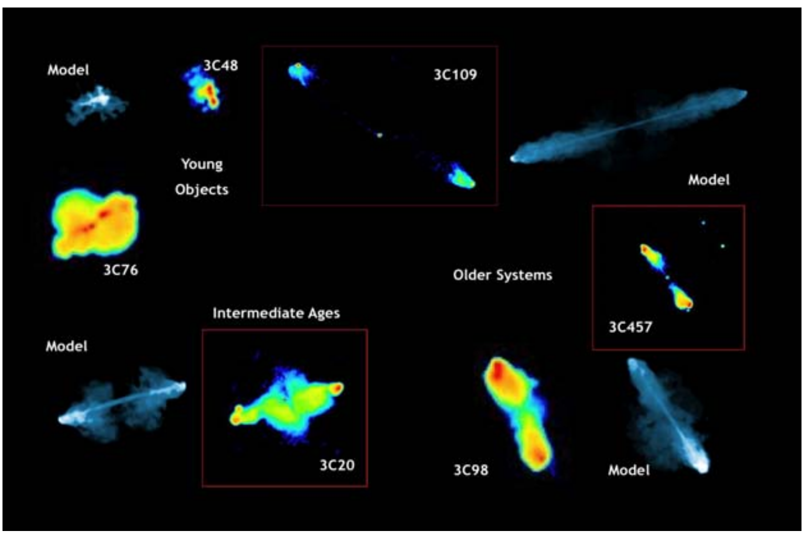
Sutherland and Bicknell, combining a luminous-dark matter isothermal potential model with an inhomogeneous gaseous disk and hot galactic atmosphere, used the ANUSF supercomputer and the radiative hydrodynamic code ppmlr (developed and enhanced at RSAA from the VH1 code of University of Virginia) to model the impact of the formation of a young radio galaxy on its host galaxy.

A massive central black hole is assumed to have developed a double-sided jet of plasma travelling outwards through the host galaxy at close to the speed of light. A fully 3D radiative model that includes the gravitational field of the host galaxy is used to define a characteristic sequence of evolution of the forming radio galaxy.

With new X-ray emission post-modelling methods, the new simulations show that the radio galaxy evolves through distinct stages. In the first, the radio jet is disrupted and deflected by the dense clouds in the galactic disk. This stage is characterised by the evolution of a nearly spherical bubble of very high pressure that heats the galaxy gas and crushes clouds, producing strong soft-X-ray emission. Eventually the jet clears a channel and is able to straighten, changing the evolution from a pressure bubble to a jet drilling through the tenuous outer galactic atmosphere.

An important outcome of this research is the development of a dynamical evolutionary sequence for radio galaxies, illustrated in the figure below, where a single simulation drawn at different times during the evolution of the model is compared to a range of powerful radio galaxies. If the sequence stands up to further analysis it may form the first link between the radio morphology and the underlying, often unseen, host structure.

Right: A single model is rendered from different points of view as it evolves, each stage compared to radio galaxies in the 3C radio catalog. The radio galaxies can be classified as dynamically young or more evolved.



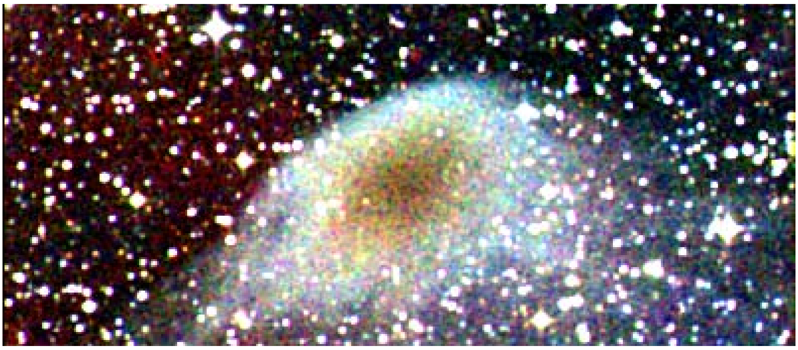
Theoretical Models of Self-Gravitating Isothermal Clouds

Self-gravitating clouds are essential for the evolution and chemistry in the interstellar medium. They are regions of ongoing or future star-formation, important for the formation of molecules, in particular molecular hydrogen, and play a vital role in the life cycle of interstellar dust grains as they grow to larger sizes in dense gas.

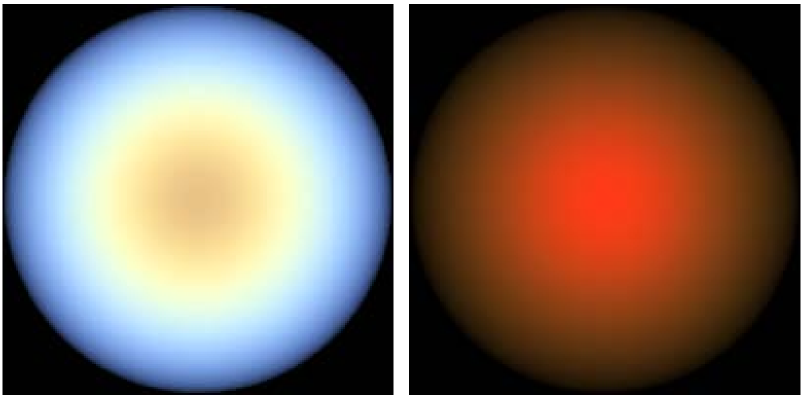
Jörg Fischera analysed radiative transfer through the clouds in terms of the pressure of the medium surrounding the cloud and the mass fraction of the cloud relative to the critical mass at which the clouds become unstable against gravitational collapse.

The radiative transfer is complicated by multiple scattering events and the fact that the light scattering, in particular in the ultraviolet and in the optical, is highly non-isotropic: as most of the light is scattered in the forward direction. To allow an interpretation of the scattered light both effects are taken accurately into account. To determine the dust re-emission Fischera used a realistic dust model where the grains have a certain composition and size distribution.

Dust extinction increases towards shorter wavelengths so that the scattered light in the optical arises predominantly from a region close to the rim of the cloud while the scattered light at longer wavelengths is more concentrated towards the cloud centre. This leads to a blue halo and a brown interior seen also in the case of the Thumbprint Nebula.



Left: Small self-gravitating clouds, such as the Thumbprint Nebula shown here, display simple, almost spherical shapes, which makes them ideal objects for studying the molecular dusty phase in greater detail. Fischera considered those isolated clouds that are stable against gravitational collapse and are illuminated solely by the interstellar radiation field.

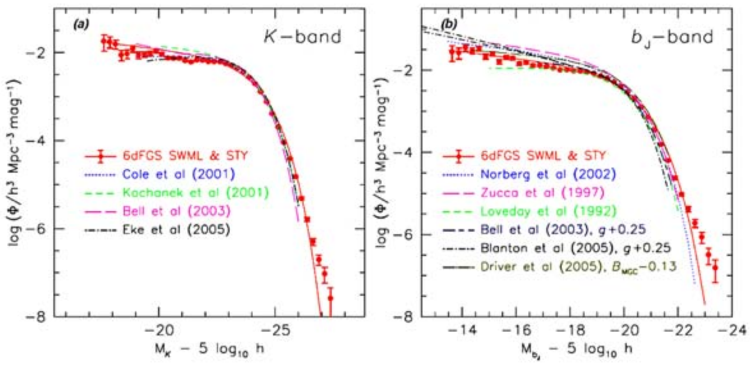


Left: An example of the modelled projection of the scattered and the emitted light of a cloud that is embedded in the interstellar medium of our galaxy.

The Luminosity Distribution of Galaxies

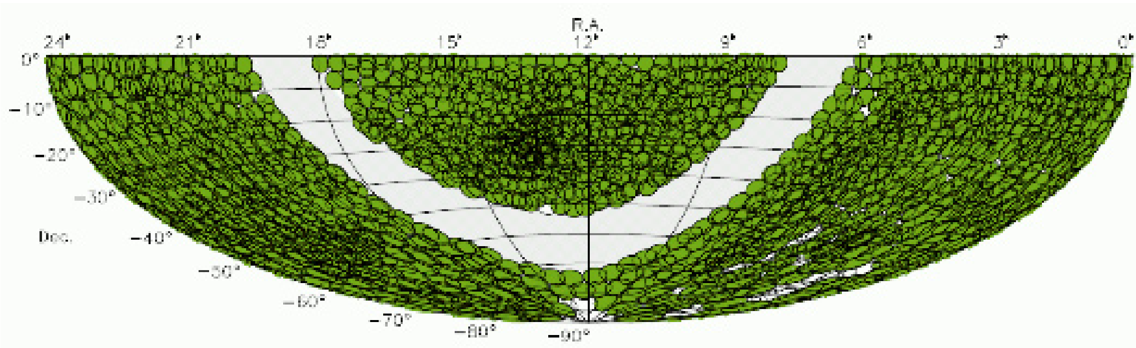
Jones (now at AAO), Peterson, Colless (AAO) and Saunders (AAO) have used the redshift measurements from the Six Degree Field Galaxy Survey (6dFGS) to determine the luminosity distribution of galaxies in a fiducial volume of space. The figure below shows the number of galaxies per cubic megaparsec per magnitude in near-infrared light (K-band at 2.2 microns) and in blue light (b_j-band at 0.45 microns). The excess of bright galaxies comes about from galaxy mergers in the centres of galaxy clusters. Integrating the luminosity distribution gives the luminosity density in terms of Solar luminosities per cubic megaparsec, ranging from 170 million in the b_j-band to 580 million in the K-band. As might be expected, this luminosity density distribution is similar to that calculated for a 12 billion year old stellar population, with perhaps a small excess of cooler stars.

Right: Luminosity functions in K(2.2 microns) and b_j(0.45 microns) bands from the Six Degree Field Galaxy Survey (6dFGS). Those from other surveys are also shown for comparison.



6dF Survey of 150,000 Galaxies

On behalf or the Six Degree Field Galaxy Survey (6dFGS) team* Jones and Peterson reported that the observations for the project have been completed. Spectra were obtained for some 150,000 galaxies in the 1539 fields shown as shaded in the figure below. The survey targets were chosen from the Two Micron All Sky Survey so that the luminosity of a target galaxy is closely linked to the stellar mass of the galaxy. The data is being analysed to measure the total mass in the local Universe, bulk flows, and the influence of local density on galaxy properties.



Above: Equal area Aitoff projection of the 6dFGS fields. The U shaped region is the area occupied by the plane of the Milky Way and is obscured by dust. The 6dFGS fields, shown as circles, overlap most where galaxies are most clustered.

* 6dF survey team Colless (AAO), Saunders (AAO), Huchra (Harvard), Lahav (Cambridge), Mamon (IAP), Wakamatsu (Gifu)

Gamma Ray Bursts and Supernovae

Exploding stars provide the homes to the most violent physical situations in the Universe. Supernovae occur in a galaxy like the Milky Way once per century. When they explode, they shine for weeks to months with a power often a billion times that of our Sun. Gamma Ray Bursts are 10000 times rarer, shining only for minutes to hours with a output of a million galaxies. These objects are the largest 'bangs' in the Universe since the big one.

Given their immense power, these objects serve as useful guides to help explore our Universe. Type Ia supernovae – a particular type of exploding star – are a highly uniform class of explosion, and by observing how bright they appear here on Earth, provide a measurement of their distances accurate to better than 10 per cent. Schmidt, and graduate students Salvo and Blackman, continue their study of these events to accurately measure distances from the nearby to the distant Universe. As part of the ESSENCE program, Schmidt and Blackman are measuring the expansion history of the Universe back from the present to 10 Billion years ago, with unprecedented accuracy. These observations are providing our best constraints on Dark Energy – discovered by Schmidt's High-Z Team in 1998. This energy, first described by Einstein as perfectly tied to the fabric of space – and known as the Cosmological Constant – remains completely consistent with current observations.

Gamma Ray Bursts, while not as uniform as their Type Ia supernova siblings, are so immensely powerful that they can be seen to the age where the first stars were born. They shine through the Universe illuminating everything over the 13 billion years in between. Schmidt and Peterson are leading an international consortium using the twin Gemini telescopes to understand these events, and to glimpse the Universe at the time of the first stars. On 4 September 2005, NASA's SWIFT satellite detected a burst of gamma rays (one of about 100 bursts that it sees in a year), which subsequent observations demonstrated was among the most distant objects ever seen by mankind. Theirs and others measurements show that it occurred in a small galaxy, having about 1/100 the mass of the Milky Way, which contained considerable amounts of iron, silicon, and carbon. These elements are formed in stars, not in the Big Bang, indicating that even at this extreme distance, many stars must have already come and gone. In 2006, Schmidt and Peterson hope to push their measurements even closer to the Big Bang.

Big Bang Misconceptions

Lineweaver and Davis identified the most common misconceptions about the Big Bang held by astronomers and the public. They analyzed and made these misconceptions explicit for a popular audience in a paper in Scientific American.

Technology

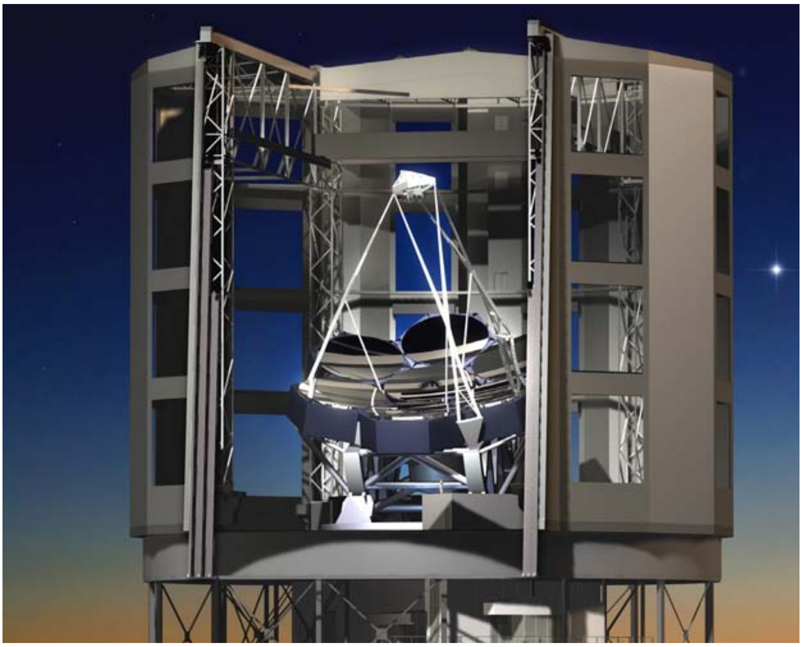
Engineering Research & Development

Extremely Large Telescopes

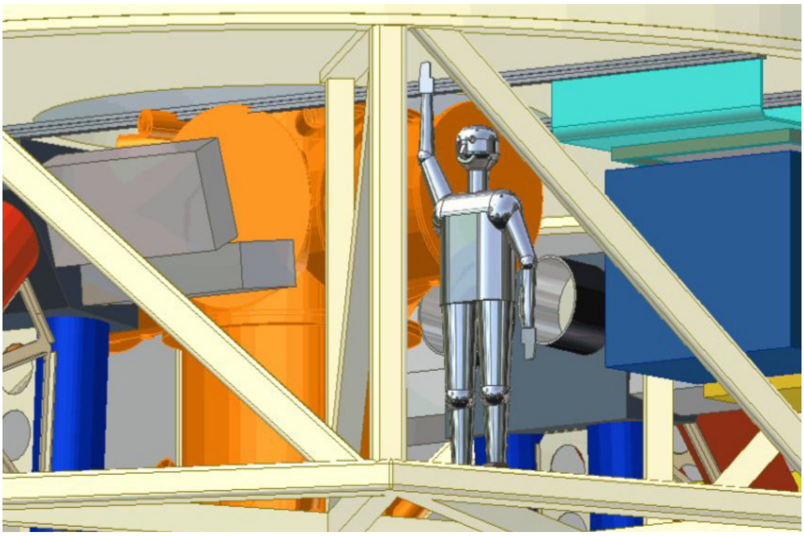
RSAA has continued to contribute towards the development of an Australian bid for membership of an ELT project, with Jenkins, McGregor and Sackett all serving on the Extremely Large Telescope Working Group (reporting to the National Committee for Astronomy). Closer links were made during the year with the Giant Magellan Telescope consortium, which had been identified by the ELTWG as the preferred international partner. Australian scientists were able to join in the project with "observer" status, with Sackett taking up this position on the GMT Board and Jenkins participating similarly in the Project Scientists' Working Group. The focus of the year for the project was the preparation of the design for a conceptual design review, scheduled for February 2006.

Closer links were also built with Australian industries with an interest in ELT technologies, with Jenkins convening an Industry Working Group of relevant companies. During the latter part of 2005 an industry capability survey was begun, as an initial phase of the preparation of an ELT business case. Sinclair Knight Merz, the international engineering consultancy, took the lead in this, with assistance from long-time RSAA partners Auspace and Electro-Optic Systems.

Engineering staff at RSAA (Conroy, Granlund and Zhelem) collaborated with the Carnegie Observatories in the development of the conceptual design of a large visible-light spectrometer for the GMT. This instrument poses many challenging problems in optics and mechanics and was a valuable first experience of ELT-scale engineering for the School.



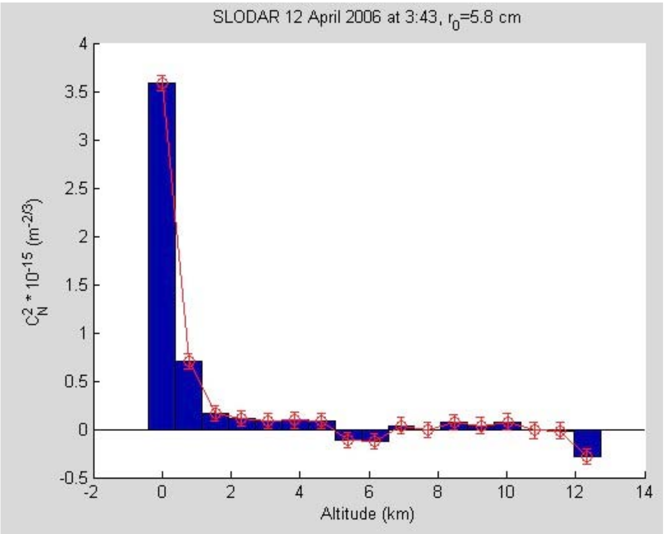
The Giant Magellan Telescope. Each of the seven mirrors will be 8.4m in diameter, comparable to the size of the current generation of the large telescopes around the world. Image courtesy of the GMT Consortium.



The focal plane area of the GMT, with a human figure drawn to scale and parts of the proposed infra-red and optics spectrographs visible. Image courtesy of the Carnegie Observatories and the GMT Consortium.

The Night-sky Turbulence Profile of Siding Spring Observatory

Conroy, Goodwin, Jenkins and Lambert (ADFA) used the Slope Detection and Ranging (SLODAR) technique, which uses the light from double stars to obtain realtime measurements of atmosphereic turbulence, to investigate the turbulence profile above Siding Spring Observatory. This is an essential first step in deciding if the seeing at SSO could be improved by adaptive optics. Results have now been collected for a year, and uniformly show the encouraging result that the bulk of the turbulence is low, around 1–2 km above the site. Low turbulence is much easier to correct and is probably associated with relatively low wind speeds. The focus of the work is now on obtaining wind speeds, as these are the other component needed to evaluate the potential of the site.



Left: A representative vertical profile of the turbulence strength C_n^2 as a function of height above the telescope. The vertical resolution and height reached is instrument- and star- dependent. Higher-resolution data are available in the boundary layer (height < 2 km).

Near-infrared Integral Field Spectrograph (NIFS)

A major achievement for 2005 has been the delivery and successful commissioning of the Near-infrared Integral Field Spectrograph (NIFS) to the Gemini North eight metre diameter telescope in Hawaii. NIFS is the first instrument built by Australia as part of our national participation in the international Gemini consortium. This achievement showcases RSAA's technical expertise and Australia's capabilities in the area of astronomical instrumentation. The NIFS commissioning set new records within the Gemini partnership with the instrument being offered to the community for Science Verification observations only two months after first light.

NIFS uses innovative optics in its integral field unit to spatially reformat light from the telescope. This allows NIFS to simultaneously record near-infrared spectra at each position in a two-dimensional field on the sky. This geometry is well-suited to extended astronomical objects such as galaxies, star clusters, and the regions around forming stars.

Equally important, NIFS is designed for use with the ALTAIR adaptive optics system on the Gemini North telescope. ALTAIR corrects the image blur produced by the Earth's atmosphere. This allows NIFS to record images at near-infrared wavelengths that are as sharp as the visible wavelength images obtained with the Hubble Space Telescope. This combination of exquisite spatial resolution and full spatial and spectral field coverage gives NIFS unprecedented abilities to study the detailed excitation and dynamics of astronomical objects.

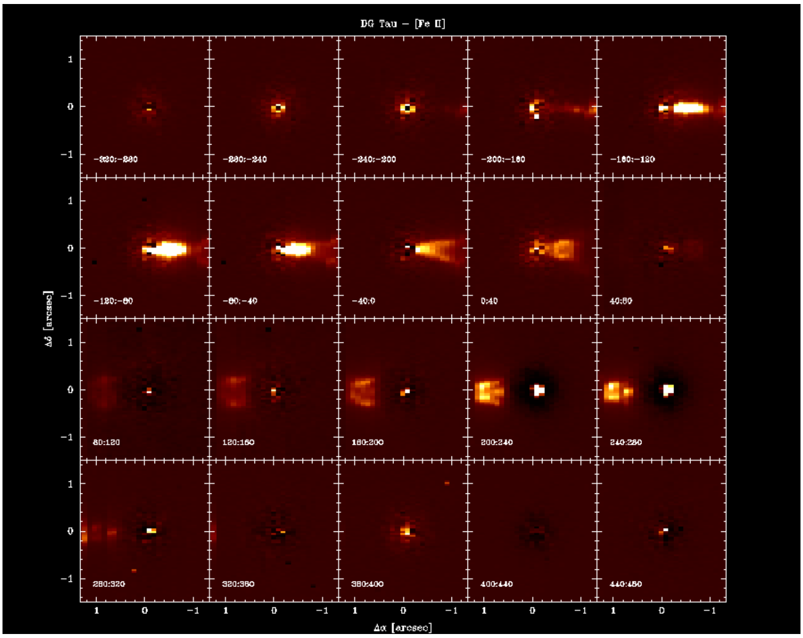
Gemini Contract

RSAA was contracted by the Gemini Observatory to build NIFS in 1999. The original instrument was destroyed in the January 2003 bushfires and was subsequently rebuilt in collaboration with Auspace Ltd, a Canberra-based aerospace company. The rebuilt NIFS was shipped to Hawaii in August 2005 and saw firstlight on the telescope on 18th October 2005.

Engineers from both RSAA and Auspace traveled to Mauna Kea Observatory in Hawaii to unpack, reassemble, and verify the operation of the instrument before it was mounted on the telescope. This was an intense time when astronomers and engineers from both Australia and the Gemini Observatory worked closely together to interface the instrument to the observatory systems and ensure that all systems were operational for the first night of observing. These preliminary tests were so successful that the first observations were obtained before astronomical twilight on the first observing night.

NIFS is a complex instrument that has extended the RSAA engineering staff in key technical areas of optics, cryogenics, detector systems, software control, and project management. Through its construction, young engineers and technicians have been trained in advanced skills, and strong links have been forged between RSAA and related areas of Australia's industrial sector.

NIFS is now in regular scientific use.



Left: NIFS images of the jet around the forming star, DG Tau. Each frame shows material at a different velocity emitting in a near-infrared transition of ionized iron. The star is located at the center of each frame. Material flowing towards Earth is seen in the top frames to the right of the star. Material moving away from the Earth is seen on the left of the star and behind an obscuring circumstellar disk.

The opportunity for the community to participate in Science Verification observations with NIFS was announced in December 2005, just two months after firstlight. This is the fastest commissioning period of any Gemini instrument. These Science Verification observations were performed in January 2006. The RSAA instrument team receives twelve nights of Guaranteed Time using NIFS on Gemini North for delivering the instrument. These observations will be made during 2006. The early observations with NIFS required bright natural guide stars for use with the ALTAIR adaptive optics system. The Gemini Observatory expects to have installed an artificial "laser guide star" system for ALTAIR by mid-2006. This will give NIFS access to many more astronomical targets in the future.

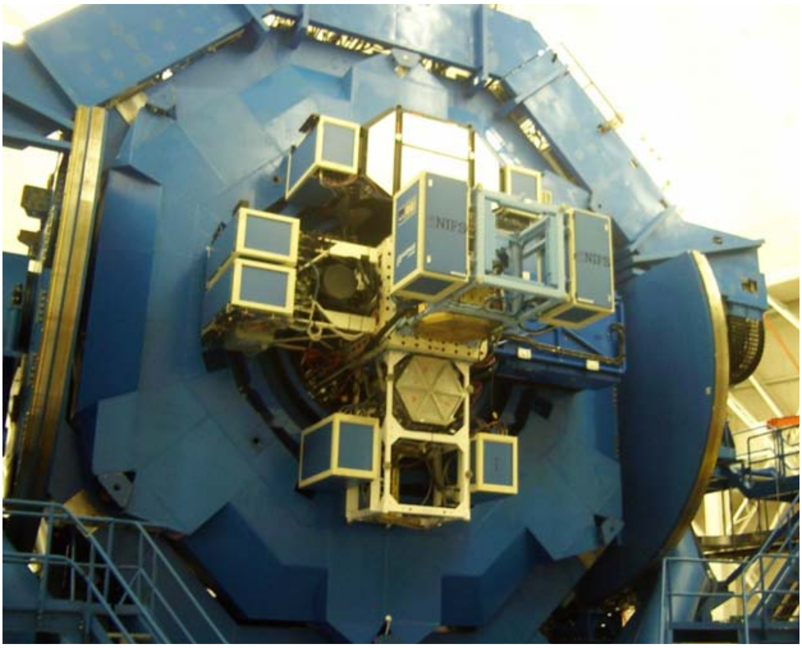
Scientific Results

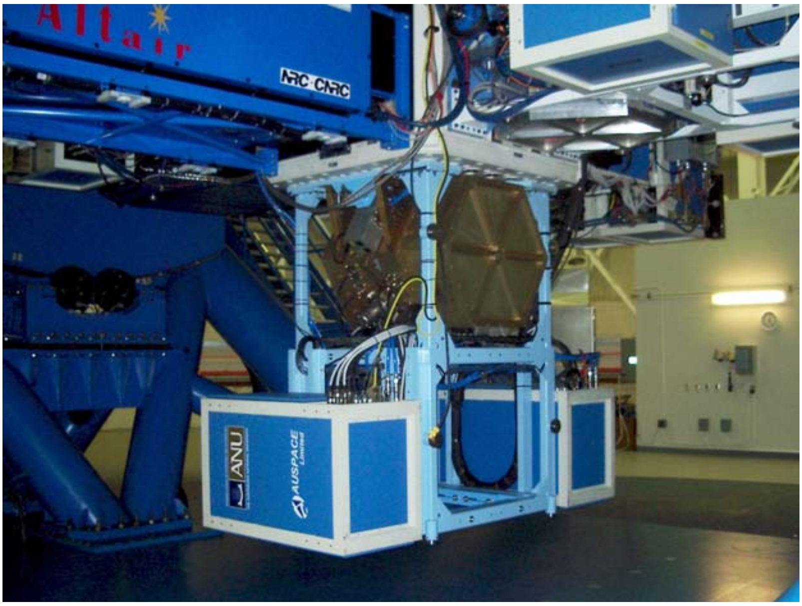
Significant scientific discoveries have already been made with NIFS. The young star, DG Tau, appears now very much as the Sun would have appeared when the Solar System was forming. It was know previously that DG Tau is accreting material and that in doing so it expels a jet of material that is responsible in some way for throttling the rate material can accrete onto the star. NIFS observations of DG Tau, obtained during the instrument commissioning, show this jet in unprecedented detail. The structures seen within the jet will allow the RSAA instrument team to study details of how this material is expelled and how stars build up their mass.

Other observations of the core of the nearby radio galaxy NGC 1275 show unprecedented detail of how material is drawn into the massive black hole at the center of this active galaxy, and how these accretion streams fuel a gaseous disk orbiting the black hole. From the dynamics of this disk, the mass of the central black hole has been measured to be nearly a billion times that of the Sun.

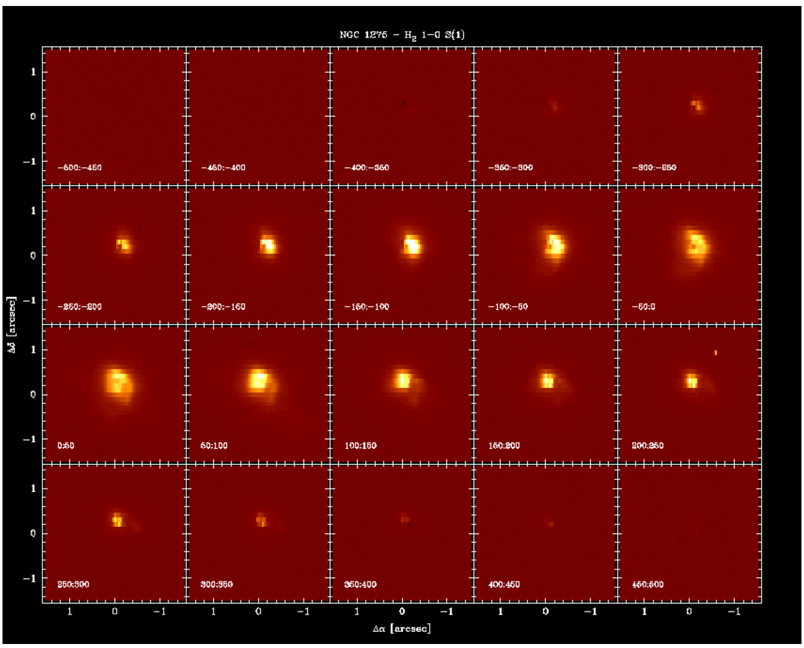
Right: Nick Porecki from Auspace Ltd assembling NIFS in the Instrument Laboratory at the Gemini North telescope.

Right: NIFS mounted at the central Cassegrain focus of the Gemini North telescope, along with other Gemini instruments around the perimiter.





Left: NIFS on the up-looking port of the Gemini North telescope.



Left: NIFS images of molecular hydrogen orbiting the massive black hole in the nucleus of the radio galaxy, NGC 1275. Each frame shows material at a different velocity. Material seen in the top frames is moving towards Earth, and material in the bottom frames is moving away from Earth. Detailed study of these data shows that the material close to the central black hole is in the form of a rotating disk.

GSAOI

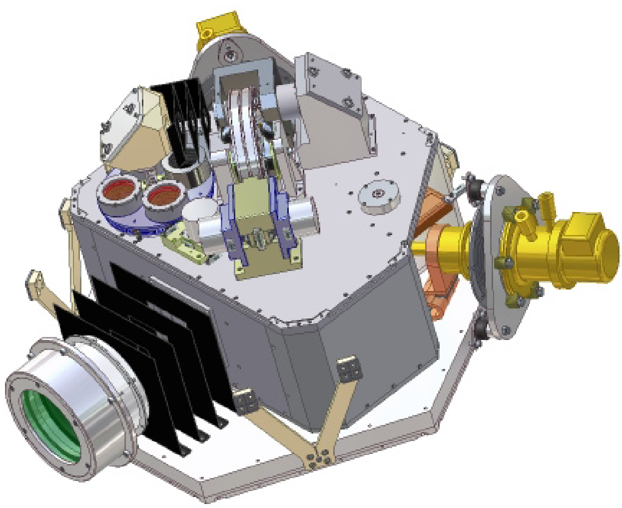
RSAA is building Australia's second instrument for the Gemini Observatory, the Gemini South Adaptive Optics Imager (GSAOI). GSAOI is a near-infrared camera that will be the workhorse instrument used with Gemini's flagship Multi-Conjugate Adaptive Optics (MCAO) system on the Gemini South eight metre diameter telescope in Chile. The MCAO system will correct the blur due to the Earth's atmosphere over a wider field than has previously been possible. GSAOI will then record diffraction-limited images of astronomical objects with 0.02 arcsecond sampling over its full 85×85 arcsecond field of view. To do this, GSAOI uses a 2×2 mosaic of four Rockwell HAWAII-2RG near-infrared detectors. GSAOI is among the first instruments world-wide to use these detectors.

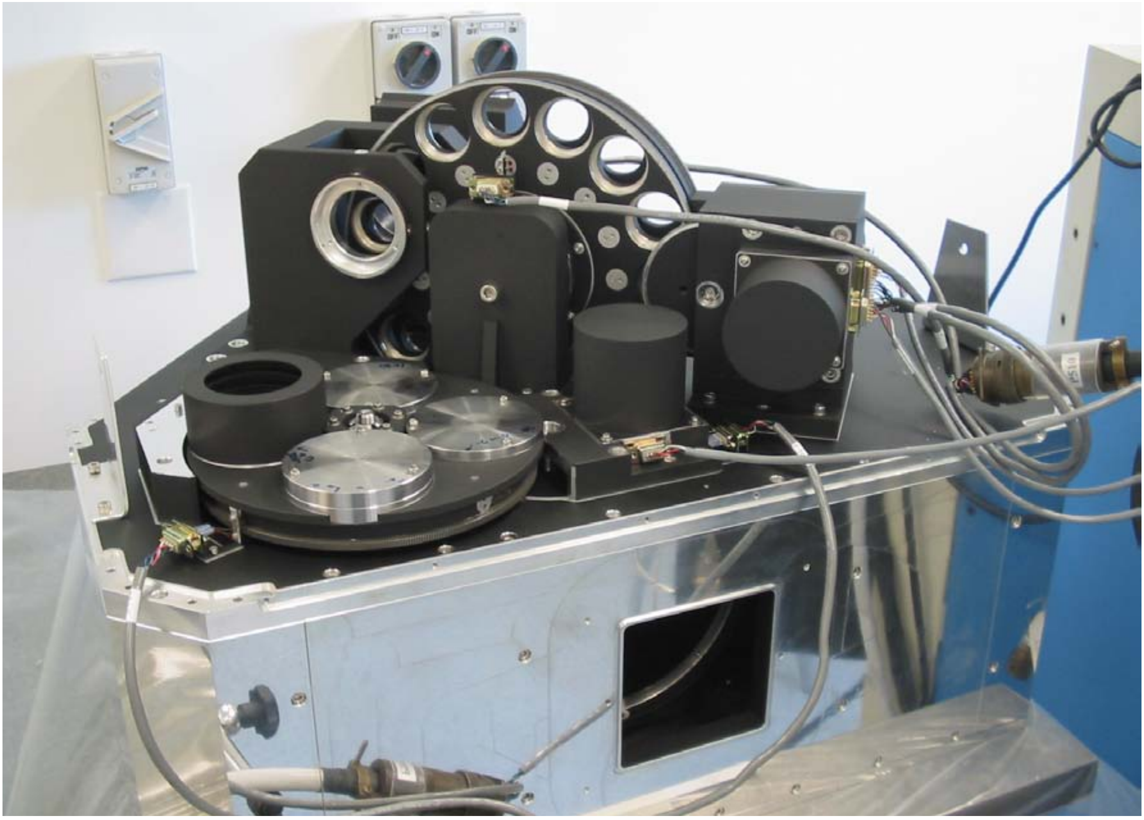
Camera & Cryostat Assembly

Through 2005, the GSAOI camera was assembled in the cryostat along with all of its optics, and the optics have been aligned and focused. Flexure tests have been performed to verify that the instrument will perform as required at all orientations on the Gemini telescope. The cryogenic mechanisms have been extensively tested to ensure that the instrument will operate reliably.

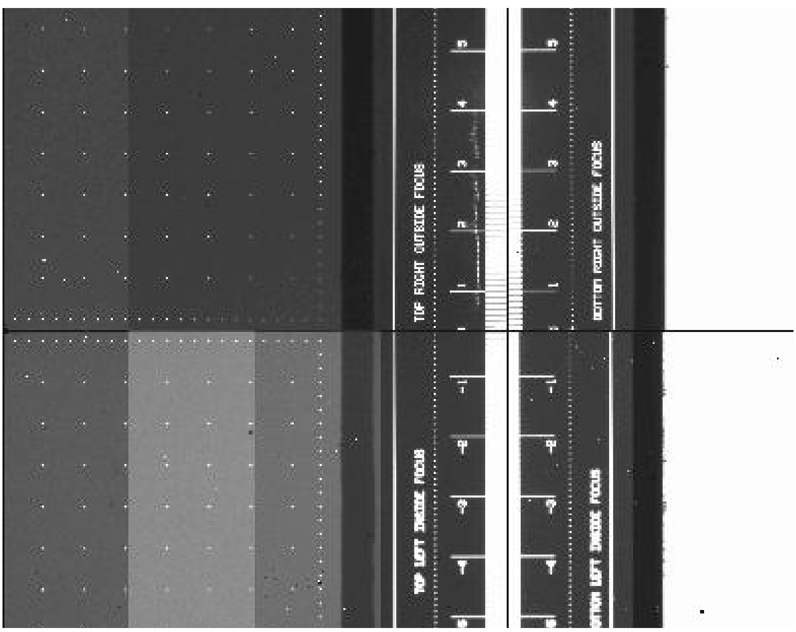
Data have been obtained with the full mosaic of four science-grade HAWAII-2RG detectors. Work is continuing to implement the range of advanced readout features that are required for GSAOI. This includes the ability to rapidly read out selected small regions of each detector while the main science exposure is continuing. These "On-Detector Guide Windows" will be used to monitor the positions of several stars in the field at frame rates of up to 800 Hz and so correct image translations due to the Earth's atmosphere and subtle telescope tracking errors.

Right: The GSAOI camera design drawing; compare with the construction on the opposite page.





Above: The GSAOI camera before installation in the GSAOI cryostat. Light enters through the dark square (lower center) and is directed through the two large filter wheels (upper center) and ultimately through the smaller wheel (left) to the detector mosaic. The whole camera operates at a temperature of -210°C to optimize performance.



Left: A test pattern exposure from the GSAOI camera. The four quadrants of the image were recorded by the four HAWAII-2RG detectors. A test pattern was mounted at the input focal plane of the camera. A grid of pinholes in the test pattern is seen at left. A sloping focus mask is located through the center. This is intentionally in-focus near its mid-point and out-of-focus at top and bottom. The right side is unobstructed, and so is over-exposed in this image.

Mileura Widefield Array – Low Frequency Demonstrator

The RSAA has joined an international consortium of universities (including Massachusetts Institute of Technology, Harvard University, University of Melbourne, Curtain University and University of Tasmania) to build a low frequency radio telescope – the Mileura Widefield Array Low Frequency Demonstrator (MWA-LFD)– in a remote, radio-quiet site in Western Australia. When complete, the 500 station antenna array will focus on three principal scientific areas: (1) Of highest priority is the detection and characterization of redshifted 21cm line signals from neutral hydrogen that were emitted during the Epoch of Reionization that occurred at redshifts above 6.5. (2) The wide field of view capabilities of the array will be exploited to perform a blind search for transient sources of radio emission 6 orders of magnitude more sensitive than any previous work in this frequency range. (3) The array will be used to probe the magnetoionic medium of the heliosphere with unprecedented precision using interplanetary scintillation and Faraday rotation techniques. Several other scientific topics, such as pulsar studies, solar bursts, the local structure of the interstellar medium, and radio recombination lines, can also be effectively addressed with the array.

The project has recently received the commitment of funding from the US National Science Foundation (NSF) through a grant to to the Massachusetts Institute of Technology, after having received prior design and prototyping support from the Australian Research Council, University of Melbourne and US NSF.

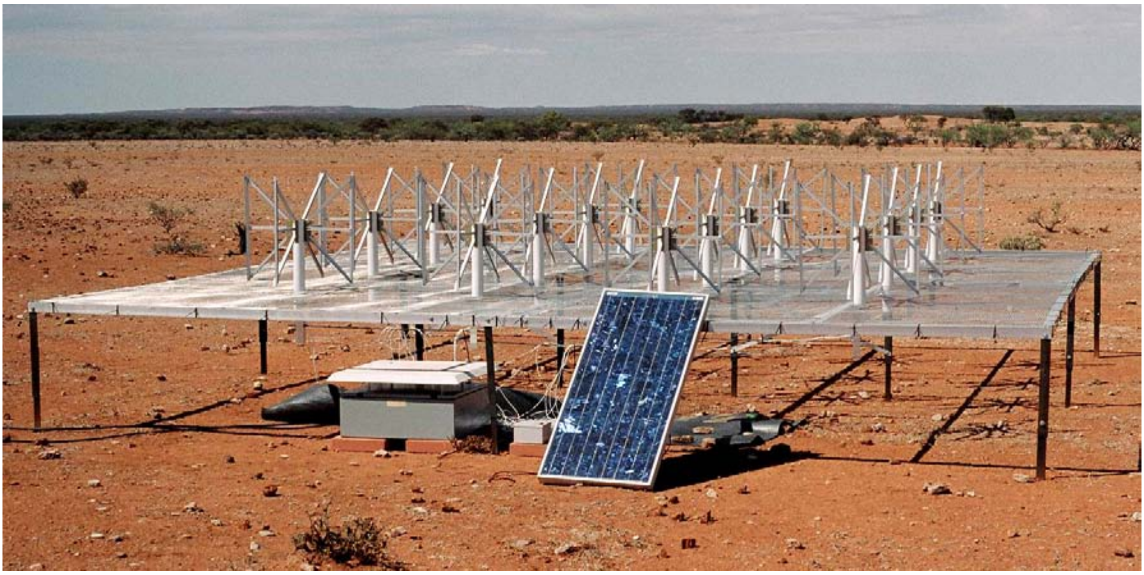
Early Deployment and Prototype Testing on Site

The year 2005 saw an Early Deployment Array come to life on Mileura Station about 200 km west of Meekathara, WA as part of a design and development effort, which included Briggs and graduate student Kocz from RSAA. The 3 station prototype interferometer array became a functioning radio telescope in the course of the year and, in that capacity, it made a sensitive sampling of the radio frequency environment in the range 80 to 300 MHz, as well as performing a few basic astronomical observations of bright radio sources, the Sun, and giant pulses from the Crab pulsar.

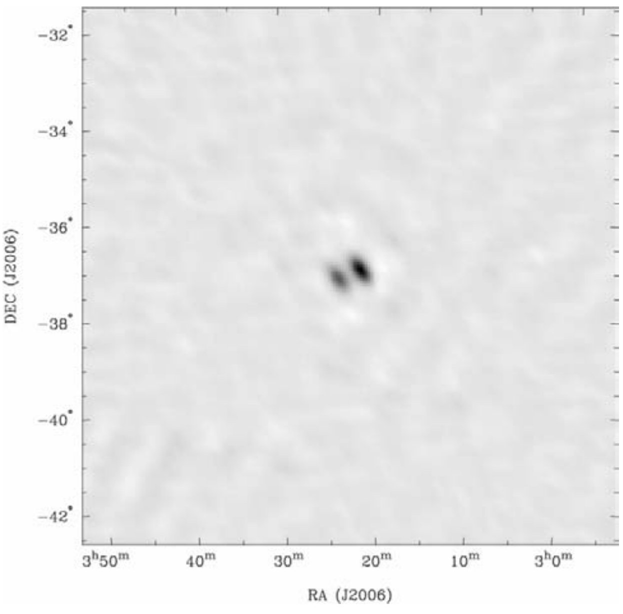
The MWA-LFD project conducted four sessions at Mileura during 2005, in March, April, June, and September each typically lasting 2 weeks at a time. The goals of the LFD Early Deployment were to (1) set up and test the antenna "tiles," 4 x 4 arrays of dipoles mounted above ground planes, illustrated in Figure 1, (2) assess the radio frequency interference environment through actual observation, and (3) gain experience in the logistics of doing radio astronomy at a remote site.

The LFD antenna tiles are phased-arrays, which are steered under computer control by sending commands to the beam-former box located next to the tile. During the Early Deployment phase of the project, the 80 to 300 MHz radio signal was amplified at the output of the beam former and then piped in low-loss coax to a caravan, where the data were processed by the "Stromlo Streamer," a recording system and software correlator built at RSAA by Briggs and Torr in collaboration with the Mologlo Observatory. The full 500 tile LFD system will have a custom designed, high-speed correlator, linked by optic fibre to each tile in order to obtain the broadband capacity for the necessary high data rates.

The LFD will take shape over the next three years, with science campaigns beginning to perform the key science programs by the end of the decade.



Above: An antenna "tile" with beam former, and solar panel on site at Mileura Station, WA. Coaxial cables run to left to a caravan containing the receiving system.



Left: A low resolution image of the bright, resolved radio source Fornax A. The map was constructed from several low frequency bands using multi-frequency synthesis techniques. The image has a dynamic range of ~100:1. While there is no new scientific discovery in making such a map of one of the strongest radio sources in the southern sky, the satisfactory construction of a synthesis map from interferometer data testifies to the success of a wide range of instrumental functionality, software, and calibration in the MWA-LFD prototype.

The WiFeS spectrograph:

Hyper-spectral imaging for the 2.3m telescope

The success of the Systemic Infrastructure Initiative proposal for the upgrade of ANU and UNSW telescopes at Siding Spring Observatory (SSO) has enabled the design and construction of an innovative, powerful and unique hyper-spectral instrument. It will be mounted at the Nasmyth A focus of the 2.3m telescope and will take maximal advantage of the properties of that telescope. This instrument, the Wide Field Spectrograph (WiFeS) will provide 950 simultaneous spectra throughout the optical frequency range. It is designed for high efficiency over the full field of view accepted by the instrument, and has a data gathering capability of 10 to 100 times the rate of the existing spectrographs.

The WiFeS spectrograph is designed to provide a unique 3-D spectroscopic functionality, enabling astronomers to obtain complete spectral and spatial coverage in a single exposure. A spatial field of 25x38 arc sec is divided into 1.0 arc sec slices on the sky and 0.5 x 0.5 arc sec pixels at the focal plane. Two intermediate spectral resolution options are available, R=3000 and R=7000.

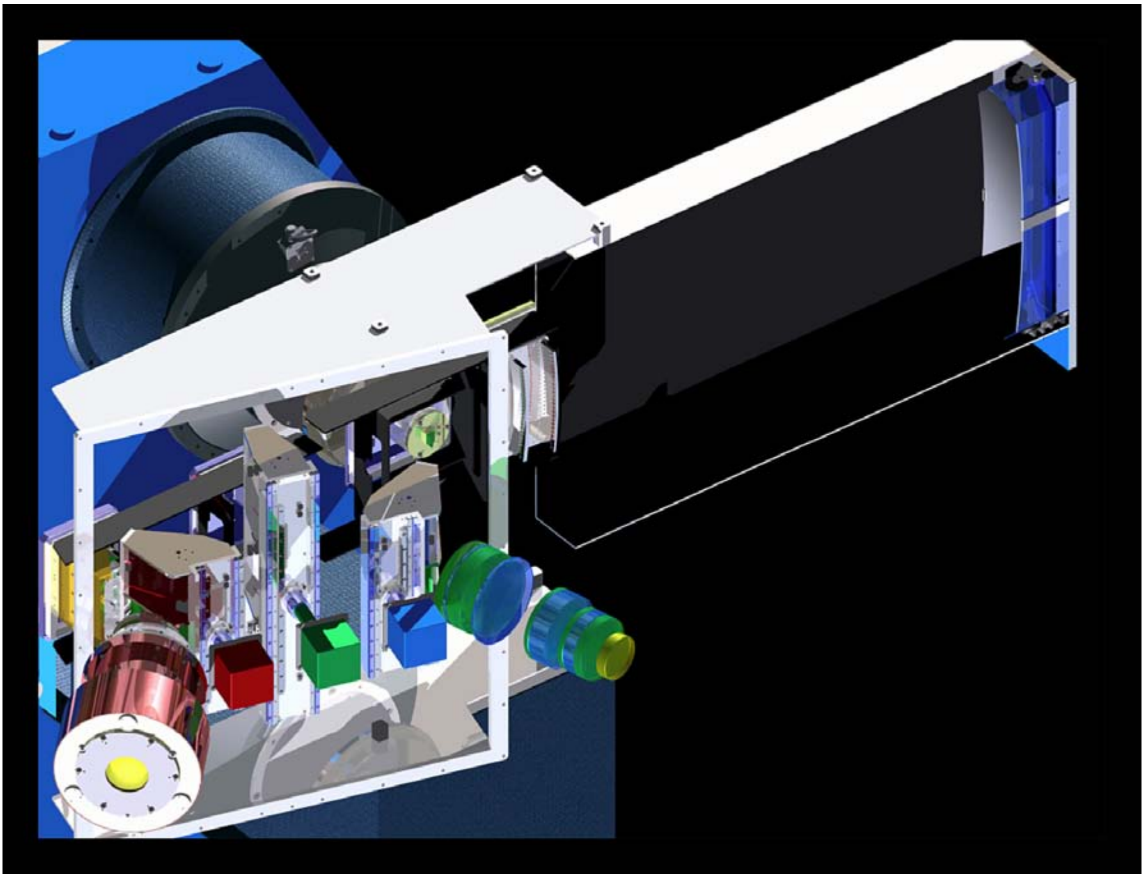
On 6 December 2005 the final WiFeS design passed its Critical Design Review, and the instrument has now been approved for construction.

Key Design Features

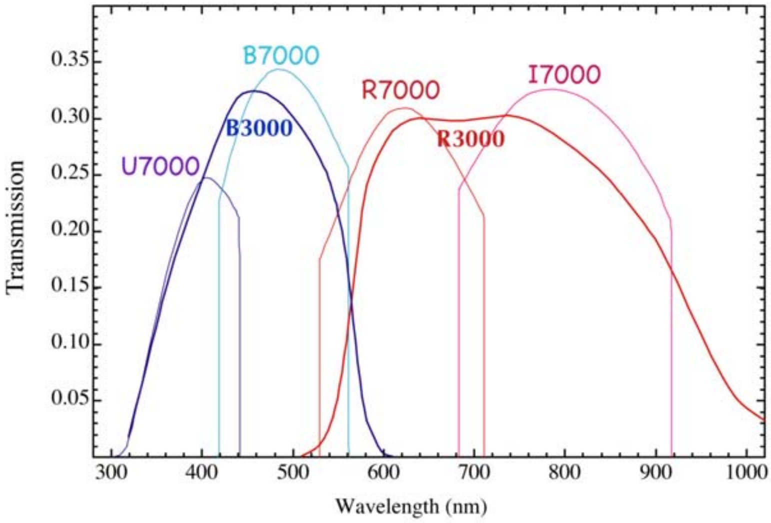
Maximisation of spectral multiplex advantage and science efficiency is being gained through:

- A double-beam design to maximize the number of independent spectral elements.
- An innovative reflective image slicing design maximizing the number of spatial elements, and giving a science field shape matched to the expected science targets.
- Use of reflective image slicing, which ensures good spectrophotometric characteristics.
- A stationary spectrograph body, which both eliminates flexure and provides a stable thermal environment. This ensures excellent spectral stability over long periods.
- Implementation of “interleaved nod-and-shuffle” allowing perfect sky background subtraction.
- Minimization of scattered light and ghost image intensity through careful design.

In addition, Volume-phased Holographic (VPH) gratings have been chosen to operate at peak efficiency. High-transmission lens optics are used in preference to mirrors, where possible. Wide-band anti-reflective coatings on all air-glass surfaces, reduce losses to < 1 per cent per surface. WiFeS will use enhanced reflectivity (>96 per cent) multi-layer coatings on all reflective surfaces. Double-beam design will double data collection rates and optimize the throughput with large-format, wavelength-optimized, and highly-efficient CCD detectors.



Above: The WiFeS instrument mechanical design. The design of the spectrograph is highly innovative and great efforts were made to maximize its data gathering efficiency to the point where it competes with 8m telescopes working on extended objects.



Left: The expected end-to-end throughput of WiFes in each observing mode. This is more than two times higher than competing instruments of this type. The bold lines are for the R=3000 modes; the thinner lines are the R=7000 modes with the two sets of gratings for each camera.

SkyMapper

This year saw the commencement of fabrication of RSAA's newest telescope, SkyMapper. SkyMapper is a 1.35 metre diameter telescope to be sited at Siding Spring Observatory. Featuring a fully sampled 5.0 square degree field of view, 5 times larger than any other southern hemisphere telescope, SkyMapper is among the first of a new breed of dedicated survey telescopes that will scan the sky with unprecedented speed. SkyMapper will conduct the Stromlo Southern Sky Survey, generating the first deep digital map of the entire southern sky.

Data obtained with SkyMapper will be shared with astronomers around the world. These data will be a boon for astronomers studying objects as diverse as nearby asteroids in our Solar System to quasars at the edge of the optically observable universe.

The design for the SkyMapper Imager was produced by Conroy, Granlund and Oates in RSAA's technical section. The design features a 268 Million pixel CCD mosaic comprised of 32 E2V deep depletion CCDs. Following successful completion of critical design review in August 2005, work has rapidly progressed on fabrication of the Imager (see figure).

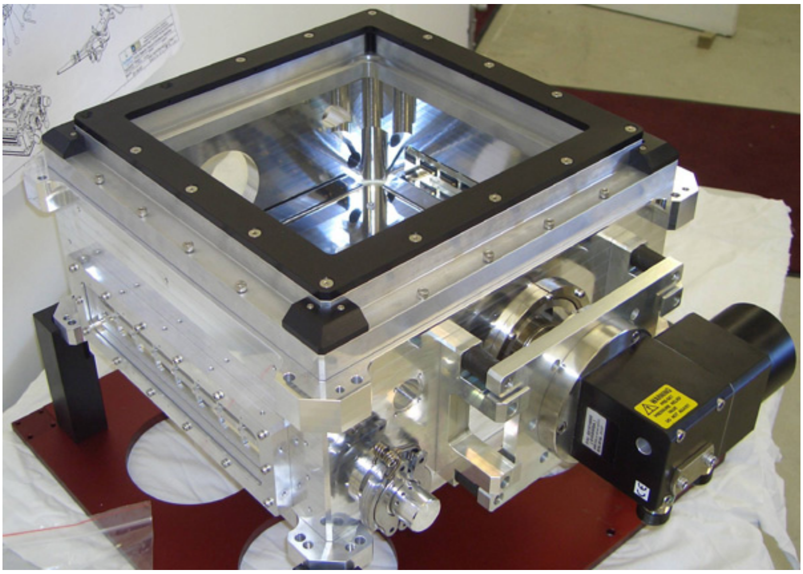
The telescope and enclosure are to be supplied by Electro Optic Systems Ltd. of Queanbeyan. Both systems completed critical design review in this year. While casting of the primary mirror in a light-weight configuration failed despite numerous attempts, the mirror blank has now been sourced as a traditional solid blank, with the project incurring only a minimal delay.

Integral to the scientific performance of SkyMapper is the software required to transform the data received at the telescope into calibrated data ready for the scientist. The Science Data Pipeline system for SkyMapper is been designed and implemented by Keller and Preston.

SkyMapper: Optimised for Stellar Astrophysics

By covering the entire southern sky, the SkyMapper data set will be the best place to look for objects that are extremely rare. One such application is the search for the first stars that formed in our galaxy. These first stars have imprinted upon their motions and chemical composition important information about conditions in the early Universe during the formation of our galaxy. Such objects are very rare; currently there are only two stars that are potential members of this first generation of stars (with RSAA astronomers taking leading roles in both discoveries).

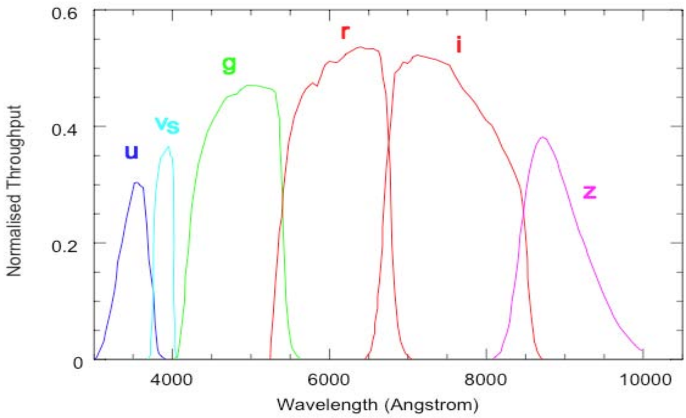
SkyMapper's key to finding these stars is in the design of the set of filters with which it will image the sky. The stars present at the formation of the Galaxy are characterised by extremely low abundances of heavy elements and this leads to subtle changes in the spectrum of these stars compared to the bulk of "normal" stars around them. Design of the filters for SkyMapper paid particular attention to optimising the ability to separate stars on the basis of temperature, surface gravity and abundance. Combined with large sky coverage, the enhanced sensitivity to abundance offered by SkyMapper is predicted to lead to a hundred-fold increase in the number of stars associated with the era of galaxy formation.



Left : The vacuum jacket for the SkyMapper Imager. The focal plane of CCDs will reside in this vessel.

Photometry

Bessell published an Annual Review of Astronomy and Astrophysics article on Standard Photometric Systems in 2005 and refined the design of filters and passbands for SkyMapper with Bloxham and Zhelem. The 309x309 mm SkyMapper *u*, *v* and *g* filters are to be sandwiches of coloured glasses; the *r*, *i* and *z* filters will have coloured glass defining the blue edge of the band and a short-pass multilayer coating to define the red edge in the *r* and *i* bands. The red edge of the *z* band will be defined by the CCD cutoff. The *u* band resembles the Stromgren *u* filter; the *v* band the DDO 38 filter; the *gri* and *z* bands are similar to the Sloan bands. The SkyMapper *v* band will be much more sensitive than the Stromgren *v* band to metallicity, at low metallicities, and should permit the identification of stars between [Fe/H] = -3 and -5.



Left: The filter set for the Stromlo Southern Sky Survey showing the predicted throughput of the combined optical and detector system.

RSAA Student Life 2005

Above: The 2005 RSAA Student's Cocktail Party.

Above: Sunset at Siding Springs

Above: Grant Kennedy refilling the detector dewar on the 40inch telescope with liquid nitrogen.

Student Programme

The RSAA Graduate Program is continuing to flourish, reaching an all-time record of 32 PhD students at the end of 2005. The student population is well balanced with 13 of the 32 being women and 14 being international students. During 2005, six new students entered the PhD program: Daniel Bayliss, Joshua Blackman, Grant Kennedy, Jonathon Kocz, Se-Heon Oh and Shane Walsh. At the end of the year, seven offers of PhD positions commencing in 2006 had already been accepted – the program continues to grow!

First Year Students

Four students completed their PhD theses during 2005: Minh Huynh, Rachel Moody, Bradley Warren and David Weldrake. We congratulate them for their achievements and for all landing prestigious postdoc positions in Australia, Europe and North America to continue their academic careers.

First Year Students

The first-year students start their PhD program by doing a three-month research project, which does not need to be in the area of the PhD thesis later chosen. In addition, during the first year the students take lecture courses covering a wide range of topics: stellar evolution and atmospheres, interstellar medium, planetary science, high-energy astrophysics, galaxies, cosmology and observational techniques, which gives them excellent exposure to modern astrophysics. Within six months of arriving, all students have selected a PhD supervisor and identified a thesis topic.

Each year, the most highly ranked incoming student is offered the Duffield scholarship. This stipend is funded from a generous donation by Miss Joan Duffield, the daughter of the first director of Mt Stromlo Observatory, Dr. Walter Duffield. The 2005 Duffield scholarship was shared by Daniel Bayliss and Grant Kennedy (both from New Zealand). Daniel's PhD thesis will be devoted to a large-scale search for extra-solar planets by looking for the tiny change in brightness when such a planet passes in front of its host star. Daniel is supervised by Professor Penny Sackett. Grant has also selected a planetary theme for his PhD work but with a more theoretical twist. He will perform sophisticated computer simulations of planet formation. His local supervisor is Dr. Paul Francis.

New Convenors

After seven years as RSAA Graduate Program Convener, Professor Ken Freeman stepped down in March 2005, handing over the responsibility to Dr. Martin Asplund and Dr. Erwin de Blok. RSAA is greatly indebted to the immense service Ken has done in recruiting top-class students to the school and looking after them so well while here (including himself supervising a large fraction of them). Ken's unselfish, dedicated work for and together with the students over many years is one of the most important factors why the RSAA graduate program has been so successful.

RSAA Graduates & Theses completed in 2005

Four RSAA students completed PhD Theses in 2005, with all four finding postdocotoral positions.

Graduate	Thesis	Current Position
HUYNH, Minh Tieu 	Constraining the Star Formation History of the Universe with Deep Radio Data	Spitzer Science Centre, Caltech USA
MOODY, Rachel Anne 	The Southern Edgeworth Kuiper Belt Survey	Macquarie, Australia
WARREN, Bradley Evan 	The Nature of High H1 Mass-to-Light Ratio Field Galaxies	McMaster University, Canada
WELDRAKE, David Thomas Frederick 	Giant Planets and Variable Stars in Globular Clusters	Max Planck, Heidelberg, Germany

RSAA Summer Scholarship Programme

Each summer the RSAA offers a number of Summer Research Scholarships, which enable suitably qualified undergraduates to spend 8 to 12 weeks at Mount Stromlo working on a research project under the supervision of an RSAA astronomer. The Scholarships are intended to provide a first-hand view of the work at a research observatory and scholars have access to state-of-the-art optical, infra-red, radio and computational facilities. Areas of research include star formation, stellar evolution, galactic dynamics, observational cosmology, active galactic nuclei, interstellar-medium physics, computational astrophysics and planetary science.

These scholarships are intended for currently–enrolled undergraduate students in universities in Australia and New Zealand completing the third or fourth year of a full-time course leading to an honours degree.

In 2005 six summer scholars attended and completed projects in a range of astronomical areas.

Scholar	Home Institution	Supervisor(s)	Project
Katie DODDS-EDEN	ANU	Dr Jorge Melendez	Habitable Systems like our own: solar twins
Eriita JONES	ANU	Dr Peter McGregor	Analysis of NIFS data
Sally LONG	UTas	Dr Charley lineweaver	Quantifying circumstellar habitable zones
Rachel SOJA	Canterbury	Professor Mike Bessell	The search for metal-deficient stars
Charlotte WORLEY	Canterbury	Dr Alister Graham	Galaxies and super-massive black holes
Wolfgang KERZENDORF	Germany	Professor Brian Schmidt	Skymapper

Public Outreach and Events

2005 Public and School Activities

The Research School of Astronomy and Astrophysics organized and participated in many outreach programs, both for the general public and focusing on college and undergraduate students.

These included:

- National Youth Science Forum
- National Mathematics Summer School
- ANU Kioloa Open Week
- National Science Week
- Siding Spring 'Astro Camp' for Year 12 College Students

A group of Year 12 students meeting the AAT for the first time.

In addition to these programs, RSAA operates Visitors' Centres at both Mount Stromlo and Siding Spring Observatories. During the year approximately 15 000 members of the public visited Siding Spring Observatory, and another 35 000 visited Mount Stromlo. In addition, during 2005 over 180 radio and numerous TV interviews were given by RSAA astronomers.

Public Outreach Telescope Domes

Mount Stromlo Observatory, often in conjunction with the Canberra Astronomical Society, also ran 'open nights' for the public on most Saturday evenings, and for events of special interest. The small telescopes used for these sessions will be permanently housed in small domes early in 2006; the domes were erected during 2005.

Left: Three 4.5m domes have been erected to house the small telescopes used to show visitors the sky. One of the telescopes is the historic 6" Farnham refractor, survivor of two bushfires.. The domes were built by AstroDomes of Yandina, Qld, and were purchased from public donations to the Stromlo Redevelopment Fund.

March 2005 "Between Light and Dark Matters"

During December and January, Drs Bruce Peterson and Simon Driver, and vacation scholar Giles Read, prepared the hundreds of plots that would be assembled into the completed artwork of ANU School of Art doctoral candidate, Ms Ruth Watson. Her work, titled "Between Light Dark Matters", was a 12 metre diameter map of the Universe comprising thousands of tiled prints on the floor of the former Yale-Columbia dome. The artwork was specifically created for the site at Mount Stromlo Observatory and exhibited over last weekend of February 2005. Ms Watson's work used data from the 2dF Galaxy Redshift Survey as the basis of its imagery. ANU astronomers based at Mt Stromlo pioneered much of the work of the international 2dFGRS collaboration, which revealed the structure, age and composition of the Universe.

Giles Read, Vacation Scholar RSAA, prepares hundreds of plots for the artwork.

Covers were used as the weather threatened.

Mr Nigel Lendon, Deputy Director of the School of Art.

Ms Ruth Watson ANU School of Art doctoral candidate, with Mr Nigel Lendon and Professor Adam Shoemaker

Above: The Artwork. Below: RSAA Director, Professor Penny Sackett, opens the exhibition.

David Malin Awards Exhibition

December 2005

A spectacular touring exhibition of some 30 award-winning astronomical images taken by amateur and semi-professional photographers, including six by an ANU staff member, was on display in December 2005 at Mt Stromlo Observatory. The images depicted the beauty of some of the best-known astronomical objects, and were winners and "highly-commended" entries in the annual David Malin Awards competition run by the Central West Astronomical Society (CWAS). David Malin is a world-renowned Australian astrophotographer and was the competition judge.

The competition has three categories of entry for both amateurs and semi-professionals – wide-field (camera shots), deep sky (telescope shots) and Solar System objects. Entries were judged not only for their technical skill but also their ability to capture the beauty of the sky and the intrinsic interest of astronomy.

ANU Fitness Centre Manager, Michael Sidonio, won the Amateur Deep Sky category for capturing a "well-known object (the Trifid nebula) expertly imaged with modest optical equipment. The digital processing was well handled and the image was interestingly oriented and cropped to include the rich surrounding star field". Michael had five other images in the exhibition.

CWAS hosted the awards and an exhibition in Parkes as part of their AstroFest event in mid-July 2005. The entries were displayed in the CSIRO Parkes Radio Telescope visitors centre during August, then the very best images were selected to form a touring exhibition. The exhibition featured at Sydney Observatory during September through November, and was at Stromlo through the holiday season.

The exhibition was opened on 8 December 2005 by the Director of the Research School of Astronomy and Astrophysics, Professor Penny Sackett and Mr David Malin. Michael Sidonio and the president of CWAS, Bishop Chris Toohey, were also in attendance.

Opening the exhibition, Penny pointed out the ideal linkage between art and science that astronomical images provide. They look spectacular and invite philosophical questions, but also provid precise data on the physics and chemistry of the Universe. She also acknowledged the close ties between amateur and professional astronomy, pointing out that astronomy was possibly the only science where amateurs make major contributions to current research.

David spoke about the technical and artistic merit of a selection of the images and the way in which astronomical imaging technology has developed. This progression was well shown by comparing the overall winner, an image of the 30Doradus region, with two images mounted next to it; a sketch of the area made at the 48" Great Melbourne Telescope in 1870 and a photograph taken with the Stromlo 74" telescope in 1957.

Michael, explaining the art of astrophotography.

The exhibition Launch.

Hermann Wehner, with the first family to visit the exhibition.

David, "These images combine the best of art and science".

Mt Stromlo Development 2004–2005

The published Annual Report of the Research School of Astronomy and Astrophysics for 2002 contained an epilogue – a Fire Report describing the events of 18 January 2003 and the devastation that occurred to the School and its facilities at Mt Stromlo. This is a report describing the situation three years on, and the progress that has been made in rebuilding Mt Stromlo.

Not all buildings at Mt Stromlo were destroyed in the fires. The Duffield and Woolley buildings, accommodating astronomers and the IT section, survived virtually unscathed. Computer records and data repositories were intact. Also the Visitor's Centre, one of the newer buildings on the mountain, suffered only minor damage. All telescopes situated on the mountain were destroyed. However as light pollution from an expanding Canberra had encroached on Mt Stromlo, more and more of the School's Australian observing took place at telescopes at the School's other site, Siding Spring in the Warrumbungle Mountains in northern New South Wales, close to Coonabarabran. Therefore the much of the astronomical science work of the School was able to continue.

Workshop Facilities

However, two important pieces of infrastructure, the workshops and the administration building, were completely destroyed. The workshops were important because the School was about to deliver a multi-million dollar instrument (the Near-infrared Integral Field Spectrograph or NIFS) to the Gemini North telescope in Hawaii following a four year design and development task. The instrument and all facilities used to produce it were destroyed, as were the design offices housed in the administration building. An early requirement was to reinstitute design and production capability at Mt Stromlo to allow construction of a replacement NIFS, as well as follow-on instruments in the planning phase.

Instrument Projects

A replacement NIFS was constructed, tested and transported to Hawaii for commissioning in November 2005. The instrument operated exactly as specified on first attempt, a tribute to the design staff. The RSAA technical team is currently building three other instruments: a Gemini South Adaptive Optics Imager to be installed on the other Gemini telescope located in Chile, a wide field spectrograph for installation on the School's 2.3 metre telescope at Siding Spring, and a large camera to be installed on a new Skymapper telescope to be erected at Siding Spring.

A more permanent solution to the School's technical design and production requirements was required, and in late 2004 a contract was let for the construction of an Advanced Instrumentation and Technology Centre (AITC). The building, valued at $13.5 million when fitted out, is being constructed to align with the Woolley and Duffield buildings along the main spur of the Mt Stromlo skyline. It will house the electrical and mechanical design workshops and laboratories, with a large integration and assembly hall attached. The integration hall and laboratories have been sized to cater for the next generation of instruments expected to be installed on Extremely Large Telescopes, currently being planned by international consortia.

A temporary workshop was quickly established on a site to the west of the main core of Mt Stromlo buildings, and two demountable structures, a mechanical design office and an electrical design office, were positioned nearby.

Demountable design offices on the western side of Mt Stromlo, with the temporary workshop in the background.

The AITC in final stage of construction in early 2006. The Duffield building is to the left.

2004–2005 Development

Administration Building

The second of the important buildings lost in the fires to be rebuilt is the old administration building, to be known as the Commonwealth Solar Observatory (CSO) in honour of its original purpose when built in the 1920s. The building contains the original offices, telescope buildings and domes constructed under the auspices of W G Duffield, Mt Stromlo Observatory's founding Director. It has exceptional heritage value. A Conservation Management Plan developed for Mt Stromlo following the fires, and published in February 2004, acknowledged that the building is of "exceptional social significance for its continued contribution to the observatory and for its role as the centre of a research institution". The building was designed by Commonwealth Architect J S Murdoch, also responsible for iconic buildings such as Old Parliament House, Hotel Canberra (now the Hyatt Hotel) and Hotel Kurrajong. The recommendation of the Conservation Management Plan, fully supported by ANU and RSAA, is that the remains of the external form and envelope of the CSO building be repaired and reconstructed, while "the interior may be adapted to suit the new use and requirements of a 21st century RSAA."

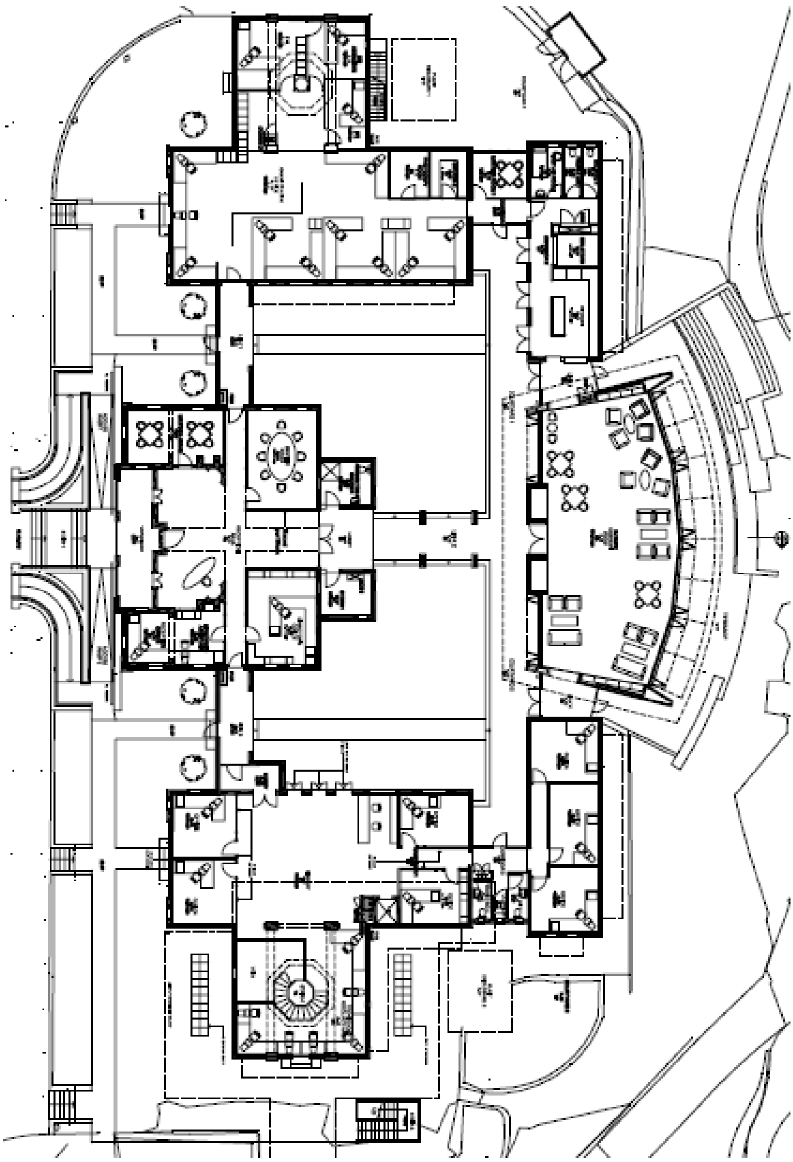
The heritage architects who had developed the Conservation Management Plan were engaged to provide a design for a repaired and reconstructed CSO, and in December 2005 a Project Manager was appointed to oversee the reconstruction through to the expected completion date in January 2007. The building's external appearance from the south, east and west will be as close to the original 1920s design as possible. The interior will house a modern suite of Director's offices complete with conference room, the western wing will accommodate the administration section, and the eastern wing under the original Sun telescope will accommodate a two-storey modern library and audio-visual research centre. The northern face comprised a section of the building constructed in the 1940s and had little heritage significance. This part will be replaced with a modern Common Room and function centre overlooking the hills to the north.

New Domes

While the majority of scientific observation for the Schools' academic staff and students is now being done at Siding Spring or telescopes overseas, RSAA has an important function of introducing the public to science, particularly astronomy, though its Outreach Program. To assist the program, three small telescope domes have been constructed on the site of the original workshop, with one to eventually house the original Farnham telescope that used to occupy the western tower of the CSO building. (See the public outreach report on page 63)

Conservation Plan

Much work needs to be done to return Mt Stromlo to the vibrant observatory in place before January 2003. A number of the telescopes remain as burnt relics in buildings that still need to be sealed, reclaimed or removed. Their scientific capability needs to be restored on Mt Stomlo or elsewhere. The original Director's residence is a shell, with no current plans to rebuild it. But resulting from the Conservation Management Plan was an 18 Months Work Plan that includes a significant element of landscape reclamation to replace the expanse of flora lost in the fires, as well as restoration work to telescopes and buildings remaining on the mountain. By the end of 2006 most of the elements are expected to be in place.



Left: A layout plan of the reconstructed interior of the CSO.

2005 Publications

Peer Reviewed Journal Publications

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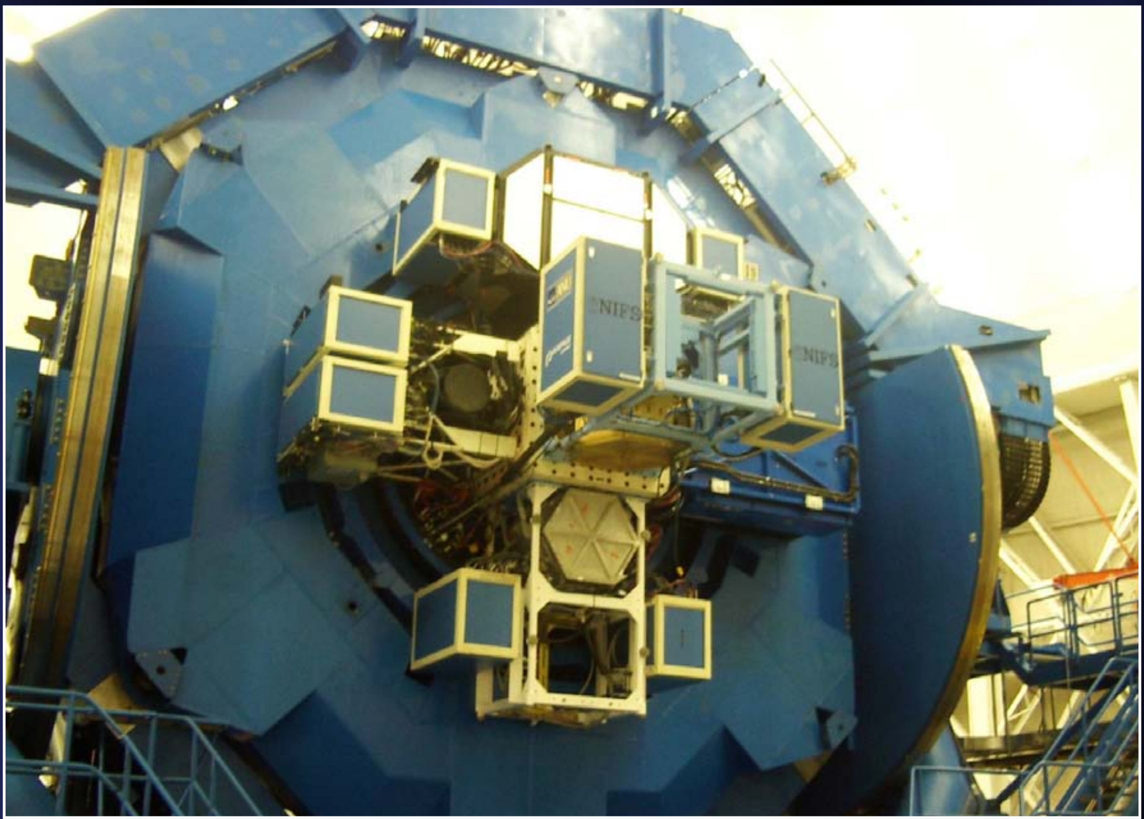

Back Cover: The Near-infrared Integral-Field Spectrograph (NIFS) attached to the Hawaii Gemini 8m Telescope.

Front Cover: Commissioning image taken with NIFS during first light testing. The very young star T Tauri is actually a triple star. The combination of Gemini and NIFS is giving image sharpness approaching that of the Hubble Space Telescope.