PROJECTS FOR THE 2013 UWA-USTC/NANJING RESEARCH TRAINING PROGRAM

1. A/Professor Michael Small & Professor Kevin Judd

One place available, you can choose from three projects:

Network dynamics

Networks of interconnected dynamical systems arise in many areas - the interaction between high voltage power plants in the electricity generation network, for example. The aim of this project is to study how the properties of the structure of the network affect the stability of the system and the interaction (synchronization) of the various dynamical systems.

Ubiquity of scale free networks

Scale free networks exhibit the unusual property of having a finite probability of possessing nodes with a very large number of connections. Despite this, scale-free networks have been found to arise in a surprisingly wide range of real world systems - from interconnection of neurons in the brain to the network of collaborations between Hollywood actors. However, there currently does not exist a good characterization of the expected distribution of scale-free networks. This programme aims to rectify this.

Tracking and Flocking

How do groups of animals interact with one another to generate collective (flocking, herding or schooling) behavior? We aim to construct mathematical models of interactions from real observational data and use this to build realistic models of collective behavior.

2. Dr. Danail Obreschkow & Dr Chris Power

Galaxy Rotations applied to Cosmology

This project targets the holy grail of cosmology. It probes the expansion of the universe and mysterious motions of galaxy clusters. The objective is to use galaxy rotations in order to indirectly measure the velocity of galaxy clusters relative to the Milky Way. To do so the student will combine cutting-edge optical and radio data available at UWA. A potential outcome is an approximate measurement of the expansion rate of the universe using only radio data. This project is important regarding our fundamental understanding of the universe, as well as regarding future observations with the Australian Square Kilometre Array Pathfinder (ASKAP). The student will have unique opportunities to collaborate with world-class scientists at UWA and collaborators at the Universities of Oxford and Cambridge. The project is likely to result in publishable results as in the case of our last exchange student from USTC.

3. Professor Michael Wise

Relative Codon Adaptation as a Marker of Horizontal Gene Transfer

In all species, when the DNA is being used to encode a protein, DNA triplets (or ”codons”) are read off and translated into the corresponding amino acids, which are joined together to form proteins. A great deal of redundancy is built into this translation process, e.g. the codons: CCA, CCC, CCG and CCT each encode the amino acid proline. This is perhaps not so surprising when you realize that the 4^3 possible codons encode only 20 amino acids. However, the level of redundancy is not uniform, with certain amino acids having just a single encoding (methionine, tryptophan) while others have six (leucine), presumably reflecting greater numbers of the corresponding anti-codons. Furthermore, different species have preferences about which encodings they prefer to use, so, for example, engineering the encoding of the polio virus capsid protein to use less favoured codons resulted in a significant attenuation of the virus (Mueller et al., J. Virol 2006). The Codon Adaptation Index (CAI) was developed some years ago to measure how optimally a gene is encoded (Sharp and Li, Nuc. Acids Res. 1987). Given the species specificity, researchers have tried to use CAI differences to identify genes that have arrived in a host genome through Horizontal Gene Transfer. Such attempts have so far proven to be unsuccessful; A number of studies in bacteria have found that low CAI is not necessarily an indicator of HGT and that differences in CAI between HGT genes and native genes can be minor (Koski et al., Mol Biol Evol 18: 404, 2001; Wang, Mol Evol 53: 244, 2001). Essentially, they found it difficult to distinguish between low CAI due to low expression and low CAI due to HGT. However, the CAI computation is based on the codon usage across a panel of highly expressed proteins (typically ribosomal proteins), and it can be shown that while CAI based on different (but overlapping) sets of highly expressed genes infers other highly expressed genes consistently, there is little consistency across the two CAI implementations for low CAI values. In other words, little can be inferred from low CAI values. What is proposed for this project is that instead of using CAI values representing just the species of interest, codon usage tables will be computed for the same set of highly expressed genes across a range of species (in principle every species for which the data is available). Then, given a query protein-coding nucleotide sequence (CDS), i.e. the actual sequence of codons, the species with the highest CAI score will be the most likely source as the encoding of the input sequence will be most consonant with that species' codon usage. The significance of using highly expressed genes is that they are unlikely to be present in a genome due to HGT (Park & Zhang, Genome Biol Evol 2012).

The following projects, numbers 4 and 5 are available in the School of Plant Biology and involve mathematical modelling in plant ecology, agriculture (crops, weeds, pests and

diseases), and plant form and function (plant physiology), and advanced quantitative methods in studies of plant (eco)physiology.

4. Associate Professor Michael Renton

(Email: michael.renton@uwa.edu.au) Professor Renton is an applied mathematician (http://www.uwa.edu.au/people/michael.renton) with a number of projects available in computational simulation modelling of plants in complex biological, agricultural and ecological systems: (for details see: https://sites.google.com/site/michaelsaamrenton/projects)

- Evolution of herbicide resistance in weeds in agricultural systems and the effect of different genetics and management strategies on the rate of this evolution
- Competition between species, individual plants, and parts of plants and the effect of spatial patterns on this competition
- Weed seed bank population dynamics and the effects of different seed biology and management strategies
- Seed dormancy, germination and persistence, and the influence of environmental factors and management options
- The optimisation of land use sequencing and analysis of tactical and strategic decisions in agricultural systems, taking into account the effects of factors such as weeds, disease, plant nutrients, yields, economics and climate variability
- Water use, root architecture, drought and climate change, in relation to applications such as the prediction and management of the establishment and survival of annual and perennial crop and pasture plants in drought-susceptible environments, or the long-term health of natural ecosystems in the face of climate change
- The spread of invasive biological organisms such as weeds, insects and plant diseases
- Predicting the fate of plant species under climate change, accounting for landscape characteristics, population dynamics and dispersal

5. Assistant Professor Charles Price

(Email: charles.price@uwa.edu.au) Professor Price is a quantitative ecologist/plant ecophysiologist (http://www.uwa.edu.au/people/charles.price) with a number of projects available in plant allometry, plant geometry, metabolic scaling theory, leaf vascular design, biological image analysis. For details see: http://www.chuckprice.info/)

- Surface area scaling in succulent plants: exploring relationships of metabolic theory and the allometry of surface area to mass, using new 3D scanning equipment and gas exchange analysers.
- Biomechanical vs. hydraulic investment in leaf veins. As leaves increase in size, they invest more in network (vein) tissue relative to non-network (lamina) tissue; however, it is unclear which of these (biomechanical or hydraulic) plays a greater role in determining network investment.
- Leaf vein topology and hydrology. Leaf networks display a dizzying array of hierarchical complexity and this project will explore how leaves of differing topology maintain flow relative to one another in various conditions environmental.
- Comparison of different leaf vein measurement approaches: There have been two main semi-automated approaches used to identify the dimensions of veins in leaves. Both approaches have advantages and disadvantages. Novel software routines we will be used compare results from these two approaches using cleared leaf images from locally growing taxa, and a suite of different statistical measures.
- Plant branching architecture. This project will determine if a fractal model is a reasonable approximation for plant branching networks, we will collect and analyse data on the geometry and topology of herbaceous and/or woody plant branching networks.

6. Dr Michael Giudici

Research projects in the Centre for the Mathematics of Symmetry and Computation

Members of the Centre conduct research in group theory and combinatorics. Group theory is the mathematical abstraction of symmetry and one can use groups to understand combinatorial structures such as graphs or geometries, or one can use combinatorial structures to understand groups.

Members of the Centre are willing to supervise a project on the topic of group theory or combinatorics, or some combination of the two. Possible projects include:

1. Graphs with certain symmery properties, such as Cayley graphs or vertex- transitive graphs

2. Configurations in finite geometries.

3. Permutation groups.

4. Algebraic graph theory. Projects have the potential to involve the use of computation through com- puter algebra packages such as GAP or Magma. More information about research in the centre can be found at http://www. cmsc.uwa.edu.au/research

7. Supervisor: Dr. Alfred Tay (who works with Nobel Laureate, Professor Barry Marshall)

Project Title: Typing of *Helicobacter pylori* clinical strains

Introduction

Helicobacter pylori is a gram negative, microarerophelic, spiral bacterium that has infected more than half of human global population. For those that are infected, all of them will develop certain degree of gastritis, but only 10% will develop clinical symptoms, such as peptic ulcer, duodenal ulcer, gastric ulcer and only about 1% will develop into a more severe disease such as gastric cancer and mucosa-associated lymphoid tissue lymphoma (MALT) (2, 9, 10). In some developing countries, children as young as 2 years old was found infected with *H. pylori.* Once infected, one is expected to remain infected in his lifetime until eradication therapy was taken (3). It is now known that eradication of *H. pylori* not only improves ulcer healing but also reduces the recurrence of gastric and duodenal ulcers.

Infection is usually acquired during childhood by intra-familial transmission and in the majority of cases infection is lifelong unless eradication by antibiotic treatment is undertaken (11, 14). The prevalence of *H. pylori* infection ranges from 25% in developed countries to more than 80% in the developing regions (14, 16, 17). *H. pylori* is commonly transmitted from mother to child (14). Despite *H. pylori* being well known for its high genetic diversity and frequent recombination, studies also suggest that recombination is rare between isolates from different continents. Therefore *H. pylori* may serve as a genetic marker of human descent and reflects the human population in which the host spent his/her childhood (1, 8, 12).

Multilocus sequence typing (MLST) of seven housekeeping genes from several hundreds of *H. pylori* strains isolated from different geographical, ethnic, and/or linguistic origins showed that *H. pylori* followed human migration out of Africa. Eight *H. pylori* populations which are designated as hpAfrica1 (isolated from countries in Western Africa and South Africa), hpAfrica2 (isolated from South Africa), hpNEAfrica (isolated from Northeast Africa), hpAfrica-Europa, hpEurope (isolated from Europe, the Middle East, India and Iran), hpEastAsia (isolated from China, Korea, Japan, New Zealand, North and South America), hpAsia2 (isolated from Northern India, Bangladesh, Thailand, and Malaysia) and hpSahul (isolated from Australian Aboriginals and Papua New Guineans) have been identified (1, 8, 12, 15). Three of these populations are further divided into subpopulations: hpEastAsia is divided into three subpopulations, hspEAsia (from East Asians), hspAmerind (from native Americans) and hspMaori (from Taiwanese Aboriginals, Melanesians and Polynesians); hpAfrica1 is divided into hspSAfrica and

hspWAfrica; hpEurope is divided into Ancestral European 1 (AE1) and Ancestral European 2 (AE2) (1, 8).

Prevalence of bacterial resistance varies in different geographic areas, and it is now known to correlate with the consumption of antibiotics in the general population (4, 13). For instance, careful use of macrolides in Northern European countries was shown with a lower *H. pylori* clarithromycin resistance rate compared to Southern European countries, where clarithromycin is largely used (5-7). During the last two decades, a widespread use of antibiotics, such as clarithromycin for respiratory infections, metronidazole for anaerobic bacteria and levofloxacin for urinary infection, has increased the occurrence of primary *H. pylori* resistance in the general population (4, 6, 13). Hence, this project is aimed to sequence the seven housekeeping genes of selected clinical strains (Table 1) and determine their *Helicobacter* population origin. The student will be trained how to operate in a PC2 facility, culture *H. pylori*, DNA extraction, run PCR, and analysis of DNA sequencing result.

Table 1. Selected clinical strains

Lab ID	Antibiotic resistant profile
11/04	Ciprofloxacin resistance
11/44	Ciprofloxacin resistance
11/54	Ciprofloxacin resistance
11/55	Ciprofloxacin resistance
11/08	Rifabutin resistance
11/20	Rifabutin resistance
11/21	Rifabutin resistance
11/35	No resistance
11/42	No resistance
11/48	No resistance

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8. Supervisors: Gravity wave group - Professor David Blair, Professor Ju Li, Associate Professor Chunnong Zhao & A/Professor Linqing Wen

1. Use Pulsar Timing Array data to detect gravitational waves from supermassive black hole binaries. http://www.ipta4gw.org/

A passing gravitational wave will affect the local space-time metric on the travel path of a radio pulse and can lead to observable fluctuations in its arrival time at Earth. There is an international effort in using pulsar timing arrays (PTAs) to detect gravitational waves. A direct detection of nanoHertz gravitational waves using PTAs is possible within this decades. The Parkes Pulsar Timing Array (PPTA) in Australia observes 20 millisecond pulsars at 2-3 weeks interval with regular monitoring commenced early 2005. PPTA offers the most regularly monitored millisecond pulsars among all efforts.

The student will have the opportunity to work with experts from the PPTA project and use data from the Parkes telescope to search for gravitational waves from binaries of supermassive black holes. The student can pick up a small project in the design of directional search methods for anisotropic gravitational wave background, optimal detections of individual gravitaitonal wave sources, signal-based detection verification, parameter estimation including localization of detected individual sources, study of gravitational wave sources, or more hands-on projects on producing scientific output from pulsar data. The students are also welcome to propose their own projects.

2. Real-time low-latency detection of gravitational waves using ground-based interferometers for prompt electromagnetic follow-up. http://www.gravity.uwa.edu.au/ (under Data Analysis)

Several advanced ground-based interferometric gravitational-wave detectors are expected to be operational around 2015. Direct detections of gravitational waves from compact binaries of neutron stars and black holes are expected within this decade. An real-time search pipeline that uses newly developed time-domain search technology has been developed in our group in collaboration with Caltech, Perimeter institute, CITA and AEI. The aim is to detect gravitational waves in real-time in the advanced detector era and pass event triggers to conventional telescopes for prompt follow up observations. The pipeline has

passed initial tests on existing detector data and on simulated online data from engineering runs for advanced detectors.

The student will have the opportunity to contribute to the on-going effort to further improve this search pipeline and use it to generate scientific outputs. The student will have access to real detector data from the past Science runs and simulated online data for future detectors for the testing. The student can also work on the development of new search methods that optimally combine data from all gravitational wave detector, develop fast method to determine the sky direction of gravitational wave sources. The student can also study the astrophysical aspect of a joint gravitaitonal wave-electromagnetic observation for advanced detectors and for a larger detector network.

3. High-performance computing using Graphics Processing Units (GPUs). http://www.gravity.uwa.edu.au/ (under Data Analysis)

We use the powerful cost-effective GPUs http://www.nvidia.com/object/what-is-gpu-computing.html together with CPUs to accelerate the gravitaitonal wave signal processing. A GPU accelerated search engine has been developed and a CPU-GPU hybrid pipeline has been developed for the real-time low-latency search mentioned above. We also look into the GPU application in industry, e.g., for resource exploration. The student will have the opportunity to use the 96-node GPU cluster from iVEC/Pawsey Fornax cluster located at the UWA. This project requires students to have basic computational skills, e.g., C programming. Knowledge of GPU/CUDA programming will help.

9. Supervisor: Professor Pan Jie (Engineering)

10. Supervisor: Professor David Coward (Physics)

Project Title - Probing gamma ray bursts: the biggest explosions in the Cosmos

Gamma ray bursts are the most energetic explosions in the Universe. Their emissions are observed by dedicated NASA satellites in the high energy, and by ground based telescopes in the optical. It is believed that gamma ray bursts are the result of massive stars collapsing to form black-holes in the distant Universe.

There are several exciting core projects available, encompassing observational, theoretical and/or software development depending on the student's interest:

1) The study of early optical emissions from gamma ray bursts.

2) Probing the gamma ray burst high energy and optical emissions – towards an understanding of the central engine.

3) There are many other projects available. For further options please contact David Coward.

11. Professor Daniel Murphy and A/Prof Deirdre Gleeson (Soil Science group)

Project Title: Effect of biochar and pH on soil microbial processes

This Research Training Project is offered in the School of Earth and Environment at the University of Western Australia with supervision by Prof. Daniel Murphy and Dr. Deirdre Gleeson. The aim of this research will be to investigate the effect of biochar amendment on low and high pH soils at a variety of water filled pore space (WFPS) in a semiarid soil collected from a field site that had been previously limed. The student will perform a laboratory based incubation experiment using field soils from our Wongon Hills Experimental Station in the central grainbelt of southwestern Australia (Wongan Hills; 30° 51' S, 116° 44' E; Acidic Ferric Yellow-Orthic Tenosol). Incubations will be performed at a range of water filled pore space (WFPS) and analyses will include measurement of nitrous oxide and carbon dioxide emissions using gas chromatography as well as abundance of total bacteria, archaea and the functional gene for both bacterial and archaeal ammonia oxidation (*amoA*) using quantative polymerase chain reaction.

12. Supervisors: A/Prof. Robert McLaughlin and A/Prof. Rodney Kirk

13. Supervisors: Professor Miranda Grounds and A/Professor Tea Shavlakadze

Project Title - “ Molecular biomarkers for age-related loss of skeletal muscle mass and function (sarcopenia)”.

Project details to follow

14. Professor Mikhail Kostylev, Condensed Matter Physics (mikhail.kostylev@uwa.edu.au)

Two projects are being offered:

High frequency magnetisation dynamics for microwave signal processing, nano- sensor applications and characterisation of magnetic nano-materials (experimental)

Magnonics [1,2] and spintronics [3] are two emerging fields of electronics which exploit electron spin rather than electron charge. Worldwide research in these fields is hoped to result in faster, more compact and more power efficient electronic devices for applications ranging from microwave signal processing to bio- and chemical sensing. The functionality of spintronic and magnonic devices is generally based on high frequency magnetic excitations such as magnetic waves, or "spin waves", which exist in a frequency range from 10MHz to 50 GHz and have sub-micrometre wave lengths.

Experimental opportunities in our group will involve the study of spin-waves and other high frequency magnetisation dynamics in various magnetic nanostructures. Experimental techniques available in our laboratory, such as ferromagnetic resonance and travelling spin wave spectroscopy will be utilised in this project. The student will also have possibility to participate in fabrication of magnetic multilayered films using the magnetron sputtering setup available in our lab and in characterisation of static magnetic properties of these materials using Superconducting Quantum Interferometer Device (SQUID) and Magneto-Optical Kerr Effect.

[1] V.V. Kruglyak et al., *J. Phys. D: Appl. Phys.* **43** 264001 (2010). [2] G. Gubbiotti, S. Tacchi, M. Madami, G. Carlotti, A. O. Adeyeye and M. Kostylev, *J. Phys. D: Appl. Phys.* **43** 264003 (2010). [3] I. N. Krivorotov et al., *Science* **307,** 228 (2005).

15. Professor Mikhail Kostylev, Condensed Matter Physics (mikhail.kostylev@uwa.edu.au)

Magnetisation dynamics and spintroni effects in magnetic nanostructures (theoretical computational)

Spintronics is an emerging field of electronics which exploit electron spin rather than electron charge. Many spintronic phenomena, such as Spin Transfer Torque [1] and Spin Hall Effect [2] are dynamic effects involving microwave oscillations (0.5- 50GHz) and waves (called spin waves) in magnetic nanostructures and multilayers. Microwave signal processing is an area important for applications in mobile telephony, satellite communications and radiolocation. Microwave devices

are still bulky and new physical approaches are urgently needed to decrease the sizes of microwave gear.

The student will be involved in construction of a numerical model and numerical simulations of interaction of microwave magnetic excitations on magnetic nanostructured materials with dc electron charge currents. It is anticipated that a numerical model will follow from this work which will allow designing a number of novel nanoscale devices for microwave signal processing in the future.

[1]] I. N. Krivorotov et al., *Science* **307,** 228 (2005). [2] J. E. Hirsch, *Phys. Rev. Lett.* 83, 1834 (1999).

16. Professor Michael Tobar

Hybrid Quantum System with the interaction between an Acoustic and Electromagnetic Resonator

This project will be done under the ARC Centre of Excellence in Engineered Quantum Systems. A superconducting cavity couple to a low-loss mechanical resonator will be built and cooled down to very low temperatures. Characterization will assist in the read-out at the quantum limit, enabling the observation of a macroscopic object to a precision that reveals quantum properties.

17. Professor Steven Smith & Drs Wenxu Zhou and Jing Li

Genetic modification of plants for insect resistance

Insect pests destroy at least 10% of crops and food every year. Insect resistance in crop plants has been achieved using the famous 'Bt' technology, in which plants produce a toxic protein from the bacterium *Bacillus thuringiensis*. However, 'Bt' technology is breaking down as insects develop resistance, and new methods are urgently required. We are developing a new technology called 'Sterol Interference' in which the sterol composition of plants is genetically modified to inhibit insect feeding or reproduction (Nes, Lopez et al. 1997; Behmer and Elias 2000; Behmer, Grebenok et al. 2011). This technology uses genes to produce naturally-occurring plant sterols, so should not only be safe for human food production but might have beneficial effects on human health.

Having changed the sterol composition of Arabidopsis plants we are now investigating the effects on plant physiology and metabolism, in addition to effects on insect feeding and growth. We also developed a sterol-limited artificial insect diet for verification plant feeding results. The research training offered will cover molecular biology and metabolomics, including gene cloning, plant genetic transformation, PCR analysis and metabolomic analysis using gas chromatography and mass spectrometry, including isolation and structure determination of novel sterols. The research is conducted in the laboratories of the Australian Research Council Centre of Excellence in Plant Energy Biology in collaboration with Hexima Ltd, a plant biotechnology company aiming to commercialise this new technology (Dunse et al. 2010).

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18. Professor Alistair Paterson and A/Professor Martin Porr

19. Professor Ian Small & Dr Sandra Tanz

A decisive biological advantage of C_4 plants is their spatial separation of photosynthetic reactions between two different cell types, mesophyll (M) and bundle sheath (BS). This compartmentalization allows greater metabolic efficiency, with studies showing up to 50% greater biomass accumulation and a higher water- and nitrogen-use efficiency in C_4 plants compared to C_3 plants. Consequently, research is focusing on transferring the C_4 pathway into C_3 crop plants such as rice, wheat and soybean (*1, 2*).

Previous studies have concentrated on nuclear gene expression of M and BS cells in C_3 and C_4 plants (*3, 4*), whereas gene expression in chloroplasts and mitochondria has mostly been overlooked. This is unfortunate because the differential expression of organellar genes between M and BS cells is fundamental to the modified biochemistry of photosynthetic reactions in C_4 photosynthesis. The overall project examines the regulation of gene expression in chloroplasts in M and BS cells, comparing closely related C_3 and C_4 species. Using laser capture microdissection to separate M and BS cells followed by quantitative PCR, *in situ* hybridization, ribosome footprinting and deep sequencing, we are studying transcription, RNA processing and translation of chloroplast genomes in the C_4 species *Cleome gynandra*. We are using these results to identify potential regulators of chloroplast gene expression in M and BS tissues using the laboratory's discoveries on similar regulators in *Arabidopsis (5)*. We focus on elucidating the regulation of the production of the carbon-fixing enzyme Rubisco, a major target in the implementation of the C_4 pathway in C_3 crop plants.

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3. Brautigam *et al* (2011) *Plant Physiol* 155:142
4. Li *et al* (2010) *Nature Genetics* 42:1060
5. Schmitz-Linneweber and Small (2008) *Trends Plant Sci* 13:663

20. Dr Peter Munro and Dr Brendan Kennedy (Optical + Biomedical Engineering Laboratory, head: Winthrop Professor David Sampson)

Project title: Development of algorithms for application in optical imaging

OBEL has a strong background in the application of optical coherence tomography (OCT) to biomedical imaging. OCT, the optical analogue of ultra-sound imaging, is now well established as an imaging technique and efforts are being directed to employing OCT as a tool for measuring nanoscopic displacement within tissue. This enables OCT to measure physiological properties and processes within the body and thus has significant potential as a clinical diagnostic tool. Displacement measurement, however, requires the development of new data processing techniques which will form the topic of this project. In particular, we are interested in techniques for performing phase unwrapping and speckle tracking.

OCT is a phase sensitive technique which means that small displacements of scatterers within a sample may be measured on a scale much smaller than the resolution of the imaging system. As will all phase sensitive techniques, measured phases take on values which are modulo 2p. We plan to investigate the application of Green's first theorem to phase unwrapping, an established technique known to be robust in the presence of noise.

Speckle refers to the intensity pattern observed due to the interference of wavefronts, each of which originate from different scattering centres, when employing coherent light. Displacement of these scatterers by a small amount leads to a shift in a speckle pattern. We plan to implement a technique for calculating the relative shift of speckle patterns between two measurements thus allowing inference of displacement within a sample.

Both projects require a solid applied mathematics background and programming skills, ideally in Matlab. Matlab programming ability is not essential as it is possible to learn this even in the short time available during the research training program.

Contact: peter.munro@uwa.edu.au

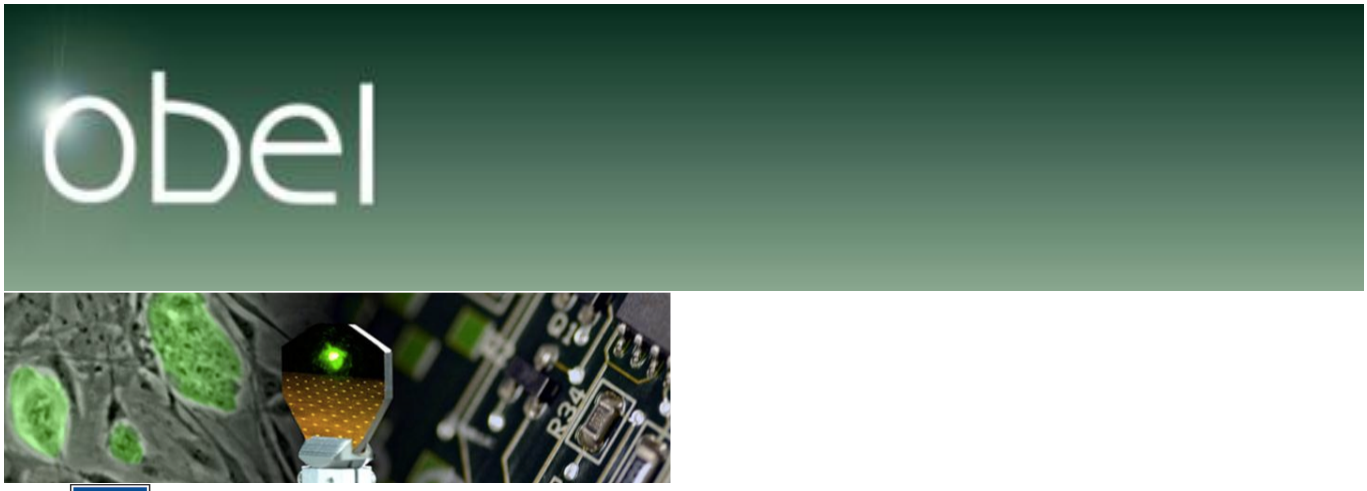
21. Professor Shaun Collin

22. Dr Eric Howell, Australian International Gravitational Research Centre

Gravitational Wave – Gamma Ray burst observations – predicting and exploring multi-messenger opportunities

Current understanding suggests a significant proportion of short hard Gamma-ray bursts (SHBs) may result from the merger of a pair of compact objects (neutron stars and/or black holes). This presents the opportunity for *multi-messenger observations* using both gravitational wave (GW) and electromagnetic instruments. We have recently calculated the event rate of SHBs using the small sample of available data (around 10 SHBs with secure redshifts – see Coward et al 2012 **arXiv:1202.2179**) and thus have inferred the potential rate of GW observations from these sources. Other than the event rate, the SHB luminosity functions are very uncertain at both high (gamma-ray, x-ray) and low energies (optical). Additionally, some studies have suggested that there is a correlation between the high and low energy gamma-ray burst data. Investigating the latter luminosity distributions and any potential correlations could provide clues of the expected rates and optimal strategies for multi-messenger observations using GWs. This project will explore these ideas using only secure SHB data and statistical techniques, some of which will be applied to SHBs for the very first time (e.g. see Howell & Coward 2012 **arXiv:1206.4151**).

23. Dr. Dirk Lorenser, Optical + Biomedical Engineering Laboratory (OBEL), UWA



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Optical simulation of multimode fiber probes for fluorescence imaging

Fiber-optic imaging systems for fluorescence microscopy are being developed by leading research laboratories worldwide [1, 2] in order to open up new methods of minimally invasive diagnosis in medical fields such as cardiology and cancer, which also have very high commercial potential.

Precise simulation of the fiber-optic imaging system is essential for achieving optimal optical designs which capture weak fluorescence signals with the highest possible efficiency. The figure below illustrates the basic concept of the imaging system. An optical fiber delivers the illumination light, which is focused into the sample by a micro-lens. The illumination light excites fluorescent markers in the biological tissue, which emit light that must be collected by the micro-lens and coupled back into the optical fiber with high efficiency. This project aims to compare two methods for simulating such probes: geometrical-optics (ray tracing) and wave optics (solution of the scalar wave equation, expansion of wave fields into guided modes of the optical fiber). After comparing the capabilities of both simulation methods, one of the methods will be used to design a fiber-optic probe and to study its fluorescence collection efficiency as a function of various parameters such as fiber numerical aperture (NA), fiber core diameter and spacing of the micro-lens relative to the fiber. This project is a part of ongoing research in our laboratory and allows the student to develop optical simulation skills which are in high demand in science and industry.

Required skills:

Solid understanding of optics and electromagnetic theory. Programming (MATLAB).

Contact:

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References:

Yoo, H., et al., Intra-arterial catheter for simultaneous microstructural and molecular imaging in vivo. Nature Medicine, 2011. 17(12): p. 1680-1685.

Lorenser, D., et al., Dual-modality needle probe for combined fluorescence imaging and 3D optical coherence tomography. Optics Letters, 2013. 38(2).

24. A/Professor Swaminathan Iyer (Group Leader, BioNan), Prof. Fiona Wood and Dr. Mark Fear

Thermo responsive polymeric scaffolds for wound healing

Every year, millions of people suffer major disability and even death from burns, caused by either domestic events like flame and boiling oil or the risks of serious burn during combat which are unlikely to diminish, given of the rapid development of new and powerful thermobaric weapons. Despite recent therapeutic advances, the mortality and morbidity from major burns remains high. Consequently, there is a pressing need to develop economical, efficient and widely-available therapeutic approaches to enhance the rate of wound re-epithelialization and restoration of the protective epithelial barrier. Skin, the largest organ of the human body, provides an essential protective barrier and serves several homeostatic/sensory functions vital to health and its functional recovery post burn injury remains the ultimate goal of wound healing research. Polymer nanoscaffolds have been extensively utilized in the design of tissue engineered constructs in delivering several growth factors for the correction of a wide range of medical conditions. A variety of polymeric scaffolds have been used to deliver growth factors, including natural or synthetic polymers that generally form either hydrogels or solid polymer scaffolds. However extended release of proteins is not easily achieved due to the release kinetics of growth factor through hydrogels being mainly diffusion controlled via the numerous aqueous channels within the hydrogels. Immobilization of the growth factor within the biodegradable hydrogel seems to improve the release kinetics, with release being controlled by the degradation of the hydrogel. Here the release kinetics are slow and progressive necrosis sets in post injury. A novel modulated delivery system would indeed be ideal, allowing the release profiles of payloads to be manipulated to match the physiological requirements of the patient. The project will explore the utility of thermo-responsive scaffolds for on-demand delivery of payloads.

25. A/Professor Swaminathan Iyer, Prof D. D. Sampson and Prof. S. Dunlop

Colloidal Upconverting NaYF4 Nanocrystals Doped with Er3+, Yb3+ and Tm3+ for biomedical imaging and diagnostics

Upconversion nanocrystals are luminescent nanomaterials that convert a near-infrared excitation into a visible emission through lanthanide doping. Compared to organic fluorophores and semiconducting nanocrystals, upconversion nanocrystals offer high photochemical stability, sharp emission bandwidths, and large anti-Stokes shifts (up to 500 nm) that separate discrete emission peaks from the infrared excitation. Along with the remarkable light penetration depth and the absence of autofluorescence in biological specimens under infrared excitation, these upconversion nanocrystals are ideal for use as luminescent probes in biological labelling and imaging technology. Organic dyes and semiconductor quantum dots that emit at higher energies via two-photon absorption processes require expensive high energy pulse lasers. Due to the relative high efficiency of the upconversion process in lanthanide-doped materials, inexpensive 980 nm NIR diode lasers may be employed as the excitation source. The realization of efficient NIR to visible upconverting nanocrystals can be exploited to develop novel dual modality drug carriers. The project will explore the synthesis and properties of doped NaYF4 nanosystems and their utility as biomarkers in vitro.