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Recent Results from The North American Nanohertz Observatory for Gravitational Waves

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1 Extended Abstract

The past year has seen the first direct detection of gravitational waves (GW), marking a huge technical and scientific milestone in physics, and inaugurating a new era of GW astronomy. While LIGO operates in the $\sim$kHz-frequency GW band, other complementary experiments, both current and future, are sensitive to different GW frequency ranges. In exact analogy with how electromagnetic observations at radio, optical and gamma-ray wavelengths explore different astrophysical phenomena, opening up the broader GW spectrum using a variety of different techniques will be necessary to fully make use of the information contained in gravitational waves. In particular, high-precision timing observations of millisecond radio pulsars (MSPs) can act as a very-low-frequency GW detector, sensitive to GW with periods comparable to the experiment duration; typically years, or nanohertz frequencies. In the nHz regime, GW signals are expected to be emitted primarily by binary supermassive black holes, objects with masses $\gtrsim 10^6 M_\odot$ that exist at the centers of galaxies. The nHz GW signals from these sources provide a new measure of the galaxy merger history of the universe. Other more exotic signal types such as GW bursts from individual merger events or from cosmic strings, may also be detectable, and these observations already constrain their properties.

In order to detect such a signal, a set of MSPs must be monitored for many years with sensitive radio telescopes. Passing GW will cause small variations in pulse arrival times; these can be detected due to the intrinsic clock-like stability of the pulsars. GW can be distinguished from other effects as the fluctuations are *correlated* between different pulsars. Our group, the North American Nanohertz Observatory for Gravitational Waves (NANOGrav) has been running such a pulsar timing array experiment for over a decade. We use the Green Bank and Arecibo radio telescopes to monitor a growing set of MSPs, starting with 17 at the beginning of the project, to 37 in our most recent published data set [1], to over 54 currently. This dramatic increase in the number of pulsars, along with equally dramatic improvements in digital instrumentation over the past few years, have allowed us to now reach GW sensitivities that are astrophysically constraining [2] and may result in a detection in the near future.

In this presentation, I will discuss up-to-date results from the project, including: our already-published "nine-year" data set [1] and its implications for the population of supermassive binary black holes [2]; our currently in-preparation "eleven-year" data set and preliminary gravitational wave results; and predictions for the future of the project in the context of current and planned large radio astronomy facilities both in the U.S. and internationally.

References

[1] Arzoumanian et al. (NANOGrav Collaboration), "The NANOGrav Nine-year Data Set: Observations, Arrival Time Measurements, and Analysis of 37 Millisecond Pulsars," *The Astrophysical Journal*, **813**, 1, 65, November 2015, doi: 10.1088/0004-637X/813/1/65.

[2] Arzoumanian et al. (NANOGrav Collaboration), "The NANOGrav Nine-year Data Set: Limits on the Isotropic Stochastic Gravitational Wave Background," *The Astrophysical Journal*, **821**, 1, 13, April 2016, doi: 10.3847/0004-637X/821/1/13.