KOZWaves 2020: The 4th Australasian Conference On Wave Science

17–19 February 2020

Singapore Theatre (B120), Glyn Davis Building (133)
The University of Melbourne, Victoria, Australia

Welcome to the 4th Australasian Conference on Wave Science and welcome to the University of Melbourne.

We hope that you enjoy the conference, and that it provides plenty of opportunities for you to connect with our wave science community.

Steering Committee: Luke Bennetts, Hyuck Chung, Ross McPhedran, Mike Meylan, Fabien Montiel.

Local Organisers: Andrew Melatos, Ann Roberts, and Alessandro Toffoli.

Thanks to the University of Melbourne for the venue and our external sponsors for financial and technical support: the U.S. Office of Naval Research Global, Technic, the National Computational Infrastructure (NCI), the Australian Meteorological & Oceanographic Society and the Australian Optical Society.

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Special thanks to Franca Tomaras for organising the icebreaker, catering, travel and accommodation for the invited speakers and many other aspects of the conference.

We acknowledge the Traditional Owners of the land on which we work, and pay our respects to the Elders, past and present

Sunday 16th February

Time	
5:00	**Registration & Icebreaker** Yasuko Hiraoka Myer Room, Sidney Myer Asia Centre The University of Melbourne, Parkville Campus

Monday 17th February

Time	
8.00	**Registration**
8:30	**Welcome**
	Session 1 Chair: Andrew Melatos
8:40	Susan Scott - Gravitational waves: Detection and discoveries
9:20	Lucy McNeil - 3D studies of gravity modes and spin in neutron star progenitors
9:40	Hannah Middleton - Searching for continuous gravitational waves from low mass X-ray binaries with known rotation frequencies
10:00	Patrick Meyers – Results from the Homestake 3D seismometer array
10:20	**Coffee**
	Session 2 Chair: Halina Rubinsztein-Dunlop
10:50	Elena Vynogradova - An efficient algorithm for multiple scatterers
11:10	Michael Smith - Wiener-Hopf solutions for submerged poroelastic plates
11:30	Qiang Sun - Helmholtz equation and non-singular boundary integral method applied to multi-disciplinary wave problems
11:50	Ken Golden - Herglotz functions and homogenization for waves in random and quasiperiodic composites
12:10	Stuart Hawkins - A fast high order algorithm for multiple scattering from extremely large three dimensional configurations
12:30	**Lunch**
	Session 3 Chair: Marie Graff
1:30	John Sader - Existence of the Navier slip condition for liquid flows around nanoparticles
2:10	Martin Kocan - Convective thermals generated by a strong explosions
2:30	Ande Raghu - Numerical investigation of a three-beam array oscillating close to a rigid wall in a fluid
2:50	Donovan du Toit - Wave propagation in structures with force-moment neutralizers
3:10	Subash Chandra Martha – Diffraction of surface water waves by a pair of asymmetrical rectangular trenches
3:30	**Coffee**
	Session 4 Chair: Ross McPhedran
4:00	Halina Rubinsztein-Dunlop - Structured light in biology and quantum atom optics
4:40	Ann Roberts - Meta-optical systems for object plane Fourier filtering
5:00	Lukas Wesemann - Nanophotonics for all-optical information processing
5:20	Faris Shahidan - Plasmonic colour printing

Tuesday 18th February

Time	
	Session 5 Chair: Ann Roberts
8:40	David Liley – Brain waves
9:20	Brian Stout - Resonant state expansion for wave propagation response functions
9:40	Erik Garcia-Neefjes - Wave propagation in thermo-visco-elastic continua
10:00	Vladislav Sorokin – A Graded Metamaterial for Broadband Vibration Isolation
10:20	**Coffee**
	Session 6 Chair: Hugh Wolgamot
10:50	Isabela Cabral – Changes in extreme waves in the Arctic Ocean
11:10	Roger Hosking – Long ocean wave: Ice shelf interaction
11:30	Fabien Montiel – Ocean wave attenuation in the Ross Sea marginal ice zone
11:50	Alberto Alberello – Stereo camera measurements of extreme waves in the Antarctic marginal ice zone
12:10	Azam Dolatshah – Wave-induced sea ice drift: An experimental perspective
12:30	**Lunch**
	Session 7 Chair: Alberto Alberello
1:30	Miguel Onorato – Enrico Fermi and the birth of modern nonlinear wave physics – Public lecture
2:20	Alberto Meucci - Projected 21st Century changes in extreme wind-wave events
2:40	Colin Whittaker – Experimental investigation of particle transport by wave groups
3:00	Amandeep Kaur – Diffraction of water waves by finite floating structure over a parabolic bottom in the presence of seawall
3:20	**Coffee**
	Session 8 Chair: Luke Bennetts
3:50	Ross McPhedran – Resonant states for scattering problems: killing mie softly
4:10	Gregory Chaplain – Reversed Conversion: Umklapp Scattering and Flat Lensing
4:30	Mike Meylan - Lax-Phillips Scattering Theory for Simple Wave Scattering
4:50	Marie Graff – How to solve inverse scattering problems without knowing the source term
5:10	Lavesh Rughunanan – Locking and veering in periodically coupled one dimensional waveguides
5:30	Yoko Furokawa – U.S. Office of Naval Research Global: Activities and funding opportunities
7:00	**Conference Dinner** Project Forty Nine, 107 Cambridge St, Collingwood VIC 3066 (venue booked for 3hour event)

Wednesday 19th February

Time	
	Session 9 Chair: Malte Peter
8:40	Kasper van Wijk – Applications of imaging and monitoring using laser ultrasonics
9:20	Elena Vynogradova - Spectral Characterization of a Finite Parallel-Plate Waveguide
	Session 10 Chair: Azam Dolatshah
9:40	Malte Peter - Graded arrays for spatial frequency separation and amplification of water waves
10:00	Wenhua Zhao – Large run-up due to tertiary wave-structure interactions in random seas
10:20	**Coffee**
	Session 11 Chair: Colin Whittaker
10:50	Nail Akhmediev - Rogue waves in various systems
11:40	Elmira Fadaeiazar - Wave turbulence and intermittency in ocean waves
12:00	Hugh Wolgamot – Experimental observation of rainbow trapping in water waves
12:20	Marzieh Derkani – Metocean conditions during the Antarctic Circumnavigation Expedition: A comparison with model predictions
12:40	**Lunch**
	Session 12 Chair: Elena Vynogradova
1:40	Richard Manasseh - Towards prediction of bubble populations using passive acoustics
2:00	Martin Sagradian - Acoustic Axisymmetric Oscillations in Finite Multi-Sectioned Cylindrical Pipes with Sound-Soft Walls
2:20	Turker Topal - Slotted Infinitely Long Metallic Cylinders of Arbitrary Cross Section and the Helmholtz Mode of Acoustic Resonators
2:40	Hyuck Chung - Acoustic behaviour of multi layered split-ring resonators
3:00	Alex Skvortsov - Vibroelastic Models of Flow Noise
3:20	**Coffee**
	Session 13 Chair: Elmira Fadaeiazar
3:50	David Skene – On the causality and predictability of surface gravity waves with applications for offshore structures
4.10	Ngan Tran – A study of the nonlinear hydrodynamic forces acting on a submerged disk-like WEC undergoing combined motions
4.30	Marine Le Gal – Numerical models of the 1771 Meiwa tsunami to better understand tsunami-reef interactions
4:50	Filippo Nelli – Sea-states reconstruction using ship motion data
5:10	**Close**

Abstracts

Nail Akhmediev, Australian National University

Rogue waves in various systems

Rogue wave is a solution of an evolution equation that has a background plus a bulging part that is localized both in time and in space. The wave which satisfies this definition naturally "appears from nowhere and disappears without a trace". One example of such function is a Peregrine breather which is a solution of the NLSE. However, this is not the only known example. There is a variety of solutions of the NLSE and other evolution equations that satisfy this criterion. They have features remarkably different from those of solitons. Several examples of rogue wave solutions and their unique properties will be considered in this talk.

Alberto Alberello, University of Adelaide

Stereo camera measurements of extreme waves in the Antarctic marginal ice zone

We report simultaneous measurements of pancake ice properties and ocean wave characteristics, from a winter voyage to the Antarctic marginal ice zone during which extreme storm conditions were encountered. Individual waves up to 8.5m were measured, the highest ever recorded this far into the marginal ice zone. The surface elevation is reconstructed in space and time, and the directional properties of the wave spectrum are analysed. Wave energy attenuates by ~50% over 100km into the ice cover, where the ice is at 100% concentration and dominated by small floes (3m in diameter). Due to differential attenuation rates, the spectral wave peak undergoes a downshift towards lower frequencies during propagation in ice and a concurrent narrowing in direction.

This is a joint work with L. Bennetts (University of Adelaide), M. Onorato (University of Turin), M. Vichi, (University of Cape Town), A. Benetazzo (Institute of Marine Sciences – CNR), H. Clarke and A. Toffoli (The University of Melbourne).

Raghu Ande, University of Canterbury

Numerical investigation of a three-beam array oscillating close to a rigid wall in a fluid

To track living, biological samples, AFM (Atomic Force Microscopy) needs to be operated in a fluid medium. An array of cantilever beams helps to scan the samples at a faster rate but the technology is yet to be established for the fluid environment. Our aim is to study and understand the effects of fluid properties on an array of oscillating beams and in particular, the fluid coupling effects (added mass and damping) on the overall dynamics of the system. In this work we study the change in dynamics with changing gaps between beams and heights from the wall at low and high Reynolds numbers. The system is excited at the left-most beam while remaining beams are kept passive. The flow is considered to be incompressible and it is solved by using the boundary integral method. The coupling effect between beams has been investigated for a three beam array. The focus is mainly on the behaviour of array of members close to the wall in the fluids. The hydrodynamic load increases with decreasing heights, damping is the dominating mechanism when it is closer to the wall at lower Reynolds number while added mass dominates at high Reynolds numbers for corresponding heights. The hydrodynamic load is comparatively low for high Reynolds numbers due to inviscid flow between beams. The effect on members close to the wall is significant compared to far away members, where the effect is almost negligible.

This is a joint work with A. K. Manickavasagam, S. Gutschmidt and M. Sellier (University of Canterbury).

Gregory J. Chaplain, Imperial College London

Reversed Conversion: Umklapp Scattering and Flat Lensing

Recent work on graded line meta-arrays has shown that geometrically sim- ple structures are capable of manipulating flexural waves in mass loaded thin elastic plates, displaying rainbow trapping and mode conversion phenomena. Further to these effects, these structures have been designed to introduce a hybridisation of trapping and conversion, the so-called reversed conversion effect. The resulting passive, self-phased arrays are capable of emulating negative refraction effects by a line. All of these effects rely on a suitably adiabatic (gentle) grading of the array geometry. In this talk we shall recap these effects, whilst developing a design paradigm for achieving the reversed conversion effect through a new mechanism which requires no grading at all; abrupt changes in periodicity are used to leverage concepts from solid state physics, namely Umklapp scattering. We shall see this effect for localised surface acoustic waves in systems of Helmholtz resonators, surface electromagnetic waves on dielectrics and for tailored conversion of sur- face Rayleigh waves to body waves in elastic media. Harnessing this new reversal mechanism allows, through leveraging the trans- fer of crystal momentum, a new class of frequency selective flat lenses, namely Umklapp lenses to be envisaged.

This is a joint work with R. V. Craster (Imperial College London).

Hyuck Chung, Auckland University of Technology

Acoustic behaviour of multi layered split-ring resonators

We compute sound field in a split-ring resonator that is made up of multiple layers of concentric circular cylinders. The cylinders are arranged in such a way that the whole structure has resonances at lower frequencies than it would have with a single cylinder. The computational method for this problem, which is based on multiple scattering theory, is accurate for any opening width of the slit rings and their orientations. Thus, many numerical experiments can be conducted to analyse the resonance behaviour. We show how the resonator can be tuned to have different resonances in the low frequency range.

Isabela de Souza Cabral, The University of Melbourne

Changes in extreme waves in the Arctic Ocean

The Arctic is responding to climate change more rapidly and intensively than any other region on Earth. Besides temperature rise and sea ice retreat, wave height is showing an increasing trend, which is leading to rapid coastal erosion. A 28-years hindcast (from 1991 to 2018) was carried out using the WW3 wave model with grid resolutions varying from 9 to 22 km to perform an extreme value analysis. The model was calibrated against buoy and altimeter data comparing different source and sink terms, sea ice concentration datasets, and wind forcing inputs. Hindcasts using ERA5 wind forcing and sea ice concentration achieved the best agreement with the observations. In order to get reliable results of the swells generated in the North Atlantic Ocean, a global model with 1 x 1 degree of spatial resolution was calibrated and validated with the same input data used for the Arctic domain. The simulations were performed in one-way nesting, where the first step was to run the global model and get the wave spectra for the points located in the boundaries of the Arctic domain. The performance of the model was further validated against altimeter observations across six different satellite missions and the results were in satisfactory agreement. The monthly evaluation of the trends in the mean significant wave height obtained by the hindcast showed increasing rates varying significantly spatially and seasonally. Hence, extreme value analysis of wave heights is carried out using a transformed stationary (TS) methodology for non-stationary time series. In contrast to the most established extreme-value theories, this method allows better estimates of extremes of environmental variables that vary in time, due to, for instance, climate change and seasonality. Such an approach becomes essential for the evaluation of extreme waves in the Arctic, where the seasonal sea ice coverage and the ice retreat affect directly the sea state. The results show a notable seasonal change and large positive trends in the 100-year return period values over the past decades, which means that extreme ocean waves are increasing as a result of environmental changes.

This is a joint work with I. Young and A. Toffoli (The University of Melbourne).

Azam Dolatshah, Swinburne University of Technology

Wave-induced sea ice drift: An experimental perspective

Sea ice drift is important for climate change, ship navigation and offshore structures' safety. The role played by ocean waves on the drift of ice floes is still unclear though. An experimental study was conducted in the wave-ice flume at the University of Melbourne. The flume has a length of 14 m, a width of 0.76 m, a height of 0.5 m height, and it is mounted in a refrigerated chamber to control temperatures. Ice cubes of 0.02 – 0.04 m (much smaller than generated wavelengths) were used to simulate the Marginal Ice Zone, an area of the ocean covered by loose ice floes. Surge amplitudes and drift velocities of ice at various concentrations under the effect of monochromatic waves of different frequencies and amplitudes were investigated. Results show that the surge amplitudes and drift velocities of ice floes depend on the incident wave frequencies and ice concentrations.

This is a joint work with A. Korosov (), L. G. Bennetts (University of Adelaide), J. P. Monty and A. Toffoli (The University of Melbourne.

Donovan du Toit , The The University of Auckland

Wave propagation in structures with force-moment neutralizers

This paper investigates the use of vibration neutralizers to suppress flexural propagating waves in an Euler Bernoulli beam. There is a continuous effort to extend the bandwidth and increase the maximum attenuation produced by vibration neutralizers. One such method has been to attach a neutralizer to a beam such that it exerts not only a force, as is most common, but also a moment. Previous studies have shown that there is both an increase in the bandwidth and maximum attenuation. However, the performance of these vibration neutralizers is not very well understood. This paper investigates the performance of a force-moment neutralizer. Simple analytical expressions are developed which aid in the physical interpretation and design of force-moment neutralizers. Analytical expressions for the bandwidth and minimum transmission are developed and compared to traditional force only resonators. It is shown that the bandwidth at high attenuation levels is significantly increased by a force-moment neutralizer. Further numerical performance measures such as the Shape Factor which is a comparison of the neutralizer to an ideal filter, are investigated.

This is a joint work with V. Sorokin and B. Mace (The University of Auckland)

Elmira Fadaeiazar, Swinburne University of Technology

Wave turbulence and intermittency in ocean waves

The evolution of surface gravity waves is driven by nonlinear interactions that trigger an energy cascade similarly to the one observed in hydrodynamic turbulence. This process, known as wave turbulence, has been found to display anomalous scaling with deviation from classical turbulent predictions due to the emergence of coherent and intermittent structures on the water surface. In the ocean, waves are spread over a wide range of directions, with a consequent attenuation of the nonlinear properties. A laboratory experiment in a large wave facility is presented to discuss the sensitivity of wave turbulence on the directional properties of model wave spectra. Statistical properties of Fourier amplitudes are analysed in this regard. Results show that the occurrence of coherent and intermittent structures results in a substantial deviation from the basic Rayleigh distribution for Fourier amplitudes in the upper frequency tail. Intermittency becomes less likely with the broadening of the wave directional spreading. There is no evidence, however, that intermittency completely vanishes.

This is a joint work with A. Alberello (University of Adelaide), Miguel Onorato (University of Turin), J. Leontini (Swinburne University of Technology), T. Waseda (The University of Tokyo), A. Toffoli (The University of Melbourne).

Erik Garcia-Neefjes, University of Manchester

Wave propagation in Thermo-Visco-Elastic Continua

Recent work in the metamaterial literature has shown the importance of taking into account the presence of visco-thermal losses through dissipation for the accurate description of acoustic fields in a variety of metamaterial designs of practical interest. Theoretical studies on the acoustics of thermo-viscous flu- ids date back to the nineteenth century with the work of Kirchhoff on acoustic propagation in a tube of circular cross section. Nevertheless, most works of this type have involved a perfect gas, particularly since for higher density fluids, fluid-structure interaction must be taken into account. Some recent results on water-filled narrow channels and the influence of the viscous boundary layers on the attenuation of energy, as well as the differences between this and the air-filled channel case will be discussed. We also note that many interesting solid metamaterials (such as membrane type media), are of a (thermo-) viscoelastic nature. It would therefore be con- venient to develop a framework that allows the study of the acoustics of thermo- viscoelastic continua, including both solids and fluids. The derivation of such a model will be introduced and put into practice by considering the canonical problem of the interaction of two thermo-viscoelastic media separated by an interface.

This is a joint work with P. A. Cotterill and W. J. Parnell (University of Manchester), D. Nigro (Thales), A. L. Gower (University of Sheffield).

Kenneth M. Golden, University of Utah

Herglotz functions and homogenization for waves in random and quasiperiodic composites

Waves interact with composite media in many important areas of application throughout the sciences, engineering, and medicine. Here we consider homogenization for waves in complex media in the quasistatic or long wavelength regime, such as the effective complex permittivity for electromagnetic waves in two phase and polycrystalline composites, and the complex viscoelasticity for ocean surface waves in the sea ice pack. In particular, these effective parameters, as well as others like the effective diffusivity for Brownian motion in a flow field, can be analyzed from the unifying point of view of treating the homogenized parameter as a Herglotz function of an appropriate complex variable, such as the ratio of the constituent permittivites. In this framework, we derive a Stieltjes integral representation for the effective parameter involving a spectral measure of a self adjoint operator which depends only on the composite microgeometry. We find rigorous bounds for effective parameters using these integral representations. Moreover, by studying the spectral properties of the underlying operator using ideas of random matrix theory, we find unexpected behavior such as an Anderson localization transition at percolation thresholds. In very recent work, we have found that from this spectral viewpoint, quasiperiodic media defined by Moiré interference patterns can interpolate between periodic and random systems in their transport and spectral characteristics.

Marie Graff, The University of Auckland

How to solve inverse scattering problems without knowing the source term

Solving inverse scattering problems using optimization techniques always presupposes knowledge of the incident wavefield and requires repeated computations of the forward problem, for which knowing the source term is essential. Here we present a three-step strategy to solve inverse scattering problems from total field measurements when the time signature of the source is unknown. Applications can be found among medical imaging and seismic exploration. For instance, in photoacoustic imaging, the ultrasound wave is generated as a response of a laser pulse excitation. Even though we can assume to know the approximate location of the source, the generated ultrasound signal is clearly unknown. Similarly, in seismic exploration, the creation of fractures or cracks in the Earth's interior can be considered as a potential source, whose signal scatterers and is recorded to help image the surrounding medium. The proposed strategy combines three recent techniques, developed for the time-dependent acoustic wave equation: (i) wave splitting to retrieve the incident and the scattered wavefields, (ii) time-reversed absorbing conditions for redatuming the data inside the computational domain, (iii) adaptive eigenspace inversion to solve the inverse problem. The main challenge lies in the combination of (i) and (ii) to reconstruct the required data to perform the solution of the inverse problem. Numerical experiments will be displayed to illustrate each step of the strategy towards the reconstruction of the scatterer from the original total field measurements.

This is a joint work with M. J. Grote (University of Basel), F. Nataf (Laboratoire Jacques-Louis Lions), F. Assous (Ariel University)

<u>Marzieh H. Derkani</u>, The University of Melbourne

<u>Metocean conditions during the Antarctic Circumnavigation Expedition: A comparison with model predictions</u>

Global wave models show considerable biases in integral wave parameters in the Southern Ocean, a remote region of the world oceans that is still poorly explored. Here, we present a database of metocean conditions compiled during the Antarctic Circumnavigation Expedition (ACE) from December 2016 to March 2017. Observations were gathered using a radar-based wave and surface current monitoring system (WaMoS-II) on board of the research vessel Akademik Tryoshnikov. Records consist of surface currents, wave spectra and concurrent integrated parameters such as the significant wave height, mean periods and mean directional spread along the expedition's track, including data in the open ocean as well as the summer Antarctic marginal ice zone. Observations were first calibrated using sea state information reconstructed from the ship motion sensors, validated against satellite observations, and then used to discuss the performance of global wave models in the Southern Ocean.

This is a joint work with K. Hessner (OceanWaveS GmbH), S. Zieger (Australian Bureau of Meteorology), S. Saeed Khan (CSIRO), L. Aouf (Meto France), F. Nelli and A. Toffoli (the University of Melbourne).

Stuart C. Hawkins, Macquarie University

A fast high order algorithm for multiple scattering from extremely large three dimensional configurations

Simulation of wave interactions with configurations containing extremely large numbers of individual particles are important in diverse applications including oceanography and atmospheric science applications. Simulations need to account for reflections between all particles, the number of which grows with the square of the number of particles. Consequently such simu- lations have been limited to only a few thousand particles. We present an efficient solver based on a Krylov subspace method combined with a fast algorithm for computing matrix vector products whose complexity (memory and CPU time) grows only linearly with the number of particles. Our matrix vector product scheme is based on a novel numerically stable expansion of the field radiated by each particle in spherical wavefunctions. We demonstrate our algorithm by simulating multiple scattering for configurations with more than a quarter of a million individual particles and associated dense complex linear systems with more than one hundred million unknowns.

This is a joint work with M. Ganesh (Colorado School of Mines).

Roger J. Hosking, University of Adelaide

Long Ocean Wave – Ice Shelf Interaction

Trans-oceanic infragravity (IG) or tsunami wave interactions with ice shelves can intermittently enhance their break-up, and thus threaten the release of sections of the Antarctic Ice Sheet that may then significantly con- tribute to rising sea levels. The larger responses of ice shelf cavities to incoming wave energy may be expected to be driven at natural resonance frequencies dependent on the physical and geometrical properties of the ice and cavity. Since the IG or tsunami waves are typically generated at a great distance away, it is reasonable to first consider a one-dimensional model to determine the natural frequencies of the shelf-cavity system (Meylan et al. J. Glaciology 63, 751-754 , 2017), and then the related responses due to such incoming long ocean waves. In the simplest model, the shelf is treated as uniform and infinitesimally thin, while the water is shallow and of constant depth. It is relatively straightforward to allow for variable flexural rigidity in the thin shelf and also a flat bed of variable depth, perhaps to introduce a bed step such as has been observed at a shelf-ocean front. Additional modelling refinements might include a shelf of finite thickness that may be partially submerged, bed curvature, and possibly even two-dimensional wave propagation where more complex shelf and bathymetry features are considered. Linear theory is of course only applicable for disturbances of sufficiently small amplitude, and more demanding nonlinear theory may well be needed to predict major ice shelf deflexions due to larger ocean wave impacts.

This is a joint work with L. Bennetts (University of Adelaide) and M. Meylan (University of Newcastle).

Amandeep Kaur, Indian Institute of Technology Ropar

Diffraction of water waves by finite floating structure over a parabolic bottom in the presence of seawall

Diffraction of water waves by a rigid, thick and finite floating structure over a parabolic bottom topography in the presence of seawall is examined towards the study of reduction of wave impact on the seawall. The parabolic bottom topography is approximated using successive steps and then the problem is solved using a matched eigenfunction expansion method. The hydrodynamic quantities such as free surface elevations, the force experienced by floating structure and seawall are investigated and plotted through different graphs to analyze the effect of various structural and system parameters. Among many results, it is highlighted that less energy is transmitted towards seawall when the floating structure is situated over parabolic bottom instead of flat bottom for oblique wave incidence. The appropriate values of length and thickness of the structure, water depth and angle of incidence provide salient information to marine and coastal engineers to design the offshore structures and creation of parabolic trench on the bottom. It is observed that the combined effect of floating rigid structure and parabolic bottom profile helps to reduce the wave load on the seawall, hence the seawall is protected. Moreover, the wave amplitude in the last region (after the structure) is small as compared to the amplitude in the first region (before the structure). This provides a calm zone between the floating structure and the seawall, which is useful for safe mooring – loading operations, and comfortable handling of cargoes and ships. Besides, it is also helpful for studying the problems in the areas of mathematical physics and other areas of engineering.

This is a joint work with S. C. Martha (Indian Institute of Technology Ropar).

Martin Kocan, Defence Science and Technology

Convective thermals generated by strong explosions

The scaling laws for the transient behaviour of convective buoyant thermals generated by strong explosions consist of two regions: (i) very strong thermal gradients at short time scales when the thermal is close to rest and (ii) weak thermal gradients at larger time scales when the velocity of the buoyant thermal is high. The conservation equations for mass, momentum and buoyancy in the non- Boussinesq case were solved numerically and analytically. For regions when the discontinuity of the density and temperature between the thermal and the surrounding environment are extreme new analytical scaling laws were derived. For the later stage of thermal evolution the well known Batchelor scaling applies. The two regions of the evolution of the buoyant thermal were confirmed by numerical modelling and validated by experimental data available in literature.

This is a joint work with A. Skvortsov (Defence Science and Technology).

David Liley, The University of Melbourne and Swinburne University of Technology

The easiest and most ubiquitous method to objectively interrogating brain function is by recording the scalp surface electrical activity using multiple electrodes – the electroencephalogram or EEG. Such activity, which represents the collective activity of billions of neurons, reveals a range of regular, spatially distributed, oscillatory phenomena colloquially referred to as 'brain waves'. However, the mechanisms by which such collective oscillatory activity arise and their implications for better understanding brain function remain largely obscure. An obvious approach to studying the genesis of such activity, and its implications for brain function, would be to simulate the billions of neurons and trillions of connections in the human brain – a computationally daunting task, that despite current computational resources, is not yet meaningfully achievable. However, because the EEG is of limited spatial resolution, with each electrode reflecting the combined activity of many thousands of neurons, bulk approaches that model spatially-averaged or coarse-grained neuronal activity may be more profitably employed. Such approaches, typically referred to as neuronal population or mean field models, are generally formulated as physiologically constrained/parametrised coupled systems of non-linear stochastic ordinary/partial differential equations. Semi-analytic and numerical solutions to these equations reveal a broad range of spatiotemporal activity, much of which accords with physiological measurement.

Marine Le Gal, Okinawa Institute of Science and Technology

Numerical models of the 1771 Meiwa tsunami to better understand tsunami-reef interactions

In 1771, a major tsunami hit the Yaeyama islands (Japan). Among them, Ishigaki Island was severely impacted with 30m run-ups on the south east coast. Like many other islands in the Pacific, Ishigaki Island is characterized by an irregular coastline with reefs. While, the propagation and inundation of tsunamis as well as current and reef interactions have been numerously analyzed, the interactions between tsunami and reef have been little studied. Moreover, most of the previous works focused on one-dimensional idealized reefs, and few real reef tsunami events have been presented. In the present study, a two-dimensional numerical approach is suggested to measure the influence of the reef for the inundation of the 1771 tsunami along the south- east coast of Ishigaki. First a reference model, simulating the historical event, was developed with a Nonlinear Shallow Water model. Second, modified models were build from the reference model by altering the reef topography. Three situations were tested : the absence of reef, the absence of channels in the reef and changes in the reef depth. In order to measure the influence of these different modifications, a new ratio, quantifying their impact along the coastline, was defined. Overall, in our simulations, the reef protected the coast reducing the maximum wave heights by an average of 12.5%. However, at local scales, the channels increased the maximum wave height by up to 40% on the nearby coasts. Finally, changes in the reef depths showed a global positive correlation with the maximum wave height at the coast. This study brought new elements to better understand the protective function of the reef. These conclusions can help to better forecast the inundation behind this given reef, resulting in more appropriate management of the coast.

This is a joint work with S. Mitarai (Okinawa Institute of Science and Technology).

Richard Manasseh, Swinburne University of Technology

Towards prediction of bubble populations using passive acoustics

Experiments were undertaken on the passive-acoustic emissions of a precisely-arranged line of bubbles. The aim was to determine if a reliable relation could be found enabling the prediction of the bubble sizes and numbers, given parameters extracted from acoustic measurements. Sound waves emitted by bubbles are responsible for most of the audible sounds associated with liquid motion. Although the sounds are easily measured, multiple scattering between nearby bubbles results in superimposed eigenmodes of mutual oscillation. These cause significant shifts in frequency spectra away from those expected for isolated bubbles, an issue that confounds inversion of acoustic spectra to predict bubble-population spectra. Bubbles were placed at precise locations in horizontal line arrays, held trapped under acoustically-transparent film. A bubble of the same size formed from an underwater nozzle at one end of the line provided the excitation for the array, owing to its natural sound emission on formation. Sounds were measured with a hydrophone. Peaks from the acoustic spectra were fitted by a semi-empirical equation based on the natural logarithm that is a limiting approximation to the acoustic-interaction sum. It was found that the size of bubbles and the number of bubbles participating in spectra-altering interactions could be successfully predicted. The trends were confirmed with a numerical simulation based on coupled-oscillator equations. The sizes and numbers of bubbles are the essential control on the gas-liquid surface area over which gases dissolve into liquids. Ocean-wave breaking is a process fundamental to the absorption of CO_2; the ocean is presently thought to sequester roughly a third of all anthropogenic emissions. In industry, control of gas-liquid mass transfer is expensive and problem- atic. A robust and reliable technique for acoustically estimating bubble populations could have widespread environmental and industrial applications. Further research should extend the present, highly idealised one-dimensional result to three dimensions.

This is a joint work with M. M. Roshid (Swinburne University of Technology.

Subash Chandra Martha, Indian Institute of Technology Ropar

Diffraction of surface water waves by a pair of asymmetrical rectangular trenches

Diffraction of obliquely incident surface waves by a pair of asymmetrical rectangular trenches in finite depth of water is examined to analyze the reduction of wave impact to protect the sea-shore. The mixed boundary value problem is handled for its solution with the aid of a system of singular integral equations of first kind which are solved numerically by using suitably designed polynomial approximations of the unknown functions. This gives rise to a system of linear algebraic equations which is solved numerically to obtain the physical quantities namely the reflection and transmission coefficients. The results for the problem involving a pair of symmetric trenches are also obtained. The effectiveness of the pair of trenches is investigated by analyzing the effect of various parameters on the physical quantities of interest which are plotted through different graphs. Among many important results it is highlighted that more energy is reflected back by a pair of trenches as compared to single trench profile, hence, less wave energy is transmitted to seaside, yielding less impact on seashore. The behaviour of zeros in reflection coefficient is observed for symmetrical pair of trenches which shows that the symmetrical designing of trenches in construction must be avoided.

This is a joint work with A. Kaur (Indian Institute of Technology Ropar) and A. Chakrabarti (Indian Institute of Science).

Lucy McNeill, Monash University

3D studies of gravity modes/waves and spin in neutron star progenitors

Angular momentum transport in massive stars that go on to form neutron stars and black holes is an outstanding problem in stellar evolution, with inconsistencies across theory, observation, and numerical simulation. In the absence of angular momentum transport in massive stars, neutron stars would be spinning close to break up frequency (< milliseconds) assuming angular momentum conservation in the progenitor iron core. However the bulk of the observed solitary neutron star population (pulsars) has birth spin periods 10-100 milliseconds. An angular momentum transport mechanism to mediate the observed birth spin distribution of pulsars with spins predicted theoretically and numerically is needed to explain this factor of ~100 difference. At the moment, angular momentum can be efficiently transported to outer layers of stars by magnetic effects and gravity waves, slowing the spins in the core. On the other hand, if these mechanisms are so efficient that they spin down the core to zero rotation before explosion, stochastic processes such as asymmetries in the explosion dynamics, and breaking of stochastic gravity waves will spin the core up again. We study both the stochastic spin up of an initially non–rotating star, and the spin down of an initially rapidly rotating star from gravity modes, to present a birth spin range predicted from 3D models for the first time using PROMETHEUS. First, we test the theory of stochastic spin up in neutron star progenitors via angular momentum transported by internal gravity waves during the final minutes before supernova explosion. Using a three--dimensional model of a 12 solar mass main sequence, initially non--rotating neutron star progenitor, we compute the angular momentum and energy flux from gravity waves over 8 minutes during oxygen burning. We find that the core angular momentum random walks, but with a correlation time that is shorter than the convective turnover time. Also, the efficiency of angular momentum transport and hence core spin up is around a factor of 100 less than that suggested in previous one--dimensional stellar evolution studies. In light of these results, stochastic spin up from gravity modes is not able to reproduce the observed neutron star spin population. We hope that these results can be used to improve wave theory in 1D stellar evolution models such as MESA. Second, we consider the spin down case and quantify the efficiency of angular momentum transport out of the core via wave filtering of gravity modes in an initially rapidly rotating progenitor. In this case, differential rotation and shear dominate the dynamics. We will present some preliminary results here and comment on whether 3D studies of gravity waves can constrain neutron start birth spin at all.

This is a joint work with B. Muller (Monash University).

Ross McPhedran, University of Sydney

Resonant States for Scattering Problems: Killing Mie Softly

Spectral (eigenvalue) methods for wave scattering problems have enjoyed immense practical and theoretical success in describing the response functions of closed (Hermitian) systems. Resonant States, also known as `Quasi-Normal' Modes and Leaky Waves, provide attractive basis sets for the spectral expansions of open radiative systems. Nevertheless, the exponential divergence of the resonant states in the far-field has been a long-standing obstacle for operating with these modes.

We show the apparent `divergences' of the resonant state scalar product integrals can be resolved analytically using the methods of distribution theory and that this leads *to exact finite normalisations* for the resonant states of spherical scatterers with real or lossy permittivities and permeabilities. The correctly normalized expansions are shown to unleash the power of the iconic `Mie' theory by re expressing the exact Mie coefficients as meromorphic functions of frequency. The methods and formulas discussed can be generalized to more complex geometries and provide physical insight into the nature of light-matter interactions.

This is a joint work with B. Stout (Aix-Marseille Université).

Alberto Meucci, The University of Melbourne

Projected 21st Century changes in extreme wind-wave events

Extreme ocean waves shape world coastlines and significantly impact offshore operations. Climate change may further exacerbate these effects increasing losses in human lives and economic activities. Studies generally agree on the trends in the mean values, yet there is no consensus on the extreme events, and whether their magnitude and/or frequency are changing. The present work applies an innovative extreme value analysis approach to a multi- model ensemble wind-wave climate dataset, derived from seven global climate models, to evaluate projected extreme wave height changes towards the end of the 21st century. Under two greenhouse gas emission scenarios, we find that at the end of the 21st century, the one in 100-year wave height event increases across the scenarios by 5 to 15 % over the Southern Ocean. The North Atlantic shows a decrease at low to mid latitudes (5 to 15 %) and an increase at the high latitudes (10 %). The extreme wave heights in the North Pacific increase at the high latitudes by 5 to 10 %. The present work suggests that pooling an ensemble of future projected ocean storms from different GCMs might significantly improve uncertainty estimates connected to future coastal and offshore wave extremes, thereby improving climate adaptation strategies.

This is a joint work with I. R. Young and E. Kirezci (the University of Melbourne), M. Hemer (CSIRO), and R. Ranasinghe (Deltares).

Patrick Meyers, The University of Melbourne

Results from the Homestake 3D seismometer array

The Homestake 3D seismometer array was installed for the dual purpose of novel seismological studies and for studying Newtonian noise–gravitational fluctuations caused by density perturbations in the Earth. Newtonian noise will be a limiting noise source for future ground-based gravitational-wave detectors, and so understanding and developing schemes for subtracting it in future gravitational-wave detectors is a priority. In this talk, I will first discuss the array configuration, and then I will present a direct measurement of the Rayleigh-wave eigenfunction using data from local mine blasts. This work shows the expected R-wave amplitude suppression with depth and a change from retrograde to prograde particle motion that is both frequency and depth-dependent. We also show that this direct measurement is largely consistent with results from traditional methods based on the local velocity structure. Finally, I will discuss new techniques for trying to separate seismic wave propagation direction and polarisation that can hopefully be used to estimate Newtonian noise.

This is a joint work with D. Bowden (ETH Zurich), V. C. Tsai (Brown University), V. Mandic (University of Minnesota, G. Pavlis and R. Caton (Indiana University).

Michael H Meylan, The University of Newcastle

Lax-Phillips Scattering Theory for Simple Wave Scattering

Lax-Philips scattering theory is a method to solve for scattering as an expansion over the singularities of the analytic extension of the scattering problem to complex frequencies. I will show how a complete theory can be developed in the case of simple scattering problems. Even for the simplest case, it requires a non-trivial generalised eigenfunction transformation to project into the space of analytic functions on the real line. The scattering operator in this space is simply the complex exponential. I will illustrate how this theory can be used to find a numerical solution, and I will demonstrate the method by applying it to the vibration of ice shelves.

Hannah Middleton, The University of Melbourne

Searching for continuous gravitational waves from low mass X-ray binaries with known rotation frequencies

Ground-based gravitational wave observatories are searching for continuous gravitational waves (persistent periodic signals) from rotating neutron stars. Neutron stars in low mass X-ray binaries (LMXB) are prime continuous wave targets. Traditional continuous wave LMXB targets, such as Scorpius X-1 have been subject to thorough searches, but these searches are hampered by a lack of electromagnetic observation of the neutron star rotation frequency (e.g. Abbott et al. 2019). In this work we describe a search for a number of other LMXBs that have high-precision measurements of rotation frequency (and also orbital parameters), allowing a finely targeted search with a modest computational cost. One challenge addressed is that the the rotation frequency itself may not be monochromatic and in fact wanders unpredictably on a timescale (~ 10 days) which may be shorter than the electromagnetic observation cadence. A hidden Markov model (Suvorova et al. 2017) can be used to search for just such a wandering frequency. In this work we search data from the second observing run of Advanced LIGO (Laser Interferometer Gravitational-wave Observatory).

This is a joint work with P. Clearwater, A. Melatos and L. Dunn (The University of Melbourne).

Fabien Montiel, University of Otago

Ocean wave attenuation in the Ross Sea marginal ice zone

We report the analysis of wave buoy measurements conducted in austral autumn and winter of 2017 during the Polynyas, Ice Production, and seasonal Evolution in the Ross Sea (PIPERS) voyage. Fourteen buoys were deployed in the advancing marginal ice zone (MIZ). A number of large wave events with significant wave height at high as 9 m were recorded. We analysed the attenuation of ocean waves with penetration in the MIZ and computed the rate of exponential decay as a function of wave period. We found that the attenuation rate peaks at about 8–10 s, consistently across the dataset. Analysis of the ice conditions (obtained from satellites or in-situ observations) reveals that fragmented sea ice composed of small floes attenuates ocean waves faster than continuous ice or an ice cover composed of large floes, suggesting inhomogeneities in the MIZ needs to be better quantified to predict wave attenuation rates.

This is a joint work with T Milne and L. Gamson (University of Otago), A. Kohout (National Institute for Water and Atmospheric Research), L. Roach (University of Washington).

Filippo Nelli, The University of Melbourne

Sea-states reconstruction using ship motion data

Sea-state data sampling is always a challenging task. It involves expensive equipment such as buoys, radars and it often requires complex setup procedures. Here we present an innovative technique to reconstruct sea-states using response amplitude operators (RAOs) and data registered by ship's motion sensors. RAO's are linear transfer functions commonly used to predict ship motions in a specific sea condition. Here they are used to convert ship's heave into the original ocean's free surface elevation. Preliminary results obtained from the Southern Ocean show a good agreement between reconstructed data and wave records about significant wave height and peak period.

This is a joint work with M. H. Derkani and A. Toffoli (The Univeristy of Melbourne)

Miguel Onorato, University of Turin

Enrico Fermi and the birth of modern nonlinear wave physics

In the early fifties in Los Alamos E. Fermi in collaboration with J. Pasta, S. Ulam and M. Tsingou investigated a one dimensional chain of equal masses connected by a weakly nonlinear spring. The key question was related to the understanding of the phenomenon of conduction in solids; in particular they wanted to estimate the time needed to reach a statistical equilibrium state characterized by the equipartition of energy among the Fourier modes. They approached the problem numerically using the MANIAC I computer; however, the system did not thermailize and they observed a recurrence to the initial state (this is known as the FPUT-recurrence). This unexpected result has led to the development of the modern nonlinear physics (discovery of solitons and integrability). In this seminar, I will give an historical overview of the subject and present new results based on the Wave Turbulence Theory.

Malte A. Peter, University of Augsburg

Graded arrays for spatial frequency separation and amplification of water waves

Wave-energy converters extracting energy from ocean waves are known to suffer from poor efficiency. We propose structures capable of substantially amplifying water waves over a broad range of frequencies at selected locations, with the idea of enhanced energy extraction. The structures consist of full or C-shaped bottom-mounted cylinders arranged in one-dimensional or two-dimensional arrays, with the cylinder properties or the array spacing graded along the array. Using linear potential-flow theory, it is shown that the energy carried by a plane incident wave is amplified within specified locations, for wavelengths comparable to the array length, and for a range of incident directions. Transfer-matrix analysis is used to analyse the large amplifications.

This is a joint work with L. Bennetts (University of Adelaide) and R. V. Craster (Imperial College London).

Ann Roberts, The University of Melbourne and

Meta-Optical Systems for Object Plane Fourier Filtering

Optical information processing is widely used for enhancing images and the visualisation of transparent objects such as live unstained cells. Spatial filters placed in the focal plane of a lens selectively absorb and/or modify the phase of the various Fourier components constituting the field, permitting modification of the output field to, for example, enhance edges, reduce noise, visualise phase gradients or remove distractors that compromise automated object identification. Propagation of light from the lens to the Fourier plane is, however, inherent in the process meaning that even if flat lenses are used, the lower bound on the distance required is of the order of millimetres. Directly modifying the Fourier spectrum using non-local, momentum filtering in the 'object' plane with a compact metasurface or other thin film would represent an enormous advance and expand the availability of all-optical information processing to environments where space, weight and power present a challenge. Here theoretical aspects of the use of nanophotonic meta-optical devices to perform object plane Fourier filtering will be discussed. The spatial dispersion of thin, periodic arrangements of optical resonators produces an optically thin film with an optical transfer function that modifies the spatial frequency content of an incident electromagnetic field. Since metasurfaces are sensitive to polarisation, the transfer function is a tensor. This transfer function can then be used to study the performance of the device in an arbitrary optical system. The basic framework will be discussed, examples provided and aspects of image formation with coherent and incoherent light presented.

This is a joint work with L. Wesemann and T.J. Davis (The University of Melbourne), and DE Gómez (RMIT University).

Halina Rubinsztein-Dunlop, The University of Queensland

Structured light in biology and quantum atom optics

Spatial light modulators (SLM) or Digital Micromirror Devices (DMD) give us a great flexibility in sculpting light. What it means is that we have perfect tools that can be used for production of configurable and flexible confining potentials and utilise them to confine atoms as well as lager scale objects and conduct novel experiments investigating light – matter interaction in these systems. Sculptured light produced using these devices promises high flexibility and an opportunity for trapping and driving systems ranging from studies of quantum thermodynamics using ultra cold atoms to trapping and manipulating nano- and micron-size objects or even making measurements in-vivo inside a biological cell as well as studying microthermodynamics and heat engines at these scales.

Lavesh Rughunanan, The University of Auckland

Locking and veering in periodically coupled one dimensional waveguides

Locking and veering are phenomena that occur in continuously coupled homogeneous wave-bearing media. At points in the dispersion curve where the wavenumbers of the uncoupled blocked system intersect, the wavenumbers will either veer apart or lock to form a complex conjugate pair in the coupled system. This behavior is well understood for continuous coupling but has also been observed in periodic systems. In this paper, the qualitative behavior of locking and veering is analysed for two, one-dimensional waveguides with discrete spatial periodic coupling. Under the effect of weak coupling, the propagation constants μ for periodic systems follow behavior equivalent to wavenumbers in the continuously coupled case. When the slopes of the uncoupled propagation constants intersect with the same sign, veering will occur in the coupled case. When the slopes intersect with opposite sign, the coupled propagation constants will lock, forming a complex conjugate pair, later unlocking. Stop bands in periodic systems can be predicted from the simpler uncoupled solutions as a result. Numerical examples are presented.

This is a joint work with B. Mace and V. Sorokin (The University of Auckland).

John Sader, The University of Melbourne

Existence of the Navier slip condition for liquid flows around nanoparticles

The Navier slip condition is regularly used to characterise the interaction of a fluid with a solid boundary. Its use at the gas-solid boundary is justified rigorously from Boltzmann's kinetic theory of gases, however no such parallel exists the liquid-solid boundary. The strongest evidence for existence of the Navier slip condition at the liquid-solid interface comes from molecular dynamics simulations. As dictated by kinetic theory, the Navier slip length is a constitutive property that holds when the flow is continuum away from the solid interface. Here, we present an experimental protocol that is used to measure the Navier slip length on individual and isolated particles with exquisite precision. Experiments consisting of thousands of measurements on individual gold nanoparticles give a constant slip length of 2.7 ± 0.6 nm–independent of particle size–providing experimental validation of the Navier slip condition for liquids.

Martin Sagradian, Macquarie University

Acoustic Axisymmetric Oscillations in Finite Multi-Sectioned Cylindrical Pipes with Sound-Soft Walls

A special version of the Method of Analytical Regularization (MAR) is developed for rigorous solution of the mixed boundary value problem for the Helmholtz equation, which describes scalar wave diffraction from acoustically soft, doubly-connected, arbitrarily shaped surfaces of revolution. The basics of the MAR approach allow us to transform an initially ill-posed problem of the first kind into a fast converging system of algebraic equations of the second kind. In this work we investigate the transmission of sound plane waves through cylindrical pipes of finite extent, focusing on the resonance response of a circular pipe and two modifications, which may be described as "multi-sectioned" finite pipes. Both modifications may be regarded as pipes with "variable" cross-section. The first represents a combination of circular pipes with different diameters; the second is a combination of a circular pipe and a spherical cavity. The investigation includes two complementary problems. The first problem is to find the complex eigenvalues for axisymmetric oscillations which may be excited in each of the three configurations. The rigorous MAR-based approach to finding the complex eigenvalues of 2D open cavities has been demonstrated in Vinogradova (J. Acoust. Soc. Am. 144, 1146- 1153, 2018) , where the elliptical cylinder with a variably placed slot has been comprehensively investigated. In this paper we extend this approach to 3D open cavities. Complex oscillations in the pipe with constant circular cross-section are calculated for various aspect ratios $L/a = 1,2,5,10$, where a is the radius and L is semi-length (semi-height) of the cylinder. Pipes with abruptly varying cross sections represent a multi-parameter system of coupled resonators. We investigate the influence of specially chosen parameters values on the coupling strength of these resonators. The second problem is to study resonance backscattering, based on calculation of the frequency dependence of the monostatic sonar cross section, $\sigma_B(k)$, $k=2\pi/\lambda$. Finding the complex eigenvalues accurately enables the prediction of resonance behavior observed in the monostatic sonar cross section. The calculation of $\sigma_B(k)$, focusing on resonance excitation, has been carried out for both the finite circular pipe and those with abruptly variable cross sections.

This is a joint work with E. D. Vinogradova (Macquarie University).

Susan Scott, Australian National University

Gravitational Waves - Detection and Discoveries

Gravitational waves were directly detected for the first time on 14 September 2015 during the first observing run of the Advanced LIGO and Advance Virgo detectors. In this talk I will discuss this unprecedented binary black hole system merger event as well as our subsequent discoveries during the first, second and current third observing runs.

Faris Shahin Shahidan, The University of Melbourne

Plasmonic Colour Printing

Plasmonic colouration arises from strong scattering and absorption at characteristic wavelengths due to the excitation of localised and propagating surface waves on metallic nanostructures. Compared to approaches based on absorption by dyes and pigments, plasmonic colour is resistant to photobleaching, is durable, has low toxicity and permits high-resolution image printing with a reduced set of materials. Here we discuss the use of a metal-insulator-metal (MIM) configuration consisting of a metallic particle 'floating' above a conducting backplane where resonance wavelengths of the structure can be tuned not only by careful control of the lateral dimensions but also the vertical geometry, specifically the gap size. This leads to a wide colour coverage of the CIE 1931 XY colour space. Conventional nanofabrication methods such as electron beam lithography (EBL) suffer not only from low throughput but also require meticulous control of electron dosage to produce nanostructures with varying heights in a single patterning process. We will present recent results obtained using a simple, scalable approach to generating plasmonic colouration via UV-assisted nanoimprint lithography (NIL) with the ability to control the vertical dimension of the structure in a single print with a simple binary mold by harnessing the nanofluidic behaviour of the polymer resist.

This is a joint work with J. Song and A. Roberts (The University of Melbourne), T. James (Reserve Bank of Australia).

David Skene, University of Adelaide

On the causality and predictability of surface gravity waves with applications for offshore structures

For optimal control of a wave energy converter, active stabilisation of a ship, or active stabilisation of an offshore wind turbine, the waves incident upon the body must be known a surprisingly long duration in advance. To address this requirement, we consider how surface gravity waves may be predicted in advance. Consider a free surface measurement of surface gravity waves at an up-wave point. The free surface at down-wave (and other nearby) points is defined by how the waves propagate. For a given wave spectrum this implies that the signal morphs due to dispersion of each frequency component in the wave field. To exactly predict the free surface at nearby locations one much therefore know the underlying wave spectrum. However, because the surface can only be measured for a finite time window the spectral resolution is inherently limited (i.e., the spectrum cannot be known in full). This implies that the free surface surrounding the measurement can only be predicted in some finite spatial-temporal region and that the prediction inherently contains errors. In this presentation I will show the underlying mathematics of this dispersive wave prediction problem. I will demonstrate that the waves surrounding the measurement are causally related by the phase velocity of the fastest and slowest waves in the field. Contrastingly, I will also show that the prediction must be made based on the groups in the wave field. It will be demonstrated that this gives a prediction region based on group velocity and guarantees an imperfect prediction. I will demonstrate these results numerically and experimentally with a FFT based wave prediction algorithm.

Alex Skvortsov, Defence Science and Technology

Vibroelastic Models of Flow Noise

A self-consistent analytical framework is proposed for estimation of flow noise intensity for a turbulent flow over elastic boundaries, such as a turbulent boundary layer. The turbulent flow is assumed to be significantly subsonic. The framework employs the well-known analogy between motion of inviscid flow and a `soft' elastic media (materials with low shear moduli). The turbulent flow is modeled as an ensemble of viscous (shear) waves and their transformation into longitudinal waves (sound) is treated as an elastic wave transformation. The proposed approach enables rapid evaluation of numerous 'what-if' scenarios such as changes of flow media, speed of the flow and elastic properties of the material and their effect on flow noise. This framework can be useful as a tool for optimal coating design to mitigate flow noise as well as for planning flow noise experiments. For the statistical model of the velocity field in a turbulent boundary layer we adopt the following model $V=\sum_k V_k \exp(i\omega_k t + i\mathbf{kr})$,where random 'mode' amplitudes V_k follow the ensemble averaging statistics $\langle V_k V_{k'}\rangle = E_k\delta(k-k')$. Here δ(·) is the Dirac delta-function, k is the wave number of a mode. The energy spectrum E_k is described by a typical power-law, $E_k = Ck^q$, where the pre-factor C and the exponent q is calculated either from experimental studies, [1] or from numerical/analytical models (for instance, for the Kolmogorov model of turbulence $q = 5/3$). For a typical vortex mode,

$V_k \sim v_*$, $k \sim 1/\delta$, $\omega_k = U_f k$, $U_f = U_0 + i\nu k$,

where v_* is friction velocity, δ is boundary layer thickness, ν is kinematic viscosity, U_0 is unperturbed velocity of the flow, $i^2 = -1$. The 'vortex-sound' transformation at the boundary is described by employing a conventional 'acoustical' model [1] for the transformation of shear waves (random 'vorticity modes') into longitudinal waves (sound) at the interfaces of layered elastic media. The proposed approach provides insightful criteria for material selection for flow noise reduction that would be very difficult to deduce by other means. More specifically, for a case of turbulent boundary layer over an elastic surface the transformation coefficient is given by an expression$\Theta \sim (\rho_m - \rho_0)$,where ρ_0 is density of the fluid, ρ_m is density of a coating material. Parameter Θ is a transformation coefficient of kinetic power of the turbulent flow into acoustic power. This expression implies that the intensity of turbulent boundary layer noise can be significantly decreased provided the material underlying the turbulent boundary layer has fluid-like properties (such as with rubber) and its density is close to the density of the fluid. This is strikingly different from an intuitive assumption of an acoustical impedance match.

This is a joint work with I. MacGillivray and P. Dylejko (Defence Science and Technology).

Mike Smith, University of Cambridge

Wiener-Hopf solutions for submerged poroelastic plates

Numerically efficient methods for capturing the interaction between water waves and submerged structures are of considerable value to the fluid-structure interaction community for fine-tuning the design of breakwaters and submerged docks, for example. The Wiener-Hopf method, a constructive procedure that relies heavily on complex analysis and residue theory, provides an efficient means when compared to other solution approaches such as finite element methods and eigenfunction matching methods. In this talk, I will describe how long waves interact with the bending modes of a horizontally submerged poroelastic plate. The semi-infinite structure is submerged in a waveguide with a rigid sea floor and a free surface. Here the primary focus is to profile both an efficient and elegant Wiener-Hopf formulation to investigate the impact of porosity on the surface wave reflection and transmission. A major advantage of using horizontally submerged plates is that such structures provide enhanced reflection of wave energy with increasing stiffness (at fixed submergence depth) and they avoid sediment buildup which is observed behind vertical barriers. Although there has been considerable research into the reflection and transmission from submerged acoustic barriers with Dirichlet or Neumann conditions, there has been comparatively little investigation on the impact of both bending waves and porosity.

This is a joint work with M. Meylan (The University of Newcastle), M. Peter (University of Augsburg), and D. Abrahams (University of Cambridge).

Vladislav Sorokin, The University of Auckland

A Graded Metamaterial for Broadband Vibration Isolation

The suppression of unwanted mechanical vibrations is important to prevent damage (or outright failure) of machines and structures. Uniform metamaterials with embedded identical local resonators were proved to be effective for vibration isolation by utilizing the local frequency bandgap, a frequency range in which travelling elastic waves attenuate. However, existing metamaterials can only suppress vibrations in a relatively narrow frequency range and may act to amplify vibrations at other frequencies. The present paper concerns the analysis and optimization of a metamaterial with graded, rather than uniform, local resonators attached. An Euler-Bernoulli beam is considered as an example and a relatively simple strategy of tuning the natural frequencies and damping ratios of the attached resonators is proposed that enables to achieve a relatively large frequency bandgap. To realize the proposed metamaterial, a piezoelectric shunting circuit is adopted allowing to easily tune properties of the local resonators. Numerical simulations of the developed piezoelectric metamaterial beam are conducted in COMSOL, with their results illustrating the effectiveness of the proposed metamaterial design strategy.

This is a collaboration with G. Hu and Andrew Austin (The University of Auckland).

Brian Stout, Aix-Marseille Université

Resonant state expansion for wave propagation response functions

We review recent progress in defining and normalizing Resonant State (RS) wave functions (also known as Quasi-Normal Modes, leaky waves, etc.). Thanks to an improved understanding of these regularization(normalization) techniques, it is now possible to use resonant states to accurately develop response functions in wave propagation systems. We review various RS regularization schemes while focusing on the Gaussian `Killing factor' technique that we have recently advocated. Advantages of the Gaussian regularization technique are that it can lead to analytical expressions for at least parts of the regularization process while also helping to better understanding alternative regularization procedures. The high accuracy obtainable with RS expansions has already been demonstrated in the case of solvable model systems like homogeneous spheres. In a second part, we demonstrate the importance of correctly including `non-resonant' response contributions when using RS expansions to make quantitative predictions (particularly when using the RS expansion far from resonant frequencies). We also present the utility of sum rules to accelerate the `convergence' of this expansion and diminish the number of RSs states that are required for making accurate numerical predictions[3] We shall discuss the insights this theory procures in the physical understanding and time domain analysis[4] of a variety of physical phenomenon like Ideal Absorption, anapoles and BICs.

This is a joint work with R. C. McPhedran (University of Sydney).

Qiang Sun, RMIT University

Helmholtz equation and non-singular boundary integral method applied to multi-disciplinary wave problems

The Helmholtz equation, $\nabla^2\boldsymbol{\varphi} + k^2\boldsymbol{\varphi} = 0$, which takes its name from the famous German scientist, Hermann von Helmholtz (1821-1894), appears in many fields of physics, in particular wave phenomena, ranging from acoustic waves, electromagnetic waves, elastic waves to the recently experimentally con- firmed gravitational waves. The waves thus described can be longitudinal (as in acoustic waves), transverse (as in electromagnetic waves) or both (as in waves in solid materials; dynamic linear elasticity). It can also be found in other physical phenomena, for instance, the Schrödinger equation for quantum mechanics, hydrodynamics (potential flow when $k = 0$), electrostatic interaction in colloidal and molecular systems when k is imaginary, and unsteady harmonic heat conduction when k^2 is imaginary, to mention a few. We would like, based on the Helmholtz equation, to demonstrate here that the physics of many complex physical phenomena mentioned above can effectively be described using one or a set of Helmholtz equations. Although this has been known for a long time from a theoretical point of view, the actual numerical implementation has often been hindered by divergence free and/or curl free constraints or other limitations. We will show that this divergence free and/or curl free constraints can in fact be replaced by one or a set of Helmholtz equations or be converted into boundary conditions. Together with the recently developed singularity-free boundary integral method to solve the Helmholtz equation $\nabla^2\boldsymbol{\varphi} + k^2\boldsymbol{\varphi} = 0$, we are thus able to develop a uniform formulation of multi-disciplinary physical problems only using one or more Helmholtz equations, and to tackle such whole set of problems accurately and efficiently in classical applied physics essentially using the same numerical framework with higher order (quadratic) elements. Chosen demonstration examples will focus on electromagnetics and dynamic elasticity as far as different physics are concerned.

This is a joint work with E. Klaseboer (Institute of High Performance Computing) and D. Y. C. Chan (The University of Melbourne).

Turker Topal, Macquarie University

Slotted Infinitely Long Metallic Cylinders of Arbitrary Cross Section and the Helmholtz Mode of Acoustic Resonators

The general solution of the Neumann boundary value problem for Helmholtz equation applied to an arbitrary cylinder with a longitudinal slot was originally obtained in using the rigorous *Method of Analytical Regularization* (*MAR*). Employing classical potential theory, one may arrive at an integral equation of the first kind with a hyper-singular kernel for the unknown density function. After applying the *MAR* (involving extraction of the singular part of the kernel and its analytical inversion) the original integral equation is transformed to an infinite matrix equation of second kind. Fast convergence of the truncated system of linear algebraic equations makes this solution an effective instrument for accurate analysis of spectral and diffraction problems for two-dimensional (2D) slotted cylinders of arbitrary cross section. This boundary value problem allows us to analyze two different physical problems simultaneously: the diffraction of $H-$polarized radiation from a slotted metallic cylinder, and the diffraction of sound waves by a slotted cylinder with sound-hard walls. In the acoustic case, we deal with the 2D acoustic (Helmholtz) resonator. Our investigation starts from spectral studies of slotted cylinders of arbitrary cross section. We first obtain its spectral "map", calculating the frequency dependence of the condition number, $condA_N(k)$, where A_N is the truncation of the matrix obtained by the MAR procedure to finite order N. The dependence $condA_N(k)$ allows us to find approximate values of the real parts of complex eigenvalues by identifying its quasi-singular points $k = k_{qs}$ which correspond to the sharp maxima of $condA_N(k)$. The values kqs are used as first approximations to the complex roots of dispersion equation $detA_N = 0$, which is solved to obtain the complex eigenvalues. The accuracy of their calculation is improved by increase as the matrix rank N (truncation number) increases. In the acoustical case, we calculated the complex Helmholtz mode for a variety of shapes. In addition, we investigated the higher order complex oscillations. In the electromagnetic case, these oscillations are interpreted as cutoff relative wavenumbers. Turning to the sound diffraction, we focus on calculation of the spectral dependence for monostatic sonar cross section, $\sigma_B(k)$ and the mechanical force $F(k)$ on walls of slotted cylinders. In electromagnetic case, we calculate the spectral dependence of the radar cross section. In both cases the focus is on *accurate* analysis of resonance diffraction.

This is a joint work with E. Vinogradova (Macquarie University).

Ngan Tran, University of Adelaide

<u>A study of the nonlinear hydrodynamic forces acting on a submerged disk-like WEC undergoing combined motions</u>

Multi-mode wave energy converters (WECs) are able to absorb power from water waves by operating in multiple degrees-of-freedom (DOF). Although this theoretically allows them to absorb up to three times more power compared to a typical heaving converter, the control and design of such systems can be more complex. In particular, the addition of pitching motion to the surge and heave modes can lead to enhanced coupling and strong nonlinearities in the hydrodynamic forces. An understanding of these nonlinear hydrodynamic forces is pertinent for the performance optimisation of these devices. In the current study, the nonlinear hydrodynamic forces acting on a submerged disk-like WEC undergoing combined motions in surge, heave and pitch is investigated. A numerical model based on the weak-scatterer (WS) approximation and developed by École Centrale de Nantes is used to capture the body-exact hydrodynamics of the submerged WEC. Due to its shape, the projected area of the WEC can experience large changes due to pitch, leading to noticeable nonlinear distortions and higher- order harmonics in the hydrodynamic forces. The effects of motion amplitude and phase relative to the incident wave on the nonlinear forces are also explored. The performance of the WEC subjected to nonlinear hydrodynamics is then briefly compared to results obtained from a linear frequency- domain (FD) model. The differences between results suggest that current linear hydrodynamic models, which are typically used for design and optimisation, may be insufficient when considering multi-mode WECs. The enhanced hydrodynamic coupling between DOFs must be considered in the design and control of these devices in order to avoid overestimating the power that can be absorbed.

This is a joint work with B. Cazzolato, N. Sergiienko, M. Arjomandi and M. Ghayesh (University of Adelaide).

Kasper van Wijk, The University of Auckland

Applications of imaging and monitoring, using laser ultrasonics

Many applications benefit from non-destructive characterization and/or monitoring. Depending of the physical properties, ultrasonic waves can be a good option for this task. In the Physical Acoustics Lab, we excite and detect these ultrasonic waves with lasers, so that the characterization happens without contacting – or damaging – the sample. A high-powered pulsed source laser creates ultrasound via the thermo-elastic effect, while a laser Doppler vibrometer detects particle velocity on the surface of our samples. Besides the previously mentioned benefits of being non-contacting and non-destructive, it is relatively easy in this setup to control source and receiver positions with mirrors mounted on computer-controlled motorised stages. In this talk, I will present what we learned from laser ultrasonic measurements about the physical properties of rocks for geophysical applications. In that case, we probe the sample under in-situ temperature and pressure conditions. Experiments on ice help us explain the temperature dependence of its physical properties, and identify annual layers in ice cores. We perform medical imaging with a photoacoustics, where the ultrasonic source generation occurs inside the body, and propagation is from inside the body to the surface. Laser ultrasound also helps us estimate the quality of fruit and timber, where wave speed and attenuation are indicators of firmness and strength, respectively.

Elena D. Vinogradova, Macquarie University

Spectral Characterization of a Finite Parallel-Plate Waveguide with Sinusoidal Corrugation

Studies of wave diffraction by finite surfaces with sinusoidal corrugations are of practical interest in many areas of applied acoustics and radio-engineering. We use two approaches, one based on the Wiener-Hopf technique combined with a perturbation method, and the other using the Method of Analytical Regularisation to perform a full wave analysis of the problem. This allows us to study accurately the problem without limitations on the depth of corrugation, the wave size of the gratings, their relative location and the frequency band. In this work we investigate the diffraction of E-polarized plane waves by finite sinusoidal gratings formed by: a) parallel corrugation; b) mirror image; and c) horizontal displacement. Configurations (a) and (b) may be treated as corrugated parallel plane waveguides with propagating complex modes or as cavity resonators of Fabry-Perot type in the regime of standing waves. The numerical analysis undertaken involves accurate calculation of the complex eigenvalues and the far-field in the resonance regime of excitation. First, we analyze the strip Fabry-Perot resonator, then study the effect of replacement of one mirror by the sinusoidal strip, and then consider the resonator comprising two sinusoidal gratings. Such a modified Fabry-Perot resonator has been comprehensively investigated at various values of the parameters: depth of sinusoidal corrugation, number of sinusoidal periods, distance between the mirrors and electrical length of the mirrors. Numerical results are mostly obtained for the lower modes, though applicability of the approach for analysis of higher modes is demonstrated. In case (c), we focus on the influence of the "air gap" between gratings on the propagation direction of the Floquet modes and also examine some related problems.

This is a joint work with K. Kobayashi (Chuo University).

Elena D. Vinogradova, Macquarie University

An Efficient Algorithm for multiple scatterers

The investigation undertaken in this work extends the previous studies of the Method of Analytical Regularization (MAR), where it was applied to the analysis of 2D potential problems for multi-conductor systems and multiple electromagnetic wave scattering by ensembles of arbitrary solid perfectly conducting cylinders. The rigorous theory developed here concerns the multiple scattering from perfectly electrically conducting cylindrical cavities with longitudinal slits. The solution so obtained is also valid when the slit widths of some or all of the cavities tend to zero, thus becoming closed cavities. There are no restrictions on the number of cavities, slit widths and relative location of cavities. From the numerous combinations available of open and closed cavities we make a selection to illustrate the resonance responses of various different systems of coupled resonators illuminated by an obliquely incident E-polarized plane wave. The basic components of open cavities are drawn from circular, elliptic and rectangular cavities and in addition, flanged rectangular cavities. We investigate linear arrays of such cavities and more complicated configurations. First, we accurately calculate the few lowest complex eigenvalues for single slotted cavities. Then we study the perturbation or shift in these eigenvalues for various configurations parametrised by distance between cavities and by slit widths. When the imaginary part of the complex eigenvalue reveals a dramatic drop in magnitude (compared with the corresponding value for a single resonator) we have "strong coupling", whereas when these values insignificantly differ from each other (if, for example, the resonators are well spaced from each other) we have "weak coupling". With this data in mind, we calculate the frequency dependence of the monostatic radar cross-section, accomplished by computation of the bi-static far-field.

This is a joint work with P. D. Smith (Macquarie University).

Lukas Wesemann, The University of Melbourne

Nanophotonics for All-Optical Information Processing

Optical Metasurfaces are artificially fabricated, ultrathin films exhibiting a tailored response to incident electromagnetic radiation. Here computational and experimental progress towards the design and demonstration of metasurfaces suitable for performing all-optical image processing will be presented. Here we present two different approaches exploiting subradiant modes on nanostructures and thin-film near-perfect absorption in metal-insulator-metal structures to perform all-optical spatial differentiation on an incident wavefield. These methods provide an avenue for the development of ultracompact devices that will perform on-chip, real-time, single-shot conversion of phase information to readily measured intensity distributions with applications ranging from optical communication and ultra-precision fibre profiling through to highly specialized live cell imaging. While the dominant resonance of a plasmonic nanostructure is usually a dipole mode, zero-dipole resonances, so called subradiant- or dark modes, that cannot be excited with normally incident, linearly polarized light, exist. Various plasmonic nanostructures have proven to exhibit subradiant characteristics. We particularly demonstrate the excitation of bright and dark modes of a radial trimer of silver nanorods and its ability to perform spatial frequency filtering. Secondly, we will discuss near-perfect absorption in metal-insulator-metal (MIM) structures and its ability to perform spatial frequency filtering on a reflected wavefield. We demonstrate experimental implementation of an Au-SiO2-Au absorber with angular dependent reflectance proving its ability to perform all-optical spatial frequency filtering. The suppression of low spatial frequencies in light reflected from both structures suggests avenues to all-optically modify the spatial frequency content of an image. We demonstrate for both approaches experimental all-optical edge enhancement in reflected amplitude images. Furthermore, recent results on the discussed and related approaches towards their employment for phase imaging, including applications to live-cell imaging, will be presented.

This is a joint work with E. Panchenko, K. Singh, T.J. Davis and A. Roberts (The University of Melbourne), and D. E. Gomez, E. Della Gaspera (RMIT University).

Colin Whittaker, The University of Auckland

Experimental investigation of particle transport by wave groups

The motion of small Lagrangian particles is affected by the interplay between the Strokes drift and the Eulerian return flow. Given that Stokes drift dominates near to the free surface, the trajectories and net drift of particles depends on the initial location of the particle within the water column, as well as the depth regime of the carrier wave and the return flow. We present an experimental study of these particle motions in a series of wave flume experiments, measuring particle trajectories using particle tracking velocimetry. Following removal of background motions, the experimental results are compared to leading-order solutions of the irrotational water wave equations for deep and finite-depth regimes, with excellent agreement. The set-down beneath the wave group becomes important in enhancing the return flow in the finite-depth case, and the removal of motions caused by a subharmonic error wave (generated by the laboratory wave maker) become more challenging in this depth regime. We discuss extensions to the work for non-Lagrangian tracer particles.

This is a joint work with R. Calvert and T. van den Bremer (University of Oxford), A. Raby (University of Plymouth), P. H. Taylor (University of Western Australia).

Hugh A. Wolgamot, University of Western Australia

Experimental observation of rainbow trapping in water waves

Recent work on chirped arrays of scatterers has shown that energy accumulates at locations where the group velocity associated with the local periodicity drops to zero. This phenomenon has been referred to as rainbow trapping because of the spatial separation of different frequencies. A chirped experimental arrangement of vertical cylinders on the centreline of a wave flume was tested in incident regular and irregular waves, at frequencies spanning a (relatively broad) band of frequencies for which significant amplification was observed in different parts of the array. Experimental observations strongly support the analytical/numerical predictions made, including: amplification in different locations of the array for different frequencies, very low transmission beyond the maximum amplification and extremely long timescales of the resonant modes. The talk will discuss the difficulties in physical testing of such a resonant system in a flume in which reflections and viscous damping play a role. To our knowledge this represents the first attempt to create rainbow trapping in water waves experimentally.

This is a joint work with A.J. Archer and J. Orszaghova (University of Western Australia), L. G. Bennetts (University of Adelaide), M. A. Peter (University of Augsburg), and R. V. Craster (Imperial College London).

Wenhua Zhao, University of Western Australia

Large run-up due to tertiary wave-structure interactions in random seas

Previous tests with regular waves reported a large run-up phenomenon on a fixed vertical plate, where the local wave surface elevations reached 4x or 5x the amplitude of the incident waves. It was further proposed that the reflected wave fields (from the body) 'slow down' the incident waves (as a shoal would) locally, through the tertiary wave interactions. The resulting local lensing induces wave focusing on the weather side of the structure, leading to significant amplitude enhancement. It has been 17 years since these results were presented. Surprisingly limited attention has been paid to the tertiary interaction phenomena other than in generalizations of the Benjamin-Feir instability in undisturbed wave fields. We also note that all the literature available for enhanced run-up has focused on regular waves, both seeking a steady state solution and investigating the time evolution of the free surface elevation. However, there are some important open questions remaining particularly for waves in a random sea, e.g. (1) whether the tertiary interactions can occur and are the effects important; (2) if so, how to identify the time evolution of run-up magnification and time lag for large events in the random signals. A series of tank tests help us to address these questions. For this study, we look at the large water surface run-up in front of a fixed box in uni-directional normally incident random waves. The wave surface elevations at the centre of the weather side can reach 4x the incident waves, much larger than the ~2x predicted from linear theory. We revisit this study, and now examine the effect of directional spreading for normally incident random waves with JONSWAP spectrum and uni-directional waves at different approach angles. Both effects weaken the tertiary interactions, and the results will be discussed at KOZWaves.

This is a joint work with P. H. Taylor and H.A. Wolgamot (University of Western Australia).

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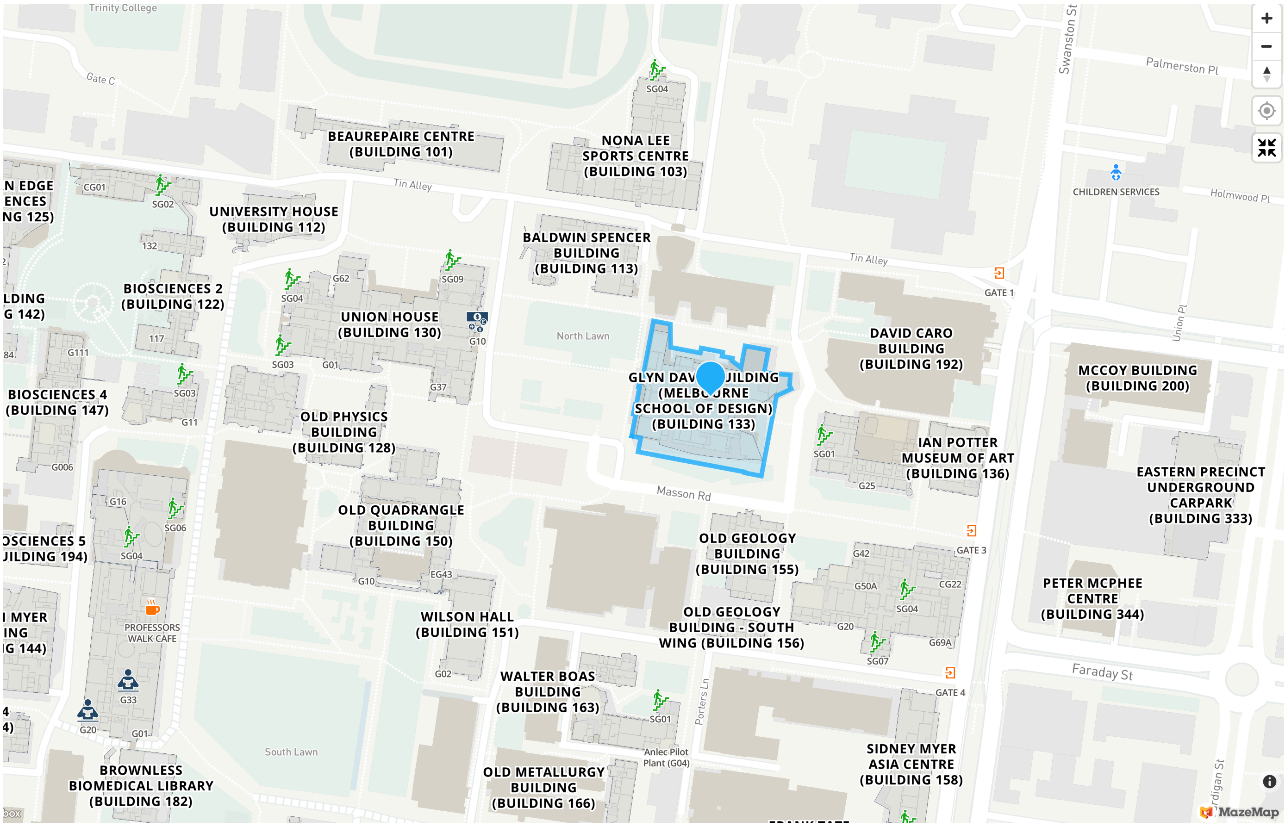
The conference venue

Singapore Theatre (B120), Glyn Davis Building (133), The University of Melbourne, Parkville Campus -- https://maps.unimelb.edu.au/parkville/building/133

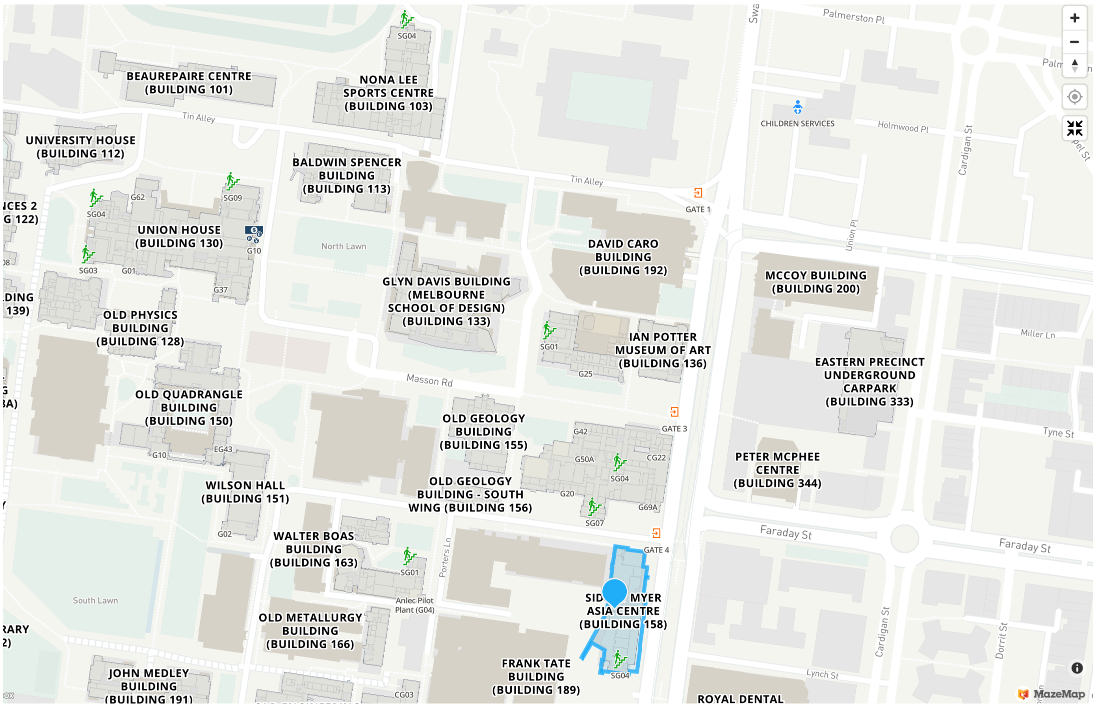


Morning/afternoon teas & Lunches

Morning teas, afternoon teas and lunches are included in the conference registration fee and will be served outside the lecture theatre.

Icebreaker

An icebreaker and light dinner is included in the registration fee and will be held on Sunday 16 February from 5pm to 8pm. The venue for this event is the Yasuko Hiraoka Myer Room – Sidney Myer Asia Centre (The University of Melbourne – Parkville Campus, https://maps.unimelb.edu.au/parkville/building/158)



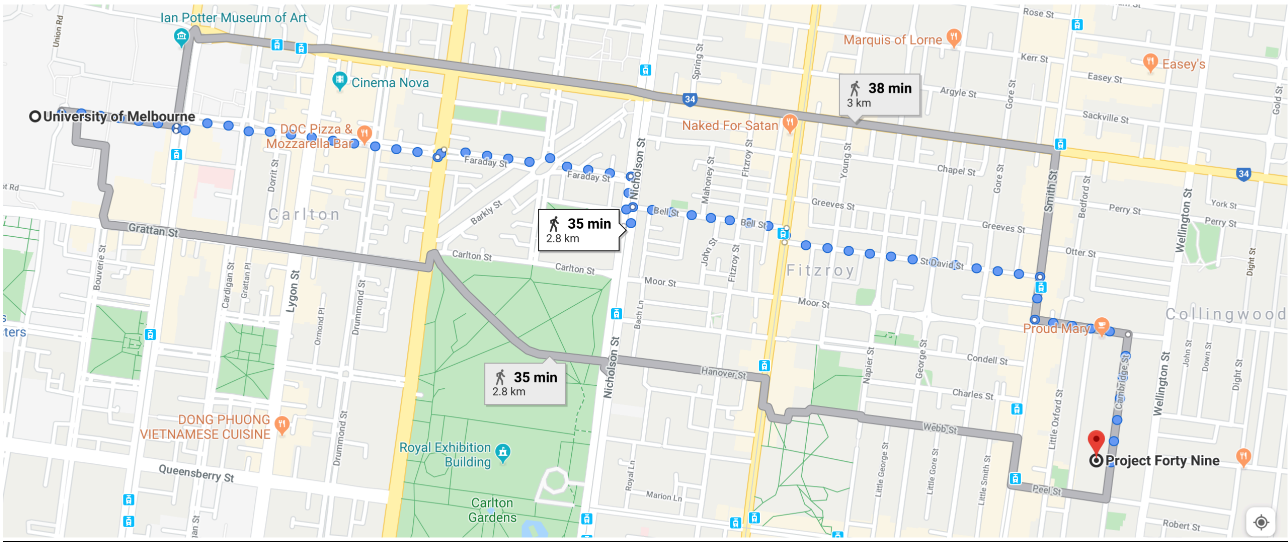
Conference Dinner

Conference dinner is included in the registration fee. It will be held at Project Forty Nine, 107 Cambridge St, Collingwood VIC 3066

https://www.google.com/maps/place/Project+Forty+Nine/@-37.804537,144.985193,15z/data=!4m5!3m4!1s0x0:0x161c7db787fae277!8m2!3d-37.804537!4d144.985193

You can get to the restaurant by taxi/uber;

Walk (about 40 min)



Or by Bus 200 or 207 from Lygon Street (corner with Faraday Street)