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Constraining Fuzzy Dark Matter Mass with Gravitationally Lensed High-z Galaxies

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Ultra-light axions are well-motivated fuzzy/wave cold dark matter (CDM) candidates that provide potential resolutions to various small-scale problems faced by conventional heavy particle CDM. Being wavy on astronomical scales, galaxy formation is suppressed below the respective de Broglie wavelength scale, resulting in a sharp turnover in galaxy luminosity functions (LF) at the faint end. Such features, however, have yet to be confirmed and have only a few hints from Hubble Frontier lensing fields (e.g. Leung et al, 2018; Atek et al, 2018). Without the supplement of deep observations at longer wavelength (covering Balmer breaks of high-z galaxies), however, the high redshift sample for these lensing fields was shown to be severely contaminated, with contamination level reaching ~60% over 3.5<z<5.5 (Zhang et al, 2025). To achieve a more robust test, we here combine existing HST observations with recent deep JWST observations by the PEARLS team on field MACS J0416, and construct a photometric redshift catalog reliable up to the redshift of z~10. By measuring the surface number density of gravitationally lensed high-z galaxies behind this massive galaxy cluster, we found no evidence of faint end turnover over redshifts 6<z<10. With this, we place a constraint on the fuzzy dark matter mass to above 2.76E-22eV at 95% confidence. We will also discuss the implication of this bound if the dark matter budget is composed of multiple copies of axions, a scenario more theoretically motivated from the perspective of String Axiverse. Using linear perturbation analysis, we argue different copies of axions may resemble an equivalent copy (with mass in between the highest and lowest axion mass, depending on relative contributions to total density) in terms of suppression (i.e. where turnover occurs in UV LFs) on large-scale structure. Hence the mass constraint we obtained (likewise for the stronger constraints from Lyman alpha forest) still allows for light (e.g. 1E-22 eV) axion to dominate individual galaxies, subject to the existence of heavier copies.

Please choose your topic

Dark Matter

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