THE EDGES OF DARK MATTER HALOS: THEORY AND OBSERVATIONS

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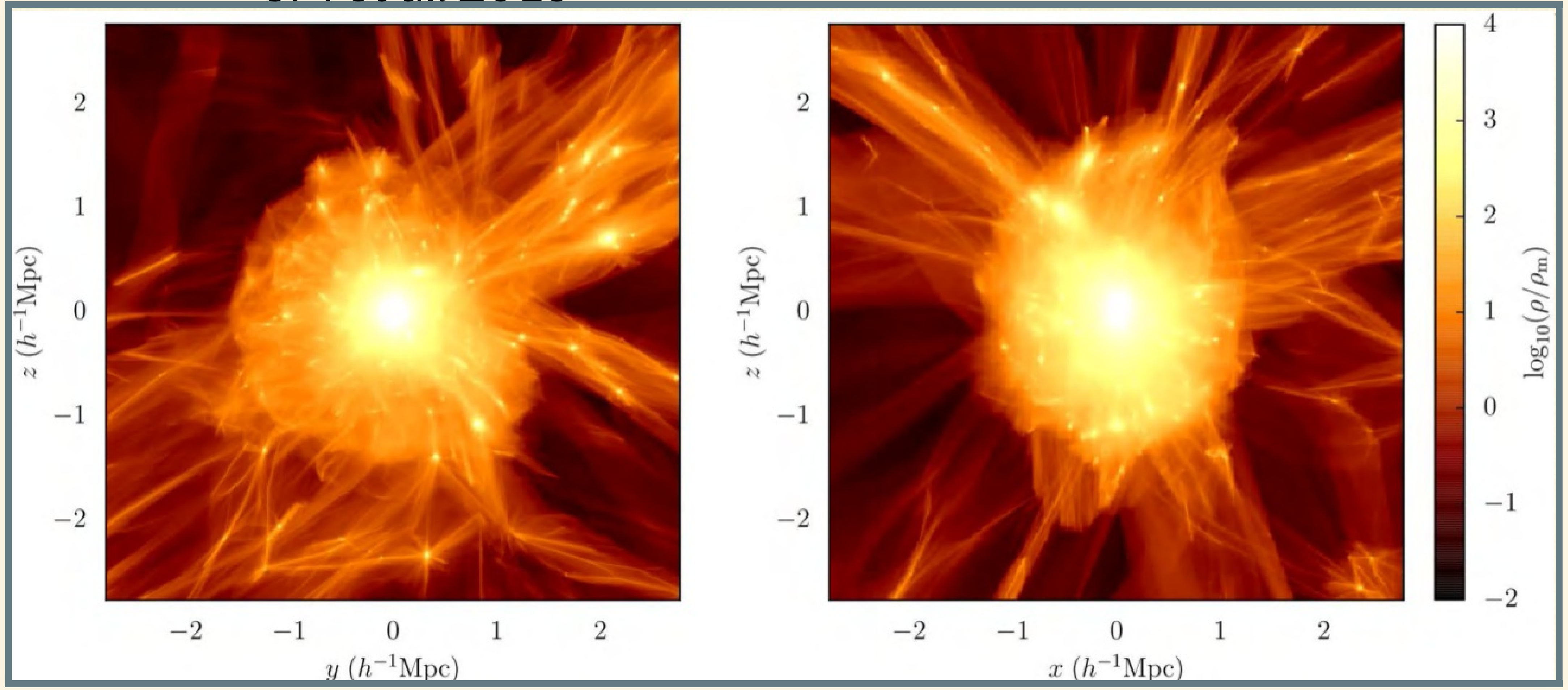
BOUNDARIES OF DARK MATTER HALOS

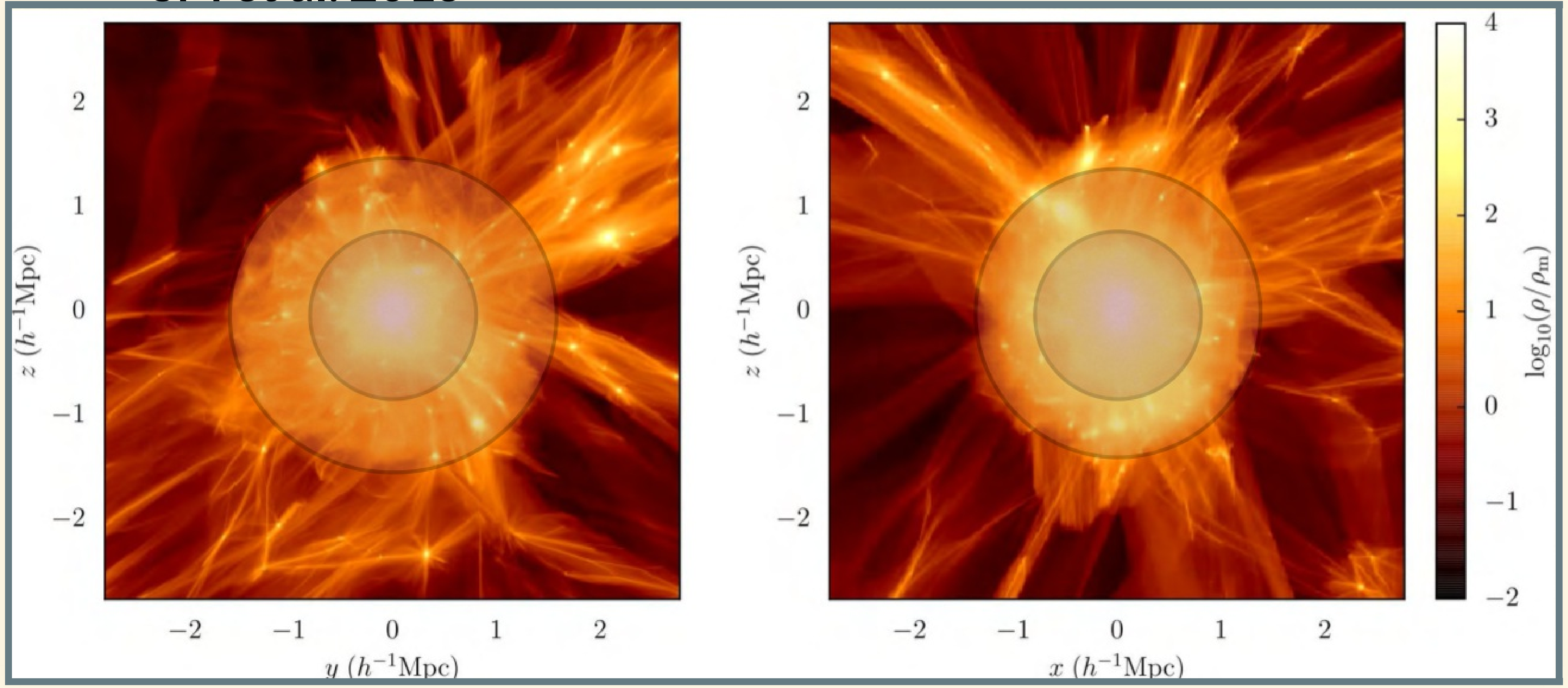
SM et al. 2015



- Universal density profile (Navarro Frenk & White '97) with $\rho \propto r^{-3}$ on large scales
- Mass formally diverges, require halo boundaries to be arbitrarily imposed
- Many different choices - $500\rho_{crit}$, $200\rho_c$, $\Delta_{vir}\rho_c$, $200\rho_m$

A SIMPLE VISUAL POP QUIZ

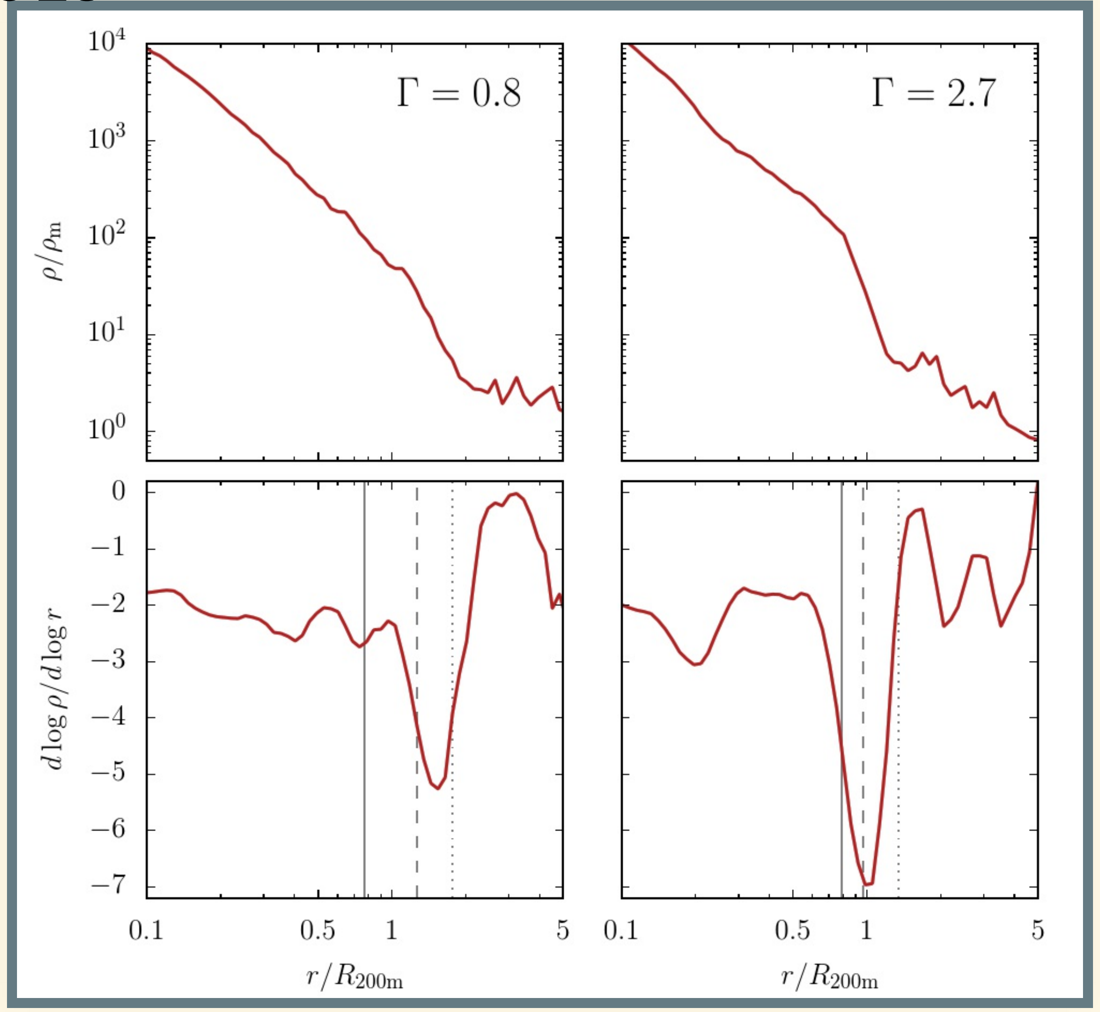
SM et al. 2015



- Where would you put the halo boundary?
  - Inner circle - A
  - Outer circle - B

THE DENSITY PROFILE OF THE TWO HALOS

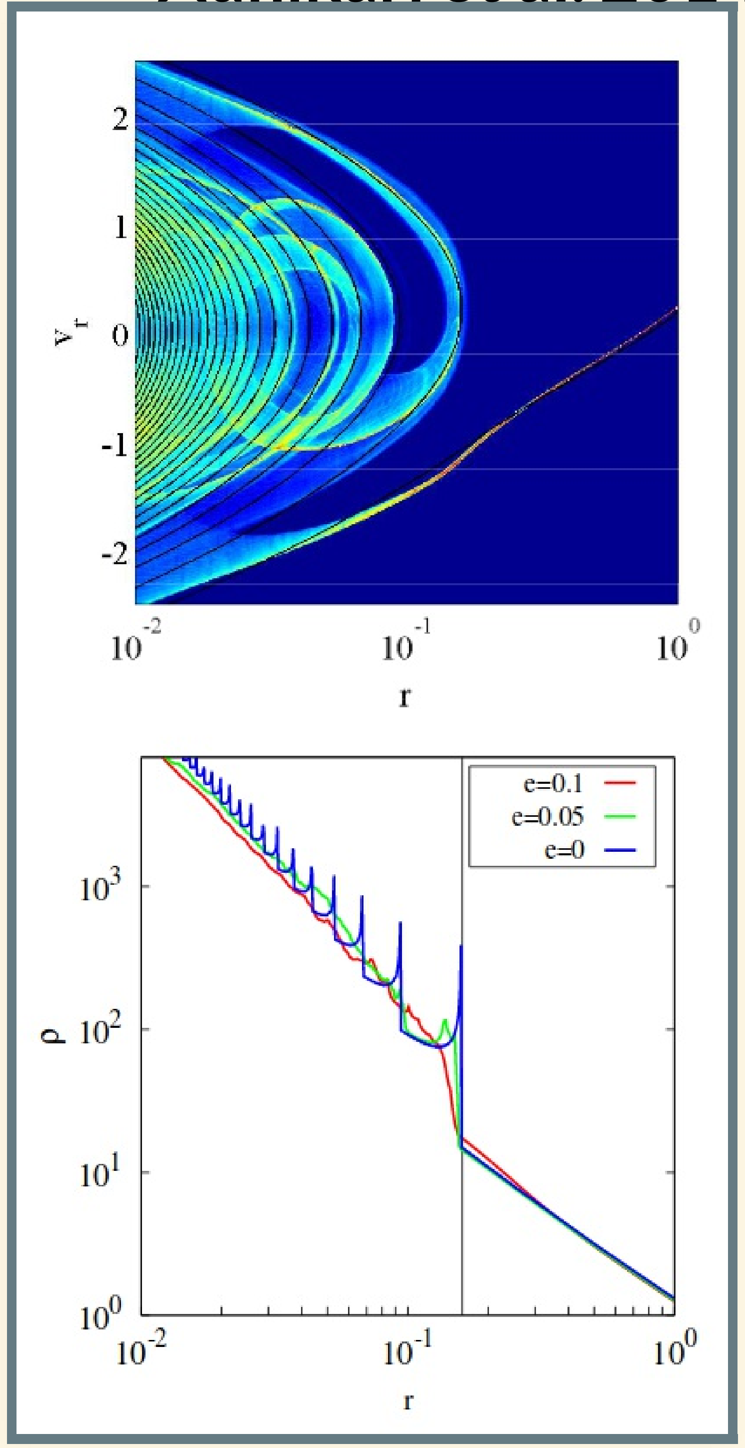
SM et al. 2015



- Sharp density jump, much steeper slopes than expected from NFW profiles (first pointed out by Diemer & Kravtsov 2014)
- Different location for the boundary even for similar mass halos

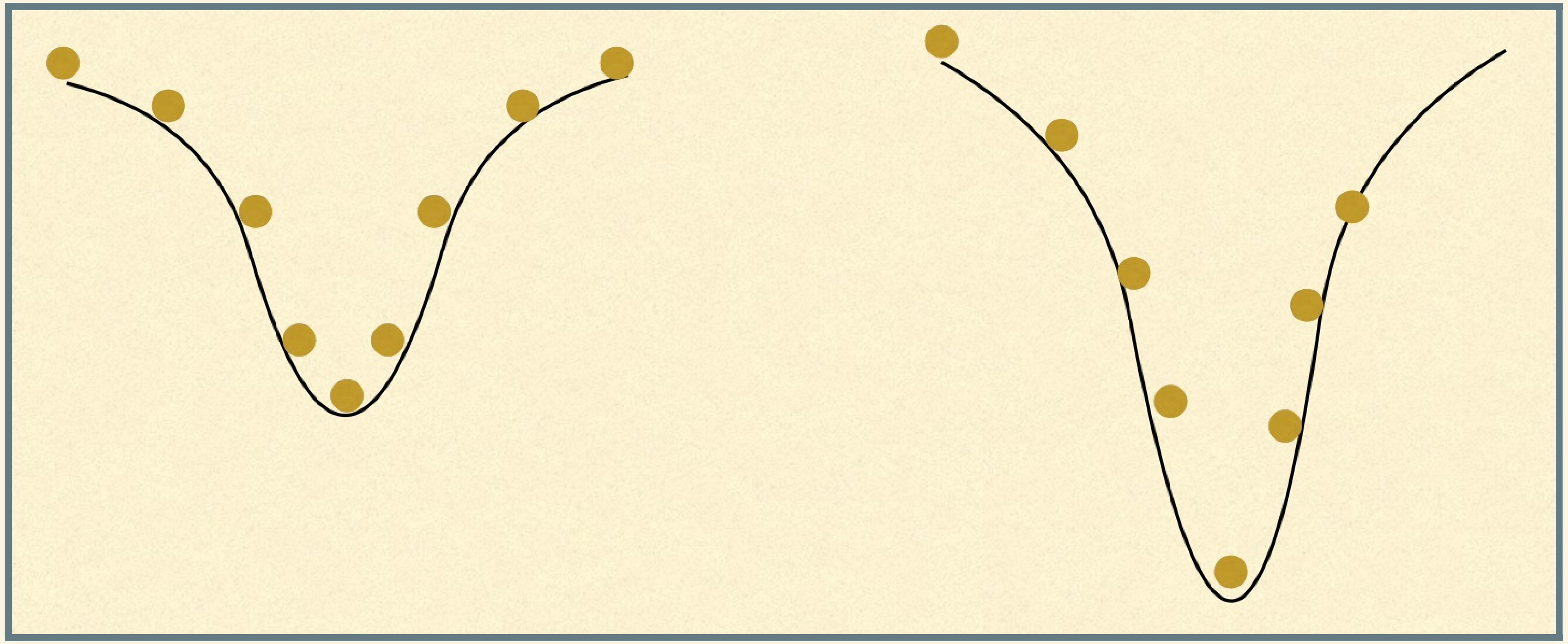
A PHYSICAL FEATURE: THE LAST CAUSTIC

Adhikari et al. 2014



- Self similar secondary infall on to an existing density peak (Fillmore and Goldreich 84, Bertschinger 85)
- The sharp drop off corresponds to the apocenter of recently accreting material
- Cleanly separates the infall region from the multi-stream region

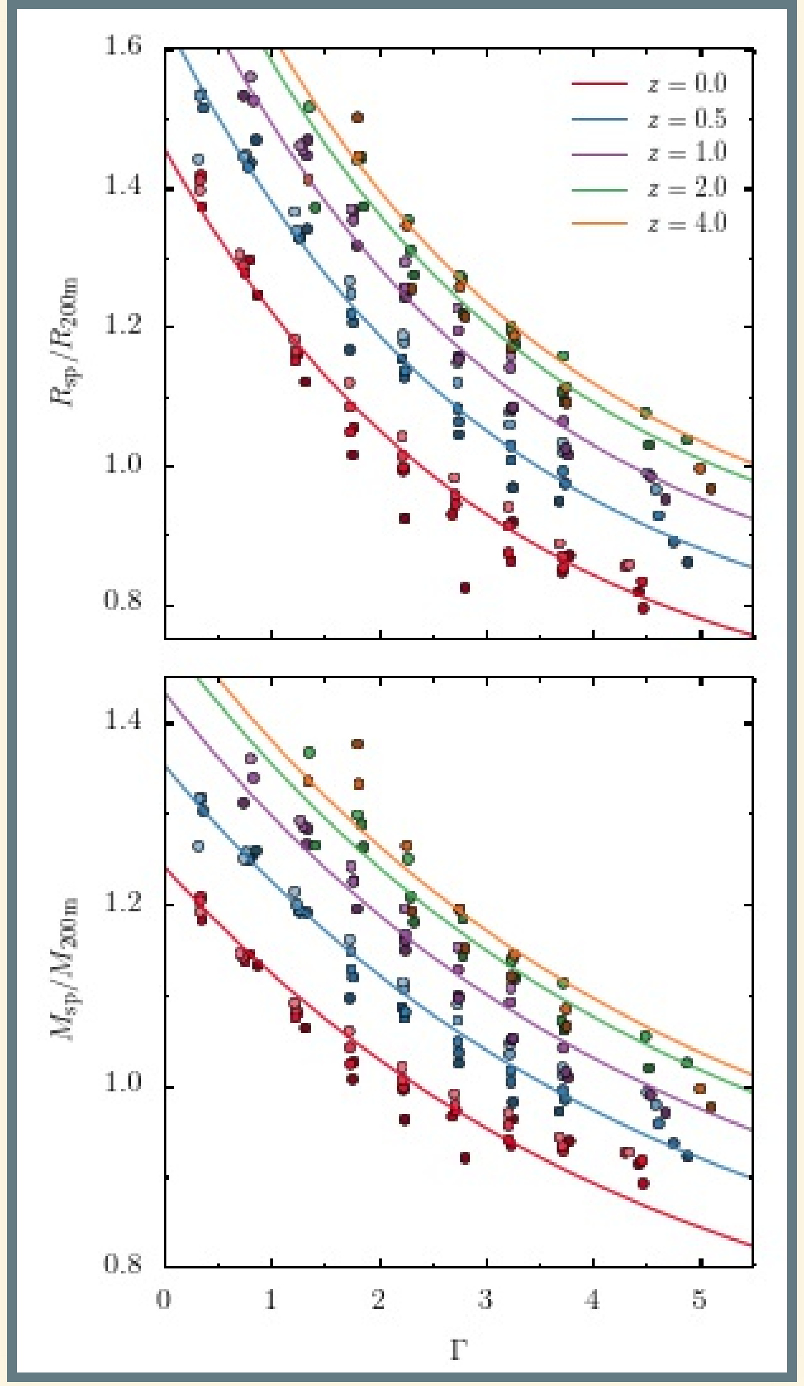
DEPENDENCE ON THE MASS ACCRETION HISTORY



- The splashback radius responds to a physical change in the halo potential
- Higher accretion rate → smaller splashback radius for the same halo mass (see also, Vogelsberger et al. 2011)

DEPENDENCE ON THE MASS ACCRETION HISTORY

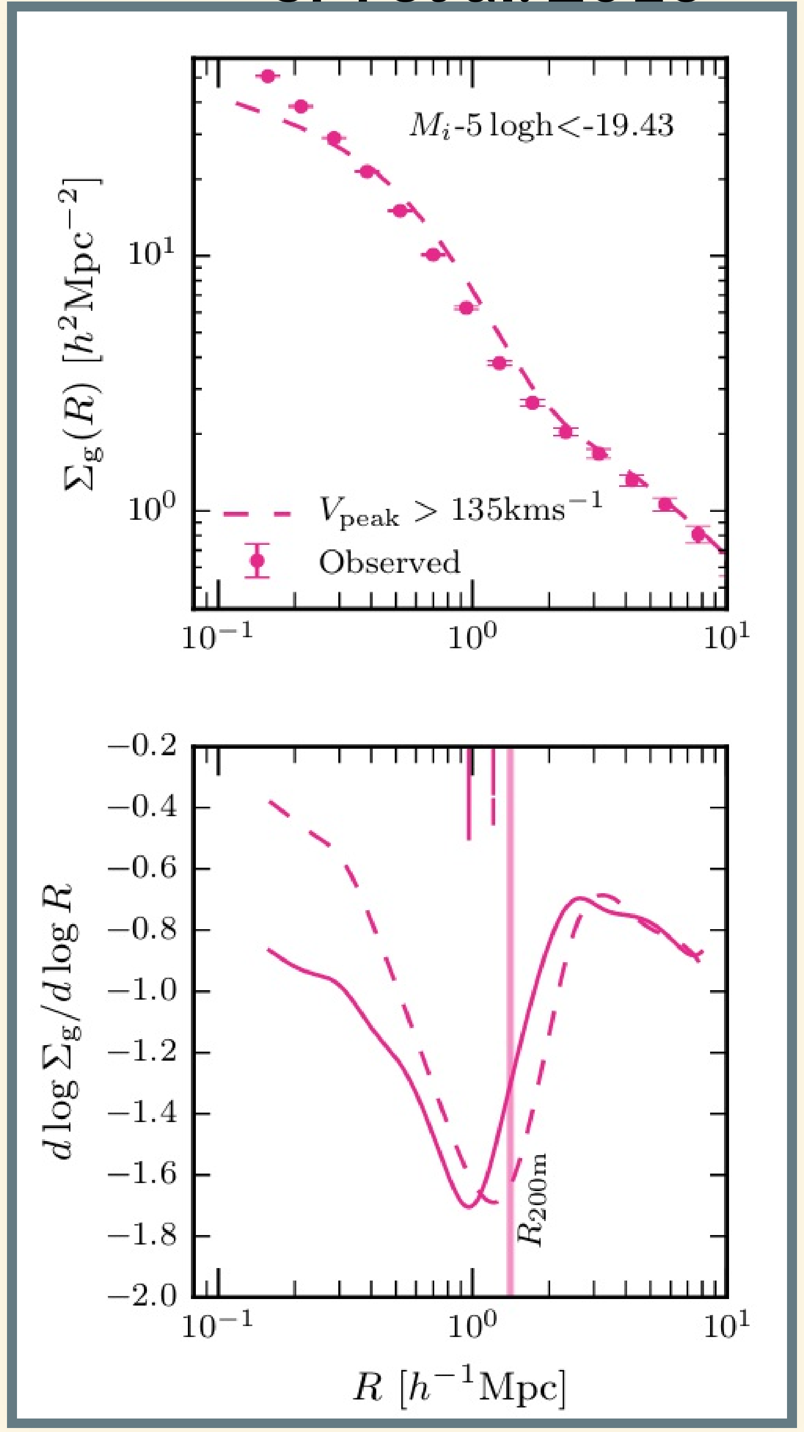
SM et al. 2015



- Stack density profiles in bins of accretion rate and mass
- Stronger redshift dependence, some mass dependence (see also Mansfield et al. 2017, Diemer et al. 2017)
- Factor two variation in the radii for fixed M_{200m}

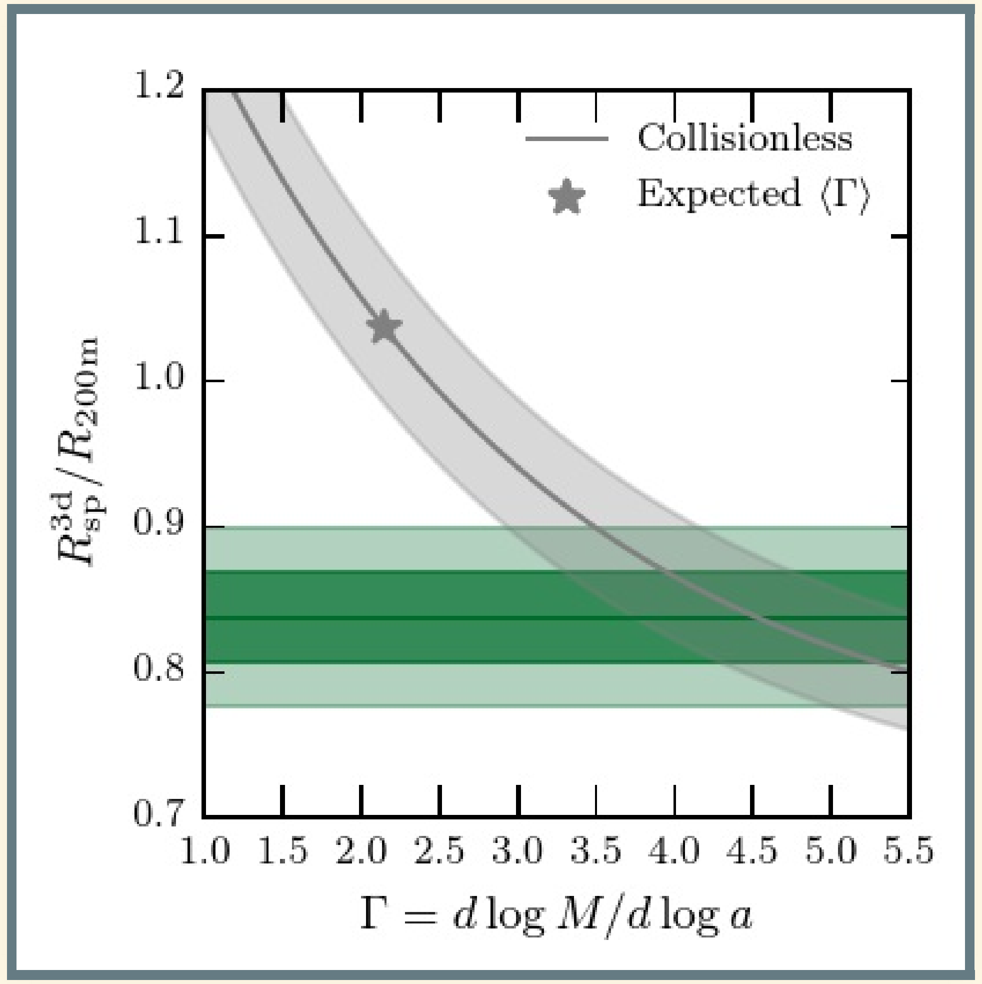
SPLASHBACK RADIUS IN OBSERVATIONS

SM et al. 2016



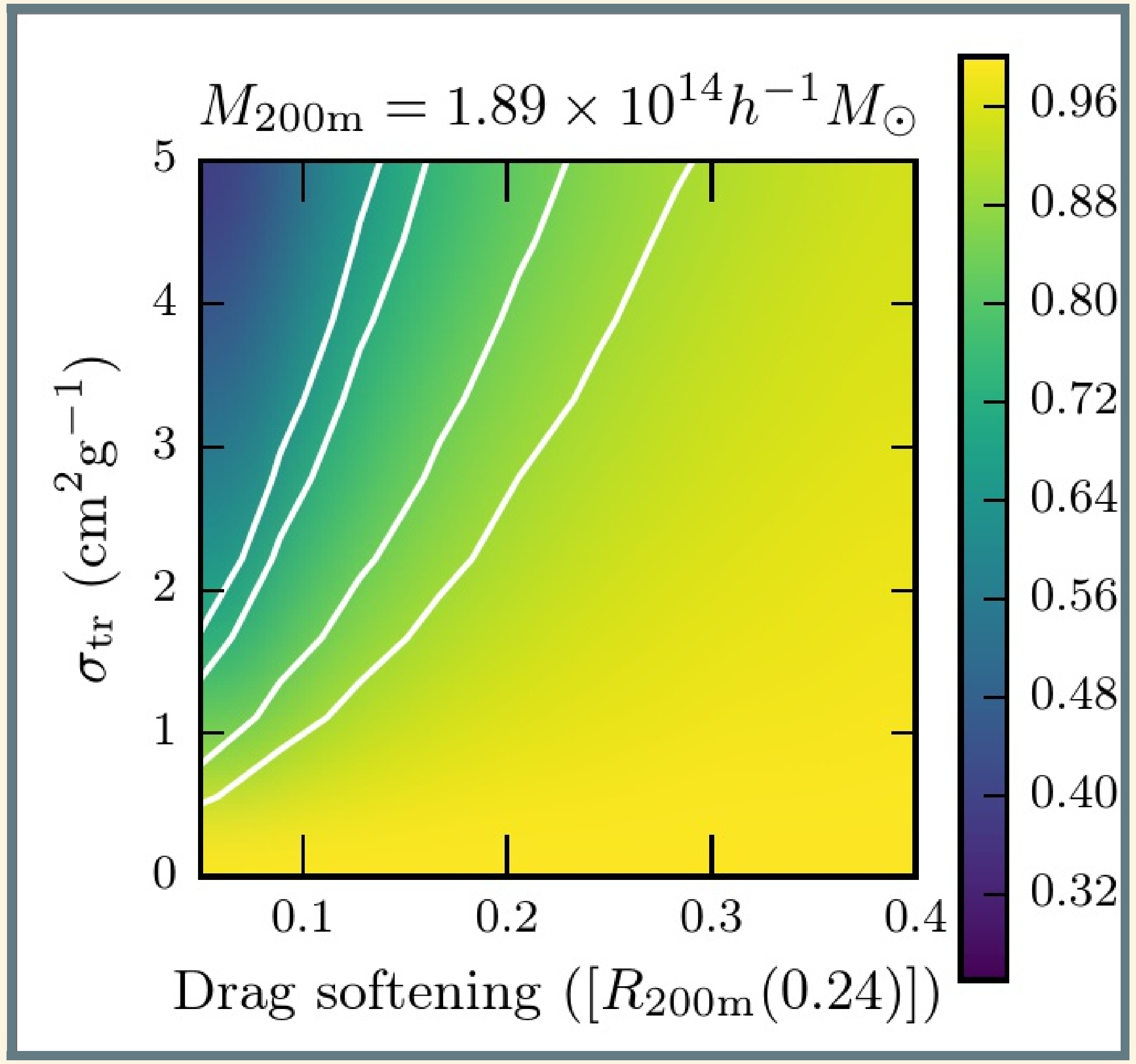
- Observed sharp density drop in the galaxy distribution around redmapper clusters
- Location is about 20 percent smaller than what is expected around clusters of the measured halo mass
- Dynamical friction does not seem to be causing the difference
- How large an accretion rate is required?

LARGER ACCRETION RATE?



- $\Gamma = d\log M/d\log a$
- Larger accretion rate would imply faster growth in the cluster mass function

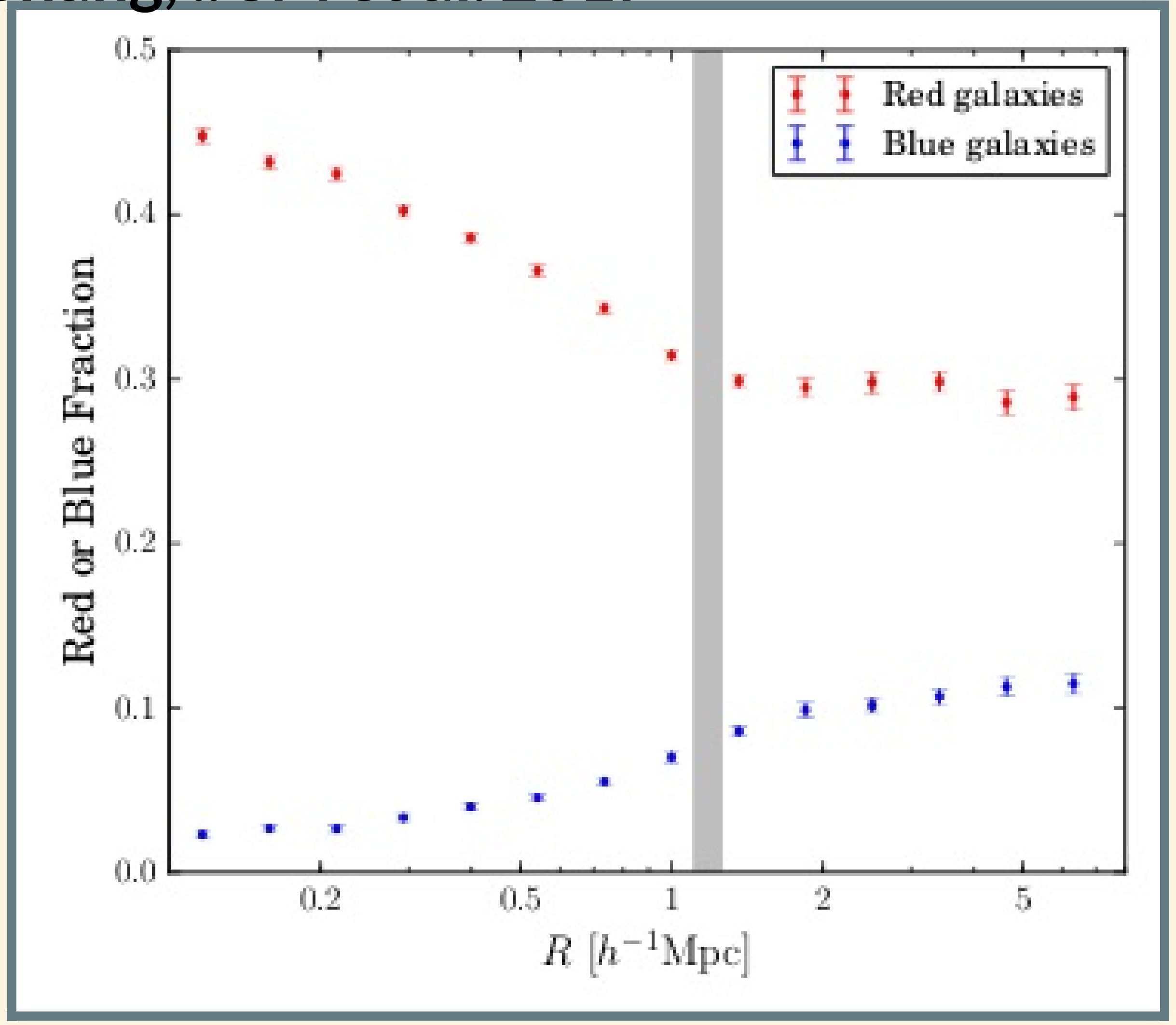
SELF INTERACTING DARK MATTER



- Assumes frequent self-interactions and a pericentric distance for the subhalo orbit inside which the drag is constant

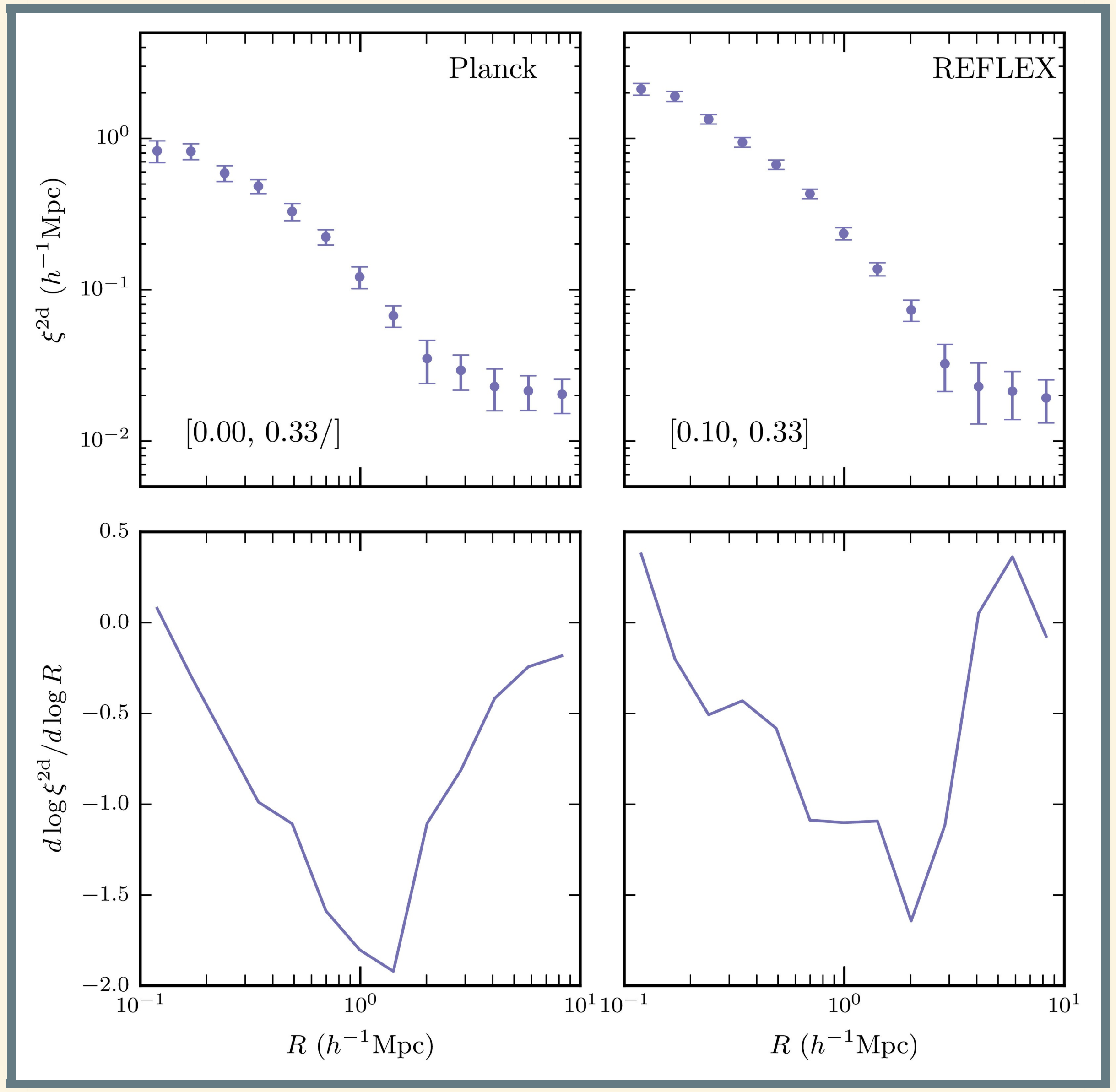
SPLASHBACK RADIUS: FRACTION OF RED GALAXIES

Baxter, Chang, .. SM et al. 2017



- Splashback radius also corresponds to a distinct upturn in the fraction of red galaxies around clusters

XRAY AND SZ CLUSTERS

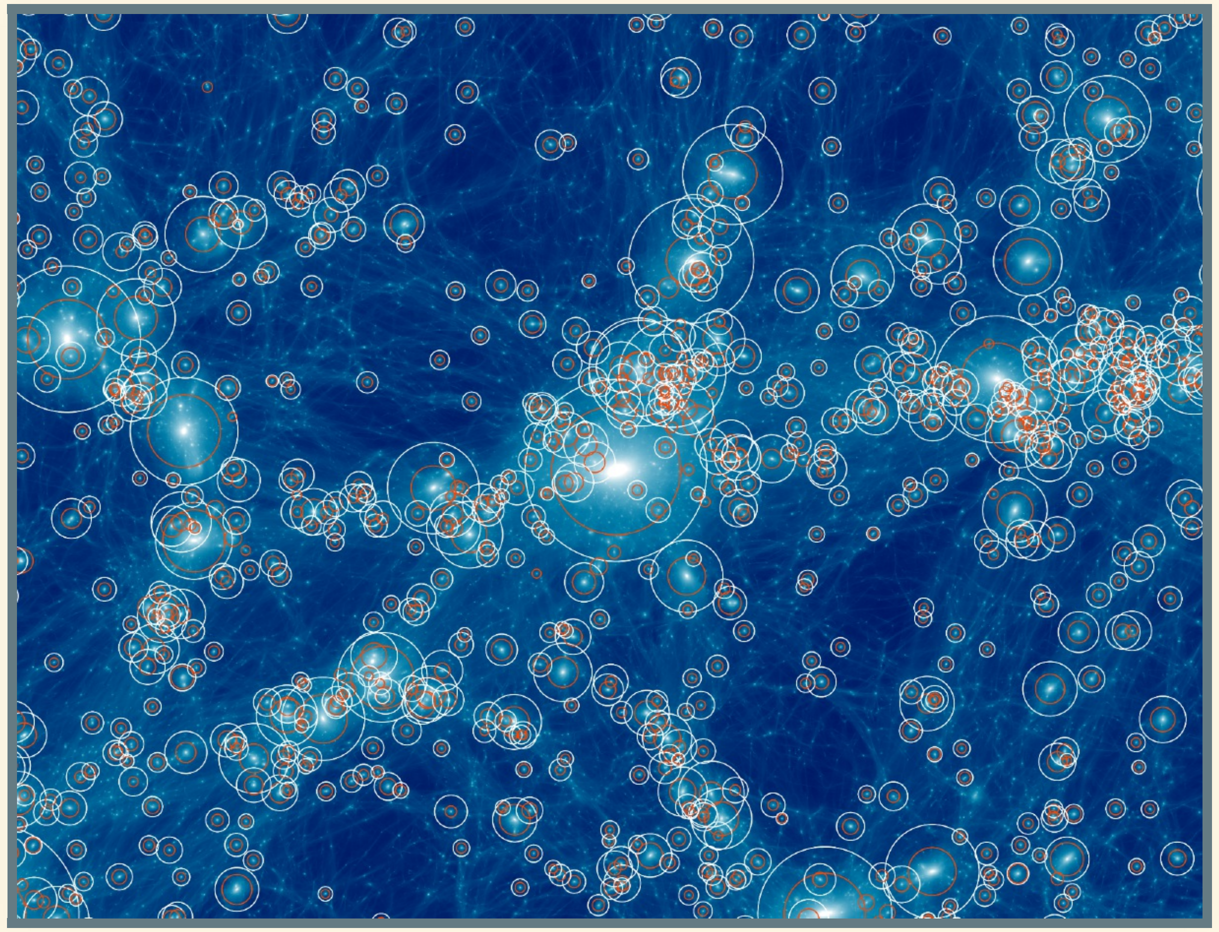


SM et al. (in prep)

- Splashback-like features around Xray and SZ clusters (work in progress, limited by sample sizes currently)

SPARTA

Diemer, Mansfield, Kravtsov, SM (2017)

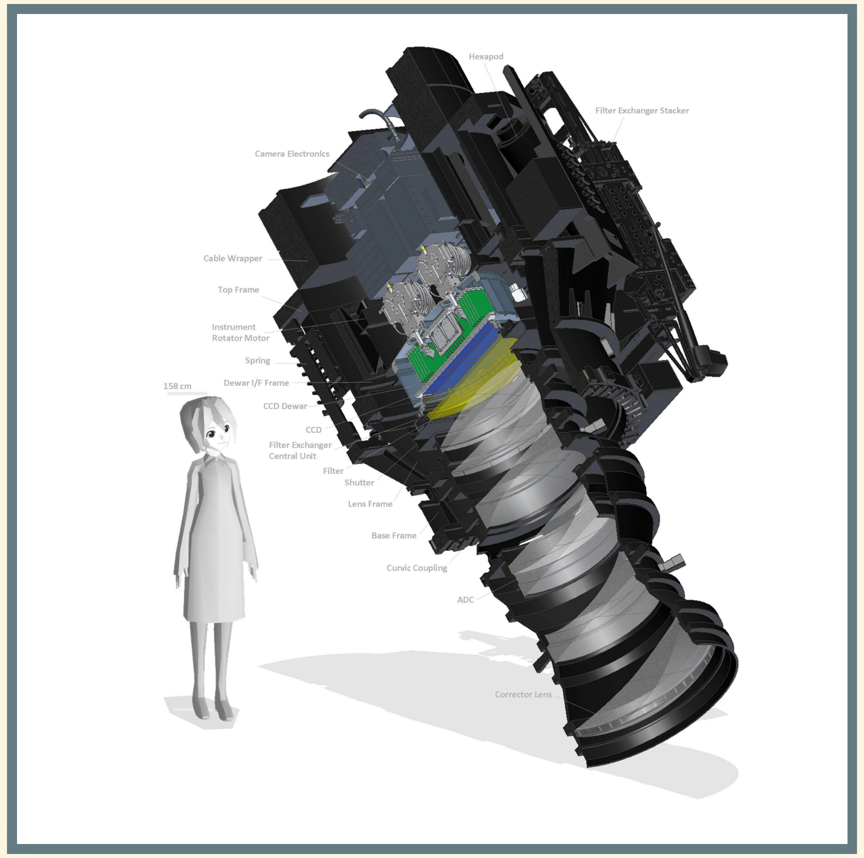


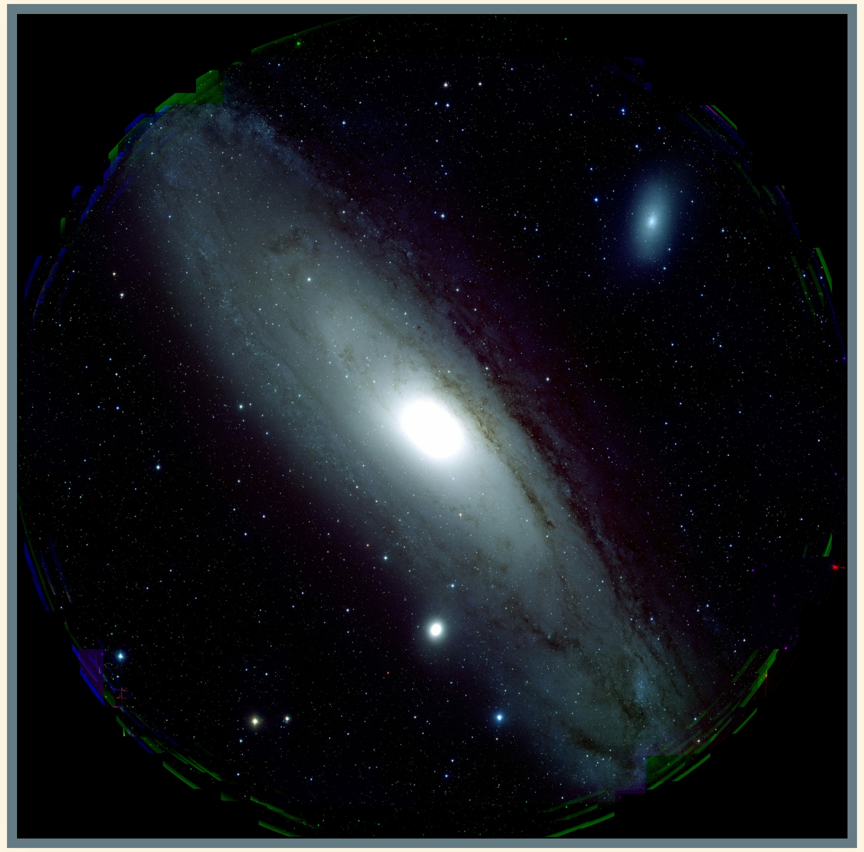
- Subhalo and Particle Trajectory Analysis (Diemer 2017) allows extraction of individual splashback events in simulations
- Halo catalogs with splashback radii based halos (coming soon)

SUMMARY

- Splashback radius is a physical boundary for dark matter halos.
- When combined with weak lensing mass estimates, it can provide a direct observable to the mass accretion rate of halos.
- We have obtained a first observational detection of the splashback radius around optically selected clusters. Other samples under active investigation.
- SParTA will be able to provide splashback radii for individual halos in simulations. Opens up the door to a more wider use of this new boundary definition.
- We are conducting a survey to look for RRLyrae stars in the MW halo to probe the edges of the MW dark matter halo.

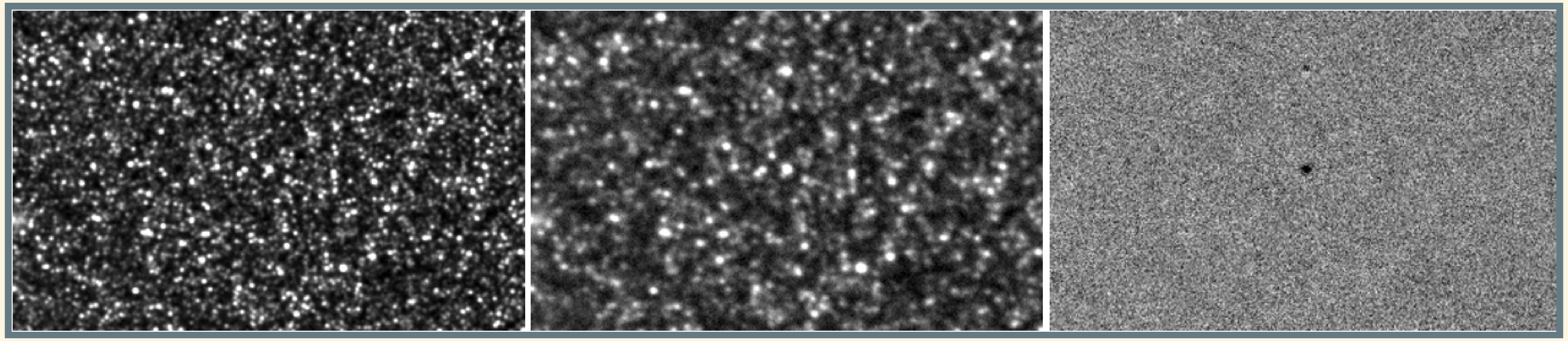
TIME DOMAIN SCIENCE WITH SUBARU HSC



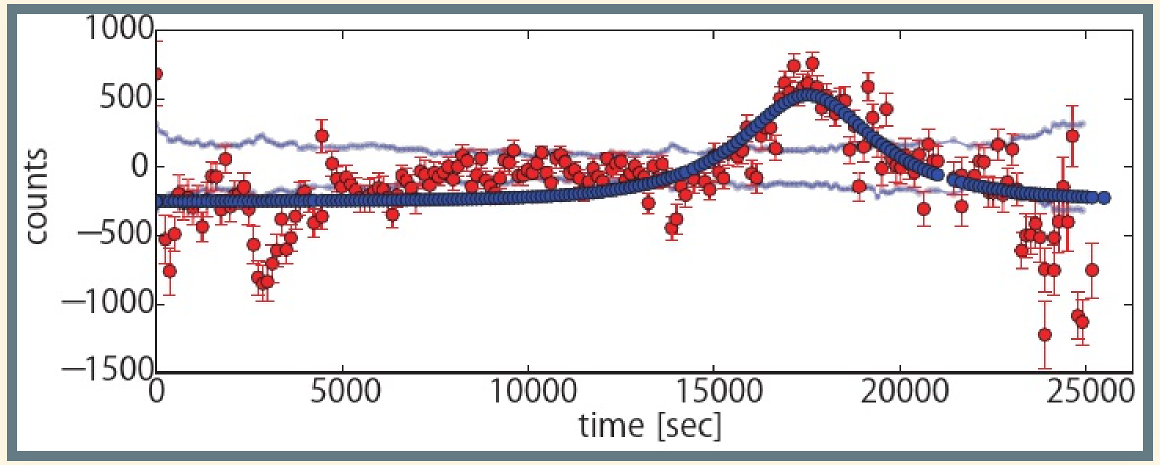


- Gigapixel camera with a large field of view (1.75 sq deg)
- Can reach 25th magnitude in r band within 90 seconds (readout 30s)
- Field of view covers entire Andromeda disk at once

IMAGE DIFFERENCE PIPELINE



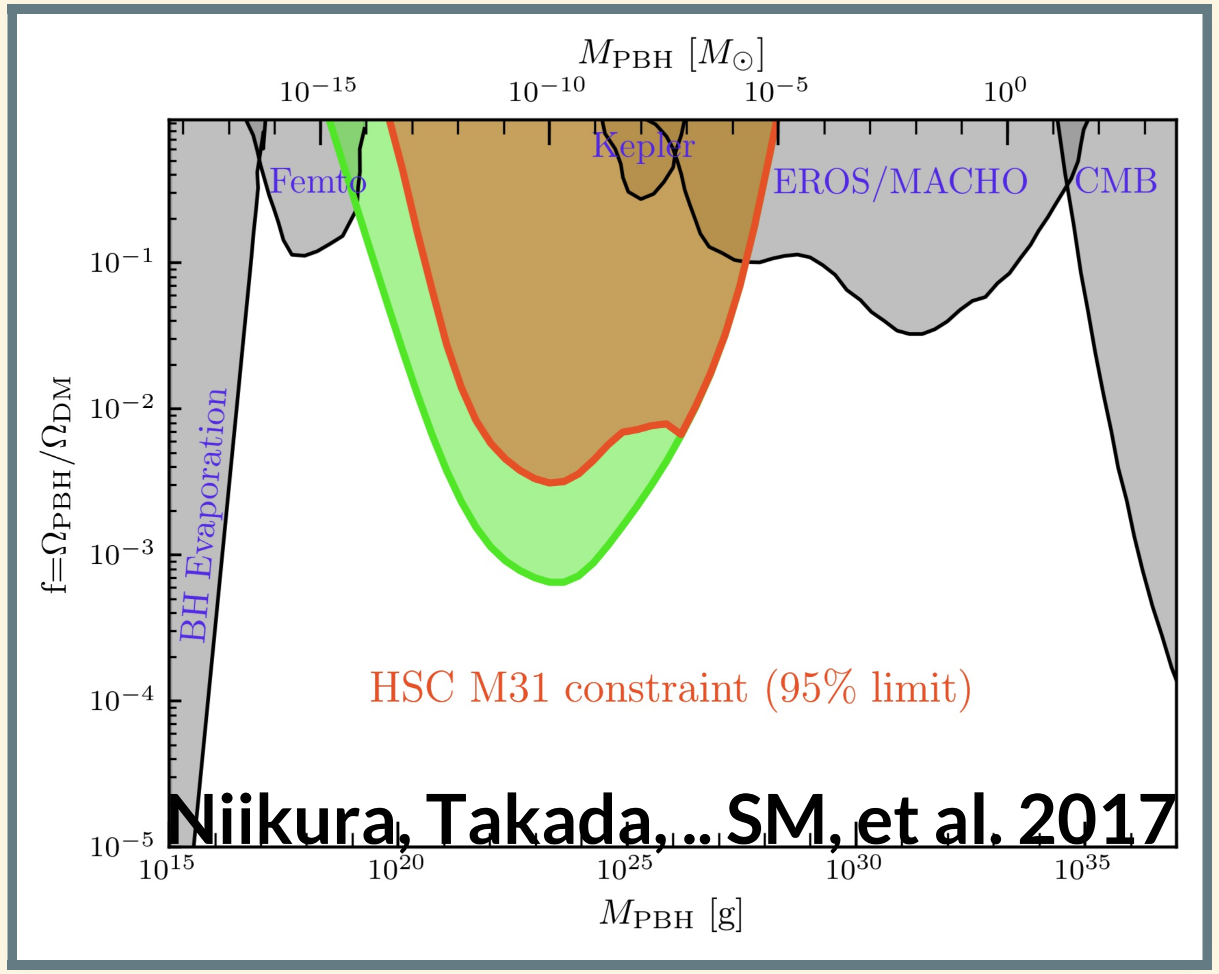
Niikura, Takada, .. SM, et al. 2017



Candidate microlensing event

Subtract PSF matched template image at best seeing from every exposure (Alard and Lupton 1998) and identify lightcurves for candidates

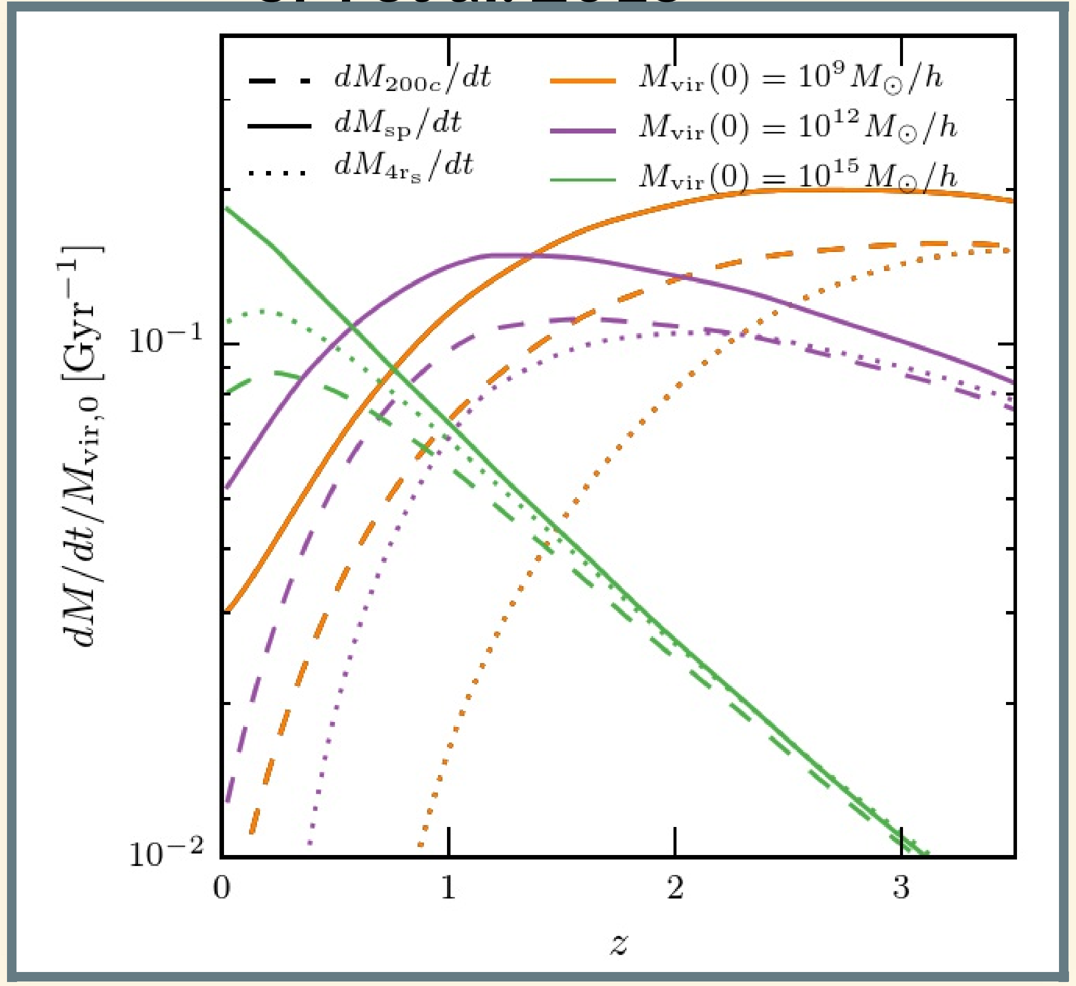
TIGHTEST CONSTRAINT ON PBH ABUNDANCE

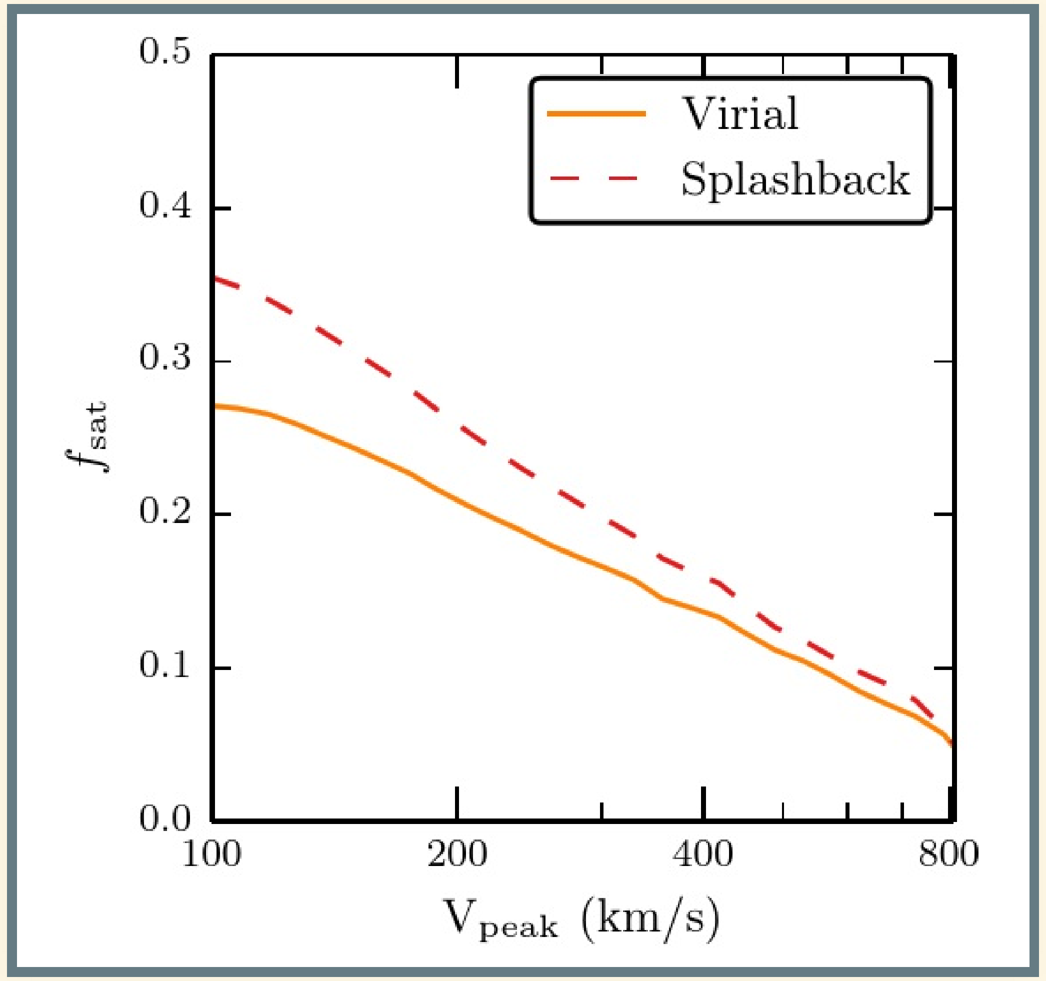


- Almost rules out the PBH DM scenario
- We are working on another survey to look for Planet Nine and RRLs in the Milky way halo (out to distances of 700 kpc)

SOME CONSEQUENCES

SM et al. 2015





- Mass accretion rates could differ by factor two at low redshifts
- Satellite fractions go up at the small mass end
- Halo assembly bias decreases at the small mass end

BOUNDARIES OF DARK MATTER HALOS

WHY SHOULD I CARE?

- Halo boundary differentiates centrals from satellites
  - Centrals and satellites undergo different physical processes in semi-analytical models, in empirical models
- Will change mass accretion rates
  - The growth of the gas content of halos is connected to mass growth histories
- For halo occupation distribution modeling
  - Defines the extent of the one halo term, and how far to populate satellite galaxies in the dark matter halo