
The University of Otago

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DEPARTMENT OF PHYSICS, UNIVERSITY OF OTAGO, NEW ZEALAND



Fig. 1: The Science III building is home to the Physics Department. This photo, taken in September, shows the spring blossom. Visible at the lower right corner is the Leith River that runs through the campus.

INTRODUCTION

The University of Otago was founded in 1869, making it New Zealand's first and thus oldest University. It enjoys a worldwide reputation for excellence, successfully balancing the traditions of its history with modern scholarship and research. Otago offers a unique campus lifestyle, creating a culture of learning that reflects the special characteristics of New Zealand together with international academic values.

The University has over 20,000 students, most of whom are based at the primary campus in the city of Dunedin in New Zealand's South Island. Located roughly midway between the equator and pole, until recently Otago was the southernmost University in the world [1]. Dunedin is comparatively small city (population 126 thousand), providing a strong "University town" feel with easy access to

the natural beauty and wildlife for which the country is internationally recognized. As well as its strong research reputation, Otago has an unmatched record in the New Zealand National Teaching Excellence Awards, plus the Dunedin campus is recognised as one of the 16 most beautiful in the world.

Living in a small city in the low population density part of New Zealand provides easy access to both mountains and sea. The city is the southernmost of New Zealand's main centres and is attractively situated at the end of a long harbour, within easy distance of mountain, lake, fiord and coastal country of outstanding natural beauty. A number of ski fields are also located nearby and ample opportunity exists for the pursuit of other outdoor activities including fishing, tramping, sailing and rafting.

The city is far enough south that aurora is regularly visible from locations only a short drive from the city, as well as penguins, seals, and royal albatross. Dunedin is 1-2 hours flight from the country's main international airports. However, like all of New Zealand, we are far from most of the world, an example being the 10 hour flying time to Singapore. Perhaps ironically, Antarctica is much more accessible (a ~ 5 hour flight), hence the strong polar research activity taking place across many Departments at Otago University - including in Physics.

OTAGO PHYSICS DEPARTMENT - OVERVIEW

The Otago Department of Physics has a vigorous research ethos. It was rated as the top Physics Department of New Zealand in the most recent Performance Based Research Fund (PBRF) round [2]. The Department's permanent staff currently consists of 16 faculty, supported by 5 teaching fellows. In addition to New Zealand our staff come from many parts of the world including Australia, China, Denmark, England, Finland, Germany, and Scotland. As a highly research active Department, we also have a large number of research only staff numbering 17. Most of these are the externally funded, including 8 research fellows and 5 postdoctoral fellows. Our research activity ranges widely, from fundamental physics through to highly applied areas in electronics. This is detailed later in the article. Funding support has also varied widely, spanning the range from Marsden Fund supported basic science [3], Centres of Research of Excellence and National Science Challenges, applied projects, through to research ready for commercialisation.

Our faculty have roles in multiple of the country's Centres of Research Excellence (CoREs). Currently, the most significant of this is the Dodd-Walls Centre for Quantum Science and Technology which started in 2015, and is part named after Professor Jack Dodd, a former Otago Head of Department. The Dodd-Walls Centre is located in the same building as the Physics Department, and its director, David Hutchinson is one of our Professors.

We are also fortunate to have strong links to Otago Museum, which opened in 1868. The current director of the Museum, Dr Ian Griffin, is a former professional astronomer and also an honorary fellow in our Department. Ian has become well known for starting the "Flight to the Lights" where Air New Zealand planes are chartered each year to fly south and view the aurora from above the clouds [4].



Fig. 2: Aurora seen from Hoopers Inlet, a 30min drive from the centre of Dunedin. Photo credit: Dr Ian Griffin.

HISTORY

In 1848 a small group of mainly Scottish settlers founded the province of Otago and began to build the city of Dunedin. Only 21 years later the University of Otago had been created by ordinance of the Provincial Council. Originally there were only three professors to handle all the teaching, one for each of Classics and English Language and Literature, Mathematics and Natural Philosophy, and the last in Mental and Moral Philosophy. Natural Philosophy was the phrase previously used [5] for what we now view as Physics, and thus the Physics Department can proudly point to being a founding discipline for Otago University. The 150th anniversary of the founding of the University will be celebrated in 2019.

When founded the original focus of the Physics Department was primarily on teaching rather than research. Nonetheless, it is hard to stop physical scientists from pondering the wider world. A quirky "claim to fame" for our Department is that we host one of the longest-running science experiments known, the Beverly Clock [6]. This clock is driven by temperature and atmospheric pressure variations. It has run since 1864 and was gifted to the Department by its inventor Arthur Beverly on his death in 1907. His substantial bequest to the University of Otago continues to provide funds for prizes and scholarships, more than 110 years later.

Other notable historical members of our Department were: Agnes Blackie who for many decades was the only woman academic in the physical sciences at Otago and was on the staff from 1919-1958; Professor Robert Jack who broadcast New Zealand's first radio programme



Fig. 3: A photo of Physics Department staff and senior students in 1926. Seated are (from left) lecturer Agnes Blackie, Professor Robert Jack and lecturer Robert Nimmo.

from Otago University in 1921; and Professor Robert Nimmo who worked on both the UK and US atomic bomb projects during World War II after being a student at Otago, and before returning to be the Professor.

The Department was also fortunate to play a role in promoting economic and social development in the Asia Pacific region through the Colombo Plan. This agreement between various Commonwealth countries saw around 3500 students come to New Zealand from the 1950s until the 1970s. As part of the Colombo Plan the Department of Physics benefited by receiving some outstanding students from Asia-Pacific. One example is Professor OH Choo Hiap, who came from Malaysia and graduated with a BSc honours degree (1969) and a PhD degree (1972). Prof. Oh went on to be the head of physics at the National University of Singapore (2000-2006) and was the key driver behind setting up the Centre for Quantum Technologies in Singapore. Another notable graduate is Datuk Mazlan Othman, also from Malaysia. She obtained a BSc honours degree (1975) and then returned and complete a PhD in 1981 – the first woman to be awarded a PhD in Physics at Otago. Dato' Othman worked as an astrophysicist in Malaysia, was a previous director of the United Nations Office for Outer Space Affairs and the director general of the Malaysia Space agency.

TEACHING

Our Department teaches in three different programmes (Physics, Energy Studies, and Electronics). Last year approximately 355 full time student equivalents took our

courses, with 51 of these at the post graduate level. About 10% of the total student number reports their home area as being international.

Otago provides a research-led learning environment. Senior faculty teach at all levels - it is normal for full professors to be teaching first year classes. It is common for our staff to be nominated for Otago Student Association teaching awards in both undergraduate teaching and postgraduate supervision. As one would hope, some end up winning these awards. Several staff have also received University of Otago Teaching Excellence Awards.

Otago University includes one of New Zealand's two medical schools, and its only dental school, as well as professional health programmes in pharmacy, physiotherapy and medical laboratory science. In New Zealand, it is possible to enter these programmes as an undergraduate or graduate student. The main undergraduate pathway is the highly competitive Health Science First Year programme, a set of prescribed first year courses allowing an "apples with apples" academic comparison between the students. We teach a very large service course (PHSI191: Biological Physics) which was designed specifically to serve the needs of the Health Science First Year pro-

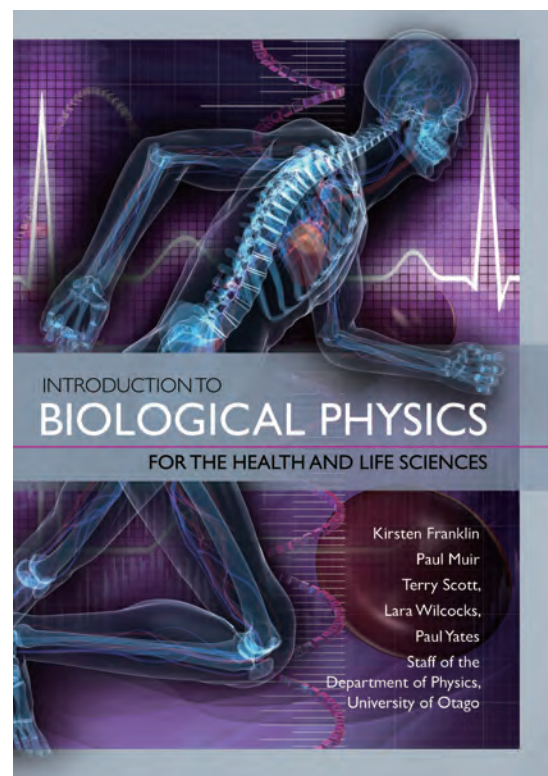


Fig. 4: Cover of the textbook written for PHSI191. We suspect PHSI191 is one of the biggest on campus undergraduate physics courses in the world.

gramme. For the last three years more than 1600 students have taken this paper, which we think is the largest Physics course in Australasia, and probably one of the biggest on-campus courses in the world! The syllabus for this paper was developed from discussions with the professional health programmes, and led to our staff producing a dedicated textbook [7]. This is now published by Wiley and used in various teaching courses internationally.

RESEARCH

Over the past 20 years the Department has had a focus on developing a vibrant and successful research culture. Indeed, in the last 10 years members of the Department have been successful in securing 16 Marsden Grants (for basic research), a number of FRST/MSI/MBIE Grants (which have a more applied focus) [8], and have participated in National Science Challenges and National Centres of Research Excellence. Rather than provide a detailed description of each research group in our department, we have chosen to provide a summary of our research interests of our staff grouped into various general areas. We encourage the interested reader to visit our research webpage (www.otago.ac.nz/physics/research/), where more detailed descriptions can be found.

Geophysics Research

Space Physics & Atmospheric Electricity

Prof Craig Rodger

- Radiation belts, electron precipitation, and ionosphere
- Space Weather
- Long range ground based remote sensing of ionosphere
- Global lightning detection

Antarctic Sea Ice

Prof Pat Langhorne

- Physical properties of sea ice
- Antarctic sea ice thickness
- Antarctic ice shelves' influence on sea ice formation processes

Ice-ocean interactions

Dr Inga Smith

- Supercooling and platelet ice formation processes
- Stable isotope analysis
- Sea ice processes in Earth System Models

Solar influence on atmosphere and climate

Dr Annika Seppälä

- Solar activity, solar storms
- Atmospheric chemistry
- Chemical-dynamical coupling
- Climate modelling and earth observation

Energy Physics Research

Energy Physics

Dr Michael Jack

- Energy system analysis
- Smart electricity grids and demand flexibility
- Molecular-scale energy conversion processes

Energy Technology

Assoc Prof Zhifa Sun

- New and integrated technologies to reduce GHG emission
- Improved energy efficiency
- Energy management

Electronics Research

Sensors & Instrumentation

Dr Tim Molteno

- Satellite navigation signals and systems
- Inference based sensor systems
- Radio Astronomical Imaging
- Image & Signal Processing

Inference

Assoc Prof Colin Fox

- Bayesian inference algorithms
- MCMC for inverse problem

Quantum Theory

Quantum gases

Prof Blair Blakie

- Theory of ultra-cold atomic gases
- Phase transition dynamics: Kibble-Zurek and Phase ordering
- Applications of computational physics
- Quantum dipolar gases
- Spinor quantum gases

Quantum Physics and Biology

Prof David Hutchinson

- Thermal field theories of ultra-cold atomic gases
- Transport in disordered media and Anderson Localisation
- Quantum processes in photosynthetic systems
- Connections between quantum physics and number theory – the Riemann hypothesis

Stochastic Superfluids

Dr Ashton Bradley

- Quantum turbulence in planar superfluids
- Open quantum systems and collective dissipative phenomena
- Quantum optics and quantum phase space methods

Solid state theory

Dr Phillip Brydon

- Superconductivity
- Unconventional superconductors

Experimental Atomic and Optical Physics Research

Nano-optics

Prof Richard Blaikie

- Super-resolution optical imaging
- Laser interference lithography
- Plasmonics

Quantum optics

Assoc Prof Jevon Longdell

- Rare-earth-ion doped solids for:
- Quantum information
- Quantum computing
- Signal processing optics

Light and matter

Assoc Prof Niels Kjærgaard

- Ultra cold matter
- Optical instrumentation
- Laser systems

Atom Manipulation and Interferometry

Dr Mikkel Andersen

- Atom manipulation with laser light
- Laser controlled atoms for making precise instruments
- Atomic interferometers

Resonant optics

Dr Harald Schwefel

- Resonantly enhanced interactions
- Dielectric microcavities
- Optical, microwave and THz frequency conversion
- Optical frequency combs

Physics Education Research

Physics Education

Dr Terry Scott

- Interaction of linguistic skills and concept acquisition in physics.
- Role of misconceptions in the development of understanding.
- Quantitative analysis of survey data in physics education.

References

- [1] This honor now goes to the National University of Tierra del Fuego in Argentina, formed in late 2010.
- [2] Tertiary Education Commission, Performance Based Research Fund Evaluating Research Excellence – the 2012 Assessment Final Report, ISBN: 978-0-478-32024-4 (Oct 2013).
- [3] The Marsden Fund provides grants for investigator led research. Incidentally, this fund is named after Ernest Marsden, of fame for his role in the Geiger-Marsden experiment under the supervisor of Lord Rutherford. Marsden moved to New Zealand in 1915 to be a professor of Physics at Victoria University in Wellington.
- [4] Web links: <http://otagomuseum.nz/blog/flight-to-the-lights-2-back-to-the-lights/> <https://edition.cnn.com/travel/article/southern-lights-flight-trnd/index.html>
- [5] For example the Principia, Newton's seminal 1687 work was entitled Philosophiæ Naturalis Principia Mathematica. This is Latin for "Mathematical Principles of Natural Philosophy".
- [6] L. E. S. Amon et al, Eur. J. Phys. 5. 195 (1984)
- [7] K. E. Franklin et al, Introduction to Biological Physics for the Health and Life Sciences, ISBN-13: 978-0470665930 (October 2010)
- [8] The Foundation for Research Technology (FRST), the Ministry for Science and Innovation (MSI) and the Ministry for Business, Innovation and Employment (MBIE) is the list of evolving names for the Government agency that invests into research for future value, growth, and critical need for New Zealand.



Craig J. Rodger is the current Head of Department at the Department of Physics at the University of Otago. He completed his PhD at Otago in 1997, and undertook a New Zealand Science and Technology Postdoctoral Fellowship at the British Antarctic Survey in Cambridge (UK). He joined the faculty of the University of Otago as a lecturer in 2001, became a professor in 2015, and Head of Department from 2016. His primary research fields are in space physics and space weather.



P. Blair Blakie is the current Deputy Head of Department at the Department of Physics at the University of Otago. Completing his PhD at Otago in 2001 he undertook postdoctoral research at the National Institute of Standards and Technology in Maryland. He then joined the Department as a lecturer in 2004 and was promoted to Professor in 2014. Blair's research interests are in ultra-cold atoms and computational physics.