The axion, motivated as a solution to the strong CP problem, is also a viable dark matter candidate. We use N-body simulations to study the formation of substructures from white-noise density fluctuations. The density profiles of our relaxed axion minihalos can be described by the Navarro-Frenk-White profile, and the minihalos' concentration number agrees well with a simple, physically-motivated model. We develop a semi-analytic formula to fit the mass function from our simulation, which agrees broadly at different redshifts and only differs at factor of two level from classic halo mass functions. This analytic mass function allows us to consider uncertainties in the post-inflation axion scenario, as well as extrapolate our high-redshift simulations results to the present.

Our work estimates the present-day abundance of axion substructures, as is necessary for predicting their effect on cosmological microlensing caustics and pulsar timing. Our calculations suggest that if pulsar timing and microlensing probes can reach recent sensitivity forecasts, they may be sensitive to the post-inflation axion dark matter scenario, even when accounting for uncertainties pertaining to axion strings. For pulsar timing, the most significant caveat is whether axion minihalos are disrupted by stars, which our estimates show is mildly important at the most relevant masses. Finally, as our gravitational simulations are scale invariant, the results can be extended to models where the dark matter is comprised of other axion-like particles and even clusters of primordial black holes.