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A Decade long timing study of a millisecond Pulsar using the GMRT

A group of scientists at the National Centre for Radio Astrophysics (NCRA), Pune conducted a decade long term timing study of a galactic millisecond pulsar (MSP) J1544+4937 with the Giant Metrewave Radio Telescope (GMRT) in India and Green Bank Telescope (GBT) in the United States. Sangita Kumari, a PhD student at NCRA under the guidance of Dr. Bhaswati Bhattacharyya carried out this longest-duration timing study of a galactic field MSP with the GMRT using the observations at multiple frequencies. This study allowed the team to get a precise estimation of MSP's velocity and several other properties. Dr. Jayanta Roy also of NCRA and Devojyoti Kansabanik another PhD student at NCRA are the other authors.

Pulsars are rotating neutron stars, which are small and extremely dense supernova remnants of very massive around 8-20 solar masses stars. We detect pulses from the pulsars only when their beam of emission is pointed towards Earth. The fastest rotating neutron stars with a spin period of less than 30 ms are called millisecond pulsars (MSP). Being extremely stable rotators, MSPs act as laboratories for the study of matter in extreme conditions. MSPs often have orbital companions. In some of the MSP systems, (called “spider MSPs”) the pulsar and the companion star could have separations as small as that between the earth and the moon.
PSR J1544+4937 discovered by GMRT in 2013, is a spider MSP rotating about its axis once in 2.16 milliseconds. This MSP is in a binary orbit with an orbital period of 2.9 hours and at least 0.17 solar mass binary companion.

Dr. Bhaswati Bhattchayya says, “The properties of pulsars can be precisely derived through a technique known as pulsar timing. It is the regular monitoring of the rotation of the neutron star by measuring the time of arrival of the individual pulses from the pulsar. The larger the span of the data set, the more precisely the parameters of the pulsar can be estimated. Timing residual is used as a metric by pulsar astronomers to quantify how precisely the parameters of the pulsar are determined.” Using wide bandwidth-sensitive observations with the GMRT, Sangita Kumari and team studied the properties of the MSP J1544+4937 over more than a decade.

This decade-long timing study of the PSR J1544+4937 binary system has allowed the team to get a precise estimation of the velocity of this MSP as well as to study its orbital behaviour and properties of the intervening medium. This decadal-long timing study also allowed them to map the variation of integrated free electron density along the line of sight to the pulsar. They also observed that the orbital period of this pulsar is changing with time, where the orbital period is sometimes increasing and sometimes decreasing, which is in contrast to other non-spider MSPs binaries where we only see the decay of the orbital period due to gravitational wave emission.

Finally, the authors also explored the possibility of inclusion of this MSP in the pulsar timing array which is an array of MSPs distributed in the sky whose primary objective is to detect the gravitational wave signal from the supermassive black hole binaries. “The 5.5 microsecond timing residuals along with the remaining trends indicate that PSR J1544+4937 may not be an ideal

MSP to include in the PTA in the current state of timing study. However, we have got a timing residual of 3.1 micro seconds while using only the upgraded GMRT system having 200 MHz bandwidth from 2018−2022," the lead author of this work Sangita Kumari mentioned.

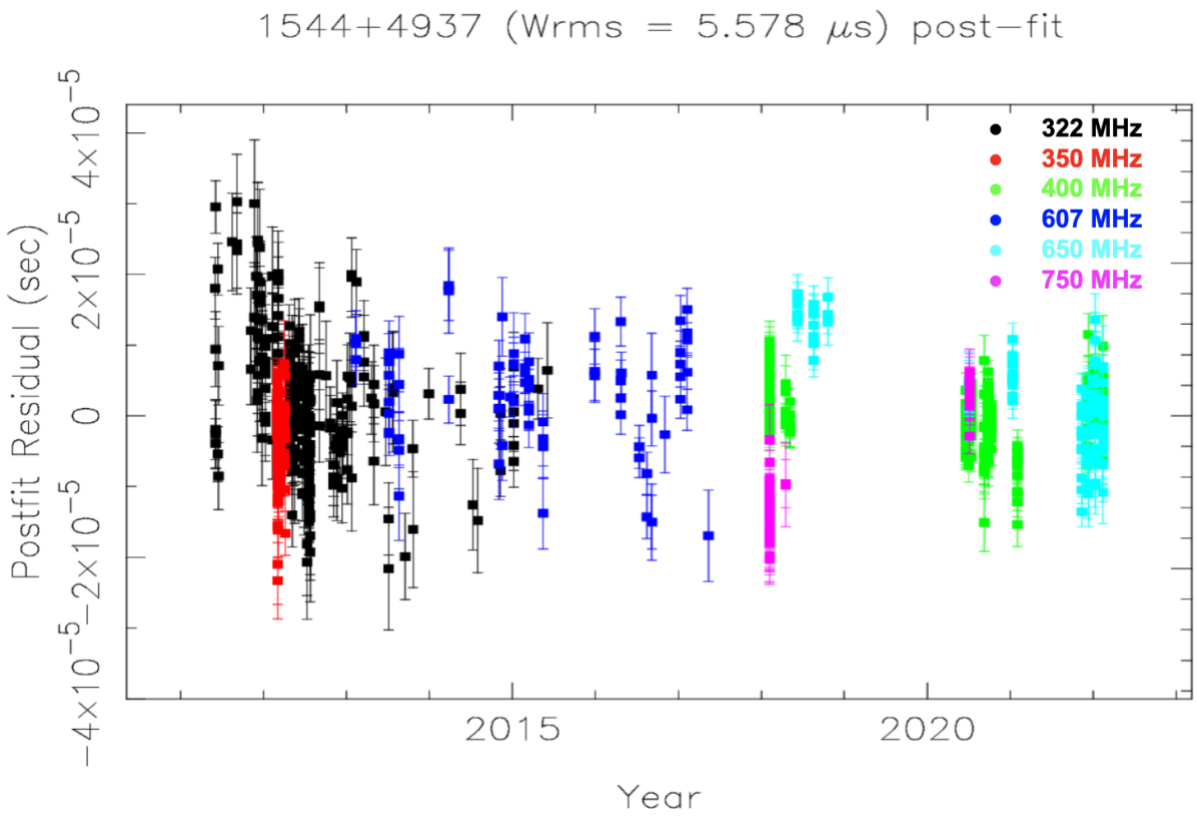

Figure shows the timing residual plot for spider MSP J1544+4937 obtained from 11 years of timing, where different color show different frequency data.

This research has recently been published in the Astrophysical Journal on 17 January 2023. It can be accessed at https://doi.org/10.3847/1538-4357/aca58b

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