Gravity lab discovered: A pulsar in a unique triple star system

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(Phys.org) —An international team of astronomers using the Green Bank Telescope (GBT) has discovered a pulsar that is orbited by two white dwarf stars. Pulsars are rapidly rotating neutron stars that can be used like precision astronomical clocks. This is the first time that astronomers have found a triple star system that contains a pulsar, and the discovery team has used the pulsar's clock-like properties to turn the system into an unparalleled precision laboratory for studying the effects of gravitational interactions.

The necessary data came from an intensive observational program using several of the world's largest radio telescopes: the GBT, the Arecibo radio telescope in Puerto Rico, and ASTRON's Westerbork Synthesis Radio Telescope in the Netherlands. The team reports their findings in the online edition of *Nature* on January 5 and will present them at the 223rd meeting of the American Astronomical Society in Washington DC on January 6.

All three stars orbit each other in a space smaller than the Earth's orbit around the Sun. This close proximity, combined with the fact that all three stars are much denser than our Sun, together provide the necessary conditions to test the true nature of gravity—in particular, the 'Strong Equivalence Principle' postulated in Einstein's theory of General Relativity. "This triple star system gives us the best-ever cosmic laboratory for learning how such three-body systems work, and potentially for detecting problems with General Relativity, which some physicists expect to see under such extreme conditions," says first author

Scott Ransom of the National Radio Astronomy Observatory (NRAO).

West Virginia University graduate student Jason Boyles originally uncovered the millisecond pulsar—some 4,200 light-years from Earth, spinning nearly 366 times per second—as part of a large-scale search for pulsars with the GBT. To use the pulsar as a gravity probe, the astronomers needed to record as many of its pulses as possible. Then, by measuring how the 'tick of the pulsar clock' varied with time, they were able to determine the orbital geometry and the masses of the three stars.

"It was a monumental observing campaign," comments Jason Hessels, of ASTRON (the Netherlands Institute for Radio Astronomy) and the University of Amsterdam. "For a time we were observing this pulsar every single day, just so we could make sense of the complicated way in which it was moving around its two companion stars." Hessels led the frequent monitoring of the system with the Westerbork Synthesis Radio Telescope.

While the astronomers were busy processing hundreds of terabytes of data, they were also building a precision model of the system. "Our observations of this system have made some of the most accurate measurements of masses in astrophysics," says Anne Archibald, also from ASTRON. "Some of our measurements of the relative positions of the stars in the system are accurate to hundreds of meters, even though these stars are about 10,000 trillion kilometers from Earth" she adds. Archibald led the effort to use the measurements to build a computer simulation of the system that can predict its motions. Archibald and the team used techniques dating back to those developed by Isaac Newton to study the Earth-Moon-Sun system, combined with the 'new' gravity of Albert Einstein, which was required to make sense of the data. Moving forward, the system gives the scientists the best opportunity yet to discover a violation of a concept called the Strong Equivalence Principle. This principle is an important aspect of the theory of General Relativity, and states that the effect of gravity on a body does not depend on the nature or internal structure of that body.

Two famous illustrations of the equivalence principle are Galileo's reputed dropping of two balls of different weights from the Leaning Tower of Pisa (possibly an apocryphal story) and Apollo 15 Commander Dave Scott's dropping of a hammer and a falcon feather while standing on the airless surface of the Moon in 1971. Lunar laser ranging measurements, using mirrors left on the Moon by the Apollo astronauts, currently provide the strongest constraints on the validity of the equivalence principle. Here the experimental masses are the stars themselves, and their different masses and gravitational binding energies will serve to check whether they all fall towards each other according to the Strong Equivalence Principle, or not. "Using the pulsar's clock-like signal we've started testing this," Archibald explains. "We believe that our tests will be much more sensitive than any previous attempts to find a deviation from the Strong Equivalence Principle." "We're extremely happy to have such a powerful laboratory for studying gravity," Hessels adds. "Similar star systems must be extremely rare in our galaxy, and we've luckily found one of the few!"

More information: Simulation by Anne Archibald: www.astron.nl/~archibald/video.html

"A millisecond pulsar in a stellar triple system," S. M. Ransom, I. H. Stairs, A. M. Archibald, J.W. T. Hessels, D. L. Kaplan, M. H. van Kerkwijk, J. Boyles, A. T. Deller, S. Chatterjee, A. Schechtman-Rook, A. Berndsen, R. S. Lynch, D. R. Lorimer, C. Karako-Argaman, V. M. Kaspi, V. I. Kondratiev, M. A. McLaughlin, J. van Leeuwen, R. Rosen, M. S. E. Roberts, K. Stovall. dx.doi.org/10.1038/nature12917

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