

N-body simulations of primordial dark matter halos

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centra



TÉCNICO
LISBOA



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Fifth Force Interactions

Light scalar field

$$\mathcal{L}(\phi) = -\frac{1}{2}\partial^\mu\phi\partial_\mu\phi - V(\phi)$$

Coupled fermion field

$$\mathcal{L}(\phi, \psi) = i\bar{\psi} (\gamma^\mu \nabla_\mu - m_\psi(\phi)) \psi$$

Interaction strength

$$\beta(\phi) \equiv -M_P \frac{\partial \ln m_\psi(\phi)}{\partial \phi}$$

Energy-momentum transfer

$$\dot{\rho}_{\phi/\psi} + 3H(\rho_{\phi/\psi} + p_{\phi/\psi}) = \pm \frac{\beta}{M_P} (\rho_\psi - 3p_\psi) \dot{\phi}$$

Fermion mass

$$m_\psi(z_{\text{in}}) \sim \mathcal{O}(\text{MeV})$$

Scaling solution

$$\Omega_\psi = \frac{1}{3\beta^2}, \quad \Omega_\phi = \frac{1}{6\beta^2}, \quad \Omega_\gamma = 1 - \frac{1}{2\beta^2}$$

Primordial Dark Matter Halos

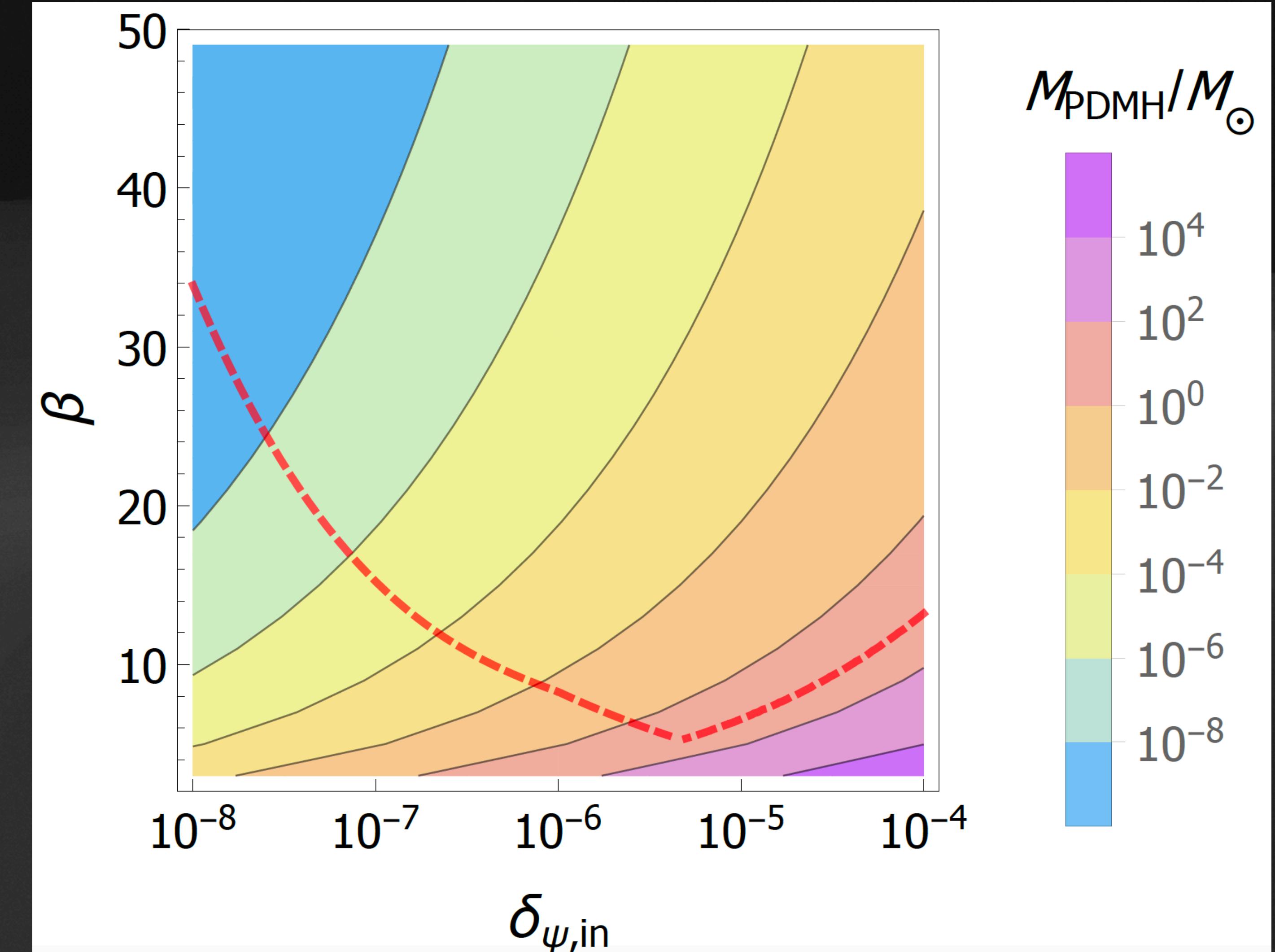
Mass

M_{\odot} solar mass

$\delta_{\psi, \text{in}}$ initial density contrast for
the fermionic field

— upper limit of the region
of parameters evading
microlensing constraints

S. Savastano *et al.*, Phys. Rev. D **100**, 083518 (2019)



Primordial Dark Matter Halos

Radius

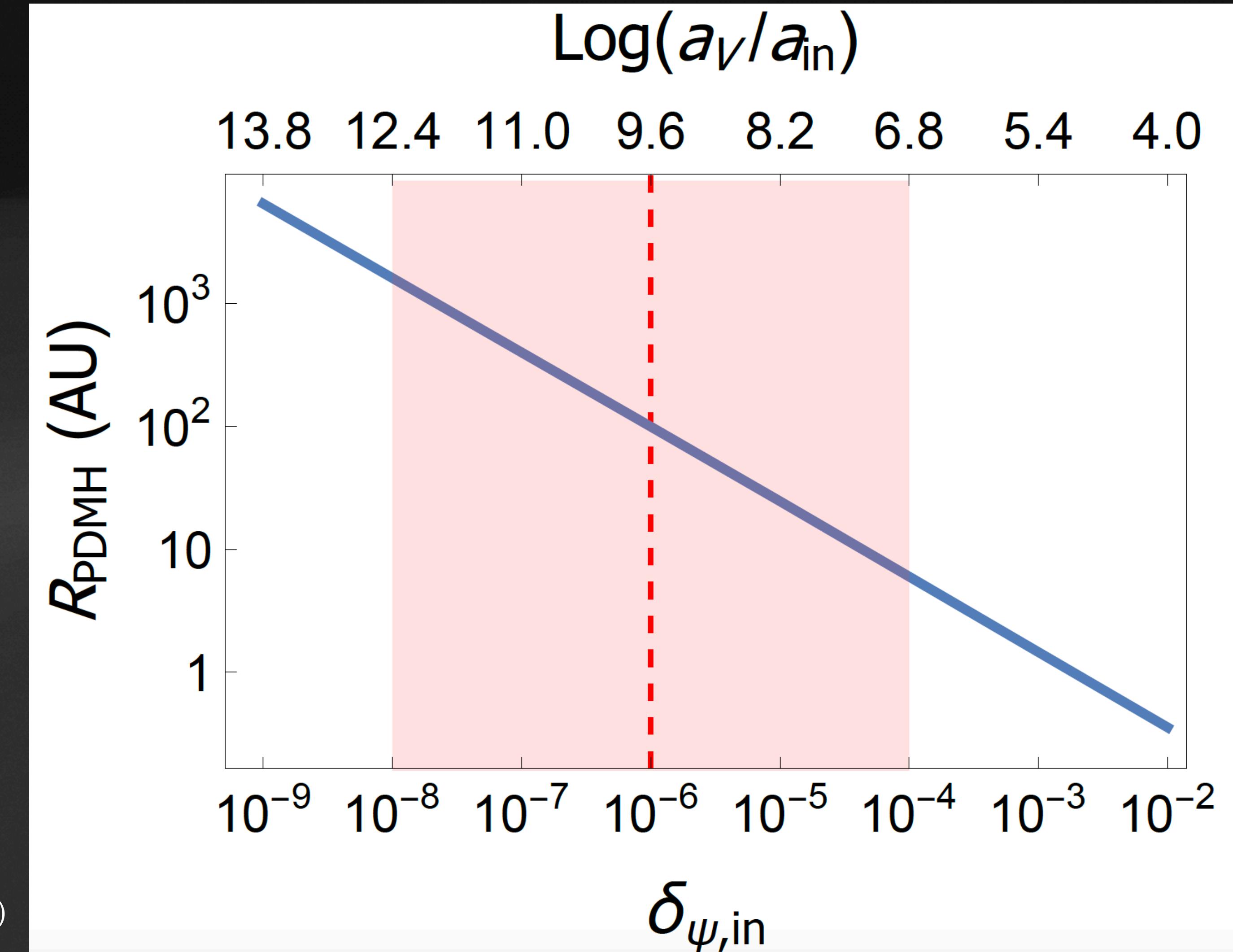
AU

astronomical unit

$$\log \left(\frac{a_V}{a_{\text{in}}} \right)$$

number of e-folds from
the onset of the scaling
regime to virialisation

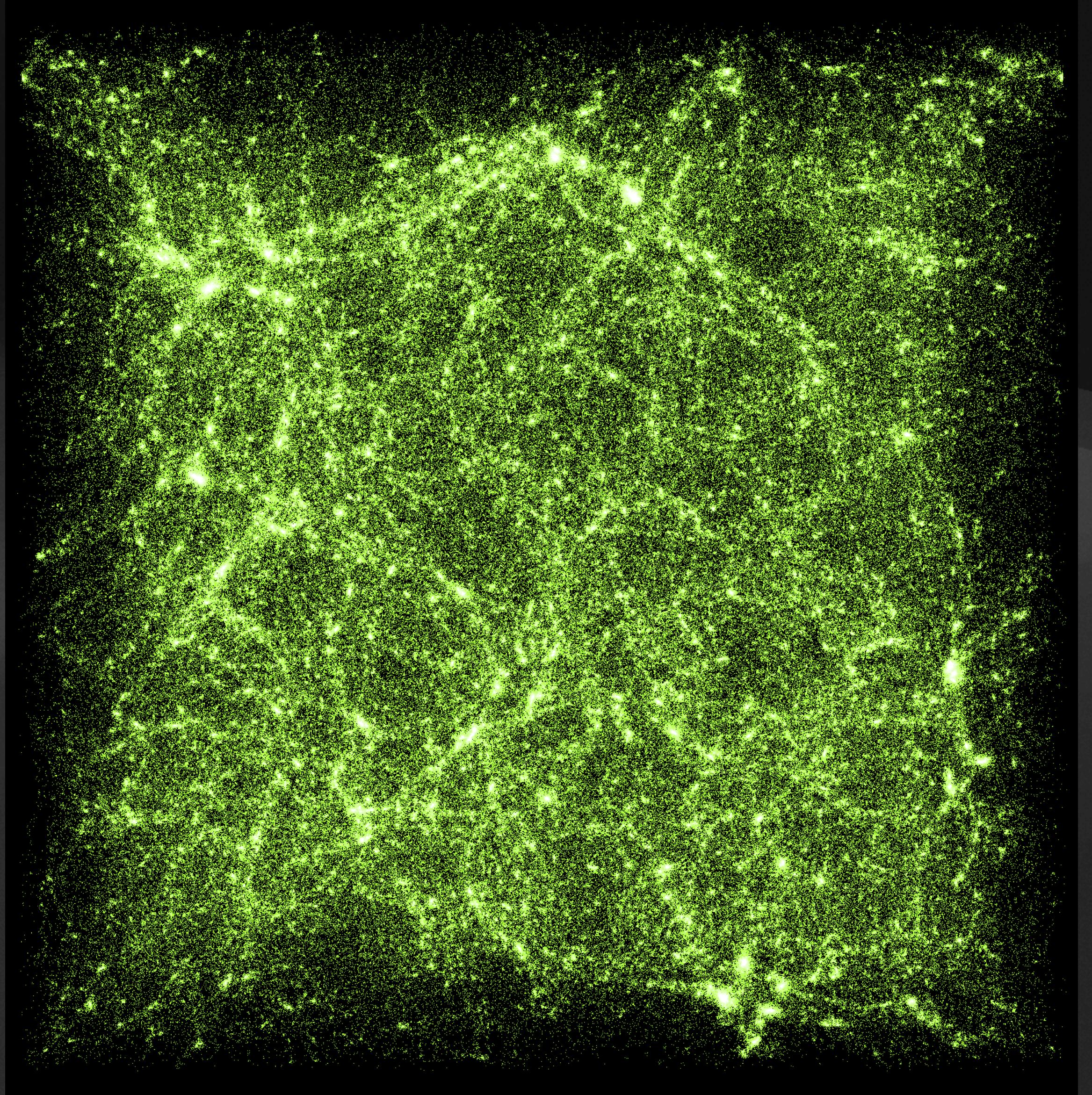
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N-Body Simulations

GADGET - Λ CDM

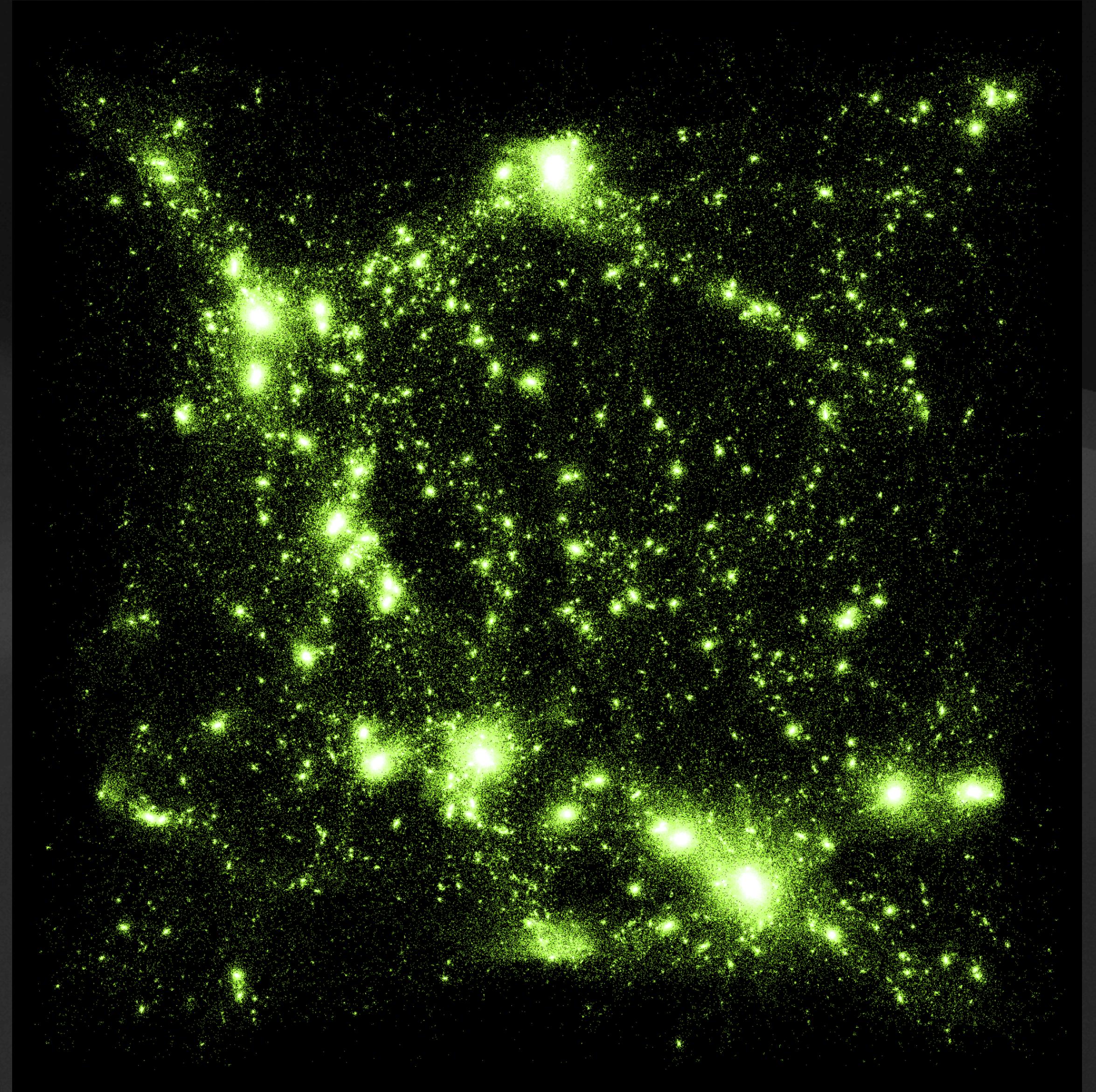
- Collision-less simulations
- Smoothed particle hydrodynamics
- Periodic boundary conditions
- Comoving coordinates
- Tree-Particle Mesh algorithm



N-Body Simulations

NU-GADGET - GNQ

- Growing Neutrino Quintessence
- Time-evolving fifth force
- Variable-mass simulation particles
- Non-constant interaction strength
- Adaptive Mesh Refinement



N-Body Simulations

My code

- Radiation-Dominated Era (RDE)
- Λ CDM control
- Initial conditions at initial redshift
- Scaling and flatness checks
- Screening mechanism



Future Prospects

- Explore whether PDMHs could account for the whole dark matter component
- Test their resistance to tidal disruptions and their possible merger history
- Study if non-sphericity could enhance their detectability
- Analyse eventually possible detection experiments
 - Gravitational-Wave Detectors
 - Stellar Streams Gaps



Thank you for your attention