Astronomers discover what may be 21 neutron stars orbiting sun-like stars

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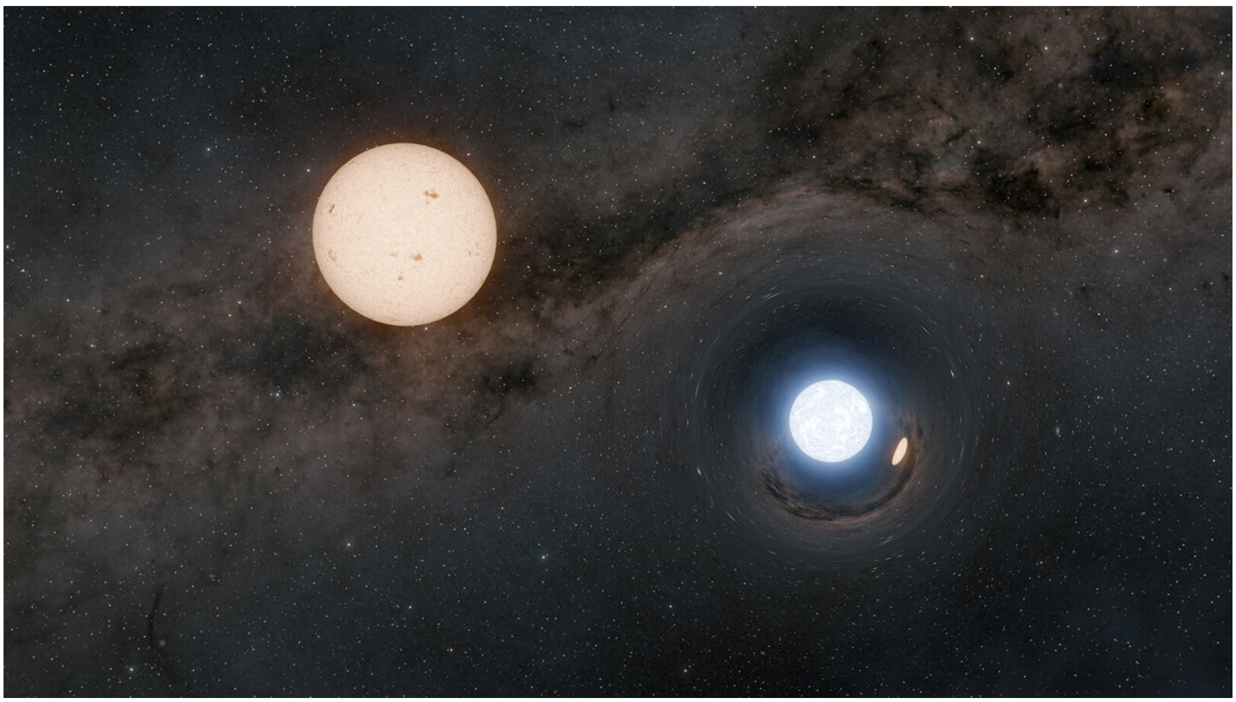

This illustration depicts a binary star system consisting of a dense neutron star and a normal sun-like star (upper left). Using data from the European Space Agency's Gaia mission, astronomers found several systems like this one, in which the two bodies are widely separated. Because the bodies in these systems are far apart, with separations on average 300 times the size of a sun-like star, the neutron star is dormant—it is not actively stealing mass from its companion and is thus very faint. To find these hidden neutron stars, the scientists used Gaia observations to look for a wobble in the sun-like stars caused by a tugging action of the orbiting neutron stars. These are the first neutron stars discovered purely due to their gravitational effects. Credit: Caltech/R. Hurt (IPAC)

Most stars in our universe come in pairs. While our own sun is a loner, many stars like our sun orbit similar stars, while a host of other exotic pairings between stars and cosmic orbs pepper the universe. Black holes, for example, are often found orbiting each other. One pairing that has proven to be quite rare is that between a sun-like star and a type of dead star called a neutron star.

Now, astronomers led by Caltech's Kareem El-Badry have uncovered what appear to be 21 neutron stars in orbit around stars like our sun. Neutron stars are dense burned-out cores of massive stars that exploded. On their own, they are extremely faint and usually cannot be detected directly. But as a neutron star orbits around a sun-like star, it tugs on its companion, causing the star to shift back and forth in the sky. Using the European Space Agency's Gaia mission, the astronomers were able to catch these telltale wobbles to reveal a new population of dark neutron stars.

"Gaia is continuously scanning the sky and measuring the wobbles of more than a billion stars, so the odds are good for finding even very rare objects," says El-Badry, an assistant professor of astronomy at Caltech and an adjunct scientist at the Max Planck Institute for Astronomy in Germany.

The new study, which includes a team of co-authors from around the world, was published in *The Open Journal for Astrophysics*. Data from several ground-based telescopes, including the W. M. Keck Observatoryon Maunakea, Hawai'i; La Silla Observatory in Chile; and the Whipple Observatory in Arizona, were used to follow up the Gaia observations and learn more about the masses and orbits of the hidden neutron stars.

While neutron stars have previously been detected in orbit around stars like our sun, those systems have all been more compact. With little distance separating the two bodies, a neutron star (which is heavier than a sun-like star) can steal mass away from its partner. This mass transfer process makes the neutron star shine brightly at X-ray or radio wavelengths. In contrast, the neutron stars in the new study are much farther from their partners—on the order of one to three times the distance between Earth and the sun.

That means the newfound stellar corpses are too far from their partners to be stealing material from them. They are instead quiescent and dark. "These are the first neutron stars discovered purely due to their gravitational effects," El-Badry says.

The discovery comes as somewhat of a surprise because it is not clear how an exploded star winds up next to a star like our sun.

"We still do not have a complete model for how these binaries form," explains El-Badry. "In principle, the progenitor to the neutron star should have become huge and interacted with the solar-type star during its late-stage evolution." The huge star would have knocked the little star around, likely temporarily engulfing it. Later, the neutron star progenitor would have exploded in a supernova, which, according to models, should have unbound the binary systems, sending the neutron stars and sun-like stars careening in opposite directions.

"The discovery of these new systems shows that at least some binaries survive these cataclysmic processes even though models cannot yet fully explain how," he says.

Gaia was able to find the unlikely companions due to their wide orbits and long periods (the sun-like stars orbit around the neutron stars with periods of six months to three years).

"If the bodies are too close, the wobble will be too small to detect," El-

Badry says. "With Gaia, we are more sensitive to the wider orbits." Gaia is also most sensitive to binaries that are relatively nearby. Most of the newly discovered systems are located within 3,000 light-years of Earth—a relatively small distance compared, for example, to the 100,000 light-year-diameter of the Milky Way galaxy.

The new observations also suggest just how rare the pairings are. "We estimate that about one in a million solar-type stars is orbiting a neutron star in a wide orbit," he notes.

El-Badry also has an interest in finding unseen dormant black holes in orbit with sun-like stars. Using Gaia data, he has found two of these quiet black holes hidden in our galaxy. One, called Gaia BH1, is the closest known black hole to Earth at 1,600 light-years away.

"We don't know for sure how these black hole binaries formed either," El-Badry says. "There are clearly gaps in our models for the evolution of binary stars. Finding more of these dark companions and comparing their population statistics to predictions of different models will help us piece together how they form."

More information: Kareem El-Badry et al, A population of neutron star candidates in wide orbits from Gaia astrometry, *The Open Journal of Astrophysics* (2024). DOI: 10.33232/001c.121261

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