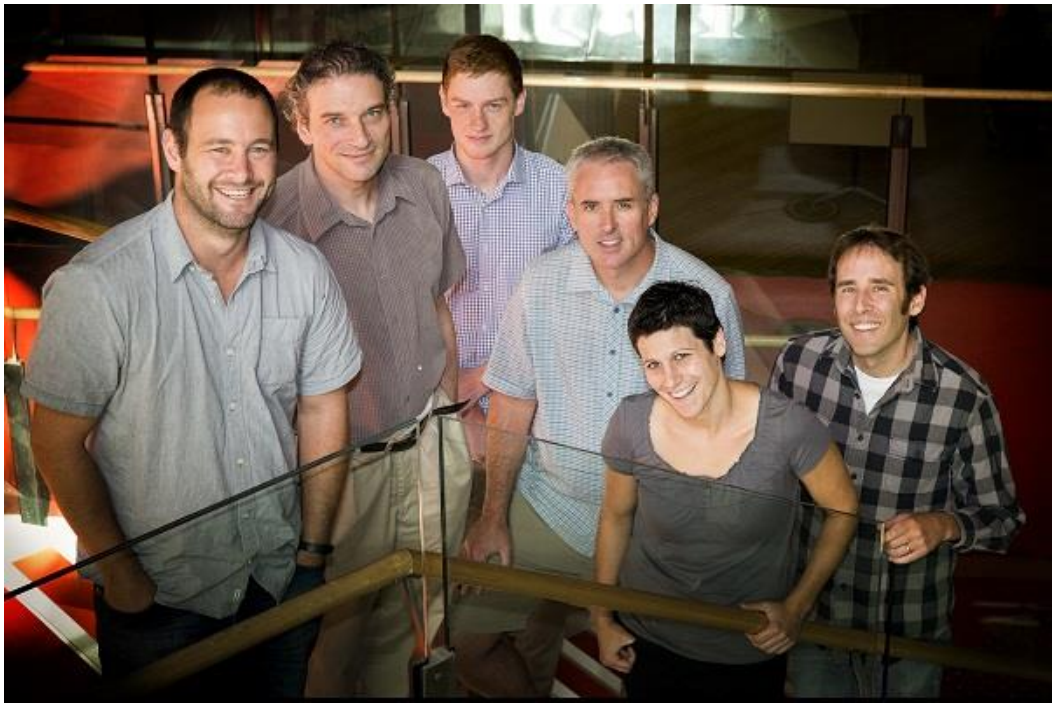
Monash University's role in the discovery of gravitational waves

A team of LIGO* Scientific Collaboration (LSC) researchers at Monash University played an important role in the design and implementation of key hardware and software components associated with the detection and interpretation of gravitational wave GW150914 in September 2015: the first ever observation of gravitational waves and the first direct detection of black holes.

The Monash team created a system of vetting detections – injecting fake gravitational waves into the detector. By showing that they could recover the fake signal, it enabled the team to verify a genuine gravitational wave.

The team played a key role in data analysis; observing and interpreting data generated by LIGO's detectors in Louisiana and Washington, USA, and were also instrumental in the design of the LIGO mirrors to control their behaviour in extreme conditions and thereby significantly increase LIGOs sensitivity to faint gravitational waves.

**Laser Interferometer Gravitational-wave Observatory*



The Monash LIGO team. L-R: Paul Lasky; Yuri Levin; Chris Whittle; Duncan Galloway; Letizia Sammut; Eric Thrane

The Monash LIGO research team

Dr Eric Thrane, Monash lecturer and member of the LIGO Scientific Collaboration

Dr Eric Thrane

Dr Eric Thrane joined the School of Physics and Astronomy at Monash from Caltech in early 2015. His research focus is astrophysics, cosmology, and gravitational-wave astronomy.

Since 2011 he has co-chaired one of LIGO's four data analysis groups, studying data from the LIGO detectors. His Monash group also works on aspects of the detectors themselves, for example, by characterising problematic noise sources, which threaten to limit LIGO's sensitivity. He and his team demonstrated that LIGO can detect simulated gravitational wave signals introduced by shaking the mirrors. This vetting process helped ensure that the collaboration could be confident in the first discovery of gravitational waves.

Dr Thrane described the discovery of gravitational wave GW150914 as monumental. “This is a watershed moment in the history of astronomy. LIGO's detection represents a whole new way of doing astronomy that can unlock the secrets of the universe. It has been a privilege to work with the international LIGO collaboration toward this discovery,” Dr Thrane said.

However, he described this first discovery as just the tip of the iceberg. “The discovery of this gravitational wave suggests that merging black holes are heavier and more numerous than many researchers previously believed. This bodes well for detection of large populations of distant black holes – research carried out by our team at Monash University. It will be intriguing to see what other sources of gravitational waves are out there, waiting to be discovered,” Dr Thrane said.

Monash research profile – Dr Eric Thrane

Dr Paul Lasky, Postdoctoral Researcher at Monash and member of the LIGO Scientific Collaboration

Dr Paul Lasky

Dr Paul Lasky is a postdoctoral research fellow in gravitational-wave astrophysics. An active member of the LIGO Scientific Collaboration since 2012, Dr Lasky’s primary responsibilities within LIGO include predicting and searching for gravitational waves from super-dense stellar corpses known as neutron stars, as well as understanding the complex physics that governs these exotic objects.

His recent technical review highlights the many possible ways neutron stars can create gravitational waves that could be detected in the very near future with LIGO. He is currently focussed on developing a method for testing Einstein's theory of General Relativity near the surfaces of black holes using observations of gravitational waves from black hole collisions such as this first event.

Dr Lasky is also an active member of both Australia's Parkes Pulsar Timing Array and the International Pulsar Timing array, which both aim to use the most rapidly spinning neutron stars (spinning faster than a kitchen blender!) to detect gravitational waves that come from the mergers of supermassive black holes weighing more than a billion times the mass of our Sun (compared to the black holes LIGO measures that weigh about 10 times our Sun). As well as developing and implementing data analysis algorithms, he is pioneering new techniques for combining gravitational-wave observations with both LIGO and pulsar timing arrays that could aid in our understanding of the earliest phases of the Universe.

Dr Lasky describes the discovery of gravitational waves as 'simply mind-blowing'. "About 1.4 billion years ago, two black holes collided in a single impact that, in less than a second, released more energy than 5,000 suns emit in their full lifetime. This energy was released as ripples of gravity that have been travelling towards Earth until, on 14 September 2015, they caused the two LIGO instruments to wobble a minuscule amount. I feel truly honoured to be a part of the amazing team that has made it possible to detect such a tiny wobble from such a cataclysmic, astronomical event," Dr Lasky said.

Monash research profile – Dr Paul Lasky

Associate Professor Yuri Levin, Monash lecturer and member of the LIGO Scientific Collaboration

Associate Professor Yuri Levin

Associate Professor Yuri Levin's key research interests are astrophysical gravitational waves, neutron stars and supermassive black holes (especially the one at the centre of our Galaxy, called SgrA*).

Associate Professor Levin completed his PhD at Caltech on the physics and astrophysics of LIGO under the mentorship of Professor Kip Thorne, one of the three founders of the LIGO project. Levin's key contribution was to develop a theoretical framework for evaluating the noise due to thermal fluctuations of the LIGO mirrors, and to point out the importance of using high-quality reflective coatings. Levin's work has been widely used within the collaboration and has guided the LIGO team in its choices of the mirror materials, optimised to increase the advanced LIGO sensitivity. Furthermore, together with his colleagues, Levin showed that a certain type of optical filter can help reduce the quantum fluctuations that interfere with gravitational-wave measurements. These filtering techniques will be implemented in future experiments with Advanced LIGO.

The Advanced LIGO discovery of gravitational waves from a black-hole merger has focused Associate Professor Levin's attention on the physics and astrophysics that can be learned from a multitude of

such mergers. “After the initial excitement, it is important to think about the next steps,” Associate Professor Levin said. “First, the detector noise has to be reduced by another order of magnitude, so that it reaches the target sensitivity for Advanced LIGO. Then a flood of new data will bring a multitude of signals such as the one we are celebrating today. We have to think intelligently about what to do with all this data.”

A film about Associate Professor Levin and his research can be found here and is free for media usage.

Monash research profile – Associate Professor Yuri Levin

Dr Duncan Galloway

Monash senior lecturer and member of the LIGO Scientific Collaboration

Dr Duncan Galloway

Dr Duncan Galloway established his research career with X-ray studies of accreting neutron stars during postdoctoral positions at the Massachusetts Institute of Technology (MIT).

His research interests include searches for gravitational waves from rapidly-rotating neutron stars, and searches for optical flashes which may accompany gravitational-wave bursts detectable by LIGO.

Preparations are already underway to fully exploit this new way of gathering information about the universe. A team of Monash researchers, in collaboration with Warwick University and other UK partners is developing a robotic optical telescope, the Gravitational-wave Optical Transient Explorer (GOTO) on the Canary Island of La Palma, to detect the optical flashes that may be associated with gravitational wave signals.

Dr Galloway explains the significance of discovering gravitational waves and what this will mean for future research. “The first detection of gravitational waves by LIGO opens up whole new opportunities in astrophysics. The identification of optical flashes associated with gravitational wave signals will enable the position of the source to be determined to much greater accuracy, and will significantly increase the amount of information that can be obtained from these extreme sources,” Dr Galloway said.

“But the really exciting aspect is the sources that we haven’t predicted, the truly unexpected discoveries that, history shows, often accompany the opening of a fundamentally new window on the universe”.

Monash research profile – Dr Duncan Galloway

Dr Letizia Sammut, Postdoctoral Researcher at Monash and member of the LIGO Scientific Collaboration

Dr Letizia Sammut

Dr Letizia Sammut is heavily involved in LIGO research and has been a member of the LIGO collaboration since 2009. She joined Monash in 2015, and is now in charge of a search for gravitational waves from the sum of many astrophysical sources, most notably mergers of black holes. This search uses techniques developed by Dr Eric Thrane (see above) and other LIGO collaborators.

Dr Sammut was inspired by an undergraduate project to pursue a PhD in gravitational wave astrophysics. During her PhD, she developed and performed searches for gravitational waves from ultra-dense neutron stars in binary orbits.

“It was incredibly exciting to be involved in the first direct detection of gravitational waves whilst in the final stages of my PhD dissertation, and in anticipation of starting my new role with the gravitational wave group in the School of Physics and Astronomy at Monash University. It is a fascinating and rewarding field within which I am delighted to be involved,” Dr Sammut said.

“Almost 100 years after Einstein first predicted their existence, the first direct detection of gravitational waves, and the direct observation of two merging black holes, marks a significant achievement in physics and astronomy, which stands on decades of instrumental and technical development,” Dr Sammut said.

Chris Whittle

Monash Science Honours Student and member of the LIGO Scientific Collaboration

Chris Whittle

During his undergraduate studies, Chris Whittle completed a research project under Dr Eric Thrane’s supervision on the prospects of utilising machine learning techniques for the detection of subthreshold gravitational wave signals amidst a sea of complicated noise patterns. Chris will be

continuing his work on investigating data analysis techniques for gravitational wave detection as an Honours student in the Faculty of Science this year.

“The fortuitous timing of my involvement with the LIGO Scientific Collaboration has afforded me a privileged insight into this momentous discovery. I am thrilled to be working with the LIGO community during such a pivotal period, and to have my own research so readily informed by the latest developments."

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