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# Fuzzy Axions and Associated Relics

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We study fuzzy axion dark matter in type IIB string theory, for axions descending from the Ramond-Ramond four-form in compactifications on orientifolds of Calabi-Yau hypersurfaces. Such models can be tested by cosmological measurements if a significant relic abundance of fuzzy dark matter arises, which we argue is most common in models with small numbers of axions. We construct a topologically exhaustive ensemble of more than 350,000 Calabi-Yau compactifications yielding up to seven axions, and in this setting we perform a systematic analysis of misalignment production of fuzzy dark matter. In typical regions of moduli space, the fuzzy axion, the QCD axion, and other axions have comparable decay constants of f_a \simeq 10^16 GeV. We find that overproduction of heavier axions is problematic, except at special loci in moduli space where decay constant hierarchies can occur: without a contrived reheating epoch, it is necessary to fine-tune initial displacements. The resulting dark matter is typically a mix of fuzzy axions and heavier axions, including the QCD axion. Dark photons are typically present as a consequence of the orientifold projection. We examine the signatures of these models by simulating halos with multiple fuzzy axions, and by computing new cosmological constraints on ultralight axions and dark radiation. We also give evidence that cosmic birefringence is possible in this setting. Our findings determine the phenomenological correlates of fuzzy axion dark matter in a corner of the landscape.

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