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Parkes Pulsar Timing Array constraints on ultralight scalar-field dark matter

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Abstract

 It is widely accepted that dark matter contributes about a quarter of the critical mass-energy density in our Universe. The nature of dark matter is currently unknown, with the mass of possible constituents spanning nearly one hundred orders of magnitude. The ultralight scalar field dark matter, consisting of extremely light bosons with m~10-22 eV and often called "fuzzy" dark matter, provides intriguing solutions to some challenges at sub-Galactic scales for the standard cold dark matter model. As shown by Khmelnitsky and Rubakov, such a scalar field in the Galaxy would produce an oscillating gravitational potential with nanohertz frequencies, resulting in periodic variations in the times of arrival of radio pulses from pulsars. The Parkes Pulsar Timing Array (PPTA) has been monitoring 20 millisecond pulsars at two- to three-week intervals for more than a decade. In addition to the detection of nanohertz gravitational waves, PPTA offers the opportunity for direct searches for fuzzy dark matter in an astrophysically feasible range of masses. We analyze the latest PPTA data set which includes timing observations for 26 pulsars made between 2004 and 2016. We perform a search in this data set for evidence of ultralight dark matter in the Galaxy using Bayesian and Frequentist methods. No statistically significant detection has been made. We, therefore, place upper limits on the local dark matter density. Our limits, improving on previous searches by a factor of 2 to 5, constrain the dark matter density of ultralight bosons with m≤10-23 eV to be below 6 GeV cm-3 with 95% confidence in the Earth neighborhood. Finally, we discuss the prospect of probing the astrophysically favored mass range m10-22 eV with next-generation pulsar timing facilities.

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