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Gravitational waves unveil previously unseen properties of neutron stars

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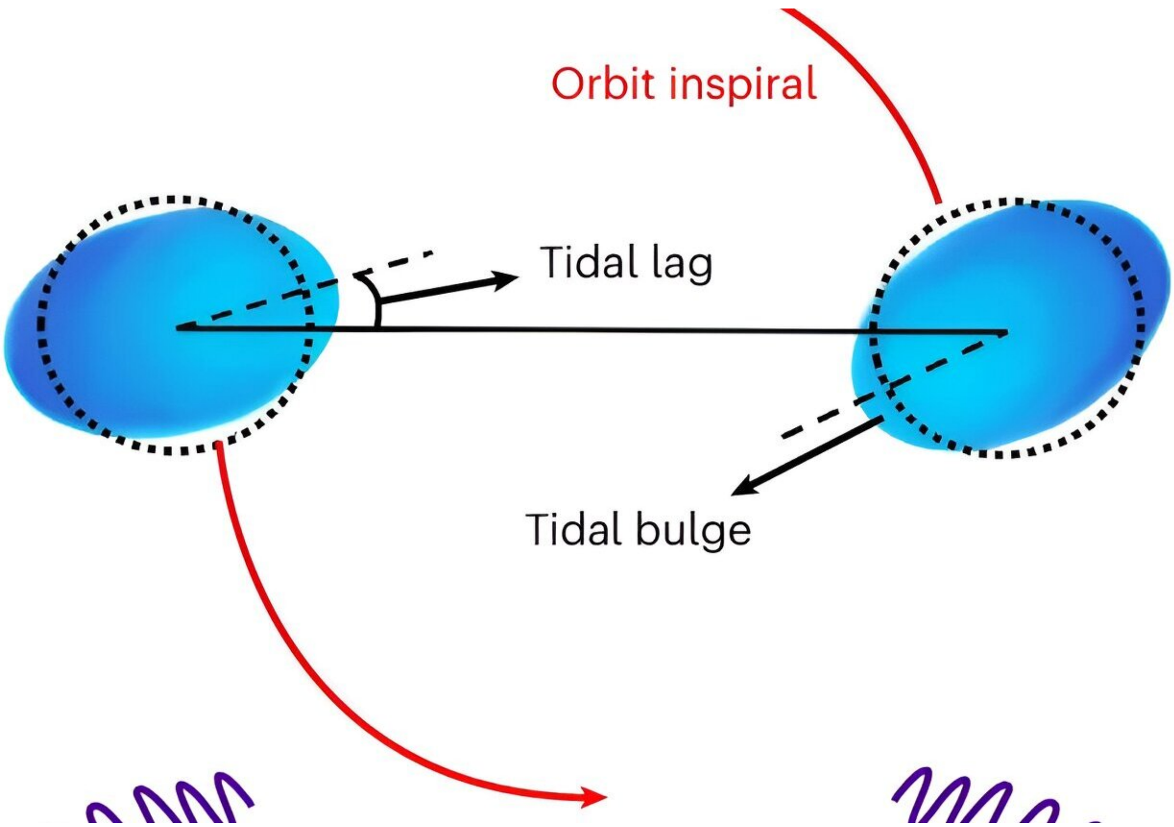

Illustration of the tidal responses of two stars in a quasi-circular binary (not to scale). Credit: *Nature Astronomy* (2024). DOI: 10.1038/s41550-024-02323-7

A better understanding of the inner workings of neutron stars will lead to a greater knowledge of the dynamics that underpin the workings of the universe and also could help drive future technology, said the University of Illinois Urbana-Champaign physics professor Nicolas Yunes. A new study led by Yunes details how new insights into how dissipative tidal forces within double—or binary—neutron star systems will inform our understanding of the universe.

"Neutron stars are the collapsed cores of stars and densest stable material objects in the universe, much denser and colder than conditions that particle colliders can even create," said Yunes, who also is the founding director of the Illinois Center for Advanced Studies of the Universe. "The mere existence of neutron stars tells us that there are unseen properties related to astrophysics, gravitational physics and nuclear physics that play a critical role in the inner workings of our universe."

However, many of these previously unseen properties became observable with the discovery of gravitational waves.

"The properties of neutron stars imprint onto the gravitational waves they emit. These waves then travel millions of light-years through space to detectors on Earth, like the advanced European Laser Interferometer Gravitational-Wave Observatory and the Virgo Collaboration," Yunes said. "By detecting and analyzing the waves, we can infer the properties of neutron stars and learn about their internal composition and the physics at play in their extreme environments."

As a gravitational physicist, Yunes was interested in determining how gravitational waves encode information about the tidal forces that distort the shape of neutron stars and affect their orbital motion. This information also could tell physicists more about the dynamic material properties of the stars, such as internal friction or viscosity, "which might give us insight into out-of-equilibrium physical processes that result in the net transfer of energy into or out of a system," Yunes said.

Using data from the gravitational wave event identified as GW170817, Yunes, along with Illinois researchers Justin Ripley, Abhishek Hegade and Rohit Chandramouli, used computer simulations, analytical models and sophisticated data analysis algorithms to verify that out-of-equilibrium tidal forces within binary neutron star systems are detectable via gravitational waves. The GW170817 event was not loud enough to yield a direct measurement of viscosity, but Yunes' team was able to place the first observational constraints on how large viscosity can be inside neutron stars.

The work is published in the journal *Nature Astronomy*.

"This is an important advance, particularly for ICASU and the U. of I.," Yunes said. "In the '70s, '80s and '90s, Illinois pioneered many of the leading theories behind nuclear physics, particularly those connected to neutron stars. This legacy can continue with access to data from the advanced LIGO and Virgo detectors, the collaborations made possible through ICASU and the decades of nuclear physics expertise already in place here."

More information: Justin L. Ripley et al, A constraint on the dissipative tidal deformability of neutron stars, *Nature Astronomy* (2024). DOI: 10.1038/s41550-024-02323-7

Provided by University of Illinois at Urbana-Champaign