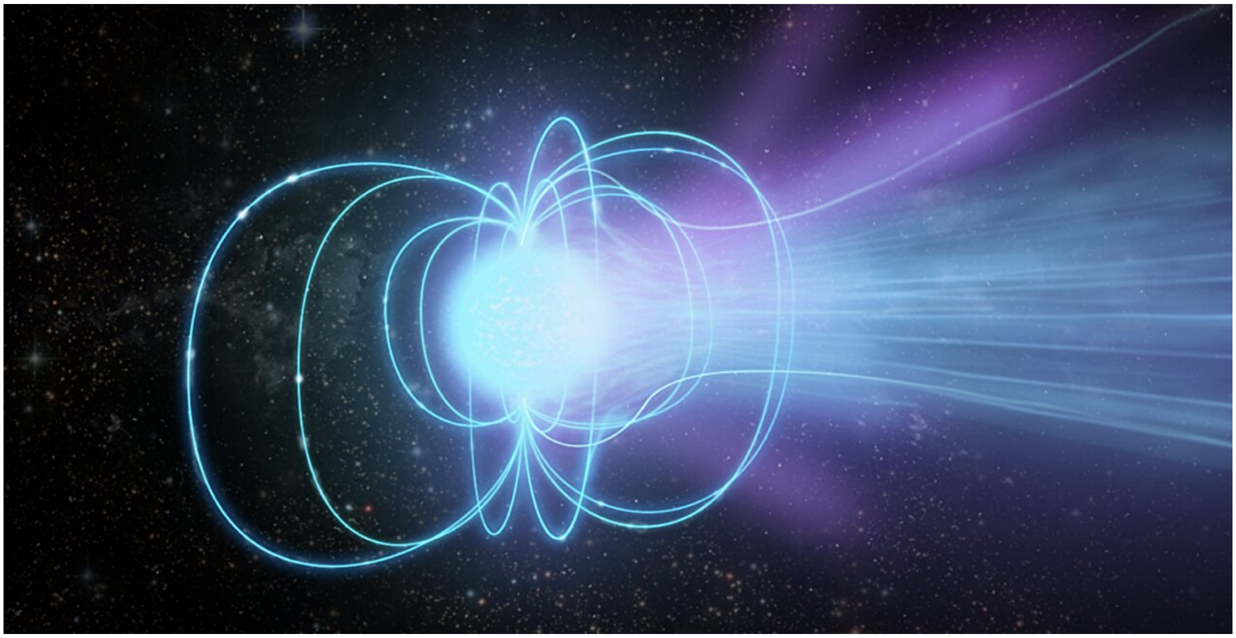
Precision measurements offer clues to magnetar's cosmic origin

August 7 2024



Magnetar Swift J1818.0-1617. Credit: NSF, AUI, NSF NRAO, S. Dagnello.

An international team of astronomers have used a powerful array of radio telescopes to discover new insights about a magnetar that's only a few hundred years old. By capturing precise measurements of the magnetar's position and velocity, new clues emerge regarding its developmental path.

When a relatively high-mass star collapses at the end of its life and explodes as a supernova, it can leave behind a superdense star called a neutron star. Extreme forces during its formation often cause neutron stars to spin very rapidly, shining out beams of light like a lighthouse.

When that beam is aligned such that it is visible from Earth, the star is also called a pulsar. And, when a neutron star forms with fast pulsar-like spin and a magnetic field thousands of times stronger than a typical neutron star, it's given the designation magnetar. These stars pack roughly double the mass of our sun into a physical size on the scale of tens of kilometers—the size of a city.

Even though there are many similarities between neutron stars, pulsars, and magnetars, astronomers are still puzzled by what conditions cause these extreme stars to evolve onto such distinct paths.

Now, a team of astronomers led by Hao Ding of the Mizusawa VLBI Observatory, National Astronomical Observatory of Japan, have used the U.S. National Science Foundation (NSF) National Radio Astronomy Observatory's (NRAO) Very Long Baseline Array (VLBA) to determine key characteristics of a newly discovered magnetar to unprecedented levels of precision.

At present, there are 30 confirmed magnetars, but only eight of these are similar enough to be relevant to this study. Ding and his team used the NSF VLBA over a period of three years to collect data on the position and velocity of the magnetar Swift J1818.0-1607, which was discovered in early 2020. Swift J1818.0-1607 is believed to be the youngest discovered thus far, and it is the fastest-spinning magnetar, rotating with a spin period of 1.36 seconds.

Swift J1818.0-1607 is located in the constellation Sagittarius. Situated on the other side of the central galactic bulge—within the Milky Way galaxy—and only 22,000 light years away, its position is relatively close to Earth. Close enough, in fact, to utilize the parallax method to accurately determine its three-dimensional location within the galaxy. (The parallax method calculates distance by using the apparent change in an object's position with respect to known, distant background objects.)

The lifespan of a magnetar is unknown at this time, but astronomers estimate that Swift J1818.0-1607 is only a few hundred years old. A magnetar's bright X-ray emissions necessitate a mechanism of extremely high energy outflow; only the rapid decay of its intense magnetic field can explain the power behind these spectral signatures. But that, too, is an extreme process.

For ordinary stars on the main sequence, bright blue stars live very short lives because they burn through their fuel far faster than their yellow siblings. The physics is different for magnetars, but they, too, likely have shorter lifespans than their pulsar relatives. "Magnetars are very young, because they cannot continue giving off energy at this rate for very long," Ding explains.

In addition, magnetars can also exhibit emissions at the low end of the electromagnetic spectrum—in radio wavelengths. For these, synchrotron radiation from the magnetar's fast spin is likely the energy source.

In synchrotron radiation, plasma surrounding the neutron star itself is so tightly wrapped against the star's surface that it rotates at very nearly the speed of light, generating emissions in radio wavelengths. These radio emissions were then detected by the NSF VLBA over three years of observations.

"The VLBA provided us with superb angular resolution for measuring this teeny-tiny parallax," Ding says. "The spatial resolution is unparalleled."

The results, published August 2024 in *The Astrophysical Journal Letters*, detail Swift J1818.0-1607's parallax as among the smallest for neutron stars, and its so-called transverse velocity as the smallest—a new lower limit—among magnetars.

Velocity in astronomy is most easily described as having two components, or directions. Its radial velocity describes how fast it is moving along the line of sight, which in this case means along the radius of the galaxy. For a magnetar such as Swift J1818.0-1607, located on the other side of the central bulge, there is too much other material in the way to precisely determine radial velocity. Transverse velocity, sometimes called peculiar velocity, describes motion perpendicular to the plane of the galaxy, and is more readily discernible.

As astronomers try to understand the formation processes that are common—and those that are different—between "regular" neutron stars, pulsars, and magnetars, they hope to use precise measurements of transverse velocity to help parse out conditions that cause a star to evolve down one of these three paths.

Ding says that this study adds weight to the theory that magnetars are unlikely to form under the same conditions as young pulsars, thus suggesting that magnetars come into being under more exotic formation processes.

"We need to know how fast the magnetar was moving when it was just born," says Ding. The formation mechanism of magnetars is still a mystery we would like to understand."

More information: Hao Ding et al, VLBA Astrometry of the Fastest-spinning Magnetar Swift J1818.0–1607: A Large Trigonometric Distance and a Small Transverse Velocity, *The Astrophysical Journal Letters* (2024). DOI: 10.3847/2041-8213/ad5550

Provided by National Radio Astronomy Observatory

Citation: Precision measurements offer clues to magnetar's cosmic origin (2024, August 7) retrieved 7 August 2024 from https://phys.org/news/2024-08-precision-clues-magnetar-cosmic.html