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Structure and kinematics of tidally limited satellite galaxies in LCDM

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rerrani.github.io

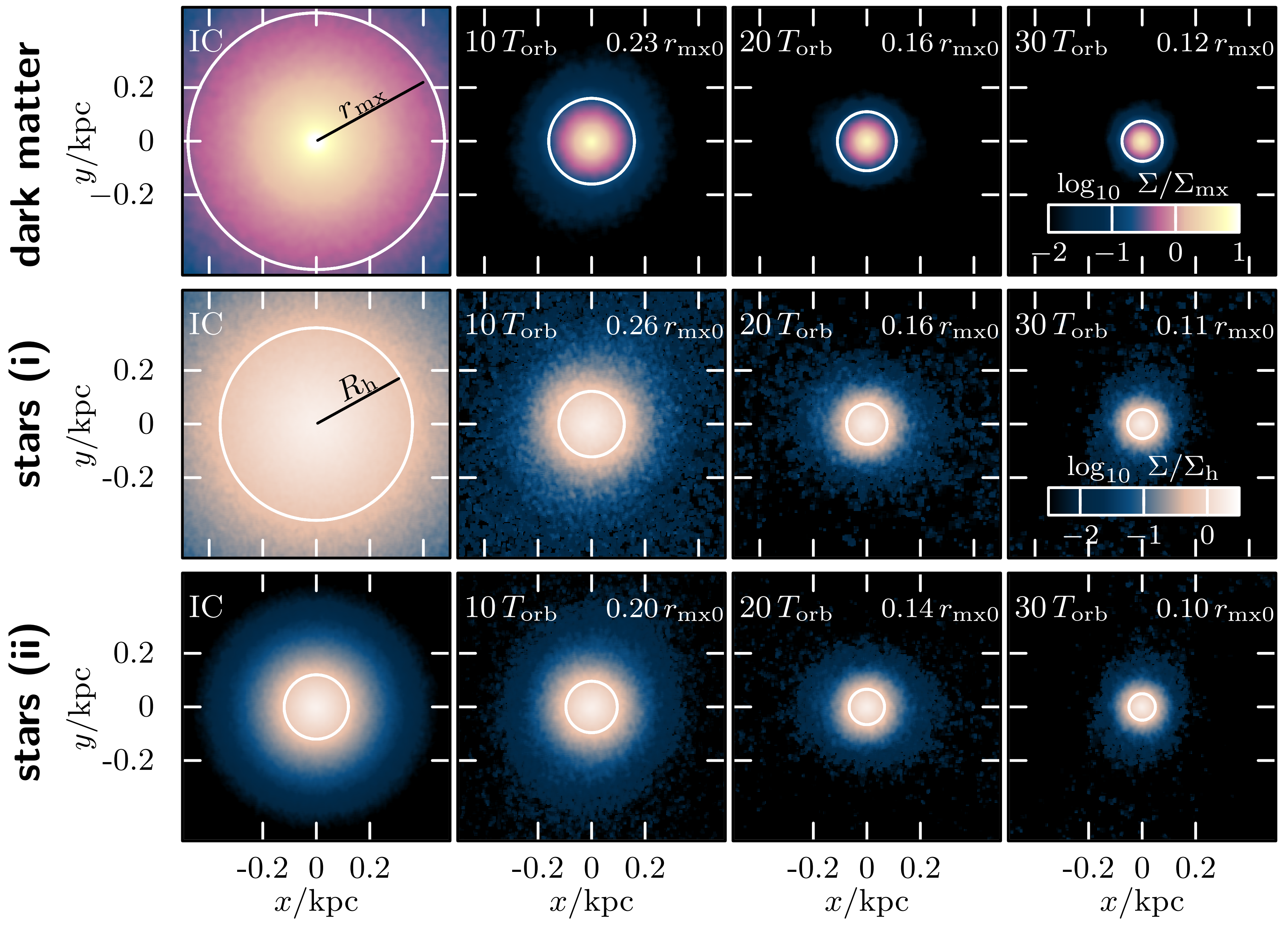

Fig. 1: The half-light radii of heavily stripped dwarf galaxies become direct tracers of the size of the cold dark matter halo they are embedded in. The top row shows apocentre snapshots of the tidal evolution of an NFW dark matter subhalo on an orbit with a pericentre-to-apocentre ratio of 1 : 5. The central and middle rows show the evolution of different stellar tracers embedded in this subhalo.

Controlled simulations. We run N-body simulations of the tidal evolution of NFW cold dark matter subhaloes on circular and eccentric orbits. Stars are modelled as massless tracers of the underlying potential, spanning a wide range of initial sizes and density profiles.

Tidal evolution. As tides strip an NFW subhalo, its characteristic size decreases, and the relative change in size decreases with subsequent pericentre passages: the tidal evolution slows down and a stable remnant state is asymptotically approached. Similarly, the half-light radii of embedded stellar components decrease during tidal stripping. Crucially, for the later stages of the tidal evolution, the size of the half-light radius follows closely the characteristic size of the dark matter subhalo they are embedded in, independent of their initial extent.

Energy truncation. Tidal evolution can be modelled in terms of binding energy: tides gradually truncate subhaloes energetically, systematically removing particles with low binding energies. The bound remnant consists of particles initially more strongly bound than the energy threshold imposed by tides. For the majority of particles, the initial binding energy alone is sufficient to determine when and whether a particle will be stripped or not. Initial and final binding energies are strongly correlated, in a way that allows the structure of the remnant to be inferred as a function of tidal mass loss. These relations hold regardless of the eccentricity of the subhalo orbit around its host.

Stellar tracers. If gravitationally unimportant, the stellar components of tidally stripped NFW subhaloes evolve according to how stars populate the initial energy distribution of the subhalo. The same gradual energy truncation applies to dark matter and stars, independent of the initial density structure or radial segregation of the stellar component. “Tidally limited” satellites have radii and velocity dispersions that trace directly the characteristic radius and velocity of the subhalo remnant.

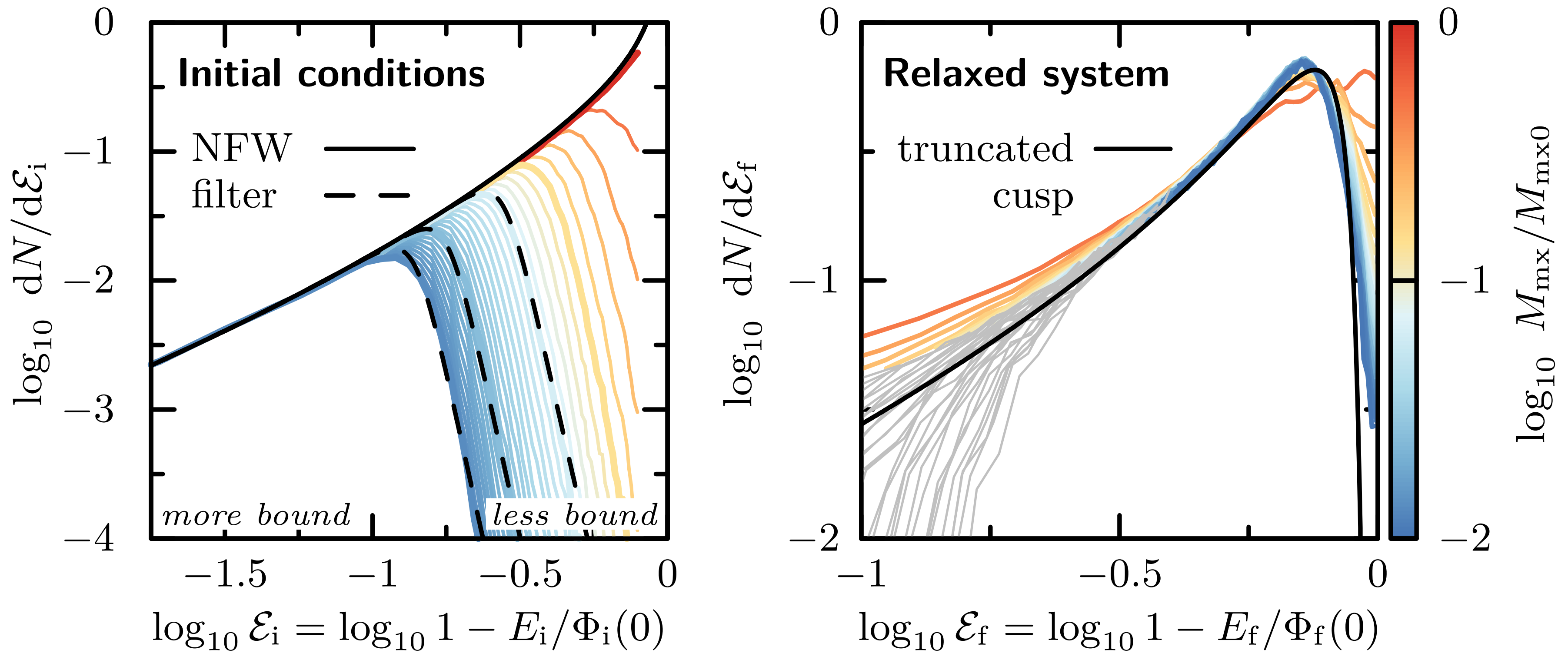

Fig. 2: Tides truncate an NFW subhalo sharply in energy, removing the least-bound particles first. The subhalo then relaxes to a new shape, which is well-approximated by an exponentially truncated cusp. The left panel shows bound particles in the ICs, the right panel bound particles in the relaxed remnant. Each curve corresponds to a simulation snapshot taken at apocentre.

Local Group galaxies. Our constraints may be expressed as a lower limit on the velocity dispersion of an embedded stellar remnant of a given size, or, equivalently, as an upper limit to the size of an embedded system of a given velocity dispersion. Inspection of available data for dwarf galaxies in the Local Group, however, reveals a number of ultrafaint satellites that breach these limits.

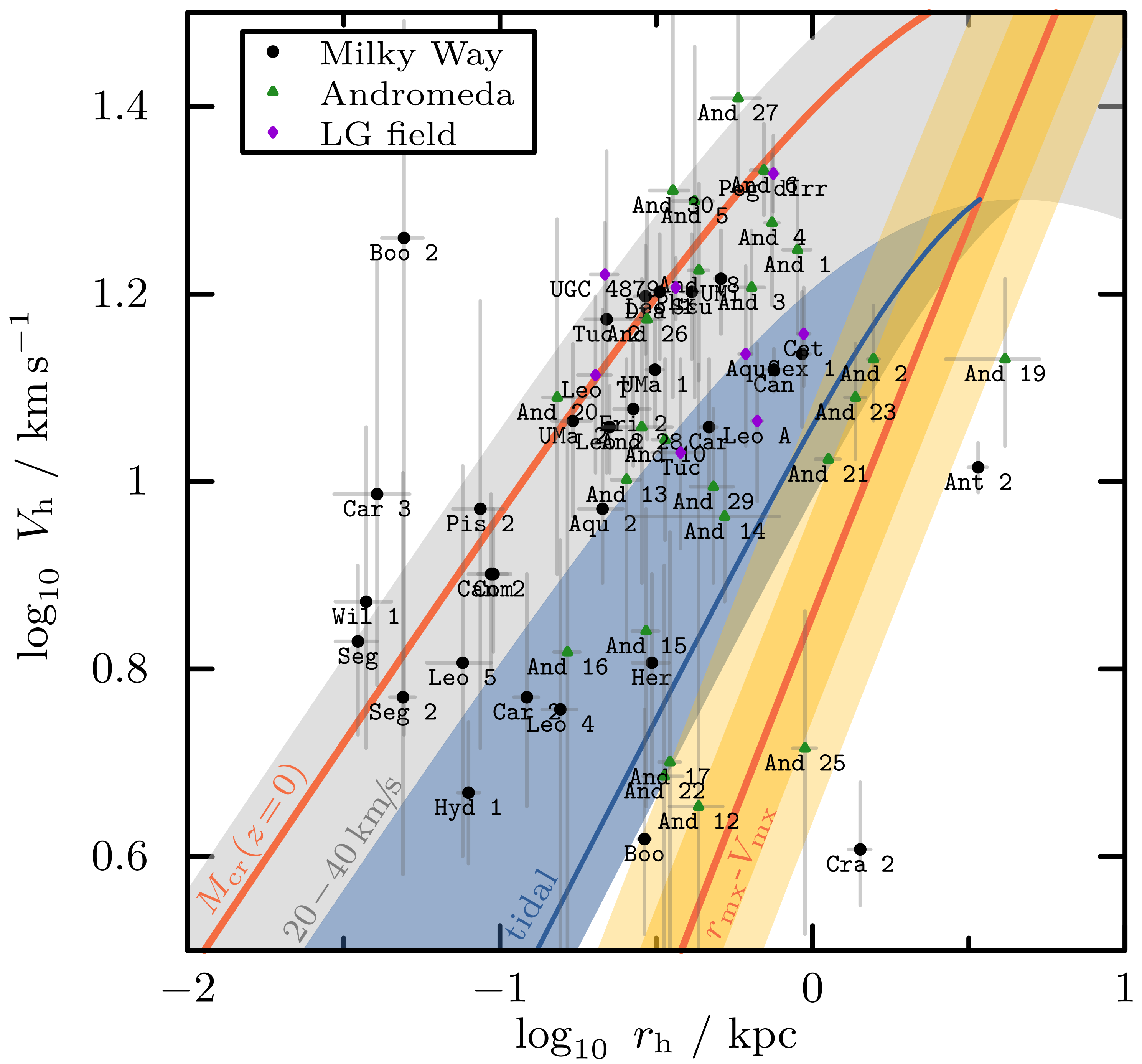

Fig. 3: The large sizes and low velocity dispersions of the Milky Way satellites Antlia-2 and Crater-2 appear in conflict with cold dark matter predictions for tidally stripped systems. Shown are 3D half-light radii and circular velocities (estimated from the observed line-of-sight velocity dispersion) for Local Group dwarf galaxies. Grey bands correspond to cold dark matter subhaloes sufficiently massive to allow star formation, while the blue shaded region shows the parameter space accessible through tidal stripping.

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