Astronomers discover clues that unveil the mystery of fast radio bursts

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The Five-hundred-meter Aperture Spherical radio Telescope (FAST) in Guizhou, China. Credit: Bojun Wang, Jinchen Jiang & Qisheng Cui

Fast radio bursts, or FRBs—powerful, millisecond-duration radio waves coming from deep space outside the Milky Way Galaxy—have been among the most mysterious astronomical phenomena ever observed. Since FRBs were first discovered in 2007, astronomers from around the world have used radio telescopes to trace the bursts and look for clues on where they come from and how they're produced.

UNLV astrophysicist Bing Zhang and international collaborators recently observed some of these mysterious sources, which led to a series of breakthrough discoveries reported in the journal Nature that may finally shed light into the physical mechanism of FRBs.

The first paper, for which Zhang is a corresponding author and leading theorist, was published in the Oct. 28 issue of *Nature*.

"There are two main questions regarding the origin of FRBs," said Zhang, whose team made the observation using the Five-hundred-meter Aperture Spherical Telescope (FAST) in Guizhou, China. "The first is what are the engines of FRBs and the second is what is the mechanism to produce FRBs. We found the answer to the second question in this paper."

Two competing theories have been proposed to interpret the mechanism of FRBs. One theory is that they're similar to gamma-ray bursts (GRBs), the most powerful explosions in the universe. The other theory likens them more to radio pulsars, which are spinning neutron stars that emit bright, coherent radio pulses. The GRB-like models predict a non-varying polarization angle within each burst whereas the pulsar-like models predict variations of the polarization angle.

The team used FAST to observe one repeating FRB source and discovered 11 bursts from it. Surprisingly, seven of the 11 bright bursts showed diverse polarization angle swings during each burst. The polarization angles not only varied in each burst, the variation patterns were also diverse among bursts.

"Our observations essentially rules out the GRB-like models and offers support to the pulsar-like models," said K.-J. Lee from the Kavli Institute for Astronomy and Astrophysics, Peking University, and corresponding author of the paper.

Four other papers on FRBs were published in Nature on Nov. 4. These include multiple research articles published by the FAST team led by Zhang and collaborators from the National Astronomical Observatories of China and Peking University. Researchers affiliated with the Canadian Hydrogen Intensity Mapping Experiment (CHIME) and the Survey for Transient Astronomical Radio Emission 2 (STARE2) group also partnered on the publications.

"Much like the first paper advanced our understanding of the mechanism behind FRBs, these papers solved the challenge of their mysterious origin," explained Zhang.

Magnetars are incredibly dense, city-sized neutron stars that possess the most powerful magnetic fields in the universe. Magnetars occasionally make short X-ray or soft gamma-ray bursts through dissipation of magnetic fields, so they have been long speculated as plausible sources to power FRBs during high-energy bursts.

The first conclusive evidence of this came on April 28, 2020, when an extremely bright radio burst was detected from a magnetar sitting right in our backyard—at a distance of about 30,000 light years from Earth in the Milky Way Galaxy. As expected, the FRB was associated with a bright X-ray burst.

"We now know that the most magnetized objects in the universe, the so-called magnetars, can produce at least some or possibly all FRBs in the universe," said Zhang.

The event was detected by CHIME and STARE2, two telescope arrays with many small radio telescopes that are suitable for detecting bright events from a large area of the sky.

Zhang's team has been using FAST to observe the magnetar source for some time. Unfortunately, when the FRB occurred, FAST was not looking at the source. Nonetheless, FAST made some intriguing "non-detection" discoveries and reported them in one of the Nov. 4 *Nature* articles. During the FAST observational campaign, there were another 29 X-ray bursts emitted from the magnetar. However, none of these bursts were accompanied by a radio burst.

"Our non-detections and the detections by the CHIME and STARE2 teams delineate a complete picture of FRB-magnetar associations," Zhang said.

To put it all into perspective, Zhang also worked with Nature to publish a single-author review of the various discoveries and their implications for the field of astronomy.

"Thanks to recent observational breakthroughs, the FRB theories can finally be reviewed critically," said Zhang. "The mechanisms of producing FRBs are greatly narrowed down. Yet, many open questions remain. This will be an exciting field in the years to come."

More information: Bing Zhang, The physical mechanisms of fast radio bursts, *Nature* (2020). DOI: 10.1038/s41586-020-2828-1

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