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The asymptotic tidal remnants of cold dark matter subhalos

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rerrani.github.io

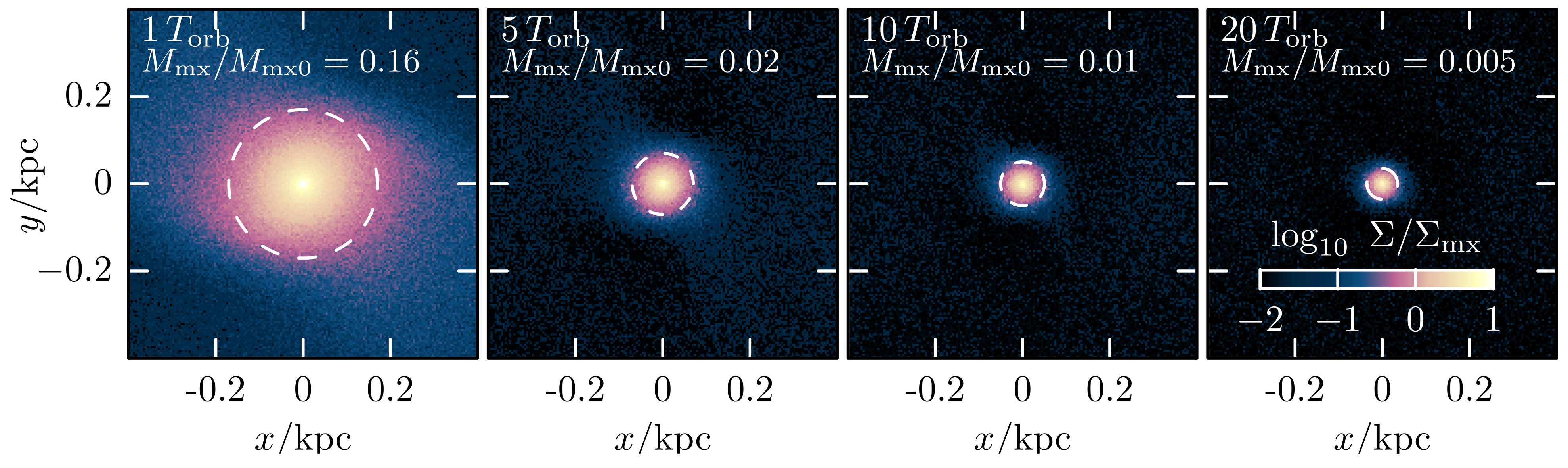

Fig. 1: The tidal mass loss of an NFW cold dark matter subhalo decelerates with time. The subhalo asymptotically approaches a stable remnant state.

Asymptotic profile. As tides strip a cold dark matter subhalo, its outer density slope steepens, while the inner density cusp remains unchanged. The shape of the stripped density profile converges, and is well-approximated by an exponentially-truncated NFW cusp,

$$\rho_{\rm asy}(r) = \frac{\rho_{\rm cut}\, r}{r_{\rm cut}} \exp\left(-\frac{r}{r_{\rm cut}}\right) .$$

The truncation radius is set solely by the mass fraction that remains bound to the remnant.

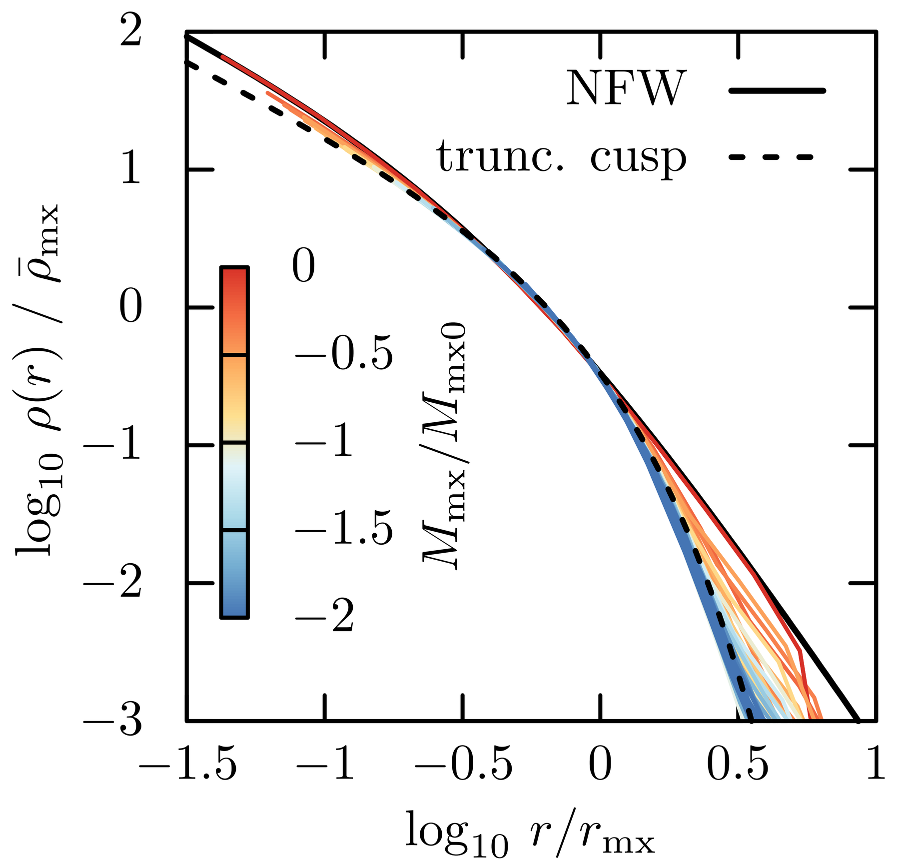

Fig. 2: Truncated cusp

Tidal tracks. Consistent with earlier work, we find that the evolution of the characteristic parameters of the remnant (e.g., $r_{\rm mx}$, $V_{\rm mx}$) depends solely on the total amount of mass lost, and that these parameters evolve along well-defined "tidal tracks", independent of orbital eccentricity or of the number of orbits required to strip the system. Our improved numerical resolution allows us to extend and revise the tidal tracks proposed in earlier studies.

Remnant mean density. The remnant properties depend on the initial density contrast between subhalo and host, expressed as the ratio of circular orbital periods within the subhalo, $T_{\rm mx0} = 2\pi r_{\rm mx0}/V_{\rm mx0}$, and the host at pericentre, $T_{\rm peri} = 2\pi r_{\rm peri}/(220\,{\rm km\,s^{-1}})$.
For subhalos with $T_{\rm mx0}/T_{\rm peri} > 2/3$ (the "heavy mass-loss regime"), the final characteristic density appears set by the mean density of the host at pericentre: the subhalo is stripped gradually until its characteristic orbital period $T_{\rm mx}$ approaches a fixed fraction of the host circular period at pericentre:

$$T_{\rm mx,\,asy} \approx T_{\rm peri}/4\ .$$

Subhalos with $T_{\rm mx0}/T_{\rm peri} < 2/3$ lose modest amounts of mass and approach asymptotically a remnant with a characteristic density set largely by its initial value.

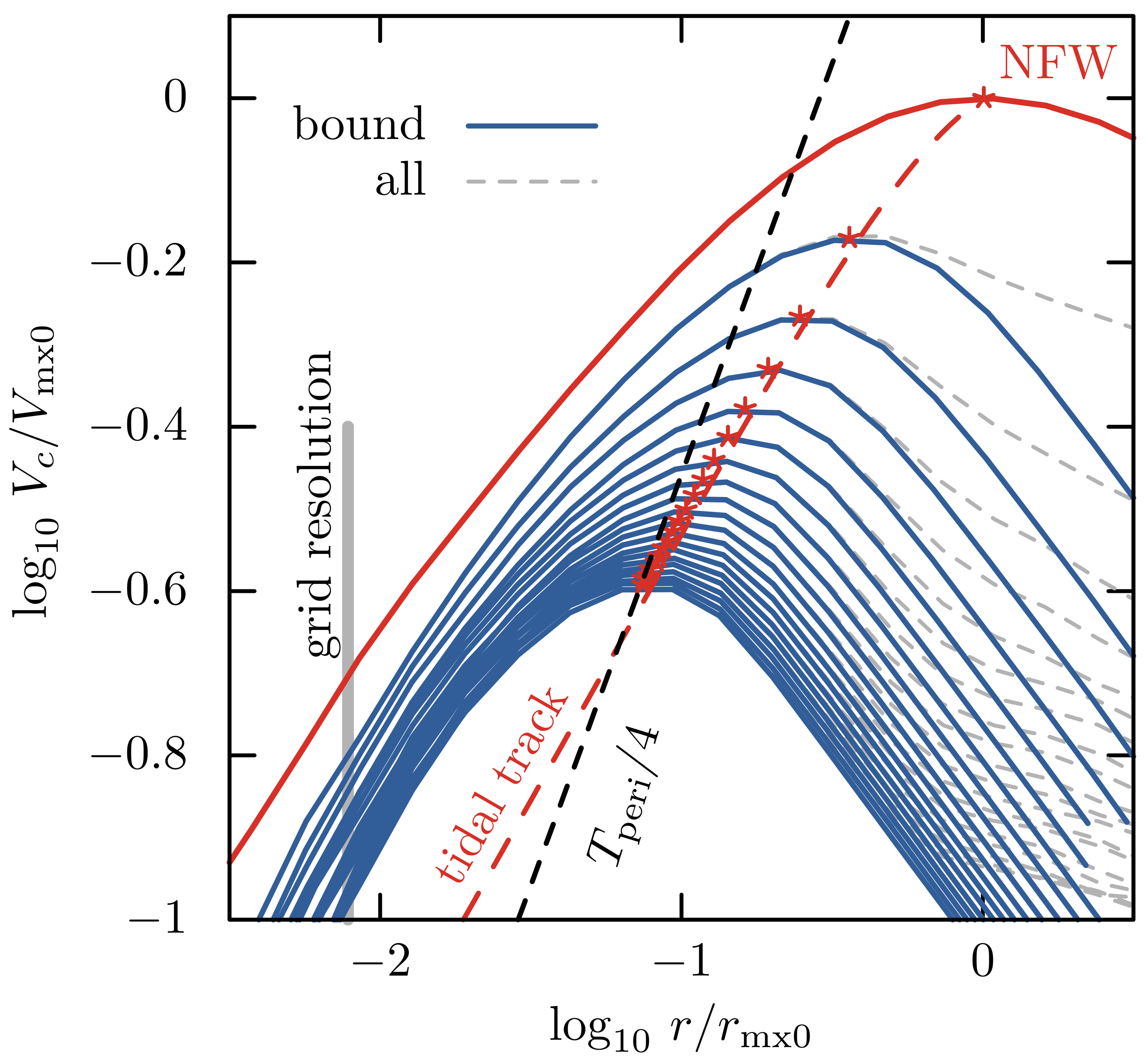

Fig. 3: The asymptotic density of a subhalo in the heavy mass-loss regime is set solely by the properties of the host at pericentre. The circular velocity curves shown are spaced by one orbital period.

Orbital eccentricity. Orbital eccentricity "delays" the tidal evolution relative to subhalos on circular orbits at equal pericentre. The asymptotic properties as well as the tidal track are independent of eccentricity. As an example, it takes approximately 5 times more orbits for a subhalo on a 1:5 orbit (and 8 times more on a 1:20 orbit) to evolve to the same stage as a subhalo on a circular orbit.

Numerical resolution. Resolving tidal remnants requires excellent numerical resolution; poorly resolved subhalos have systematically lower characteristic densities and are more easily disrupted. Even simulations with excellent spatial and time resolution fail when the final remnant is resolved with fewer than 3000 particles enclosed within its radius of maximum circular velocity.

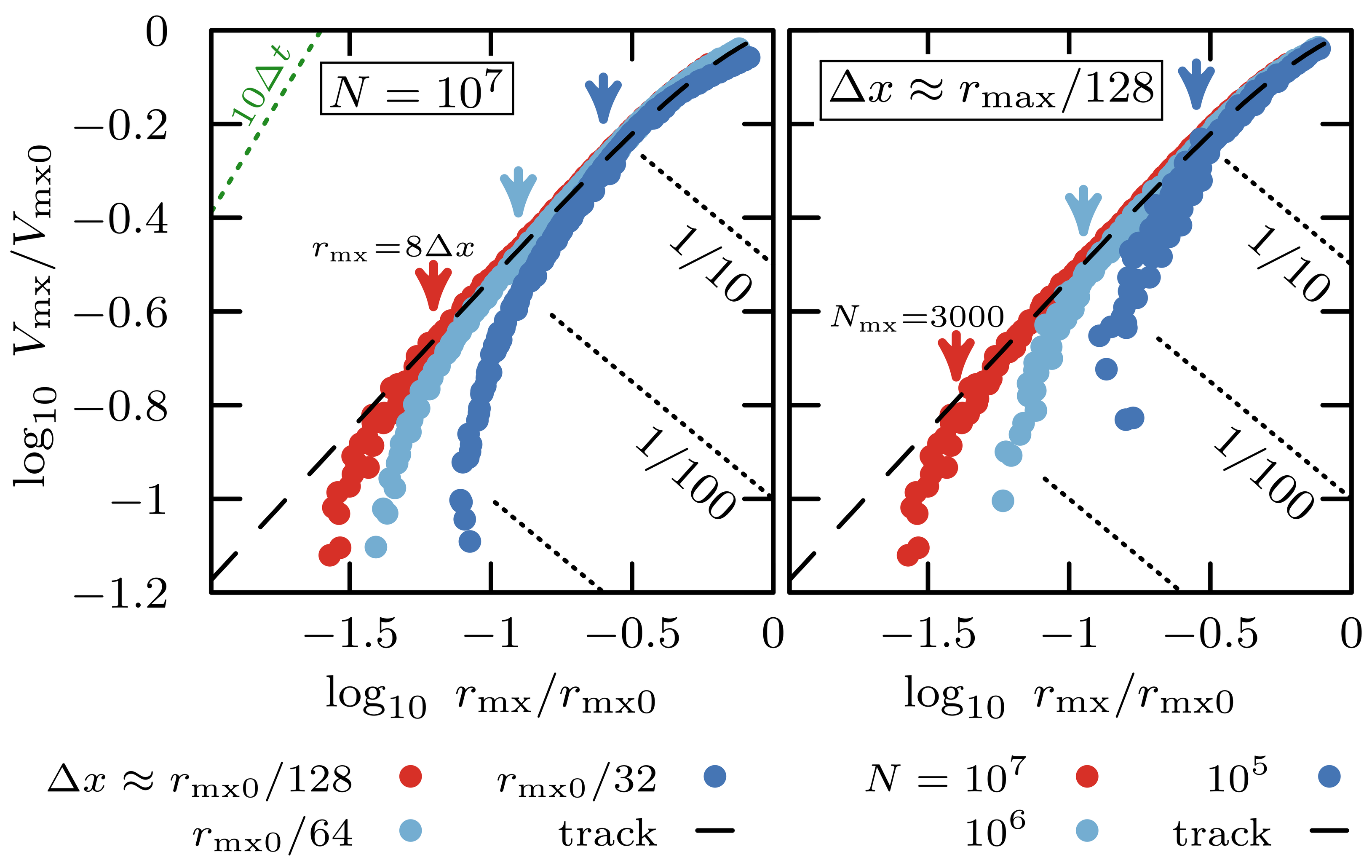

Fig. 4: The evolution of subhalo structure in simulations is highly sensitive to resolution. Poorly resolved halos systematically deviate from the *tidal track* and disrupt. Left: fixed particle number N, varying grid resolution Δx. Right: fixed Δx, varying N.

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