National Centre for Radio Astrophysics (NCRA)-TIFR, Pune

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GMRT discovers more slowly spinning neutron stars near stellar graveyards

A team of scientists from NCRA with the GMRT High Resolution Southern Sky (GHRSS) survey has discovered two new slow pulsars from the same data which have been searched earlier for pulsars. The team could discover these pulsars which were missed by previous search methods in the same data, due to a new superior algorithm designed to discover pulsars equally efficiently with all ranges of periods and widths. More importantly, for longer period pulsars with narrow widths, the new search algorithm is providing much higher sensitivity than the conventional search technique. The team reported two new pulsars with exceptionally narrow widths possibly revealing the missing pulsar population by previous surveys.

Certain massive stars burn their nuclear fuel and eventually collapse in violent explosions called the supernova. A compact city-sized object called Neutron stars remains close to the center of the explosion remnant. Neutron stars are extremely dense and harbor the strongest magnetic fields found in the universe. They rotate rapidly and are able to extract energy from their rotation to form beams of radiation. When these beams sweep past the observer, a sequence of regular pulses is seen, and hence they are named pulsars (see figure 1 for an artist's impression of pulsars). Over time, the pulsar slows down due to the loss of rotational energy and its rotational period becomes longer. It is predicted that if the period is extremely long then the pulsar can no longer radiate and moves to the so-called pulsar graveyard, which is a range of pulsar periods and magnetic field strengths that are not enough to sustain the radiation process. However, the discovery of long-period pulsars like J2144-3933, with a rotation period of 8.5s, challenged the emission theories as it is in the pulsar graveyard and still emitting in radio frequencies. Thus an efficient search for pulsars near this steller graveyard can constrain the theoretical model explaining the cessation of radio emission. However, one of the major reasons behind the lack of long-period pulsars needed to probe the emission conditions near the graveyard is the bias introduced by conventional pulsar search methods. The conventional search method is highly susceptible to excess noise at longer timescales, introduced by the slow variations in telescope system gain and radio frequency interferences from terrestrial radio sources enshrouding the population of long-period pulsars.

The scientists at National Centre for Radio Astrophysics (NCRA) are conducting GMRT High Resolution Southern Sky (GHRSS) survey since 2014 and have discovered 31 neutron stars so far, which happen to be the highest number to be found per sky area so far. However, the existing pulsar population from the GHRSS and other ongoing surveys with telescopes around the world are lacking long-period pulsars due to the underlying search algorithm which looks for signals in the pulsar spin-frequency domain. In this work, aided by new technological advancement, the team applied an alternative search algorithm to look for periodic signals from pulsars in the time domain with optimal mitigation of contributions from instrumental variation and terrestrial interferences. With simulated data and real GHRSS survey data, the team showed that the new search method is performing significantly better than the conventional search technique, especially for long period pulsars. Benefited by this, the GHRSS survey is now discovering many long-period pulsars, the population missed in the conventional search method. One of the newly discovered pulsars, PSR J1517-31b, has a long rotation period of 1 s and an unusually narrow duty cycle (ratio of pulse width and rotation period). Figure 2 shows the series of averaged pulses from this pulsar along with the folded profile of the pulsar. With the implementation of the new search technique, GHRSS can be one of the leading surveys to discover many new interesting long-period pulsars. These discoveries will populate the region close to the pulsar graveyard, which in turn will help us to answer some of the unresolved mysteries of pulsar radio emission.

The team led by a Ph.D. student from NCRA, Shubham Singh with scientists from NCRA, University of Manchester, UK, National Naval Laboratory, US, and West Virginia University, US, has recently published the new technique of efficiently searching for pulsars with discoveries in the Astrophysical Journal, in July 2022.

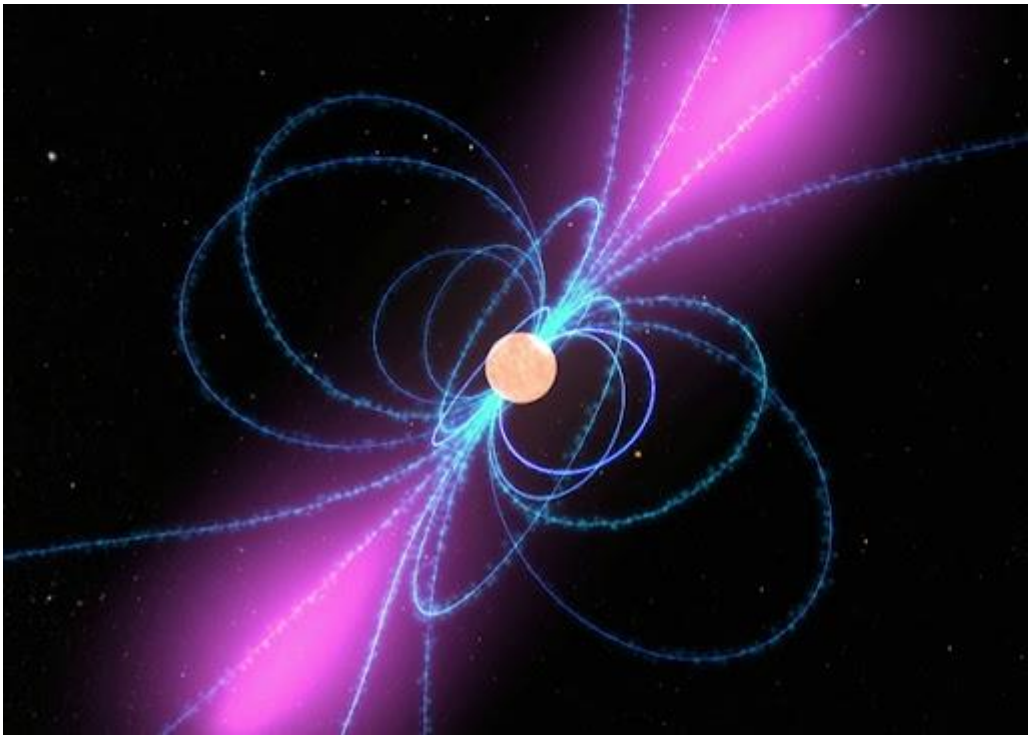

Figure 1: 'pulsar_image.jpg', caption: An artist's impression of a rotating magnetized neutron star, emitting radio beams (fig courtesy: Astronomy.com)

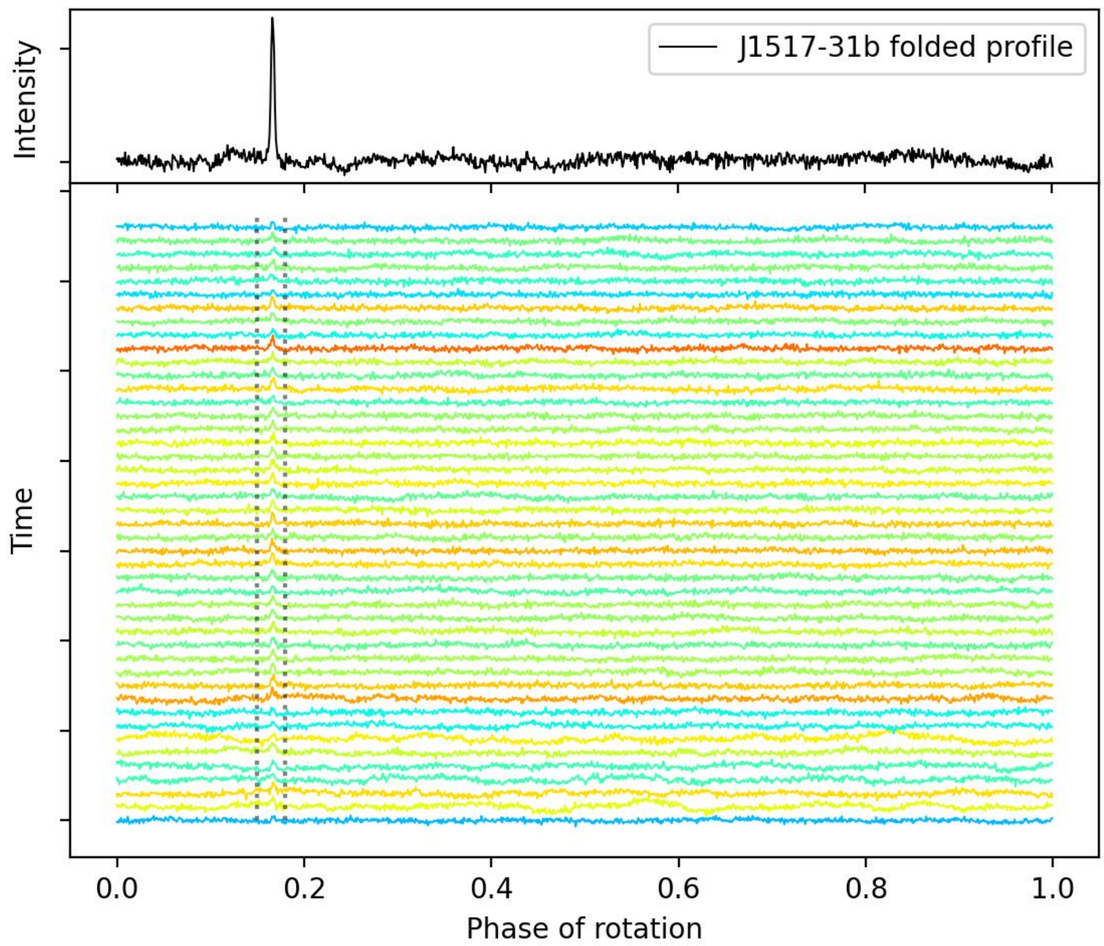

Figure 2: '1.1s_pulsar.png', caption: Stacked pulses from the new pulsar J1517-31b. The phase range marked by two vertical lines contains the narrow pulsed signal from the pulsar. The folded profile of this pulsar is shown in the upper panel of the figure.

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