



PRESS RELEASE – PARIS – 13 DECEMBER 2021

Einstein wins in the end (once again)

- Einstein's theory of gravity, general relativity, has not been disproven once in over a century, despite relentless efforts from scientists to find its faults.
- Pulsars are stars toward the end of the stellar life cycle, emitting radio waves that sweep through space like a lighthouse: they can be detected by radio telescopes in the form of highly regular flashes.
- Seven radio telescopes observed a double pulsar for 16 years, thereby enabling a series of high-precision tests of the theory of general relativity... which still holds true.

An international team involving researchers from the CNRS, the University of Orléans, and Observatoire de Paris-PSL¹ has conducted a 16-year experiment subjecting the theory of general relativity to the most rigorous series of tests ever conducted. Seven radio telescopes studied a unique pair of late-stage stars (pulsars), revealing new relativistic effects predicted by the theory that had never before been observed. These observations, which agree with Einstein's theory with an accuracy better than 99.99%, were published in *Physical Review X* on 13 December 2021.

Over 100 years after Albert Einstein presented his theory of gravity, scientists across the globe are continuing their efforts to find flaws in general relativity. Any deviation from its predictions could be the sign of a new physics combining theories that describe the infinitely small (quantum world) as well as the infinitely large.

To this end, an international team led by the Max Planck Institute for Radio Astronomy (Bonn, Germany) studied a unique system consisting of two pulsars that orbit one another: highly compact, rapidly-rotating stars in the final stages of the stellar life cycle that are magnetized,² and produce beams of radio waves that sweep across the sky like a lighthouse. These characteristics make this system an ideal laboratory for testing general relativity. The system was discovered in 2003, and was observed for 16 years by seven radio telescopes. The Nançay decimetric radio telescope (Cher, France), which is managed by the Observatoire de Paris-PSL, the CNRS, and the University of Orléans, recorded the radio pulses emitted by one of the pulsars for one-hour periods two or three times per week, over the course of a decade.

The data gathered (approximately one million precisely-timed radio pulses in total) enabled scientists to detect numerous relativistic effects, as well as to measure seven parameters of the theory of general relativity, some in unprecedented fashion. For example, the strong gravitational field of each rapidly-moving pulsar curves spacetime around it, thereby deflecting the trajectory of the radio waves emitted by the other pulsar. Not only do telescopes detect the delay in the signal compared to when it propagates in a straight line, but the tiny angle of this deviation (0.04 degrees) was measured for the first time.

The team also tested a cornerstone of Einstein's theory, the emission of gravitational waves (tiny oscillations in spacetime), with a precision 1,000 times greater than direct detection using gravitational-wave detectors³. They also observed a consequence of the famous equation $E = mc^2$ —namely that the pulsar's radiation is accompanied by a loss of mass—in addition to the dilation of time, which passes more slowly in the presence of a strong gravitational field.

All of these observations are in perfect agreement with Einstein's theory. If it does indeed have flaws, even more rigorous tests will be needed to identify them.

To learn more:

Press release by the Max Planck Institute for Radio Astronomy: www.mpifr-bonn.mpg.de/pressreleases/2021/12

The Nançay Radio Astronomy Station website: www.obs-nancay.fr

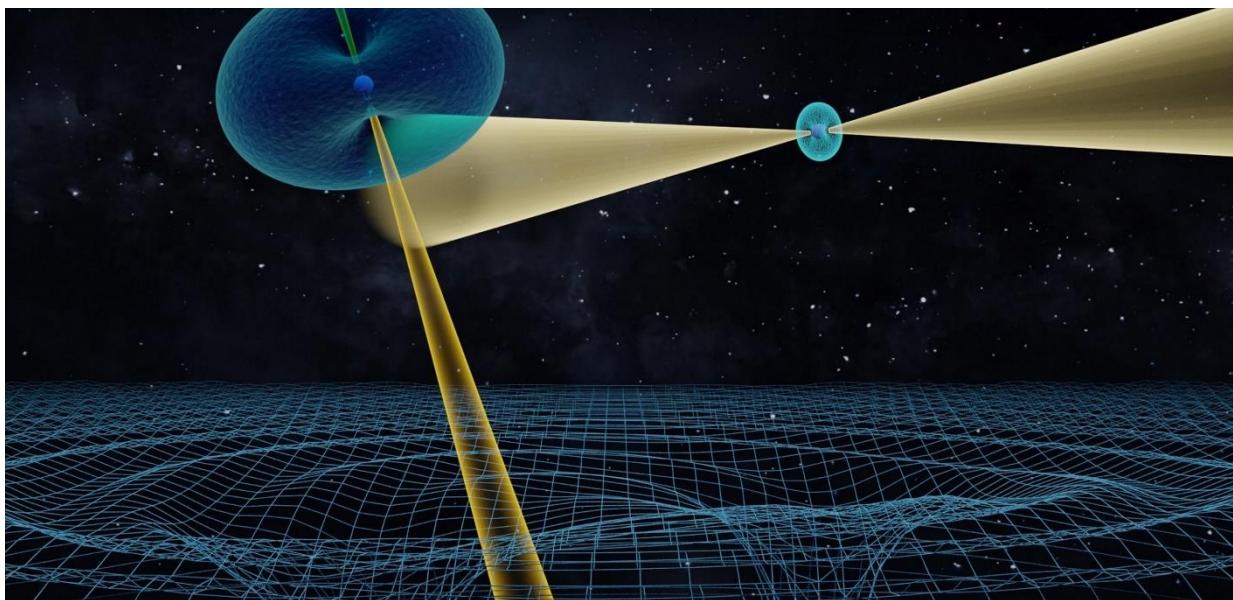
A photo report on the Nançay Radio Astronomy Station is available in the CNRS Images library: images.cnrs.fr/reportage-photo/rep000628

Notes

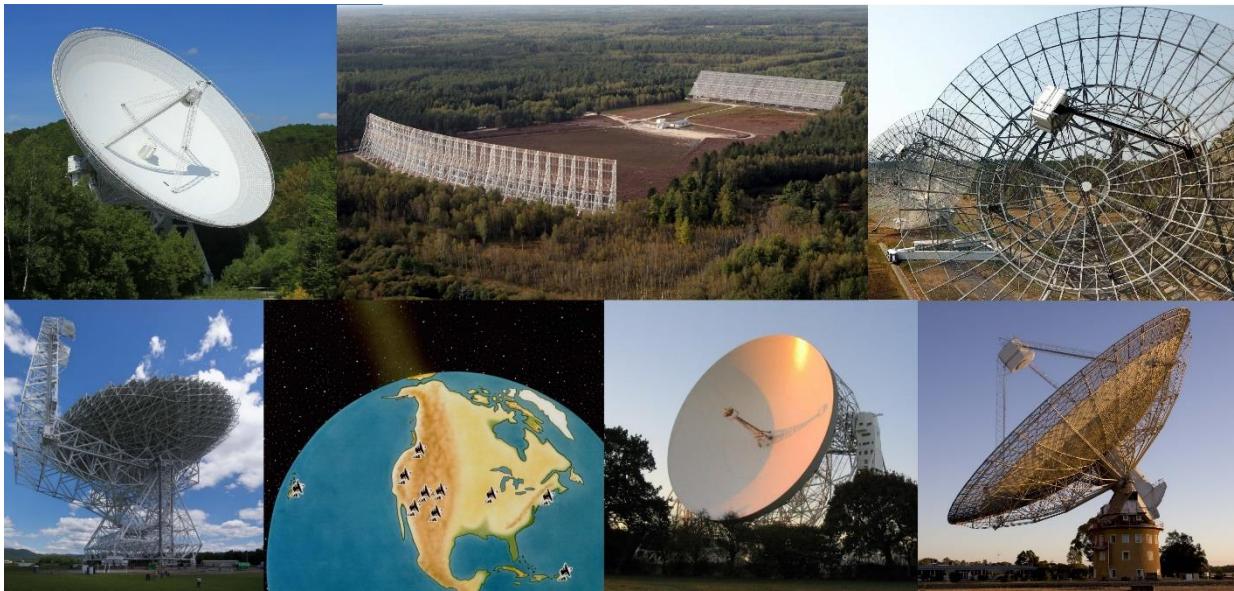
¹ Working at the Laboratoire de physique et chimie de l'environnement et de l'espace (CNRS/CNES/Université d'Orléans), Nançay Radio Astronomy Station (Observatoire de Paris-PSL CNRS/Université d'Orléans) and Laboratoire Univers et théories (Observatoire de Paris-PSL/CNRS).

² In this case, their mass is 30% greater than that of the Sun, with a diameter measuring only 24 km. The two stars orbit one other in just 147 minutes at a velocity of 1 million km/h. As one of them rotates very quickly (44 times per second), it was an ideal candidate for this study.

³ These gravitational waves carry away part of the energy in the system, which gradually shrinks: gravitational waves are thus detected indirectly by measuring this loss of energy.



Artistic impression of the Double Pulsar system, where two active pulsars (emitting beams of radio waves) orbit each other in just 147 min. The orbital motion of these extremely dense neutrons star causes a number of relativistic effects, including the creation of ripples in spacetime known as gravitational waves. The gravitational waves carry away energy from the systems, which shrinks by about 7mm per days as a result. The corresponding measurement agrees with the prediction of general relativity within 0.013%. © Michael Kramer/MPIfR



The seven radio telescopes used for observations of the double pulsar PSR J0737-3039. Clockwise from upper left: Effelsberg Radio Telescope (Germany), Nançay Radio Telescope (NRT, France), Westerbork Synthesis Radio Telescope (WSRT, The Netherlands), Parkes Radio Telescope (Australia), Jodrell Bank Telescope (UK), Very Long Baseline Array (VLBA, U.S.), Green Bank Telescope (GBT, U.S.). © Norbert Junkes/MPIfR (Effelsberg), J.P. Letourneau/Observatoire de Nançay (NRT), ASTRON (WSRT), ATNF/CSIRO (Parkes), Anthony Holloway (Jodrell Bank), NRAO/AUI/NSF (VLBA & GBT).

Bibliography

Strong-field Gravity Tests with the Double Pulsar, Michael Kramer, Ingrid H. Stairs, Richard N. Manchester, Norbert Wex, Adam Deller, William A. Coles, Masooma Ali, Marta Burgay, Fernando Camilo, Ismaël Cognard, Thibault Damour, Gregory Desvignes, Robert Ferdman, Paulo C. C. Freire, Steffani Grondin, Lucas Guillemot, George B. Hobbs, Gemma Janssen, Ramesh Karuppusamy, Duncan R. Lorimer, Andrew G. Lyne, James W. McKee, Maura McLaughlin, L. Elias Münch, Nihan Pol, Andrea Possenti, John Sarkissian, Ben W. Stappers and Gilles Theureau. *Physical Review X*, 13 December 2021.

Contacts

CNRS Researcher | Ismaël Cognard | T +33 2 38 25 79 08 | ismael.cognard@cnrs-orleans.fr

University of Orléans Researcher | Lucas Guillemot | T +33 2 38 25 52 87 | lucas.guillemot@cnrs-orleans.fr

CNRS Press Officer | Véronique Etienne | T +33 1 44 96 51 37 | veronique.etienne@cnrs.fr

