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Constraining Ultralight Scalars with Neutron Star Superradiance

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We demonstrate that rotational superradiance can be efficient in millisecond pulsars. Measurements from the two fastest known pulsars PSR J1748-2446ad and PSR B1937+21 can place bounds on bosons with masses below 10^-11 eV. The bounds are maximally good at masses corresponding to the rotation rate of the star, where scalar interactions that mediate forces ~ 10^7 times weaker than gravity are ruled out, exceeding existing fifth force constraints by 4 orders of magnitude. For certain neutron star equations of state, these measurements also constrain the QCD axion with decay constant around ~ 10^19 GeV, ruling out axions with masses between 5*10^-13 and *310^-12 eV. The observed absence of pulsars above ~ 700 Hz despite the ability of the neutron star equation of state to support frequencies as high as ~ 1500 Hz could be due to the superradiant damping of the stellar rotation as a result of its coupling to a new particle of mass ~ 1500-3000 Hz with Yukawa couplings to nucleons. Although similar bounds have been placed by black hole superradiance, we note these bounds are strong functions of the (difficult to measure) black hole rotation rate, and thus the present bounds benefit from the extreme reliability of pulsar period measurements.

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