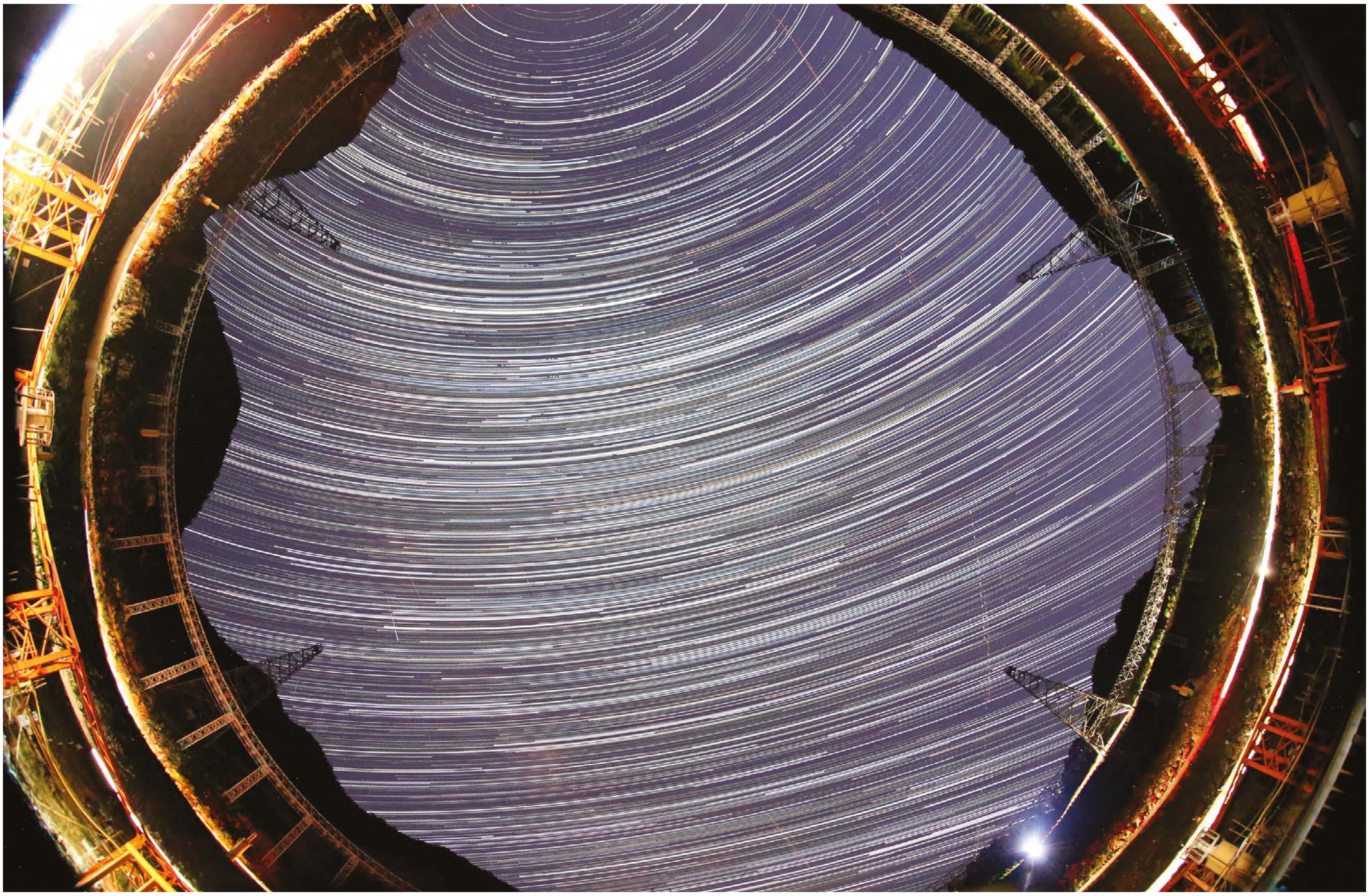
News in focus



A view from the Five-hundred-meter Aperture Spherical Telescope in Guizhou, China, which monitored pulsars to detect gravitational waves.

MONSTER GRAVITATIONAL WAVES SPOTTED FOR THE FIRST TIME

Using beacon stars called pulsars, a decades-long effort has found space-time ripples that are light years wide.

By Davide Castelvecchi

Gravitational waves are back, and they're bigger than ever.

After the historic first detection of the space-time rattles in 2015 using ground-based detectors, researchers could now have rediscovered Albert Einstein's waves with an entirely different technique. The approach tracks changes in the distances between Earth and beacon stars in its Galactic neighbourhood called pulsars, which reveal how the space in between is stretched and squeezed by the passage of gravitational waves.

Whereas the original discovery spotted waves originating from the collision and merger of two star-sized black holes, the most likely source of the latest finding is the combined signal from many pairs of much larger black holes — millions or even billions of times the mass of the Sun — slowly orbiting each other in the hearts of distant galaxies. These waves are thousands of times stronger and longer than those found in 2015, with wavelengths of up to tens of light years. By contrast, the ripples detected since 2015 using a technique called interferometry are just tens or hundreds of kilometres long.

"We can tell that the Earth is jiggling due to gravitational waves that are sweeping our Galaxy," says Scott Ransom, an astrophysicist at the US National Radio Astronomy Observatory in Charlottesville, Virginia, and a senior member of NANOGrav, one of four collaborations that announced separate results on 29 June[1–4].

"We're not using the 'd' word — for detection — yet," says Ransom. "But we do think this is strong evidence." Each group has seen hints of an expected signature of gravitational waves, but without the statistical certainty of a firm discovery, Ransom and others say. Researchers will now pool their data to see whether they can reach that threshold together.

"If this is confirmed, we'll have 20 years of work studying this new background," says Monica Colpi, who studies the theory of gravitational waves and black holes at the University of Milan–Bicocca in Italy. "It will put an army of astrophysicists to work."

Catching a wave

Three collaborations have amassed decades' worth of pulsar data and are reporting similar results: the North American group NANOGrav; the European Pulsar Timing Array, with the contribution of astronomers in India; and the Parkes Pulsar Timing Array in Australia. A fourth collaboration, the Chinese Pulsar Timing Array, says it has found a signal with merely three years of data, owing to the exceptional sensitivity of the Five-hundred-meter Aperture Spherical Telescope (FAST), which opened in 2016 in the Guizhou region.

Keija Lee, a radio astronomer at Peking University in Beijing who led the FAST study, says he was not surprised by the result[4]. "My calculation for the gravitational-wave sensitivity of FAST observation was done back in 2009, when I was a PhD student."

All the groups use massive radio telescopes to monitor 'millisecond' pulsars. These are incredibly dense neutron stars that spew radio waves from their magnetic poles. Each time a pulsar rotates on its axis, its radio beam travels in and out of the line of sight to Earth, resulting in a pulse with regular intervals. Millisecond pulsars rotate the fastest, up to several hundred times per second.

"We can use them basically as clocks," says Andrew Zic, a radio astronomer at the Australia Telescope National Facility in Sydney and a lead author of the Parkes paper[3]. Slight changes in the arrival time of a pulsar's signals can mean that the space between the star and Earth has been altered by the passage of a gravitational wave.

The timing of a single pulsar would not be reliable enough to detect gravitational waves. Instead, each collaboration monitors an array of dozens. As a result, they have found a signature called the Hellings–Downs curve, which 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. NANOGrav was first to spot the signal[1], and reported it to colleagues in 2020. But the team decided to wait for the other collaborations to see hints of the curve before publishing.

"Seeing the Hellings–Downs curve actually appear for the first time in a real way – that was a beautiful moment," says Chiara Mingarelli, a gravitational-wave astrophysicist at Yale University in New Haven, Connecticut, and a member of NANOGrav. "I'm never tiring of seeing it."

"This finding will put an army of astrophysicists to work."

Alberto Vecchio, an astrophysicist at the University of Birmingham, UK, and a member of the European team, says his first reaction when he saw his group's results[2] was, "Bloody hell, there could be something interesting here."

The long game

Einstein first predicted gravitational waves in 1916. On 14 September 2015, the twin detectors of the Laser Interferometer Gravitational-Wave Observatory (LIGO) in Louisiana and Washington State confirmed his prediction by detecting a burst of waves from the merger of two black holes. Physicists have since captured gravitational waves from dozens of such events.

If the latest signal is from the combined gravitational waves of thousands of pairs of supermassive black holes 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. Colpi says a major implication is that each of the pairs will ultimately merge – creating bursts similar to the ones seen by LIGO, but on a much larger scale. The signals of some of these collisions will be detected in space by the Laser Interferometer Space Antenna (LISA), a European Space Agency mission due to launch in the 2030s.

Researchers hope that they will eventually go beyond the Hellings–Downs curve and see signals of individual supermassive-black-hole binaries close enough to the Milky Way – and therefore loud enough, in gravitational-wave terms – to stand out against the background signal. "To see an isolated source, it has to be really strong," says Vecchio.

But for now, other origins of these waves cannot be ruled out, including possible residual gravitational noise from the Big Bang.

"It's been a long and patient game," says Zic. "Now we're really starting to open the window into this ultra-low-frequency gravitational-wave spectrum."

1. Agazie, G. *et al. Astrophys. J.* **951**, L8 (2023).
2. Antoniadis, J. *et al.* Preprint at https://arxiv.org/abs/2306.16214 (2023).
3. Reardon, D. J. *et al. Astrophys. J.* **951**, L6 (2023).
4. Xu, H. *et al. Res. Astron. Astrophys.* **23**, 075024 (2023).

PHILOSOPHER WINS CONSCIOUSNESS BET WITH NEUROSCIENTIST

The pair wagered decades ago over when they would learn how the brain achieves consciousness.

By Mariana Lenharo

A 25-year science wager has come to an end. In 1998, neuroscientist Christof Koch bet philosopher David Chalmers that the mechanism by which the brain's neurons produce consciousness would be discovered by 2023. Both scientists agreed publicly on 23 June, at the annual meeting of the Association for the Scientific Study of Consciousness (ASSC) in New York City, that it is an ongoing quest – and declared Chalmers the winner.

What ultimately helped to settle the bet was a study testing two leading hypotheses about the neural basis of consciousness, whose findings were unveiled at the conference.

"It was always a relatively good bet for me and a bold bet for Christof," says Chalmers, who is now co-director of the Center for Mind, Brain and Consciousness at New York University. But he also says this isn't the end of the story, and that an answer will come eventually: "There's been a lot of progress in the field."

The great gamble

Consciousness is everything that a person experiences – what they taste, hear, feel and more. It is what gives meaning and value to our lives, Chalmers says.

However, despite a vast effort, researchers still don't understand how our brains produce it. "It started off as a very big philosophical mystery," Chalmers adds. "But over the years, it's gradually been transmuting into, if not a 'scientific' mystery, at least one that we can get a partial grip on scientifically."

Koch, who holds the title of meritorious