Basic Research

New FAST Discoveries Shed Light on Pulsars

Using the Five-hundred-meter Aperture Spherical radio Telescope (FAST), a research team led by Prof. HAN Jinlin from the National Astronomical Observatories of the Chinese Academy of Sciences (NAOC) has designed and conducted a survey for pulsars, sources of regular radio pulses in the Universe. According to the data released online at http://zmtt.bao.ac.cn/GPPS/, as of May 20, the team detected a total of 212 pulsars, including many very faint pulsars, 42 millisecond pulsars (MSPs), and 16 pulsars in binaries.

The team reported 201 of the newly-discovered pulsars in the journal *Research in Astronomy and Astrophysics* on May 18.

Pulsars are compact remnants of the death of bright, massive stars. They have the strongest magnetic field, highest density and fastest rotation among celestial bodies in the Universe, and show significant relativistic effects in systems of binary compact stars.

Since the first pulsars were discovered in 1968, so far about 3,000 pulsars have been found in total. Among them, about 400 of them have a period less than 30 milliseconds and are very stable in rotation.

Prof. HAN and his team designed a snapshot survey strategy so that a small patch of sky of a size of nearly a half degree can be stared for five minutes by the FAST 19 beam receiver, and fully covered in 21 minutes with 4 times of such a watch. This survey is known as the Galactic Plane Pulsar Snapshot (GPPS). The entire visible sky near the Milky Way will be completely hunted for pulsars in the next five years.

This is the first sensitive search for weak pulsars down to the microJy level and has been selected as one of FAST's five key science projects. Such a survey can detect pulsars with a flux density down to 5 microJy, about a magnitude weaker than previous surveys by other radio telescopes over the world.

Up to now, GPPS has searched about only 5% of the planned sky. "At this early stage of the project, this is an impressive total," said Prof. R.N. Manchester of CSIRO Astronomy and Space Science, Australia, commenting on the team's paper, which reported their discoveries of the first 201 pulsars.

Among the newly discovered pulsars, some have strange pulse dispersion properties. Dispersion is the measure of total electron density along the path from a pulsar to Earth and is a good indicator of pulsar distance. The higher the dispersion measurement, the greater the distance. GPPS has uncovered pulsars with very high dispersion measurements that challenge the best current models of electron density distribution in the Milky Way.

Based on these models, these pulsars with higher dispersion measurements would be located outside the Milky Way. However, they are more likely to be inside the Milky Way. This suggests the electron density in the

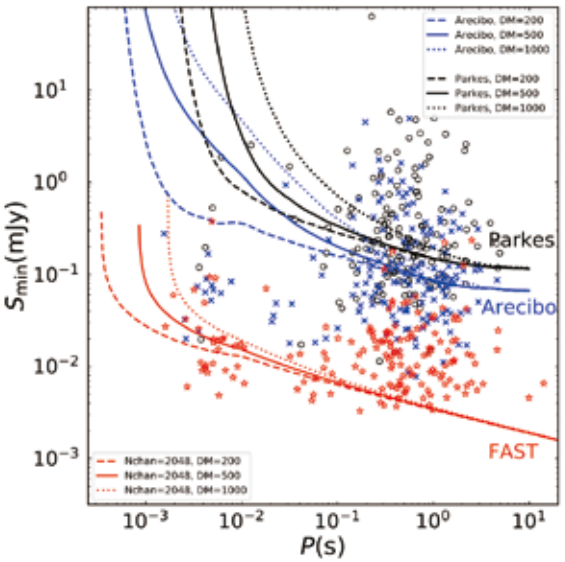

Figure 1: The FAST GPPS survey is able to detect pulsars one magnitude weaker than other telescopes, offering the best sensitivity for hunting pulsars. (Image by NAOC)

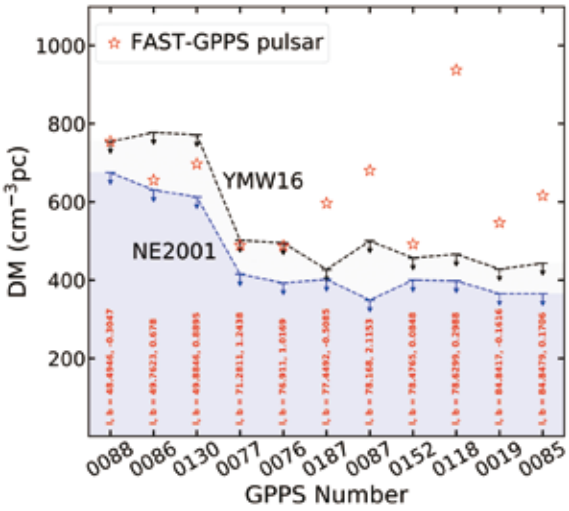

Figure 2: Some newly discovered pulsars have dispersion measures much higher than expected values, challenging the best current models of electron density distribution in the Milky Way. (Image by NAOC)

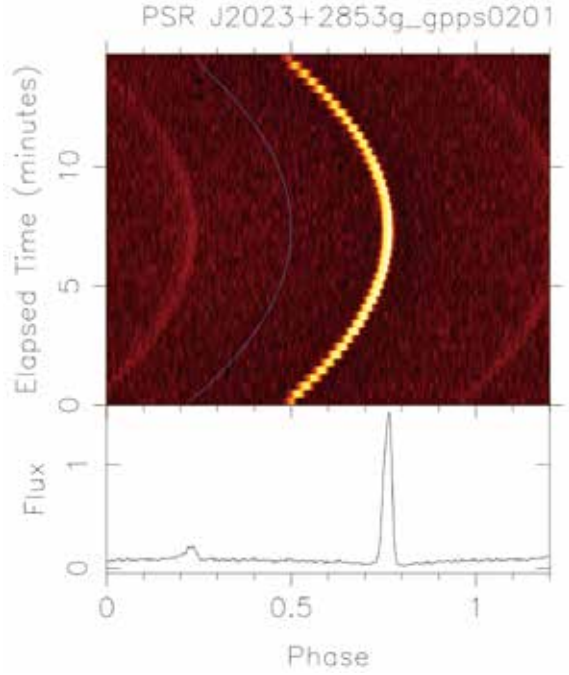

Figure 3: The newly discovered binary pulsars show a very clear phase shift even within the 15-minute-only observation by FAST. (Image by NAOC)

Milky Way, especially in the direction of its spiral arms, might be underestimated. In other words, the newly discovered pulsars reveal more electrons in the Milky Way's spiral arms than had ever been known.

So far 42 pulsars found in the survey have a period less than 30 milliseconds, making them newly discovered MSPs. "The GPPS survey has already increased the number of known MSPs by nearly 10 percent, a remarkable achievement," said Prof. Manchester. Among them, 14 have a companion around, so do the two long-period pulsars. "No doubt some of these will turn out to be excellent probes of gravitational theories," he added.

In addition, GPPS has discovered many pulsars with special features. For example, some produce flashing emissions that keep switching on and off, and some others emit just a few pulses over many minutes. For many previously known pulsars, the FAST survey has obtained data with an extremely high signal-to-noise ratio, which has improved the parameters for 64 pulsars.

"FAST has the promise for the study of compact objects in the universe, and helps us learn more about the fundamental physics and astrophysics," said Prof. Jim Cordes from Cornell University, a reviewer of the study.

To meet the goal of GPPS, the FAST team keeps going on the observations and the dataset undergoes frequent updating. Since May 18 when they reported their first discoveries, the team has found 11 more pulsars, turning the total number from 201 to 212. More are coming.

This project is supported by the National Natural Science Foundation of China.

More about the FAST-GPPS survey is available at http://zmtt.bao.ac.cn/GPPS/.

(Source: NAOC)

Media Contact
XU Ang
National Astronomical Observatories
E-mail: annxu@nao.cas.cn

Reference

J. L. Han, C. Wang, & P. F. Wang, et al. The FAST Galactic Plane Pulsar Snapshot survey: I. Project design and pulsar discoveries. *Research in Astronomy and Astrophysics*, (21)5, 107, (2021). (doi: 10.1088/1674-4527/21/5/107)