Dark Matter Halos:

Causes & Consequences of Halo Mass Loss

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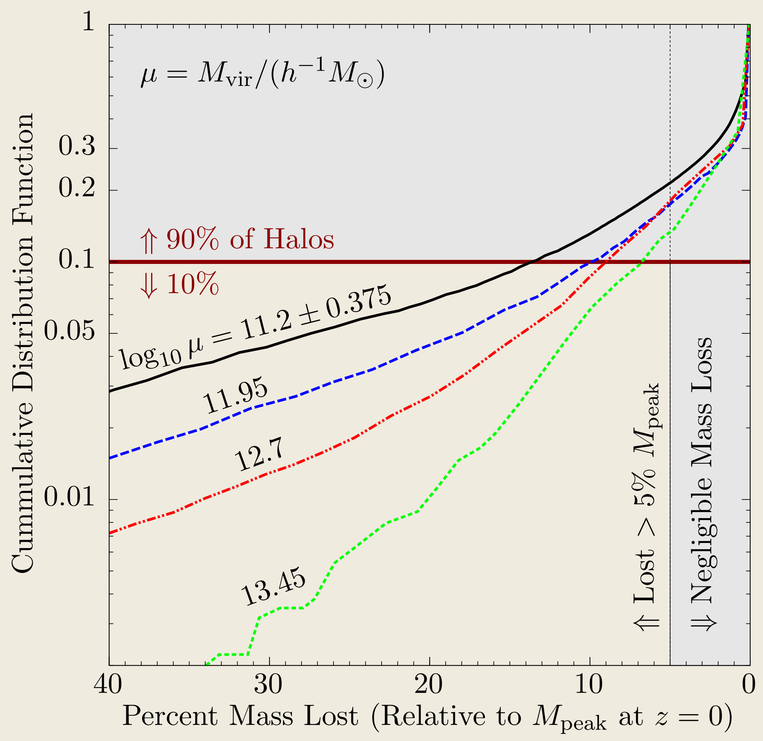
1 ABSTRACT

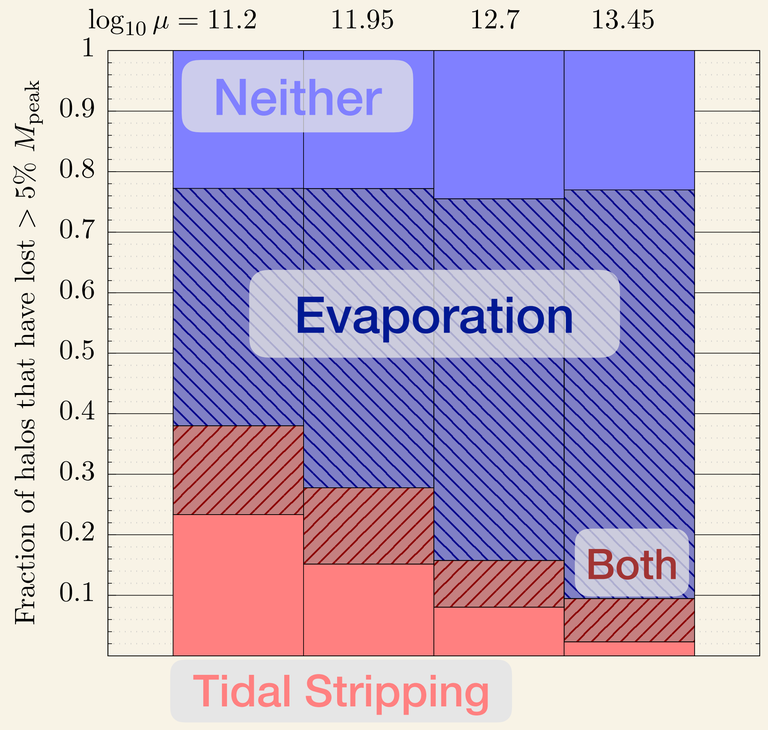
We study the properties of distinct dark matter halos that have a virial mass $M_{\rm vir}$ at $z=0$ less than their peak mass $M_{\rm peak}$ and identify **two primary causes of halo mass loss: evaporation after a major merger** and **tidal stripping by a massive neighboring halo**. Major mergers initially boost $M_{\rm vir}$ and typically cause the final halo to become more prolate and less relaxed and to have higher spin and lower NFW concentration. As the halo relaxes, high energy material from the recent merger gradually escapes, temporarily resulting in a net negative accretion rate that reduces the halo mass by 5-15% on average. Halos that experience a major merger around $z=0.5$ typically reach a minimum mass around $z=0$. Tidal stripping occurs mainly in dense regions, and it causes halos to become less prolate and have lower spins and higher NFW concentrations. Tidally stripped halos often lose a large fraction of their peak mass (> 20%) and most never recover (or even re-attain a positive accretion rate). Low mass halos are often strongly affected by both evaporative mass loss and tidal stripping, while high mass halos are predominantly influenced by evaporative mass loss and show few signs of significant tidal stripping.

2 Is halo mass loss common?



At $z=0$, 22% of low mass halos ($\log\mu$ =11.2) have lost more than 5% of their peak mass, and 7% have lost more than 20%. Only 12% of high mass halos ($\log\mu$ =13.45) have lost > 5% of their peak mass.

3 Why do halos lose mass?



Most halos lose mass via evaporation after a major (or minor) merger. Pure tidal stripping accounts for 23% of low mass halos that have lost mass, but very few high mass halos. Some halos experience both evaporation and tidal stripping. Around 22% of halos that have lost mass neither had a recent major merger nor experienced tidal stripping (rather, these typically experienced evaporation after a minor merger).

4 What happens when halos lose mass?

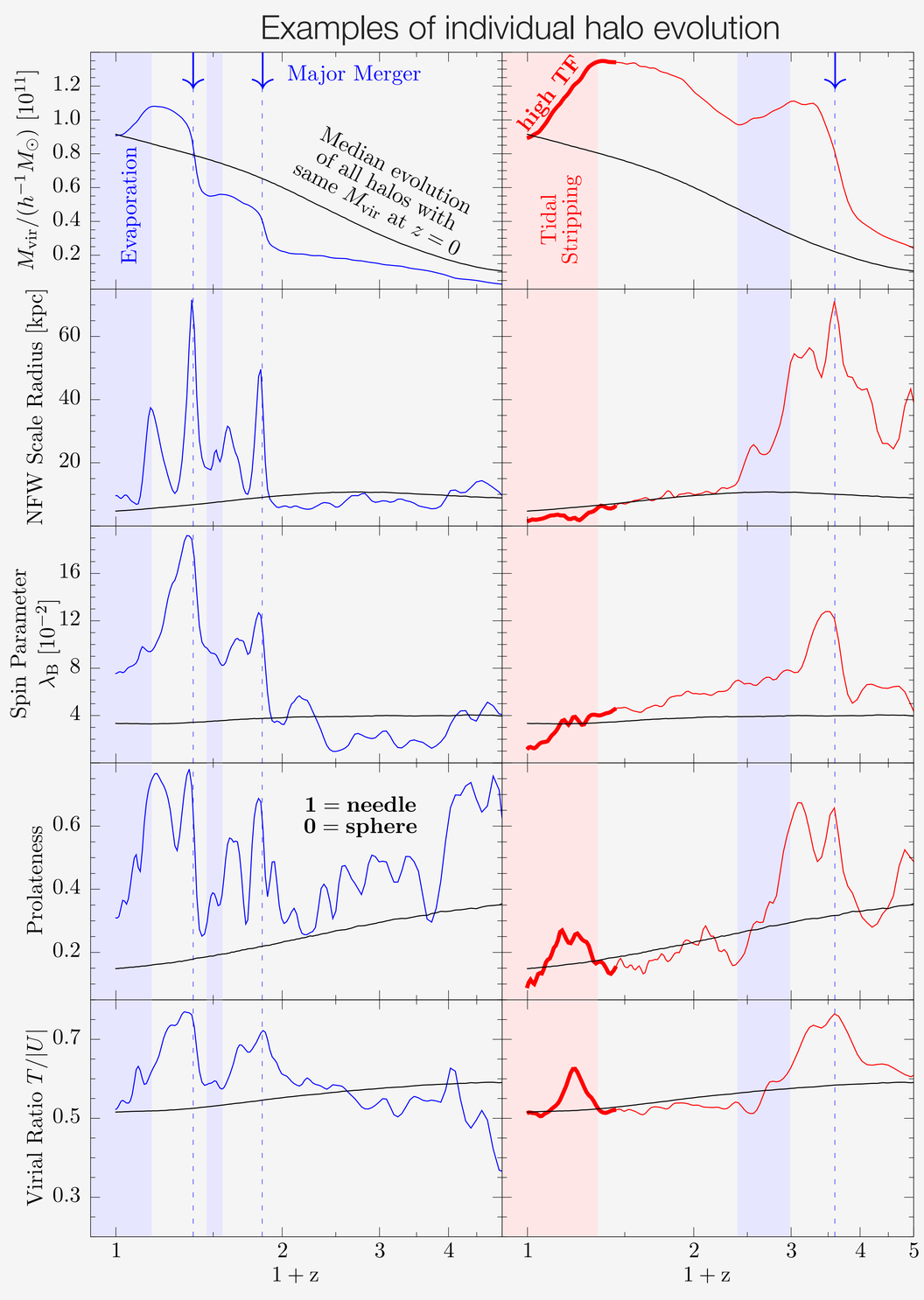
Tidal Stripping:

Strong tidal force from a nearby massive halo removes loosely bound particles from a halo. 40% of tidally stripped low mass halos lose more than 20% of their peak mass. Tidally stripped halos develop:

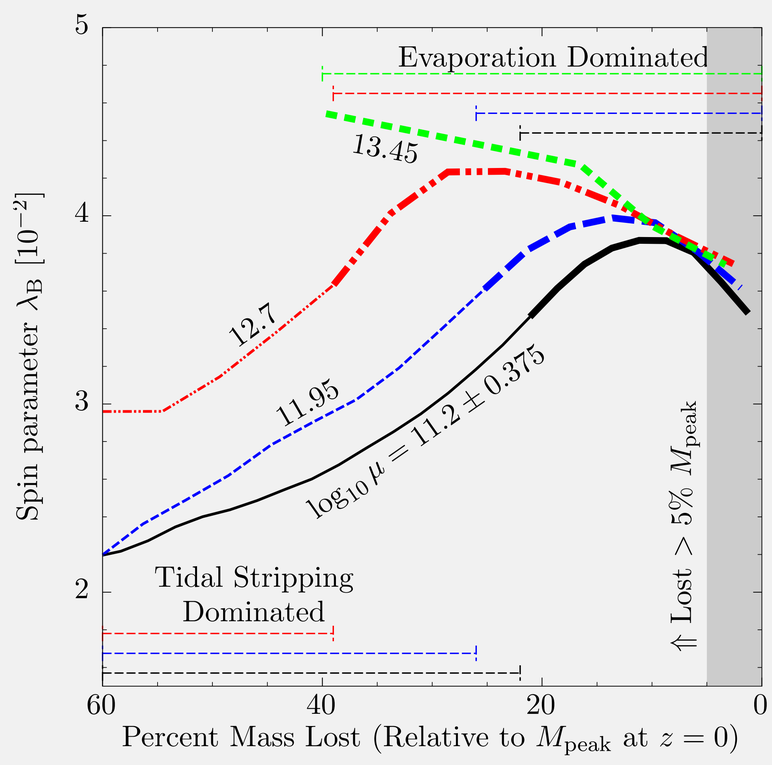
- **Low NFW scale radius** (high concentration) due to steepening outer profile
- **Low spin parameter** due to preferential removal of high angular momentum material
- **Low prolateness** (they become rounder) due to preferential removal of particles on highly elliptical orbits.

Evaporation:

Major mergers typically cause **temporary jumps in NFW scale radius, spin parameter, and shape**. As halos relax after a merger, they shed high energy material (evaporate) and **settle back to lower values of scale radius, spin parameter, shape, and viral ratio**. After a major merger, halos typically lose 5-15% of their peak mass through evaporation.



5 Extending this analysis to all halos



- Low mass halos ($\log\mu$ =11.2) that have lost 5-15% of their peak mass most commonly experienced evaporative mass loss (temporarily high spin parameters).
- Low mass halos that have lost greater than 20% of their peak mass typically are actively being tidally stripped (low spin parameters). More heavily stripped halos have lower spin parameters.
- Some low mass halos are strongly affected by tidal stripping, while high mass halos predominantly experience evaporative mass loss.

6 Connection to environment density

The median accretion rate of halos in high density environments is dramatically lower than in average density environments. A majority of **low mass halos** ($\log\mu$ =11.2) **in high density environments have negative accretion rates — they are losing mass via tidal stripping** (see **Lee et al. 2017 doi:10.1093/mnras/stw3348** for a full discussion of how halo properties depend on environment density). Tidal stripping rarely occurs in low density environments, since halos typically do not have massive neighbors nearby (tidal force strength correlates strongly with environment density). **Evaporative mass loss** is not as constrained by environment density, and **is common at all environment densities.**