Indian Pulsar Timing Array charts interstellar weather to capture black hole symphony

The Indian Pulsar Timing Array (InPTA) announced its first official Data Release or the InPTA DR1, published recently by the Publications of the Astronomical Society of Australia (Tarafdar et al. 2022, https://doi.org/10.1017/pasa.2022.46). The InPTA is an Indo-Japanese collaboration of about forty radio-astronomers working together with the International Pulsar Timing Array (IPTA) towards the detection of low-frequency gravitational waves. This InPTA data release stems from three and a half years of observation using the upgraded Giant Metrewave Radio Telescope (uGMRT) operated by NCRA-TIFR near Pune. The uGMRT is capable of conducting simultaneous multiband observations with receivers recording in parallel. This feature grants InPTA the unique strength to measure interstellar electron densities with the highest precisions obtainable as yet. It is a critical addition to the combined data pool of all the PTA consortiums.

The first direct detection of gravitational waves in 2015 (awarded the 2017 Nobel Prize in Physics) heralded a new era of 'gravitational wave astronomy'. Gravitational waves detected so far have resulted from the final phases of stellar mass black hole or neutron star mergers. The frequencies of such signals range from tens to hundreds of cycles per second and these last only for thousandths of a second. But certain black holes can grow to millions or even billions of times the solar mass. Orbiting pairs of such 'supermassive black holes' (SMBH) are capable of generating very low-frequency gravitational waves beyond the detectable ranges of earth-based or even future space-based detectors. As the InPTA team explains, "what we can detect till now are akin to large intermittent waves crashing loudly upon the seashore. But spacetime is continually brimming with tiny ripples oscillating once in a billion seconds. Imagine a symphony. The alto sections blare during crescendos, while bass sections play the fundamental progressions throughout. The interplay of gravitational waves in the universe is similar to a symphony being played by nature. We have been eavesdropping upon the crescendos, while there is a persistent rumble, an incessant buzz, forming the basis of this cosmic melody."

Measurement of fine delays in the arrival times of radio pulses from old revived pulsars called millisecond pulsars (MSP), is the technique being pursued by the PTAs to detect background gravitational waves propagating in the intervening medium. MSPs are the best natural time-keepers. Any remnant delay in their incredibly periodic radio pulses after compensating for known delay effects should carry imprints of the yet undetected tiny ripples in spacetime - 'the nano-Hertz gravitational waves'. But there's a catch! The authors explain, "the symphony has a hiss underneath making the lower notes inaudible. We must filter these distracting sounds to enjoy the true symphony. The 'interstellar weather' is the strongest source of such noise. Components in the incoming radio pulses are scattered differently by the vast ocean of the interstellar medium (ISM) lying in between. These random fluctuations are difficult to model. The only way out is to measure them with as high precision as possible. That is precisely what the InPTA has been able to achieve. With millisecond pulsars as our probes, we measure the noise produced by the changing medium between us, so that together with the other PTAs, we can listen to the symphony of black holes in the universe." In addition to the global hunt for low-frequency gravitational waves, the first InPTA data release also forms the basis of recent findings and ongoing investigations by the Indo-Japanese alliance. As a combination of data amongst various PTAs gets underway, anticipations fly high for the discovery of nanohertz gravitational waves in the very near future.

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