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Cold, warm or self-interacting? The impact of dark matter microphysics on subhalo detectability with strong gravitational lensing

The underlying nature of dark matter significantly impacts the formation and evolution of halos, as well as the properties of the subhalo population they host. The inner region of a subhalo's density distribution is particularly sensitive to dark matter microphysics, with alternative dark matter models leading to both cored and steeply-rising inner density profiles. This work investigates how the lensing signature and detectability of dark matter subhalos in mock HST and Euclid-like strong lensing observations depends on the subhalo's radial density profile, especially with regards to the inner power-law slope, β. We demonstrate that the minimum-mass subhalo detectable along the Einstein ring of a system is strongly dependent on β. For example, steep subhalos with $\beta \sim 2.2$ (resembling core-collapsed subhalos that can arise from dark matter self interactions) can be detected down to total halo masses an order-of-magnitude lower than their NFW counterparts. We also demonstrate how accurately one can measure and distinguish cored versus steep inner density slopes. The results of this work highlight how subhalo detections, or lack-thereof, from current and upcoming lensing surveys, can be extremely informative for constraining dark matter models that predict the existence of a large population of very steep, low-mass subhalos. We advocate for future substructure searches to model subhalos using a flexible profile that accounts for the wide diversity of subhalo properties predicted by different dark matter models.

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