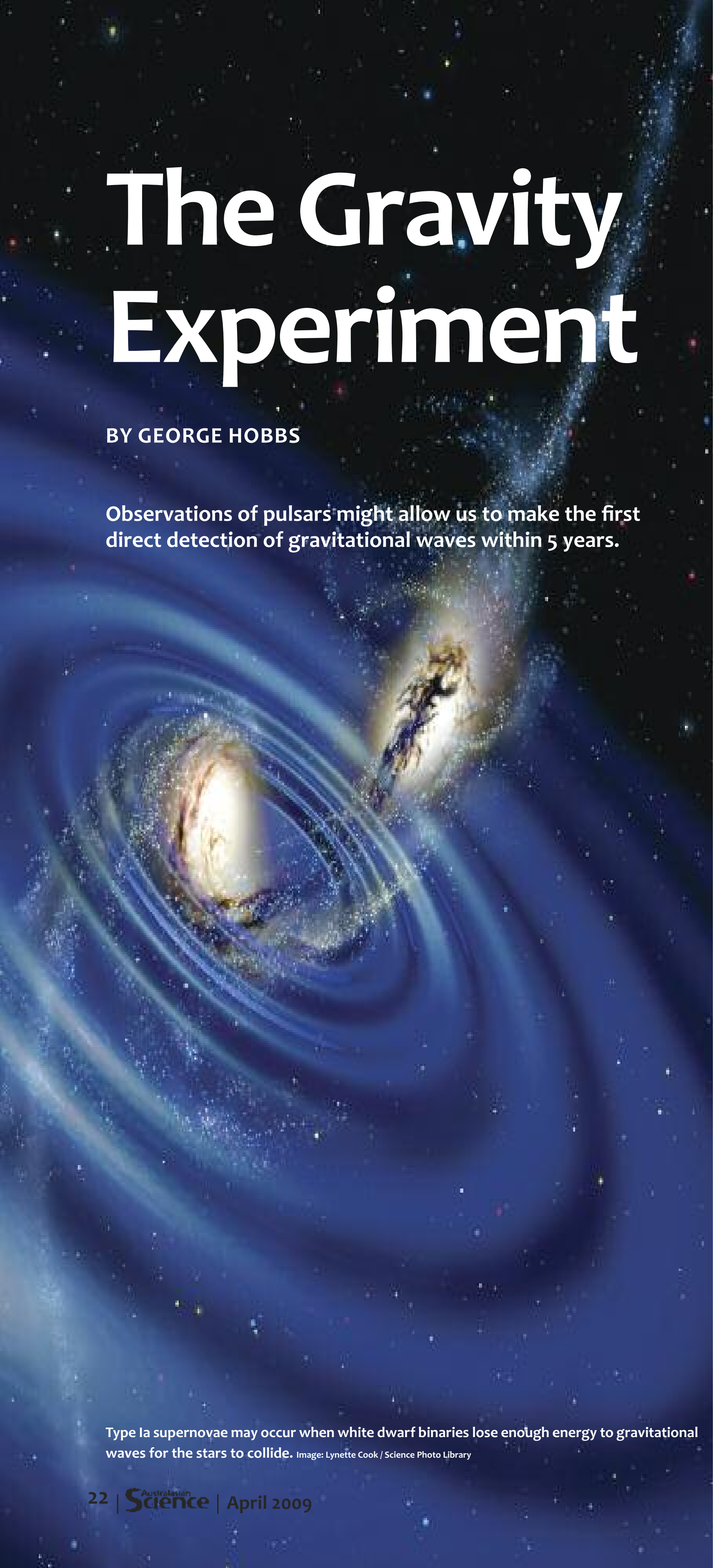
# The Gravity Experiment

BY GEORGE HOBBS

**Observations of pulsars might allow us to make the first direct detection of gravitational waves within 5 years.**



Type Ia supernovae may occur when white dwarf binaries lose enough energy to gravitational waves for the stars to collide. Image: Lynette Cook / Science Photo Library

As you read this article the whole of space and time around you is stretching and shrinking. Even our own bodies become first a little longer, then a little shorter, then fatter, then thinner. How do we know this?

Well, actually we don't. In 1916, Albert Einstein published a theory – the general theory of relativity – in which he described a new way of thinking about the concepts of space and time. His theory suggests that space is curved because of the presence of massive objects like the Sun, planets, black holes and your own body. If these objects accelerate (e.g. two black holes orbit each other) then the entire fabric of space and time will warp and waves in this hypothetical fabric will emanate from the objects. These waves have been given a name: gravitational waves.

Do these waves actually exist? Nobody knows. We've certainly never seen one, but we have good reasons to believe that they are all around us and exist throughout the Universe.

To start with, many parts of Einstein's theory have been confirmed by experiment. Secondly, in1974 a rapidly spinning star known as a pulsar was discovered by two astronomers, Russell Hulse and Joe Taylor. Because this pulsar was shown to be orbiting another star, Einstein's theory predicts that gravitational waves would have to be emitted from the system. Astronomers carried out a careful study of the orbit of the pulsar and showed that it was changing in exactly the way expected if the system was emitting gravitational waves.

So we are confident that such gravitational waves exist and hope to study their properties as they pass through our solar system. For instance, we would like to know where the waves are coming from.

Many groups around the world have already tried to detect them, but the effect of a gravitational wave is tiny on any detector that we can build. For example, two neutron stars orbiting each other in our galaxy would create gravitational waves that stretch a detector out of shape by a tiny fraction of the size of an atomic nucleus. Unsurprisingly, all groups searching for these waves have so far failed.

The most modern detectors on Earth may be able to detect gravitational waves within a few years. The Laser Interferometer Gravitational Wave Observatory (LIGO) consists of two detectors situated in the USA. Each detector is made up of two large vacuum tubes, each 4 km in length and perpendicular to each other. Strong laser beams are sent down the two tubes and bounce off mirrors at the end of each tube. This allows the scientists to obtain a precise measurement of changes in the lengths of the tubes. As a gravitational wave passes it will make one tube become a little larger and the other a little shorter. In order to detect the expected waves, LIGO must be able to detect variations in length that are so small that they require the world's largest precision optical instruments to measure them.

An even more ambitious project is the Laser Interferometer Space Antenna (LISA) being developed by the European and American space agencies. LISA will consist of three spacecraft flying five million kilometres apart from each other in an equilateral triangle. Lasers will be used to study variations in the relative distances between the spacecraft to detect gravitational waves.

Whereas LIGO will be able to detect gravitational waves emanating from coalescing neutron stars and supernovae, LISA will detect lower frequency waves that are produced by black holes that are orbiting each other.

At the Parkes radio telescope in Australia we have chosen a different approach in the attempt to try and detect gravitational waves. In collaboration with astronomers from China and the USA, we will use the telescope to observe a set of 20 pulsars for the Parkes Pulsar Timing Array project.

Pulsars, thought to be the remnant of large stars that have exploded in a supernova, were discovered in 1967 by British astronomers and have since been studied in great detail worldwide. The remnant star rotates very fast (typically once every second), has a large mass (more massive than our Sun) and very strong magnetic field. Pulsars are very stable (think of them as giant fly-wheels in space), and we receive a pulse of radio radiation every time they rotate.

The pulsars that we have chosen to observe are among the fastest rotating objects that we know. Our fastest pulsar rotates once every 1.5 milliseconds, making it faster than a kitchen blender.

As pulsars are so stable we can predict the arrival time of every single pulse from each of the pulsars over the course of many years. In fact our most recent results show that we can predict the arrival time of every pulse from one pulsar with an accuracy of about a millionth of a second over many years. With the new hardware recently installed at the telescope we hope to do even better.

If gravitational waves pass close to the pulsar and/or the Earth then the relative positions of the telescope and the pulsar will slightly change. We are searching for the small variations in the pulse arrival times that would occur because of the presence of such gravitational waves. By studying the variations in the arrival times of many pulsars spread over the sky we will be able to study the properties of any gravitational waves that are passing the Earth.

The gravitational waves that we may be able to detect are created in the distant Universe as galaxies collide. We believe that most large galaxies have supermassive black holes in their cores. After two galaxies collide, the black holes coalesce and emit gravitational waves. It is these waves, emitted from thousands of coalescing black holes throughout the Universe, that we hope to detect. It is

**PULSE@Parkes allows high school students to carry out observations of pulsars using the Parkes radio telescope**

also possible that detectable gravitational waves were produced in the very early Universe (much less than 1 second after the Big Bang).

So far we do not have long enough data sets to allow us to detect these gravitational waves but we believe that a detection could be made within the next 5 years or so if we continue to improve our observing systems. However, the pulsar observations that we have so far recorded at Parkes are among the most precise ever made. Our data sets can already be used to study the pulsars themselves, to search for unknown planetary objects in our own solar system and even to check atomic clock timescales on Earth. We have also used our observations to study the properties of the plasma that lies between the pulsars and the Earth and to probe the solar corona, the outer layers of our Sun.

Within a few decades gravitational wave astronomy may be as commonplace as X-ray and gamma-ray astronomy is today. Gravitational wave astronomers of the future will be able to study black holes, the structure of space and time and the very early Universe.

In order to inspire the people who will one day be leading this research we have started a project called PULSE@Parkes, which allows high school students to carry out observations of pulsars using the Parkes radio telescope. The project has many goals. For professional research, the student observations provide us with more data for the gravitational wave detection experiments. From the point of view of the students and their teachers, they get to learn about astronomy, pulsars and gravitational waves while using one of the world's greatest telescopes.

Even though it is possible that the Parkes radio telescope may be used to make the very first detection of gravitational waves, the telescope is not large enough to study the waves in detail. We are planning to combine our data with other observations obtained with European and North American telescopes, which should significantly increase our sensitivity to gravitational waves.

However, a detailed study of these waves will require a new and much larger telescope. Fortunately the astronomy community, represented by more than 15 countries, is already planning a new radio telescope, the Square Kilometre Array (SKA), which will be ideal for this research. It will have a collecting area of one square kilometre, much larger than any existing telescope. The SKA is planned to be operational by around the year 2020 and will be sited either in Western Australia or southern Africa.

Nobody has yet detected a gravitational wave. The Parkes Pulsar Timing Array project is one of a few experiments around the world aiming to detect these ripples in the fabric of space and time. We expect that a detection will be made within the next decade and astronomers will then be able to use gravitational wave telescopes to study objects in the Universe such as supermassive black holes in distant galaxies.



George Hobbs is a Research Scientist with CSIRO's Australia Telescope National Facility. More information about pulsars and the timing array project can be obtained from http://www.atnf.csiro.au/research/pulsar. The student project, PULSE@Parkes, is described at www.outreach.atnf.csiro.au/education/pulseatparkes/.