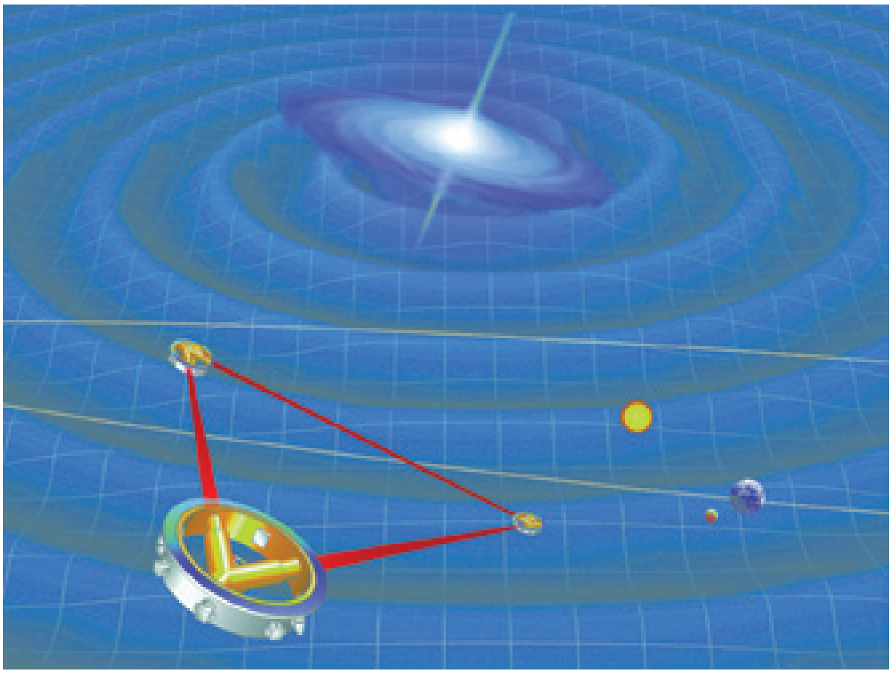
Detecting gravitational waves from space

The cosmos is full of massive objects undergoing furious motion – exploding stars (supernovae), neutron stars spinning hundreds of times per second (pulsars), and black holes forming. In 1916, Albert Einstein predicted that accelerated masses like this would produce a type of gravitational wave. These are extremely weak, but with the advent of exciting new technology, they should now be detectable if the objects are massive enough, and moving sufficiently fast.



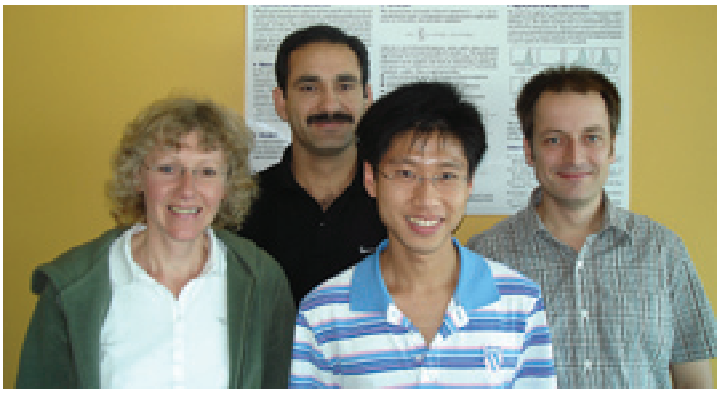
The three LISA spacecraft will be placed in a triangular formation of orbits, and will detect gravitational waves. Image: NASA/JPL-Caltech

It is a thrilling time for experimental gravitation studies. Around the world, a number of extremely precise gravitational wave detectors are coming online. In the United States, the Laser Interferometer Gravitational Wave Observatory (LIGO) has three ground-based detectors. A French-Italian collaboration has built a similar detector, called Virgo, near Pisa, and around 2015, the US and the European Union hope to launch a similar system into space, the Laser Interferometer Space Antenna (LISA).

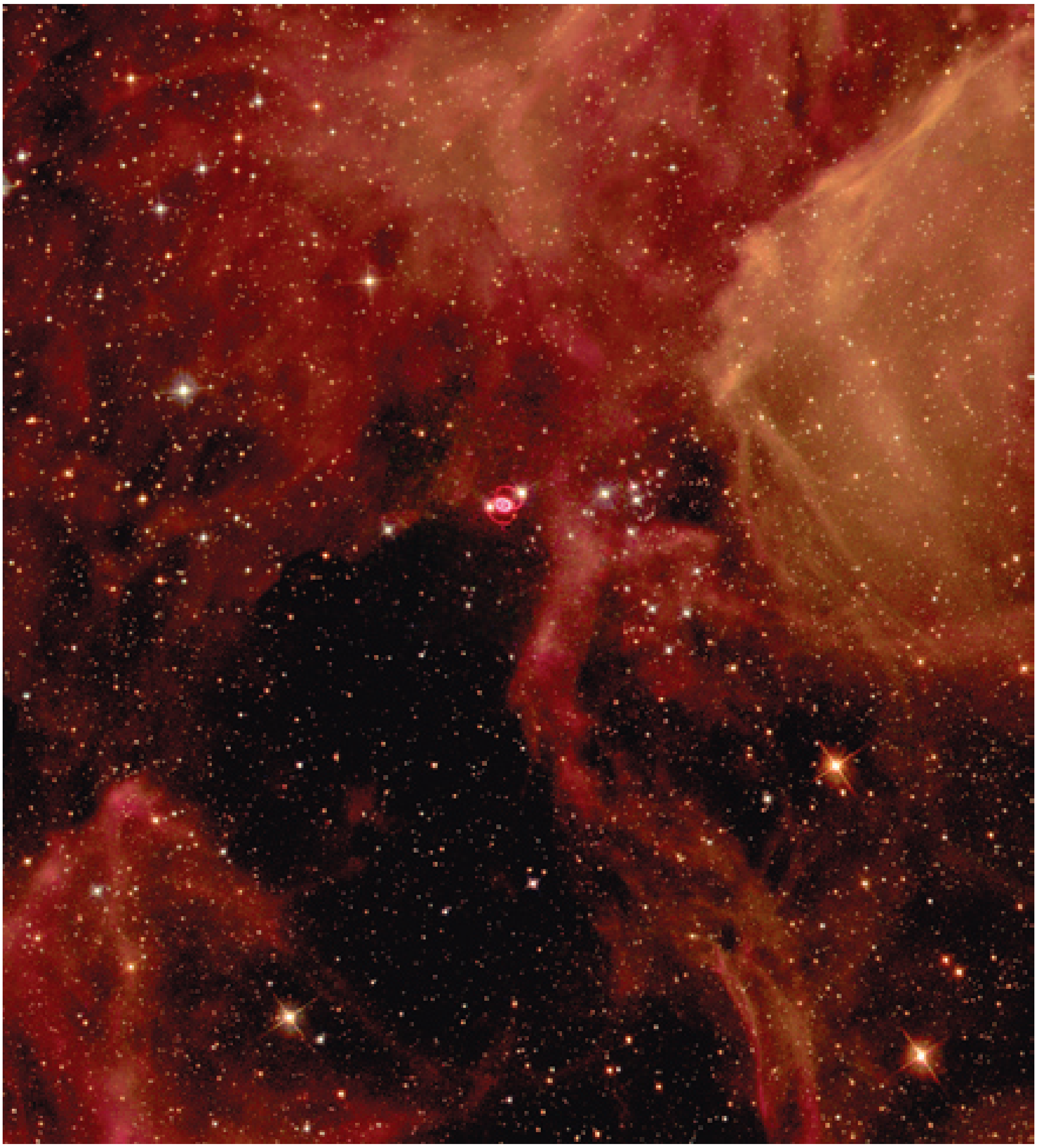
With support from the Marsden Fund, Dr Renate Meyer of the Department of Statistics at The University of Auckland, and Professor Nelson Christensen of the Physics and Astronomy Department at Carleton College, Minnesota, USA, are developing statistical methods by which the data from these detectors can be converted into information about the astrophysical systems that are producing these waves. Using new statistical and computational techniques, Dr Meyer, Professor Christensen and their students have demonstrated that the highly complex signals can be deciphered and understood. The interdisciplinary research team has published a number of articles in leading physics journals, and now gravitational wave researchers from around the globe are adopting these techniques.

The research project has provided material for two PhD theses. Dr Richard Umstaetter has recently received his PhD from the Department of Statistics and been awarded with The University of Auckland Best Doctoral Thesis Award. Dr Umstaetter demonstrated how data from detectors like LIGO and Virgo could be used to provide information about pulsars. In addition, he developed a technique whereby LISA could deal with the tens of thousands of signals from binary star systems that will swamp and confuse the detectors. Dr Umstaetter's LISA work has set off an avalanche of studies from other researchers who are customising his techniques. Dr Umstaetter accepted a NASA post-doctoral fellowship earlier this year and is continuing his LISA data analysis research at the NASA Jet Propulsion

Professor Nelson Christensen in the control room of the LIGO-Livingston observatory.



Dr Renate Meyer, Asad Ali, Sunny Chui and Christian Roever. Photo: Stephen Cope



Supernova SN1987A in the Large Magellanic Cloud. Astronomers in New Zealand were the first to witness the explosion of this star in 1987. Photo: NASA Headquarters – Greatest Images of NASA (NASA-HQ-GRIN)

Laboratory of the California Institute of Technology in Pasadena.

Christian Roever is on-track to complete his PhD in statistics at The University of Auckland this year, and has accepted a post-doctoral fellowship at the Max-Planck-Institut fuer Gravitationsphysik in Germany. As part of his research, Christian has developed techniques whereby LIGO, Virgo and LISA can observe the signals from two objects, typically neutron stars or black holes, spiralling into one another. These signals are highly complex, but Christian Roever, Dr Meyer and Professor Christensen have advanced methods by which the information about the binary star system can be visualised. Only in this way can gravitational wave data be transformed so that gravitational wave astronomy can be performed. Two further PhD students, Asad Ali and Sunny Chui, have recently joined the team to research the identification of extreme mass ratio binaries in LISA data and LIGO supernovae gravitational wave signals, respectively.

This new area of astronomy will see LIGO, Virgo and LISA functioning as a new type of telescope. The observations of the decay of these binary star systems could provide an opportunity to actually observe the formation of a black hole. This research could help to confirm one of the most significant predictions of Einstein's theory of general relativity, namely the existence of black holes.

FOR MORE INFORMATION, CONTACT

Dr Renate Meyer
Department of Statistics
The University of Auckland
Private Bag 92019, Auckland 1142
Tel: (09) 373 7599 ext. 85755
Email: meyer@stat.auckland.ac.nz