Australian Institute of Physics NSW Branch

2021 Postgraduate Awards Event Schedule

The 2021 Awards Event is sponsored by:

2021 AIP Postgraduate Awards

The **NSW AIP Branch** will hold its **Annual Postgraduate Awards event** on **Tuesday 9 November 2021** by **Zoom** from **2:00pm.**

Each University has invited a postgraduate physics nominee to compete for the **AIPNSW Postgraduate medal** and the **RSNSW Jak Kelly prize.**

These awards have been created to encourage excellence in physics postgraduate work, and all nominees who participate in the Postgraduate Awards Day will receive a **special award** recognising the nominee's high standing.

Students will make a **15-minute online presentation** on their postgraduate **research in Physics**, and the presentation will be judged on the **criteria (1) content and scientific quality, (2) clarity and (3) presentation skills as included in the judges' criteria.**

Zoom Event Link

Event: AIP NSW Postgraduate Awards
Date: Tuesday Nov 9, 2021
Time: 02:00 PM Canberra, Melbourne, Sydney
Join from PC, Mac, Linux, iOS or Android:
https://aarnet.zoom.us/j/87483503215?pwd=MCt3WUIrdTBUWEhuVVhnUjJOSjJhUT09
Password: 809165

2021 Judging Panel

- Dr Jesse Shore – **Prismatic Sciences**
- Tibor Molnar – **Honorary Research Associate, Department of Philosophy, University of Sydney**
- Dr Timothy Van der Laan – **Australian Institute of Physics NSW**
- Dr Erik Aslaksen **– The Royal Society of New South Wales**

Criteria for AIP Postgraduate Awards

All candiates will present a **max 15-minute presentation** *(not including questions)*. The judges score and rank the candidates according to: (1) Content and Scientific Quality, (2) Clarity and (3) Presentation Skills. The judges combine their results to determine the winner. *Decisions by the panel are final*.

1. **Content and scientific quality are important criteria**. The presentation must be interesting, and the material should be seen to be significant within the field of research. Context is important for establishing what the state of current research in the field is and how the described research contributes to and extends current knowledge. The candidate must balance the competing demands of providing a clear explanation to the non-specialist and illustrating the techniques and methods to allow a meaningful assessment of the presenter's own understanding and contributions to the research. The context can be further clarified during the question-and-answer session.

1 = Strongly Disagree
3 = Neither Disagree nor Agree
5 = Strongly Agree

A. Content and Scientific Quality Matrix				**Total____/20**	
(i) Interesting	1	2	3	4	5
(ii) Significant	1	2	3	4	5
(iii) Addresses Research Gap/Need	1	2	3	4	5
(iv) Contributes and Extends Knowledge	1	2	3	4	5

2. **Clarity** is a skill which is required to communicate a subject requiring years of study into a 15-minute presentation. The judges are looking for the presenter's ability to communicate the essence of the research without becoming excessively encumbered with detail. A proper introduction, good exposition and meaningful conclusions are important factors in providing a clear presentation.

B. Clarity Matrix				**Total____/20**	
(v) Communicates Essence	1	2	3	4	5
(vi) Good Introduction	1	2	3	4	5
(vii) Good Exposition and Explanations	1	2	3	4	5
(viii) Meaningful Conclusion	1	2	3	4	5

3. **Presentation skills** include the best use of audio-visual aids, speaking ability, eye contact, efficient use of time, projecting a professional and confident attitude, preparedness and response to questions.

C. Presentation Skills Matrix				**Total____/20**	
(ix) Preparation and Use of Time	1	2	3	4	5
(x) Use of Audio-Visual	1	2	3	4	5
(xi) Professional and Confident	1	2	3	4	5
(xii) Response to Questions	1	2	3	4	5

Prepared by: Dr Frederick Osman
2021 Awards Convenor

2021 AIP Postgraduate Schedule

- ***2.00pm*** **Welcome by Dr Frederick Osman (AIP Awards Coordinator)**

- ***2.05pm*** **Sobia REHMAN, Macquarie University, Department of Physics and Astronomy**

  An integrated hybrid chip-fibre platform for the generation of mid-infrared light

- ***2.25pm*** **Florian LIST, University of Sydney, School of Physics**

  Dim but not entirely dark: A deep learning-based analysis of the Fermi Galactic Centre Excess

- ***2.45pm*** **Joe Zhiyu CHEN, University of New South Wales, School of Physics**

  Chasing neutrons in the sky

- ***3.05pm*** **Zain MEHDI, Australian National University, Department of Quantum Science and Technology**

  Thermal Dissipation in Two-Dimensional Quantum Turbulence

- ***3.25pm*** **Matthew B. JAMES, University of New England, School of Science and Technology, Physics and Electronics**

  Monte Carlo modelling of $^{98}Mo(n,\gamma)^{99}Mo$ utilising a clinical scale plasma fusion neutron source

- ***3.45pm*** **Simon WHITE, University of Technology Sydney, School of Mathematical and Physical Sciences**

  Quantum photonics with hexagonal boron nitride quantum emitters

- ***4.05pm*** **Ankit SHRESTHA, University of Wollongong, School of Physics/ISEM**

  Constraining models of inflation with galaxy clustering

- ***4.25pm*** **Closing of 2021 AIP NSW Postgraduate Awards**

An integrated hybrid chip-fibre platform for the generation of mid-infrared light

Sobia REHMAN

Department of Physics and Astronomy, Macquarie University

Abstract

While it has been shown that radiation at mid-infrared wavelengths has tremendous potential in applications as diverse as environmental monitoring, medical diagnosis, and many others, virtually all of demonstrations to date have been carried out in a controlled laboratory environment due to the non-existence of suitable field-deployable light sources. While fibre-based lasers dominate light-based technologies in the visible and near-infrared part of the electromagnetic spectrum, the development of mid-infrared fibre lasers for real-world applications is hindered by the lack of integrated optical components in this critically important spectral region.

This project is aimed at breaking this bottleneck by utilizing the femtosecond laser direct inscription technique to create a novel hybrid chip-fibre platform for the development of fully integrated mid-infrared guided-wave laser systems.

Dim but not entirely dark: A deep learning-based analysis of the Fermi Galactic Centre Excess

Florian LIST
School of Physics, University of Sydney

Abstract

A fundamental question regarding the gamma-ray Galactic Centre Excess (GCE) in the *Fermi* data is whether the underlying structure is point-like or smooth. This debate, often framed in terms of a millisecond pulsar or annihilating dark matter origin for the emission, awaits a conclusive resolution. We show that convolutional neural networks are able to accurately recover the flux of inner Galaxy emission components as well as the source-count distributions (SCDs) of the point-source populations.

In the *Fermi* data, we find a faint GCE described by a median SCD peaked at a flux of $\sim 4 \times 10^{-11}$ counts / cm^2 / s (corresponding to $\sim 3 - 4$ expected counts per source), which would require $N \sim O(10^4)$ sources to explain the entire excess (median value N = 29,300 across the sky). Although faint, this SCD allows us to derive the constraint $\eta_P \leq 66\%$ for the Poissonian fraction of the GCE flux η_P at 95% confidence, suggesting that a substantial amount of the GCE flux is due to point sources.

Chasing neutrinos in the sky

Joe Zhiyu CHEN
School of Physics, University of New South Wales

Abstract

In spite of its immense success, the Standard Model of Particle Physics is incomplete. One important missing piece of the puzzle is the neutrino mass scale. While neutrino oscillation experiments have firmly established that this mass scale must be non-zero, the neutrino's weakly-interacting and hence elusive nature makes this quantity notoriously difficult to pin down in the laboratory. As a result, no measurement of the neutrino mass scale exists at present.

Interestingly, it has emerged in recent years that the answer to this Particle Physics puzzle may lie in Observational Cosmology. The standard Big Bang theory predicts a background of relic neutrinos, analogous to the cosmic microwave photon background. At a density of 400 neutrinos per cubic centimetre, the sheer abundance of these relic neutrinos ensures that they play a role in every stage of the Universe's evolution. The neutrinos' masses, in particular, leave a distinct imprint on the spatial distribution of galaxies and galaxy clusters. It is through detecting this signature that we may one day measure neutrino masses with cosmological observations.

Forthcoming probes such as the Euclid mission, will survey the galaxy distribution with unprecedented coverage and resolution, sufficient to measure neutrino masses down to 0.1 eV. To enable this measurement, my task as a theorist is to ensure theoretical modelling of the large-scale galaxy distribution accurately reflects the physical properties of the relic neutrino background. At UNSW, we have developed a state-of-the-art simulation pipeline for modelling large-scale structure formation in the presence of neutrino masses. Using two novel techniques to capture the neutrino clustering behaviour, our approach culminates in the most efficient use of high-performance supercomputing to achieve full non-linear evolution of matter over the span of 10 billion years. These techniques will contribute to the global community's effort to expand our understanding of fundamental physics.

Thermal Dissipation in Two-Dimensional Quantum Turbulence

Zain Mehdi
School of Physics, Department of Quantum Science and Technology, Australian National University

Abstract

Turbulence, the chaotic and irregular flow of fluids, is one of the most ubiquitous physical phenomena in our universe. Despite centuries of investigation, turbulence is still considered to be an open problem, and first principles analyses of turbulent flow is generally intractable.

Over the past few decades, the investigation of turbulence in quantum fluids has become a significant area of research. In quantum fluids such as superfluid Helium and Bose-Einstein Condensates (BECs), vorticity of the fluid flow is *quantized*, leading to a unique form of turbulent flow known as *quantum turbulence*. The study of quantum turbulence is not only interesting for its fundamental physics, but also because it offers a new pathway for understanding universal aspects of turbulence at macroscales, and how its microscopic origins.

This presentation will focus on a critical aspect of quantum turbulence modelling, dissipation. Typically, dissipation due to interactions with a thermal cloud is included in quantum turbulence modelling by the addition of a mechanism known as *number-damping*, where energy dissipates through loss of atoms to the thermal cloud. However, modelling to-date has neglected an equivalent dissipation process known as *energy-damping*, where energy can be lost in number-conserving interactions with the thermal cloud. Recent work has demonstrated energy-damping can be significant far from equilibrium, suggesting it may play a crucial role in the highly out-of-equilibrium dynamics of quantum turbulence.

We have recently performed the first simulations of quantum turbulence in a two-dimensional system that include the energy-damping dissipation process. In this presentation we will present some of these results and discuss the interesting new phenomena that are observed. These results, and the future work of this project, will pave the way for a more comprehensive understanding of turbulence in two-dimensional quantum fluids.

Prepared by: Dr Frederick Osman
2021 Awards Convenor

Monte Carlo modelling of $^{98}Mo(n,\gamma)^{99}Mo$ utilising a clinical scale plasma fusion neutron source

Matthew B. James
School of Science and Technology, Physics and Electronics, University of New England

Abstract

The γ-emitter technetium-99m (^{99m}Tc, $t_{1/2} \approx 6$hr) accounts for >80% of medical radionuclide imaging procedures worldwide. Currently ^{99m}Tc is extracted in the clinic as a β-decay product of molybdenum-99 (^{99}Mo, $t_{1/2} \approx 66$hr), sourced from a small number of research fission reactors worldwide, including ANSTO's OPAL reactor. Since 2009, reactor shutdowns and technical problems (*e.g.* 2018-19 at OPAL) created critical ^{99m}Tc shortages, prompting investigations into alternative ^{99}Mo production.

This project investigates an alternative clinical-scale synthesis of ^{99}Mo via ^{98}Mo capture of neutrons from a fusion plasma.

$$^{98}Mo(n,\gamma)^{99}Mo \xrightarrow{\gamma} {}^{99m}Tc$$

Few publications have thoroughly investigated this approach. Recently, Mausolf *et al.* [1] assessed the viability of ^{98}Mo neutron capture, concluding that ^{99}Mo specific activity would be too low.

However, this talk reports on recent improvements in inertial electrostatic confinement (IEC) cathode materials [2] and Monte Carlo simulations of novel geometries and material combinations which suggest promising clinically useful yields of ^{99}Mo via this pathway. The viability is being assessed using Monte Carlo simulations (*GEANT4* [3] and *MCNP* [4]) to be validated against measurements using the IEC plasma fusion device (Prof. Joe Khachan *USyd*) and at the ANSTO facility in Sydney.

The significance of this research is: 1) Decentralisation of ^{99m}Tc production with cost-reduction and increased availability for remote locations; 2) Reduction of ^{99}Mo decay yield-loss due to long transport times; 3) Reduced reliance on reactor-based sources thus reducing undesirable aspects of fission reactor operation *e.g.* nuclear waste storage, security issues and a hospital's reliance on fission reactor operation cycles.

1. Mausolf, E.J., *et al*. (2021). *Pharmaceuticals,* **14**:875*.*
2. Bowden-Reid, R., Khachan. J. (2020). *Phys. Plasmas*, **28**:042703.
3. GEANT4 Collaboration (2003). Nucl. Instrum. Methods. Phys. Res., **506**(3):205.
4. Los Alamos Scientific Laboratory. Group X-6. (1979). MCNP: A general Monte Carlo code for neutron and photon transport. Los Alamos, N.M.:[Springfield, Va.]:Dept. of Energy, Los Alamos Scientific Laboratory.

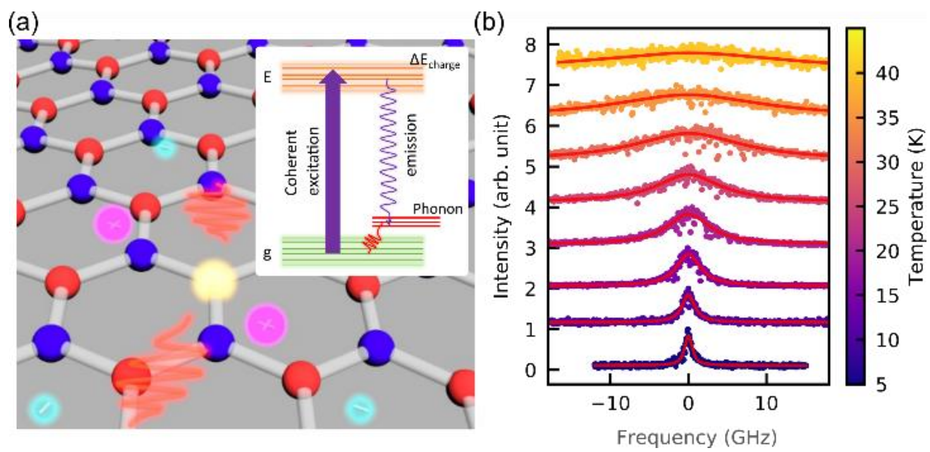
Quantum photonics with hexagonal boron nitride quantum emitters

Simon WHITE

School of Mathematical and Physical Sciences, University of Technology Sydney

Abstract

Single photons emitted from defects in two dimensional materials, such as hexagonal boron nitride (hBN), have a plethora applications in future quantum information technologies. Fourier transform limited lines and coherent excitation (excitation of the system using the same energy that is emitted) is of integral importance for many of these quantum applications, as they can be prerequisites for multiphoton quantum interference. Cooling hBN emitters in a cryogenic environment enables study with resonant excitation and can elucidate the factors that limit achieving Fourier Transform limited spectral lines. Specifically, we study the coupling of the hBN single photon emitter with lattice vibrational mode (causing phonon dephasing) and local field fluctuations (causing spectral diffusion), via resonant excitation spectroscopy.



Our findings demonstrate co-excitation using a weak non-resonant laser alters the decay pathways for photoluminescence, which results in a reduced probability for the emitter to decay into long lived metastable states, and therefore increases the resonant photoluminescence from the emitter. We also find that the linewidths of hBN quantum emitters are phonon broadened, even at 5K! And show spectral diffusion is dependent on excitation power, which can be minimized by working well below saturation power. These results are integral for future utilization of hBN quantum emitters in quantum information and communication.

Constraining models of inflation with galaxy clustering

Ankit SHRESTHA
School of Physics/ISEM, University of Wollongong

Abstract

In the currently accepted theory of inflation, the early universe is permeated by a quantum scalar field which, although is extremely homogeneous, still has small inhomogeneities referred to as primordial perturbations. Over time, these perturbations grow under gravitational influence to form celestial bodies such as planets, stars and galaxies. This theory is well established with numerous predictions supported by observations including the Gaussian and the adiabatic nature of these perturbations, and the near scale invariance of their power spectrum. Nonetheless, the uncertainties in the observations still leave some room for other theories with similar predictions such as multi-field inflation, which naturally leads to slight deviations from the Gaussianity and adiabaticity of the perturbations that can still be within the uncertainty range of the observations. A natural place to test the predictions of multi-field inflation would be in galaxy redshift surveys, which map out the positions of millions of galaxies.

My project focusses on determining and plotting theoretical expressions for the galaxy power spectrum and bispectrum in terms of the power spectra of primordial perturbations. To do so, I use a technique called galaxy bias expansion to relate the density/distribution of galaxies in the present universe to the primordial perturbations that seeded their formation. In this bias expansion, I introduce terms for non-Gaussian initial conditions and non-adiabatic perturbations. I include a particular type of non-adiabatic perturbation called Compensated Isocurvature Perturbations (CIPs), which are relative perturbations between baryonic matter and dark matter since these would directly affect the distribution of galaxies.

My research has found that non-Gaussian and non-adiabatic perturbations can only provide significant contributions on very large scales ($k^{-1} \sim 5 \times 10^3\ h^{-1}Mpc$), while current galaxy surveys can only probe the scales $k^{-1} \sim 10^2\ h^{-1}Mpc$. Nevertheless, future galaxy surveys that can probe larger scales have the potential to place stronger constraints on the initial conditions and therefore constrain models of inflation.