# Microlensing 22
# Auckland, New Zealand
# 25–28 January 2018

## Welcome Address and Introduction

Welcome to Microlensing 22! On behalf of the Scientific Organising Committee, thank you for participating in this year's conference. If you have any questions or problems, please do not hesitate to come and chat with either me or Amy Edwards, our conference manager, and we will do our best to help.

I hope you will enjoy your time in Auckland and perhaps take the opportunity to travel further afield around this beautiful country. If you have any tourism questions, a travel advisor will be available for you to consult while the conference registration desk is open.

The Department of Physics at The University of Auckland is committed to providing a harassment-free environment. This conference has adopted the London Code of Conduct and all participants are required to abide by this Code. If you have any questions about the Code of Conduct, please contact Nicholas Rattenbury. The Code itself is given below.

Included next is the complete programme for the conference. As ever, there may be last minute changes to the programme line-up and we will endeavour to make you aware of any changes well in advance.

Nicholas Rattenbury, for the SOC:

Rachel Akeson (Caltech/IPAC)
Valerio Bozza (University of Salerno)
Scott Gaudi (The Ohio State University)
Calen Henderson (Caltech//IPAC-NExScI)
Jessica Lu (University of California Berkeley)
David Nataf (Johns Hopkins University)
Nick Rattenbury (University of Auckland)
Rachel Street (Las Cumbres Observatory)
Takahiro Sumi (Osaka University)
Andrzej Udalski (Warsaw University)

# London Code of Conduct

The organisers are committed to making this meeting productive and enjoyable for everyone, regardless of gender, sexual orientation, disability, physical appearance, body size, race, nationality or religion. We will not tolerate harassment of participants in any form.

Please follow these guidelines:

- Behave professionally. Harassment and sexist, racist, or exclusionary comments or jokes are not appropriate. Harassment includes sustained disruption of talks or other events, inappropriate physical contact, sexual attention or innuendo, deliberate intimidation, stalking, and photography or recording of an individual without consent. It also includes offensive comments related to gender, sexual orientation, disability, physical appearance, body size, race or religion.

- All communication should be appropriate for a professional audience including people of many different backgrounds. Sexual language and imagery is not appropriate.

- Be kind to others. Do not insult or put down other attendees.

Participants asked to stop any inappropriate behaviour are expected to comply immediately. Attendees violating these rules may be asked to leave the event at the sole discretion of the organisers without a refund of any charge.

Any participant who wishes to report a violation of this policy is asked to speak, in confidence, to Nicholas Rattenbury (SOC and LOC chair).

This code of conduct is based on the "London Code of Conduct", as originally designed for the conference "Accurate Astrophysics. Correct Cosmology", held in London in July 2015.

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# Conference Background and Theme

The following is part of the announcement for the conference, and I repeat it here for posterity – or for those who come across this programme in the future and are curious about what drove our field at this time.

For a quarter of a century, gravitational microlensing has been used as a channel for astrophysical discovery.

Microlensing is:

- increasing our knowledge of stellar populations in the Milky Way and other galaxies,
- constraining the frequency and mass function of compact objects, including black holes, white dwarfs, and brown dwarfs,
- probing the structure of the inner Galaxy and the properties of the stellar population that resides there,
- discovering Earth-mass exoplanets from the outer habitable zone out to beyond the snow line,
- becoming a part of space-based observation programmes which are building a map of the planetary abundance in our Galaxy, including an exploration of the frequency and mass function of free-floating planets.

Our community has grown, but will need to grow further to meet the challenges put in front of us by new and existing ground and space-based observatories. Current observational efforts produce data at a rate that is a challenge to analyse with our present resources and tools. We need to address this as we move forward into an era of WFIRST/LSST microlensing.

Our theme for this meeting is loosely centered on how to prepare for the coming decade of microlensing observations and the data they will bring.

We will discuss what tools we presently have to analyse data, whether and how these can be best adopted as a standard in the field, what tools or skills are missing from our present capabilities, and how we can address these gaps.

Microlensing has a lot to offer the broader astrophysical community. In turn, we must reach out to our colleagues in the fields of statistics, computer science, and astroinformatics to let them know of the opportunities and tensions in our field, and to build links with these communities.

# Programme and Venue

### Welcome Reception

The Welcome Reception will be from 7pm, Wednesday 24th January in the Level 1 foyer of the Owen G. Glenn Building (Building number 260 on attached campus map). Drinks and nibbles will be provided. Registration will be open during the Reception and on Level 0 the following morning.

### Conference Dinner

Our Conference dinner will begin at 7pm (with drinks and nibbles available from 6.30pm), Saturday 27th January at the Fale Pasifika (Building number 275).

### Breakout sessions

There are a number of break-out sessions scheduled during the conference, following lunch on each day. This is time set aside for you to self-organise chats with colleagues on topics of mutual interest. There are a number of separate rooms available for our use during these sessions and I hope that you find these sessions useful.

### Poster presentations

We also have time in the programme set aside for those presenting posters to advertise these to the attendees. This will be just prior to morning tea on the first day of the conference – each speaker to advertise their poster in no more than one minute.

# Thursday, 25th January 2018

| Time start | Title | Name |
|---|---|---|
| 09:00 | Welcome Address and WiFi password | Nicholas Rattenbury |
| | Session 1: Current Survey and Project Results and Summaries | Chair: N. Rattenbury |
| 09:30 | Invited talk: Exploring the shortest microlensing events | Przemek Mróz |
| 10:00 | OGLE-IV in 2017 and Next Observing Seasons | Andrzej Udalski |
| 10:15 | Update on the MOA project | Ian Bond |
| 10:30 | The ROME/REA Project | Yiannis Tsapras |
| 10:45 | Poster Presentations | |
| 10:55 | MORNING TEA | |
| | Session 1: con't | Chair: A. Bhattacharya |
| 11:15 | Status and Plans for KMTNet | Sun-Ju Chung |
| 11:30 | The Spitzer Microlensing Campaign: an update | Sebastiano Calchi Novati |
| 11:45 | Invited talk: Angie Wolfgang | Angie Wolfgang |
| 12:15 | LUNCH | |
| 13:15 | BreakOut Session One | |
| 14:45 | Invited talk: New Insights Into the Inner Milky Way | Gail Zasowski |
| | Session 2: Code Development | Chair: R. Street |
| 15:15 | VBBinaryLensing 2.0: a fast and robust code for light curve computation | Valerio Bozza |
| 15:30 | Resolving the lens for MACHO-97-BLG-28 | Joshua Blackman |
| 15:45 | The numerical kernel approach revisited - a public open source difference imaging pipeline | Markus Hundertmark |
| 16:00 | AFTERNOON TEA | |
| 16:20 | Proper motion measurements with OGLE data in microlensing studies | Jan Skowron |
| 16:35 | pyLIMA: A Progress Report | Etienne Bachelet |
| 16:50 | Invited talk: Bayesian inference in astronomy: past present and future | Sanjib Sharma |

# Friday, 26th January 2018

| Time start | Title | Name |
|---|---|---|
| | Session 3: Future Surveys and Projects | Chair: C. Henderson |
| 09:00 | The Keck Key Strategic Mission Support Program for WFIRST | David Bennett |
| 09:15 | An overview of the Microlensing Science Investigation Team's work | Matthew Penny |
| 09:30 | Meridian Microlensing with LSST | Daniel Rothchild |
| 09:45 | Opportunities for microlensing science in the LSST era | William Clarkson |
| 10:00 | Microlensing Returns from LSST | Martin Donachie |
| 10:15 | WFIRST microlensing analysis challenges | Rachel Street |
| 10:30 | Invited talk: Chasing the Southern Lights around and above New Zealand | Ian Griffin |
| 11:00 | Announcements | |
| 11:05 | MORNING TEA | |
| | Session 3 cont'd | Chair: D. Nataf |
| 11:25 | 3D structure of lens systems | Wei Zhu |
| 11:40 | Photometry of K2 Bulge data | Radek Poleski |
| 11:55 | Announcements | |
| 12:00 | The Robo-AO-2 facility for rapid near-HST resolution imaging from the ground | Christoph Baranec |
| 12:30 | LUNCH | |
| 13:30 | BreakOut Session Two | |
| | Session 3: cont'd | Chair: R. Akeson |
| 14:30 | Characterization of microlensing planets | Aparna Bhattacharya |
| 14:45 | Invited talk: Difference-Imaging Photometry with pyDIA | Michael Albrow |
| 15:15 | The Auckland Programme for Space Systems | Nicholas Rattenbury |
| | Session 4: Microlensing Black Holes | Chair: V. Bozza |
| 15:30 | Detecting Isolated Stellar Mass Black Holes through Astrometric Microlensing Using HST | Kailash Sahu |
| 15:45 | Photometric microlensing with Gaia | Katarzyna Kruszynska |
| 16:00 | AFTERNOON TEA | |
| 16:20 | Searching for an intermediate mass black hole in M22 | Noé Kains |
| 16:35 | Intermediate Mass Black Hole Microlensing in the 2020s | Will Dawson |
| 16:50 | M31 Microlensing | Hiroko Niikura |

## Saturday, 27th January 2018

| Time start | Title | Name |
|---|---|---|
| | Session 5: Specific Event Analysis | Chair: A. Wolfgang |
| 09:00 | Unique solutions for the physical properties of a microlens | Calen Henderson |
| 09:15 | The cold Neptune-mass planet OGLE-2015-BLG-1670Lb | Clément Ranc |
| 09:30 | The closest-source microlensing event discovered toward Taurus | Akihiko Fukui |
| 09:45 | The 2016 CFHT-K2C9 microlensing survey | Shude Mao |
| 10:00 | Analysis of the Planetary Microlensing Event OGLE-2017-BLG-0406 with Spitzer Data | Yuki Hirao |
| 10:15 | Invited talk: Astrobiology and the Search for ET-life in the Solar System | Kathy Campbell |
| 10:45 | Announcements | |
| 10:50 | MORNING TEA | |
| | Session 6: Galactic Science | Chair: S. Gaudi |
| 11:05 | Using the MOA database and the eclipse time variation method | Man Cheung Alex Li |
| 11:20 | Gravitational wave followup by the MOA collaboration | Fumio Abe |
| 11:35 | The Challenge of Extinction | David Nataf |
| 11:50 | Observing high extinction fields with WFIRST | Geoff Bryden |
| 12:05 | LUNCH | |
| 13:05 | BreakOut Session Three | |
| 14:35 | Archiving and Community Use of Microlensing Data | Rachel Akeson |
| | Session 6: Galactic Science cont'd | Chair: S. Gaudi |
| 15:05 | Confronting Galactic models and microlensing data with MaBulS | Supachai Awiphan |
| 15:20 | Microlensing of white dwarfs | Hajime Kawahara |
| | Session 7: Statistics | Chair:G. Zasowski |
| 15:35 | Quantifying the Evidence for a Planet in Astronomical Data | Benjamin Nelson |
| 15:50 | AFTERNOON TEA | |
| 16:10 | Planet formation theory | Daisuke Suzuki |
| 16:25 | Microlensing planets : accurate mass measurement and spatial distribution | Jean-Philippe Beaulieu |
| 16:40 | Intermediate mass MACHOs | Nathan Golovich |
| 16:55 | Optical Medium approach | Saswati Roy |
| 17:10 | Summary of developments at Auckland | Nicholas Rattenbury |
| 17:25 | CLOSING STATEMENTS | Nicholas Rattenbury |

## Sunday, 28th January 2018

Sight-seeing in Auckland or further afield.

## Posters

| Time start | Title | Name |
|---|---|---|
| Poster | Analysis of event OGLE-2017-BLG-0173Lb | Kyu-Ha Hwang |
| Poster | Analysis of event OGLE-2017-BLG-1038 | Amber Malpas |
| Poster | Analysis of events having Parallax signal in 2017 | Sarang Shah |
| Poster | Detecting microlensing events using a random f... | Daniel Godinez |
| Poster | HST WFC3 stellar proper motions in the Galacti... | Richard Barry |

# Microlensing 22 Abstracts

## Exploring the shortest microlensing events

25 Jan
09:30

Przemek Mróz

Theories of planet formation predict the existence of a population of unbound (free-floating) planets. Gravitational microlensing provides a unique tool for studying these objects. The first results of Sumi et al. (2011) claimed that Jupiter-mass free-floating planets are as common as main-sequence stars. However, these results appear to disagree with censuses of substellar objects in young clusters and star-forming regions and with predictions of planet formation theories. I will present new results of the analysis of a six times larger sample of microlensing events discovered by the OGLE-IV survey during the years 2010-2015, which shed new light on the population of free-floating planets. I will also discuss the first results of the joint analysis of the OGLE and KMTNet data from 2016 and 2017 observing seasons and present the most interesting short-timescale binary events.

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## OGLE-IV in 2017 and Next Observing Seasons

25 Jan
10:00

Andrzej Udalski

Quick status of the OGLE 2017 microlensing season as well as future OGLE-IV plans will be presented.

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25 Jan
10:15

## Update on the MOA project

Ian Bond

The Microlensing Observations in Astrophysics (MOA) Project completed its 12th Galactic Bulge season in 2017 with the 1.8 m survey telescope and 80 megapixel camera, and continues to observe other targets year round. Since 2006 MOA has alerted over 5000 microlensing events in real-time together with a number of other astrophysical transient events. More transients events have been revealed in offline analyses of the data. MOA also played a part in identifying the optical counterpart of the gravitational wave source GW170817. I will review the 2017 viewing season, presenting some highlights, and discuss future plans for MOA as a facility for time critical astrophysics.

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25 Jan
10:30

## The ROME/REA Project

Yiannis Tsapras

The ROME/REA microlensing campaign is a 3-year Key Project running on the Las Cumbres Observatory (LCO) robotic network of telescopes. It combines regular multi-band observations and reactive follow-up from the LCO sites in Chile, South Africa and Australia.

I will present a summary of the project and its first observing season.

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25 Jan
11:15

## Status and Plans for KMTNet

Sun-Ju Chung

I present a current status and future plans of KMTNet (Korea Microlensing Telescope Network) microlensing experiments, which include an observational strategy, pipeline, event-finder, and collaborations with Spitzer. The KMTNet experiments were initiated in 2015. From 2016, KMTNet observes 27 fields including 6 main fields and 21 subfields. In 2017, we have finished the DIA photometry for all 2016 and 2017 data. Thus, it is possible to do a real-time DIA photometry from 2018. The DIA photometric data is used for finding events from the KMTNet event-finder. The KMTNet event-finder has been improved relative to the previous version, which already found 857 events in 4 main fields of 2015. We have applied the improved version to all 2016 data, except 5 subfields. As a result, we find that 2413 events are found, and out of them, 354 are found in KMTNet-K2C9 overlapping fields. For increasing the detection efficiency of event-finder, we are working on filtering false events out by machine-learning method. In 2018, we plan to measure event detection efficiency of KMTNet by injecting fake events into the pipeline near the image level. Thanks to high-cadence observations, KMTNet found fruitful interesting events including exoplanets and brown dwarfs, which were not found by other groups. Masses of such exoplanets and brown dwarfs are measured from collaborations with Spitzer and other groups. Especially, KMTNet has been closely cooperating with Spitzer from 2015. Thus, KMTNet observes Spitzer fields. As a result, we could measure the microlens parallaxes for many events. Also, the automated KMTNet PySIS pipeline was developed before the 2017 Spitzer season and it played a very important role in selecting the Spitzer target. For the 2018 Spitzer season, we will improve the PySIS pipeline to obtain better photometric results.

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## The Spitzer Microlensing Campaign: an update

25 Jan
11:30

Sebastiano Calchi Novati

The Spitzer team is conducting a 5 year campaign (2014-2018) to measure the microlensing parallax of  170/year microlensing events toward the Galactic bulge taking advantage of Spitzer's position along its heliocentric orbit, currently at more than 1 Au from Earth. The main goal of the program is to measure the mass and the distance of lens systems that contain planets. I am going to report on the current status of the project with a focus on the 2017 campaign.

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## Invited talk: Angie Wolfgang

25 Jan
11:45

Angie Wolfgang

Angie's Invited talk

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25 Jan
14:45

## New Insights Into the Inner Milky Way

Gail Zasowski

Galactic bulges contain dense, information-rich fossil records of star formation and galaxy assembly, encoded in the morphology and chemo-dynamical patterns of the stellar populations. The Milky Way's bar/bulge is the only one in which we can resolve the positions, chemistry, and kinematics of individual stars, but despite sophisticated models that can reproduce the bulk stellar dynamics and metallicities, work is still ongoing to understand the formation and subsequent evolution of our bar/bulge's numerous populations. This talk will briefly review the current general consensus on the bar/bulge's structural, kinematical, and chemical properties as derived from observational evidence and theoretical simulations. I will highlight areas of recent development, particularly via infrared observations able to pierce the thick dust clouds towards the inner Galaxy, and explore some of the (many) interesting outstanding questions that future efforts will try to resolve.

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25 Jan
15:15

## VBBinaryLensing 2.0: a fast and robust code for light curve computation

Valerio Bozza

VBBinaryLensing has rapidly become the reference code for light curve computation in microlensing in the last two years. We present new upgrades to the code, including: the Skowron and Gould algorithm for root finding, a criterium that chooses whether to accept the point-source approximation or to go for the full contour integration, relative and absolute precision settings, reference time for parallax parameters, a full calculation for extended-sources-point-lens to arbitrary accuracy.

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## Resolving the lens for MACHO-97-BLG-28

25 Jan
15:30

Joshua Blackman

MACHO-97-BLG-28 is a binary microlensing event with two lenses in the dwarf regime. Now that 20 years have passed since its discovery we are able to resolve the lens and the source using high-angular resolution adaptive optics (AO) imaging from KECK. First I will discuss how we use the open source microlensing modelling package pyLIMA (Bachelet 2017) to re-model the event light curve without this AO constraint. We use the original PLANET photometry from Chile, South Africa and Australia to derive the caustic geometry and physical parameters. We then use the KECK data to determine the lens flux and the amplitude and direction of the lens-source relative proper motion. Finally, we add the AO constraint to refine the physical parameters of the system.

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## The numerical kernel approach revisited - a public open source difference imaging pipeline

25 Jan
15:45

Markus Hundertmark

With the increasing tendue of ongoing and future telescopes, a fast and robust data reduction pipeline is essential not only for finding microlensing events but also for characterizing subtle planetary features. Since the introduction of the numerical kernel solution by Bramich (2008), the approach has been used by various teams for different purposes. For many years, the RoboNet team has relied on the original implementation for successfully reducing microlensing follow-up data. After the deployment of the larger Sinistro cameras (26.5 x 26.5 arcmin) on the 1m telescopes of the Las Cumbres Observatory (LCO), it became apparent that a different approach is required in order to achieve a timely data-release. For the new ROME/REA Key project, the RoboNet team is preparing a novel open source python implementation of the pipeline with the aim of improving the usability and making it faster. Two of the guiding principles are to keep a code structure that can be readily parallelized and which minimizes the data storage requirements. In this talk, we outline the current development status and discuss ways to adapt the approach for real-time usage and highlight how the information content of the image can be assessed and exploited in more efficient ways.

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25 Jan 16:20

## Proper motion measurements with OGLE data in microlensing studies

Jan Skowron

Microlensing event parameters extracted from the light curves alone are often degenerated. Additional constraints on the geometry of the event, and hence its physical interpretation, can be provided by the proper motion measurement of the blended light. With over two-decades-long constant monitoring of large portions of the Galactic bulge, under good seeing conditions and with relatively small pixel-size, the OGLE project acquired an unprecedented dataset that can be employed for such measurements. I will discuss methods, their limits, and results from recent studies that used proper motion measurements from the OGLE images. In the dense fields required for microlensing studies, this dataset will remain an important asset for the future, as neither GAIA nor LSST plan to extensively monitor this region.

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25 Jan 16:35

## pyLIMA: A Progress Report

Etienne Bachelet

I will present the progress made on pyLIMA, an open source modeling software. Since the binary modeling is release, I will present the methods we use, performance and results on already published events.

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25 Jan 16:50

## Bayesian inference in astronomy: past present and future

Sanjib Sharma

Monte Carlobased Bayesian data analysis has now become the method of choice for analyzing and interpreting data in almost all dis- ciplines of science. In astronomy, over the past decade, we have also seen a steady increase in the number of papers that employ Monte Carlobased Bayesian analysis. New, efficient Monte Carlobased methods are continuously being developed and explored. In this talk, we will look at the origin and the development of Bayesian inference in the past. Next, we discuss some useful methods like Bayesian hierarchical modeling and ways to solve them. Finally, we note that big data poses unique challenges for doing Bayesian inference. To this end, we discuss some techniques that hold great promise in future.

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## The Keck Key Strategic Mission Support Program for WFIRST

26 Jan
09:00

David Bennett

NASA has awarded our WFIRST-related team 20 half-nights on the Keck telescopes over the next 18 months for high angular resolution laser guide star adaptive optics follow-up observations of planetary and stellar binary microlensing events. Our observations will also provide mass measurements or constraints for up to 60 exoplanets discovered by microlensing. Our observations will also allow us to test and develop the primary method that we expect WFIRST to use to determine exoplanet masses using both planetary and stellar binary events. We welcome input from the microlensing community concerning target priorities and opportunities.

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## An overview of the Microlensing Science Investigation Team's work

26 Jan
09:15

Matthew Penny

Launching in the mid-2020s, WFIRST will revolutionize the search for planets with microlensing. I will provide an update on the status of the mission following the WIETR panel's report, and give an overview of the work of the Microlensing Science Investigation Team in the past year.

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## Meridian Microlensing with LSST

26 Jan
09:30

Daniel Rothchild

The Large Synoptic Survey Telescope (LSST) promises to make a "movie of the sky", creating a vast dataset of well-sampled transients across the Southern sky. Its field of view of  10 square degree and its 30-second exposure time allow LSST to image about 5,000 square degrees of sky twice every night, with each field observed in two different bands. With an optimal non-rolling cadence, transient scientists should be able to expect that every visible field will be imaged in all of grizy approximately every 6 days (assuming 10,000 square degrees of sky visible per night).

The current baseline cadence implemented by the LSST Operations Simulator (OpSim) does not sample the sky at this rate. In grizy, typical median inter-night gaps to a given sky pixel range from 15-30 days. In addition, while most fields are imaged twice per night, rarely are those exposures taken in different bands.

I will present work on an alternative cadence, developed jointly with Chris Stubbs at Harvard University, that concentrates observations close to the meridian. Our cadence achieves typical inter-night gaps for grizy of 5-15 days, and each field is observed in two bands per night; all without sacrificing any efficiency on the overall static survey. Using LSST's Metrics Analysis Framework (MAF), we have demonstrated that our cadence achieves 5x higher performance on a simple microlensing MAF metric.

The theme of this meeting is how to prepare for the coming decade of microlensing observations. Without more input from the scientific community in the coming months, the LSST project may implement a cadence that is suboptimal for microlensing science. Constructing and implementing MAF metrics that cover microlensing science objectives is the most effective way to help LSST's Science Advisory Committee differentiate between proposed cadences. I am happy to help conference participants get started writing such metrics.

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26 Jan
09:45

## Opportunities for microlensing science in the LSST era

William Clarkson

With its combination of wide field of view, high photometric precision, broad wavelength range, and survey uniformity on timescales of a decade or more, LSST should make important contributions to several areas of microlensing science, particularly (but not limited to) cases with relatively slow, relatively rare stellar microlensing events that play out on timescales of months or more. These observations in turn could set new constraints on Galactic structure and the compact object mass function, with impact in a broad range of astrophysical areas of inquiry.

With main survey operations currently expected to start in 2023, a large community effort is underway to maximise LSSTs science return, by quantitatively comparing the impact of various candidate survey strategies on several important science cases, including microlensing. I will demonstrate some example figures of merit for microlensing science, and suggest ways in which the microlensing community can contribute to the effort.

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## Microlensing Returns from LSST

26 Jan
10:00

Martin Donachie

The Large Synoptic Survey Telescope (LSST) is a next-generation, ground-based observatory currently under construction in Chile. With a 3.2 gigapixel CCD camera (the largest ever built) and a 8.4m primary mirror it will observe 18,000 square degrees of sky every 3-4 nights, in six passbands (ugrizy). Coming online in the early 2020s and observing continually for the next decade, the telescope will provide unprecedented coverage of the night sky, impacting across virtually every area of astronomy. I will outline some of the opportunities this presents in terms of microlensing, specifically, and discuss current work seeking to characterise the suitability of competing observing strategies in regard to these science cases.

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## WFIRST microlensing analysis challenges

26 Jan
10:15

Rachel Street

WFIRST will produce thousands of high cadence, high photometric precision lightcurves of microlensing events, from which a wealth of planetary and stellar systems will be discovered. However, the analysis of such lightcurves has historically been very time consuming and expensive in both labor and computing facilities. This poses a potential bottleneck to deriving the full science potential of the WFIRST mission. To address this problem, the WFIRST Microlensing Science Investigation Team designing a series of data challenges to stimulate research to address outstanding problems of microlensing analysis. These range from the classification and modeling of triple lens events to methods to efficiently yet thoroughly search a high-dimensional parameter space for the best fitting models.

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## Chasing the Southern Lights around and above New Zealand

26 Jan
10:30

Ian Griffin

This presentation will describe my obsession with photographing the Aurora Australis from various sites in Southern New Zealand, showcasing some of the images I have taken since moving to Dunedin in 2013. I will also share the story of how a single image taken in 2015 eventually led to the first ever charter flight to the antarctic circle specifically to observe the aurora australis in March 2017.

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26 Jan
11:25

## 3D structure of lens systems

Wei Zhu

Current and future microlensing observations can detect dozens of (if not hundreds of) triple-object systems. So far there have been six such systems detected, including two multiple-planet systems and another four hierarchical triples (planets in binaries). Although microlensing can only measure the projected positions (rather than 3D positions) of the lens objects, we can constrain the 3D structure of these systems by combining the stability criterion and the a priori of some trivial parameters (e.g, inclination). Here I apply this method to some interesting systems, and present the results that we learn about the architectures of these systems as well as the outer planetary world in general.

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26 Jan
11:40

## Photometry of K2 Bulge data

Radek Poleski

I will present MCPM method for extracting photometry from K2 Bulge data. The limitations of the method will be discussed.

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26 Jan
12:00

## The Robo-AO-2 facility for rapid near-HST resolution imaging from the ground

Christoph Baranec

We are in the process of building the next-generation Robo-AO-2 system that will combine near-HST angular resolution across visible and near-infrared (NIR) wavelengths (lambda = 400  1800 nm), unmatched observing efficiency, and extensive, dedicated time on the UH 2.2-m. The prototype Robo-AO (http://robo-ao.org) completed a survey to find contaminating sources to all  4000 Kepler exoplanet candidate host stars, and, with the forthcoming Robo-AO-2 system, we will enable high-acuity, high-sensitivity follow-up observations of several tens of thousands of objects per year. This will be perfect for discovering, characterizing and monitoring of blends of targets from microlensing surveys (as well as other large area surveys). Robo-AO-2 will also respond to target-of-opportunity events within minutes, minimizing the time between discovery and characterization, and will interleave different programs with its intelligent queue. Robo-AO-2 will be permanently mounted on the UH 2.2-m, will be available year round, will add tip-tilt correction capability to mV 17 and will enable excellent, ¡110 nm RMS, image quality on bright, mV¡9, objects using a new stellar wavefront sensor.

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## Characterization of microlensing planets

26 Jan
14:30

Aparna Bhattacharya

Microlensing is unique in its sensitivity to cold low mass wide orbit planets. But one of the biggest challenges of current ground based microlensing is that the ground based light curve data fails most of the times to provide us with the physical masses of the planet and the host star. We can measure the mass of these planets and their host stars through several different methods: microlensing parallax and the lens detection from the high resolution images are the two most important methods among them. I will focus on developing the method of characterization of these planets and their host stars using follow up observations with HST. I will also demonstrate the technique and how to overcome its challenges due to contamination from the companions and nearby unrelated stars with multiple examples. This will help to characterize thousands of cold low mass wide orbit exoplanets in WFIRST era and complete the exoplanet census - a mission started by Kepler.

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## Difference-Imaging Photometry with pyDIA

26 Jan
14:45

Michael Albrow

pyDIA is a freely available code for time series difference-imaging photometry of crowded star fields. Lower-level routines come in GPU-accelerated and CPU versions, to implement numerical kernel image subtraction and PSF-fitting photometry. At a higher level, python routines give the functionality to construct data processing pipelines.

I will discuss the structure of the code, and how to use it. Examples will be shown of how it is being used to process microlensing data from the KMTNet survey.

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26 Jan
15:15

## The Auckland Programme for Space Systems

Nicholas Rattenbury

The Auckland Programme for Space Systems is a University-wide student competition to scope, design, research and build a space satellite. I will describe the motivations for the programme, our progress and prospects for the future.

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26 Jan
15:30

## Detecting Isolated Stellar Mass Black Holes through Astrometric Microlensing Using HST

Kailash Sahu

A significant fraction of the mass of an old stellar population should be in the form of non-luminous, isolated black holes (BHs). Yet there has never been an unambiguous detection of a solitary BH—not surprisingly, since the expected accretion rate from the ISM is extremely low, and thus they emit essentially no radiation. The only technique available to detect such isolated BHs is astrometric microlensing—the relativistic deflection of light from background stars.

Out of the hundreds of bulge microlensing events found annually by the OGLE and MOA surveys, a few are found to have very long durations (¿200 days). A majority of the long-duration events with no light contribution from the lens are expected to be caused by lenses that are isolated BHs. To test this hypothesis, we are carrying out high-precision astrometry of a few long-duration events using the Hubble Space Telescope. For the first event, we have clearly detected astrometric shifts caused by the lens which suggests that mass of the lens is about 0.5 solar mass. Although the lens in this case is not a black hole, the detection of astrometric signal demonstrates that our program is sensitive to detecting black holes and measuring their masses. We will report the first results from this program.

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## Photometric microlensing with Gaia

26 Jan
15:45

Katarzyna Kruszynska

On the 19th of December 2013 Gaia Space Satellite was launched by European Space Agency. Its main goal is to measure proper motions and parallaxes of over 1 billion stars in Milky Way. However, ever since the first data has been acquired in 2014, Gaia has observed much more than that. Up to this day its alerting system of sudden change in brightness of observed sources (AlertPipe) has detected around 3000 transients. More than 30 of them have been classified as microlensing candidates from all over the sky, with a spectacular binary event in the Northern disk, Gaia16aye, among them.

Microlensing events detected and observed by Gaia offer a possibility for registering not only photometric effect, but also its astrometric counterpart. This will provide additional data, that will help to break degeneracies for single source-single lens events, which might lead to mass measurements of lenses and, in particular, to discovering lensing black holes.

We will present the best microlensing events that have been found by Gaia and which had additional data from the ground, including OGLE, SMARTS and telescopes within the OPTICON network. Additionally, for some of the events at least two spectra were obtained at different magnifications, in order to constrain the blending and the nature of the lens.

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## Searching for an intermediate mass black hole in M22

26 Jan
16:20

Noé Kains

I will present the results from a project aiming to search for possible astrometric deflections of Bulge stars caused by microlensing by an intermediate-mass black hole (IMBH) in the core of globular cluster M22. We analysed archival observations of the cluster from the Hubble Space Telescope spanning over 20 years, identified Bulge stars in the images, and used available and improved software to extract astrometry from these data. We then fitted astrometric models to each resulting astrometric time-series, in order to check whether a signal was detected in any Bulge star near the core of the cluster, where an IMBH would be located. We also used our astrometric models for stars with no astrometric microlensing signal detections to place limits on the mass of an IMBH present in the core of M22, by comparing our results to simulations and detection probability estimates we published in 2016 paper.

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26 Jan
16:35

## Intermediate Mass Black Hole Microlensing in the 2020s

Will Dawson

The discovery of gravitational waves from merging intermediate mass black holes by LIGO is arguably one of the most important scientific discoveries of the 21st century. However, we are left with a number of fundamental questions related to this newly discovered population of black holes. Many of these questions can be most directly answered by microlensing measurements of the of abundance and mass spectrum of black holes in the Milky Way. Given the current LIGO rate of discovery it is promising that current microlensing surveys, such as OGLE, MOA, KMTNet, and ZTF, as well as future surveys, such as LSST and WFIRST, can potentially detect and characterize 10's-1000's of intermediate mass black holes in the Milky Way. I will review the aspects of parallax and astrometric microlensing specifically related to intermediate mass black holes that enables the direct measurement of black hole mass for both isolated as well as binary black hole lenses. I will also present simulations forecasting the capability of LSST and WFIRST to detect and characterize various populations of black holes both independently and collaboratively. I will also demonstrate the capability of the extremely large telescopes of the 2020's to facilitate a new regime of microlensing measurement.

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26 Jan
16:50

## M31 Microlensing

Hiroko Niikura

We carried out a dense cadence survey of Andromeda Galaxy (M31) to search for micro-lensing effects on stars in M31 due to primordial black hole (PBH), which is a viable candidate of dark matter. The Subaru Hyper Suprime-Cam (HSC) allows us to cover the entire bulge and disk regions with one pointing thanks to its wide field-of-view. We developed a method of identifying variable star candidates based on the image difference technique, that is now fully integrated in the HSC pipeline. We found various kinds of variable stars such as star flare, contact binary stars, and eclipse of white dwarf star, but found only one possible candidate of PBH microlensing expected to more than a few hundreds candidates if all dark matter is made of PBHs. The results, based on only one-night HSC observation, allows us to put most stringent upper bound on the abundance of PBHs of lunar mass scales.

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## Unique solutions for the physical properties of a microlens

27 Jan 09:00

Calen Henderson

Two mass-distance relations are required to uniquely solve for the physical properties of a microlens. The lens flux characterization channel, which involves observing a lensing event with a high-resolution facility, provides one such relation, and is thought to be one of the primary avenues of lens characterization for the detections predicted for WFIRST. Events from the recent Spitzer and K2C9 satellite parallax initiatives are particularly useful events to observe, as their measurements (or constraints) of the microlens parallax and Einstein radius facilitate an independent check on the derived lens properties. Here I will describe my observational and analysis methodology and present initial results from recent programs using NIRC2 on Keck II to take adaptive optics (AO) data on microlenses from satellite parallax campaigns.

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## The cold Neptune-mass planet OGLE-2015-BLG-1670Lb

27 Jan 09:15

Clément Ranc

The microlensing event OGLE-2015-BLG-1670 was first detected by the OGLE collaboration, and has been densely observed by the MOA and KMTNet collaborations, especially in July, 2015, when an anomaly occurred. The best light curve model points out that the blending dominates and the source is too faint to perform any high resolution follow-up observations. It is mainly due to the high extinction along the line of sight of this event which is located at a low Galactic latitude (l=-1.1), close to WFIRST fields. I will present how does the analysis of this event lead to the idea that the light curve features are due to a lens with a planet-to-star mass ratio $q \approx 6.5 \cdot 10^{-}5$ and a projected separation $s \approx 1.1$ in units of the Einstein radius. In particular, I will discuss the advantage of using an affine-invariant ensemble sampler to explore degenerate solutions in microlensing, even when several parameters are highly correlated. The microlensing parallax is not clearly constrained for this event, but the detection of finite-source effects yields a measurement of the angular Einstein radius $\theta_{\mathrm{E}} \approx 0.48\,\mathrm{mas}$, and provides one mass-distance relation. I derive the probability distributions of lens physical properties by using a Bayesian analysis that includes a prior from a Galactic model. The resulting distributions show that the lens most likely consists in a $19\,\mathrm{M_E}$ Neptune-mass planet orbiting a $\sim 0.7\,\mathrm{M_\odot}$ star beyond the snow-line and located at 6.7 kpc from the Earth. Such cold/icy Neptune-mass planets are thought to be very common, especially in outer orbits.

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27 Jan
09:30

## The closest-source microlensing event discovered toward Taurus

Akihiko Fukui

On Oct. 31 2017, a Japanese amateur astronomer discovered a transient brightening event on a V=14 mag star toward Taurus. We recognized it as a possible microlensing event based on our independent multi-band, wide-field photometric survey and publicly available ASAS-SN light curve, and started spectroscopic and photometric follow-up observations from Nov. 1. We confirmed that this event is well explained by microlensing with the maximum amplitude of about 10. The source star is an F5 dwarf located at 700pc from us, which is the closest among all micolensing events discovered to date, followed by the 7th-mag-reached event discovered toward Cassiopeia in 2006 (1kpc). Because of the closeness of the source and lens, we might be able to characterize the lens object in detail in the future. Moreover, the detection of an anomalous feature in the light curve around the peak was reported by Nucita et al., who tentatively interpreted it as evidence of an Earth-mass planet orbiting the lens. In this contribution we will report on our follow-up observations of this spectacular event.

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27 Jan
09:45

## The 2016 CFHT-K2C9 microlensing survey

Shude Mao

2016 CFHT-K2C9 multi-color (g, r and i) microlensing survey with the Canadian-France-Hawaii Telescope (CFHT) conducted during the 2016 *K2* microlensing campaign. In this talk, I will present the difference imaging analysis (DIA) photometry and the calibration process for CFHT data. Then I will describe how to use CFHT multi-color data to predict the microlensing source flux in the *Kepler* bandpass and predict stellar angular diameter for microlens source. I will also demonstrate the analysis of a short ($\sim$4.5 days) microlensing event OGLE-2016-BLG-0795. The microlensing parallax measured from *K2* strongly suggests that the lens is a stellar-mass object even though the timescale is relatively short. Finally, I will discuss the implications of this work and other interesting *K2* events.

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## Analysis of the Planetary Microlensing Event OGLE-2017-BLG-0406 with Spitzer Data

27 Jan
10:00

Yuki Hirao

I will report the progress of the analysis of the planetary event OGLE-2017-BLG-0406. This event was expected to reach high magnification and observed by several telescopes. MOA detected the anomaly in real time just after the peak, and the light curve modeling indicates that the lens system has the mass ratio of q = 7.e-4 and the separation of s = 1.12. The Spitzer space telescope also observed this event, which gives us to measure the microlensing parallax and constrain the lens mass.

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## Astrobiology and the Search for ET-life in the Solar System

27 Jan
10:15

Kathy Campbell

How do geologists and astrobiologists search for life beyond Earth? By looking backwards into 'deep time' (> 3 billion years ago) to unearth signs of earliest life on our planet and to determine the types of paleoenvironments in which it took hold and flourished. These first biota, which lived under extreme environmental conditions compared to today, may provide clues to finding life elsewhere, extant or fossil. Astrobiologists and planetary scientists also look to other planetary bodies and moons that may be/have been habitable. This talk will explore habitability, early terrestrial life, and current astrobiological targets in the Solar System, including Icy Worlds and with an emphasis on hydrothermal and martian studies. An overview of the new, cross-disciplinary research centre at Auckland will also be introduced. It has a focus on the origin and evolution of the Universe and its life, and a mission to bring together earth scientists, physicists, biologists, chemists, philosophers and others to tackle 'Big Questions' in foundational cosmology, abiogenesis, astrobiology, and mind and cognition.

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27 Jan
11:05

## Using the MOA database and the eclipse time variation method

Man Cheung Alex Li

Detecting microlensing events requires wide-field monitoring towards the sky. Microlensing surveys such as MOA would therefore result in massive photometric data which are also beneficial to the study of variable stars. Here, following the recent publication of MOA eclipsing binary catalog, we present the discovery of the MOA eclipsing binaries with tertiary companions using eclipse time variation method.

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27 Jan
11:20

## Gravitational wave followup by the MOA collaboration

Fumio Abe

Joint observations of gravitational wave and electromagnetic wave unveiled extreme astronomical phenomenon. In August 2017, first gravitational wave GW170817 caused by a coalescence of neutron star binary was detected by LIGO. The electromagnetic counterpart GRB170817A/AT2017gfo was observed FermiGBM, Integral and many optical, infrared and radio telescopes. The observations confirmed the relation between NS-NS merger, short GRB, and kilo-nova. Such multi-messenger observations are expected to open new frontier in astronomy. Kilo-novae are thought to be potential candidates of sources of heavy elements. To identify kilo-novae, optical and infrared observations are particularly important.

Optical follow-up observations of gravitational wave can be done with microlensing observation telescopes as a by-product. Wide-field telescopes for microlensing survey are particularly useful to find optical counterparts of gravitational waves because the positions are not well constrained. The world-wide observation networks are useful to monitor kilo-novae for 24 hours a day particularly for southern sky. Light curves in multiple pass bands would be useful for understanding nature of kilo-novae.

The MOA collaboration has been conducted follow-up observations for the gravitational wave events occurred in first and second observation period (O1 and O2) of LIGO. In this talk, I will report observations by MOA for the gravitational wave events including GW170817/AT2017gfo. Then, Ill discuss prospects for future observations.

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## The Challenge of Extinction

27 Jan
11:35

David Nataf

I review the challenge of non-standard, variable, and differential extinction toward the Galactic bulge, predominantly in the context of the WFIRST microlensing campaign. Recent developments have identified the issues of differential reddening along the 3D axis, as well as the steeper infrared extinction curve, as confounding factors that need to be addressed and accounted for. These have implications both for the selection of fields, as well as the interpretation of individual events.

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## Observing high extinction fields with WFIRST

27 Jan
11:50

Geoff Bryden

Microlensing surveys generally neglect the very center of the galaxy due to the very high optical extinction. The future NASA flagship mission, WFIRST, however, will operate at near-IR wavelengths, such that its optimal target fields may be in more central regions of higher stellar density. To test this, we are using UKIRT's wide-field near-IR camera to survey the galactic bulge. Based on a conservative initial selection of variable lightcurves, we have classified 73 lightcurves during the 2015 and 2016 seasons as microlensing events, of which 62

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## Archiving and Community Use of Microlensing Data

27 Jan
14:35

Rachel Akeson

I will discuss several ongoing and future projects aimed at making microlensing data and tools available to both the microlensing and the wider astronomical communities. These projects include collecting planetary microlensing events from the literature for the NASA Exoplanet Archive, archiving light curves from the Kepler/K2 and follow-up campaigns, and plans for the data in the WFIRST microlensing survey. One specific example is the public release of photometry from the ongoing near-infrared UKIRT microlensing survey through th5 Exoplanet Archive. This release includes 2016 and 2016 H-band data, which were acquired in support of a Spitzer microlensing campaign and K2 Campaign 9 and I will discuss lessons learned from the ingestion and release of this survey data. I will also provide suggestions on how the microlensing community can help with these efforts, including using standard notations, terminology, and tabular data when publishing results.

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27 Jan
15:05

## Confronting Galactic models and microlensing data with MaBulS

Supachai Awiphan

The microlensing surveys on the Galactic bulge have provided useful information in the search for exoplanets and for the study of Galactic structure. From our previous study (Awiphan et al. 2016), we developed the first interactive multi-wavelength microlensing simulation called MaBulS (Manchester-Besancon microlensing Simulator, http://www.mabuls.net). We performed the first field-by-field microlensing maps comparison of the Besancon population synthesis Galactic model and MOA-II microlensing observations (Sumi et al. 2013). Recently, the OGLE survey published statistical data of 2,617 microlensing events (Mroz et al. 2017). In this work, we use MaBulS to simulate microlensing event rates of OGLE-IV fields and compare the event rates with the published OGLE-IV event rates. However, the Besancon model shows the lack of low-mass stars and brown dwarfs in the model. Therefore, the field-by-field comparison between the Besancon model and OGLE-IV data can be used to estimate the mass function slope of low mass stars and brown dwarfs in each Galactic component.

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27 Jan
15:20

## Microlensing of white dwarfs

Hajime Kawahara

We discovered several white dwarfs (WDs) that gravitationally magnify their main-sequence (MS) companions on edge-on orbits, through a systematic GPU search for long-period pulses in the Kepler data. We jointly modeled such self-lensing light curves and radial velocity time series to derive the WD mass. We found that those binaries has WD mass of 0.6 Msolar, binary orbital periods of 1-2 yr, and low but non-zero eccentricities. The inferred WD mass and orbital separation suggest that the WD progenitor experienced Roche-lobe overflow onto the MS companion. This may imply a nearly stable mass-transfer history as has also been proposed for some blue-straggler binaries, although the current orbits are slightly smaller than theoretically expected and the origin of non-zero eccentricities remains unclear. Located in the currently unexplored regime of the post-interaction systems, these self-lensing WDMS binaries would be an ideal sample to understand the diverse outcomes of binary interactions, as well as the origin of blue strugglers.

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## Quantifying the Evidence for a Planet in Astronomical Data

27 Jan
15:35

Benjamin Nelson

In the pioneering days of exoplanets, one could almost discover new planets in data by eye. Today, planet hunters have achieved high enough spectroscopic and photometric precision to detect subtle rocky exoplanets but also stellar activity that can masquerade as planetary signals. This confusion has led to some contentious exoplanet claims, especially in radial velocity (RV), which in turn motivated teams to adopt a more rigorous statistical framework. In particular, many have developed algorithms to compute a Bayesian "evidence" $p(d|M)$ for $n$ planets in their data. Unfortunately, the relative strengths and weaknesses of these methods are largely unknown to the exoplanet community since no one has applied them all in the same context. Furthermore, $p(d|M)$ is a notoriously expensive calculation even in relatively low ( 3-10) dimensions.

I will highlight a data challenge presented to the RV community with the goal of computing the Bayesian evidence for 0/1/2/3-planets in 6 synthetically generated RV datasets. Participating teams applied a variety of frequentist and Bayesian methods to assess model evidence (e.g., AIC, BIC, cross-validation, Laplace approximation, importance sampling, nested sampling) assuming the same physical and noise models. We find most methods claim very high precision in their evidence estimates ($log(p(d|M) \sim 0.01$) but median values can range in orders of magnitude, even for 1-planet models. I will also discuss algorithms that show promise for efficiently analyzing hundreds or potentially thousands of datasets. The reliability of these evidence calculations has important implications on setting "discovery" thresholds and planning future observations, and these lessons may carry over to the microlensing community.

All of the results are currently hosted on github:
https://github.com/EPRV3EvidenceChallenge/Inputs

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## Planet formation theory

27 Jan
16:10

Daisuke Suzuki

Planet formation theories have been being developed even before the first detection of exoplanets. However, there are a lot of mechanisms we do not understand correctly. Observational constraints are needed to study how planetary systems form. In this talk, we compare the planet frequency estimated from the microlensing survey (Suzuki et al. 2016) with that simulated by population synthesis models. Two different synthesis models are used for the comparison: Ida & Lin 2004 and Mordasini et al. 2009. We find that the estimated planet frequency around 50 Earth mass is higher than the simulated ones by factor 30. This discrepancy would not be explained by changing the migration strength in the synthesis models.

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27 Jan
16:25

## Microlensing planets : accurate mass measurement and spatial distribution

Jean-Philippe Beaulieu

Microlensing is probing the unique population of planets behind the snow line, distributed towards the Galactic Bulge. Although relative physical parameters are known to good precision from the modelling of the light curves, high angular resolution observations with adaptive optics (KECK, VLT, SUBARU) or HST are an excellent route to accurately constraint the physical parameters of the systems. We revisit physical parameters 18 planetary systems detected by microlensing and compare with earlier analysis. We then compare the spatial distribution of all the planetary system with physical parameters constrained by high angular resolution. With our revised distance to the lenses, we found that the systems tend to be clustered in the Sagittarius or Scuttum-Crux arms, or at the tip of the bar.

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27 Jan
16:40

## Intermediate mass MACHOs

Nathan Golovich

In the 1990s, the MACHO Project observed the LMC, SMC, and galactic bulge over the course of several years in order to search for microlensing events due to massive compact halo objects (Machos) present in the Milky Way dark matter halo. With the LMC light curves, based on 5.7 years of data, they detected 15 microlensing events with timescales ranging from 34 to 230 days and concluded that galactic dark matter composed of Machos with mass below 10 solar masses can not comprise more than 40% of the galactic halo mass. The recent LIGO detections of merging black holes in the mass range 1060 solar masses have renewed interest in intermediate-mass Machos as a dark matter candidate. In this talk, I will discuss an improved analysis scheme using Bayesian detection techniques. This method is sensitive to microlensing event timescales of up to a few thousand days, which probes the mass range of interest provided by the LIGO detections. I will present early results from our re-analysis of the MACHO Project archival data of LMC, SMC, and galactic bulge.

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## Optical Medium approach

27 Jan
16:55

Saswati Roy

The gravitational deflection of light ray is an important conclusion of Einstein's General Theory of Relativity. The deflection of light ray was first observed in the year 1919 during solar eclipse. Theoretically, the deflection of light ray due to heavy mass, considering different space-time, can be obtained by using different methods such as null geodesic approach, perturbation method, optical medium approach etc. Out of all the methods, optical medium approach is very new and more acceptable to get the exact value of deflection angle of light ray without any approximation. In this method, we define the deflection of light ray with respect to the refractive index of the medium. Here, we will consider different space-time curvature and apply the optical medium approach to evaluate the deflection angle of light ray due to heavy mass. And hence one comparison will be made with the common approach as null geodesic approach for different space-time curvature.

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## Summary of developments at Auckland

27 Jan
17:10

Nicholas Rattenbury

I summarise the exoplanet and algorithm development activity at the University of Auckland and prospects for developing this further over the next few years.

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## CLOSING STATEMENTS

27 Jan
17:25

Nicholas Rattenbury

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Poster

# Analysis of event OGLE-2017-BLG-0173Lb

Kyu-Ha Hwang

We present microlensing planet OGLE-2017-BLG-0173Lb, with planet-host mass ratio either $q \simeq 2.5 \times 10^{-}5$ or $q \simeq 6.5 \times 10^{-}5$, the lowest or among the lowest ever detected. The planetary perturbation is strongly detected, $\Delta\chi^2 \sim 10,000$, because it arises from a bright (therefore, large) source passing over and enveloping the planetary caustic: a so-called “Hollywood” event. The factor $\sim 2.5$ offset in $q$ arises because of a previously unrecognized discrete degeneracy between Hollywood events in which the caustic is fully enveloped and those in which only one flank is enveloped, which we dub “Cannae” and “von Schlieffen”, respectively. This degeneracy is “accidental” in that it arises from gaps in the data. Nevertheless, the fact that it appears in a $\Delta\chi^2 = 10,000$ planetary anomaly is striking. We present a simple formalism to estimate the sensitivity of other Hollywood events to planets and show that they can lead to detections close to, but perhaps not quite reaching, the Earth/Sun mass ratio of $3 \times 10^{-}6$. This formalism also enables an analytic understanding of the factor $\sim 2.5$ offset in $q$ between the Cannae and von Schlieffen solutions. The Bayesian estimates for the host-mass, system distance, and planet-host projected separation are $M = 0.39^{+}0.40_{-}0.24\,M_\odot$, $D_L = 4.8^{+}1.5_{-}1.8\,\mathrm{kpc}$, and $a_\perp = 3.8 \pm 1.6\,\mathrm{AU}$. The two estimates of the planet mass are $m_p = 3.3^{+}3.8_{-}2.1\,M_\oplus$ and $m_p = 8^{+}11_{-}6\,M_\oplus$. The measured lens-source relative proper motion $\mu = 6\,\mathrm{mas\,yr}^{-}1$ will permit imaging of the lens in about 15 years or at first light on adaptive-optics imagers on next-generation telescopes. These will allow to measure the host mass but probably cannot resolve the planet-host mass-ratio degeneracy.

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Poster

# Analysis of event OGLE-2017-BLG-1038

Amber Malpas

I will describe modelling results from KMT, OGLE and Spitzer data for event OGLE-2017-BLG-1038.

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## Analysis of events having Parallax signal in 2017

Poster

Sarang Shah

Orbital Parallax is a useful method in constraining the mass of the lens. This signal is detected in those events which have the Einstein Crossing Time (tE) a significant fraction of the year. There are many events which have a long tE but only those events which have the transverse velocity of the lens parallel to the velocity of the Earth around the sun have a measurable parallax signal. I present the analysis of the events monitored in 2017 by KMTNet which show a parallax signal in them. I also check for the degeneracy in these events with the binary source orbital motion.

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## Detecting microlensing events using a random forest classifier

Poster

Daniel Godinez

This project explores the performance of a random forest classifier to detect microlensing events in wide-field surveys. Through this branch of supervised machine learning, we have developed an algorithm that utilizes photometric lightcurve information and by computing a set of statistical metrics, classifies a lightcurve as either microlensing event, a variable source, or otherwise a constant star that shows no variability. We tuned the algorithm for microlensing detection in the Palomar Transient Factory (PTF) and in the process set up a multi-stage process that utilizes the random forest classifier as an initial filter  we find that less than one percent of lightcurves inputted are flagged as plausible microlensing, requiring a visual inspection for confirmation. Out of an initial test using 3.5 million lightcurves, we identify several lightcurves that exhibit the features of microlensing, but which are unconfirmed owing to the relatively sparse dataset used for testing. Were currently awaiting access to the galactic plane and bulge data, where we expect the microlensing detection rate to be higher. By tuning this algorithm for early microlensing detection in the upcoming Zwicky Transient Facility (ZTF), we seek to employ a multi-process platform that utilizes the classifier to flag ongoing microlensing events, and forwards along the event for telescope follow-up.

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Poster

# HST WFC3 stellar proper motions in the Galactic bulge

Richard Barry

We present stellar proper motions in the Galactic bulge from Hubble Space Telescope Wide Field Camera 3 observations of Stanek's window from two epochs approximately two years apart. This dataset lies within the currently proposed Wide-eld Infrared Survey Telescope (WFIRST) microlensing survey field of regard. Proper motions are described for approximately 80,000 stars down to 25th mag in V band and 22nd mag in H band. Cuts on the proper motions allow us to produce cleaned bulge luminosity functions with less than 2% contamination from disk objects. Articial star tests are preformed and used to obtain photometric completeness measurements. Further, we derive an updated microlensing event rate and planet detection efficiency in this field of the bulge. These new detection rates will have implications for potential exoplanet yields during the WFIRST microlensing campaign.

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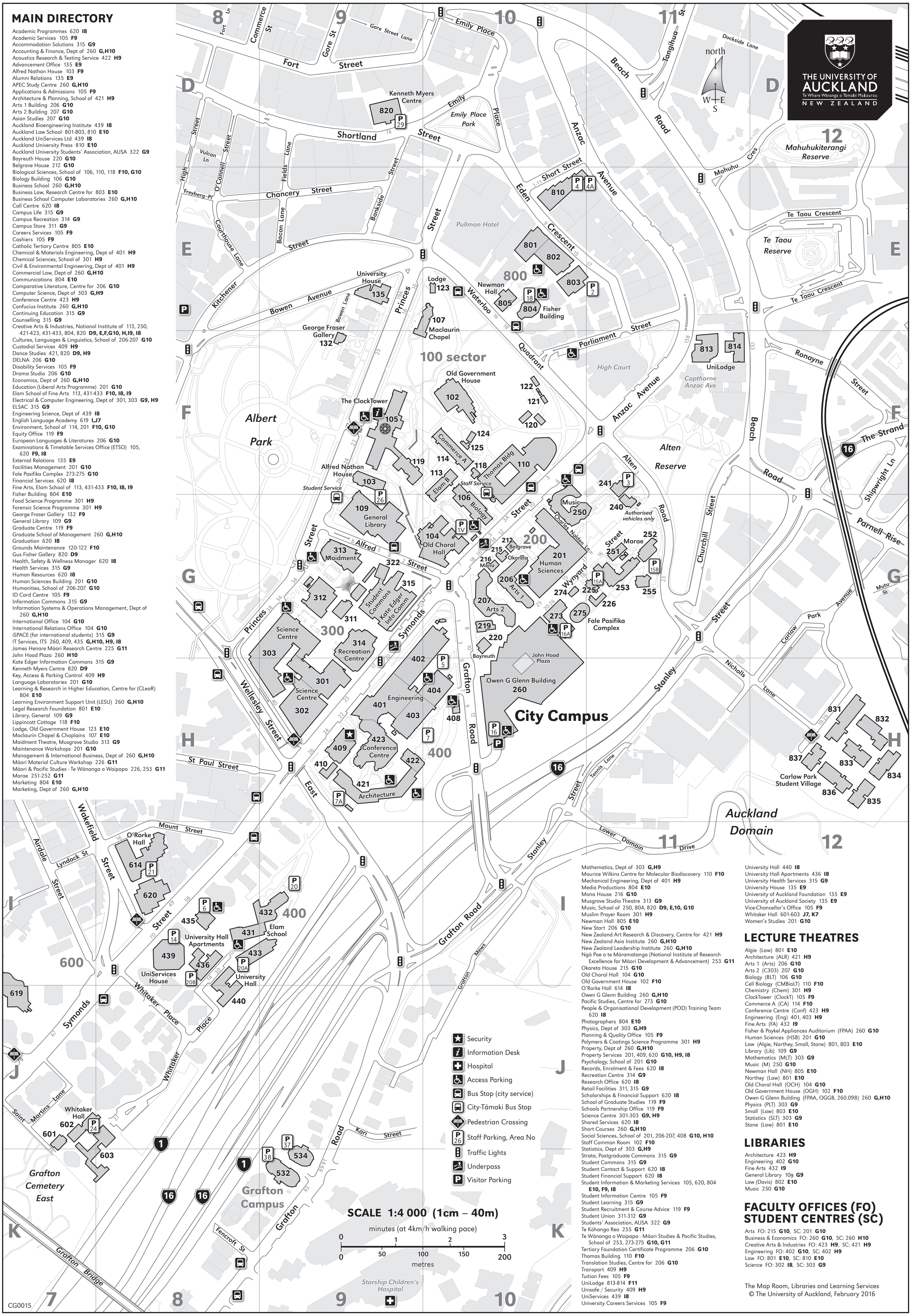
# Author Index




## MAIN DIRECTORY

Academic Programmes 620 **I8**
Academic Services 105 **F9**
Accommodation Solutions 315 **G9**
Accounting & Finance, Dept of 260 **G,H10**
Acoustics Research & Testing Service 422 **H9**
Advancement Office 135 **E9**
Alfred Nathan House 103 **F9**
Alumni Relations 135 **E9**
APEC Study Centre 260 **G,H10**
Applications & Admissions 105 **F9**
Architecture & Planning, School of 421 **H9**
Arts 1 Building 206 **G10**
Arts 2 Building 207 **G10**
Asian Studies 207 **G10**
Auckland Bioengineering Institute 439 **I8**
Auckland Law School 801-803, 810 **E10**
Auckland UniServices Ltd 439 **I8**
Auckland University Press 810 **E10**
Auckland University Students' Association, AUSA 322 **G9**
Bayreuth House 220 **G10**
Belgrave House 212 **G10**
Biological Sciences, School of 106, 110, 118 **F10, G10**
Biology Building 106 **G10**
Business School 260 **G,H10**
Business Law, Research Centre for 803 **E10**
Business School Computer Laboratories 260 **G,H10**
Call Centre 620 **I8**
Campus Life 315 **G9**
Campus Recreation 314 **G9**
Campus Store 311 **G9**
Careers Services 105 **F9**
Cashiers 105 **F9**
Catholic Tertiary Centre 805 **E10**
Chemical & Materials Engineering, Dept of 401 **H9**
Chemical Sciences, School of 301 **H9**
Civil & Environmental Engineering, Dept of 401 **H9**
Commercial Law, Dept of 260 **G,H10**
Communications 804 **E10**
Comparative Literature, Centre for 206 **G10**
Computer Science, Dept of 303 **G,H9**
Conference Centre 423 **H9**
Confucius Institute 260 **G,H10**
Continuing Education 315 **G9**
Counselling 315 **G9**
Creative Arts & Industries, National Institute of 113, 250, 421-423, 431-433, 804, 820 **D9, E,F,G10, H,I9, I8**
Cultures, Languages & Linguistics, School of 206-207 **G10**
Custodial Services 409 **H9**
Dance Studies 421, 820 **D9, H9**
DELNA 206 **G10**
Disability Services 105 **F9**
Drama Studio 206 **G10**
Economics, Dept of 260 **G,H10**
Education (Liberal Arts Programme) 201 **G10**
Elam School of Fine Arts 113, 431-433 **F10, I8, I9**
Electrical & Computer Engineering, Dept of 301, 303 **G9, H9**
ELSAC 315 **G9**
Engineering Science, Dept of 439 **I8**
English Language Academy 619 **I,J7**
Environment, School of 114, 201 **F10, G10**
Equity Office 119 **F9**
European Languages & Literatures 206 **G10**
Examinations & Timetable Services Office (ETSO) 105, 620 **F9, I8**
External Relations 135 **E9**
Facilities Management 201 **G10**
Fale Pasifika Complex 273-275 **G10**
Financial Services 620 **I8**
Fine Arts, Elam School of 113, 431-433 **F10, I8, I9**
Fisher Building 804 **E10**
Food Science Programme 301 **H9**
Forensic Science Programme 301 **H9**
George Fraser Gallery 132 **F9**
General Library 109 **G9**
Graduate Centre 119 **F9**
Graduate School of Management 260 **G,H10**
Graduation 620 **I8**
Grounds Maintenance 120-122 **F10**
Gus Fisher Gallery 820 **D9**
Health, Safety & Wellness Manager 620 **I8**
Health Services 315 **G9**
Human Resources 620 **I8**
Human Sciences Building 201 **G10**
Humanities, School of 206-207 **G10**
ID Card Centre 105 **F9**
Information Commons 315 **G9**
Information Systems & Operations Management, Dept of 260 **G,H10**
International Office 104 **G10**
International Relations Office 104 **G10**
iSPACE (for international students) 315 **G9**
IT Services, ITS 260, 409, 435 **G,H10, H9, I8**
James Henare Māori Research Centre 225 **G11**
John Hood Plaza 260 **H10**
Kate Edger Information Commons 315 **G9**
Kenneth Myers Centre 820 **D9**
Key, Access & Parking Control 409 **H9**
Language Laboratories 201 **G10**
Learning & Research in Higher Education, Centre for (CLeaR) 804 **E10**
Learning Environment Support Unit (LESU) 260 **G,H10**
Legal Research Foundation 801 **E10**
Library, General 109 **G9**
Lippincott Cottage 118 **F10**
Lodge, Old Government House 123 **E10**
Maclaurin Chapel & Chaplains 107 **E10**
Maidment Theatre, Musgrove Studio 313 **G9**
Maintenance Workshops 201 **G10**
Management & International Business, Dept of 260 **G,H10**
Māori Material Culture Workshop 226 **G11**
Māori & Pacific Studies - Te Wānanga o Waipapa 226, 253 **G11**
Marae 251-252 **G11**
Marketing 804 **E10**
Marketing, Dept of 260 **G,H10**
Mathematics, Dept of 303 **G,H9**
Maurice Wilkins Centre for Molecular Biodiscovery 110 **F10**
Mechanical Engineering, Dept of 401 **H9**
Media Productions 804 **E10**
Mona House 216 **G10**
Musgrove Studio Theatre 313 **G9**
Music, School of 250, 804, 820 **D9, E,10, G10**
Muslim Prayer Room 301 **H9**
Newman Hall 805 **E10**
New Start 206 **G10**
New Zealand Art Research & Discovery, Centre for 421 **H9**
New Zealand Asia Institute 260 **G,H10**
New Zealand Leadership Institute 260 **G,H10**
Ngā Pae o te Māramatanga (National Institute of Research Excellence for Māori Development & Advancement) 253 **G11**
Okareta House 215 **G10**
Old Choral Hall 104 **G10**
Old Government House 102 **F10**
O'Rorke Hall 614 **I8**
Owen G Glenn Building 260 **G,H10**
Pacific Studies, Centre for 273 **G10**
People & Organisational Development (POD) Training Team 620 **I8**
Photographers 804 **E10**
Physics, Dept of 303 **G,H9**
Planning & Quality Office 105 **F9**
Polymers & Coatings Science Programme 301 **H9**
Property, Dept of 260 **G,H10**
Property Services 201, 409, 620 **G10, H9, I8**
Psychology, School of 201 **G10**
Records, Enrolment & Fees 620 **I8**
Recreation Centre 314 **G9**
Research Office 620 **I8**
Retail Facilities 311, 315 **G9**
Scholarships & Financial Support 620 **I8**
School of Graduate Studies 119 **F9**
Schools Partnership Office 119 **F9**
Science Centre 301-303 **G9, H9**
Shared Services 620 **I8**
Short Courses 260 **G,H10**
Social Sciences, School of 201, 206-207, 408 **G10, H10**
Staff Common Room 102 **F10**
Statistics, Dept of 303 **G,H9**
Strata, Postgraduate Commons 315 **G9**
Student Commons 315 **G9**
Student Contact & Support 620 **I8**
Student Financial Support 620 **I8**
Student Information & Marketing Services 105, 620, 804 **E10, F9, I8**
Student Information Centre 105 **F9**
Student Learning 315 **G9**
Student Recruitment & Course Advice 119 **F9**
Student Union 311-312 **G9**
Students' Association, AUSA 322 **G9**
Te Kōhanga Reo 255 **G11**
Te Wānanga o Waipapa - Māori Studies & Pacific Studies, School of 253, 273-275 **G10, G11**
Tertiary Foundation Certificate Programme 206 **G10**
Thomas Building 110 **F10**
Translation Studies, Centre for 206 **G10**
Transport 409 **H9**
Tuition Fees 105 **F9**
UniLodge 813-814 **F11**
Unisafe / Security 409 **H9**
UniServices 439 **I8**
University Careers Services 105 **F9**
University Hall 440 **I8**
University Hall Apartments 436 **I8**
University Health Services 315 **G9**
University House 135 **E9**
University of Auckland Foundation 135 **E9**
University of Auckland Society 135 **E9**
Vice-Chancellor's Office 105 **F9**
Whitaker Hall 601-603 **J7, K7**
Women's Studies 201 **G10**

## LECTURE THEATRES

Algie (Law) 801 **E10**
Architecture (ALR) 421 **H9**
Arts 1 (Arts) 206 **G10**
Arts 2 (C303) 207 **G10**
Biology (BLT) 106 **G10**
Cell Biology (CMBioLT) 110 **F10**
Chemistry (Chem) 301 **H9**
ClockTower (ClockT) 105 **F9**
Commerce A (CA) 114 **F10**
Conference Centre (Conf) 423 **H9**
Engineering (Eng) 401, 403 **H9**
Fine Arts (FA) 432 **I9**
Fisher & Paykel Appliances Auditorium (FPAA) 260 **G10**
Human Sciences (HSB) 201 **G10**
Law (Algie, Northey, Small, Stone) 801, 803 **E10**
Library (Lib) 109 **G9**
Mathematics (MLT) 303 **G9**
Music (M) 250 **G10**
Newman Hall (NH) 805 **E10**
Northey (Law) 801 **E10**
Old Choral Hall (OCH) 104 **G10**
Old Government House (OGH) 102 **F10**
Owen G Glenn Building (FPAA, OGGB, 260.098) 260 **G,H10**
Physics (PLT) 303 **G9**
Small (Law) 803 **E10**
Statistics (SLT) 303 **G9**
Stone (Law) 801 **E10**

## LIBRARIES

Architecture 423 **H9**
Engineering 402 **G10**
Fine Arts 432 **I9**
General Library 109 **G9**
Law (Davis) 802 **E10**
Music 250 **G10**

## FACULTY OFFICES (FO) STUDENT CENTRES (SC)

Arts FO: 215 **G10**, SC: 201 **G10**
Business & Economics FO: 260 **G10**, SC: 260 **H10**
Creative Arts & Industries FO: 423 **H9**, SC: 421 **H9**
Engineering FO: 402 **G10**, SC: 402 **H9**
Law FO: 801 **E10**, SC: 810 **E10**
Science FO: 302 **I8**, SC: 303 **G9**

The Map Room, Libraries and Learning Services