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Unravelling dark matter halo dynamics: from prompt cusps to universal profiles

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The study of dark matter halos is pivotal in unravelling the nature of dark matter particles, their detection and structure formation in the universe. Our work aims to track and investigate dark matter halo dynamics, from the initial collapse of tiny perturbations forming prompt cusps to the gradual evolution of their profiles into the universal NFW(Einasto) profile. We examine a specific set of earth mass and solar system sized microhalos, generated from initial conditions composed of Gaussian random fields and crossed sin-waves, in numerical simulations using Ramses-N body and ColDICE-Vlasov codes. We analyze the cusp's density profile, test analytical predictions for its slope, and track its extent and stability in the face of continuous accretion and mergers. Furthermore, we verify predictions for the profile in various spatial regions of the halo, study the effects of angular momentum and tidal fields and specifically, what leads to the universal NFW profile. We also investigate phase-space distribution, velocity and anisotropy parameter profiles to study the dynamics including numerical artefacts like radial orbit instabilities. Analytical studies of the complex multi-stream dynamics inside a collapsed halo using self-similar models already exist with predictions for the particle trajectories, phase space distribution, mass and density profiles. Moreover, prior numerical studies claim that the halos accrete largely onto intermediate and large radii with little to no impact on the inner cusp, eventually reaching the universal NFW(Einasto) profile. We test these claims and construct a qualitative description of halo dynamics and its evolution through different phases.

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