Can Tides Disrupt Cold Dark Matter Subhaloes?

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Tidal evolution of dynamical times. The internal period $t_c(r)$ of a circular orbit of radius r in cuspy dark matter subhaloes tends towards zero for $r \to 0$, whereas for cored models, it approaches a constant, non-zero value. Consequently for cuspy subhaloes there is always a subset of radii for which $t_c(r) \ll T_{orb}$. As the strongest tidal interaction happens on a timescale of some fraction of the orbital period T_{orb} within the host halo, we can assume that for particles with $t_c(r) \ll T_{orb}$, the tidal interaction is perceived as a mere adiabatic perturbation. Using empirical formulae for the tidal evolution of structural parameters of subhaloes obtained from controlled simulations, Fig. 1 shows how dynamical times evolve with tidal mass loss: for cuspy subhaloes, $t_c(r/a)$ decreases (where a is the profile scale radius), and in turn the fraction of particles that react adiabatically increases. Furthermore with $t_c(r/a)$ decreasing, cuspy subhaloes have increasing multiples of their dynamical time to relax and reach equilibrium between subsequent tidal interactions.

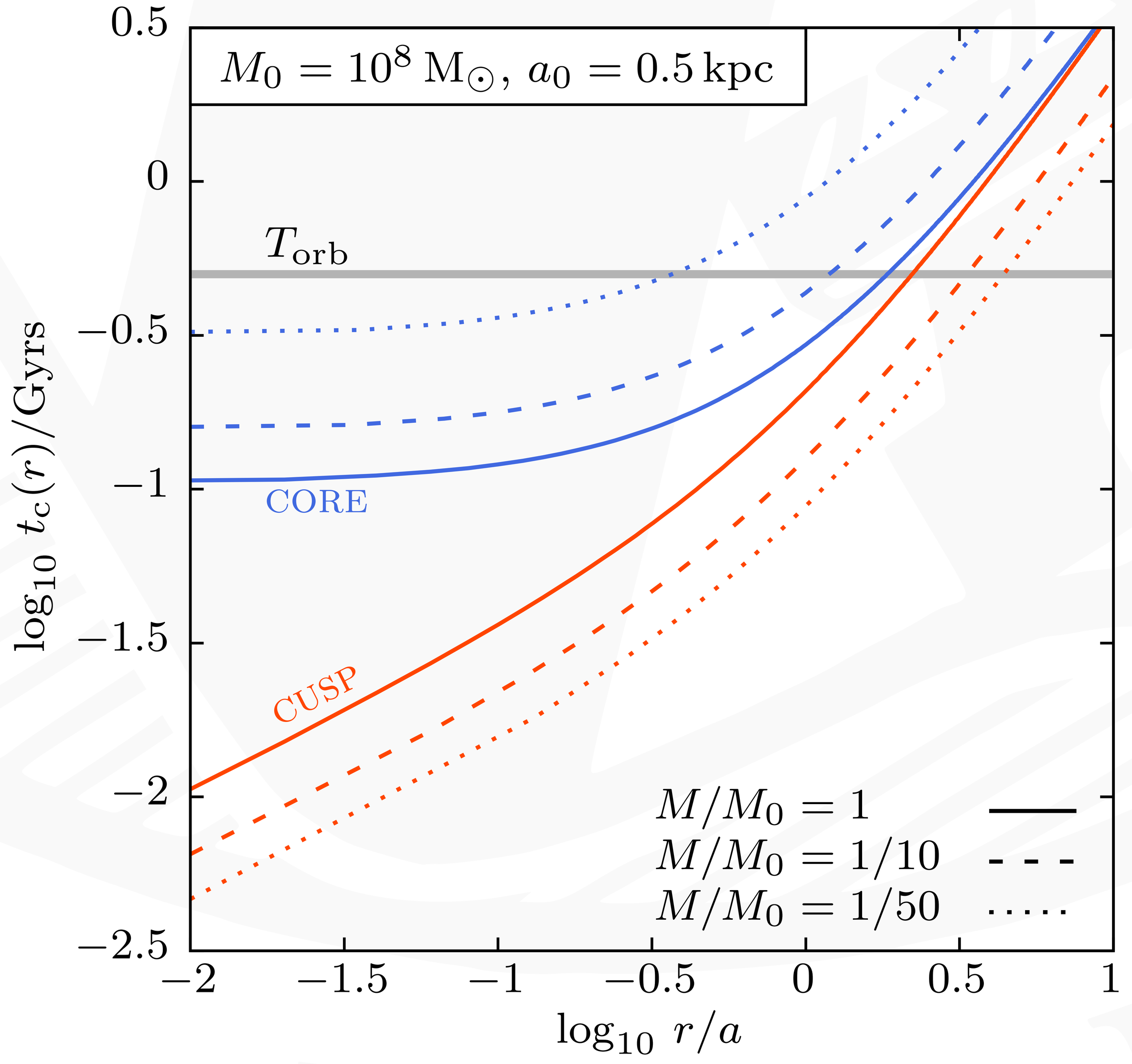

Fig. 1: Dynamical times $t_c(r/a)$ for cuspy subhaloes decrease during tidal stripping, and the fraction of particles in the subhalo which react adiabatically to the tidal perturbation increases. This is shown for Dehnen profiles, denoting by a the scale radius and by M/M_0 the remnant bound mass fraction.

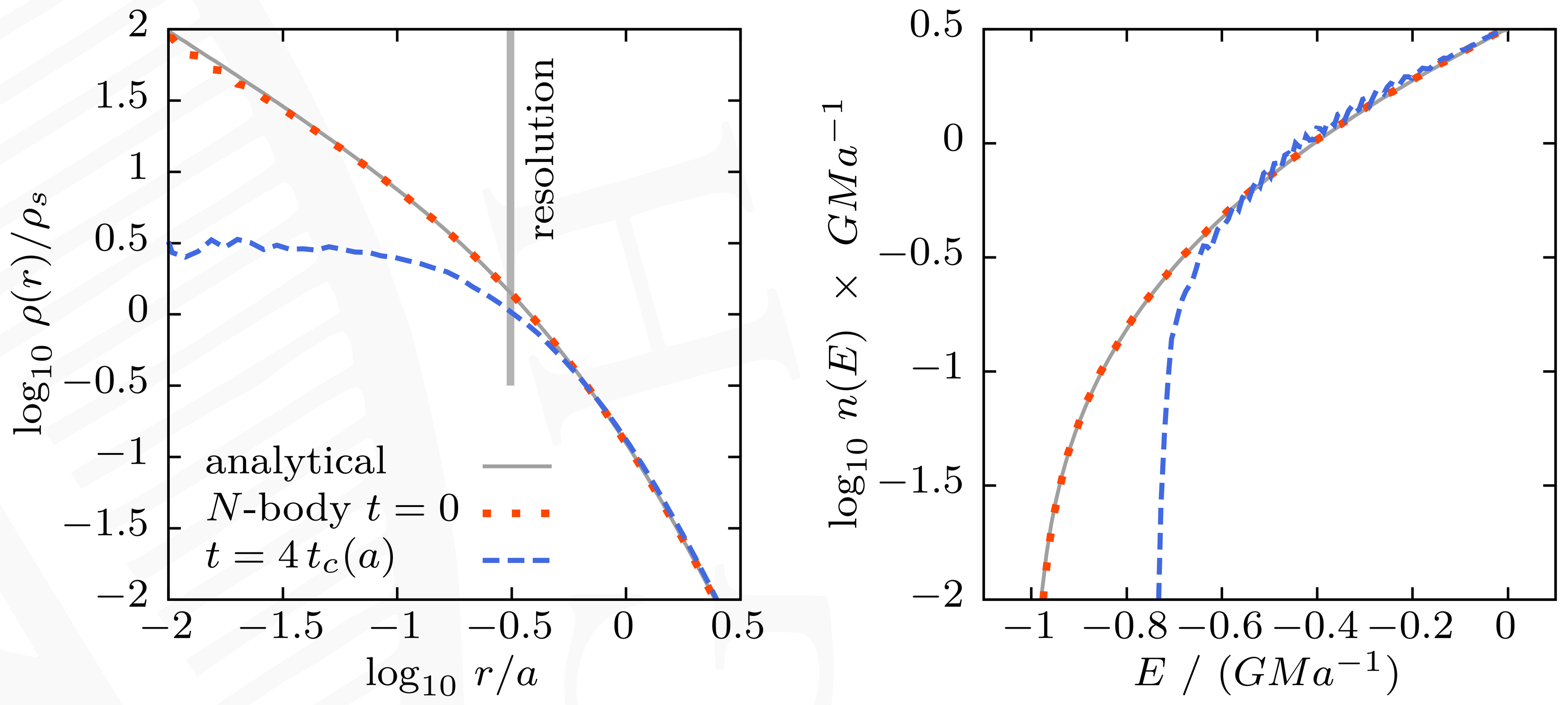

Fig. 2: A cuspy subhalo (in isolation) forms a density core on the scale of the spatial resolution of the simulation.

Cusp reconstruction. In simulations, cuspy subhaloes form artificial density cores (Fig. 2). Motivated by the results of numerical experiments that the central slope of the dark matter profile remains unaffected by tidal evolution, we aim to reconstruct the density cusp for a subhalo in a Milky Way-like host. For this purpose, at apocentre, we fit an $\{\alpha, \beta, \gamma\}$-profile to the bound particles of the subhalo, fixing the central slope $\gamma = 1$ and matching r_{max} and $M_{max} = M(< r_{max})$ of the simulated subhalo, where by r_{max} we denote the radius of maximum circular velocity. We then generate an equilibrium N-body realisation of $N = 10^7$ particles of the fitted density profile, and place it on the orbit of the simulated subhalo. By periodically reconstructing the density cusp, we can follow the tidal evolution of the subhalo for arbitrarily large fractions of tidally stripped mass. **We therefore argue that dark matter subhaloes with cuspy density profiles cannot be completely disrupted by smooth tidal fields.**

Micro-galaxies. Using a distribution-function based approach, we embed massless stellar tracers in the cuspy subhalo, tailored to match the Tucana III dwarf. We follow the tidal evolution of the model down to sub-solar luminosities and a luminosity-averaged line-of-sight velocity dispersion of $\sigma = \langle \sigma_{los}^2 \rangle^{1/2} < 0.5\,\mathrm{km\,s^{-1}}$ (Fig. 3). The embedded dwarf galaxy is not disrupted by tides.

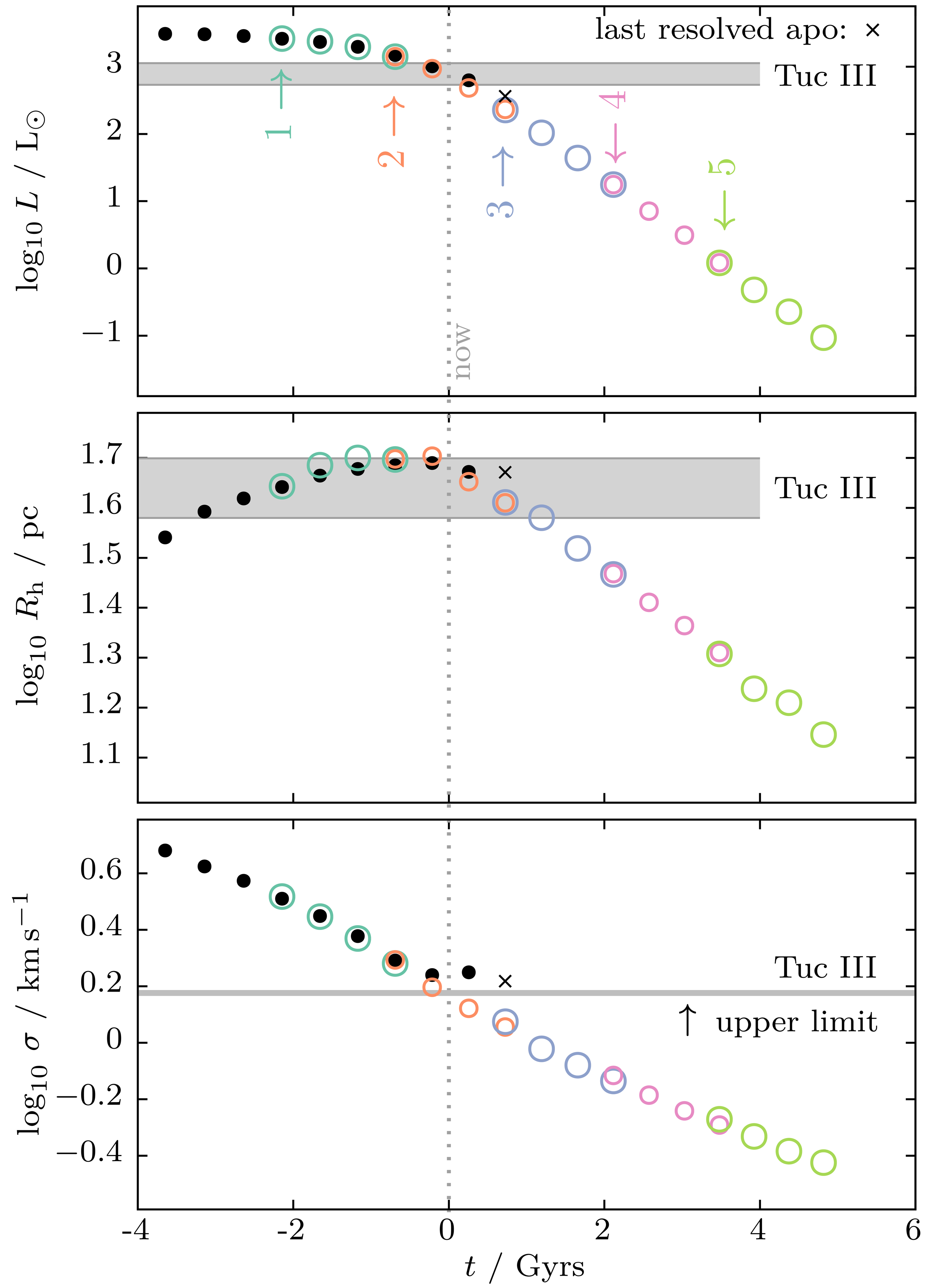

Fig. 3: Tidal evolution of a dSph galaxy (tailored to match the Tucana III dwarf) embedded in a cuspy subhalo. Tides can strip dSph galaxies down to sub-solar luminosities. Remnant *micro-galaxies* would appear as co-moving groups of metal-poor, low-mass stars of similar age, embedded in sub-kpc dark matter subhaloes. Numbered open circles indicate the periodical cusp reconstructions, whereas filled circles correspond to the initial simulation.

RE & J. Peñarrubia (2019), `arXiv:1906.01642`