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Where my DAEMON hides – The emergence of cosmic structures following power-laws

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Large-scale N-body simulations have successfully reconstructed cosmic structure formation with increasing resolution and complexity, as observations corroborate. Complementary efforts have arrived at a hydrodynamical theory that explains cosmic structure evolution up to the non-linear regime. While the statistical properties of mass density perturbations for the observable universe as a whole become comprehensible, it is still unknown why our heuristic approaches for the characterisation of individual, locally collapsed mass agglomerations work so well.
In particular, we lack an explanation why mass density profiles like the Navarro-Frenk-White profile or other composites of power laws arise in dark-matter N-body simulations and successfully match halo profiles inferred by observations like gravitational lensing effects.

As a first step towards one general dark matter mass density profile that replaces the heuristically inferred fitting functions, I introduce the "DArk Emergent Matter halO explanatioN" (DAEMON, [1]) which explains self-similar dark matter halo morphologies forming under scale-free gravitational interaction. DAEMON thus bases power-law mass density profiles and composites thereof on sound mathematically and physically fundamental principles:
Understanding the particle distributions as discrete samplings of a corresponding smooth mass density, DAEMON explains the cusp-core problem in the halo centre as an inhomogeneous, statistical sampling. The transition to isothermality marks the shift to a homogeneously sampled region. As scale-free Newtonian gravity does not favour a specific halo boundary, our choice of a boundary relative to the particle distribution sets the power-law index in the outer regions.

This simple but powerful explanation of halo morphologies can be employed to make simulations more efficient or facilitate the choice of lens models in strong gravitational lensing to mention two applications that profit from this progress in understanding cosmic structures.

[1] https://doi.org/10.1142/S0218271820430178

The approach also received a honourable mention at the Gravity Research Foundation Essay Contest 2020: https://doi.org/10.1142/S0218271820430178

Primary author: WAGNER, Jenny (Bahamas Advanced Study Institute & Conferences)

Presenter: WAGNER, Jenny (Bahamas Advanced Study Institute & Conferences)

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