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A boosted gravitational wave background for primordial black holes with broad mass distributions and thermal features

Primordial black holes (PBHs) with a wide mass distribution imprinted by the thermal history of the Universe, which naturally produces a high peak at the solar mass scale, could explain the gravitational-wave events seen by LIGO/Virgo and up to the totality of the dark matter. We show that compared to monochromatic or log-normal mass functions, the gravitational wave backgrounds (GWBs) from early PBH binaries and from late binaries in clusters are strongly enhanced at low frequency and could even explain the NANOGrav observations. This enhancement comes from binaries with very low mass ratios, involving solar-mass and intermediate-mass PBHs at low frequency, solar-mass and subsolar-mass at high frequency. LISA could distinguish the various models, while in the frequency band of ground-based detectors, we find that the GWB from early binaries is just below the current LIGO/Virgo limits and above the astrophysical background, if they also explain black hole mergers. The GWB from binaries in clusters is less boosted but has a different spectral index than for neutron stars, astrophysical black holes or early PBH binaries. It is detectable with Einstein Telescope or even with the LIGO/Virgo design sensitivity.

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