DEPARTMENT OF PHYSICS
HONOURS PROJECTS – 2016

Honours Coordinator: Prof B Dawson
Theoretical/Maths Physics Adviser: Dr R Young
Medical Physics Adviser: Dr S Penfold
Guidelines for choosing a project.

In the process of selecting a research topic, begin by investigating offerings from at least two of the sections in this handbook. The sections broadly reflect the research groupings within Physics. You need to discuss specific projects with at least one of the supervisors named with each project.

It is also possible to undertake a project that is Physics by its nature but is offered outside of the Physics discipline. Such projects are usually not listed in this handbook. If you have a strong interest in such a project, you should discuss this with the Honours Coordinator to see if the project is suitable, and if appropriate supervision is possible.

You are to identify two projects to form your first and second choices. If there is more than one supervisor named, you will need to specify the principal supervisor - of your choice.

Choosing a project is not like an auction, or a fire sale, where the goods go either to the highest bidder or to the first comer. Final decisions on who does which project are not made until all students have indicated their preferences. This is done as early as possible in the academic year.

In several sections, specific projects are not listed, rather broad areas are given, and the actual projects are decided in consultation with your chosen supervisor. In the other sections, the projects are more specific and in the event that more than one student chooses a project, discussions will take place between the students, supervisors and the Honours Coordinator and decisions taken accordingly.

Once you have a project, you need to choose your principle supervisor and discuss with them, the possible appointment of a co-supervisor(s). Having a co-supervisor is important, because there may be absences (foreseen or unforeseen) of the principal supervisor during the year, and you will then always have a source of advice. The Honours Coordinator can assist with these discussions.

It occasionally happens that a student discovers, after embarking upon it, that the project is unsuitable for them. Hopefully this realisation will happen (if it does happen) early in the year and a new project found. If you find that you are in this situation you should discuss this with the Honours Coordinator as soon as possible.

As part of your project you will be expected to present a twenty minute talk to your fellow students and interested staff. This will happen in late August or early September. Though compulsory, the talk is not actually assessed – it’s function is to make you assess your project and, especially, what you need to do to wrap up the project. You will also need to write a report (a short thesis) on what you accomplished in your project. This is assessed and will be due at the end of October. The remaining assessment takes the form of an interview in which you discuss the project with a panel of four or five academic staff members of Physics.
A - SPACE AND ATMOSPHERIC PHYSICS
(Supervisors: Prof Iain Reid, Assoc Prof Murray Hamilton, Dr David Ottaway, Dr Andrew MacKinnon, E/Prof Bob Vincent, Dr Bronwyn Dolman, Dr Joel Younger and Dr Stuart Anderson)

A-1 Characterisation of Southern Mid and High Latitude Ionospheric Clutter (MacKinnon, Ward and Holdsworth)
A-2 Temperature Measurement in the Upper Atmosphere using Meteor Radar (Reid, Younger)
A-3 Design of a Mini-Doppler Rainfall Radar (Reid & Dolman)
A-4 Meteorological Phenomena Observed in Sonde Data (Reid, Dolman & MacKinnon)
A-5 Radar Imaging (and Radar Interferometry) of the Atmosphere (Reid)
A-6 A Mini-VHF radar (Reid & MacKinnon)
A-7 A GPS-Locked Remote Radar Receiving System (Reid)
A-8 VHF Observations of Ionospheric Echoes (Reid & Vincent)
A-9 Active and Passive Measurement of Atmospheric Trace Gases (Hamilton & Vincent)
A-10 Radio Acoustic Sounding System (RASS) for Temperature Profiling (MacKinnon & Reid)
A-11 Understanding Atmospheric Dynamics Using Rayleigh Scattering (Ottaway, Reid & MacKinnon)
A-12 Radar Estimations of Rainfall (Reid & Dolman)
A-13 Portable UHF Wind Profiling Radar (Reid & Dolman)
A-14 Radar and Lidar measurements of vertical velocity (Reid & Dolman)
A-15 Balloon Observations of the Atmosphere (Reid & Vincent)
A-16 GPS Measurements from Ground and Space (Vincent & MacKinnon)
A-17 Optical Studies of the 80 to 100 km Height Region (Reid)
A-18 Meteor Astronomy Using Single-Station Meteor Radar (Reid & Younger)
A-19 Cloud microphysics (Hamilton)

B - HIGH ENERGY ASTROPHYSICS
(Supervisors: E/Prof Roger Clay, Prof Bruce Dawson, Dr Jose Bellido, Assoc Prof Gavin Rowell and Dr Gary Hill)

B-1 Studying the Highest Energy Particles in Nature with the Pierre Auger Observatory (Dawson, Bellido, Hill, Clay)
B-2 Studying the Sun with a new Cosmic Ray Muon Detector (Supervisors: Clay & Dawson)
B-3 Simulating The Askaryan Radio Array (Supervisors: Hill)
B-4 High-energy neutrino astronomy with the IceCube detector at the South Pole (Supervisors: Hill)
B-5 Multi Messenger Astronomy with TeV Gamma Rays and Gravitational Waves (Supervisors: Ottaway, Rowell)
B-6 Study Of Nature's Extreme Particle Accelerators at Tera-Ev (10^{12} eV) Gamma-Ray Energies With HESS and Other Telescopes (Supervisors: Rowell)
B-7: The Cherenkov Telescope Array (Supervisors: Rowell, Dawson, Clay)
C - THEORETICAL PHYSICS
(Supervisors: Prof Derek Leinweber, Prof Anthony Thomas, Prof Tony Williams, Dr Ross Young, Dr James Zanotti, Dr Hrayr Matevosyan, Dr Rodney Crewther, Dr Ayse Kizilersu & Assoc Prof Max Lohe)

C-1 Lattice Gauge Theory (Kamleh, Leinweber, Williams, Young & Zanotti)
C-2 Effective Field Theory (Leinweber, Thomas & Young)
C-3 Nuclear Theory (Thomas)
C-4 Models of Hadrons and Hadronic Interactions (Matevosyan, Thomas & Zanotti)
C-5 Quantum Field Theory (Crewther, Thomas, Williams, Young & Zanotti)
C-6 Complex Systems (Kizilersu, Leinweber, Lohe, Thomas & Williams)
C-7 Theoretical High Energy Physics – see section D2 of High Energy Physics

D - HIGH ENERGY PHYSICS
(Supervisors: Prof Anthony Thomas, Prof Tony Williams, Dr Ross Young, Dr Paul Jackson & Dr Martin White)

D-1 Experimental High Energy Physics (Jackson, White)
D-2 Theoretical High Energy Physics (Thomas, White, Williams & Young)
D-3 High Energy Physics Phenomenology (Jackson, Thomas, White, Williams & Young)

SECTION E - MEDICAL PHYSICS
(Supervisors: Penfold, Bezak, Ramm, Shepherd, Jackson)

E-1 Proton Radiation Therapy (Penfold)
E-2 Four-dimensional Solid State Dosimetry (Rutten and Santos)
E-3 Adaptive Radiotherapy with Deformable Image Registration (Penfold and Shepherd)
E-4 Neural Network Modelling of Cancer Systems (Douglass and Penfold)
E-5 Medical Imaging (Collins, McRobbie and Midgley)

F - OPTICS & PHOTONICS
(Supervisors: E/Prof Jesper Munch, Assoc Prof Heike Ebendorff-Heidepriem, Assoc Prof Peter Veitch, Dr David Ottaway, Dr Yinlan Ruan, Dr Wenqi Zhang, Dr David Lancaster, Dr Shahraam Afshar, Prof Tanya Monro (UniSA))

F-1 Coherent Laser Radar For Wind Sensing And Pollution Transport Studies. (Veitch, Ottaway & MacKinnon)
F-2 Numerical Simulation of Aperture Synthesis with a Hartmann Wave-Front Sensor (Veitch)
F-3 New Wavefront Sensing Techniques for Advanced LIGO (Ottaway, Veitch & Munch)
F-4 Filtering of Night Sky Background in High Energy Gamma-Ray and Cosmic-Ray Telescopes (Rowell, Monro, Dawson, Clay)
F-5 Remote Methane Sensing For Greenhouse Gas Abatement (Veitch, Ottaway & Lancaster)
F-6 Development of 650nm Lasers for the Study of Mesosphere (Veitch & Ottaway)
F-7 A New Class of Germanate Glass Microstructured Fibre Lasers (Ottaway, Ebendorff-Heidepriem & Lancaster)
F-8 Mid- Infrared Fibre Lasers Operating between 3-4µm (Ottaway & Munch)
F-9 Harnessing nanoparticles in glass optical fibres (Ebendorff-Heidepriem, Monro)
F-10 Nonlinear optics in optical waveguides: Can we control photons by photons? (Luiten, Afshar, Ebendorff-Heidepriem, Lancaster & Lohe)
F-11 Electrically controlled optical devices (Zhang & Monro)
F-12 Nanolasers for biosensing (Francois & Monro)
F-13 Near-Field Optical Imaging of Waveguiding and Surface Plasmons in Metal Nanowires within Subwavelength Structures (Ruan and Francois)

SECTION G - ENVIRONMENTAL LUMINESCENCE
Physics Honours Projects 2016

(Supervisors: Nigel Spooner, Lee Arnold, David Ottaway, Heike Ebendorff-Heidepriem, Don Creighton.)

G-1; Geochronology:
G-2; Defence & National Security.
G-3; Mining and Mineral Processing

SECTION H – PRECISION MEASUREMENT

(Supervisors: Prof. Andre Luiten, Dr James Anstie, Dr Philip Light, Dr Chris Perrella, Dr Richard White.)

H-1; Sensing & Spectroscopy
H-2; Quantum Atom-Fibre Photonics
H-3; Frequency Standards & Distribution

SECTION J - BIOPHYSICS

(Supervisors: Bronwyn Dolman and Iain Reid)
J – 1; Modeling the Aussie Rules Football kick

SECTION K - SEMICONDUCTOR PHYSICS

(Supervisors: Dr David Huang)
K– 1; Structure-property relationships in organic semiconductors

SECTION L - GEOPHYSICS

(Supervisors: Professor Sandy Steacy, Dr Derrick Hasterock (Earth Sciences))

L-1 ; Fault based forecasting of earthquakes in the Cook Strait, New Zealand
L-2 ; Developing a new physical / statistical model for earthquake forecasting
A – SPACE AND ATMOSPHERIC PHYSICS

(Iain Reid, Murray Hamilton, David Ottaway, Andrew MacKinnon, Robert Vincent, Bronwyn Dolman, Joel Younger and Stuart Anderson)

The atmosphere, from the ground to space, is a complex system. The challenge of space and atmospheric physics is to unravel and describe the many physical processes which influence this region, and hence weather and climate. The Space and Atmospheric Physics Group is heavily involved in the development of new technologies to detect different atmospheric parameters, including winds, temperature, water vapour, cloud phase and plasma density. The equipment used for these measurements includes a number of different radar and lidar systems, optical imagers, satellite observations, GPS receivers, and in-situ sensors. The group also engages in theoretical investigations to characterize the underlying physical processes at work, which can combine elements of signal analysis, electrodynamics, fluid mechanics, chemistry, statistical mechanics, and computational physics.

The University of Adelaide operates a number of radars and other sensors at sites across the world, including a world-class field site at Buckland Park, one of the most significant keystone sites in the southern hemisphere (located 45 minutes north of Adelaide). Some of the present sensors at the Buckland Park site include, a MF (Medium Frequency) square-kilometre radar, an ST (Stratospheric-Tropospheric) radar, BL (Boundary Layer) radars, a Meteor radar, Airglow imagers, photometers and spectrometers. At the end of 2012 a Rayleigh lidar will begin operating from the newly constructed Buckland Park Lidar Facility. This lidar will enable studies of the previously difficult to measure region from 20-80 km. Plans to deploy several additional lidars for atmospheric observations and monitoring are underway. The Space and Atmospheric Physics group has additional sensors located at field sites at Darwin, Antarctica and Indonesia. All of these instruments can be combined together with satellite observations and other networks to obtain a global perspective.

Samples results for some of the systems can be viewed at:

ACTIVE ATMOSPHERIC REMOTE SENSING

A-1; CHARACTERISATION OF SOUTHERN MID AND HIGH LATITUDE IONOSPHERIC CLUTTER
Supervisors ( Andrew MacKinnon, Bruce Ward and David Holdsworth DST Group (Defence))

The principle objective of this project is to relate ionospheric clutter measured on the Tiger Buckland Park (SA) and Bruny Island (Tas) radars with clutter measured in the backlobe of the JORN OTH radar located in WA. There is an additional possibility of measuring clutter from an experimental HF radar with similar coverage to the Tiger Buckland Park radar.

The aim of this project would be to characterise the clutter and identify the ionospheric source of features observed in the data. The Tiger radars are operated automatically to a pre-defined schedule. The person undertaking this project would need to assist with scheduling of the radars and analyse the recorded data.

The radars operated by DST Group (Defence) will be operated by Defence personal and de-classified data provided to the student. The student will be able to be involved in planning the data collection and may be able to participate in the collection of data by the experimental radar.

There are significant differences in the processing applied to the Tiger and Defence radars. One of the activities will be to understand the relationship between observations with the two systems. The more significant activity will then involve characterisation of the observations and identification of the ionospheric sources including the use of raytracing through ionospheric models.

A-2; TEMPERATURE MEASUREMENT IN THE UPPER ATMOSPHERE USING METEOR RADAR
(Supervisors: Iain Reid & Joel Younger)

Meteor radars detect tens of thousands of ionized trails left by meteoroids entering the atmosphere every day. Radar echoes from meteor trails decay over time, at a rate related to the atmospheric temperature. These measurements are a potentially important tool for detecting changes in global climate, which are predicted to involve a cooling in the mesosphere region. Recent studies of the same meteor trails using two different radar frequencies at the same time suggest that existing theory does fully describe the evolution of meteor trails over time.

Data from three meteor radar locations are available at three distinct latitudes: tropical (Darwin, NT), mid-latitude (Buckland Park, SA), and polar (Davis Station, Antarctica). This project could involve analysing large amounts of radar echo decay data to infer dynamical processes in the atmosphere, assessing the effect of the geomagnetic field on plasma diffusion, assembly of long-term measurements to search for climactic trends, or a more theoretical approach to investigating the effects of plasma chemistry on the diffusion of meteor trails.
A-3; DESIGN OF A MINI-DOPPLER RAINFALL RADAR
(Supervisors: Iain Reid & Bronwyn Dolman)

Scanning weather radars use empirical relationships to calculate rainfall rates from the measured returned power. These empirical relationships are updated in real time using the rain gauge network. Rain gauges can only provide surface information, while the rain rate is variable in the descent from cloud to ground. Vertically pointing radars are capable of retrieving the rain rate throughout the vertical column from cloud to ground, and therefore offer additional information over rain gauges. This project will look at designing a low cost mini-Doppler radar system, capable of retrieving rainfall rates. The project will be assisted by ATRAD Pty Ltd, an Adelaide based radar design and manufacturing company, and provides an opportunity for the student to experience industry life. Working with ATRAD, the student will design a 55 MHz antenna array with a narrow beamwidth, which will then be connected to existing electronics at the University of Adelaide field site. The student will consider the applicability of different antenna types, and will evaluate the data in comparison to that collected with a co-located rain gauge.

A-4; METEOROLOGICAL PHENOMENA OBSERVED IN SONDE DATA
(Supervisors: Iain Reid, Bronwyn Dolman and Andrew MacKinnon)

A field campaign was conducted at the University of Adelaide field site, Buckland Park, in February and March 2011. During the campaign, 136 GPS sondes were launched from the field site, measuring wind speed and direction, pressure, temperature and humidity. Bureau of meteorology staff also took standard ground meteorological data, including cloud type and sky coverage. In this project, the student will examine the sonde data, and the meteorological phenomena evident therein. As an example, atmospheric wave activity was observed in the sonde data during the campaign. The student will investigate the occurrence of these waves, and attempt to determine their genesis.

A-5: RADAR IMAGING (AND RADAR INTERFEROMETRY) OF THE ATMOSPHERE
(Supervisors: Iain Reid and Andrew MacKinnon)

Re-entry of the Shuttle shows that severe turbulence can be encountered at heights near 90 km. Little is known about the source of these irregularities, but information can be obtained by examining the angular spectrum of backscattered radar signals. The 2 MHz radar facility run by the Atmospheric Physics Group at Buckland Park is operated in one of two modes. In the first, the entire 1 km diameter array is used to form narrow radar beams and the facility operates as a Doppler radar. In the second, antennas are used to record radiowaves partially reflected from the 60-100 km region of the atmosphere at three closely spaced locations on the ground. These returns are then used to determine the velocity of motion of the ground diffraction pattern of the radiowaves, and ultimately, of wind velocities in this height region.

Data obtained in the latter experimental configuration can also be analysed as for an interferometer. The information then available includes the variation of returned signal strength with off-vertical angle and the mean angle of arrival of the radar returns. This information can be interpreted to provide details of atmospheric irregularities and wave motions in the upper atmosphere. The aim of this project is to obtain suitable data, develop appropriate data analysis routines and apply these to the data and interpret the results in conjunction with Spaced Antenna and Doppler Radar data to yield information about atmospheric irregularities and wave motions in the upper atmosphere.

A-6; A MINI-VHF RADAR
(Supervisors: Iain Reid and Andrew MacKinnon)

Over the last 10 years a small VHF radar has been successfully developed for investigating the atmospheric Boundary Layer, which such systems now used throughout the world. These radars have utilized antenna arrays of 12 to 27 antennas. There is some utility in using only three Yagi antennas for the system, and the suitability of this arrangement will be investigated in this project. Such a system is highly desirable due to its significantly smaller footprint along with the ability for rapid deployment. Such a system could be used for a wide range of applications from radar education through to rapid deployment near bushfires to obtain valuable realtime information about windfields. A prototype of this system has been deployed at the Buckland Park field site. This project will require you to develop an understanding of some antenna theory, and some aspects of RF work. The effect of antenna spacing and coupling on the analysis will be examined. Coincidental measurements from co-located radar and radiosonde launches from Adelaide will be used to validate any results obtained.
A-7; A GPS-LOCKED REMOTE RADAR RECEIVING SYSTEM
(Supervisor: Iain Reid)

Our radar systems utilize backscatter from the atmosphere to measure various parameters and generally operate in mono-static mode, that is, the transmitter and receiver are co-located. It is possible to operate bi-static radar systems in which the transmitter and receiver are spatially separated. In this case, the systems can be synchronized using GPS receivers and or atomic clocks. This technique can be applied to any of our existing radar systems. In this project, you will develop a GPS system or atomic clock system to allow a remote receiving system to be added to an existing radar system.

A-8; VHF OBSERVATIONS OF IONOSPHERIC ECHOES
(Supervisors: Iain Reid and Robert Vincent)

Echoes aligned with the Earth’s magnetic field have been observed from the ionosphere in the northern hemisphere using frequencies in the VHF band. They have not been observed in the southern hemisphere. In this project the new 55 MHz radar at BP will be used to look for these echoes. The project will involve the construction of a suitable antenna and its use with the new radar. This project offers the opportunity to develop a new field of study.

A-9; ACTIVE AND PASSIVE MEASUREMENT OF ATMOSPHERIC TRACE GASES
(Supervisors: Murray Hamilton and Robert Vincent)

Water vapour and Methane are two important trace gases in the atmosphere; the first is the dominant greenhouse gas and the second perhaps the most topical, on account of the recent prominence of unconventional gas extraction. Knowledge of the spatial and temporal variability of each is crucial.

The routine measurements made around the world are too sparse and infrequent to properly capture this variability; in the case of water, for weather and climate modelling; and in the case of methane, for ascribing responsibility for the anthropogenic emissions.

This project could develop along a couple of paths; first is developing a lidar (active) that measures Raman-scattered light from water, and which will ultimately be deployed at Davis Station in Antarctica as part of a larger campaign to understand the influence of the Southern Ocean in the Earth’s climate system. Second is to quantify methane leaks, based on a knowledge of the local atmospheric conditions and measured methane concentrations. This last project will suit a student who enjoys field work.

A-10; RADIO ACOUSTIC SOUNDING SYSTEM (RASS) FOR TEMPERATURE PROFILING
(Supervisors: Andrew MacKinnon and Iain Reid)

Temperature profiles of the atmosphere are typically obtained using expensive radiosondes attached to weather balloons. This technique gives high vertical resolution but very poor temporal resolution. Additionally the balloon is advected by the background wind, hence measurements at the higher heights can be 100's of km from the launch site. Temperature profiles can alternatively be obtained by incorporating an acoustic source with a radar. The acoustic wave is detected by the radar with an accurate measure of the subsequent doppler velocity being obtained, as the speed of sound is dependent on temperature an estimate of the temperature can be made. Several high power (~140dB) low frequency speakers have been acquired and initial trials at the Buckland Park field site (40km north of Adelaide) have resulted in temperature profiles with accuracy of greater than 1C to over 54km.

Further areas of research would be tailor to the student's interests and could include: optimizing speaker location depending on wind conditions, optimizing acoustic waveform using theoretical, modelling and experimentation, determining optimal acoustics source (i.e. a few powerful compared with a multitude of small speakers), detailed comparison with radiosonde soundings or campaign-based trials observing meteorological phenomena. Visits to the Buckland Park field site would be essential.

A-11; UNDERSTANDING ATMOSPHERIC DYNAMICS USING RAYLEIGH SCATTERING
(Supervisors: Ottaway, MacKinnon & Reid)

Laser radar or lidar is one of the most promising techniques for characterizing the dynamics and transport phenomena of the atmosphere. It permits the accurate measurement of specific atmospheric constituents, pollutants, reaction products, temperature and wind velocity to name a few.

We have recently installed a lidar facility at our field site (Buckland Park) that has amongst the highest power collecting area product of any such lidar in the world. This will enable us to characterize the temperature dynamics of the atmosphere between 30 km and 100km. In collaboration with our colleagues at the Australian
Antarctic Division we are planning on extending the sensitivity of the instruments between 5 and 30 km which will allow us to study aerosols and momentum/energy transport between different layers of the atmosphere. Potentially, these observations will be used to improve Australia’s climate model (ACCESS).

A-12; RADAR ESTIMATIONS OF RAINFALL
(Supervisors: Iain Reid & Bronwyn Dolman)

TWP-ICE was an international field campaign, conducted in Darwin in January and February 2006. The campaign brought together many in situ and remote sensing instruments, including surface weather instruments, radars, and probes aboard aircraft. The University of Adelaide deployed a vertically pointing radar for the campaign, which was used to estimate rain rates.

Weather radars calculate rain rates using an empirical relationship, the coefficients of which are updated in real time using the rain gauge network. The rain rate between the cloud base and the surface can vary, as microphysical processes such as evaporation initiate. In this project, the student will look at methods of identifying the dominant microphysical process, and the relationship between this process, and the observed rain rate at the surface. The student will use both radar and rain-gauge data, and examine errors in the weather radar rain rate calculations.

A-13; PORTABLE UHF WIND PROFILING RADAR
(Supervisors: Iain Reid & Bronwyn Dolman)

ATRAD Pty Ltd is an Adelaide based radar design and manufacture company, with strong links to the University of Adelaide. ATRAD has recently developed a new portable wind profiling radar, operating in the UHF band. The radar is small enough to be deployed on roof tops, and so can be used for purposes such as urban wind profiling, or rapid deployment in bush fire wind forecasting. This project will look at optimizing system performance. This could involve antenna spacing, and antenna design, or signal processing, dependent on the interests of the student. The project will be conducted in collaboration with ATRAD, and will provide a keen insight into working in the radar industry.

A-14; RADAR AND LIDAR MEASUREMENTS OF VERTICAL VELOCITY
(Supervisors: Iain Reid & Bronwyn Dolman)

Wind profiling radars have been the instrument of choice for measuring winds when high temporal resolution is desired. Both the technology and data processing techniques are relatively mature. More recently, near infrared Doppler lidars have been used to measure vertical winds. The principal of operation is similar to radar, where optical power is returned from micron-sized particles, and the vertical velocity is calculated from the frequency shift. The University of Adelaide operates a wind profiling radar in Darwin, which is co-located with a Doppler lidar. This project will look at the comparison of profiler and lidar vertical velocity measurements, the relative accuracies of both systems, and examine the weather conditions under which particular systems out-perform the other.

A-15; BALLOON OBSERVATIONS OF THE ATMOSPHERE
(Supervisors: Iain Reid, Murray Hamilton, Bronwyn Dolman (ATRAD) and Robert Vincent)

The ready access of cheap mobile phones and cameras as telemetry and measurement devices suggests that together with simple balloon flights, unique and interesting in situ investigations of the atmosphere can be made.

For example much remains to be done in understanding the formation of cloud particles, be they ice crystals or liquid droplets. The measurement of cloud particle shapes and sizes is important to weather and climate modelling, because the radiative properties of a cloud depend very much on the phase, size and shape of the particles, and this determines whether a cloud has a net cooling or warming effect on the Earth's surface.

Mixed phase clouds, which contain both ice and liquid, are particularly interesting and have thrown up several challenges such as their longevity. A barrier to improving our understanding of these matters is the lack of a low-cost means of measuring the ice-fraction; only specialised radars, or aircraft (dangerous!) can probe the interior of a mixed phase cloud. We are developing a low-cost optical instrument called a polarsonde to address this problem. These fly with regular weather balloons, and currently an improved digital version is being developed in collaboration with a local company.

Projects in this area include investigating holography or plenoptic microscopy as means to image cloud particles, studying the scattering properties of hexagonally shaped crystals as a surrogate for ice, or validating the polarsonde itself! This last will involve fieldwork (in Tasmania) to prepare for an upcoming voyage of the new CSIRO ship, the RV Investigator, during which Southern Ocean Clouds will be studied.
Higher in the atmosphere, simple payloads would be developed for use with small balloons with potential applications on superpressure balloon (SPB) studies of the lower stratosphere. Through collaboration with the French Space Agency (CNES) and Ecôle Polytechnique in Paris we have access to SPB that provide a powerful new tool to investigate atmospheric processes in a region that is significantly impacted by climate change and that is difficult to study directly.

**A-16; GPS MEASUREMENTS FROM GROUND AND SPACE**  
(Supervisor: Andrew MacKinnon and Robert Vincent)

Signals from the constellation of GPS (Global Positioning System) satellites are now being used for scientific research in areas other than the original purpose of accurate position location. Propagation of the two microwave signals transmitted from each satellite is determined by the refractive index of the atmosphere, which is in turn determined by the electron density in the ionosphere, the temperature profile of the atmosphere and, in the lowest part of the atmosphere, by water vapour. This project will use GPS measurements made using 3 to 4 dual-frequency GPS receivers to construct a small network with a spacing of ~30 km and study variation in electron density in the ionosphere and atmospheric water vapour. The project will give the opportunity to carry out research in the rapidly changing field of GPS observations, which have wide application in atmospheric physics and meteorology. Measurements of GPS signals received on low-orbit micro satellites such as the recently launched COSMIC constellation provide a global perspective and will also be used to compare with the ground-based network. Additional recent access to the Victorian GPSnet and AuScope GPS networks will allow high spatial resolution measurements of both electron density and water vapour to be obtained from over regions of Victoria and Australia, respectively.

**A-17; OPTICAL STUDIES OF THE 80 TO 100 KM HEIGHT REGION**  
(Supervisor: Iain Reid)

Naturally occurring airglow from the 80 to 100 km height range can be used to investigate many aspects of this region. The Buckland Park field site houses several instruments for studying various emissions from this height range. These include:

- An all-sky imager for investigating dynamics and temperatures using the optical emissions in the Infrared from OH at heights near 85 km, and from O₂ near 94 km,
- A Three Field Photometer for investigating the dynamics of the 85 and 95 km height regions using emissions from OH and from atomic oxygen, respectively, and
- A spectrometer for investigating OH and O₂ derived temperatures in the 80 to 100 km height region.

Operation of the instruments is automated. The results are be used together with radar and other optical observations of the region to investigate internal atmospheric waves.

**A-18; METEOR ASTRONOMY USING SINGLE-STATION METEOR RADAR**  
(Supervisors: Iain Reid & Joel Younger)

Meteor trails are formed when bodies enter Earth’s atmosphere at tens of kilometres per second, leaving trails of ionized material in their wake. Theses thin columns of plasma can be detected by ground based radar. Meteor radar echoes are usually formed when the path of the meteor is perpendicular to the line of sight to the observing radar. This means that the direction of an individual meteor is not known beyond a plane perpendicular to the detection vector. If there are many meteor detections, this ambiguity can be overcome by using statistical methods to generate activity maps showing the directions of strong showers.

Meteor shower data can then be used for a variety of purposes including: determining the orbits of debris streams responsible for meteor showers, investigating the ablation process for meteors in the atmosphere, and testing the performance of meteor radars relative to other detection methods. As the University of Adelaide operates a number of meteor radars across the world, this project could involve assembling data from different sites to produce a virtual global meteor shower observatory.

**A-19; CLOUD MICROPHYSICS**  
(Supervisors: Murray Hamilton)

Clouds are unsurprisingly an integral part of the climate system, but perhaps surprisingly there are many puzzles regarding their formation and evolution. One such puzzle is around the presence of super-cooled liquid water (SLW) – why is there so much and why is it so persistent? One part of the world where there is more SLW than expected is the atmosphere over the Southern Ocean. This discrepancy is one of the most important sources of uncertainty in weather and climate models which predict the net heating/cooling of the earth, and whether water in clouds is liquid or solid has a large effect on the transport of radiative heat through the atmosphere.
We are addressing this question by developing balloon-borne optical instruments to measure the amount of liquid water, compared to ice, in a cloud, and where there is ice, to see what crystal form the ice particles adopt. We will be flying some of these instruments from the new CSIRO ship RV Investigator over the Southern Ocean in early 2016, and hopefully again in 2017.
B – HIGH ENERGY ASTROPHYSICS
(Roger Clay, Bruce Dawson, Jose Bellido, Gavin Rowell and Gary Hill)

B-1; STUDYING THE HIGHEST ENERGY PARTICLES IN NATURE WITH THE PIERRE AUGER OBSERVATORY
(Bruce Dawson, Jose Bellido, Roger Clay and Gary Hill)

The Pierre Auger Observatory in western Argentina has been built to detect giant cascades of particles created in our atmosphere by the highest energy particles known in the Universe. These ultra-high energy cosmic rays (protons and atomic nuclei), with energies up to $10^{20}$ eV, are thought to originate in the most extreme environments in the Universe. The Auger Observatory uses an array of particle detectors spread over 3000 square kilometres, in conjunction with 27 large optical telescopes, to measure and characterise the incoming cosmic rays - their arrival directions, energies and estimates of their mass.

The University of Adelaide is a founding member of the Auger collaboration, with wide ranging responsibilities across the Observatory’s mission. Projects will vary from year to year, and can be tailored to the interests and strengths of the student. They may include work on event reconstruction (finding the best way of converting raw data into the best estimates of cosmic ray directions, energy and mass); understanding the mass estimates in terms of contemporary particle interaction physics; testing hypotheses about cosmic ray sources by matching arrival directions with galaxy distributions of various types; or using infra-red cameras to characterise night-time cloud over the Observatory. Finally, from 2015 the Observatory is embarking on a hardware upgrade to sharpen its ability to distinguish between cosmic rays of low and high mass (charge), and there will be projects dedicated to this. We encourage students to talk to us to find out what is new and topical.

B-2; STUDYING THE SUN WITH A NEW COSMIC RAY MUON DETECTOR
(Supervisors: Roger Clay and Bruce Dawson)

Low energy galactic cosmic rays reach us after travelling through the solar heliosphere. The heliosphere is filled with magnetic fields which have their origin in the Sun and the solar wind so, as the state of the Sun changes, the number of detected low energy cosmic rays changes. It is then possible to use data from cosmic ray detectors to study the conditions in the heliosphere.

Those conditions affect spacecraft and astronauts (space weather) and travellers in long distance passenger aircraft.

We have recently completed a new cosmic ray muon detecting system. This project will evaluate it and, together with data from other systems around the Earth, use its data to study the state of the Sun and the radiation levels in its surrounding heliosphere.

B-3; SIMULATING THE ASKARYAN RADIO ARRAY
(Supervisor: Gary Hill)

The energy spectrum of cosmic rays (CR) extends up to at least $10^{20}$ eV. At these ultra-high energies (UHE) CR are probably extragalactic, possibly accelerated in jets of active galaxies. In travelling through the Universe, CR protons can interact with photons of the cosmic microwave background to produce pions, which through the pi-mu-e decay chain produce neutrinos. These CR produced UHE neutrinos are referred to as cosmogenic neutrinos, or GZK neutrinos after Greisen, and Zatsepin & Kuzmin predicted these interactions in 1966. The GZK neutrino energy spectrum is expected to peak around $10^{18}$ eV.

The Askaryan Radio Array (ARA) is a brand new neutrino telescope which the Adelaide group is involved in and which is currently being constructed at the South Pole. It will eventually operate at $10^{16}$ eV to $10^{20}$ eV energies. Detection of the small expected flux of neutrinos at these energies requires a huge collecting area. To achieve such collection areas, neutrino interactions are detected via radio emissions, which can be detected one kilometre or more from the interaction point in the ice. Neutrinos produce showers of particles, which through development of a negative charge excess, moving close to the speed of light through the ice, produce radio Cherenkov emissions.

The ARA will consist of an array of radio antennas embedded deep in polar ice. Antennas deployed over the last two south pole summer seasons are operational, with more to be deployed in the 2012/13 summer season. It is anticipated that funding will then be approved for an 80 square kilometre array, which should detect the first GZK neutrinos. A similar method, but using the moon instead of ice and radio telescopes instead of embedded antennas, has already been used the LUNASKA project by the Adelaide group.

This honours project will involve using a toy model of the radio emission from cascades initiated by neutrino interactions in ice to simulate the detection of UHE neutrinos by the ARA. Good computing skills are required for this project.
B-4; HIGH-ENERGY NEUTRINO ASTRONOMY WITH THE ICECUBE DETECTOR AT THE SOUTH POLE
(Supervisor: Gary Hill - gary.hill@adelaide.edu.au)

The IceCube detector is the world’s largest high-energy particle detector. Instrumenting a cubic kilometre volume of the clear ice below the South Pole Station, Antarctica, this detector has many science goals, all of which may be explored as Honours projects for 2015.

The IceCube collaboration announced the first detection of high-energy astrophysical neutrinos in late 2013, starting a new form of astronomy. Now that we have observed these events, we want to understand what sources in the Universe they are coming from, and how they were produced. These neutrinos are thought to be produced during the acceleration and interaction of the highest energy particles in nature, at as-yet unknown sites in the Universe. These could include the centres of active galaxies, gamma-ray bursts, and supernovae. The Universe may also be aglow in diffuse fluxes of neutrinos from the sum of all sources, or from the interactions of the highest energy cosmic rays on the cosmic microwave background radiation. There is much work to be done in analysing the neutrino data, and determining which of these possible sources, or mixture of sources, is responsible for the events we see.

In addition to the primary study of the distant neutrino sources, there are other scientific goals of IceCube. The detector currently records thousands of atmospheric neutrinos each year, which are a beam for studying the boundaries of modern particle physics. Dark matter, the hypothesised missing 25% of the Universe, may be observable in IceCube as a signal resulting from neutralino capture and annihilation in the Sun and centre of the Earth. The detector is also a powerful low energy supernova neutrino detector.

Honours projects which would contribute to these IceCube science goals could cover many important areas - e.g. correlating the astrophysical neutrinos with other type of detections (cosmic rays, gamma rays), looking for structure in the neutrino sky, improving the energy and directional reconstruction of the neutrinos, and working on detector calibration, simulation and statistical analysis methods. Theoretical studies of potential neutrino sources are also critical to the mission of the experiment.

B-5; MULTI-MESSENGER ASTRONOMY WITH TEV GAMMA RAYS AND GRAVITATIONAL WAVES
(Supervisors: David Ottaway and Gavin Rowell)

Multi messenger methods are becoming common place in astrophysics but as yet very little work has been done on the combination of TeV gamma-ray and gravitational wave observations. This project offers the exciting possibility of being involved in the birth of a new powerful technique.

Continuous wave gravitational wave observations are computationally limited and there remains the exciting possibility that a gravitational wave signature remains undetected in the existing LIGO data. The aim of this project is to conduct a gravitational wave search in the areas of the sky that are bright in TeV gamma-rays but mysteriously, nothing else.

B-6; STUDY OF NATURE’S EXTREME PARTICLE ACCELERATORS AT TERA-EV (10^{12} EV) GAMMA-RAY ENERGIES WITH HESS AND OTHER TELESCOPES
(Supervisor: A/Prof G.P. Rowell)

The High Energy Stereoscopic System (HESS) detects gamma-rays at TeV (10^{12} eV) energies and above, and has made significant contributions to our understanding of the high energy Universe. Over 100 sources of TeV gamma-ray emission have been discovered, most of them with HESS. The types of sources include shell-type supernova remnants, pulsar powered nebulae, compact X-ray binary systems, molecular clouds, radio galaxies and jet-powered active galaxies.

There are opportunities to study extended sources which may include supernova remnants, pulsar nebulae, star formation regions and also mysterious unidentified sources, as well as searching for transient/bursting sources in HESS data. These types of study can greatly help in addressing the origin of the gamma-ray emission as well as new information about the type of particles accelerated to extreme energies and where they are accelerated.

Comparison with images from other energies (radio, X-ray, low energy gamma-rays and neutrinos) may also be performed with a particular emphasis on radio data used to survey interstellar gas clouds (we use the Mopra radio telescope in Australia for this purpose).

Students will gain experience in data analysis algorithms using a variety of computer languages such as C, C++, Perl and Fortran within the Linux/Unix operating system as well as specific software packages dealing with astronomical images (such as miriad, ftools, ds9 etc.).

See these websites for more details: http://www.physics.adelaide.edu.au/astrophysics/gpr/research.html
TeV gamma-ray astronomy is rapidly progressing and large-scale arrays of telescopes are being planned. The Cherenkov Telescope Array (CTA) is gathering momentum and prototype telescopes are now being constructed. The full array is expected to comprise over 100 telescopes.

This project will be to investigate the performance of CTA layouts using different analysis methods based on the timing of the detector signals and other enhancement. Our group has shown that timing can greatly help in improving the angular resolution and robustness to night sky background changes. Additional aspects of this study will be to examine the CTA performance at the highest gamma-ray energies >10 TeV which is motivated by searching for the accelerators of the highest energy cosmic-rays in our galaxy, and improve the energy resolution of the telescopes for dark-matter searches.

Other projects in this area include - Investigating the performance of CTA telescopes at Australian sites as a possible expansion of the array (the main CTA sites are in Chile and the Canary Islands) and astrophysical calculations to predict how CTA will reveal the nature of the gamma-ray emission towards a variety of gamma-ray sources seen by HESS.

Students will gain practical experience with computer languages such as C, C++, Perl within the Linux/Unix operating system as well as specific high level analysis packages such as ROOT and PAW. There is also the possibility for hardware based studies of silicon base photon sensors similar to those used in the CTA telescope cameras.

See these websites for more details:
http://www.cta-observatory.org
SECTION C - THEORETICAL PHYSICS

The theoretical physics research activities described below cover a broad range of topics and are primarily carried out under the umbrella of the ARC Centre for the Subatomic Structure of Matter (CSSM).

C-1; LATTICE GAUGE THEORY
(Supervisors: Kamleh, Leinweber, Williams, Young, Zanotti)

Quantum Chromodynamics (QCD) describes the interactions between quarks and gluons as they compose particles such as the proton and neutron. Lattice gauge theory provides the only comprehensive method to extract, with controlled systematic errors, first-principles predictions from QCD for a wide range of observable phenomena. By discretising space-time onto a hypercubic lattice, we are able to directly study the properties of this highly non-perturbative theory. These numerical simulations are extremely challenging, requiring state of the art high performance computing techniques and the use of the world’s fastest supercomputers.

Having such powerful tools on hand allows for the study of a variety of interesting phenomena relevant to international experimental efforts in particle and nuclear physics, such as excited state spectroscopy, hadronic interactions, probing the structure of the proton and other hadronic particles, hadronic decays, and the vacuum properties of QCD. In addition, visualizing the massive amounts of data created in lattice simulations provides deep insight into the fundamental mechanisms of QCD and hadron structure.

C-2; EFFECTIVE FIELD THEORY
(Supervisors: Leinweber, Thomas, Young)

Physicists around the world are focussed on revealing the phenomena emerging from the theory of Quantum Chromodynamics (QCD). QCD is the fundamental quantum field theory underlying the strong interaction. It explains the origin of 99% of the mass of the visible universe (the Higgs mechanism generates the other 1%).

At low energies, the quark and gluon fluctuations of QCD are frozen into "colourless" states called hadrons (eg. proton, neutron, pion etc.). Using these low-energy degrees of freedom and the symmetries of QCD, Effective Field Theories (EFTs) make it possible to derive model-independent properties of QCD.

Two common, and necessary, approximations made in lattice QCD simulations are the use of heavier-than-physical quark masses and the squeezing of the system into a finite volume. EFTs provide a robust framework for understanding the physical consequences of these approximations, and therefore provide the essential link between lattice simulation results and Nature. Here at Adelaide, we are developing innovative techniques which serve to guide and interpret research at international experimental facilities with a particular emphasis on: structure, resolving the distribution of quarks and gluons inside hadrons; and dynamics, underlying the excited state resonance spectrum of QCD.

C-3; NUCLEAR THEORY
(Supervisor: Thomas)

Traditionally the atomic nucleus has been regarded as a collection of bound protons and neutrons. However, with the discovery of quarks and a more fundamental theory of the strong interaction, namely Quantum Chromodynamics, it has become clear that the old view needs to be replaced. Indeed, the change of the properties of protons and neutrons in matter is the topic of a great deal of research effort around the world.

It seems likely that such changes may be critical to understanding the equation of state of dense matter and hence the properties of neutron stars. Having a quark-level understanding of dense matter will also be necessary in order to explore the phase transition to quark matter at high density and temperature. Finally, the nucleon-nucleon force itself also needs to be derived from the quark level.

C-4; MODELS OF HADRONS AND HADRONIC INTERACTIONS
(Supervisors: Matevosyan, Thomas, Zanotti)

While lattice QCD provides by far the best approach to the direct, numerical evaluation of hadronic properties. In parallel with these lattice calculations, there are important reasons for developing transparent models which can be used to aid the interpretation of lattice results, analyse experimental data and suggest new experiments. Ideally these models should incorporate, as far as possible, the known properties of QCD, including its symmetries. The model of Nambu and Jona-Lasinio (NJL), for example, provides a covariant framework which respects the chiral properties of QCD while allowing near analytic solutions for many problems.
We are especially interested in using models such as NJL, or even the MIT bag, to calculate hadron properties, to calculate reactions involving hadrons and to build quark models of atomic nuclei. Of particular topical interest, in the light of major experimental programs around the world, is the calculation of parton distribution functions (of nucleons, hyperons and nuclei), fragmentation functions, generalised parton distributions and novel phenomena such as the Collins and Sivers effects which promise insight into the orbital angular momentum of quarks within hadrons.

**C-5; QUANTUM FIELD THEORY**

(Supervisors: Crewther, Thomas, Williams, Young, Zanotti)

When quantum mechanics is mixed with relativity, position cannot be an operator, and it becomes necessary to quantise fields. Typically there are gauge fields (photon, gluon and the weak W,Z fields of the Standard Model, plus gravitons -- yet to be understood) and matter fields (lepton, quark and scalar fields such as the Higgs scalar boson). There are generalisations to higher symmetries such as grand unified theories and supersymmetry (see Section D2) and also to string theory. There are also non-polynomial field theories such as chiral Lagrangians. [Projects in string theory and quantum gravity are not suitable for honours projects and will not be offered].

Projects can be phenomenological or mathematical in character, and may include classical aspects like monopoles or toy models such as two-dimensional theories. The focus may be on technique - making calculations finite (renormalization and anomalies), giving particles mass (Higgs mechanism or dimensional transmutation), unifying interactions (higher symmetries) -- or data which is either hard to explain (weak hyperon decays, non-zero neutrino masses, the definition of angular momentum in a gauge theory, etc.) or requires precision theoretical calculation (radiative corrections, low-energy Standard Model tests).

**C-6; COMPLEX SYSTEMS**

(Supervisors: Kızılsu, Leinweber, Lohe, Thomas, Williams)

Complex systems appear in diverse disciplines such as physics, economics, banking and finance, ecosystems, molecular biology, neuroscience, psychology and sociology.

Typically these systems are comprised of a large number of interconnected components which interact collectively, leading to emergent behaviour, such as self-organization, which is not apparent from the properties of the underlying components. As an example of complex systems in financial markets, there is considerable interest in developing a mathematical understanding of the dynamics of the order book, which records all bids to buy and sell on the stock market at the milli- to micro-second level.

Examples in physics are models in statistical mechanics, many body theory, dynamical systems, and in particular networked dynamical models in which a large number of nodes interact nonlinearly across a network which has various connectivity properties. Each node can behave classically, such as a harmonic oscillator or a chaotic system, or even as a quantum system. For certain models with suitable nonlinear interactions all nodes of the complex system can oscillate in synchrony to a common frequency, a remarkable phenomenon which has been extensively studied over the past decade. Dynamical complex systems are generally investigated by means of numerical computations, particularly for nontrivial network topologies, although there is scope for advanced theoretical and mathematical analysis.

**C-7; THEORETICAL HIGH ENERGY PHYSICS – SEE SECTION D2 OF SECTION D HIGH ENERGY PHYSICS**
SECTION D: HIGH ENERGY PHYSICS

The research activities of the High Energy Physics (HEP) group in the Department of Physics are largely carried out under the umbrella of the ARC Centre of Excellence for Particle Physics at the Terascale (CoEPP) of which Adelaide is one of four nodes (University of Adelaide, University of Melbourne, Monash University and the University of Sydney).

D-1; EXPERIMENTAL HIGH ENERGY PHYSICS
(Supervisors: Jackson, White)

Our group works on the ATLAS experiment at the CERN Large Hadron Collider. As a member of this international collaboration we have a variety of responsibilities and activities, all of which can be joined at the honours level. We are performing several analyses of ATLAS data searching for physics beyond the Standard Model using new techniques invented in Adelaide. With the discovery of the Higgs Boson in 2012 (and the award of the Nobel prize in 2013) applying this constraint to searches at the LHC is extremely topical. Searches being pioneered in Adelaide include those for direct production of 3rd generation Supersymmetric particles, searches involving heavy leptons (e.g. taus) and other pair produced new states. These are complemented by an inclusive search for displaced vertices arising from long-lived heavy particle decays. Core techniques in Monte Carlo generation, simulation and charged particle tracking can also be studied to impact a broad range of measurements.

Our group is designing and testing new methods for readout of the data from the ATLAS experiment through fast data acquisition electronics. There are opportunities to develop software for the current detector system and for the upgraded high luminosity LHC running. We are further involved in Beam Loss Monitors for studies that will be used in the design of the protection system for Compact Linear Collider design, the next big machine in high energy physics. ATLAS data analyses are intimately related to projects in phenomenology (see Section D3) and machine learning techniques to study constraints on signatures of Dark Matter. These studies combine a variety of collider physics and astrophysical sources.

D-2; THEORETICAL HIGH ENERGY PHYSICS
(Supervisors : Thomas, White, Williams, Young)

It is an exciting time to be a physicist with the apparent recent discovery of the Higgs Boson as predicted by the Standard Model and with being on the verge of discovering a rich landscape of new physics Beyond the Standard Model (BSM); despite its success at explaining an enormously wide range of known physical phenomena, the current Standard Model describes only the behaviour of ordinary matter, which is a mere 4.6% of the universe’s total mass-energy content! Dark Matter accounts for around 23% and Dark Energy accounts for the remaining 72% of the universe's mass-energy.

Evidence from gravitational lensing, galactic rotation curves and the cosmic microwave background radiation strongly suggests that approximately 23% of the universe’s mass-energy and 83% of the mass is comprised of the mysterious quantity known as Dark Matter. There are many searches underway to probe the nature of this Dark Matter, both directly and indirectly, including cryogenic detectors buried deep beneath the ground.

In addition to the mysteries of Dark Matter and Dark Energy, there are extremely compelling reasons to believe that the Standard Model is not the complete story and that it must inevitably be extended to include BSM. The apparent unification of the electromagnetic, weak and strong forces at the scale of $10^{16}$ GeV strongly argues for the existence of so-called Grand Unified Theories (GUTs), which include all three in a single unified model. In addition, the quantum effects of gravity can no longer be ignored at scales of $10^{19}$ GeV (the Planck scale) and at such a scale we need to build a Theory of Everything that includes gravity.

The available projects include supersymmetry (SUSY), GUTs, dark matter, extra-dimensional models, composite Higgs models, and scale invariant theories. Projects will typically involve one or more of these concepts. The projects will involve building and studying predictions of models of BSM physics and will be most suited to students with either a theoretical interest or a combined theoretical plus computational interest.

D-3; HIGH ENERGY PHYSICS PHENOMENOLOGY
(Supervisors: Jackson, Thomas, White, Williams, Young)

Phenomenology is the interface between theoretical and experimental high energy physics. While there is some overlap with D2 above, the emphasis on these projects is in performing extensive and careful calculations of particle physics models so as to allow a direct comparison with experimentally measurable quantities. As explained above, the Standard Model (SM) cannot be the final answer and any theory of new physics should show up in lots of experiments including high-energy accelerator searches (such as the Large Hadron Collider and previous collider experiments), neutrino mass and mixing data, direct and indirect dark matter search experiments, low energy precision measurements, flavour physics, rare decays and in cosmology. The challenge
of the phenomenologist is to calculate in detail the expected signals in each of these experiments, and to work out which new theories of physics are still viable given current measurements and which can be tested in new accelerators should they be constructed.

The Adelaide High Energy Physics group is heavily involved in the detailed phenomenology of supersymmetry (SUSY), including calculations in non-standard SUSY models, SUSY dark matter studies and the invention of new techniques for finding supersymmetric particles at the Large Hadron Collider. We also study the detailed observable phenomenological consequences of non-SUSY scenarios, including extra dimensional scenarios, effective dark matter models and general grand unified theories.

Finally, the Adelaide group is leading an international effort to take all current astrophysical and particle data to measure generic new theories of physics using state of the art computational techniques. We welcome applications from students wishing to do a combination of experimental, computational and theoretical work.
SECTION E - MEDICAL PHYSICS  
(Supervisors: Penfold, Bezak, Ramm, Shepherd, Jackson)

Research in Medical Physics operates in collaboration with Medical Physicists working in hospitals around Adelaide. One of the strengths of the program is the opportunity it provides for students to work in a hospital environment and to gain insight into clinical procedures. An honours project in medical physics can provide an excellent introduction to the M.Phil. or to a Ph.D. in this field, and to a medical physics career. The program is coordinated by Dr Scott Penfold. Research in Radiotherapy Physics is carried out in the Department of Medical Physics at the Royal Adelaide Hospital. Projects in Medical Imaging Physics are available at both Flinders Medical Centre (Radiology) and the Royal Adelaide Hospital (Nuclear Medicine).

E-1 PROTON RADIATION THERAPY  
(Supervisors: Penfold)

Proton therapy is an emerging form of cancer treatment. In comparison to conventional radiotherapy which is delivered with high energy X-rays, proton therapy is delivered with magnetic scanning of energetic proton beams. Protons are capable of delivering less dose to healthy tissues than X-rays and thereby have the potential to reduce the side-effects of treatment. The particle accelerators required for proton therapy and significantly larger and more expensive than those required for X-ray therapy, which has restricted the widespread use of proton therapy. While there are no proton therapy accelerators in Australia, the Royal Adelaide Hospital is engaging with Government to establish the first National centre. The RAH has acquired a proton therapy treatment planning system that allows for simulation of treatments.

Projects offered in proton therapy are simulation/calculation based and would suit a student with an interest in computing. Projects include:

• Inverse optimization in intensity modulated proton therapy
• Image reconstruction in proton computed tomography
• Radiobiological modelling of treatment outcome from proton therapy

E-2 DEVELOPMENT OF A 2D DIODE ARRAY FOR REAL-TIME TUMOUR TRACKING IN LINEAR ACCELERATOR GATED TREATMENTS  
(Supervisors: Santos and Rutten)

Respiratory gated treatments are becoming more common in order to reduce motion uncertainties. We have developed a custom Quasar phantom to replicate patients breathing motion in both anterior-posterior abdomen, and inferior-superior lung movements. Currently one diode is used to measure linear accelerator time delay during a gated treatment. Two Arduino microcontroller boards have been utilised to control the motors, read the diode and write to an SD card. In this project, a 2D, radiation sensitive diode array is to be developed which could be inserted into the lung phantom and provide a real time assessment of the radiation beam – target overlap for a realistic simulation of therapy on moving targets.

E-3 RADIOBIOLOGICAL MODELLING IN ADAPTIVE RADIOTHERAPY WITH DEFORMABLE IMAGE REGISTRATION  
(Supervisors: Penfold and Shepherd)

Typically, a course of radiotherapy is planned and optimized for a patient based on their anatomy prior to treatment. As a course of treatment may last for 5 weeks, significant anatomical changes may occur between the start and conclusion of treatment. This means that the original plan may no longer be optimal and can result in a lower likelihood of tumour control or higher likelihood of normal tissue complication. Adaptive radiotherapy attempts to account for this by modifying the original treatment plan throughout the course of treatment.

In this project the student will work with advanced image registration tools and radiobiological models to predict and compare the treatment outcomes resulting from several approaches to adaptive radiotherapy. The project is suited for students with an interest in computing and image processing. The student will work closely with staff at the Royal Adelaide Hospital.

E-4 NEURAL NETWORK MODELLING OF CANCER SYSTEMS  
(Supervisors: Douglass and Penfold)

Neural Networks provide a method of modelling complex nonlinear systems that are not easily modelled with a closed-form equation. Examples where neural networks have been shown to accurately model complex systems includes: stock markets and artificial intelligence. Radiobiology is an example of such a complex system. Cell survival and carcinogenesis is a complex non-linear system involving numerous chemical, biological and physical pathways which are extremely difficult to model.
Computerised neural networks consist of interconnecting “nodes” with one or more weighted inputs and outputs. Each node and its weighted inputs are “trained” using input data with corresponding output data. By applying this procedure to model a radiobiology system, the neural network will model the complex behaviour in a “black box” approach. By collecting published cell survival data from the literature and using this model to train the neural network, the model should be capable of predicting cell/tumour survival after irradiation under a wide range of conditions.
SECTION F - OPTICS & PHOTONICS

(Supervisors: Dr Shahraam Afshar, Dr Heike Ebendorff-Heidepriem, Assoc Prof Murray Hamilton, Dr David Lancaster, Prof Tanya Monro, E/Prof Jesper Munch, Dr David Ottaway, Prof Iain Reid, Dr Yinlan Ruan, E/Prof Bob Vincent and Assoc Prof Peter Veitch)

Optics and photonics is an active and vibrant area of research at the University of Adelaide. Potential projects span a broad range of areas, including laser physics, sensing (in many forms), and optical fibre research.

From 2009, the Optics and Photonics group, led by Prof Jesper Munch and the Centre of Expertise in Photonics, led by Prof Tanya Monro joined together, along with key researchers from other disciplines across Adelaide University, to create IPAS, the Institute for Photonics and Advanced Sensing. IPAS is already enhancing our research capabilities and creating new research opportunities, as is clear from the list below.

The honours projects listed below have been loosely grouped into sub-classifications.

OPTICAL REMOTE SENSING

F-1; COHERENT LASER RADAR FOR WIND SENSING AND POLLUTION TRANSPORT STUDIES
(Supervisors: Veitch, Ottaway & MacKinnon)

High speed, remote sensing of atmospheric winds speeds using coherent laser radar is required for a variety of important environmental and industrial applications, including the measurement of wind speeds for wind-farms, the investigation of air-bone pollution transport for mining and industrial developments and the detection of wind-shear at airports. We have developed state-of-the-art Er:YAG laser systems for these applications and you could be part of exciting project; either working with the laser systems and perhaps using them for real-life measurements, or investigating the use of these systems for advanced atmospheric tomography.

F-2; NUMERICAL SIMULATION OF APERTURE SYNTHESIS WITH A HARTMANN WAVE-FRONT SENSOR
(Supervisor: Peter Veitch)

Aperture synthesis combines measurements of optical parameters over small portions of a large aperture to create a map of these properties over the whole aperture. This is technique is employed in state-of-the-art systems that use interferometers to measure these parameters. Our Hartmann wave-front sensor can measure these parameters with much better accuracy and precision than an interferometric sensor however. In this computational project, you will investigate numerically the use of Hartmann wave-front measurements for aperture synthesis.

F3; NEW WAVEFRONT SENSING TECHNIQUES FOR ADVANCED LIGO
(Supervisors: Ottaway, Veitch & Munch)

Large scale gravitational wave detectors are kilometre scale detectors that sense passing gravitational waves by monitoring the separation of suspended 40kg test masses. Ultimately the performance of these interferometers will be limited by quantum mechanics applied to the position and momentum of these 40kg objects. The impact of this so called quantum noise will be reduced by having extremely high power optical field circulating within the instruments. The Advanced LIGO detectors will have nearly 1 MW of circulating power in the detector. It is anticipated that third generation detectors may have more and may rely on detector topologies that will be even more sensitive to optical distortions.

To ensure that these instruments operate as planned, new methods for sensing the optical distortions of the mirrors may be needed that make use of the circulating fields themselves to probe the shape of the mirrors. To do this we will develop and test new detectors based on extremely high speed cameras that are found in modern computer gaming systems. In doing this project a student will gain experience in the techniques used in ultra-high precision interferometry.

F-4; FILTERING OF NIGHT SKY BACKGROUND IN HIGH ENERGY GAMMA-RAY AND COSMIC-RAY TELESCOPES
(Supervisors: Gavin Rowell, Tanya Monro, Bruce Dawson, Roger Clay)

Gamma-ray and Cosmic-Ray astronomy from the ground depends critically on telescopes' ability to distinguish the night sky background (NSB)from signal light. For gamma-ray telescopes (like HESS [1]) this signal
light is the broad band (blue-UV peaked) Cherenkov radiation, whereas for cosmic-ray telescopes (like the Pierre Auger Observatory [2]), the signal is the many series of nitrogen fluorescence lines (also blue-UV peaked). Interestingly the signal for gamma-ray telescopes is often part of the background light for cosmic-ray telescopes and vice-versa. This project will first investigate the feasibility of applying narrow-band filters to help improve the signal to background ratio for both types of telescopes. Preliminary work [3] suggests this could have some advantages. A second component of the project will be to explore technical ways to apply such filtering, via light guides, fibres and/or other means. For example the idea of using Bragg diffraction gratings in fibres to filter the near infrared(NIR) series of OH night sky lines [4] has dramatically improved the prospects for new NIR spectroscopy in optical astronomy.

References

F-6; REMOTE METHANE SENSING FOR GREENHOUSE GAS ABATEMENT
(Supervisors: Ottaway, Veitch & Lancaster)

Methane is one of the most critical greenhouse gases because it ‘traps’ significantly more infrared radiation per unit mass than does CO₂. Two of the major contributors to the methane releases are emissions from agriculture and gas leakage from natural gas pipelines. For example it has been estimated that upwards of 3% of Canada’s total greenhouse footprint is due to the gas leaking from gas pipelines. Finding these leaks and correctly evaluating the emissions from agriculture is not trivial. Hence there is an urgent need for a method of determining the spatial distribution of methane gas.

We are currently developing a new technology for the remote detection of methane using solid state lasers. This project has the potential to develop technology that could make a massive positive impact on both industry and the environment. Projects are available in both the hardware and data analysis side of this project.

F-6; DEVELOPMENT OF 650NM LASERS FOR THE STUDY OF MESOPHERE
(Supervisors: Peter Veitch and David Ottaway)

Photochemistry in the atmospheric region between 80 to 120 km is critical to life on earth. To obtain an accurate understanding of this region it is critical to determine its temperature dynamics. It has been shown that the optimal way of achieving this is by utilizing frequency double alexandrite lasers to probe the spectroscopy of iron located in this region. However the alexandrite lasers currently used are extremely inefficient and expensive which means limits utility. It is therefore critical to develop new lasers to probe this region. In this project a new laser architecture will be developed that has the potential to revolutionize this form of LIDAR and allow for the first time a grid on such LIDARs to deployed and attain a global understanding of this critical region of the atmosphere.

LASERS AND NON LINEAR OPTICS

In a nonlinear fibre, light changes the properties of the material it is propagating in. As a result, it is possible to manipulate light using light, which opens up rich new physics and applications. The following projects F11 -13 are based on different aspects of nonlinearity in optical fibres.

F-7; A NEW CLASS OF GERMANATE GLASS MICROSTRUCTURED FIBRE LASERS
(Supervisors: Heike Ebendorff-Heidepriem & David Lancaster)

While silica-based fibre lasers possess almost ideal laser characteristics, they cease to be transparent beyond 2μm. Germanate glasses are an appealing and as yet relatively unexplored choice for the fabrication of fiber lasers at longer wavelengths. The combination of good thermal properties, low phonon energy, and ability to be doped with high rare-earth concentrations make these glasses attractive for laser operation on untested laser transitions in the 2-3μm wavelength range. By taking advantage of the low temperature softening point of germanate glass, we have developed germanate glass extrusion methodologies. This approach enables the formation of unique microstructured geometries that cannot be made in any other way. This project will advance
the fabrication and characterization of germanate fibres, conduct spectroscopic measurements of rare earth doped germanate glasses, and work towards demonstration of a microstructured germanate fibre laser.

F-8; MID-INFRARED FIBRE LASERS OPERATING BETWEEN 3-4μM
(Supervisors: Ottaway, Munch & Henderson-Sapir)

Recently we have demonstrated a fibre laser operating at 3.6μm which is the longest wavelength that a fibre laser has been ever demonstrated at room temperature. The transition on which this laser has been demonstrated has the potential to operate between 3.2 – 3.9 μm. This is an extremely important band because a number of important molecules including the greenhouse gases methane and ethane and volatile substances such as formaldehyde have transitions in this band. Demonstrating lasing that spans this entire band will enable applications as diverse as remote sensing of greenhouse gases using laser-radar devices, on-the-spot monitoring of trace gases in exhaled breath that could enable early identification of certain diseases and even jamming heat seeking missiles.

The goal of this project will be to continue the previous work with the fibre laser currently in place and demonstrate the tunability of this laser transition. In addition, initial work into modifying the current laser setup to enable short pulse operation is expected. This modification is needed as a first step necessary for the creation of a laser-radar device based on our fibre-laser technology.

This project is of experimental nature and will suite a student with a hands-on attitude who enjoys lab-work. The work will involve lasers, optical system, fibre optics and significant work with test and measurement instruments.

F-9; HARNESSING NANOPARTICLES IN GLASS OPTICAL FIBRES
(Supervisors: Heike Ebendorff-Heidepriem and Tanya Monro)

The drivers for our work include the development of nonlinear fibre-based devices for all-optical data processing, switching and optical limiting. Our recent work on the development of a new theoretical model for nonlinear pulse propagation in highly nonlinear fibres, fabrication of the world’s smallest core optical fibres, and experimental confirmation of our new theoretical model has attracted a lot of attention in science community. Within this project, we like to extend our new nonlinear model to include nonlinear polarisation. The project will include fabrication of subwavelength elliptical core fibres, which can be shown to have high nonlinear polarisation. Using the fabricated fibres, their nonlinear polarisation characteristics will be investigated experimentally and compared to those predicted by the model. The field of nonlinear processes in subwavelength waveguides is a new field of research in which our discipline plays a pioneering role.

F-10; NONLINEAR OPTICS IN OPTICAL WAVEGUIDES: CAN WE CONTROL PHOTONS BY PHOTONS?
(Supervisors: Andre Luiten, Shahrar Afshar, Heike Ebendorff-Heidepriem, David Lancaster and Max Lohe)

Controlling photons by photons (nonlinear optics) is an exciting field in optics with applications in optical signal processing, quantum computing and sensing. At the University of Adelaide (Institute for Photonics and Advanced Sensing), we have the state of the art fabrication facility to fabricate fibres with high nonlinearity. We are also one of the pioneers in the field of the theory of nonlinear processes in optical waveguides and collaborate with several international groups.

We offer a suite of Honours projects in the field of nonlinear optics in optical fibres. Depending on the background and the interest of students, each project can have different elements with different weighting of fabrication, theory/simulation and experiment. Some examples of projects are: Third and one-third harmonic generation in optical fibres, Development of highly nonlinear composite fibres, Nonlinear polarization switching in optical waveguides, Nonlinear pulse propagation in multimode-multicore fibres, Dispersion measurement in multimode fibres, Highly nonlinear optical fibres and cold atoms for nonlinear quantum applications, and Development of microstructured optical fibres for signal processing. The expertise of the supervisory team covers different elements for each project, providing extensive and efficient support for students.

Interested students will have a meeting with the supervisory team in which they can discuss the students’ background and interest and possible projects.

F-11; ELECTRICALLY CONTROLLED OPTICAL DEVICES
(Supervisors: Wenqi Zhang and Tanya Monro)

By incorporating metal electrodes within the fibre cross-section, it is possible to use electric fields to control the light signal within the fibre. This offers an attractive new approach to using electrical signals to modulate light,
and for generating new wavelengths. By applying this approach to novel high index glasses, we aim to induce unprecedentedly large nonlinear effects to enable the development of new devices for optical data processing.

OPTICS APPLICATIONS

F-12; NANOLASERS FOR BIOSENSING
(Supervisors: Alexandre Francois and Tanya Monro)
We have recently demonstrated that it is possible to get a microsphere located at the tip of an optical fibre to lase, opening up the possibility of devices that could be deployed within a catheter inside the human body to detect disease. This project proposes to advance our fundamental understanding of the limits of performance of such nanolasers, with the aim of advancing towards the detection of single molecules.

F-13; NEAR-FIELD OPTICAL IMAGING OF WAVEGUIDING AND SURFACE PLASMONS IN METAL NANOWIRES WITHIN SUBWAVELENGTH STRUCTURES
(Supervisor: Yinlan Ruan, and Alexandre Francois)
Surface plasmon polaritons form at metal-dielectric boundaries as a result of the intense photon-electron interaction, and are tightly bound to the interface, which results in strong field enhancement for sensing, nonlinearity and imaging applications. The excitation of surface plasmons by light is denoted as a surface plasmon resonance (SPR) for planar surfaces or localized SPR for nanometer-sized metallic structures. It has been suggested that SPRs have the potential to allow very-large-scale integration of photonic devices at high packing densities. A major challenge, however, is how to create nanoscale metallic structures in which the impact of high optical absorption in the metal is reduced while preserving the advantage of strong metal-light interaction. We have successfully fabricated subwavelength holes less than 30 nm diameter within a soft glass microstructured fiber core. By filling these holes with metals, parallel metal nanowires will be formed to enable SPR propagating longer distance due to largely reduced metal nanowire size, thus much lower SPR loss. The aim of this project is to use this approach to demonstrate high field enhancement in metal filled soft glass microstructured fibres by using direct near-field optical imaging. One key challenge would be to fabricate such structure and more specifically to investigate potential techniques to fill the nanoscale holes of a subwavelength microstructured fibre with silver or any other metal that can support surface plasmons.
G - ENVIRONMENTAL LUMINESCENCE
(Supervisors: Nigel Spooner, Lee Arnold, David Ottaway, Heike Ebendorff-Heidepriem, Don Creighton)

The Environmental Luminescence group studies a range of real-world problems requiring the detection of ultra-low levels of light, of relevance to Environmental Monitoring, Quaternary Geology, Archaeology, Palaeontology, Earth Sciences, and Defence and National Security. Our research interests lie both in the underlying physics and in the applications. The facilities are located in the Prescott Environmental Luminescence Laboratory in the state-of-the-art “The Braggs” building.

The use of luminescence for measurement of the radiation dose absorbed by natural minerals – an essential component in finding the age of artefacts and geological formations - is a core area of research for luminescence dosimetry and geochronology (Thermoluminescence and Optical Dating).

In collaboration with DSTO we have expanded our program to include the study of radiation absorption by artificial materials. This is a niche application for Forensic and Retrospective Dosimetry (population dose reconstruction) purposes following radiological events such as the Fukushima accident. We are also now developing a range of activities in the areas of real-time sensing of radiation and mineral species identification for mining and mineral processing.

G-1; Geochronology: Recently acquired luminescence readers enable the optical dating of individual grains of minerals, and the unique spectral and spatially-resolved capabilities at extremely low light levels of our “3D-TL” spectrometer and Photon-Counting Imaging System (PCIS) offer opportunities for R&D of new Geochronological techniques. These include methods exploiting spatial resolution to improve and extend the current single-quartz grain optical dating techniques by applying TL and OSL analysis to the same individual grains of grain arrays and for measurement of depth-dose profiles and surface studies, and time-resolved OSL analysis for mechanism investigations. These apparatus also enable photon-counting sensitivity to be applied using red and near-IR luminescence emissions, opening major new areas including the potential to increase the time range for TL dating and to broaden the suite of known environmental dosimeter materials.

G-2; Defence & National Security: TL and OSL dosimetry can reveal prior exposure to radiation after the ionising radiation sources or radioisotopes have been removed, i.e., in situations where it is not possible to obtain radiation dose data by any other means, such as in the clean-up phase following a radiological event. In these applications, luminescence complements “conventional” radiation detection methods: the radiation damage detected by luminescence in the aftermath of exposure to ionising radiation is closely analogous to a persistent fingerprint, and applications in which this capability fills a unique role include Retrospective Population Dosimetry following a radiological event or nuclear accident, and Forensic Analysis. However, luminescence dosimetry properties have been comprehensively studied for very few natural crystalline minerals, chosen for their potential for Geochronology, and a similarly small number of modern man-made materials. We conduct research programs both to discover new opportunistic dosimeter materials, both natural and artificial, and to extend the applicability of known dosimeter minerals.

G-3; Mining and Mineral Processing: We are currently developing focus on research for mining & mineral processing and material characterisation, in collaboration with the Institute for Mineral and Energy Resources. This includes the real-time monitoring of radiation fields and radionuclide detection using radiation-sensitive optical fibres, and creating novel fluorescence analysis techniques using our new facilities, notably a UV-IR Spectrofluorimeter/ OPA lasers for mineral identification and materials characterisation.

Project: New tools for mapping radioactivity in metal ore: Metal ores that have very low radioactivity can command a significant price premium on the global metal ore market. Therefore there is a strong economic driver to understand the distribution of radionuclides throughout metal ore samples to enable smart mining techniques to reduce the level of radionuclides in ores that are exported from Australia. A number of projects are available that will contribute to the development of new photonic tools required to allow the mapping of these radioactive isotopes, which can occur at the part per trillion level. This project is particularly suitable for students who are interested in applying their physics knowledge to an applied physics problem that is important to Australia.

We invite discussion with students interested in engaging in any of the wide range of projects enabled by the Environmental Luminescence group research activities.
Physics Honours Projects 2016

H - PRECISION MEASUREMENT

(Supervisors: Prof. Andre Luiten, Dr James Anstie, Dr Philip Light, Dr Chris Perrella, Dr Richard White.)

A defining feature of our technological society is a hunger for more accurate and precise measurement and sensing. Important real world applications such as: the Global Positioning System (GPS), magnetic imaging, radar, optical fibre communications and even mobile phones, all rely on developing ever more accurate and precise measurements.

The Precision Measurement Group works to build instruments to meet this technological demand. We develop and extend measurement platforms of high value to fundamental physics; with an increasing focus on industrial, medical and defence contexts.

We have many projects available, and encourage interested students to meet with us and tour the lab. Please contact Andre Luiten (andre.luiten@adelaide.edu.au) to arrange a tour and meet with potential supervisors.

A more in-depth summary of the research areas of the precision measurement group is presented below. We also encourage students to visit our website (http://www.adelaide.edu.au/ipas/research/nls/pmg-research/) for even more detail.

H-1; Sensing & Spectroscopy

The optical frequency comb is a Nobel Prize winning innovation in laser technology that is poised to revolutionise spectroscopy. We use this massively parallel laser source to characterise atomic and molecular samples with unprecedented precision, accuracy, and speed. We also specialise in precision laser absorption and two-photon spectroscopy, both within conventional cells and fibre based architectures, with applications in fundamental physics, frequency standard development and quantum computing.

We are developing a program of high-precision sensing based on precision optical techniques using specialised lasers to probe crystalline-disc whispering gallery resonators, primarily for precision measurements of temperature, as well as all optical atomic magnetometers for precision magnetometry.

H-2; Quantum Atom-Fibre Photonics

The advent of micro-structured optical fibre has revolutionised methods for creating strong interactions between light and matter. Within our group we utilise both hollow-core fibre and exposed-core fibre to tailor and control light and matter interactions. This is achieved by confining light to small volumes, generating intense optical fields, while allowing an atomic vapour to be present within the same small volume.

We make use of this technology to guide cold atoms through fibre, implement both classical and quantum optical switches and produce compact optical frequency standards.

H-3; Frequency Standards & Distribution

We are developing optical and microwave sources having extremely high frequency stability for high impact experiments. These include direct measurement of Einstein’s time dilation effect, as well as frequency references for: leading-edge atomic clocks, optical and radio astronomy, and radar applications.

We are also developing a fibre dissemination network to allow fast and precise frequency comparison between frequency standards within different laboratories. This can be extended to time dissemination over large scales for applications such as the square kilometre array (SKA) radio telescope.

J  - BIOPHYSICS

(Supervisors: Bronwyn Dolman and Iain Reid)

J – 1; Modeling the Aussie Rules Football kick

Simple physical systems such as spring-mass systems can be used to model muscle function, with the advantage of the governing laws of motion being well known. These simple models can then be used to examine how various muscles behave in different sporting settings, and under various regimes known to cause injury such as fatigue. This project will look at the function of a human leg when kicking an Australian Rules Football. Motion capture data is available, and will be used in conjunction with OpenSim, an open source musculoskeletal model and dynamical simulator. Following the lessons learned from the simulator, a simple model with well defined laws of motion will be designed to examine the function of kicking in Australian Rules Football.
K - SEMICONDUCTOR PHYSICS  
(Supervisors: Dr David Huang)  

K-1 ; Structure-property relationships in organic semiconductors  

Organic electronic devices, such as polymer solar cells, show promise as cheap and flexible alternatives to conventional silicon-based electronics. But organic devices are generally much less efficient than their inorganic counterparts. The microstructure of organic semiconductor films, which often consist of phase-separated electron donor--acceptor mixtures, has a substantial impact on device performance. But the microstructure is difficult to control and its impact on electronic properties is still poorly understood. In particular, the generation of free charges in many donor-acceptor systems has been found to be more efficient than predicted by simple models of Coulomb binding at a structureless interface, but the origin of this enhanced efficiency, possibly driven by structure-induced interfacial energetic disorder or delocalisation of electron-hole pairs, is currently not well understood.

This project will will use statistical mechanics, quantum theory, and molecular dynamics and Monte Carlo simulations to investigate the roles of disorder, dipolar anisotropy, and delocalisation at donor-acceptor interfaces on charge separation, transport and recombination, as well as strategies for optimising these properties by tuning the interface structure.

L - GEOPHYSICS  
(Supervisors: Professor Sandy Steacy, Dr Derrick Hasterock (Earth Sciences))  
(contact: sandy.steacy@adelaide.edu.au or derrick.hasterok@adelaide.edu.au)  

L-1 ; Fault based forecasting of earthquakes in the Cook Strait, New Zealand  

Coulomb stress changes from large earthquakes affect the location and timing of subsequent ones. Aftershocks, for example, commonly occur in areas of Coulomb stress increase and there is also evidence of large earthquake triggering, for example along the North and East Anatolian Faults in Turkey. These Coulomb stress changes can be used to calculate changes in the likelihood of damaging earthquakes but to date these forecasts have been based on 2D maps, not applied to individual faults.

The Cook Strait sequence in 2013 consisted of an initial M=5.9 earthquake followed by 2 M=6.5 events about 3 weeks apart. The sequence may be consistent with cascading triggering from the initial earthquake but faults are poorly mapped in New Zealand and hence a combined areal / fault based model for Coulomb stress triggering is required. The aim of this project is to develop such a model for the Cook Strait sequence, and depending on the results, to forecast earthquake rates in the new model.

Training will be provided in programming and numerical modelling (Matlab and Fortran)

Figure: (Left) Coulomb stress changes following the initial M=5.9 earthquake resolved on mapped faults. The focal mechanisms show the sequence of the first M=6.5 event. (Right) 2D map of Coulomb stress changes from the first M=6.5 earthquake.
L-2 ; Developing a new physical / statistical model for earthquake forecasting

Coulomb stress changes from large earthquakes affect the location and timing of subsequent ones. Aftershocks, for example, commonly occur in areas of Coulomb stress increase and there is also evidence of large earthquake triggering, for example along the North and East Anatolian Faults in Turkey. These Coulomb stress changes can be used to calculate changes in the likelihood of damaging earthquakes and Steacy has recently led the development of a combined Coulomb/statistical approach to Canterbury seismic hazard using the STEP (Short term earthquake probabilities) model to compute the statistics.

A competing statistical model is ETAS (epidemic triggering of earthquakes) which has demonstrated significant skill when applied to a number of earthquake sequences. The aim of this project is to repeat the Canterbury work using the ETAS instead of the STEP model. If successful, one result would be the development of the first Coulomb/ETAS model which would likely be publishable in a mainstream geophysics journal.

Training will be provided in programming and numerical modelling (Matlab and Fortran)

Figure: Forecast earthquake rates following the 2010 Darfield earthquake in Canterbury, New Zealand. Red and yellow indicate areas of highest likely rate, blues lowest. Black circles indicate the epicentres of the $M \geq 4$ aftershocks. The asymmetry of the forecast reflects the Coulomb stress map.