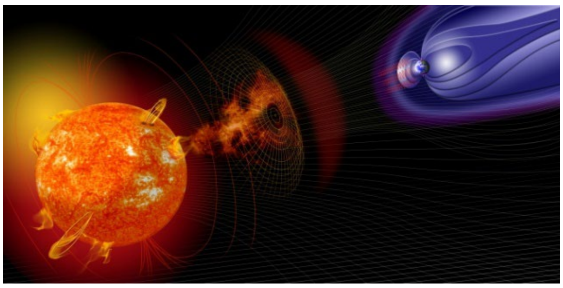
THE UNIVERSITY OF NEWCASTLE AUSTRALIA

DISCIPLINE OF PHYSICS

HONOURS AND UNDERGRADUATE RESEARCH PROJECTS

2026



Undergraduate Research in the Discipline of Physics

School of Science

There are a number of strong research themes in the discipline of physics in areas such as:

- Solar, space and astrophysics
- Nanomaterials
- Laser physics and quantum systems
- Medical Physics
- Organic Electronics

We encourage undergraduates to get involved in research throughout their degree. By doing so you will learn and develop skills in searching, selecting and retrieving information from scientific sources, skills in project management, experimental research skills as well as skills in presenting scientific information in a clear and concise manner, both orally and in writing. These will provide you with a strong foundation for your future career, whether it be in the industrial, commercial or academic sector.

There are three main ways to get involved in research:

a) ***Summer research project:*** Short paid undergraduate research projects over summer.
b) ***SCIE3500:*** A 10-unit undergraduate course consisting of a research project under the supervision of an academic staff member. Assessment is based on a progress report, a research notebook, a final project report and an oral presentation. The course is open to third year students who have successfully completed at least 140 units and have a cumulative GPA of at least 5.0 and is offered in both semesters, plus the winter term. Course outline link here.
c) ***Honours research project:*** A full-year research project after completion of the Bachelor of Science or another cognate degree. A minimum GPA of 5.0 is required for entry into honours. Program handbook link here. This year is 50% coursework and 50% research.

This booklet contains a list of undergraduate research projects currently available in the discipline. Academics are listed in alphabetical order. In all cases you should discuss potential projects with prospective supervisors before trying to enrol or apply.

Prof David Pontin

(02) 4055 3261
david.pontin@newcastle.edu.au
https://www.newcastle.edu.au/profile/david-pontin

Analysing flows on the Sun's surface to untangle the problem of coronal heating
Observations of the Sun reveal that its outer atmosphere ("corona") is around 1000 times hotter than its surface, a fact that has defied explanation since it was first realised nearly 80 years ago. Recent promising results suggest a resolution to this problem, involving tangling/braiding of the magnetic field lines in the corona by plasma flows on the surface. However, current methods for extracting these flows from observational data have severe shortcomings. In this project the aim is to use data from the latest NASA missions to better measure the surface flows and the vector components of the surface magnetic field during the braiding of coronal field lines to better constrain this proposed mechanism for atmospheric heating. This project could focus either on data analysis and processing, or on mathematical models and measures of complexity, depending on the student's interest. It is suitable for students with interests in Physics or Mathematics.

The structure of the Sun's magnetic field and implications for understanding the solar wind
The solar wind is a stream of plasma coming from the Sun in which the Earth is embedded. Its conditions around the Earth are called "space weather", and understanding/predicting this space weather is economically important due to its ability to disrupt communications, endanger astronauts, and damage power systems and satellites. The goal of this project is to analyse magnetic field structures in the Sun's atmosphere that are thought to be source regions for the slow, unsteady component of the solar wind that is poorly understood. This will involve working with new, high-resolution observations of the Sun's surface magnetic field from the latest NASA space missions. Using this data, the goal is to extrapolate to find the magnetic field in the Sun's atmosphere (which can't be measured directly), and then to analyse the structures present in this magnetic field. This will be a computational project that will involve writing codes/modifying existing codes to analyse and visualise these structures using, e.g., python.

Understanding energy conversion in turbulent, magnetised plasmas
Magnetic and velocity fields in plasmas exhibit a turbulent behaviour on a wide range of scales, from galaxies to the Sun to laboratory plasmas on Earth. Turbulence appears inherently messy/chaotic, but one path to understanding the energy conversion in such plasmas is to study the spatial distribution of different magnetic field structures. The aim of this project is to develop algorithms that compare the correlations between structures present in the magnetic field and measures of energy conversion. This will provide insight into the fundamental phenomenon of plasma turbulence – relevant for understand plasmas in space, the Earth's atmosphere, and lab fusion devices.
This project could focus either on data analysis and processing, or on mathematical/statistical analysis, depending on the student's interest. It is suitable for students with interests in Physics or Mathematics.

Properties of elementary heating events in solar coronal loops
One of the leading theories for how the plasma in "coronal loops" reaches such high temperatures is by a so-called "braiding" process where the surface motions cause a tangling of the magnetic field lines in the loops. This in turn leads to the formation of intense electric currents, which are required to convert stored magnetic energy to heat. The idea of this project would be to explore how these elementary heating events work in new, high-resolution simulations. This will involve developing algorithms to quantify the properties of the electric current "sheets" in the simulation data, and then looking at what the signatures of these processes would be in solar observations. This project is suitable for students with interests in Physics or Mathematics.

Exploring the complexity of stellar magnetic fields
In recent years techniques have been developed to measure that magnetic field on the surfaces of stars. These magnetic fields are crucial for driving a range of phenomena like winds and flares that can affect the habitability of orbiting planets. The goal of this project would be to take the computational tools that we use for analysing the complexity of the Sun's magnetic field, and apply them to these stellar magnetic field data. This project is suitable for students with interests in Physics or Mathematics.

Dr Hannah Schunker

(02) 4055 3484
hannah.schunker@newcastle.edu.au
https://www.newcastle.edu.au/profile/hannah-schunker

Average 3D supergranule in numerical simulations
One of the dominant scales of convection on the Sun is supergranulation, which has length-scales of 20-40 Mm and time scales of 24-48 hours. However, it is not known how deep supergranules extend below the surface. In this project the student will compute the divergence of the horizontal flows from pre-computed numerical hydrodynamic simulations of the convection in the Sun's near-surface to identify supergranules. The student will then create the average supergranule and as a function of depth below the surface to understand the subsurface structure and extent.

Emerging magnetic active regions on the Sun
It is not known how the magnetic field emerges from the deep interior of the Sun onto the surface. To understand the common physics driving the emergence, we need to look at many active regions. In this project, the student will develop a pipeline to process state-of-the-art observations from NASA's Solar Dynamics Observatory to identify suitable emerging active regions, and corresponding control regions. This work will contribute to a living database of emerging active regions. The student will apply their strong coding skills to learn sophisticated data analysis techniques.

Modelling Stellar Light Curves
The rotation of stars can be measured from their light curves. Starspots are regions of strong magnetic fields on the surface of stars, which are cooler and darker. When a starspot rotates onto the visible hemisphere of the star the light is dimmed. Regular dimming of the stars light can be used to measure the rotation rate, however the latitude of the starspot and inclination of the star is ambiguous. In this project, the student will use existing models to create stellar light curves including limb darkening, starspot size, lifetimes and latitudes, as well as stellar inclination to visualise the visible surface of the star in relation to the modelled light curve. This will involve coding in python and learning stellar physics.

What drives Joy's Law?
Joy's Law is a statistical phenomenon where the polarity pairs of established magnetic regions on the Sun are inclined towards the equator. It is thought that the Coriolis force is responsible for driving this inclination, but it is not clear what velocities the Coriolis Effect is acting on. The student will select active regions from an existing database that show a strong anti-Joy's Law and compare the surface flows throughout the evolution to those obeying Joy's Law. The student will then make calculations of the expected Coriolis force based on the flows.

Dr Lachlan Rogers

(02) 4055 7574
lachlan.rogers@newcastle.edu.au
https://www.newcastle.edu.au/profile/lachlan-rogers

Stretching quantum interactions in diamond to the limit
Tiny glowing artificial atoms in diamond, called colour centres, can be used to store and process quantum information through the manipulation with laser light and microwaves. Important aspects of these physical interactions are dictated by the exact colour centre shape which in turn is strongly influenced by the surrounding diamond crystal. This project aims to explore the changes in colour centre properties that arise from mechanical deformation of the crystal. The results will fit into the development of strain-engineering as a novel approach to improve quantum memories in diamond. This experimental project will involve measuring glowing diamonds in a fluorescence microscope, optical spectroscopy, and data analysis in python.

Qantum "optics" of heat in diamond
Photons "bunch", or arrive simultaneously in groups, for thermal light, but they do the opposite ("antibunch") when emitted by a single-photon emitter. Atomic impurities in diamond, called colour centres, are excellent single-photon sources. Diamond is also a solid-state crystal and so hosts quantum vibrations called phonons, which are essentially heat energy. This project will use various laser wavelengths to excite colour centres so that information about the phonons can be obtained by optical measurements of photons from the glowing diamonds.

Counting quantum emitters
Single quantum emitters are important building blocks for quantum computing, quantum communication, and quantum information technologies. Most such emitters are much smaller than can be resolved in a microscope, and so it is important to have techniques that can reliably identify when one is isolated on its own. Photon timing gives the clue, because a single emitter cannot emit two photons exactly simultaneously! This project will use Bayesian probability theory to develop new analysis techniques for the photon statistics to enable more reliable identiification of the number of emitters. It will involve simulations and inference development in Python.

Looking for quantum emitters in 2-D diamond
Graphene is well-known as a 2-D carbon material, and it has different chemical bonds to those in diamond. Joining two layers together with diamond carbon bonds creates "diamene" - a kind of 2-D material that looks like graphene but acts like diamond! This project aims to do spectroscopy on diamene samples to search for colour centres analogous to those studied in diamond. It will involve laser spectroscopy, confocal fluorescence microscopy, and can also involve sample growth and preparation.

Professor Paul Dastoor

(02) 4921 5426
paul.dastoor@newcastle.edu.au
https://www.newcastle.edu.au/profile/paul-dastoor
Centre for Organic Electronics

Biosensors from Plastic Electronics

Diabetes currently affects over 300 million people worldwide, a number that is predicted to rise to over 500 million by 2020. Diabetes sufferers are condemned to a lifetime of painful, invasive blood testing many times a day. Research in the Centre for Organic Electronics (COE) has already demonstrated that low cost glucose biosensors can be fabricated by simply incorporating bioactive materials (such as enzymes) into organic thin film transistors (OTFTs). Using soft electronic polymers as the matrix for the bioactive material eliminates the need for complex molecular surface assembly. This project will involve designing, building and characterising OTFT biosensors for diabetes management. The goal of this project is the development of a flexible and inexpensive printable biosensor. This project is suitable for students with backgrounds in Physics, Chemistry and Engineering.

Helium Atom Beam Microscopy: Using Quantum Mechanics to Image Delicate Surfaces

Scanning helium atom microscopy offers the tantalizing possibility of using the wave-particle nature of helium atoms to image the structure of delicate surfaces with unprecedented resolution. This project will involve developing the new ARC-funded helium beam microscope at Newcastle and producing preliminary images. This project will involve collaboration with the Cavendish Laboratory at the University of Cambridge. This project is suitable for students with backgrounds in Physics, Chemistry and Engineering

Extending the Spectral Response of Organic Solar Cells

State-of-the-art organic solar cells are limited by the wavelength response of the active semi-conducting polymer layer since these materials typically only photogenerate charges below 500 – 550 nm. In the natural world, plants use a range of porphyrin-based molecules (such as chlorophyll) to allow photosynthesis to occur across the solar spectrum. This project aims to develop photovoltaic devices containing novel light harvesting molecules. The goal of this project is to develop printed solar cells that generate electricity from the entire solar spectrum. This project is suitable for students with backgrounds in Physics, Chemistry and Engineering

Extending the Lifetime of Organic Solar Cells

One of the current challenges limiting the rapid uptake of organic solar cells is the limited lifetime of these devices. This project will study novel device architectures with the goal of developing extended lifetime solar cells devices. This project is suitable for students with backgrounds in Physics, Chemistry and Engineering

Field Ionisation Helium Detection using Carbon Nanotubes

Scanning helium microscopy is an emerging imaging technology that uses low energy (<50 meV) helium atom beams as a completely non-perturbing probe of nanoscale structure. However, this exciting new technology is currently limited by the lack of an effective 2D imaging system for neutral He atoms. Carbon nanotubes (CNTs) offer the possibility of acting as effective field ionisation tips for He atoms thus allowing them to be detected. This project will aim to grow CNT arrays using the chemical vapour deposition (CVD) system in the Centre for Organic Electronics. This project is suitable for students with backgrounds in Physics, Chemistry and Engineering

Large Area Printing of Organic Solar Cells

The development of new sources of renewable energy is urgently required if the worst effects of man-made climate change are to be avoided. This project will build on the recent exciting advances made by the Centre for Organic Electronics (COE) in device fabrication to develop new methods for printing large photovoltaic arrays based on semi-conducting polymers. This project will make use of the new state-of-the-art printing system that has been recently purchased by the COE for developing organic electronic circuits. This project is suitable for students with backgrounds in Physics, Chemistry and Engineering.

Novel Electrodes for Organic Solar Cells

The capability of organic solar cells to provide large scale global sustainable energy solutions will be limited by the current high costs and supply issues associated with the current electrode materials. This project will explore novel transparent conducting materials to address the issue of developing low cost electrode structures for these exciting new devices. This project is suitable for students with backgrounds in Physics, Chemistry and Engineering.

Novel Encapsulants for Organic Solar Cells
State-of-the-art organic solar cells are limited by the durability and lifetime of the active layer materials in these blended devices. This project will study the role of new encapsulant materials and structures to extend the lifetime of these devices. This project is suitable for students with backgrounds in Physics, Chemistry and Engineering.

Phase Contrast Mechanisms in Scanning Helium Microscopy
The aim of this multinational collaborative research project is to develop the world's first imaging detector for neutral helium atoms for use in a new surface-imaging instrument – the scanning helium microscope. Scanning helium microscopy is an emerging imaging technology that uses low energy (<50 meV) helium atom beams as a completely non-perturbing probe of nanoscale structure. Currently, there is little understanding of the mechanisms that would provide contrast in this microscopy. The ultimate goal of this project is to understand the phase contrast mechanisms that would operate in scanning helium microscopy and is motivated by recent research by Prof Dastoor and colleagues at the University of Cambridge. This project will involve modelling work with the goal of understanding the phase contrast processes. This project is suitable for students with backgrounds in Physics, Chemistry and Engineering

Structure and Morphology of Conducting Polymer Blends
Conducting polymer blends underpin all of the activities of the Centre for Organic Electronics, especially in the areas of organic solar cells and biosensors based on organic transistors. This project will study the role of structure and morphology in these blend materials as characterised by advanced synchrotron based techniques. This project is suitable for students with backgrounds in Physics, Chemistry and Engineering.

Ultra-fast Laser Spectroscopy of Organic Electronic Materials
The charge generation and charge conduction mechanisms involved in organic electronic devices occur on extremely short timescales and as such are not well understood. This project will aim to use a state-of-the-art femtosecond laser spectroscopy system to probe these mechanisms using pump-probe spectroscopy. This project is suitable for students with backgrounds in Physics, Chemistry and Engineering

Professor Joerg Lehmann

(02) 4014 3689
joerg.lehmann@health.nsw.gov.au
https://www.newcastle.edu.au/profile/joerg-lehmann
Medical Physics Research Group

Real-time measurement and verification of breast position during radiation therapy
The LEILA study has developed a system for measurement of real-time breast position during treatment using MV imaging with the treatment beam. This can be used to ensure treatment accuracy for deep-inspiration breath-hold treatments which spare heart dose and also to compare positioning techniques. It includes a multi-centre study collecting data on treatment positioning. This project will analyse breast-positioning data collected during treatment.

Dosimetry audits and SEAFARER
The SEAFARER Cancer Australia project is the investigation of the sensitivity and specificity of dosimetry measurements performed throughout Australia to check treatment plan dose calculations and treatment delivery accuracy. Data from over 40 national and international centres is being collected for different types of treatments. We are building a cloud-based platform to perform studies of international practices to assist with standardization of radiation oncology practice and to assist low and middle-income countries and clinical trials. This project will investigate dosimetry accuracy and audit patterns in different countries.

Reference dosimetry for kV x-ray systems used for cell and small animal irradiations
Dosimetry for cell and small animal irradiations for radiation oncology research is complex and difficult with currently high uncertainties. This project will investigate the accuracy of existing models and also perform Monte Carlo simulations and measurements

Professor Peter Greer

(02) 4014 3607
peter.greer@health.nsw.gov.au
https://www.newcastle.edu.au/profile/peter-greer
Medical Physics Research Group

Improvement and international investigation of stereotactic radiosurgery treatments
We have formed an international consortium of centres in Australia, United States and Europe to investigate and standardize dose calculations for complex brain treatments where multiple small lesions are treated to very high doses using intensity modulated beams. This project will investigate a novel virtual three-dimensional dose measurement technique using flat-panel imager for these treatments, and remotely assess and compare dose delivery accuracy at each centre in the consortium.

Multiplexed dosimetry and imaging system for radiation oncology
Currently flat-panel imagers used to form patient images with the treatment beam are designed purely for imaging and perform poorly for dosimetry due to the high atomic number of the phosphor scintillator that introduces an extreme energy-dependence of the signal, requiring complex algorithms and corrections to obtain dose. TOPAS Monte-Carlo studies have shown that a grid or chequerboard optical filter that alternately blocks or passes the optical photons from the scintillator can produce interleaved imaging and dosimetry signals, This project will further assess and optimise the design and investigate its suitablity for linac beam dose measurements.

Development of a method for real-time in-patient dose reconstruction during patient treatments
We have developed the world's first real-time treatment verification system in radiation oncology. The current Watchdog system calculates a predicted image set with a physics model and in real-time compares the measured image frames after the treatment beam has passed through the patient to the predicted images. This project will extend this to deriving dose in the patient model in real-time in transit dosimetry situation and compare predicted to measured doses within the patient in real-time.

Dr Jonathan Goodwin

(02) 4014 4950
Jonathan.goodwin@health.nsw.gov.au
https://www.newcastle.edu.au/profile/jonathan-goodwin
Medical Physics Research Group

CIMBA-B: APT-CEST Imaging for Metabolic Assessment in Brain Tumours

Treatment response assessment in brain tumours has always been challenging and is increasingly being seen as important due to advances in personalised medicine. It has been evident for some time that there is a discordant between functional and morphological findings of both imaging and histopathology. Multi-parametric MRI using a combination of different MRI sequences, is used as a surrogate for treatment response with evidence indicating a benefit in some tumours, including brain tumours. However, direct measurement of tumour metabolism has been challenging due to the need for invasive procedures to access tumour tissues. Non-invasive metabolic imaging with MRI therefore, is another attractive option. Amide Proton Transfer Chemical Exchange saturation transfer (APT-CEST) MRI is an emerging imaging technique to obtain functional information about the tumour microenvironment and is a potential biomarker for response assessment needing further evaluation.

Deep learning enabled gold fiducial detection for MRI only prostate treatment planning

Gold seed fiducial markers are routinely implanted in the prostate to assist with image guidance during radiotherapy. On CT and kV imaging, these markers are clearly visualised, allowing accurate localisation during simulation and treatment delivery. However, in MRI-only treatment planning, visualisation is more challenging due to the hypointense appearance of both gold seeds and prostatic calcifications resulting from their negative magnetic susceptibility. This creates potential ambiguity for fiducial segmentation in patients with intraprostatic calcifications, which can compromise MRI-only workflows. To address this issue and improve the simulation-treatment pipeline for MRI-only prostate radiotherapy, a deep-learning model trained to detect gold seeds on Tl-weighted GRE images was implemented as a software container on the MRI system using OpenRecon to provide inline segmented images that can be exported directly to the treatment-planning system. This project continues to look at ways of improving the technique for clinical implementation.

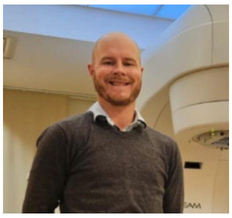
Functional avoidance in liver radiation therapy planning

Radiation induced toxicity in liver cancer patients has been linked to reduced quality of life and poor prognosis. Incorporating regions of relative higher liver function as avoidance structures during radiation treatment planning may lead to improved patient outcomes. In this study we explore novel MRI based methods for generating functional liver maps for incorporating into radiation treatment planning.

Synthetic CT for abdomen and lung

While MRI offers superior soft tissue contrast for contouring tumour targets and defining organs at risk, CT is typically required for dose calculation. However, co-registration of CT and MRI images during radiation treatment can lead to anatomical mismatch for anatomies such as liver and lung. In this study we are working with Siemens Healthineers, CSIRO and Liverpool Hospital to develop AI generated synthetic CT images, which would enable an MRI only workflow for abdomen and lung patients.

Dr Ben Zwan



(02) 4320 9868
Benjamin.zwan@health.nsw.gov.au
https://www.newcastle.edu.au/profile/ben-zwan
Medical Physics Research Group

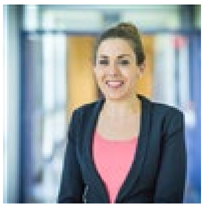
Four-dimensional dose reconstruction in a virtual motion phantom
Respiratory tumour motion can significantly impact the delivered radiation dose during radiotherapy and result in poor treatment outcomes for patients. We have developed a novel method to verify the dose received by tumours undergoing respiratory motion. This method relies on Megavoltage images acquired using an electronic portal imaging device (EPID). In-house software is employed to reconstruct the delivered dose in a "virtual" motion phantom using the EPID images. The resultant 4D dose can then be compared to the intended dose to verify the accuracy of the dose delivery with motion. This project will focus on (1) making improvements on the existing methodology to incorporate more complex tumour motion and (2) retrospectively analyse of past Liver and Lung cancer treatments using the method.

Treatment Verification for Ultra-Hypofractionated Breast Radiotherapy
Standard practice in breast cancer radiotherapy is rapidly evolving. Previously radiation dose was administered in smaller amounts spread over 15 to 25 sessions – referred to as fractions. This "fractionation" approach reduces the negative effects of radiation on healthy tissue and results in a safer treatment. Recently, practice has changed to treat breast cancer patients with higher dose per session and in only five fractions, referred to as ultra-hypofractionation. While there are key advantages to this faster treatment regime, there may be detrimental effects if the radiation is not accurately targeting the breast tissue and avoiding key health-tissue – for example, the heart. As part of an ethically approved study, we are collecting X-ray images during five-fraction breast cancer radiotherapy treatments. This project will utilise previously developed research software to automatically extract anatomical features from the X-ray images, to measure the accuracy of the deliveries and ensure patient safety.

Real-time Error Detection using Machine Learning
We have previously developed software to detect treatment delivery errors for routine linear accelerator quality assurance. This system, QUAVER, utilises electronic portal imaging device (EPID) images acquired in real-time during complex radiotherapy deliveries to assess the accuracy of the beam collimation system and dose output. QUAVER has been applied offline (without the presence of a patient) at Central Coast Cancer Centre, Gosford and Calvary Mater Newcastle. Further work is required to develop this system to be applied in real-time during patient treatments to allow errors to be detected before they can cause potential harm to patients. This project will leverage existing image analysis techniques combined with novel machine learning methods to perform these checks in real-time.

Evaluation of a New Radiotherapy Technique: RapidArc Dynamic
In collaboration with industry partner, Varian Medical Systems, we will be evaluating the performance of a new commercial radiotherapy delivery technique, RapidArc Dynamic. This new technique is the most complex commercially available technique worldwide on standard linear accelerators. It allows rotating beam collimation and enables complex beam fluences to be delivery both through rotating gantry angles and from fixed angles in a single delivery. This project will focus on evaluating the clinical benefits of this novel technique including (a) quantifying radiation dose benefits within the patient (b) assessing if treatment time is increased/decreased and (c) verification that dose is delivered accurately to the patient.

Dr Renee Goreham



(02) 4913 8252
renee.goreham@newcastle.edu.au
https://www.newcastle.edu.au/profile/renee-goreham

Aptasensor Platforms Using Nanoparticles

Aptamers offer highly selective binding to extracellular vesicles (EVs) and cancer-associated biomarkers, making them ideal recognition elements for biosensing. When combined with nanomaterials such as quantum dots (QDs) and gold nanoparticles (AuNPs), which provide optical and electrochemical transduction respectively, these bioconjugates can be engineered into highly sensitive, low-cost diagnostic tools. Integrating aptamers with QDs and AuNPs aligns with the Goreham Group's focus on developing breath and EV-based diagnostics. This project involves engineering and comparing QD- and AuNP-based aptasensor formats for a selected target—such as an EV surface protein or model analyte—and evaluating their analytical performance. Students will quantify binding affinity and specificity, determine limits of detection, and assess sensor stability, regeneration, and tolerance to complex matrices such as biological buffers or model biofluids.

Summary:

Students will develop and compare QD- and AuNP-based aptasensor systems, optimise bioconjugation methods, and produce a validated, reproducible protocol for sensitive biomarker detection compatible with existing Goreham Group diagnostic workflows.

Understanding Aptamer Binding with Neutron Beams

Neutron specular reflectometry (SR) and small-angle neutron scattering (SANS) provide powerful techniques for resolving nanoscale interfacial structures and understanding biomolecular binding in situ. This project focuses on using these methods to model and interpret data from the Goreham Group's existing experimental studies rather than conducting new beamtime experiments. Students will develop and refine structural models describing how aptamers and nanoparticles interact with surfaces or membrane mimics, using parameters such as layer thickness, roughness, solvent contrast, and density distribution. By comparing these models to the group's benchtop electrochemical and fluorescence binding data, students will gain insight into the mechanisms of aptamer–nanoparticle interaction and the factors influencing biosensor performance.

Summary:

Students will analyse and model existing SR and SANS data to interpret aptamer and nanoparticle binding behaviour, contributing to a deeper understanding of nanoscale sensor interfaces and guiding future biosensor design.

Engineering Tissue-Like Phantoms for Optical Tomography

Optical tomography and diffuse optical imaging require well-characterised tissue-mimicking phantoms that replicate the scattering and absorption properties of biological tissues. This project involves designing, fabricating, and characterising solid or gel-based phantoms with tunable optical properties in the red to near-infrared range (630–900 nm). Students will use agarose, gelatin, or PDMS matrices combined with intralipid as a scattering agent and India ink or haemoglobin analogues as absorbers. The phantoms will be tested for optical stability and reproducibility using transmittance, reflectance, or integrating sphere measurements. Optional inclusions may be embedded to simulate tumour-like or vascular regions, providing realistic calibration samples for optical imaging systems.

Summary:

Students will create and characterise reproducible tissue-like phantoms to support the calibration and validation of optical tomography systems, generating a set of reference materials and data useful for ongoing imaging research in the group.

Synthesis & Characterisation of QDs and AuNPs

Producing nanoparticles in-house provides precise control over their size, surface chemistry, and optical or electrochemical properties, enabling consistent performance across biosensing and imaging applications. This project focuses on developing reproducible syntheses for gold nanoparticles (AuNPs) and cadmium-free quantum dots (QDs), such as InP/ZnS systems. Students will explore ligand exchange and surface functionalisation strategies compatible with aptamer attachment, including thiolated or carboxyl-terminated linkers. Comprehensive characterisation will be carried out using UV–Vis absorption, fluorescence spectroscopy, dynamic light scattering (DLS), zeta potential

measurements, and electrochemical analysis. The resulting data will be compiled into a "property library" linking synthesis parameters to key functional outcomes, such as emission wavelength, charge, and colloidal stability.
Summary:
Students will synthesise and characterise AuNPs and QDs, establishing standardised protocols and property correlations that will feed directly into future aptasensor and imaging developments within the Goreham Group.

Characterising Aptamer–Protein Interactions by Molecular Dynamics
Understanding how aptamers interact with their target proteins at the molecular level is essential for improving diagnostic performance. This project uses molecular dynamics (MD) simulations to explore the structural stability and binding mechanisms of aptamers with EV-associated proteins such as CD63 and CD44. Students will perform all-atom MD simulations in explicit solvent using the Amber99SB-ILDN force field and analyse trajectory data to identify structural features contributing to binding strength and selectivity. Key analyses will include root mean square deviation (RMSD), radius of gyration (Rg), hydrogen bonding patterns, and interfacial contact mapping.
Summary:
Students will gain experience in computational biophysics, performing MD simulations and structural analyses to identify key residues and conformational states responsible for high-affinity aptamer binding.
Proteomic Exploration of Lung Cancer EV Biomarkers

Identifying universal and disease-specific EV biomarkers is vital for early cancer detection.
This project involves mining public proteomic datasets to identify consistent protein signatures present in lung cancer-derived EVs. Using databases such as Vesiclepedia and UniProt, students will curate datasets, perform differential expression analysis, and visualise protein interaction networks to highlight potential aptamer targets.
Summary:
Students will compile a biomarker reference list for lung cancer EVs, supporting future aptamer design and validation efforts within the breath diagnostics program.

Dr Stuart Gilchrist

Stuart.Gilchrist@newcastle.edu.au
https://www.newcastle.edu.au/profile/stuart-gilchrist

Modelling Solar Magnetic fields with Physics-Informed Neural Nets

The solar corona is the hot, extended outer atmosphere of the Sun, whose structure and dynamics are governed by the coronal magnetic field. Explosive reconfigurations of the coronal field gives rise to solar activity such as solar flares and coronal mass ejections. However, direct observation of the coronal magnetic field is challenging. Instead, it is typically inferred—or extrapolated— from spectro-polarimetric observations taken in the denser, cooler solar photosphere. This extrapolation process involves solving three-dimensional nonlinear boundary-value problem, which traditional computational methods often struggle to handle efficiently and accurately.

Physics-Informed Neural Networks (PINNs) are a recently developed approach to solving such challenging problems in computational physics. PINNs leverage neural networks—a form of machine learning—to find solutions to systems of differential equations. This method offers several advantages: it is more robust to noisy data than conventional numerical techniques and also allows for flexible implementation, making it easier to test different boundary conditions and physical models.

This project focuses on developing and experimenting with PINNs to perform Nonlinear Force-Free Field (NLFFF) extrapolations of the solar coronal magnetic field. The work will involve machine learning, Python, physics, and numerical and computational methods.

Validation of solar coronal magnetic field models

Explosive reconfigurations of the solar coronal magnetic field give rise to solar activity such as flares and coronal mass ejections, which directly impact Earth. Understanding these events, with the ultimate goal of predicting them, is a long-term objective of heliophysics. Unfortunately, studying these events is challenging because the solar coronal magnetic field is poorly observed, I.e. it is difficult to constrain via remote sensing methods. Quantitative information on the strength, direction, and structure of the field is particularly difficult to infer, and this limitation constrains the study of coronal physics.

In the absence of direct observations, it is necessary to rely on data-driven modelling, which combines physical models with observations of the magnetic field at the photosphere. These coronal field “extrapolations” have become a fundamental tool for investigating the corona. However, constructing the three-dimensional field via extrapolation is non-trivial, and the accuracy of these methods is not well understood because the basic ground truth—the coronal magnetic field—is unavailable for comparison.

Can we really trust the magnetic fields produced by extrapolation models? This is the question that model validation seeks to answer. In this project, we will use state-of-the-art observations of the Sun in X-ray and Extreme Ultraviolet (EUV), along with optical spectro-polarimetric data, to explore what we can—and cannot—learn about the corona through extrapolations. The project offers scope for theory, modelling, observations, and statistical analysis.

Dr Tom Evans

(02) 4055 3229
tom.evans-soma@newcastle.edu.au
https://www.newcastle.edu.au/profile/tom-evans-soma

Atmospheric characterisation of a hot Jupiter using the James Webb Space Telescope (JWST)
WASP-121 b is a gas giant exoplanet orbiting extremely close to its host star with an orbital period of approximately 30 hours. Temperatures in the upper atmosphere of the planet vary dramatically from ~3000 kelvin on the dayside down to ~1000 Kelvin on the nightside. Using the NIRSpec instrument onboard JWST, we've observed a spectroscopic phase-curve for WASP-121 b covering the ~3-5 micron wavelength range. Various research projects related to this dataset are possible, including:

- Measuring how radiation is transmitted through the atmosphere to decipher the contrasting properties of the dayside and nightside hemispheres.
- Studying the morphology of the primary transit signal to search for evidence of differing atmospheric conditions at the morning and evening terminators of the planet.
- Detailed comparison of the emission spectra obtained at the start and end of the observation to search for evidence of variability in the atmospheric properties over ~10 hour timescales ('exo-meteorology').

Atmospheric characterisation of various exoplanets using the Hubble Space Telescope (HST)
Until JWST launched in late 2021, HST had been the premier observatory for studying exoplanet atmospheres. Projects are available to analyse and interpret atmospheric spectra obtained from unpublished HST observations for a number of exoplanets:

- HD 209458 b is the original transiting exoplanet (an archetype of the hot Jupiter class) and remains one of the most favourable observational targets. Data are available for both the dayside emission spectrum and the atmospheric transmission spectrum.
- HAT-P-18 b is a 'warm' (<1000 kelvin) Saturn-sized exoplanet orbiting an active host star. Atmospheric transmission data are available spanning the optical-to-near-infrared wavelength range. In particular, the optical data complement infrared data from JWST that have recently been published.
- TOI-270 c and d are two 'temperate' (<500 kelvin) sub-Neptune exoplanets orbiting a common red dwarf star, discovered by the Transiting Exoplanet Survey Satellite (TESS). Atmospheric transmission data are available for both planets at near-infrared wavelengths.

Modelling exoplanet atmospheres in the JWST era
The quality of the spectra we are now measuring for exoplanets with JWST far surpass those that had represented the state-of-the-art until just two years ago. This project would involve modelling the transmission of radiation through exoplanet atmospheres and comparing the resulting spectra to those that have been recently acquired with JWST and published in the peer-reviewed literature. In doing so, the aim is to learn the chemical and thermal properties of the planetary atmosphere. This in turn can help us to refine our understanding of how radiative transfer, chemistry, and dynamics couple together in atmospheres that are unlike any we encounter in the solar system.

Exploring Survey Outcomes for the Habitable Worlds Observatory
The Habitable Worlds Observatory (HWO) is a planned flagship NASA mission designed to directly image and characterise Earth-like planets around nearby stars, searching for signs of habitability and life beyond the solar system. While its design and target list are still being refined, HWO aims to detect reflected light from terrestrial exoplanets and measure their spectra — potentially revealing atmospheres similar to Earth's. This project will explore possible outcomes of HWO's future surveys. Using the current catalogue of potential target stars and publicly available frameworks for simulating astronomical survey yields, the project will model how different assumptions about the frequency and properties of Earth-like planets affect the number and types of worlds HWO might detect. Because the

true occurrence rate of Earth twins remains highly uncertain, this project allows these parameters to be adjusted — much like tuning the terms in a Drake Equation — to see how survey expectations change. The goal is to understand how sensitive HWO's scientific return will be to key unknowns in exoplanet demographics and to identify what kinds of discoveries would be most likely under different scenarios.

Dr Xiaojing Zhou

(02) 4921 6732
xiaojing.zhou@newcastle.edu.au
https://www.newcastle.edu.au/profile/xiaojing-zhou

Organic Electronics, Nanomaterials and Biosensors

Organic semiconducting materials are very versatile with a wide scope of applications in transistors, light-emitting diodes, photovoltaics and bio-compatible interfaces for medical devices. My research explores all aspects of the above-mentioned areas.

Organic Transistor: A transistor made from an organic semiconducting material is called organic transistor. Organic transistors are conventionally fabricated in nitrogen glovebox to eliminate any absorption of oxygen and water molecules. My goal is to develop air compatible organic transistors that can be manufactured and tested in air.

Graphene Electrode: Graphene is an emerging nanomaterial with versatile applications. This project is to investigate the growth mechanisms experimentally and theoretically of graphene from different carbon sources and explore the potentials of graphene as a transparent and conductive electrode for organic photovoltaics or photo-catalytic reaction cells. This project suits students from chemistry, physics or chemical engineering disciplines.

Electrodeposition of Functional Metal Nanoparticles on Graphene Electrode: Electrodeposition is an easy and low-cost method to manufactory metal nanoparticles. Different electrode materials play an important role in controlling the formation of those nanoparticles in sizes, shapes and chemical composition. This project is to investigate copper nanoparticles formation using different electrodes, from gold, silicon to carbon-based graphene electrodes. The growth mechanisms will be examined to elucidate the effects of surface morphology, surface energy of the electrodes on the nanoparticle formation.

Non-enzymatic Biosensors: Conventional biosensors are based on enzymes as the sensing elements to provide selectivity. Enzymes are bio-catalysis. However, enzymes can only survive in the restricted biological suitable environment and most commercially available enzymes are very expensive, which limits biosensors' accessibility due to their cost. This project is to explore user friendly and cost efficiency disposable biosensors without involving enzymes.