# SCHOOL OF PHYSICS

## ANNUAL REPORT 2004

# Contents

# Head of School's Report

This report comes with a new author this year, as Prof. John Storey stepped down as Head of School at the end of 2004, after six years in what was his second term in this position. Having learnt after just five months in the job what a demanding and often thankless task the role of Head of School is, I must express my admiration for John's obvious high levels of dedication and commitment to the School. Moreover, he must be acknowledged and thanked for the leadership he amply showed as Head, both in making difficult decisions when they were needed, and in undertaking numerous new initiatives. Indeed the publication of this Annual Report each year, show-casing the School's achievements, is just one such initiative!

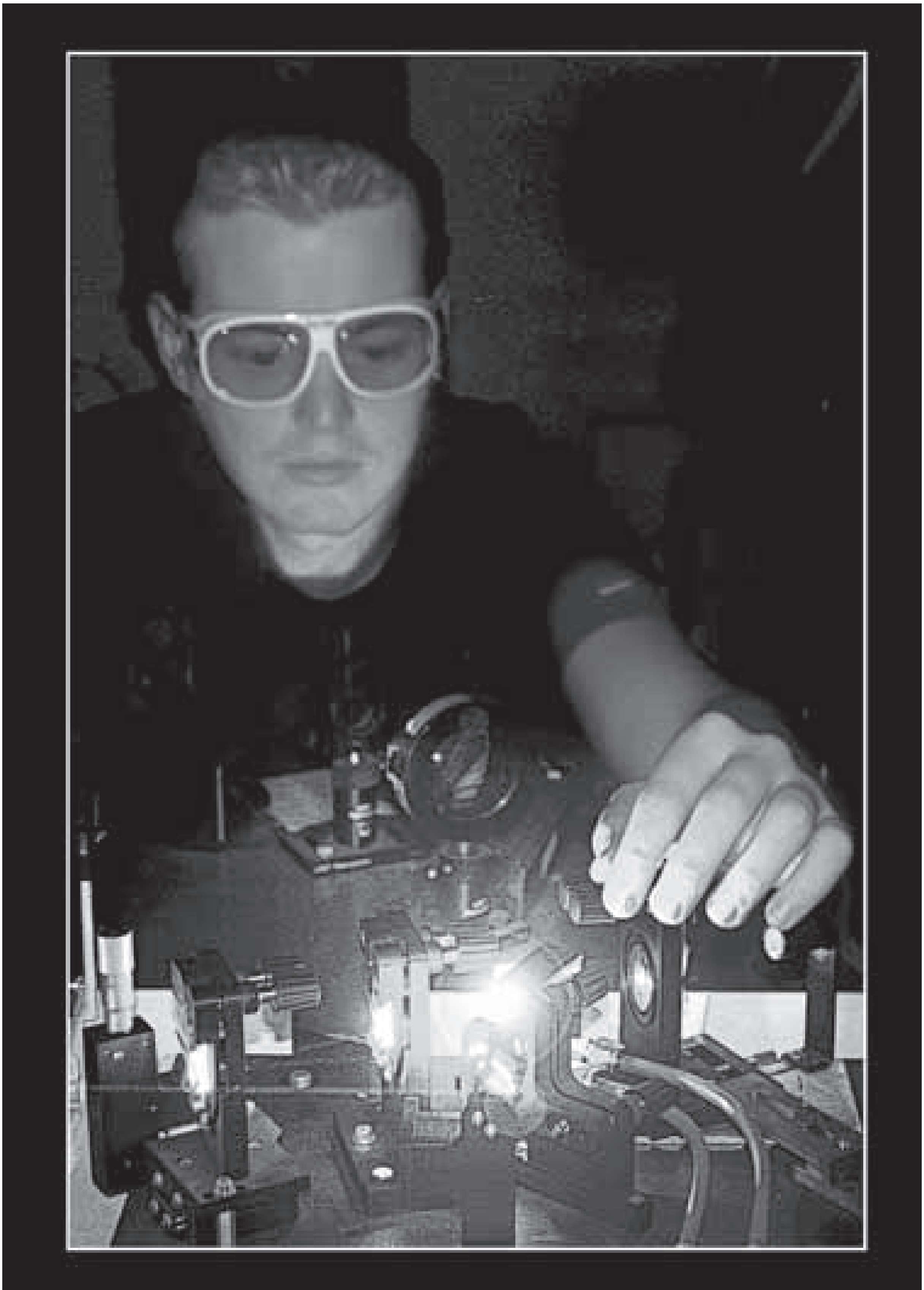
For this, our 2004 report, we have chosen a 'people' theme for the cover, with a montage of shots of many of our staff and postgraduate students. As a new Head of School this has particular significance to me, since I have rapidly become well aware that all staff – both academic and general – as well as our students, have an integral part to play in the success and well-being of the School. In particular, as well as having many 'high flyers' in our School (whose contributions quite rightly dominate this report), we also have many 'quiet achievers' who provide the all important support for our research and teaching activities. The day-to-day running of our OH&S systems, the operation of our teaching laboratories and maintenance of their aging equipment, and the continual provision of 'demonstrations' for inspiring our first year lecture classes, are just a few key examples of the outstanding efforts of those in this latter category.

As evidenced by the contents of this report, 2004 was a year in which the School more than maintained its reputation as a 'high achiever' in the areas of teaching, research, and linkages with the national and international physics communities. A particular highlight was the award of the 2004 Australian University Teaching Committee's Award for Physical Sciences to Prof. Joe Wolfe. Joe also distinguished himself in research through being awarded the French Acoustical Society's International Medal for his outstanding work in the area of music acoustics. The School was also very pleased to have its refurbished First Year 'Alpha' Laboratory and adjacent flexible learning space and courtyard/barbeque areas completed and come into operation.

Finally, the School has always operated in a changing senior management environment, and 2004 was no exception. At the beginning of the year, Prof. Michael Archer took over as the new Dean of the Faculty of Science, bringing much needed new energy and direction to the faculty. However, Prof. Rory Hume resigned as Vice-Chancellor in April, which was a great pity given his interest in the School and the constructive interactions he had had with many of its research groups and staff. Prof. Hume's successor is Prof. Mark Wainwright, who was the Deputy Vice-Chancellor (Research) and had previously been the Dean of Engineering and Acting Dean of Science at UNSW. In addition to these changes, the School continued to operate with a significant financial deficit – a situation which is unsustainable and which looms as its greatest challenge in 2005 and beyond.

Professor Warrick Couch
Head of School
May 2005

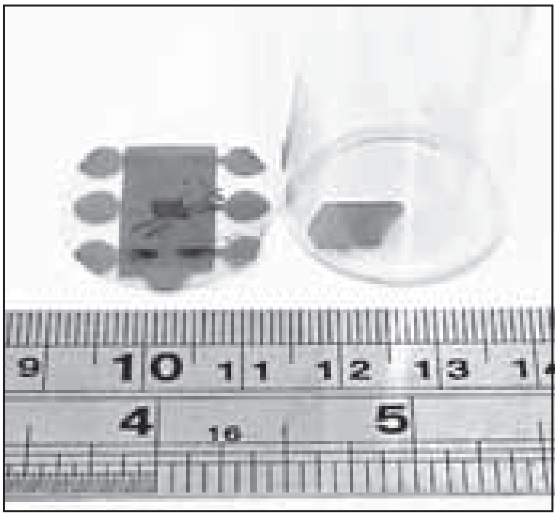
# Research Highlights



# Organic electronic devices

Plastics are generally considered to be poor conductors of electricity. However, polymers can be made conductive by manipulating their chemical structure so that they contain long chains of alternating single and double carbon bonds. This has lead to the development of ‘plastic electronics’, with a number of associated advantages including mechanical flexibility, robustness, chemical versatility, low weight, and most significantly low cost and ease of large scale production. Organic electronics is also a growing area of basic research as much of the electronic properties of organic semiconductors are still poorly understood.

An important factor in developing field-effect transistors (FETs) using organic materials is how to improve the electrical mobility (i.e., how easily current can flow through the device) to a level sufficient for practical applications. To do this you just need to reduce the disorder in your conducting system by moving from an amorphous structure (currently most conducting polymer materials consist of a tangled spaghetti of very long molecules) to more ordered structures, for example, crystals formed from small conducting molecules. The most interesting and potentially useful molecular crystals for FET applications are polyacene crystals, which consist of molecules that contain up to 5 benzene rings fused together into a linear chain.

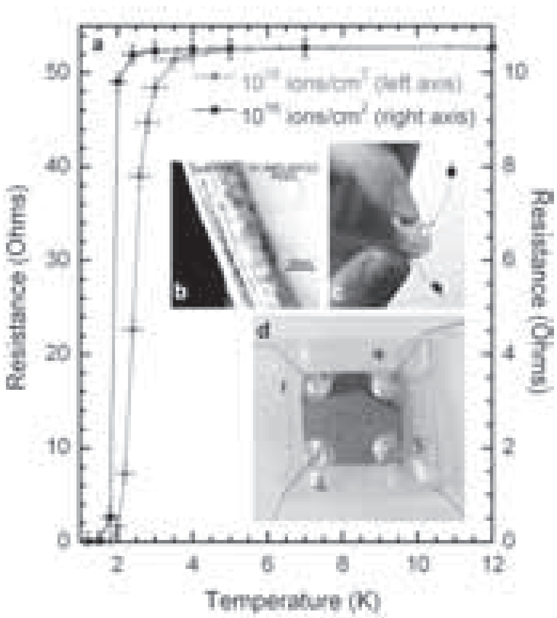



*Photograph of a Rubrene molecular crystal (right) and an FET device based on this material (left).*

We spent much of 2004 working on developing our first research-quality organic crystal FETs for this new project. This included building and optimizing furnaces for physical vapour growth of various organic molecular crystals, and developing a capability to produce elastomer transistor stamps for making the FETs. In late 2004, we produced our first high-quality crystals and made our first working FET device and in the year ahead we will begin exploring the electronic properties of these molecular crystal FETs in more detail.

We have also continued our measurements on the electronic properties of ion-implanted plastics as part of an ongoing collaboration with Paul Meredith’s group at the University of Queensland. In late 2003 we discovered both metallic conductivity and superconductivity at very low temperatures in this new material. This discovery has resulted in the filing of an Australian Preliminary Patent Application in June.

Adam Micolich, Alex Hamilton,
Jack Cochrane and Ali Rashid




*a) Resistance vs. temperature data demonstrating superconductivity in our ion-implanted plastic material. b) SEM image of the cross-section of the device showing the buried Sn-C conducting layer, c) and d) Photographs of two of our measured sample.*

# Centre for Quantum Computer Technology

The Australian Research Council Centre for Quantum Computer Technology has now completed 5 years of operation. Since its inception in 2000, with some 80 staff and students in three universities, the Centre has doubled in size with more than 150 staff and students in 2004 across six universities, and has published some 400 publications.

**Bottom-up Atomic Assembly of Si:P Qubits**

During 2003 we demonstrated the ability to insert individual P atoms into a Si(001) surface with atomic precision and fabricated one of the first devices ever to be made by STM (scanning tunnelling microscope) patterning. In 2004 we have built on these successes and, with the aim of controllably incorporating P atoms for qubit scale-up, now understand the detailed surface chemistry of the phosphine gas $PH_3$ – Si(001) surface adsorption system. We performed exhaustive experimental studies of the phosphine doped silicon surface, see Figure 1. A detailed first-principles survey of all conceivable dissociation products has allowed us to identify all the species on the surface and produce a reaction pathway to P incorporation in silicon.

Once an array of P atoms has been formed on the surface it is important to image the P dopants beneath the Si(100) surface after encapsulation. Such buried-dopant imaging can confirm that the integrity of the array has not been compromised during MBE overgrowth. Figure 2(a) is a filled state image of a H-terminated Si surface that has been patterned to say 'CQCT'. After $PH_3$ dosing, annealing and encapsulation in silicon the same surface is shown in Figure 2(b). Under normal scanning conditions it is difficult to observe the STM patterned array under this surface. As such we have taken spectroscopic I-V curves at each point in the topographic image, a technique called scanning tunnelling spectroscopy which allows us to identify the unique signature of buried phosphorus dopants.

By developing a registration technique last year, we were able to overcome the difficult challenge of making electrical contact to STM-patterned buried dopant layers once the chip was removed from the STM. Over the past year we have now fabricated the narrowest phosphorus-doped conducting wires in silicon. We find that with widths below 25nm the wires stop conducting and detailed investigations are underway to understand this.

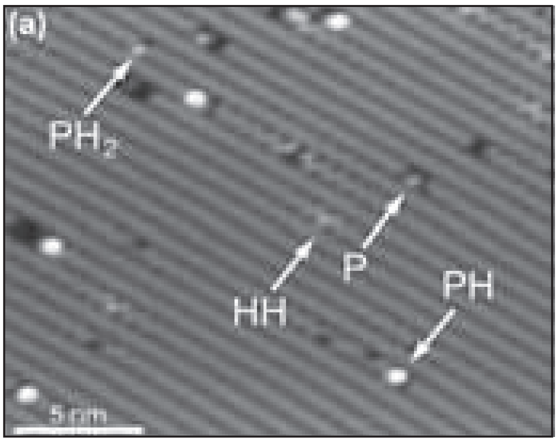



*Figure 1: STM images of the Si(001) surface after exposure to phosphine gas. The arrows indicate four species formed as a result of phosphine dissociation that were identified in our studies.*

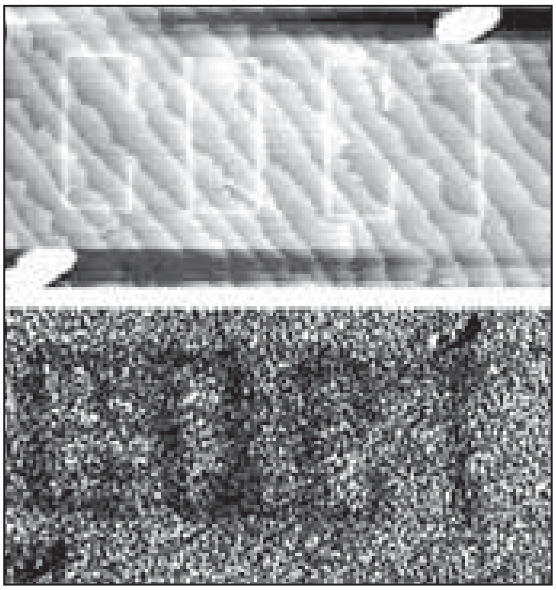


*Figure 2: (a) Filled state STM image of a hydrogen terminated Si(001) surface after it has been patterned with the STM to form the letters CQCT and (b) STS measurements of the same surface after it has been phosphine dosed and encapsulated in silicon, highlighting the integrity of the buried dopants after encapsulation.*

**Silicon-based Si:P Qubits via Ion Implantation**

In 2003 Centre researchers constructed and demonstrated a double quantum dot structure, implanted with ~600 phosphorus atoms in silicon using phosphorus ion implantation. During 2004 the teams at UNSW and the University of Melbourne significantly advanced the single-ion detection capability to unambiguously register a single phosphorus ion impact with near 100% confidence. With these detectors it is now possible to configure a device with a precisely counted number of implanted P atoms.

Over the past year a wide variety of ion-implanted structures were measured using both dc and rf SETs (single electron transistors). Nanostructures have been designed to study charge transport and disorder effects in the implanted Si:P environment. A combination of direct current (I-V) measurements and simultaneous indirect charge sensing using a surface SET can yield information about the nature of defects in the barrier between locally doped (implanted) regions. Figure 3(a) depicts such a 'nanoMOSFET' device and shows data in which Coulomb blockade is observed in the I-V characteristic, indicative of charging in small 'puddles' created by stray dopants or defects in the nanoMOSFET channel.

In Figure 3(b), a single implanted P-cluster with source-drain leads allows direct transport measurements to be correlated with remote charge detection using a surface SET. In the low conduction regime the highly sensitive SET detection enables studies of single electron tunnelling on the cluster and barrier control. When operated at radio frequencies using our rf-SET capability we observe a very clear sawtooth potential on the central dot, with random occupancy of non-equilibrium charge states which increases with temperature – see Figure 3(c).

A prerequisite for the coherent manipulation of a Si:P system is the application of gate signals on time scales significantly faster than the qubit dephasing time. During 2004 we developed a cryogenic platform, combining ultra-fast gate signals with our existing twin rf-SET charge detection capability. This has been very successful and we have now been able to use microwave signals (~40 GHz) to coherently drive transitions between the two basis states |0> and |1> under continuous measurement with the SET.

Robert Clark, Michelle Simmons and Alex Hamilton

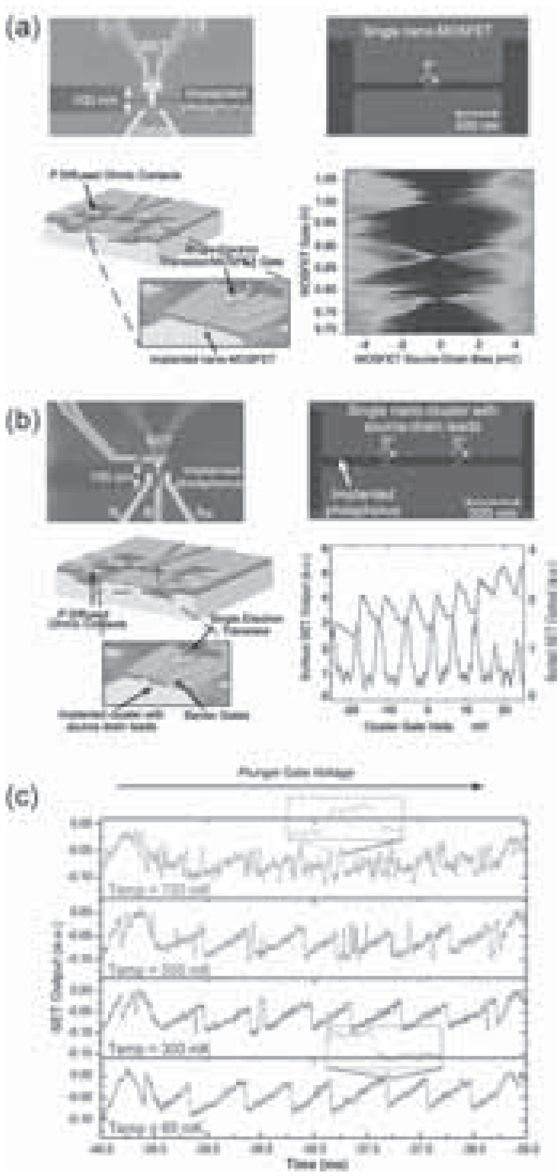



*Figure 3: (a) SEM images, schematic diagrams and data for Si:P nanoMOSFET and Si:P metallic dot with source-drain leads, respectively. (c) Periodic charging of the central dot for device in (b), detected using an rf-SET.*

# Quantum antiferromagnets: theory meets experiment

The Heisenberg model, described by the Hamiltonian

$$H = J\sum_{\langle ij\rangle}[S_i^z S_j^z + \lambda(S_i^x S_j^x + S_i^y S_j^y)], \quad \lambda \le 1$$

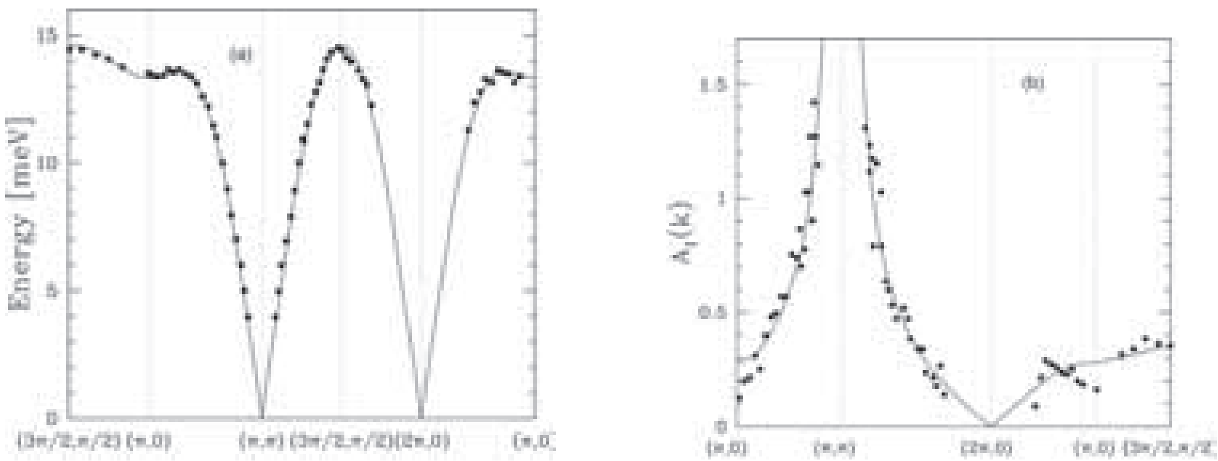
has served, for many years, as a generic model for understanding and describing antiferromagnetic order in solids. Until relatively recently the low energy properties of this model could only be calculated approximately, via spin-wave theory. In such a situation it is never clear whether discrepancies between theory and experiment are due to the shortcomings of the approximate calculation or the inadequacy of the model.

Quantities that can be most readily compared between theory and experiment are the energies of low energy quasiparticle excitations (magnon dispersion curves), which can be measured via inelastic neutron scattering, and the dynamical or integrated structure factors, which reflect the underlying dynamics of the system and are proportional to the total scattering intensity.

In recent years our group, and others, have developed powerful series expansion techniques which are able to compute dispersion relations and structure factors to high accuracy. This allows, for the first time, a reliable comparison between the model and real materials. Figure (a) shows the recently measured magnon dispersion curve for the quasi two-dimensional material $(CuDCOO)_2 \cdot 4D_2O$ (CFTD) and our series results, with one fitting parameter J=6.13meV. We have also computed the 1-magnon spectral weight, and Figure (b) compares our results with experimental measurements for CFTD. In both cases the agreement is excellent.

With the building of new and more powerful neutron scattering facilities, including the new Lucas Heights research reactor, more precise data, including measurements of multiparticle states, are becoming available and allowing ever more detailed testing of theoretical models.

Weihong Zheng, Chris Hamer and Jaan Oitmaa




*Comparison of the 1-magnon dispersion energy and spectral weight $A_1(\mathbf{k})$ for CFTD (solid points) and our series results.*

# Astronomy from Antarctica

In last year's Annual Report we told the dramatic story of how, in a battle against time, we designed and built an instrument to measure the atmospheric turbulence over Antarctica. We can now tell you the rest of the tale, in which it is revealed that the instrument, called MASS, exceeded our wildest expectations. But first, some background...

MASS stands for Multi-Aperture Scintillation Sensor, and is a device to measure refractive index fluctuations in the earth's atmosphere. This phenomenon is of great interest to astronomers who wish to obtain the best view of the distant stars and galaxies, and hence will seek out the best sites to build new telescopes. We had good reasons to believe that the Antarctic plateau would be an excellent site, but to prove it we needed to deploy the MASS experiment. A complicating factor was that MASS had to operate with no humans present, and it had to provide its own electricity, heat, and satellite communications. Fortunately, the last three requirements were met by the AASTINO, a self-contained laboratory that had been previously designed and built in the School of Physics.

In February 2005 the MASS was installed in the AASTINO at Dome C, a remote summer-only station on the Antarctic plateau. Jon Lawrence aligned it using observations of 3 stars, a difficult operation considering that the sun was continuously above the horizon for 24 hours a day. The station closed in mid-February, and our only contact with MASS since then has been via satellite. In April/May/June we took six weeks of data on several bright stars, and the data showed that the atmospheric turbulence was between two and three times less than the best observing sites currently known.

The data from MASS was so impressive that our paper on the topic was published as a Nature Letter in September. Our next goal is to obtain funding for a 2-m aperture telescope at Dome C. Such a telescope would take advantage of the superb conditions there to produce images that would rival those of the Hubble Space telescope.

Michael Ashley, Jon Lawrence,
Suzanne Kenyon and John Storey

*Suzanne Kenyon at Dome C, Antarctica, with the AASTINO in the background.*

# Seasonal variations in size-resolved chemistry and aerosol optical properties in Sydney, Australia

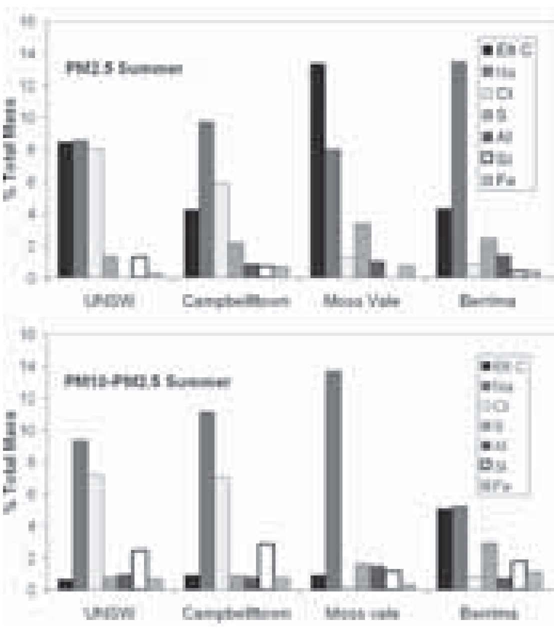
Atmospheric aerosols (small particles) are among the most heterogeneous of the Earth's atmospheric components. Primary aerosols are injected directly into the atmosphere (e.g. desert dust, sea spray, smoke particles), while secondary aerosols are produced by gas-to-particle conversion of precursor gases such as $SO_2$ and biogenic compounds. Each may be the result of either natural or anthropogenic processes. Once in the atmosphere they may undergo further processing, especially within cloud droplets, leading to further changes in characteristics. Hence it is not just the concentrations, or column 'loadings', of aerosols, but also the properties of the aerosol populations themselves that vary in space and time.

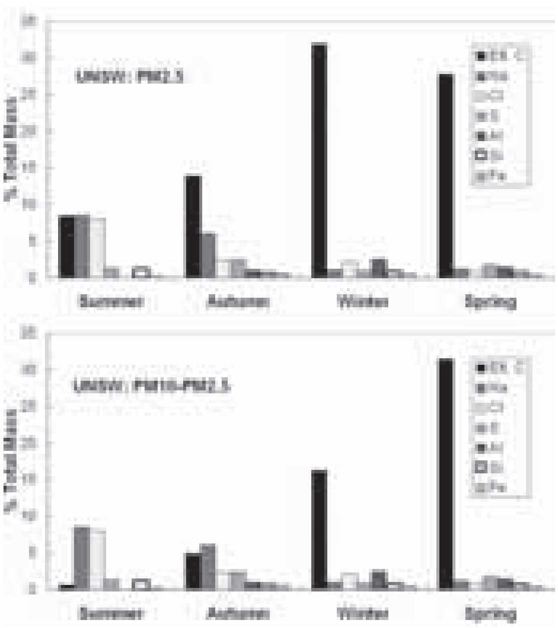
In recent years it has become evident that knowledge of the size-resolved chemical composition of atmospheric aerosols is important in determining optical properties such as refractive index, scattering and absorption coefficients, extinction and hygroscopic growth. These properties affect the way radiation is scattered and absorbed as it passes through the atmosphere, and thus are important for the calculation of aerosol radiative forcing and atmospheric correction of satellite images, as well as local air quality and visibility.

Samples were collected at four sites (University of New South Wales, Campbelltown, Berrima and Moss Vale) during the summer, autumn, winter and spring of 2003. These samples were collected using a PM2.5 ('particulate matter' less than 2.5 microns) and a PM10 sampler. This allows us to determine the properties of both the fine mode (less than 2.5 microns) and coarse mode (2.5 to 10 microns). The samples have been analysed using Ion Beam Analysis (IBA) to provide elemental composition, and selected samples have also been analysed by Scanning Electron Microscopy (SEM).

The IBA results show seasonal differences within sites and between sites, as well as differences, in at least some cases, between PM2.5 and PM10-PM2.5 composition at particular sites. The figure on the left shows results for 7 key elements (elemental carbon, sodium, chlorine, sulfur, aluminium, silicon and iron) at all sites and both modes, for the summer season, while the figure on the right shows the results at UNSW for all seasons. The most significant difference shown in this data is the fact that elemental carbon, the major contributor to aerosol absorption of sunlight, is overwhelmingly concentrated in the fine mode. We now propose to follow up this important finding with a new sampler which will allow considerably improved size resolution.

Taleb Hallal and Gail Box



# Searching for extra-solar planets from Siding Spring and the South Pole

At first thought, attempting to find planets orbiting around stars other than our Sun would appear to be almost impossible. Any light from the planet would be swamped by that from the vastly more luminous star. However, some fraction of planets will occasionally pass in front of their host stars as viewed from the earth, and when they do so, the light from the star will be slightly reduced. While the chances of such an event are small, there are so many stars in our Galaxy that the overall probability of detection is quite high.

We are employing this technique for finding so-called 'extra-solar' planets on two telescopes: the UNSW Automated Patrol Telescope (APT) at Siding Spring Observatory, and the Vulcan-South telescope at the US Amundsen-Scott South Pole Station. Michael Ashley and Jessie Christiansen visited the South Pole to help set up this latter experiment. The grand hope is that we shall find a planet/star system with suitable properties to enable us to study the characteristics of any atmosphere present around the planet, during transit. In principle, spectral features could be identified such as molecular oxygen and/or methane that may indicate the presence of life elsewhere in the universe.

During the year Michael Ashley and John Webb were awarded an Australian Research Council LIEF grant for $376k to build a new CCD camera for the APT. The camera is being constructed at the Anglo-Australian Observatory and should see first light in 2006. It will increase the APT efficiency by at least a factor of ten and makes our extra-solar planet survey extremely competitive.

Marton Hidas, Jessie Christiansen,
Michael Ashley and John Webb

*The Vulcan-South telescope at the Amundsen-Scott South Pole Station. Photo: J. Dana Hrubes.*

# Remarkable stability of atomic shells helps in calculations

It is very well known that electrons in atoms are grouped in shells. What is not so well known is that these shells are very much independent of each other.

Figure 1 shows the result of self-consistent field calculations of electron densities for $Pb^{4+}$, $Pb^{22+}$, $Pb^{54+}$ and $Pb^{72+}$ ions which have 5, 4, 3, and 2 shells correspondingly. One can see that removing the contribution of the upper-most shell from the self-consistent field has only small effect on the next shell and practically no effect on other shells. In the end all ions have almost the same electron densities for each shell. This is a surprising fact given that the electron energies are, in contrast, very different.

To understand this phenomenon one can use a classic analog of electron shells presented in Figure 2. A charged sphere creates no electric field inside itself and cannot affect electrons moving in its interior region. The classic analog of an electron energy is the energy to move an electron from the interior region to infinity. One has to cross all charged spheres to do this. Therefore, the energy does depend on the shells. However, electron movement in the interior region does not depend on this energy. In other words, an electron feels no effect from outer shells unless it crosses them.

Now, how does this help in calculations? Suppose we need to calculate the electron structure of an atom with several valence electrons. The independence of shells means that we can start the calculations from a positive ion with all valence electrons removed. The electron densities and the effective field will still be the same. This leads to the simplest form of perturbation theory with the number of terms in every order being several times smaller than in the case of any other initial approximation.

Calculations for Ge, Sn, Pb, Ba, Ra and their ions show that applying this scheme leads to a significant improvement of the accuracy of calculations compared to methods available before. Areas of research which are to benefit from this development include searches for variation of fundamental constants, study of parity and time invariance violation in atoms and many other important problems.

Vladimir Dzuba

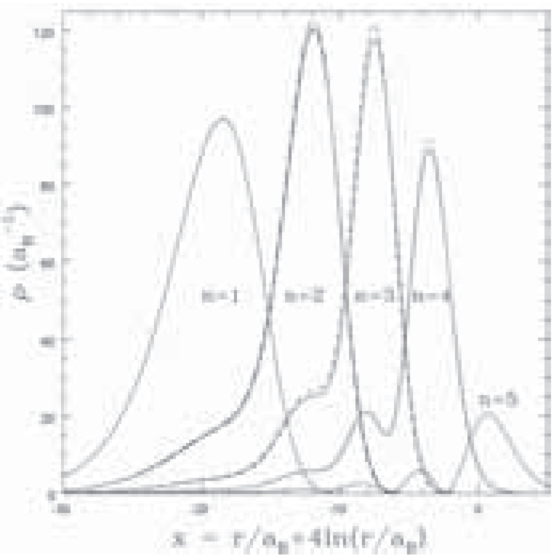



*Figure 1: Electron densities of atomic shells from n=1 to n=5 for $Pb^{4+}$ (solid line), $Pb^{22+}$ (dotted line), $Pb^{54+}$ (short dash), $Pb^{72+}$ (long dash).*

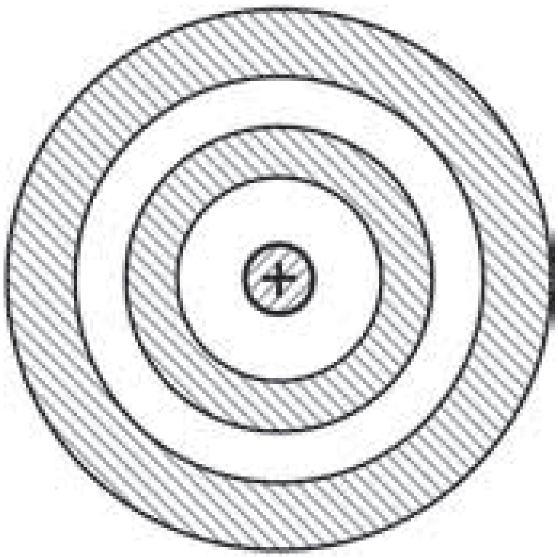


*Figure 2: Classic analog of atomic shells. Negatively charged spheres around a positively charged ball.*

# Mind-bending study leave

At the end of 2003 I was overjoyed to find that I was granted Special Study Program leave for the second half of 2004.

The start was the International Workshop on Plant Membrane Biology at AGRO Montpellier, France, July 6 - 10. I have attended this conference series every three years since 1980! I presented five posters and met many colleagues old and new. The molecular biology content of the conference proceedings has grown greatly. I feel that this powerful approach is missing in my research.

We then drove across Europe, through my native Czech Republic and into Germany, where I talked to my Ph.D student Chris Cherry-Gaedt. Our long drive finished in Glasgow, visiting Mike Blatt, who is Regius Professor of Botany. I have started *Chara* culture for Mike to be used for teaching electrophysiology. We used Mike's superb fluorescence confocal microscope to find that fluorescent pH indicator BCECF uptake into *Chara* highlights small organelles, but not the bulk of the cytoplasm, as was previously believed. We are still processing results.

After returning to Sydney I attended the 4th Symposium of the International Research Group on Charophytes, 25 - 27 September at Ranelagh House, Robertson, NSW, where I presented a talk. I have met this group of fellow 'charologists' for the first time, although I have read some of their papers. The group is interested in the history of charophytes and finds their fossilized parts in ancient rocks. There were charophytes 400 million years ago! The group has taken me on an excursion to Lightning Ridge, where opalised charophytes can be found. I was not lucky enough to find any, but enjoyed looking!

Back in Sydney it was time for another new direction: I spent a week at ANSTO with Chris Garvey, performing low angle neutron scattering of charophyte cell walls. Our experiments aimed to find differences in the wall structure between salt-tolerant and salt-sensitive charophytes. We have struck some problems with keeping the samples wetted with $D_2O$ to provide contrast and will continue experiments in 2005.

I had arranged with Federation Fellow Mark Tester, who was once my fellow 'charologist' in Cambridge to give me some training at the Australian Center for Plant Functional Genomics in Adelaide. My project was to extract messenger RNA from salt-tolerant charophyte *Lamprothamnium* and inject it into the salt-sensitive *Chara*. Can we make *Chara* temporarily salt-tolerant? I learned to extract mRNA from *Lamprothamnium* (as shown in the picture below). The procedures involved a new discipline (for me) to keep the experiment free from contamination. Large amounts of *Lamprothamnium* plants were needed and I organised a trip to Lake Budgewoi on the Central Coast, where I was lucky to find some. I have perfected the injection procedure and produced the first batch *Lamprothamnium* RNA injected *Chara* cells. My time ran out at this point. There are many control experiments to perform and so I have submitted an ARC proposal to continue these experiments with the help of a Postdoctoral Fellow with a molecular biology background. Wish me luck!

Mary Beilby

*Mary Beilby at the Australian Centre for Plant Functional Genomics in Adelaide, South Australia.*

# Early stages of star formation

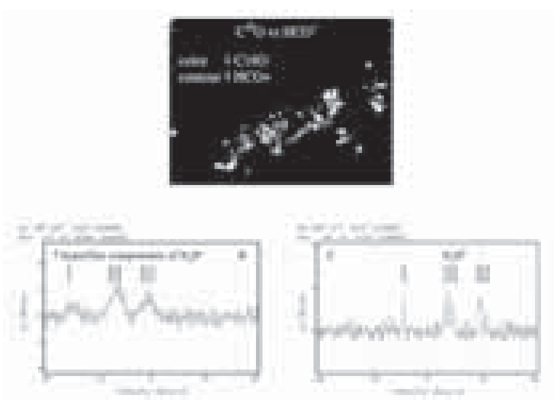
Our own galaxy, the Milky Way, is a vast ecosystem of stars. Not a biological one like the Earth's, but a physical and chemical one. From the spaces between the stars, gas and dust collect under their own gravity to form new stars, which live the majority of their lives burning nuclear fuel at their centres. When this fuel runs out, their death throes return a large fraction of their material, enriched in heavy elements by their nuclear fires, to interstellar space, thus beginning the cycle over again.

The beginning of this cycle, the formation of stars, is still somewhat of a mystery, especially for stars which are several times more massive than our Sun, or for large clusters of stars. How do such large stars assemble themselves, individually and in clusters? A simple theory would predict massive clusters could not be as tightly packed as we see. Do massive stars drive off their nascent gas in the same way as low-mass stars? Do they have similar, or any, solar systems? The mysteries of massive star formation are important since these stars, while few in number, are a major part of the engine driving the Galactic ecology. Their impressive energy output heats and stirs large tracts of the Galaxy, while their nuclear cauldrons ensure there are plenty of heavy elements in available for future generations of stars to form rocky planets and solar systems. In contrast, the formation of isolated low-mass (or Sun-like) stars is much more common than massive star formation, and a little better understood; however we still lack details about the prevalence of solar systems, the formation of planets, and the clearing of the stars' gaseous cocoons.

We have begun 2 major projects in 2004 in order to systematically address some of these questions. Using the Mopra dish of the Australia Telescope, CHaMP is collecting a large database of properties of medium- and high-mass star formation throughout the Milky Way by looking at different tracers of dense interstellar gas. In collaboration with Yoshi Yonekura at Osaka Prefecture University and members of the NANTEN group at Nagoya University, we will be able for the first time to build a reliable picture of the typical evolution of these rare but powerful engines of galactic ecology. The second large survey, also primarily using the Mopra radio telescope in collaboration with Tyler Bourke and Phil Myers of Harvard University and others, is part of the Spitzer Space Telescope Legacy Program 'C2D - From Cores to Disks'. This project is similarly compiling detailed and uniform data on low-mass star forming clouds in our local Galactic neighbourhood.

We obtained our first comprehensive data for both projects at Mopra last winter (see figure), and are scheduled for much more time this coming winter (2005). Analysis of the data obtained so far is ongoing, and has already produced some intriguing results, which we are preparing for publication.

Peter Barnes



*[A] NANTEN maps of a section of the Milky Way, showing a number of distant, high-mass, dense molecular clouds in the constellation of Carina. The colours and contours show that the two 'dense-gas tracers' $C^{18}O$ and $HCO^+$ do not precisely trace the same gas, presumably due to physical and chemical variations in conditions inside the clouds. [B] CHaMP spectrum of $N_2H^+$ line observed at Mopra from one of these star-forming clouds, showing the broad, blended profiles typical of high-mass star formation. [C] Mopra $N_2H^+$ spectrum from a nearby, low-mass cloud in Vela. Note in this case how the hyperfine components of the spectrum are easily separated.*

# Torsional motion in strings: another reason why it's so hard to get a good sound from a bowed instrument

A bow induces sideways or transverse motion of the string. Rosin on the bow hair ensures that static friction with the string may be much greater than kinetic. Consequently, in a cycle of normal playing, the string travels with the bow at a nearly constant, low velocity (the stick phase), then slides rapidly past the bow in the opposite direction (the slip phase).

However the bow acts on the surface of the string, not at its centre, and so exerts a twisting or torsional force. This excites additional torsional waves that travel along the string. These torsional waves exert only a small torque on the bridge and so produce little sound by themselves. Nevertheless, they can have an important effect on the overall sound produced.

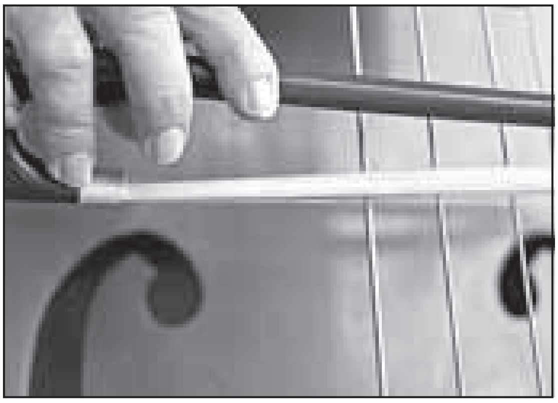
The motion of the point of contact between bow and string depends on both the transverse speed $v$ of the string, and on the torsional velocity $\omega$. During the stick phase, $v+r\omega$ must equal the bow speed, where $r$ is the radius of the string. The familiar transverse modes of the string are in harmonic ratios and so produce a periodic wave. However, there is no *a priori* harmonic relationship between the torsional and transverse waves. Consequently the torsional waves may produce non-periodic motion or jitter at the bow-string contact. This can have a considerable effect on the perceived sound.

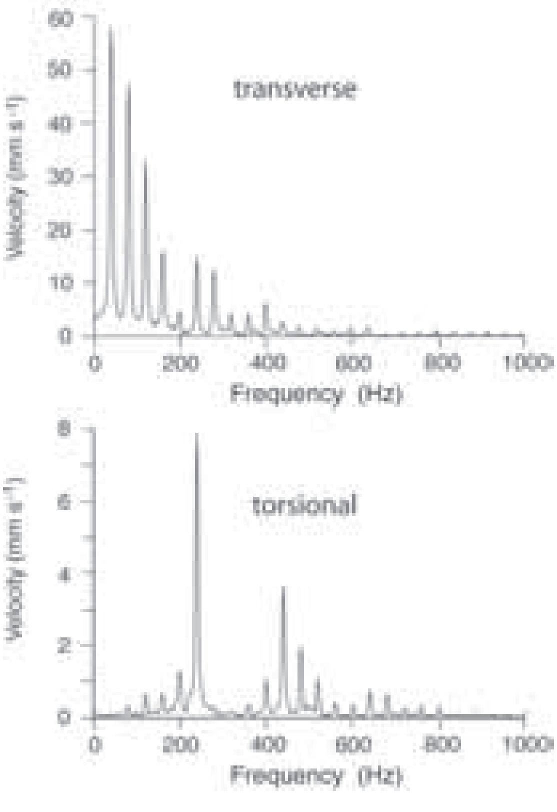
The bowed string has been studied for centuries by scientists, including Helmholtz and Raman. It is thus a little surprising to discover that the relative magnitudes and phases of the torsional and transverse motion had not been measured. We did this electromechanically by attaching tiny sensing coils, using the large strings of a double bass.

The magnitude of the torsional waves was surprisingly large – see figure. When the strings were bowed by experienced players the torsional motion was always phase-locked to the transverse waves, producing highly periodic motion. The spectrum of the torsional motion includes the fundamental and harmonics of the transverse wave, with strong formants at the natural frequencies of the torsional standing waves in the whole string. Finding (quickly) the subtle combination of force and speed that controls the non-harmonic torsional waves seems to be a skill that string players must learn.

Our web site has sound files of both the transverse and torsional velocity signals of the phase-locked signals.

Eric Bavu, John Smith and Joe Wolfe






*Simultaneous measurements of the transverse and torsional velocity of a bowed bass string.*

# Tamm metastable surface states in very low energy electron diffraction

Very low energy (0–40 eV) electron scattering from surfaces contains information about electron surface states, atomic positions at surfaces and surface potentials including the barrier potential. At higher energies information about the surface states and potentials is mostly lost and the data is sensitive mostly to structural information of the lateral positions of surface atomic and molecular species.

Over the last ~30 years of analysing such reflectance data in the low energy regime, much difficulty has occurred in accounting for all observed features and disentangling their origins to deduce surface properties.

In particular, a feature which occurs on certain metal surfaces of face centred cubic metal structures has been difficult to explain.

In a preliminary analysis last year it was speculated that this extra peak could be due to scattering from the gradual rise of the average interstitial potential on approach to the surface from the bulk inner potential value.

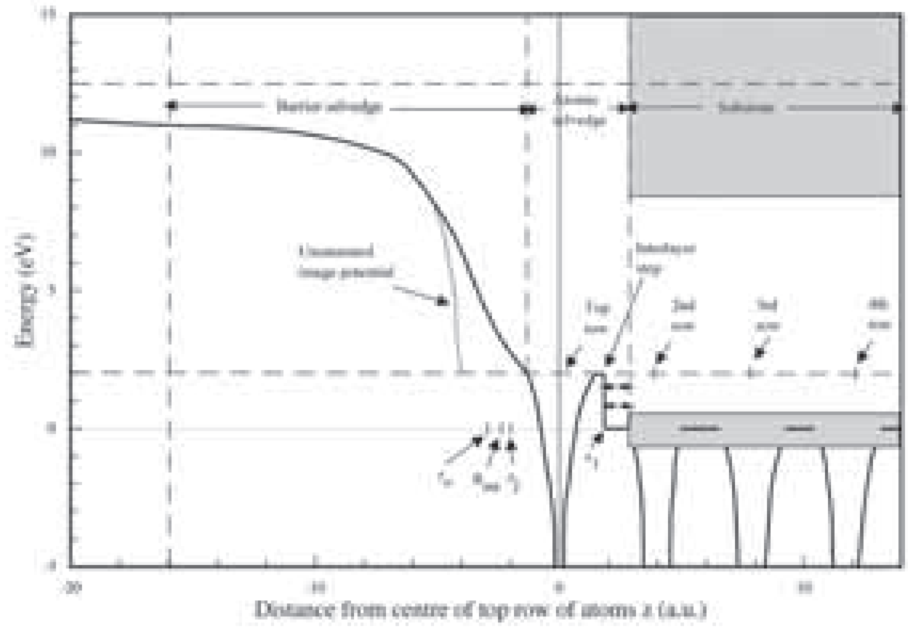
To test this possibility, a calculation of the elastic electron reflectivities was performed which included all multiple scattering at a step potential inserted between the top atomic layer and the next atomic layer in the crystal. This had not been included in any calculation before.

This mechanism did produce the required experimental feature which is due to a Tamm-type metastable surface state.

The result shows that this type of scattering mechanism is very important in the low energy regime and should be included in the theoretical model. With this inclusion ambiguity in interpreting experimental data should be eliminated.

Properties of these systems are particularly important because alkali metals adsorbed on these surfaces have the potential to be used as quantum electronic devices which would operate at room temperature.

Marlene Read




*The double-headed arrows in the diagram show the scattering mechanism which gives rise to the formation of a Tamm metastable surface state. In this case the electron is confined to a region between the bulk band gaps and the rise of the interstitial potential near the surface.*

# Dissecting distant galaxies into their star-forming parts

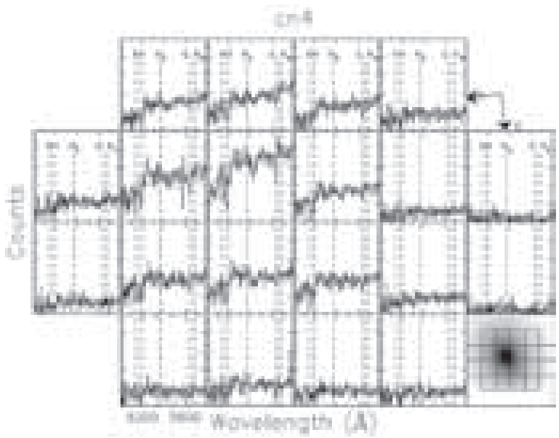
For astronomers, spectroscopy is one of their major tools for measuring and deciphering the physical characteristics of the extra-terrestrial objects they observe. Stellar spectroscopy has matured to the point where the surface temperature, gravity, abundance, motions, and magnetic field strength of stars can be measured as a matter of course. For galaxies, these same properties can be measured, albeit in an average sense for the ensembles of stars and gas clouds that are contained within these vast and generally much more distant systems. In addition, the age of and thus the time at which stars in galaxies formed, and hence the levels of current and past star formation activity, are also vital pieces of information that spectroscopy can provide, since they directly address the most fundamental of questions – how do galaxies form and evolve?

In trying to reconstruct the formation and evolutionary history of galaxies, astronomers also have another important factor on their side and that is their ability to look back in time and see galaxies as they were when the universe was significantly younger than its present age. However, they pay a price for this in that the galaxies are so distant that they are both very faint and barely resolved above the 'natural' resolution of ground-based telescopes. Hence spectroscopy of these 'faint fuzzy blobs' is very challenging.

The new generation of 8-10m class telescopes, with their much superior light-grasp and image quality, has opened up a completely new era, making it feasible to spatially resolve distant galaxies and obtain spectra at different locations across their face. Such observations have been greatly facilitated through the development of spectrographs with an 'integral field unit' (IFU) which, using mirror and/or lenslet/optical fibre technology, provides a means of subdividing their field of view into a series of contiguous spatial pixels and producing a spectrum for each. Using such IFU spectrographs on the 8m Gemini and VLT telescopes, we have employed this 'spectroscopic dissection' approach to understand the physical mechanisms that are driving the rapid evolution in what are known as 'E+A' galaxies. These enigmatic galaxies, which are found in significant numbers in high redshift clusters, have a spectral signature which indicate they have gone through a recent burst of star formation activity, which for some mysterious reason has been suddenly truncated.

Our observations of these galaxies (a typical example is shown in the accompanying figure) have yielded some surprising results. Most notably, there appears to be a dichotomy in star formation geography. In some E+A galaxies, the recently formed population of new stars is very much concentrated towards their centre, which point to galaxy merging and tidal interactions most likely triggering and then halting the recent star formation activity. In the other E+A galaxies, the distribution of newly formed stars is more widespread, and in some cases more prominent in the outer (disk) regions, suggestive of an abrupt truncation of the star formation right across the disk of an active, spiral galaxy. Such a truncation event is more likely due to the interaction of the galaxy with the hot intracluster gas in which it is embedded. Hence it would appear that at least two mechanisms are responsible for the rapid evolution associated with E+A galaxies. The challenge now is to further elucidate the circumstances under which they operate, a task we are undertaking through further observations with the Gemini telescopes.

Michael Pracy, Warrick Couch,
Chris Blake and Kenji Bekki




*An example E+A galaxy (bottom right panel) dissected into a spatially contiguous grid of 20 spectra (remaining panels).*

# The Delta Quadrant survey

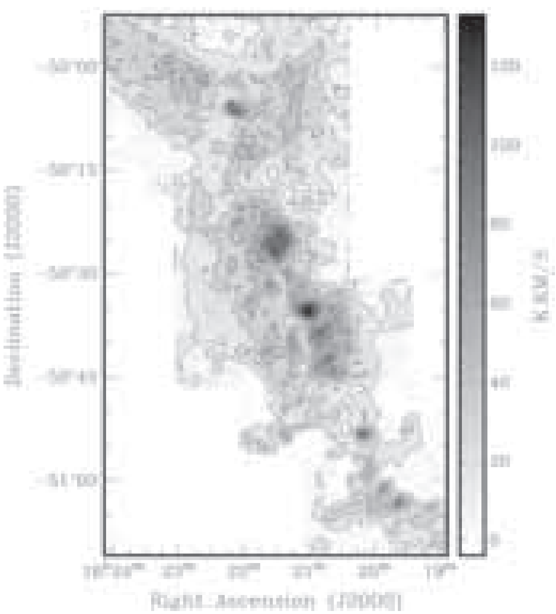
A comprehensive model that explains how stars form remains elusive to astronomers. It is generally accepted that the gas and dust in giant molecular clouds collapses to form a gravitationally-bound nascent stellar system, but what causes and regulates this collapse? The formation of the minority of objects that are single, low-mass systems is well-studied, but the obscuration provided by the dense dust in sites of massive star formation, coupled with their relatively large distances from us, make these objects more difficult to observe and hence to study. In recent years, a potentially comprehensive model of star formation has arisen that focuses on the role played by turbulence in driving and regulating stellar birth. The precise origin of the turbulence is unknown but may arise due to large-scale Galactic flows of gas or expanding supernova bubbles. The models detail how the turbulence cascades across all spatial scales and can both encourage the formation of clumps in molecular clouds and disrupt any already-forming clumps, hence it can both drive and regulate the rate of star birth.

In order to provide observational constraints for this promising theory, we have developed a programme of molecular spectral line observations with the Mopra telescope of a degree-sized region of a giant molecular cloud complex situated in the fourth quadrant (hence 'Delta Quadrant') of our Galaxy. The express purpose of this programme is to detect the effects of turbulence in the molecular cloud and compare it to the local star forming efficiency in order to elucidate the link between the two. The programme began in 2004 with 10 weeks spent mapping the molecular cloud in the $^{13}CO$ (J=1-0) 110-GHz transition. The image shows the total intensity map of the carbon monoxide molecule's emission.

The observers who dedicated their time to make these observations were primarily members of the UNSW star formation group – Indra Bains, Michael Burton, Maria Cunningham, Steve Longmore, Cormac Purcell, Patricia Sparks, Andrew Walsh and Tony Wong – plus some dedicated 'friends' of the group such as Bruce Fulton and Gary Deragopian. Typically, two observers spent a week at a time at the telescope, 7 hours drive from Sydney in the Warrumbungles National Park, near the town of Coonabarabran.

We are currently analysing the $^{13}CO$ data and using specific analysis techniques to investigate the signatures of turbulence present in this molecular cloud complex.

Indra Bains



*The integrated 13CO emission from the ~1 degree square region of the molecular cloud complex observed by Mopra in the Delta Quadrant Survey. The Mopra beam size at the frequency of the J=1-0 13CO transition is 30 arcsec.*

# The Stephen Sanig Research Institute

Drs. Galina Kaseko and Tohsak Mahaworasilpa are focusing on developing their Cell Manipulation & Expression Technology. This requires combined knowledge of physics, biophysics, biology, immunology, molecular biology and biochemistry and allows them to study, manipulate and modify biological cells, especially the cells involved in the human immune system. Preliminary results from their research work showed that under appropriate conditions the technology could be used to create new human cell lines that can be cultured in the laboratory and have the potential to express and produce biopharmaceutical materials. These have the potential to be used for diagnosis, prevention and/or treatment of infectious diseases, cancer, or inflammatory diseases.

Meningococcal is an acute bacterial infection that can result in death within hours, or permanent disability, if not recognised and treated in time. In Australia, some 700 people are infected each year, most often children and young adults, resulting in 10-15 % death. Most survivors experience problems including visual or hearing loss, learning disabilities and mental retardation, seizures, and amputation of limbs. With the strong support of the Stephen Sanig Foundation and the Faculty of Science, the two scientists have included meningococcal study and research in laboratory core programs. Consequently, the Stephen Sanig Research Institute (SSRI) was set up within the Department of Biophysics toward the end of 2004. This initiative provides an opportunity to apply this unique technology to develop new biopharmaceutical products targeting meningococcal disease.

*From left to right: Mr. Yosi Tal, Dr. Tohsak Mahaworasillpa, Dr. Ora Dar, Dr. Eli Opper, Dr. Galina Kaseko and Mr. Robin Millner.*

Also this year the two scientists took an initial step towards the establishment of a research collaboration with a group led by Professor David Naor from the Hebrew University, Israel, to develop a new product for rheumatoid arthritis. This is an autoimmune disease affecting millions of people world wide. Characterized by joint swelling and pain, it causes the body's immune system to attack joints and the lining of internal organs resulting in permanent disability over a period of time. There is no cure, and existing treatment methods focus on relieving pain, reducing inflammation, stopping and slowing joint damage. Prof. Naor's group has identified a critical element in rheumatoid arthritis pathogenesis, which enables a new approach to a management of the disease. A memorandum of understanding was signed on behalf of Prof. Naor by Dr. Eli Opper, the Chief Scientist of Israel's Ministry of Industry and Trade during his visit to Australia in September. The partnership's aim is to combine Prof. Naor's insight with SSRI's unique human protein development technology to create a new biopharmaceutical compound delivering superior treatment.

Galina Kaseko and Tohsak Mahaworasilpa

*From left to right: Mrs. Sue-anne Sanig (President of the Stephen Sanig Foundation), Dr. Galina Kaseko, Kimberley Sculli (a survivor of meningococcal meningitis), Mr. Suraphan Boonyamanop and Mrs. Naiyana Boonyamanop (H.E. Thai Consul General and his wife) and Dr. Tohsak Mahaworasilpa.*

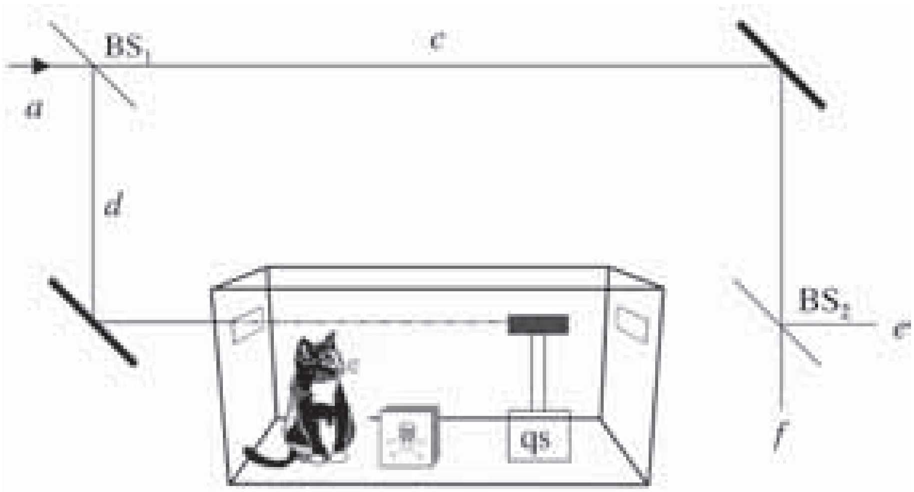
# Measurement: Look! No hands

Quantum physics is very successful in predicting the measured properties of quantum systems (e.g. electrons, atoms, molecules) but does not concern itself with unmeasured properties. In one view, quantum physics is incomplete because physics should be concerned with describing an objective physical reality for both measured and unmeasured properties. The effort to 'complete' quantum mechanics is rewarding not only because of its fundamental interest but also because it leads to practical innovations. To a significant extent, the exciting developments in quantum information theory, quantum cryptography and quantum computing over the last decade or so can be seen to flow from research on the foundations of the subject in the last third of the last century, especially in the area of the Bell inequalities after 1964.

I am interested in a time-symmetric formulation of quantum physics in which the future and the past determine both the measured and unmeasured properties of a quantum system. This idea is counterintuitive, because of our subjective experience of a clear distinction between the future and the past, but there does not appear to be any objection to the concept within physics itself.

One practical consequence of the research is the possibility of using the phenomena of interaction-free measurement to improve the sensitivity of experimental techniques. In interaction-free measurement it is possible to detect the presence of an object without interacting with it in the sense of changing the energy, momentum or any other property of the object. For example, we could find out whether Schroedinger's cat was alive or dead without disturbing in any way the contents of the box containing the cat. There are more practical consequences, for example the possibility of measuring the spectrum of a sample without causing any transitions between the energy levels that are involved in producing the spectrum.

David Miller




*A version of Schroedinger's cat: if the hammer falls, the poison is released and the cat is in trouble. Assume that the hammer is exquisitely sensitive and will fall if any form of radiation or matter whatsoever touches it. Can you find out (measure) whether the hammer is still in place without making it fall? Yes, you can. The interferometer is set up so that, in the absence of the hammer, light or a photon entering on path* a *leaves on path* e *with probability equal to one due to interference between the paths* c *and* d*. If the hammer is in place, the interference cannot take place and so a photon entering on path* a *can leave on path* f*. Therefore detection of a photon on path* f*, means the hammer is in place but the photon has not touched the hammer (otherwise it could not have reached* f*)! Therefore, you can achieve the aim, at least in some runs of the experiment.*

# Centre of galaxies

Activity at the centres of galaxies is visible across most of the history of the universe: to understand the gravitational, radiative, dynamical, chemical and magnetohydrodynamic processes that occur in such regions we need to start with a clear picture of the centre of our own Galaxy. These processes drive galactic evolution on all scales. The stellar component is largely obscured by dust and can only be studied laboriously, if at all, at infrared wavelengths. Through radio spectroscopy, in particular millimeter-and submillimeter-wave spectral line observations, we can measure the large scale morphology, dynamics and thermodynamic properties of Galactic center gas.

Together with a group at the Harvard-Smithsonian Center for Astrophysics, the inner three square degrees of the Galaxy has been mapped at frequencies between 450 GHz and 810 GHz to trace spectral lines originating from dense atomic and molecular gas. The observations were performed during the austral winter seasons of 2001, 2002 and 2003 at the Antarctic Submillimeter Telescope and Remote Observatory (AST/RO) located at 2847m altitude at the Amundsen-Scott South Pole Station. These observations have been combined with other surveys to construct a new picture of gas structures in this interesting region of the Galaxy.

The resulting images show that emission from gas in the Galactic center region is complex, with chaotic, asymmetric, and nonplanar structures making up hundreds of clouds, shells, arcs, rings, and filaments. On scales of a few hundred to a few thousand light years the gas is loosely organized around closed orbits in the rotating potential of the underlying stellar bar. Gas on certain classes of non-intersecting orbits having a density near 3000cm$^{-3}$ is rendered marginally unstable against gravitational coagulation into a few giant molecular clouds: indeed some gas is seen to be bound into cloud complexes, while some is sheared by tidal forces into a molecular intercloud medium of a kind not seen elsewhere in the Galaxy. The multimillion-solar-mass clouds are dense, as they must be to survive in the Galactic tide, and are sinking toward the center of the Galactic gravitational well as a result of dynamical friction and hydrodynamic effects. The deposition of these massive lumps of gas upon the centre will fuel a starburst or an eruption of the central black hole. Depending on the accretion rate near the inner resonances, this process cycles with a timescale of order some tens of millions of years.

The next starburst in the Milky Way may occur within the next 10 million years. Some 30 million solar masses of matter will flood inward, overwhelming the black hole at the galactic centre. The black hole will be unable to consume most of the gas, which will instead form millions of new stars, the more massive of which will burn their fuel quickly and explode as supernovae and irradiate the surrounding space. With so many stars packed so close together as a result of the starburst, the impact on the entire Galactic centre will be dramatic enough to kill any life on an Earth-like planet.

Wilfred Walsh

*There goes the neighborhood. On this hypothetical world near the centre of the Milky Way, the planet's sun descends toward the horizon at left. The bright supernova exploding at upper right lends an ominous feeling because its radiation is about to wipe out the alien life on this world. (image: David A. Aguilar, CfA)*

# One thousand million light years from home

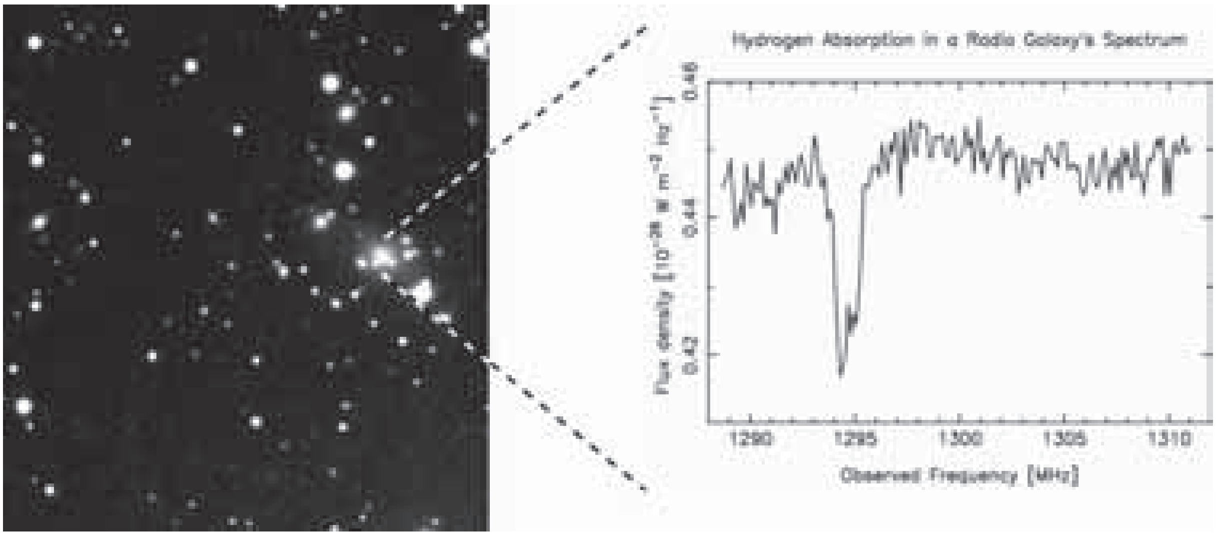
Most matter in the universe is in the form of hydrogen, either inside stars, self-gravitating clouds or free-floating gas. When heated, for instance by nearby stars, the gas is easily seen by its own light. When cold, however, it can be hard to detect. A useful property is that hydrogen absorbs light and radio waves of particular wavelengths that pass through the cloud, leaving characteristic absorption lines in the spectra of the background radiation source. Detection of such lines can betray the presence of otherwise undetectable gas along the line-of-sight to the background source.

One such source of radiation is the radio galaxy PKS 1555-140, 1.3 billion light-years away in the constellation Libra. This galaxy has a super-massive black hole at its centre (with 20 million times the Sun's mass), the presence of which accelerates electrons close to the speed of light, producing a strong radio source in the centre of the galaxy. This radio emission is absorbed by cold hydrogen undergoing the spin-flip transition at 1420 MHz. We observe this at 1294 MHz, giving the same redshift as the galaxy.

From the spectrum, obtained with Australia Telescope Compact Array at Narrabri in July 2004, we see that the gas is spread over 400 km/s, indicative of galactic rotation – further evidence for association with the galaxy. From the velocity width and the depth of the line, for ~100 atoms per cubic centimetre at a temperature of ~ -200 C, we can infer a cloud size of < 100 light years: relatively small compared to the size of the galaxy.

Interestingly, the absorption line appears to have at least two peaks, indicating that there are possibly several separate gas clouds present. Collisions between galaxies are common and we believe that interactions with the other nearby galaxies in this system may have stirred up the surrounding gas, creating the complex absorption line profile. This hypothesis should be confirmed by up-coming optical observations from Siding Spring Observatory.

Matthew Whiting, Steve Curran
and Steve Longmore




*(left) A true-colour image of the sky surrounding PKS 1555-140. The radio galaxy itself is the large one located between the ends of the two dashed lines.*
*(right) The Compact Array spectrum that reveals the presence of hydrogen gas.*

# Quantum electronic devices

The QED group studies the properties of advanced transistor devices, at nanometer length scales where quantum effects become significant.

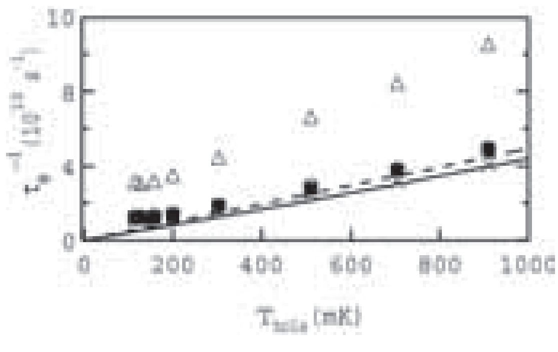
A fundamental question for high quality field-effect transistors is whether, since the electrons are confined to a very thin (two-dimensional) channel, quantum effects will always make them insulating – even if they appear to be metallic at finite (room) temperature. To tell the difference between insulating and metallic ground-states it is necessary to cool the devices close to the absolute zero of temperature, and then compare the data with theory to predict whether the resistance will remain finite as $T \rightarrow 0$. In high quality devices this process has been hampered by a large discrepancy between theory and experiment. In 2004 we published the first comparison of five different theories with experimental investigations of the quantum interference correction, and showed that the discrepancy between theory and experiment can be eliminated by using more sophisticated models to analyse experimental data.

A second highlight this year was the development of a new type of extremely low disorder field effect transistor, using custom grown semiconductor wafers produced at the NTT Basic Research Laboratories in Japan. Ph.D. student Warrick Clarke devised new processing techniques to turn these wafers into functional transistors for studying quantum corrections to classical conduction. Low temperature measurements revealed extremely large hole mobilities (up to 600,000 $cm^2V^{-1}s^{-1}$), as well as unexpectedly strong metallic behaviour that appears to be at odds with many current theories.

A second topic we are studying is how do interactions between very closely spaced semiconductor devices affect their electronic properties? This work is being performed in collaboration with the University of Cambridge (UK) and Boise State University (USA). The devices we use have two conducting layers separated by an insulating barrier only 2.5nm thick. At low temperatures and high magnetic fields, holes in the two layers bind together to form a new quantum phase – an excitonic superfluid – similar to the atomic Bose-Einstein Condensates that were the subject of the 2001 Nobel Prize in Physics. We are now studying interaction effects in bilayer coupled 1D quantum wires.

Martin Aagesen, Warrick Clarke, Alex Collins, Carlin Yasin, Oleh Klochan Romain Danneau, Adam Micolich, Alex Hamilton and Michelle Simmons

*Dr. Romain Danneau and Warrick Clarke performing low temperature measurements of coupled quantum wires fabricated at UNSW.*




*Phase breaking rate for 2D holes (time to lose their coherent wave-like nature) as a function of temperature. Solid and dashed lines are predictions of Fermi liquid theory; open triangles are obtained by analysing data using simplest model while solid symbols are obtained using more complex models and show far better agreement with theoretical expectations.*

# The evolution of the universe

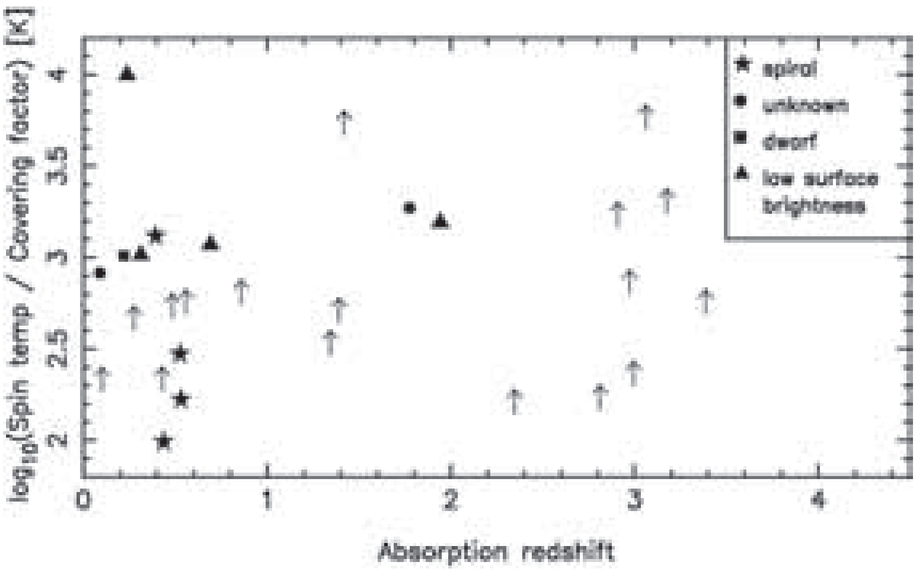
Astronomical observations allow us to look into the past, as the light reaching earth now has been travelling from its source for billions of years. Astrophysicists at UNSW have been using these measurements to discover more about the evolution of the universe.

Neil Crighton, John Webb and colleagues studied a high redshift quasar to determine the abundance of deuterium in the young universe. Deuterium is important because it was produced in the first few seconds of the life of the universe and essentially none has been produced since. The amount of deuterium made depended sensitively on the density of the universe and so determining the deuterium abundance today provides a unique probe of one of the fundamental parameters of cosmology. Interestingly, the value we found seems to disagree with independent estimates from the microwave background. This remains a puzzle at the moment.

In last year's report John Webb, Steve Curran and collaborators at Cambridge presented the first ever measurement of the cosmological evolution of molecular hydrogen abundance in the earlier Universe. Since then, we find that the temperature of the neutral hydrogen gas in these dense clouds, which intersect the lines-of-sight to distant quasars, does not necessarily increase with look-back time, as is currently believed, and that the observed effect is due to the smaller absorbing cross sections at larger look-back times. This is contrary to the current consensus, but is consistent with hierarchical galaxy formation scenarios, where the population of dwarf galaxies in the early Universe have merged to form the larger, near-by (and hence more recent) spirals.

Dmitriev, Victor Flambaum and John Webb used observations of the helium abundance (4He is produced in the big bang) in conjunction with CMB data to explore whether the laws of physics were the same in the early universe as they are today. This general topic is currently a very active area of physics and astronomy, following our previous tentative measurement of a tiny change in the value of one of the constants of Nature (the fine-structure constant).

John Webb, Steve Curran, Neil Crighton and Victor Flambaum




*Temperature/covering factor as a function of redshift. The symbols represent galaxies in which cold neutral hydrogen has been detected and the arrows represent lower limits. This plot in conjunction with our other work shows that apparently high temperatures are produced when the covering factor is (incorrectly) set to unity. The highest redshift of 3.4 corresponds to a look-back time of 11.6 billion years.*

# Violins: do they improve with playing?

Whether it is a product of the passage of time, the exposure to the atmosphere, or the amount of playing, many violinists believe that oldies are goodies, and spurn inexperienced instruments. When the Powerhouse Museum wanted to buy an instrument for its collection, an opportunity arose to examine these questions. Three years ago, renowned maker Harry Vatiliotis made two very similar instruments from wooden plates, seasoned for 80 years, that had originally been intended to make a cello. Thus the bellies came from adjacent areas of the same slab of spruce, and both backs came from the same sample of maple.

During and after construction, they were subjected to acoustical tests and, when finished, to playing and listening tests. Since then, one has been maintained in museum conditions, unplayed, while the other belongs to busy Sydney musician Romano Crivici. How have they changed?

Three tests have now been conducted. The instruments were compared when new, after 3 years (in 2004) and then four days later, after the played instrument only had been adjusted during a session involving the owner and the maker. During this session, new strings and bridge were fitted, and minor adjustments were made to the soundpost.

The first good news for the experiment was that the playing and listening tests on the new instruments gave results that showed no statistically significant differences. Harry really can make two very similar instruments! Another interesting result is that, in the further two tests, panels of experienced violinists who played the instruments blindfolded, or who listened to them, also gave similar results.

Three years playing is not enough, it seems to make a discernable difference. Three years is not considered a long time for an instrument of which there are examples still being played after hundreds of years. The investigators hope that this study will continue, with this pair of instruments, for a time comparable with the age of these older violins.

Ra Inta, John Smith and Joe Wolfe

*Violinist Romano Crivici, luthier Harry Vatiliotis and Michael Lea, curator of music at the Powerhouse Museum, with the 'Powerhouse Twins'.*

# ‘On-the-fly’ mapping with Mopra

2004 saw the first operations of ‘on-the-fly’ mapping with the Mopra radiotelescope. Until recently, the main mode of operation of Mopra has been a simple point and shoot method, giving you one spectrum each time you point the telescope. To fully understand astrophysical phenomena, it is essential to know how dust and gas is distributed in the sky, not just what it is doing at one point in the sky. Therefore mapping is a very useful part of astrophysics. The new method of ‘on-the-fly’ mapping has greatly increased the efficiency of the telescope.

I have used this method to observe one interesting region of massive star formation within our Galaxy. The observations were made during October 2004 when the weather was not good enough for our main observing project. The region contains two distinct centres of massive star formation that show starkly different qualities: one appears to be well developed and is associated with a very bright infrared source, the other has no infrared counterpart whatsoever – presumably because it is at such an early phase of evolution that the protostar has no had the chance to heat up its surroundings yet. With no infrared counterpart, this second younger source has been something of a mystery until the recent Mopra observations. The maps show that a whole host of complex molecules – the signatures of star formation – are associated with the younger source and not the older source. $^{13}CO$ (an isotope of carbon monoxide), $HCO^+$ (hydrogenated carbon monoxide), $N_2H^+$ (diazenylium), $CH_3CN$ (methyl cyanide) and even $CH_3OH$ (methanol) are detected here, confirming that this source is one of the youngest sites of massive star formation known.

Andrew Walsh

*The Mopra Telescope, at Coonabarabran, NSW.*

# Teaching Highlights

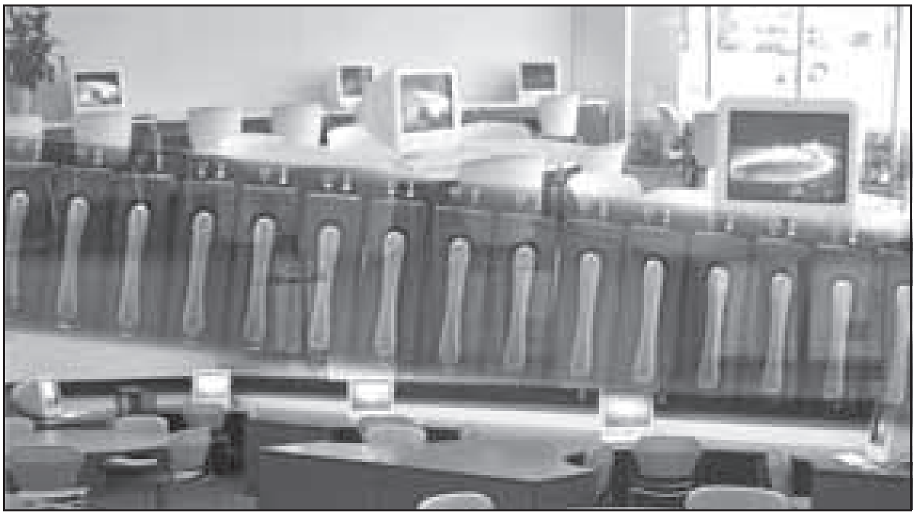
# First year laboratory IT makeover

In the Main Building Alpha Laboratory annex and First Year study areas, Physics Information Technology Support installed 18 new eMacs running Mac OS Panther. Additionally, 48 existing iMacs in the Alpha Laboratory that once ran Mac OS Classic have been upgraded to also run Panther. Legacy Mac OS Classic software was upgraded to the most recent Mac OS versions, and the latest Microsoft Office suite was installed on all Macintoshes. These changes provide a more engaging, stable and homogenous computing environment for students while enabling fine-grained administrative control and automation.

On the management front, the First Year Laboratory server computer has been upgraded to the latest Mac OS server operating system. Account replication and network fail-over to a secondary server creates robustness. Software updates and application overlays are regularly deployed automatically over the network to each Macintosh without human intervention. To speed new workstation deployment, a standard operating environment can be sent over the network to Macintoshes, thus obviating manual operating system installation.

A new tape backup library with a compressed capacity of approximately 1.6 terabytes has been deployed to backup our core workstations and servers. This tape unit facilitates long-term archiving that was not possible using the previous hardware. User files on the undergraduate and general-purpose workstations are now stored on a disk area that can survive a hard disk crash without affecting workstation operation. Critical data such as user files and mail is mirrored to a disk staging area that stores multiple differential copies. In addition to creating several safety layers to protect user data, this mirroring scheme increases the likelihood that data can be recovered in a timely manner.

Kristien Clayton and David Jonas



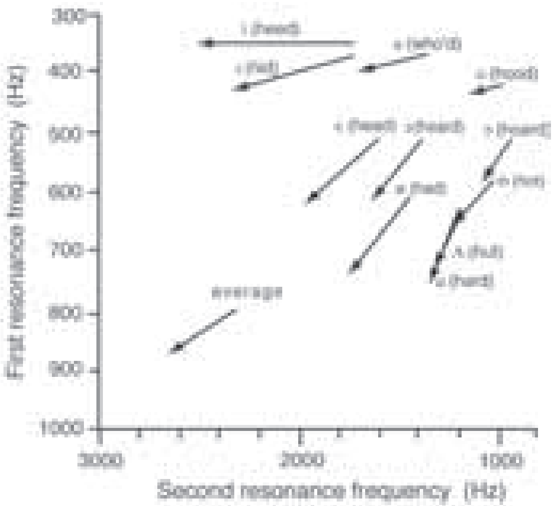
# Physics participation project goes to press

Part of the undergraduate experience in Physics at UNSW is doing real research in a real research lab. Tina Donaldson and Diana Wang did theirs in acoustics, where they were able to experience scientific research all the way from planning to publication — a rare experience for first year students.

The acoustics lab has developed a technique to study the acoustical response of the vocal tract. The technique measures the tract's properties directly, rather than inferring them from the sounds produced. One of its first uses (by an honours student) was to study the resonances of the vocal tract used in the speech of a sample of young male university students—a sample drawn from the school's teaching laboratories. Tina and Diana's project was to study a comparable sample of young female university students and to compare the 'vowel maps', plots of the resonance frequencies that characterises vowel sounds in different languages and accents.

So they brought in their friends, made the measurements and, with a bit of help, did the analysis. The results appeared in a scientific paper, with their supervisors as coauthors. One of the figures from the paper shows that the resonance frequencies are higher for women, although the ratio is much less than the ratio of fundamental frequencies. Different length vocal tracts are one explanation, but social effects are probably important, too: whether you are tall or short you are likely to learn the accent appropriate to your sex.

Tina Donaldson, Diana Wang,
John Smith and Joe Wolfe




*The frequencies of the first two resonances of the vocal tract for the eleven vowels of Australian English. The head and tail of each arrow are the mean values for women and men, respectively. The reversed axes are traditional in phonetics because such a plot closely resembles a plot of jaw height versus tongue position (front-back).*

*Undergraduate students, Diana Wang and Tina Donaldson.*

# An astronomical adventure on Mauna Kea, Hawaii

After a competitive application process, I was awarded time on the James Clerk Maxwell Telescope (JCMT), so I had to travel to Hawaii in August in order to fulfil the observing allocation of five nights. The JCMT is a 15-metre submillimetre telescope located near to the summit of Mauna Kea ('White Mountain') Hawaii at an altitude of 13,500 ft. Fortunately the mountain did not live up to its name, there was no snow fall, and we managed to obtain some first class submillimetre observations destined for my thesis.

After spending a night in Hilo in my 'deluxe ocean view' room, I headed to Hale Pohaku (HP) – located three-quarters the way up the mountain of Mauna Kea at an altitude of 9,000 ft. There is a strict rule in force which dictates that no one for any reason can spend more than 12 hours at the summit of Mauna Kea. This means that astronomers eat, sleep and play at HP, and drive to the summit for observing - a very rough and steep climb in a four wheel drive.

Once at the telescope, we had to climb the stairs (an arduous task at an altitude of 13,500 ft!) to the control room. I had a tour of the telescope, which if you've ever climbed a telescope you would know requires even more stairs. After the exhausting tour, I had to settle in for 9 hours of observations. The upper level of the building in which the JCMT is located also rotates with the telescope throughout the observations. It was rather interesting making bathroom breaks since the toilet (located on the bottom floor, which didn't rotate) appeared to be in a different location each time. The return trip back to the control room was just as disorienting since the stairs would continue to move during your break.

After 5 nights observing and 5 days of data reduction, I said 'goodbye' to HP and returned to Sydney appreciative for the experience to observe at the largest telescope in the world designed for submillimetre observations and for the chance to visit and interact with astronomers from one of the world's first class observatories.

Tracey Hill

*Telescopes on the summit of Mauna Kea. Foreground: The Caltech Submillimetre Observatory (CSO). Centre: The 15m James Clerk Maxwell Telescope (JCMT). Background: The submillimetre array (SMA).*

# Postgraduate students

Eight students were awarded their PhD in 2004. They were:

**Saskia Besier**
Thesis: The proximity effect in low redshift quasars

**Till Boecking**
Thesis: Organic and biofunctional layers on silicon

**Tilo Buehler**
Thesis: The Twin rf-SET: correlated single charge detection on microsecond time-scales

**Timothy Byrnes**
Thesis: Density matrix renormalization group: a new approach to lattice gauge theory

**Emilia Gevorkian**
Thesis: Crystallographic and biophysical studies of recombinant mitochondrial Chaperonin 10

**Tammy Humphrey**
Thesis: Mesoscopic quantum ratchets and the thermodynamics of energy selective electron heat engines

**Jill Rathborne**
Thesis: Young massive stars:  traffic lights for nearby star formation

**Steven Schofield**
Thesis: Atomic-scale placement of individual phosphorus atoms in silicon(001)

Over thirty postgraduate students are studying for their Graduate Certificate, Graduate Diploma, and Masters degree in Optoelectronics and Photonics. At the end of 2004 the first students to study entirely via distance completed their Masters degrees. These students came to UNSW for four intensive weeks completing experiments in the photonics laboratory, but completed the rest of their degree away from the campus, in locations as varied as New Zealand, Malaysia and Mongolia! Distance education is proving a popular option for students in these programs, not just for students living outside Sydney, but for those whose work commitments do not allow them to regularly attend classes on campus.

In 2004 the School offered Postgraduate Assistantships (PA's) for the first time. PA's are postgraduate students in the School who take part in teaching undergraduate laboratory, tutorial and online classes. In addition to a stipend, they also receive training in tertiary education. It is hoped that the scheme will not only provide financial assistance to postgraduate students while they are studying, but that the experience will help when they are seeking jobs after graduation.

Every year the School of Physics holds a postgraduate poster day, where PhD students make posters to present their research to the School. Prizes are given for the best posters; in 2004 the winners were Suzanne Kenyon(first year); Steven Longmore (second year) and Julian Berengut (higher year).

# Exploratorials: linking physics to the real world

In 2004 the School of Physics introduced a new way of teaching physics, which aims to link the theoretical world of the lecture theatre to the real world as we experience it. The development of 'Exploratorials' has been funded by a UNSW Capital Grant and is a collaborative project between Professor Joe Wolfe, Associate Professor Richard Newbury, Dr Maria Cunningham, George Hatsidimitris and Dr John Smith of the School of Physics, and Dr Iain McAlpine of EDTEC.

One of the problems with conventional physics teaching is the gap between lectures and laboratory work. Students fail to make the connections between the theory they learn in lectures, the problems they learn to solve in tutorials, and the workings of the real world. Careful laboratory work is an essential part of any physics course as it is important for the students to gain practical skills and understand the limitations of theory in describing the real world. However, it is only possible to cover a small amount of the theory in experimental work.

In response to the challenge of providing a more integrated course we have introduced 'Exploratorials' – a three hour learning activity that requires students to solve tutorial problems using real equipment. The students have homework questions to do both before and after the Exploratorial to extend the learning experience. There are Exploratorials that cover motion, fluid flow, waves and music, electricity and magnetism, and modern physics.

One of our most popular Exploratorials is on projectile motion: students launch a ball from a metal ramp and have to predict where the ball will land. They use a mixture of measurement and theory to make the prediction, but no practice runs are allowed. When the students are satisfied that they know where the ball will land they tell the laboratory demonstrator who places a cup at the indicated spot. Marking is easy – if the ball lands in the cup the answer is correct!

The students work in groups for the Exploratorials and the element of competition between the groups to see who can get the answer right and who finishes first brings a real atmosphere of excitement to the laboratory, engaging students and teachers alike.

In 2004 Exploratorials were successfully trialled with two physics courses, and we are now looking at developing more Exploratorials and introducing them to other courses.

Maria Cunningham

*Laboratory demonstrator Ra Inta (centre) working with a group of first year students in an Exploratorial.*

# SCHOOL HIGHLIGHTS

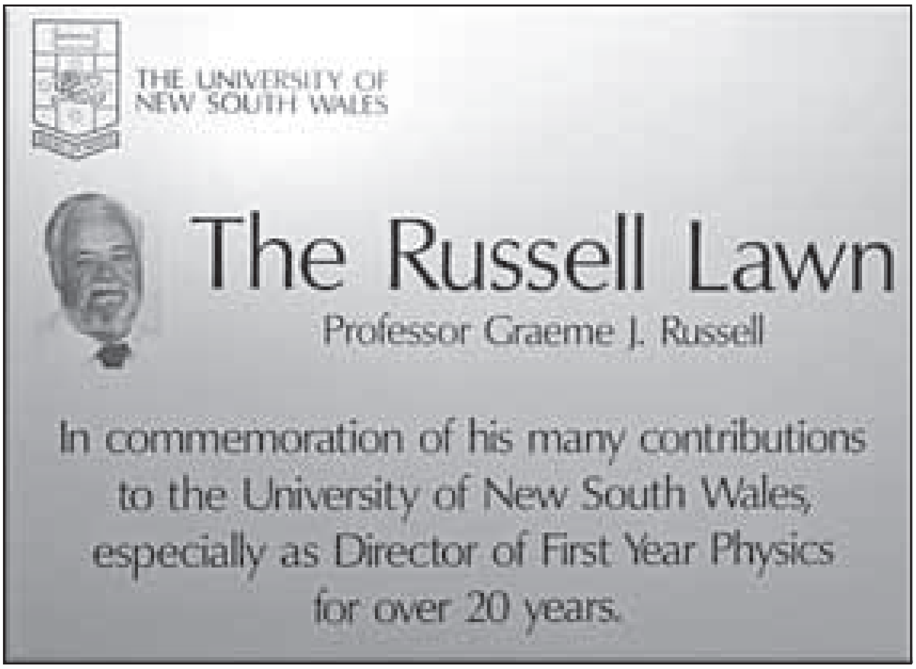
# New look for an old building

The School of Physics is housed in the Old Main Building, the first permanent building to be built on the Kensington campus of UNSW. Over fifty years the university campus has grown around this building. However, what was once the main entrance of the Old Main Building now faced away from the main concourse and most students and visitors entered through courtyards which were also used as loading docks. This was not a welcoming impression of the School! In these same fifty years, teaching methods and technologies have changed. ITET Fellowships and U21 awards had provided staff of the School with opportunities to investigate some of the innovative teaching practices in use around the world, and to implement new teaching methods at UNSW would require new laboratory facilities.

Over the last two years, the School's store, loading dock and gas storage facilities were moved from the courtyard which faced the rest of the campus, to the other side of the building. The first year optics lab was demolished and replaced with a flexible study area which could be used for the newly introduced exploratorials, group work and student presentations. A new entrance to the building was constructed, and the First Year Office was moved downstairs to be near the entrance and the first year labs. The courtyard was landscaped, and Jaycar Electronics donated a gas barbeque, for the use of UNSW staff and students.

In 2004, all construction was finally completed, and in September the official opening was held. The courtyard has been named 'The Russell Lawn', after the late A/Prof Graeme Russell who had been the first year physics director for twenty years. We were honoured to have his family and some of his classmates from the UNSW physics classes of 1958-1960 attend the dedication. After the formalities Gary Johnston, the CEO of Jaycar, and undergraduates from the Physics Student Society fired up the first of what will be many barbeques.

We hope to continue renovating the Old Main Building, and improving our facilities for teaching physics in the 21$^{st}$ century. Hopefully soon we will be able to renovate our second and third year teaching laboratories!




*The previous page shows the new entrance to the School of Physics and part of the newly landscaped Russell Lawn.*

# The transit of Venus

How far away is the Sun? In an attempt to answer this fundamental question the British Admiralty sent Captain James Cook to Tahiti in 1769 measure the transit of Venus. This occurs when the planet comes directly between the Earth and the Sun and so is visible as a black spot, slowly moving across the face of the Sun. Through the application of geometry, measuring the time the transit starts and finishes, as seen from different parts of the Earth's surface, it is then possible to estimate the distance to the Sun. From Tahiti, Cook then set sail to search for the great southern continent, to claim it for the British crown.

Transits of Venus are rare events, occurring in pairs over a century apart. The last transit was in 1882, so when the black dot of Venus crossed the edge of the Sun on June 8$^{th}$ 2004 it was an event no living person had witnessed. In Sydney that day Venus was in the western sky, well placed for observation from UNSW. As Cook's landing place in Botany Bay is also visible from UNSW, the combination of science and history was irresistible. We held a public viewing of the transit, from the Scientia Building on the UNSW campus.

The ABC's Jennifer Byrne compered and Aboriginal elder Uncle Norm Newlin welcomed us to the land of the Eora people. Michael Burton from the Department of Astrophysics, then described the science of the transit and how it was used in an attempt to measure the distance to the Sun (it turned out not to be easy with the instruments available in Cook's day). John Gascoigne, Head of the School of History, then commented on the historical significance of the event which lead to European colonisation of Australia. Finally the Dean of Science, Mike Archer, talked about the impact of biological discoveries made on Cook's venture along the east coast of Australia, and the unique flora and fauna that was recorded.

Four telescopes were placed along the balcony to show the transit in different guises. One was used to project the Sun onto a large screen, so that the progress of Venus could be gauged by all. Other telescopes looked at the Sun through various filters, allowing a direct view of the event, as well as of the solar weather. The fourth telescope was directed towards the planet Jupiter, showing that celestial bodies are indeed visible in the daytime if you know where to look.

If you missed the big event, we get another chance in 2012, but it's a long wait to the next transit after that!

Michael Burton

*Two ways of watching the transit of Venus – through a telescope fitted with a solar filter, or viewing an image of the sun projected onto a screen.*

# ARC Nanotechnology Network

In late 2003 the ARC announced a new funding scheme to establish research networks to support some of Australia's key research areas. The aim of this scheme was to increase interactions and collaborations between researchers working in these key areas by providing funding to support joint workshops, conferences, short and long-term visits, distinguished international visitors, etc.

The Networks scheme consisted of a two stage process – an initial seed-funding round to establish potential networks that would then move through, or amalgamate to form larger networks in a second full networks round.

In the initial seed-funding round, we submitted a proposal to establish the 'Young Investigators Network on Next Generation Electronic Devices', which aimed to bring together and support early career researchers from a wide variety of disciplines (physics, chemistry, biology and engineering) who are working on developing new electronic devices – an area with strong economic and technological opportunity for Australia. This network had seven members from various schools at UNSW, as well as members from CSIRO, University of Queensland, Australian National University, University of Newcastle, University of Wollongong and Flinders University. Our proposal was one of around 120 networks to receive seed-funding from the ARC, however, given that only around 20 networks would survive the next round, it was clear that our network would need to amalgamate with other seed-funded networks to remain viable.

For the full networks round we decided to amalgamate with three other seed-funded networks in closely allied areas of research – the Australian Semiconductor Nanotechnology Network, The Nanoparticle Network and The Australian Network on Microelectronics, Optoelectronics and Micromechanical Systems – to form the ARC Nanotechnology Network, a bid led by Prof. Jagadish from the Australian National University. Ultimately, this larger bid was one of only 24 networks funded and we were awarded $1.9M of funding across 5 years for 2005-2009. As the chief investigator on the 'Young Investigators Network on Next Generation Electronic Devices'' bid, Dr Adam Micolich was invited to be on the management committee for the Nanotechnology network.

The ARC Nanotechnology Network (ARCNN) is now becoming established with an office and two administrative personnel based at ANU. In 2005 the network will run a one and a half day postgraduate symposium to be held in conjunction with the Australian Workshop on Nanotechnology at the University of Western Australia in July 2005. This symposium is to provide a forum where postgraduate students working on nanotechnology research can present their work, meet other students and researchers, and interact with other research groups in Australia. The ARCNN also plans to support nanotechnology-related conferences and workshops, in addition to organizing its own events, as well as provide support for short and long-term collaborative visits for Ph.D. students and early career researchers within Australia, support for distinguished international visitors and perform a number of educational and outreach activities on nanotechnology.

Adam Micolich, Michelle Simmons
and Alex Hamilton

# Maximising potential in physics

At the end of 2003, a group from the School of Physics; Marion Stevens-Kalceff, Maria Cunningham, Susan Hagon and Kate Wilson, were awarded an UNSW Equity Initiative Grant for a project entitled 'Achieving Maximum Potential in the School of Physics' The focus for the 2004 grants was the development of initiatives to bring about the necessary structural and cultural changes to address the under-representation of women in academic positions in Schools/Centres and Faculties within the University.

During 2004, with the assistance of Aileen Woo, a graduate from UNSW's School of Sociology, we have been gathering information on all aspects of academic life within the School of Physics. This has involved collating statistics on all teaching duties, including lecturing, tutorial and laboratory supervision, research student supervision, research grants received, as well as details such as ages and academic levels of staff. Staff also completed a questionnaire about their work. Finally, two focus groups were held, one for female academics, one for males, to explore some of the issues raised by the statistics and questionnaires in greater detail.

The School of Physics currently has 22% female academic staff, which is comparable to the percentages in the student and postdoctoral feeder groups. While there was no evidence of deliberate, systemic discrimination within the School, it was found that the female academic staff had not progressed in their careers at the same rate as their male colleagues. This appears due to a variety of factors including allocation of teaching duties and different career paths taken by male and female staff, especially in the early stages of their academic careers. A final report, including all results and recommendations, is currently being written.

All staff in the School have been very supportive of this initiative and it is hoped that the changes implemented as a result of this research will help develop a more equitable environment, where the full potential of all academic staff can be maximised, not only for the current academic staff, but also for new staff who join the School in the future.

Marion Stevens-Kalceff, Maria Cunningham,
Susan Hagon and Aileen Woo

*Marion Stevens-Kalceff, Maria Cunningham, Susan Hagon and Aileen Woo, who have been investigating the factors influencing academic progression in the School of Physics.*

# Indium and Arsenic:
# School of Physics OHS Committee

Indium in the eye and arsenic in the autoclave are just two of the more exotic safety incidents that weren't expected to occur in our School over the past year.

Investigating incidents such as these is part of the job of Jon Everett, our safety officer, who is also responsible for the overall safe use of hazardous substances, record keeping and hazard reports. Jon works with other safety officers in the Faculty of Science, and reports to the Occupational Health and Safety (OHS) committee, which meets about five times per year.

About twice a year, Jon can be found with Joji Conducto and Bob Starrett, the building SECOs, who have put on their orange helmets and, with the gentle persuasion of the emergency warning system and a bevy of helmeted wardens, orchestrated a smooth and orderly building evacuation.

Jon Everett is also one of the school's qualified first-aid officers. There is one in each of the teaching laboratories, and in many other areas throughout the school.

Of course Jon is not the only person in the school with specific safety related responsibilities. In 2004 the OHS committee had eight other members: Jack Cochrane, chair and general staff representative; John Tann, laser safety officer and general staff representative; Krystyna Wilk, radiation safety officer and academic staff representative; Pritipal Baweja, workshop representative; Justin Dinale, Ra Inta and Paul ten Boom, student representatives; Martin Brauhart, CQCT representative; John Storey, Head of School; and Galina Kaseko, systems development.

Splitting the building up in to smaller areas – laboratories, corridors, office spaces, teaching rooms, etc – and allocating these spaces to an area supervisor, has meant that maintenance, safety inspections, inductions of new staff, training, chemical inventories, and reporting is now managed at a local level. Quarterly inspections have been introduced as a health and safety check for these areas, and the School OHS committee follows up these reports with an annual inspection.


*An undergraduate physics student wearing the correct protective gear and demonstrating a safe way to dispense liquid nitrogen.*

# School visits

This year, as a break from intensive computer programming, Cormac Purcell and Steven Longmore, PhD students from the Department of Astrophysics, visited two high schools with the Starlab inflatable planetarium. Here is an account of one such visit:

A large crowd of curious 12-17 year olds gathered as we began to inflate the silvery canvas dome. Questions ranged from 'Is it a bouncy castle?' to 'Will it take off?' We assured them neither. It resembled nothing so much as a flying saucer squatting in the basketball court.

We had an hour to impart a wonder of the heavens to 30 excited teenagers squeezed into 5-m diameter circle. Dimming the lights brought some squeals from the more nervous, but these soon turned into gasps as we 'turned on' the night sky. If only we had such power in the real world! The most difficult part of astronomy is grasping the scale of the Universe. Steve brought it all down to earth using ping-pong balls and peanuts. I continued with a description of the life cycle of stars. Impressively, as soon as I asked which was our nearest star I was immediately told 'The Sun'. No fooling this lot.

We touched on the lighter side of astronomy and told the story of Orion fighting Scorpio and why Corvus the crow was cast into the heavens for losing Crater, the cup of Zeus.

Of course there was some practical lessons on how to find your way home from the pub, by finding south using the Southern Cross.

Speaking from experience there is nothing as rewarding as talking to a group of enthusiastic young people about a subject you love. I encourage everyone to try it.

Cormac Purcell

*The Starlab inflatable planetarium.*

*Steven Longmore, inside the Starlab, explaining the night sky to high school students.*

# Dirac Medal awards

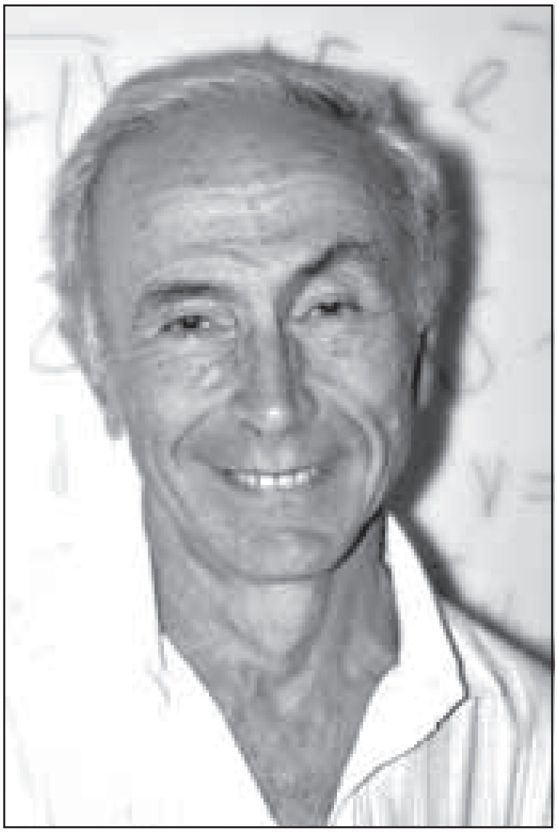
The Silver Dirac Medal for the Advancement of Theoretical Physics is awarded to commemorate the visit to the University in 1975 of Professor P.A.M. Dirac, one of the greatest theoretical physicists of the twentieth century. Two medals were awarded in 2004.

The first medal was awarded to Professor Edward Shuryak, the Director of the Institute for Nuclear Theory at the State University of New York at Stonybrook. He proposed the so-called 'instanton liquid' model of the QCD vacuum, considering the "vacuum" (ground state) as an ensemble of interacting non-linear fluctuations called instantons. This picture has recently been shown to predict the spectrum of elementary particles very well. Another theme of his research has been the behaviour of matter at extreme temperatures and pressures, when 'elementary' particles melt to form a completely new phase of matter, called the 'Quark-Gluon Plasma' (QGP), He showed that under such conditions the 'colour' charges of the quarks are screened rather than confined.

Professor Shuryak gave a public Dirac lecture on the topic 'Quark-Gluon Plasma: Part of the Big Bang Recreated in the Laboratory'. To observe and study the Quark-Gluon Plasma (QGP), a dedicated collider complex RHIC has been built, at Brookhaven National Laboratory. Two gold nuclei, accelerated to 200 GeV per nucleon each, are smashed together, producing a small fireball of QGP. It was found that it explodes hydrodynamically, in what was called a Little Bang, with many amusing parallels to the Big Bang.

The second medal was awarded to Professor Iosif B. Khriplovich, Chief Scientist at the Budker Insititute of Nuclear Physics at Novosibirsk in Russia, and Chair of Theoretical Physics at Novosibirsk University. Professor Khriplovich is a Member of the Russian Academy of Science. His most striking discovery is that in so-called non-Abelian gauge theories the interaction is reduced at small distances ('asymptotic freedom'). The Standard Model of elementary particles was constructed on the basis of these theories. Khriplovich published his calculation in 1969 for the SU(2) theory describing the weak interaction part of the Standard Model. Four years later a similar result was obtained for the strong interaction part of the Standard Model (Quantum Chromodynamics) by Politzer, Gross and Wilczek. The discovery of asymptotic freedom made a revolution in high energy physics, and last year Politzer, Gross and Wilczek were awarded the Nobel Prize for this work. Khriplovich has also made an important contribution to the discovery of violations of the fundamental symmetry – parity – in atoms, and the discovery of an electromagnetic moment violating fundamental symmetries – the nuclear anapole moment. He gave a public Dirac Lecture on 'Black Holes, Classical and Quantum', demonstrating that black holes should possess entropy and temperature. Thus, black holes should radiate.

Chris Hamer



*Professor Iosif Khriplovich*

# Teaching and research awards for Joe Wolfe

Professor Joe Wolfe was awarded the 2004 Australian University Teaching Committee's Award for Physical Sciences and Related Studies. He was one of six academics from universities around Australia honoured with an individual teaching award. The Australian Awards for University Teaching, now in their eighth year, are focused on raising the status of university teaching. Joe's award nomination cites a 'highly motivational teacher with tremendous commitment and outstanding talent who is extremely responsive to students' needs'. Especially noted was a new course, Physics Thinking, developed by Joe for advanced science students.

In December 2004, Joe was also awarded the French Acoustical Society's International Medal (la Médaille Étrangère) for his outstanding results in the area of music acoustics.

Joe has achieved the rare accomplishment of winning accolades in teaching and research at the same time.

*On December 8, 2004, Federal Minister for Education Brendan Nelson (left) presented Professor Joe Wolfe with the Australian University Teaching Committee's Award for Physical Sciences and Related Studies.*

# Honorary Doctorate awarded

In October 2004, UNSW awarded an honorary Doctorate of Science to Mr Peter Gillingham, one of the world's most eminent instrument scientists and telescope engineers.

Mr Gillingham has had a career in astronomy spanning more than 30 years and his contributions to astronomical instrumentation have had a profound influence on developments in this field. He has played a leading role in the development of the Anglo-Australian Telescope and also made a significant contribution to the success of Japan's largest telescope, Subaru. He was the first person to promote Antarctica as a site for high-resolution optical astronomy, and was instrumental in establishing the UNSW Antarctic astronomy group. This group now leads the world in Antarctic site testing, and in 2004 they obtained results which validated Mr Gillingham's theory that Dome C in Antarctica will provide viewing conditions which are 2-4 times better that anywhere else on earth.

*Mr Peter Gillingham, at the UNSW graduation ceremony where he was awarded an honorary Doctorate of Science. (Photo: Alex Clark, UNSW)*

# Awards and Prizes

**Michael Burton**
Finalist, Eureka Awards for Science – Book Prize (Tales of the Universe)

**Aliz Derekas**
First prize for the best poster presentation by a student at the 2004 ASA Conference for the poster 'A first-overtone RR Lyrae star with cyclic period changes.'

**Paul Dickens**
New South Wales Physics and Industry workshop in 2004, first prize (shared) for his poster 'Modeling the acoustics of woodwind instruments: a new tool for makers.'

**David Kruss**
First prize (shared with Richard Provo, University of Auckland), practical section, ANU National Undergraduate Physics Competition

**Michael Murphy**
'Best PhD thesis from the Faculty of Science' for his work on searching for space-time variations in the fine-structure constant

**Frank Rueß**
Best student oral contribution, 28th Annual Condensed Matter and Materials Meeting, Wagga, Australia.

**Andrew Sunderland**
First prize, theory section, ANU National Undergraduate Physics Competition

**Joe Wolfe**
Australian University Teaching Committee's Award for Physical Sciences and Related Studies

**Joe Wolfe**
The Médaille Étrangère of the French Acoustical Society for his outstanding results in the area of music acoustics

*Andrew Sunderland being presented with first prize in the theory section of the ANU National Undergraduate Physics competition*

*David Kruss and Richard Provo, winners of the practical section of the ANU National Undergraduate Physics Competition. (Photos: ANU)*

# Staff of the School of Physics

## Professors

**Robert Clark**
Experimental investigation of quantum physics in low dimensional semiconductors and semiconductor nanostructures and their application to the next generation of electronics and computing.

**Hans Coster**
Electrical properties of living cells and the membranes surrounding cells. Impedance spectroscopy and the electro-dynamics of cells in radio frequency electric fields leading to the creation of hybrid cells which have the potential to produce therapeutic materials such as monoclonal antibodies. Related research includes electrodisinfection of water, biosensors and molecular films.

**Warrick Couch**
Optical astronomy, observational cosmology, galaxy evolution and formation particularly in rich clusters; large-scale structure and galaxy redshift surveys; supernovae, distant searches, rates in nearby galaxies.

**Victor Flambaum**
Theoretical Physics: Publications in atomic, nuclear, elementary particle, solid state, astrophysics, quantum chaos and statistical theory.

**Michael Gal**
Experimental Condensed Matter Physics: the study of the optical properties of semiconductors, semiconductor layer structures and interfaces; optoelectronics; optical instrumentation, particularly modulation spectroscopy and ultra-fast laser spectroscopy.

**David Neilson**
Condensed Matter Theory: Strongly correlated electron systems in semiconductors; metal-insulator transition in 2D; disordered electron glass; electron bi-layers; quantum wires; superconductor-nanostructure interfaces.

**Michelle Simmons**
Experimental condensed matter physics: nanofabrication and cryogenic measurement of quantum electronic devices. Understanding how ultra-pure, low dimensional systems conduct electricity. Atomic-scale fabrication of a solid-state silicon-based nuclear spin quantum computer using scanning tunneling microscopy (STM) and molecular beam epitaxy (MBE).

**John Storey**
Infrared, far-infrared, mm and radio astronomy, HII regions, molecular clouds and star formation; infrared detectors and instrumentation; electronics, imaging, Antarctic astronomy.

**Oleg Sushkov**
Quantum many body theory including work in condensed matter, nuclear and atomic physics.

**Joe Wolfe**
Musical Acoustics: investigations of musical instruments, of the human vocal tract and of their interaction. Information, coding and processing of sound in the ear and in artificial systems. Thermal physics in biology, especially cryobiology and water relations.

## Associate Professors

**Michael Ashley**
Astronomical instrumentations; infrared astronomy in Antarctica; optical transients from gamma ray bursts; wide-field photometric surveys.

**Michael Box**
Radiative transfer in the earth's atmosphere; multiple scattering, perturbation techniques; climate effects of aerosols, remote sensing from satellites; scattering by haze and cloud particles.

**Michael Burton**
Infrared astronomy, including the interstellar medium, supernova remnants, shock and fluorescent excitation of molecular clouds, star formation and the galactic center; millimeter astronomy, Antarctic astronomy, science communication.

**Seán Cadogan**
Magnetism and hyperfine interactions in metallic compounds; Amorphous metallic alloys; Mossbauer Spectroscopy, neutron scattering, muon spin relaxation.

**Paul Curmi**
Structure and dynamics of biological macromolecules; x-ray crystallographic studies of protein structure; molecular dynamics simulations; protein folding and stability, understanding the function of enzymes at atomic level.

**Chris Hamer**
Lattice gauge theory of the strong interactions; critical phenomena in statistical mechanics.

**Alex Hamilton**
Quantum transport phenomena in low dimensional semiconductor structures (2D quantum wells, ID quantum wires, and 0D quantum boxes), and the effects of inter-device interactions in multi-component semiconductor nanostructures; solid state quantum computation.

**David Miller**
Condensed matter physics

**Gary Morriss**
Equilibrium and nonequilibrium statistical mechanics, chaotic dynamical systems, molecular hydrodynamics.

**Richard Newbury**
Experimental condensed matter: low dimensional semiconductor systems, mesoscopic devices. Studies involving very low temperature, high magnetic field. High pressure physics. Superfluidity and superconductivity.

**John Webb**
Cosmology, hubble space telescope observations; quasar spectroscopy; light element abundances; variability in the Fundamental Constants.

## Senior Lecturers

**Mary Beilby**
Molecular basis of salt tolerance in plants. Unusual transport systems in marine algae bryopsidophyceae multimedia in research and teaching.

**Marlene Read**
Surface state band structure, electron and positron scattering from solid surfaces, surface structure analysis. Electrodynamics; relativistic mechanics ('special relativity'); geometrodynamics ('general relativity'). Physics education.

**John Smith**
Electrical characteristics of biological and artificial membranes. Electrodiffusion theory. Acoustics of musical instruments and the vocal tract; optimization of impedance measurements

**Marion Stevens-Kalceff**
Condensed matter physics, microcharacterisation of the defect structure of wideband gap materials, irradiation induced defect generation and transformation, advanced electron and ion microscope techniques and scanning probe microscopy.

## Lecturers

**Gail Box**
Inversion of multispectral radiometer data to obtain information about aerosol size distribution; aerosols and the visual air quality of Sydney; relationship between physical and chemical properties of aerosols and their optical properties.

**Maria Cunningham**
Molecular line astronomy; millimetre wave astronomy; observational interstellar chemistry; biomolecules in the interstellar medium; chemistry of star formation regions.

**Peter Eyland**
Spherical cap harmonic analysis.

**Adam Micolich**
Experimental studies of the electron properties of strongly interacting semiconductor nanostructures. Fabrication and measurement of organic electronics and nanodevices.

**Krystyna Wilk**
Isolation, characterization and structure determination of algal light harvesting proteins. Research involves crystallization of proteins and analysis of x-ray diffraction data obtained for protein crystals.

## Emeritus Professors

**Heinrich Hora**
Laser and plasma theory (quantum and relativistic effects) multivalley band theory for semiconductors.

**H. Julian Goldsmid**
Thermoelectric materials and devices.

**Jaan Oitmaa**
Solid state theory: Phase transitions and critical phenomena; magnetism; lattice dynamics; superconductivity.

## Adjunct Professors

**Brian Boyle**
Cosomology, the large scale structure of the Universe and the properties of quasars.

**Neville Fletcher**
Music acoustics.

**Robert Robinson**
Strongly correlated $f$-electron systems, magnetism in uranium intermetallics, the dynamics of amorphous materials and neutron-scattering instrumentation.

## Adjunct Associate Professors

**Michael James**
Membrane.

**Anatoly Rosenfeld**
Research and development of silicon semiconductor radiation detectors for spectrometry and dosimetry of nuclear radiation with application in high energy physics and radiation oncology and diagnostic. Study of change collection in silicon detectors and their radiation damage. Theoretical and experimental macro-micro dosimetry in mixed radiation fields on different radiation oncology modalities.

## Adjunct Senior Lecturers

**Peter Barnes**
Astrophysics.

**Nigel Freeman**
Medical physics.

**Galina Kaseko**
Antibody response of human lymphocytes upon antigenic stimulation in vitro (in vitro immunization of human lymphocytes).

**Tohsak Mahaworasilpa**
Effects of electric fields on biological cells; electro-mechanics of biological cells; electrical cell fusion for the production of human hybridomas; human monoclonal antibody production from hybridomas.

**Richard Smart**
Development and validation of internal dosimetry techniques with specific application to modalities.

## Research Staff

**Soren Andresen**
Fabrication, measurements and modelling of silicon based quantum computer devices based on electronic states of individual phosphorus donors.

**Indra Bains**
Astrophysics.

**Kenji Bekki**
Astrophysics; numerical simulations of galaxy processes.

**Christopher Blake**
Astrophysics; large-scale structure studies using distant radio galaxies; cosmology.

**Till Boecking**
Optoelectronics.

**Rolf Brenner**
Design, fabrication and low-temperature electrical characterization of phosphorous-in-silicon devices, fabricated both by ion-implantation (top-down) and STM lithography (bottom-up)

**Louise Brown**
Biophysics.

**Tilo Buehler**
Development of fabrication and measurement technology towards quantum limited detectors of relevance for quantum computing.

**Robert Bursill**
The theory of excited states in conjugated molecules, computational quantum chemistry, low-dimensional systems in condensed matter, lattice gauge theory.

**Matthew Butcher**
Use of STM lithography in silicon to fabricate novel quantum electronic devices, and installation of a new four point probe system for the electrical characterization of novel hybrid silicon-organic devices.

**Stephen Curran**
Astrophysics- observational cosmology.

**Neil Curson**
Fabrication of nanoscale devices and studies into gas/surface reactions, using scanning tunneling microscopy.

**Romain Danneau**
Organic electronic devices

**Andrew Ferguson**
Application of low temperature measurement of silicon nanostructures to the quantum measurement program.

**Hsi Sheng Goan**
The strength of hyperfine and exchange interactions of P donors in Si. Characterise sources of noise and decoherence in SETs.

**Frederick Green**
Theory of non-equilibrium transport and noise in nanostructures and devices.

**Steven Harrop**
Structure and architecture of proteins by x-ray crystallography.

**Fay Hudson**
Nanofabrication and infrastructure development for the Integrated Quantum Computer Devices program.

**Neil Kemp**
Mesoscopic devices.

**William King**
Protein structure.

**Michael Kuchiev**
Multiphoton many-electron processes in atoms in strong laser fields. Atomic collisions which result which result in the final states with several low-energy charged particles; physics of instantons and its application to quantum gravity.

**Jon Lawrence**
Astrophysics.

**Charles Lineweaver**
Cosmology: temperature fluctuations in the cosmic microwave background; cosmological constant; combining constraints from the cosmic microwave background with constraints from other cosmological data; exobiology.

**Lars Oberbeck**
Fabrication of atomic-scale devices in silicon using scanning tunneling microscopy (STM) and molecular beam epitaxy (MBE) towards silicon quantum computing.

**Louise Ord**
Astrophysics.

**Andre Phillips**
Airborne remote sensing; infrared instrumentation and satellite communications.

**Ali Rashid**
Organic electronic devices

**Thilo Reusch**
Using scanning probe microscopy to fabricate novel quantum electronic devices in silicon and scanning tunneling spectroscopy to help identify different adsorbates on the silicon surface and the use of different substrates for gating devices.

**David Reilly**
Physics of quantum-measurement of cryogenic (mK) temperatures, focusing on radio-frequency single electro-transistors and spin interactions in quantum wires.

**Virginia Shepherd**
Plant cell biology; fluorescence microscopy, cytoskelton, cell-to-cell communication, dynamic vacuoles, action potentials, the ascent of sap, Australian native fish (especially gudgeons) ostracods, life of temporary ponds, history and philosophy of science; life and work of JC Bose.

**Jesko Sirker**
Solid state theory.

**Alexandre Tarnopolsky**
Music acosutics.

**Stephen Thomas**
Atmospheric Physics.

**Panayiotis Tzanavaris**
Astrophysics.

**Andrew Walsh**
Astrophysics.

**Wilfred Walsh**
Astrophysics.

**Alexander Weisse**
Solid state theory.

**Matthew Whiting**
Astrophysics.

**Tony Wong**
Astrophysics.

**David Woods**
Astrophysics; galaxy clustering and evolution, gravitational lensing, high redshift galaxy clusters and Virtual Observatory development.

**Wei Hong Zheng**
Lattice gauge theory, statistical physics and condensed matter theory. Linked cluster expansion techniques; phase transition and critical point phenomena.

## Visiting Professors

**Wallace Geldart**
Solid state theory.

**Poul Erik Lindelof**
Nanostructures.

**Benno Schoenborn**
Biophysics – neutron diffraction and impedance studies of important biomolecules.

**Alan Walker**
Mechanisms of solute transport in plant cells; models for mycorrhizal infection and root growth in plants and of combined nitrogen movement through ecosystems.

## Visiting Associate Professor

**Robert Stening**
Electric currents and fields in the ionosphere, winds and tides in the upper atmosphere which drive these currents. Lunar tidal effects on the ionosphere; computer models of the low-latitude ionosphere.

## Visiting Fellows

**Arthur Anderson**
Use of ultrasonic techniques to study oxygen related structural changes and processes in high temperature superconductors and the relationship of these phenomena to superconductivity.

**Sundar Christopher**
Atmospheric physics

**Vladimir Dmitriev**
Atomic and nuclear theory.

**Michael Drinkwater**
Hidden galaxies in the local universe. Leader of the Fornax Spectroscopic Survey in collaboration with A/Prof. Warrick Couch (UNSW) and A/Prof. Rachel Webster (Melbourne).

**Madan Kaila**
High temperature superconductor materials and devices; to develop materials/devices for optical/infrared radiation detection; carry out mathematical/computational modelling to design optimum performance detectors for use at 77K.

**Tooru Taniguchi**
Theoretical physics.

**Christopher Young**
Photometric surveys of galaxies.

## Visiting Research Fellow

**Mika Jormakka**
Protein structure.

## Research Assistant

**Melinda Taylor**
Astrophysics

## Administrative Staff

**Ranji Balalla**
First Year Office

**Joji Conducto**
Administration & Finance

**Patricia Furst**
Administration & Teaching

**Susan Hagon**
Teaching

**Karen Jury**
CQCT

**Venus Lim**
CQCT

**Stephen Lo**
Administration & Finance

**Galina Kaseko**
Administration

**Savita Sardana**
CQCT

**Alisha Toft**
CQCT

**Robert Walton**
CQCT

## Professional Officers

**Nathan Boddam-Whetham**
CQCT

**Gabriel Caus**
First Year Computing Laboratory

**Terry Chilcott**
Biophysics

**Jeremy Chu**
Atomic Fabrication Facility Laboratory

**Jack Cochrane**
Magnetic Materials & Mesoscopic

**Vladimir Dzuba**
Theoretical

**Jon Everett**
Astrophysics

**David Jonas**
Computing

**Patrick McMillan**
Third Year Laboratory

**Barry Perczuk**
Third Year Laboratory

**Bob Starrett**
Semi-Conductors

**John Tann**
Optoelectronics & Musical Acoustics

**Frank Wright**
SNF

## Technical Consultant UNIX

**Kristien Clayton**
Computing

## Cryogenics Manager

**David Barber**
CQCT

## Senior Technical Officers

**Michael Benton**
Second Year Laboratory

**George Hatsidimitris**
Webmaster

**Garry Keenan**
Demonstration Unit

**Ping Lau**
Electronic Workshop

**Andre Skougarvesky**
CMP & SNF

## Technical Assistants

**Diana Edler**
First Year Laboratory

**Susan Fraser**
First Year Laboratory

## Acting Foreman

**Ken Jackson**
Mechanical Workshop

## Laboratory Craftsman

**Pritipal Baweja**
Mechanical Workshop

## Store Officer

**Dave Ryan**
Administration

## Casual Research Assistants

**Andrew Botros**
Musical Acoustics

**Jane Cavanagh**
Musical Acoustics

**Yi Qin**
Atmospheric Physics

**Frank Reuss**
Quantum Electronic Devices

**Tamara Reztsova**
Atmospheric Physics

**Sebastian Schnelle**
First Year Teaching

**Thomas Sobey**
CQCT

**Aileen Woo**
Equity Project

## Casual OHS Coordinator

**Michelle Fitzgerald**
CQCT

## Casual Technical Officers

**Dror Ben-Naim**
First Year Teaching

**Jessica Dempsey**
First Year Teaching

**Jamie Kelly**
First Year Teaching

**Steven Longmore**
Astrophysics

## Casual Technical Assistants

**Paul Dickens**
Demonstration Unit

**Ra Inta**
Demonstration Unit

**Tamara Reztsova**
Demonstration Unit

## Casual Laboratory Supervisor

**Jack Sandall**
Student Staff Workshop

## Casual Professional Officer

**Michelle Rudd**
CQCT

# Postgraduate students

**Marc Ahrens**
Supervisors: A/Prof A. Hamilton; Dr A. Greentree
Investigations of Coherent Effects in Qubits Using High-Frequency and Fast Pulse Electronics

**Christopher Angstmann**
Supervisors: A/Prof G. Morriss; A/Prof P. Curmi
Dynamical Systems, Application to the Lorentz Gas

**Elizabeth Angstmann**
Supervisor: Prof V. Flambaum
Variation of Fundamental Constants

**Julian Berengut**
Supervisor: Prof V. Flambuam
Many-Body Theory and Violation of Fundamental Symmetries

**Alan Blood**
Supervisors: Prof H. Coster; Dr T. Chilcott
Biological Effects of Alternating Electric Fields

**Zahra Bouya**
Supervisors: Dr G. Box; A/Prof M. Box
Atmospheric Aerosols and Effects in Sydney

**Rolf Brenner**
Supervisors: Prof R. Clark; A/Prof A. Hamilton
Measurement of $Al/Al_2O_3$ Single Electron Transistor Devices

**Paolo Calisse**
Supervisor: Prof J. Storey
Antarctic Site Testing for Astronomy

**Jessie Christiansen**
Supervisors: A/Prof M. Ashley; Prof J. Storey
Extra Solar Planets from Antarctica

**Warrick Clarke**
Supervisor: A/Prof A. Hamilton
Experimental Condensed Matter Physics

**Nadia Court**
Supervisors: Prof R. Clark; Dr D. Reilly
Readout and Control for a Silicon Quantum Computer

**Neil Crighton**
Supervisor: A/Prof J. Webb
Observational and Theoretical Cosmology

**Steven Crothers**
Supervisors: A/Prof J. Webb; A/Prof M. Ashley
Extra-solar Planets: Optimal Photometry Methods

**Jessica Dempsey**
Supervisor: Prof J. Storey
Antarctic Astrophysics

**Aliz Derekas**
Supervisor: A/Prof M. Ashley
Astrophysics

**Paul Dickens**
Supervisors: Prof J. Wolfe; Dr J. Smith
Flute Acoustics

**Thi Hanh Dinh**
Supervisor: Prof V. Flambaum
Theoretical Physics

**Chas Egan**
Supervisors: A/Prof J. Webb; Dr C. Lineweaver
Astrophysics

**Claudia Fritz**
Supervisor: Prof J. Wolfe
Interaction Between The Clarinet and the Vocal Tract of the Player

**George Georgevits**
Supervisors: A/Prof M. Ashley; Prof J. Storey
Astrophysics

**Kuan Goh**
Supervisors: Prof M. Simmons; Dr L. Oberbeck
Encapsulation and Electrical Isolation of Phosphorous Qubits in Silicon

**Michael Green**
Supervisor: Prof J. Wolfe
Acoustics of Organ Pipes, Especially Scaling and Related Phenomena

**Daniel Grether**
Supervisors: Dr C. Lineweaver; A/Prof M. Ashley
Celestial Mechanics, Exoplanets, Statistical Analysis

**Taleb Hallal**
Supervisor: Dr G. Box
Atmospheric Physics

**Toby Hallam**
Supervisors: Prof M. Simmons; Dr L. Oberbeck
Hydrogen Lithography as a Tool to Realising Atomic Scale Devices

**Marton Hidas**
Supervisor: A/Prof J. Webb
Observational Astrophysics

**Tracey Hill**
Supervisors: A/Prof M. Burton; Dr M. Cunningham
Massive Star Formation

**Suhrawardi Ilyas**
Supervisor: Prof M. Gal
Optical Spectroscopy

**Ra Inta**
Supervisors: Prof J. Wolfe; Dr J. Smith
Guitar Acoustics

**Suzanne Kenyon**
Supervisors: Prof J. Storey; A/Prof M. Ashley
Instrumentation for Antarctic Astronomy

**Oleh Klochan**
Supervisor: A/Prof R. Newbury
Transport in Low Dimensional Semiconductors

**Maja Kuzmanoski**
Supervisor: A/Prof M. Box
Atmospheric Radiation

**Andreas Luescher**
Supervisor: Prof O. Sushkov
Condensed Matter Physics - Strongly Correlated Electrons

**Dene Littler**
Supervisors: Dr S. Breit; A/Prof P. Curmi
Structure of CLIC Proteins

**Steven Longmore**
Supervisors: Prof J. Storey; A/Prof M. Burton
Star Formation

**Mykhaylo Marchenko**
Supervisor: Prof V. Flambaum
Many-Body Theory

**Dane McCamey**
Supervisor: A/Prof A. Hamilton
Quantum Computing: Studies of Silicon Interfaces, Charge States and Spin Properties

**Erin McKay**
Supervisor: Dr R. Smart
Radiation Dosimetry Techniques

**John Mclennan**
Supervisors: Prof J. Wolfe; Dr J. Smith
Accoustics and Mechanics of Violins and Components of Violins

**Gabriel Mititelu**
Supervisor: A/Prof J. Webb
Astrophysics

**Timur Mukhamedjan**
Supervisor: Prof O. Sushkov
Strongly Correlated Electrons

**Andrew Mynott**
Supervisors: A/Prof P. Curmi; Dr L. Brown
The Relationship Between Star Formation and Turbulence in Molecular Clouds

**Johan Noor**
Supervisor: Prof H. Coster
Membrane Biophysics

**Matthew Owers**
Supervisors: Prof W. Couch; Dr P. Nulsen
Galaxy Evolution Studies with a Particular Emphasis on Evolution in Clustered Environments

**Masoumeh Pashaeinejad**
Supervisor: Prof B. Allen
Targeted Alpha Therapy

**Michael Pracy**
Supervisor: Prof W. Couch
Evolutionary Studies in Clusters of Galaxies

**Cormac Purcell**
Supervisor: A/Prof M. Burton
Massive Star Formation

**Peter Reece**
Supervisor: Prof M. Gal
Optical Spectroscopy of Semiconductors

**Frank Ruess**
Supervisors: Prof M. Simmons; Dr N. Curson
Towards the Realisation of a Silicon Based Quantum Computer

**Steven Schofield**
Supervisors: Prof R. Clark; Prof M. Simmons
Atomic Manipulation of Silicon Surfaces Using STM

**Clare Sloggett**
Supervisor: Prof O. Sushkov
Lattice Gauge Theory

**Robert Smalley**
Supervisors: A/Prof J. Webb; A/Prof M. Ashley
A Search for Extra Solar Planets

**Philip Smith**
Supervisors: A/Prof P. Curmi; Dr L. Brown
Biophysics

**Patricia Sparks**
Supervisors: Dr M. Cunningham; A/Prof M. Burton
Molecules in External Galaxies

**Jutta Stark**
Supervisors: Dr C. Lineweaver; A/Prof J. Webb
Cosmology and Information Theory

**Paul ten Boom**
Supervisor: A/Prof J. Webb
Cosmology

**Philip Thomson**
Supervisor: Dr J. Dunlop
Acoustic Measurements in Marine Sediments

**Hiroyuki Toyozumi**
Supervisor: A/Prof M. Ashley
Computational Astronomy

**Tony Travouillon**
Supervisor: A/Prof M. Burton
Antarctic Astronomy

**Alexander Von Brasch**
Supervisor: Prof J. Oitmaa
Condensed Matter Theory

**Rena Widita**
Supervisors: Dr L. Holloway; Prof H. Coster
Radiotherapy Planning

**Matthew Williams**
Supervisor: Dr P. Hoban
Intensity Modulated Radiotherapy

**Carlin Yasin**
Supervisor: Prof M. Simmons
Experimental Condensed Matter Physics