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

Press Note – 13th July 2021

uGMRT uncovers the signature of a cannon ball fired from the Sun, using pulsars!

A group of nearly 20 astronomers, under the banner of Indian Pulsar Timing Array (InPTA), have for the first time detected the effect of a Coronal Mass Ejection (CME) from the Sun in the signal from a millisecond pulsar using the upgraded Giant Metrewave Radio Telescope (uGMRT). This space weather effect on a pulsar from the Sun is the first of its kind ever reported. This was possible only due to unique wideband and low frequency capabilities of the uGMRT.

The Indian Pulsar Timing Array (InPTA) is a group of nearly 20 astronomers studying pulsars, the most accurate clocks in the universe. The pulsars are the end products of massive stars. They are very massive and rotate extremely fast. As they rotate, the beams of their radio waves sweep the sky, which are seen as radio flashes with a high degree of periodicity. InPTA records signals from these clocks using the upgraded Giant Metrewave Radio Telescope (uGMRT), once every 14 days, to time these clocks to discover very low-frequency Gravitational waves. Gravitational waves were predicted by Einstein and are ripples in space and time. They change the way clocks tick as these waves pass by. While higher frequency Gravitational waves are being discovered by terrestrial detectors, like LIGO and VIRGO, the low frequency Gravitational waves can be discovered using changes in the clock period of pulsars. InPTA, along with other international pulsar timing groups, is a member of the International Pulsar Timing Array (IPTA) consortium aiming to discover a very low-frequency spectrum of Gravitational waves.

Discovering Gravitational waves requires determining the time of arrival of the radio flashes from pulsars to an accuracy of tens of nanoseconds. But, changes in the medium between us and stars produce time-varying delays and makes this precision worse. This is where the uGMRT helps to improve the precision. InPTA astronomers can measure these changes with an unprecedented precision because of the unique seamless frequency coverage of the uGMRT from 300 to 1400 MHz. While this is critical to the discovery of nanohertz Gravitational waves, this ability also allowed InPTA to uncover the effect of a solar explosion on February 23, 2019.

Our Sun produces massive explosions as its interior churns and twists its magnetic field. These massive eruptions, called Coronal Mass Ejections (CMEs), travel in space along with the solar wind, consisting of charged particles. Such an explosion

is akin to a cannon firing a cannonball. The CMEs, interacting with this solar wind, can increase the density of electrons between the Earth and the Sun. Such changes in the property of the medium between Earth and Sun affects the accuracy of measurement of periods from pulsars. Indian pulsar timing array astronomers uncovered the evidence of such a fireball using high precision pulsar timing with the uGMRT. InPTA astronomers discovered an increase in the delay in the signal from a millisecond pulsar, PSRJ2145-0750, while analysing the first year data of InPTA with the uGMRT. This excessive delay was observed on February 24, 2019. On this day, the pulsar was located away from the path of the Sun as well as the Sun was not very active. However, a weak coronal mass ejection (CME) eruption had occurred on the Solar surface the previous day. This solar event was detected by the space-based satellites and was directed towards the Earth. The large bubble of magnetized-plasma of CME was compressed by the high speed solar wind resulting in a dense plasma region along the line of sight to the pulsar. The pulsar signal passed through this highly compressed medium on 24 February 2019 causing an extra delay and an increased level of dispersion of the pulsar signal. This space weather effect on a pulsar is the first of its kind ever reported.

While this discovery was serendipitous, it may be noted that it was possible only due to unique wideband and low frequency capabilities of the uGMRT, which is one of its kind radio telescopes in the world. This discovery also demonstrates the breadth of science made possible by the uGMRT and the important role InPTA will play in the eventual detection of gravitational waves with the pulsar timing arrays. The results of our study was published in the Astronomy & Astrophysics journal on July 6, 2021 (https://doi.org/10.1051/0004-6361/202140340). The preprints is available in https://arxiv.org/abs/2101.05334

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