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Probing self-interacting neutrinos with large-scale structure observations

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According to the Standard Model (SM), neutrinos begin to free-stream as the Universe cools to approximately 1.5 MeV, leaving distinctive imprints in cosmological observables. Interestingly, several analyses have revealed that some cosmic microwave background (CMB) data allow a cosmological scenario in which, due to self-interactions, the onset of neutrino-free streaming occurs close to the epoch of matter-radiation equality. While such results could hint at new physics at early times, this non-standard neutrino free-streaming scenario could arise from an accidental feature in the CMB data. To clarify this situation, we investigate, in a CMB-independent way, whether the large-scale distribution of galaxies allows for this cosmological scenario. We find that galaxy power spectrum data also aligns with this scenario, discarding the possibility of an accidental feature in the CMB. We further investigate the relevance of this non-trivial agreement between CMB and large-scale structure (LSS) data by analyzing both data sets employing the simplest representation of self-interacting neutrinos in cosmology. Our analysis reveals that, due to the S_8 discrepancy, self-interacting neutrinos fail to simultaneously accommodate a consistent scenario for both the CMB and galaxy power spectra, emphasizing the need to consider a broader range of phenomenologies in the early Universe. Our findings also highlight some of the challenges ahead if we aim to uncover the underlying free-streaming nature of neutrinos using spectroscopic surveys.

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