The NANOGrav 12.5-year Data Set: Observations and Narrowband Timing of 47 Millisecond Pulsars

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We report on our high-precision timing of 47 millisecond pulsars in the fourth data set from the North American Nanohertz Observatory for Gravitational Waves (NANOGrav). We provide timing solutions for these pulsars that account for the Earth’s position in the Solar System, the pulsar’s relative motion to the Solar System, the pulsar’s motion if it is in an orbit with a binary companion, the time-varying interstellar medium, and more. We introduce new techniques for processing pulse profiles to improve our time-of-arrival calculations and reduce unwanted outliers. This is one of two papers covering the data set, with the companion on “wideband” timing. The data set is publicly available and is already being analyzed for the most stringent constraints on the stochastic gravitational-wave background and individual continuous-wave sources.

The Data Set:
- Telescopes used: 100-m Green Bank Telescope and the 305-m Arecibo Observatory
- Millisecond pulsars observed: 47 (2 added)
- Timespan: 12.9 years (July 30, 2005 – June 30, 2017)
- At least two years of data on each pulsar
- Radio frequencies: 300 MHz to 2.5 GHz
- Largest data volume presented: PSR J1713+0747, with 38,000 times of arrival (TOAs)
- Timing packages used: TEMPO, TEMPO2, PINT
- 12.5-yr data set available at data.nanograv.org

New Approaches:
- Automated timing pipeline for rapid, consistent, and reproducible results in iPython Jupyter Notebook framework
- Mitigation of backend sampler “ghost images”
- Improved TOA estimation at low pulse S/N
- Two-step automated analyses to remove outlier TOAs

Papers Using Data Set:
- Lam et al. 2018b: a second interstellar medium “timing event” toward PSR J1713+0747
- Lam et al. 2019: frequency dependence of pulse jitter in the 12.5-yr data set
- Stovall et al. 2019: a laboratory for stellar evolution with PSR J2234+0611
- Deneva et al. 2019: high-precision X-ray timing with NICER and comparison with radio observations
- Cromartie et al. 2019: the highest mass pulsar known

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