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Editorial: White, the Forum, and a cosmos "awash" with gravity waves

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The 2022 Forum

When I became editor of the *Journal & Proceedings* in 2016, there had been one Royal Society Forum. Since then there have been six more. Unfortunately, a pattern has appeared of presenters taking the easy way out by not also writing a paper, for publication in the *Journal*. In 1918 there was a single no-show, but for the 2022 Forum, the number of presenters who did not supply a paper has risen to six of sixteen presenters (including some academics). For this reason, I hope the reader can overlook the necessary informality of transcripts published as papers in this issue. On the other hand, not everyone is an academic. It would be unfortunate if Forum presenters were restricted to those who could (who would) also write a paper. Last year's Forum was definitely enriched by the participation of at least two people who were in no way academics.

The 2022 Forum, "Reshaping Australia: Communities in Action," had five sessions. Session 1, Setting the Scene, was addressed by Richard Holden, Alison Frame, Kalinda Griffiths, and James O'Donnell. Session 2, Health and Communities, was addressed by Bernie Shakeshaft, Sally Redman, Elizabeth Elliott, and Maree Teesson. Session 3, Natural and Built Environment, was addressed by Louise Adams, David Schlosberg, Tone Wheeler, and Angelica Kross. Session 4, Education, was addressed by Peter Shergold, Pasi Sahlberg, Kim Beswick, and Lisa Jackson Pulver (who stood in at short notice for Marcia Langton). Session 5, Summary and Solutions comprised a discussion among Julianne Schultz (the Moderator and Rapporteur), Ariadne Vroman, and Lisa Jackson Pulver.

Hugh White

In July last year Hugh White spoke to the Society on the dilemmas raised for Australia by the rising power of China, and the problems faced by an Australia, torn between our defence agreement with the USA and our contacts with our major trading partner, China. All presentations at Ordinary General Meetings are made available on the Royal Society YouTube channel. As well as making these available to those who might have missed the presentation, this allows us to see which talks are most popular. There is no doubt that Hugh White's talk (with over 36,000 views as of a few days ago) has been by far and away the most popular ever. This spurred me to ask Hugh if we could convert the transcript of his 2022 talk into a paper. He agreed, and it is published in this issue.

I had intended to include two more papers on military themes, but the size of the Forum report means that readers will have to await the December issue for them, together with five other accepted papers. These six are listed (with links) on the Accepted Papers web page.[1]

1 https://royalsoc.org.au/council-members-section/561-acceptedpapers

Sadly, this issue contains obituaries of three Fellows who have died recently: past president Ragbir Bhathal FRSN, Christopher Fell AO FRSN, and Jeremy Davis AM FRSN.

"Awash" with gravity waves

Recently the scientific columns have been full of the results published by five national research teams about gravity waves. First predicted by Einstein in 1916, over the past few years we have been able to detect isolated gravity waves reaching Earth as a consequence, we believe, of the collisions of black holes, both in our galaxy and further afield. The new announcements refer to a different sort of gravity wave — not one that occasionally reaches us, but gravity waves that wash over us continuously, with much lower frequencies, or longer wavelengths. These new gravity waves have been deduced from the measurements of signals from pulsars, those stars which appear to be producing extremely regular radio pulses.

In 1967, Cambridge PhD student Jocelyn Bell was analysing data gathered from a bespoke radio telescope she and her supervisor, Antony Hewish, had built at the Mullard Radio Astronomy Observatory. That summer, she was looking at rolls of chart paper etched with the inked recordings of galactic radio waves, and she spotted a source with repeated pulses against the background noise of the stars. The signal was remarkably regular, pulsing every 1⅓ seconds, and, since it followed sidereal time, it came from the stars, not from Earth.

On 25 November 1967, she discovered a second source, and then a third and fourth, of pulsating signals. In February 1968, Hewish and Bell announced their discoveries in a paper in *Nature*. Soon, other teams of astronomers had reported a regular radio pulse from the heart of the Crab nebula, the remains of the supernova of 1054 AD. This confirmed that the source was probably a neutron star. It caused great interest and a reporter from the London *Daily Telegraph* dubbed these sources "pulsars," for pulsating radio sources.

We now know that a pulsar is a neutron star with intense magnetic fields which accelerate particles into two powerful beams that blast from either magnetic pole of the star. Every time the star spins, the beams sweep the Earth, resulting in a periodic pulse. Hence the pulses are incredibly regular. Over 1000 pulsars are now known.

Just how important this discovery was only became clear in the following decades. The existence of pulsars suggested that the hypothesized black holes — dead stars collapsed to a single point — might also exist. The first black hole was confirmed in 1971 in the constellation Cygnus. On 9 January 1992, the first confirmed exoplanets were discovered orbiting a pulsar in the constellation Virgo.

Another use for pulsars has recently emerged. It became clear to observers that the pulses were fluctuating slightly: For almost two decades, since 2004, groups including the Parkes Pulsar Timing Array (using the Parkes Murriyang Radio Telescope — "the Dish") and other groups (in China, Europe, India, and North America[2]) have been observing pulsars, and measuring the nanosecond delays in the pulses. What could cause such delays?

2 The North American Nanohertz Observatory for Gravitational Waves (NANOGrav) consortium.

It is hypothesized that these fluctuations are being caused by gravity waves, ripples in spacetime, as predicted by Einstein, and so reveal how the space between Earth and each pulsar is stretched and squeezed by the passage of gravitational waves. If the signals come from the combined gravitational waves of thousands of pairs of "supermassive black holes" (SMBHs) believed to lie at the centres of all galaxies across the Universe, it would be the first direct evidence that such binaries exist and that some have orbits tight enough to produce measurable gravitational waves. SMBHs are millions, or billions, times the mass of the Sun, but remain elusive because no light can escape them. The minute fluctuations in the measured regularity of observed pulsars, however, provides us with evidence of their existence, and also a way of indirectly observing them.[3]

On 14 September 2015 the first gravity waves were detected by the LIGO[4] (and later VIRGO, GEO, and TAMA) observations. But the black holes causing these first gravity-wave bursts are orders of magnitude smaller than those associated with SMBHs. And these first gravity waves are relatively high-frequency "chirps," caused by relatively small, star-sized black holes circling each other or colliding, not by SMBHs. These high-frequency waves, with wavelengths of tens or hundreds of kilometres, do not affect the regularity of pulsars' observed pulses; and the newly confirmed low-frequency waves cannot be observed by the LIGO observatories, only revealed by the minute fluctuations in the observed pulsar pulses.

This June, in a coordinated series of papers published in *Astrophysical Journal Letters*, the five national research groups, using their own data sets, announced the observation of low-frequency gravity waves, ripples in spacetime with periods of up to 30 years,[5] travelling at the speed of light. They based their conclusions on decades of observation of about 100 known pulsars. These low-frequency gravity waves have been described as resulting in a cosmos "awash" with gravity waves, if very weak.

How are these ultra-low-frequency "rumbles" produced? It is believed by the interaction of such massive objects as SMBHs binaries. As more data are accumulated, the rumbles are observed to come from different parts of the sky, with slightly different variations in regularity in the pulsars' signals. That is, the signals from pulsars in different places in the cosmos fluctuate slightly differently, perhaps because of different local SMBHs.[6]

The five observation groups recently met at Port Douglas, Queensland, under the auspices of the International Pulsar Timing Array (IPTA), a global consortium. They will combine their separate data sets to increase the sensitivity to these gravity waves many-fold.

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3 The likelihood of the latest results being down to chance is close to one in 10,000, making it compelling evidence, although this still falls short of the one-in-a-million "gold standard" in physics for claiming evidence of detection of a new phenomenon. It could also be a remnant of residual gravitational noise from the Big Bang.

4 Laser Interferometer Gravitational-Wave Observatory.

5 A wave travelling at the speed of light with a period of 30 years must have a wavelength of 30 light-years, and a frequency of 1.056 nanohertz (= 1/period).

6 The Hellings-Downs curve predicts how, in the presence of gravitational waves coming from all possible directions, the correlation between pairs of pulsars varies as a function of their separation in the sky.

Astronomers are ecstatic at the results of these decades of observations. For one thing, we know little about the elusive SMBHs,[7] and these low-frequency gravity waves provide a new avenue for observing these elusive objects, that are otherwise obscure. Might we learn more about those enigmatic phenomena — dark matter and dark energy — from studying these? Perhaps.

Housekeeping

Thanks to Jason Antony for his tireless efforts to type-set the *Journal*, both on-line and print versions.

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7 In May 2022, the first image of Sagittarius A* was released, confirming it to be a black hole at the centre of the Milky Way. This was the second confirmed image of a black hole, after Messier 87's SMBH in 2019.