Pushing the boundary on ultralow frequency gravitational waves

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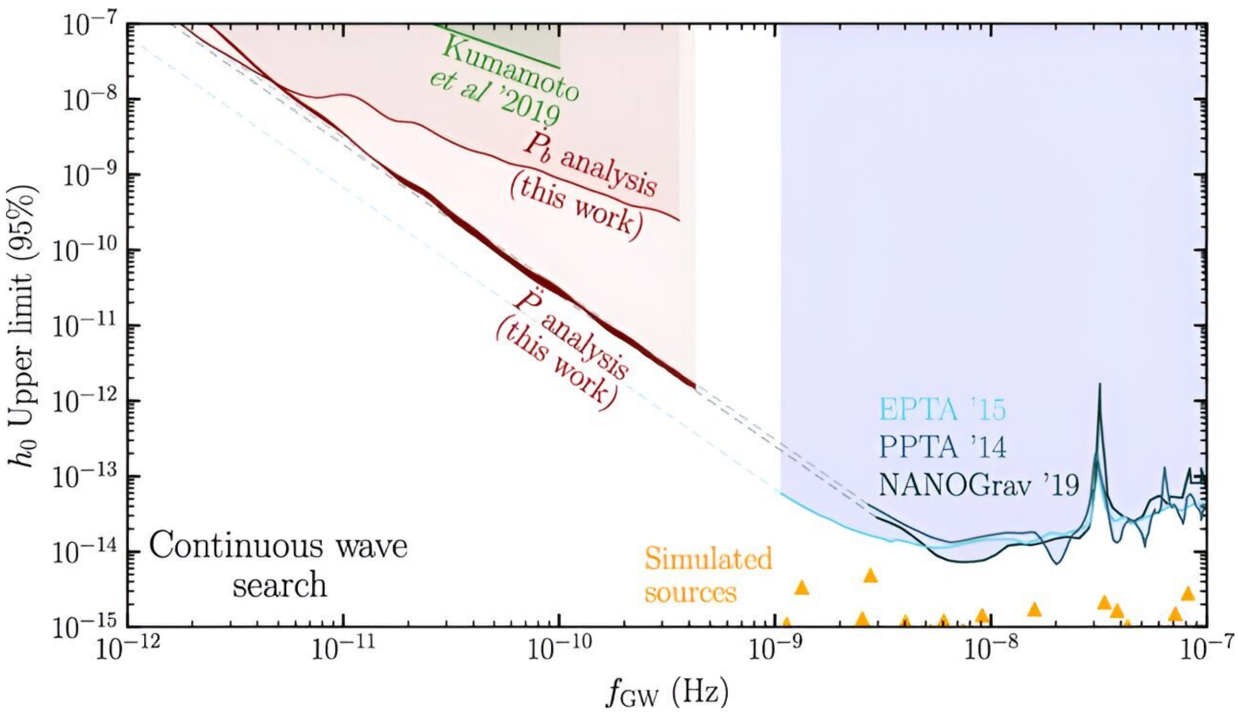

Sensitivity of pulsar timing arrays to continuous-wave sources from inspirals of supermassive black hole using $\ddot{P}$ and $\dot{P}_b$ analyses (red). Credit: *Physical Review Letters* (2024). DOI: 10.1103/PhysRevLett.132.101403

A team of physicists has developed a method to detect gravity waves with such low frequencies that they could unlock the secrets behind the early phases of mergers between supermassive black holes, the heaviest objects in the universe.

The method can detect gravitational waves that oscillate just once every thousand years, 100 times slower than any previously measured gravitational waves.

"These are waves reaching us from the farthest corners of the universe, capable of affecting how light travels," said JEFF DROR, Ph.D., an assistant professor of physics at the University of Florida and co-author of the new study. "Studying these waves from the early universe will help us build a complete picture of our cosmic history, analogous to previous discoveries of the cosmic microwave background."

Dror and his co-author, University of California, Santa Cruz postdoctoral researcher William DeRocco, published their findings in *Physical Review Letters*.

Gravitational waves are akin to ripples in space. Like sound waves or waves on the ocean, gravitational waves vary in both frequency and amplitude, information that offers insights into their origin and age. Gravitational waves that reach us can oscillate at extremely low frequencies, much lower than those of sound waves detectable to the human ear. Some of the lowest frequencies detected in the past were as low as one nanohertz.

"For reference," Dror explained, "the frequency of sound waves created by an alligator roar is about 100 billion times higher than this frequency—these are very low-pitched waves."

Their new method of detection is based on analyzing pulsars and neutron stars that emit radio waves at highly regular intervals. Dror hypothesized that searching for a gradual slowdown in the arrivals of these pulses could reveal new gravitational waves.

By studying existing pulsar data, Dror was able to search for gravitational waves with lower frequencies than ever before, increasing our "hearing range" to frequencies as low as 10 picohertz, 100 times lower than previous efforts that detected nanohertz-level waves.

While gravitational waves with frequencies around a nanohertz have been detected before, not much is known about their origin. There are two theories. The leading idea is that these waves are the result of a merger between two supermassive black holes, which, if true, would give researchers a new way to study the behavior of these giant objects that lie at the heart of every galaxy.

The other main theory is that these waves were created by some sort of cataclysmic event early in the universe's history. By studying gravitational waves at even lower frequencies, they may be able to differentiate these possibilities.

"Looking ahead, the next step is to analyze newer data sets," Dror said. "The datasets we used were primarily from 2014 and 2015, and a huge number of pulsar observations have been undertaken since that time."

Dror also plans to run simulations on mock data using UF's HiPerGator supercomputer to unravel cosmic history further. The supercomputer can efficiently run large, complex simulations, significantly reducing the time required to analyze data.

More information: William DeRocco et al, Using Pulsar Parameter Drifts to Detect Subnanohertz Gravitational Waves, *Physical Review Letters* (2024). DOI: 10.1103/PhysRevLett.132.101403. On *arXiv*: DOI: 10.48550/arxiv.2212.09751

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