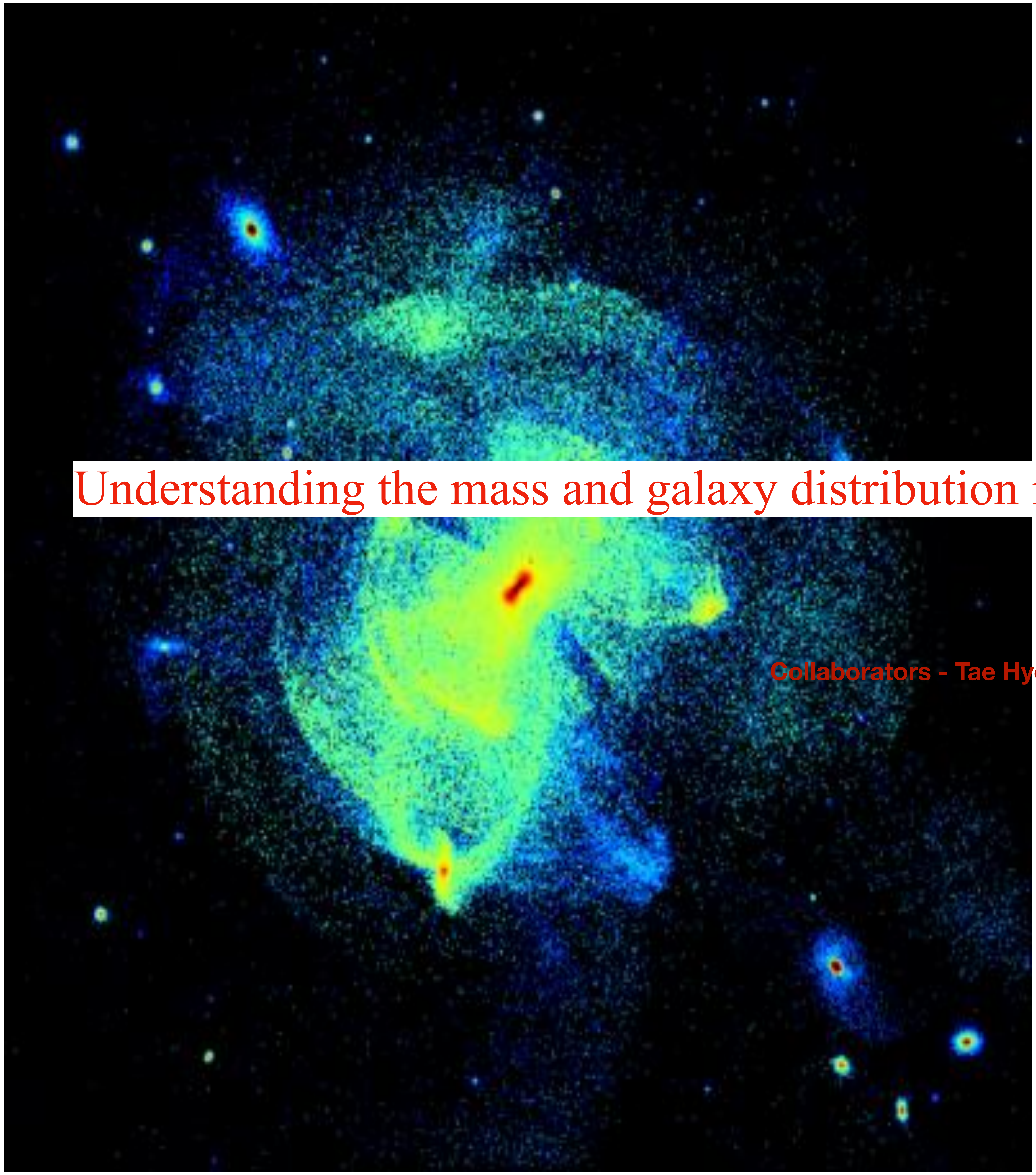
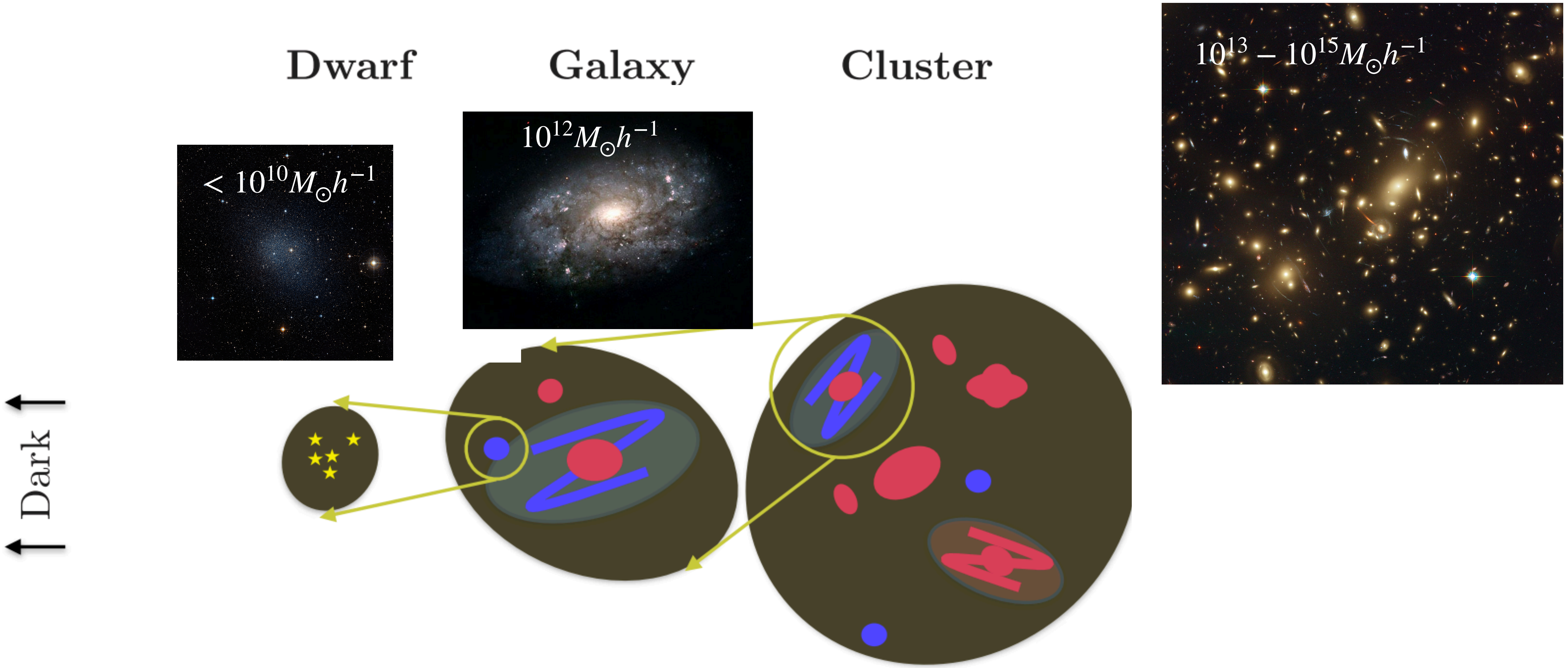


Understanding the mass and galaxy distribution in Clusters: A perspective from the edges of DM halos

Susmita Adhikari
University of Chicago
CMB- S4 meeting

Collaborators - Tae Hyeon-Shin, Chihway Chang, Eric Baxter, Bhuvnesh Jain and others (incl. DES & ACT collaboration)



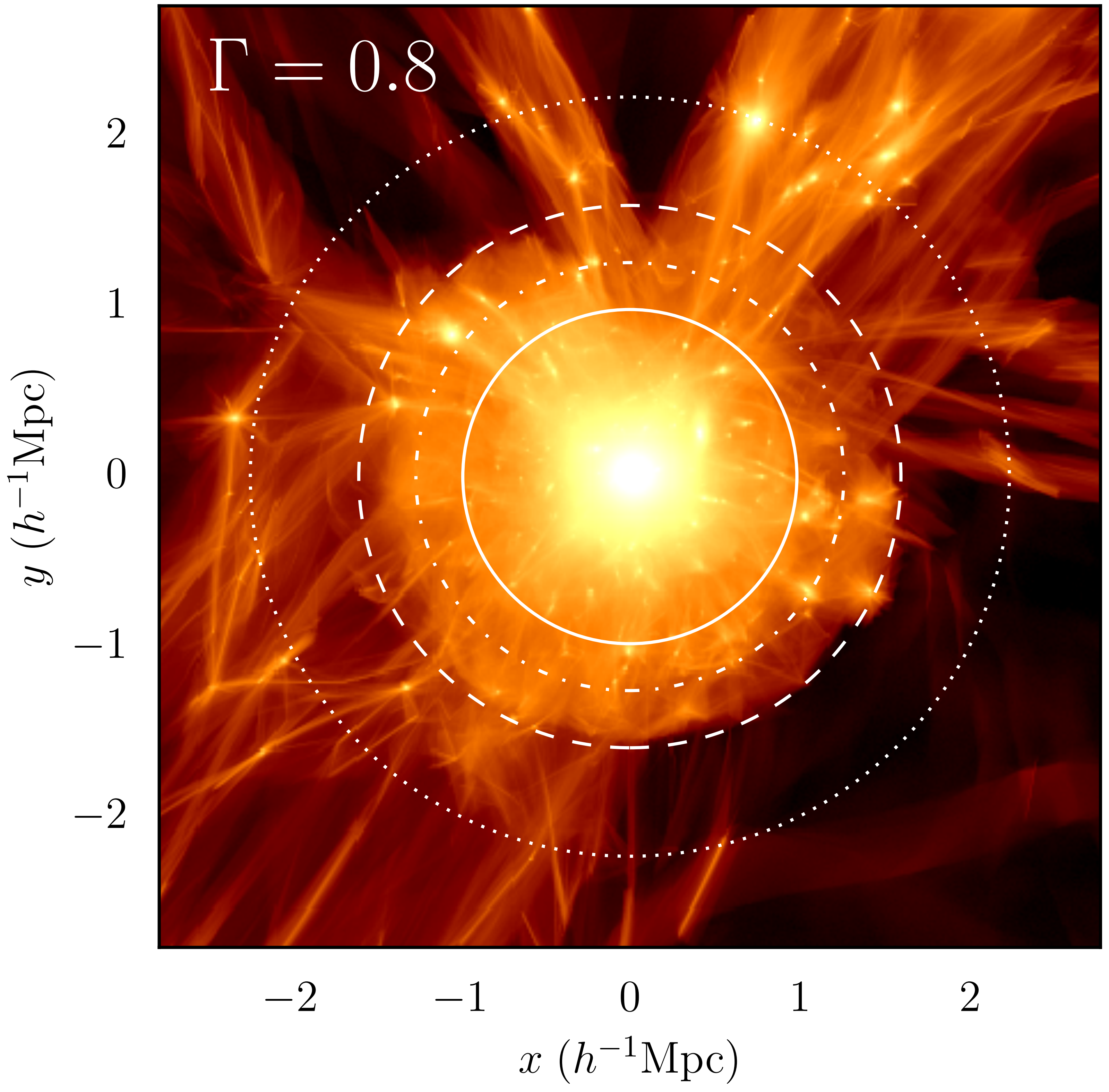
$v_{\rm vir} \sim M_{\rm vir}^{1/3}$:	$10 - 1000$ km/s	$100 - 1000$ km/s	$1000 - 2000$ km/s
$R_{\rm vir} \sim M_{\rm vir}^{1/3}$:	$10 - 100$ kpc	$100 - 1000$ kpc	$1 - 2$ Mpc
$R_* \sim 0.02 R_{\rm vir}$:	$\sim 0.1 - 1$ kpc	$\sim 1 - 10$ kpc	~ 20 kpc
$k_{\rm hm} \sim M_{\rm vir}^{-1/3}$:	$\sim 4 - 40\ {\rm Mpc}^{-1}$	$\sim 0.4 - 4\ {\rm Mpc}^{-1}$	$\sim 0.2 - 0.4\ {\rm Mpc}^{-1}$

credit: Buckley and Peter 2017

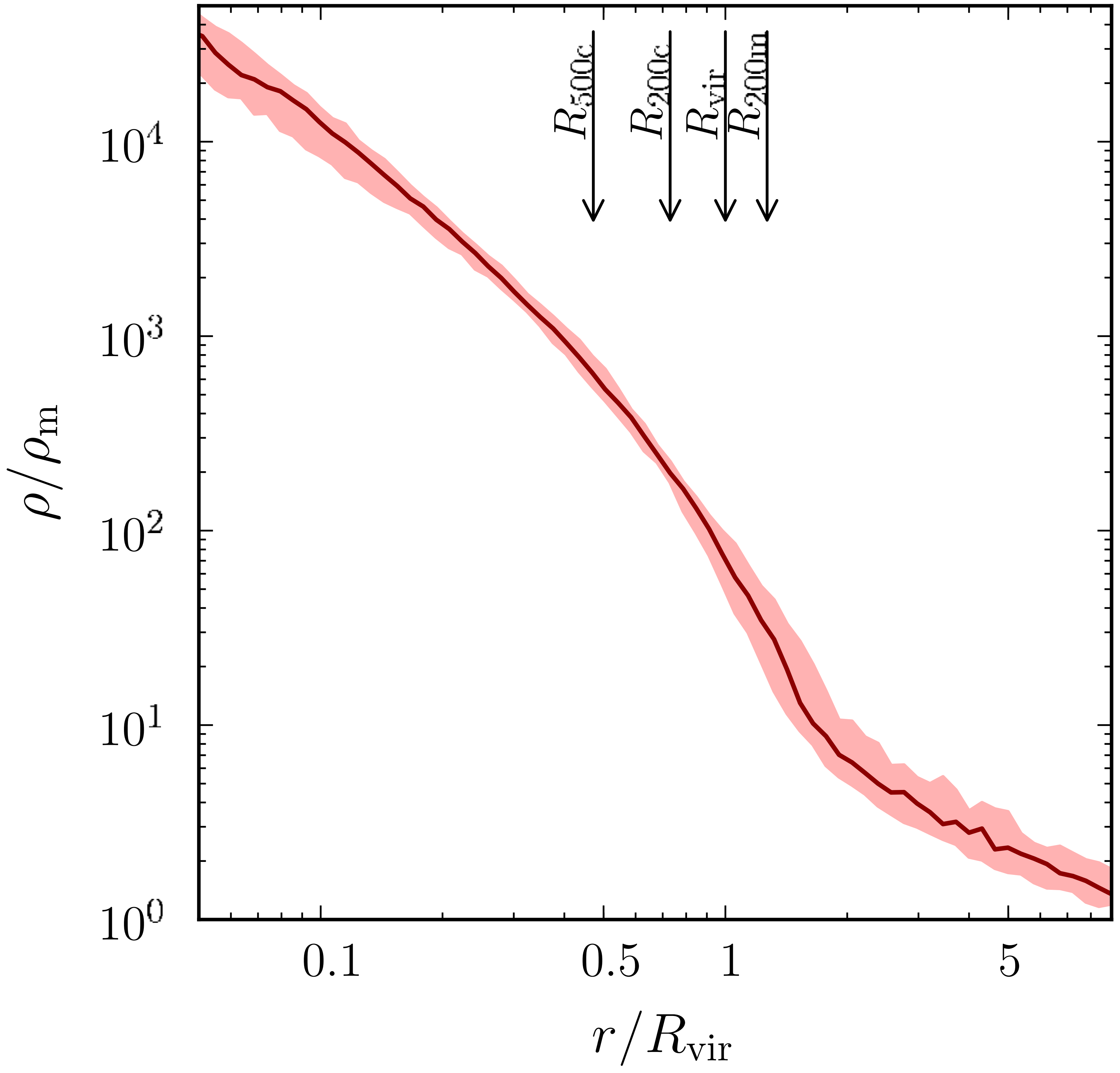
Looking at the most massive dark matter halos

The structure of a Dark Matter Halos

Where is the boundary of a Dark Matter Halo?



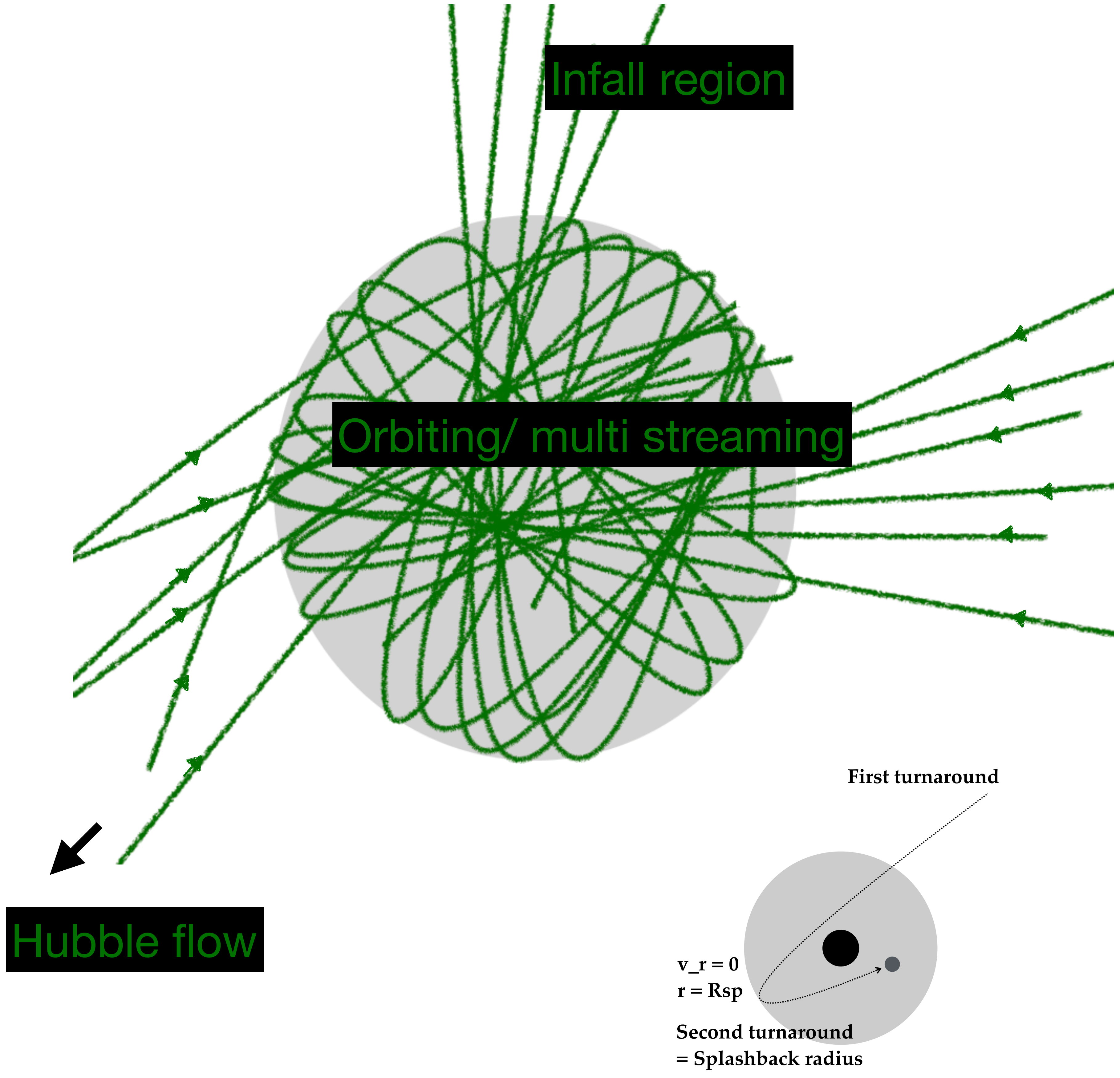
More et al. 2015

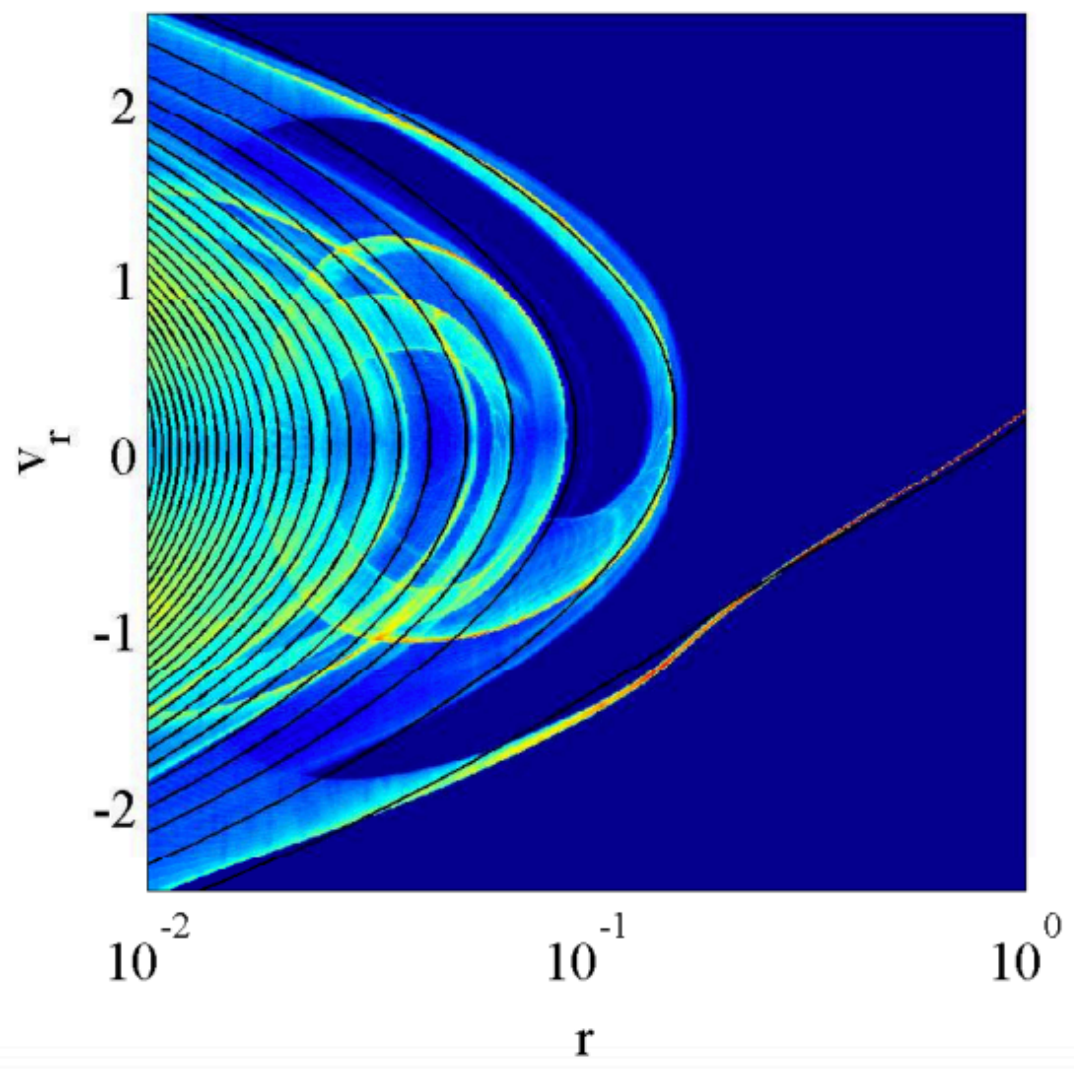


Diemer & Kravtsov 2014

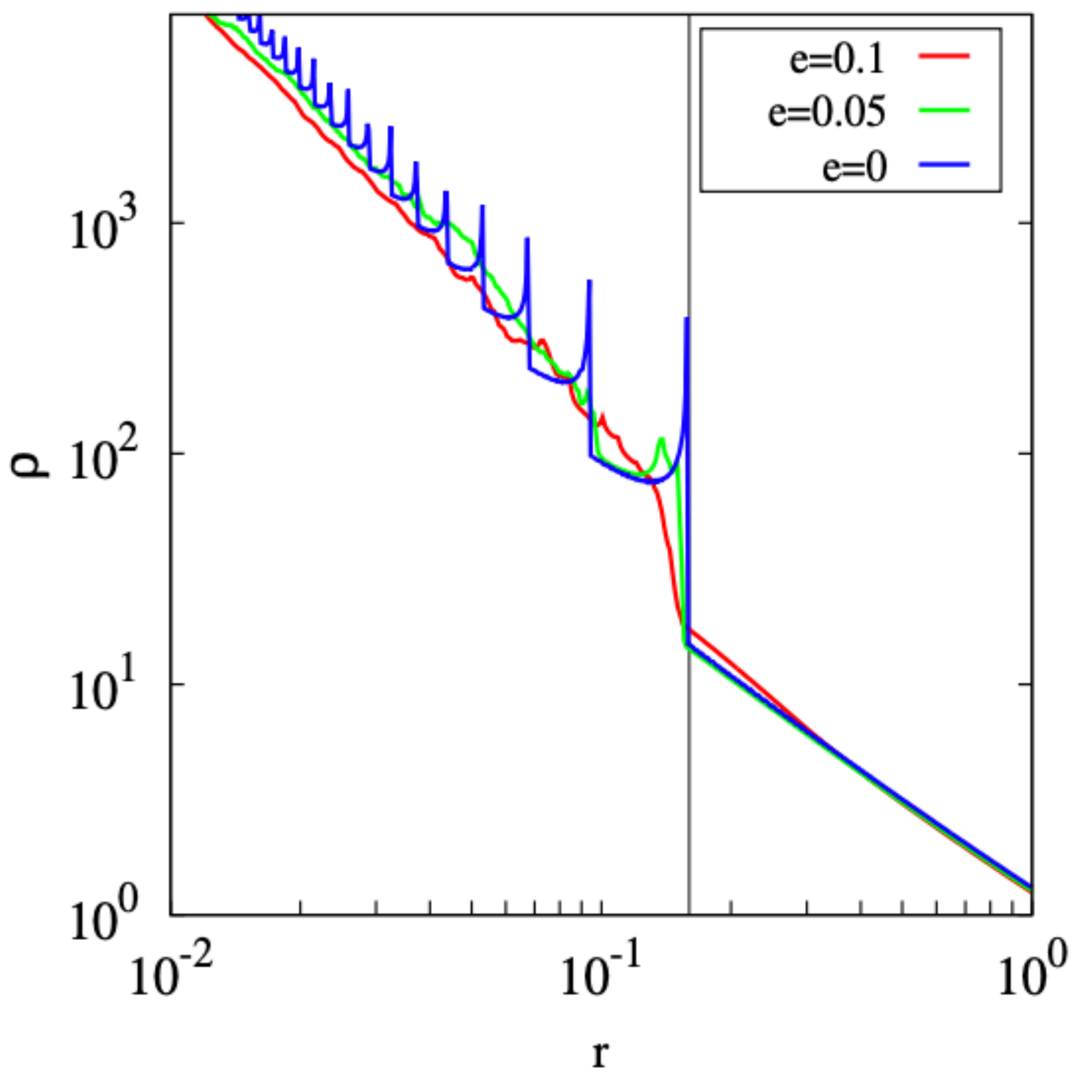
$$M_\Delta = \frac{4}{3}\pi R_\Delta^3 \Delta \rho_{\mathrm{ref}}$$

The structure of a dark matter halo





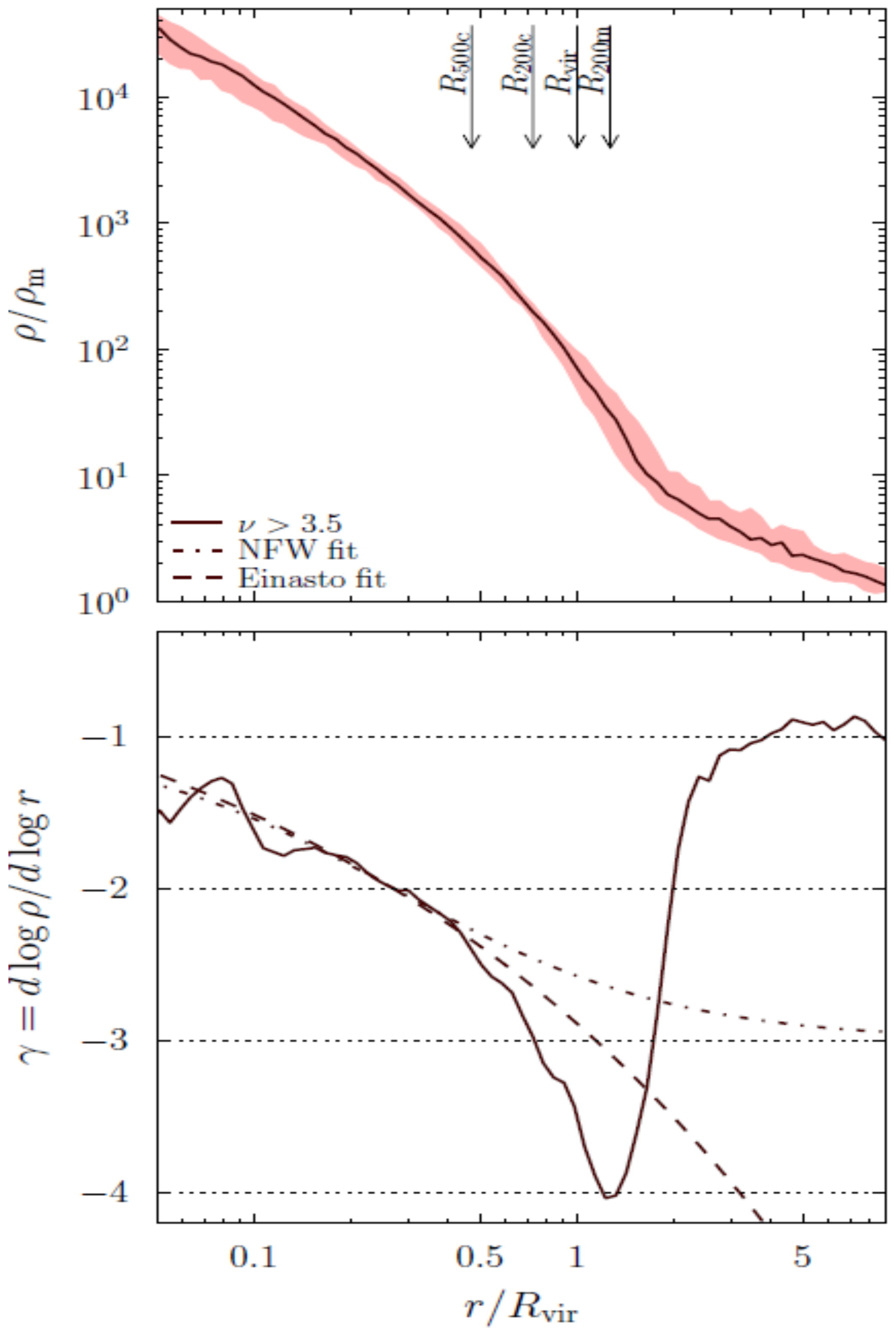
Phase space of a halo



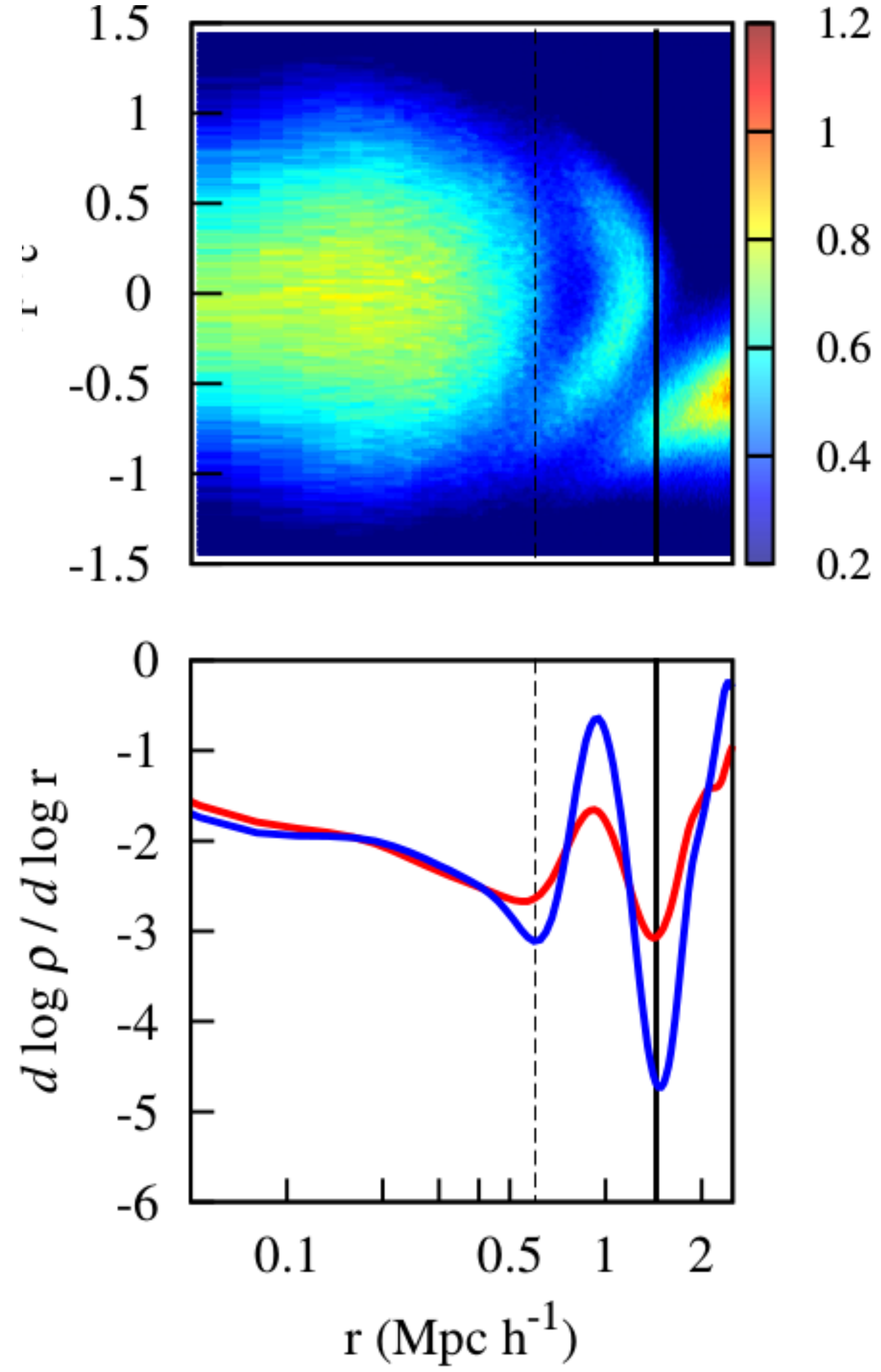
Density around a halo

Adhikari, Dalal, Chamberlain 2014

Why is this feature interesting?



Dimmer & Kravtsov 2014



Adhikari et al. 2014

- **It forms the boundary of the dark halo**
- **Physical definition of halo mass**
- **The splashback radius probes growth history of the halo.**
- **It forms at the boundary that separates the virialized region of a halo from the infalling region.**
- **Fundamental length scale in the halo structure, should be present if there is a dark matter halo.**
- **Simple to understand formed by the most recently accreted material - that is not yet phase mixed.**
- **Inner regions of halos are often dominated by baryons**
- **Accessible observationally!**

The various effects that the outskirts can probe (theory)

Gravity - Adhikari et al. 2018, Contigiani 2018

SIDM - Banerjee et al. 2019

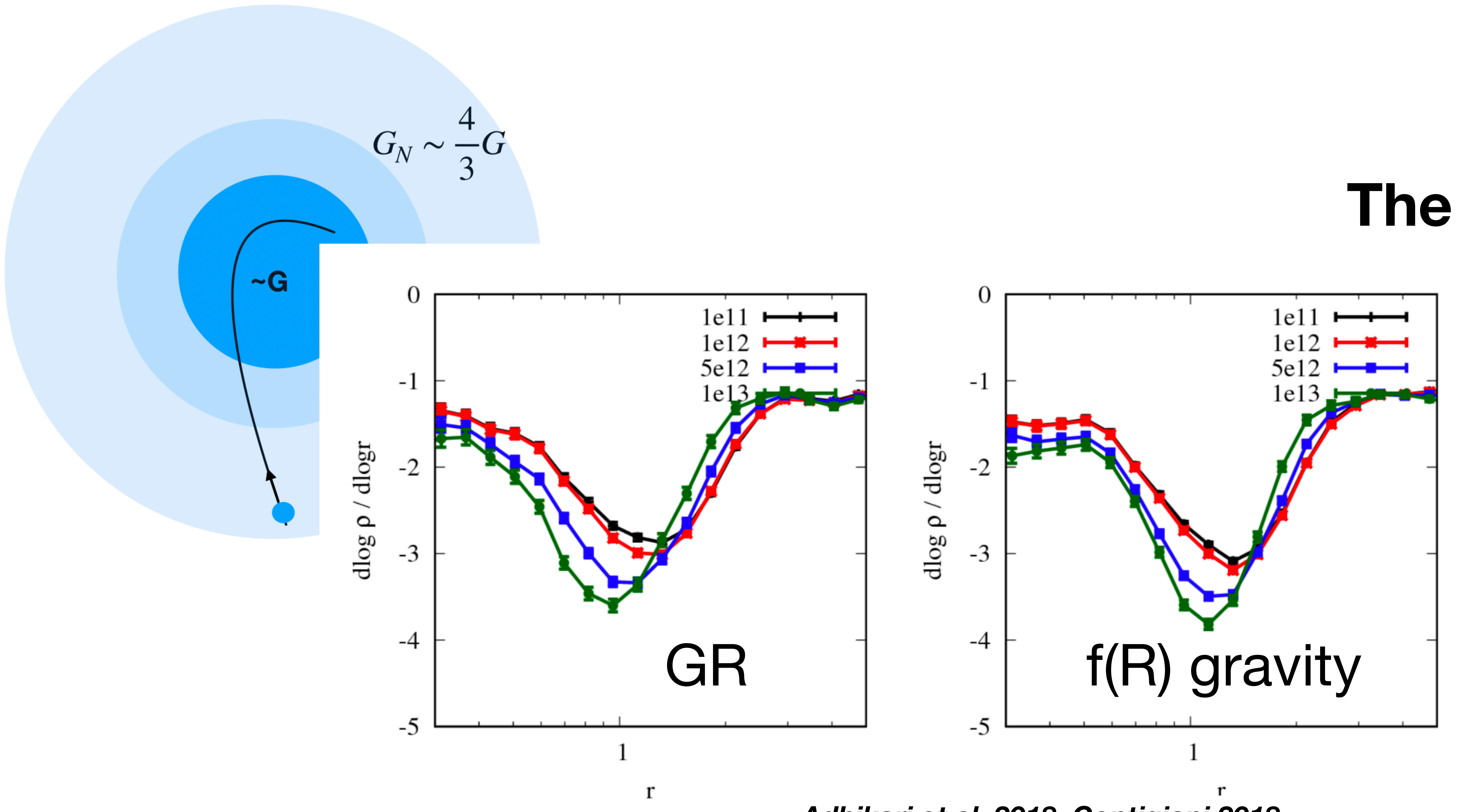
Assembly Bias - Chue et al. 2017, Mansfield et al. 2019

Accretion histories - Xhakaj et al. 2019

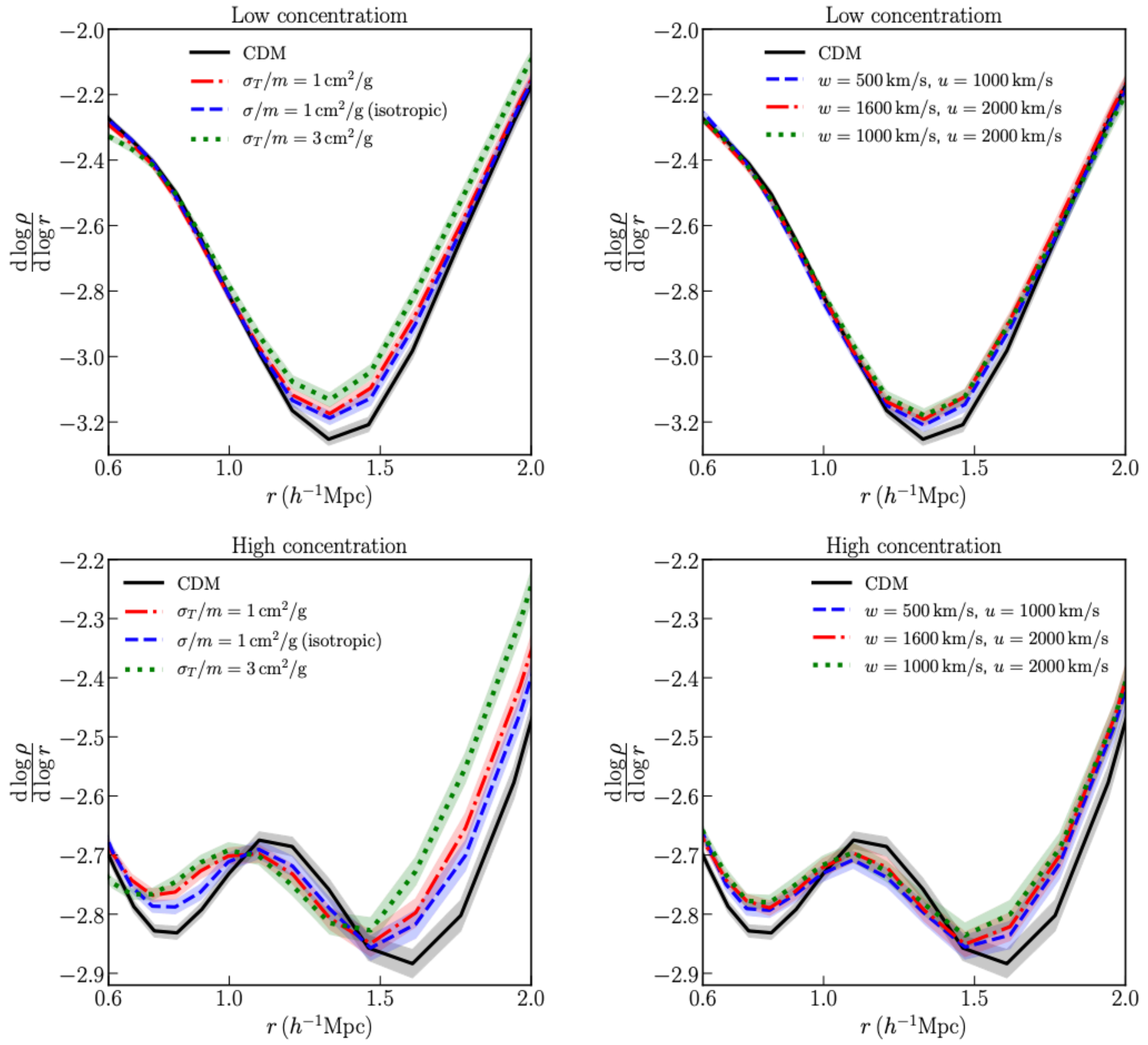
Dynamical Friction - Adhikari et al. 2015

Hubble Constant - Wagoner et al. 2020 , Aung et al. in prep

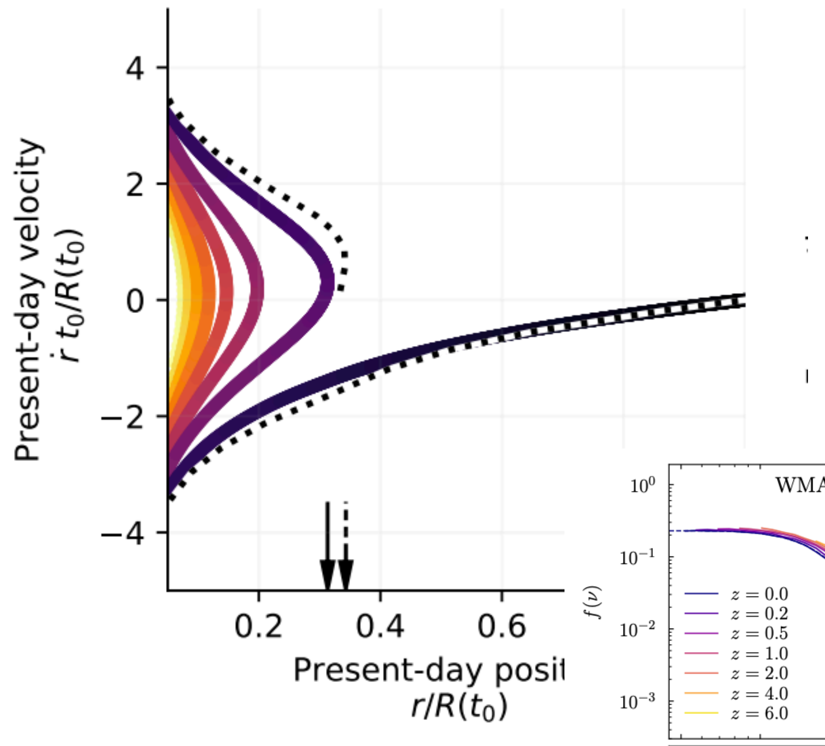
Halo mass function - Diemer et al. 2020

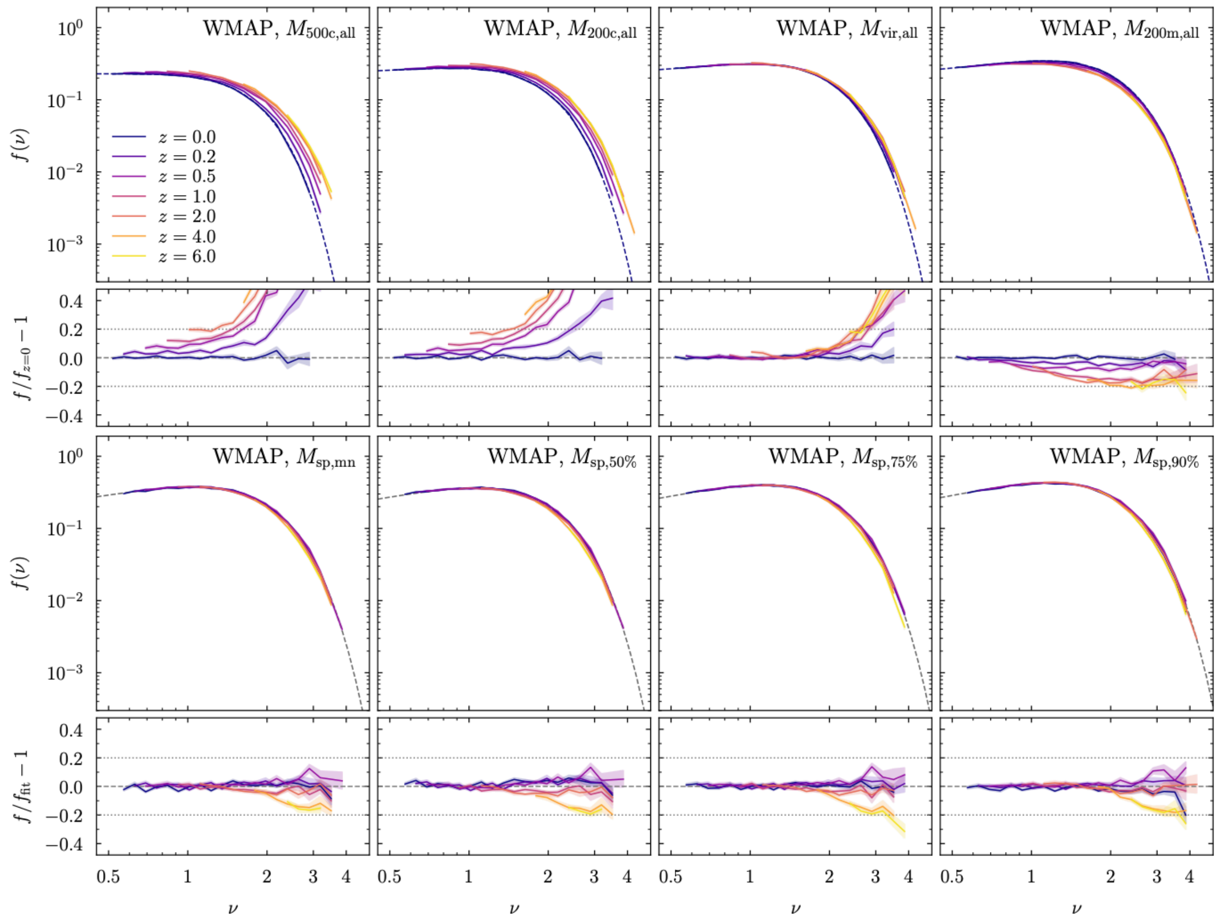


Adhikari et al. 2018, Contigiani 2018



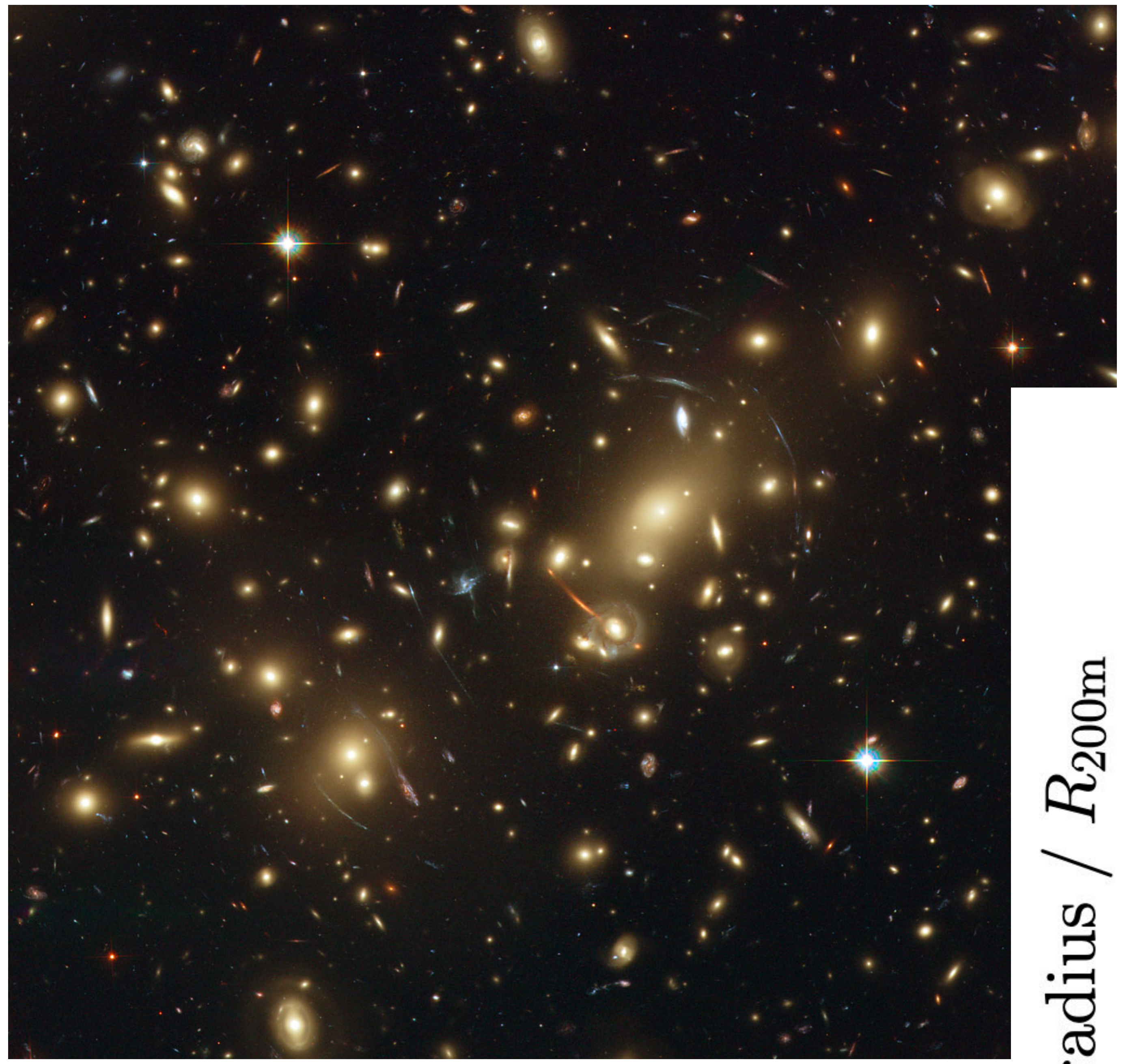
Banerjee et al. 2019





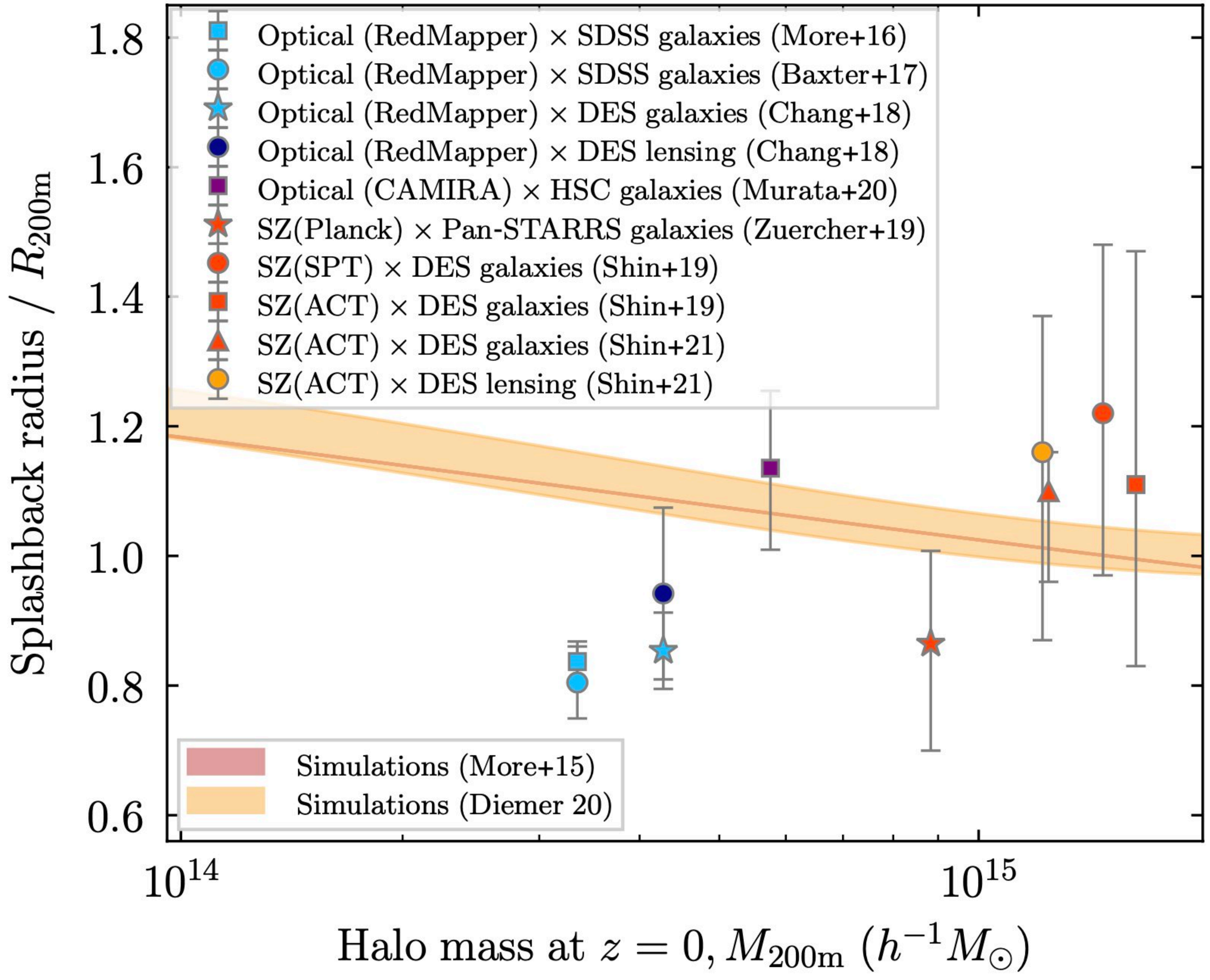
Diemer et al. 2020

Observations of Splashback radius



Measurement - Number density of galaxy in projection as a function of radius and weak lensing profiles

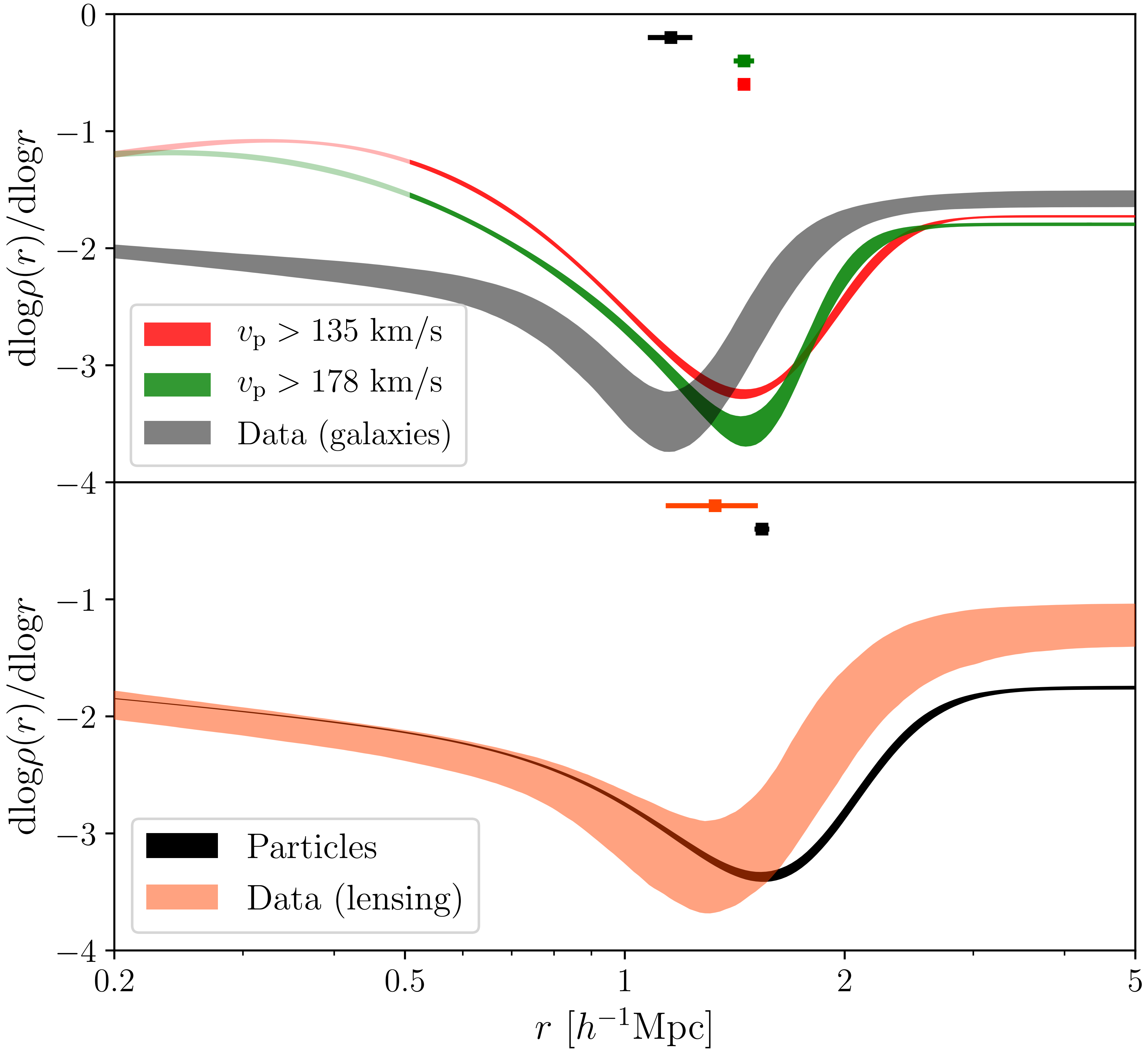
$$\Sigma(R) = \int_{-h_{\rm max}}^{h_{\rm max}} dh\, \rho(\sqrt{R^2 + h^2})$$



Credit: Benedikt Diemer

Splashback radius in DES Y1

Measurements of using RedMaPPer clusters



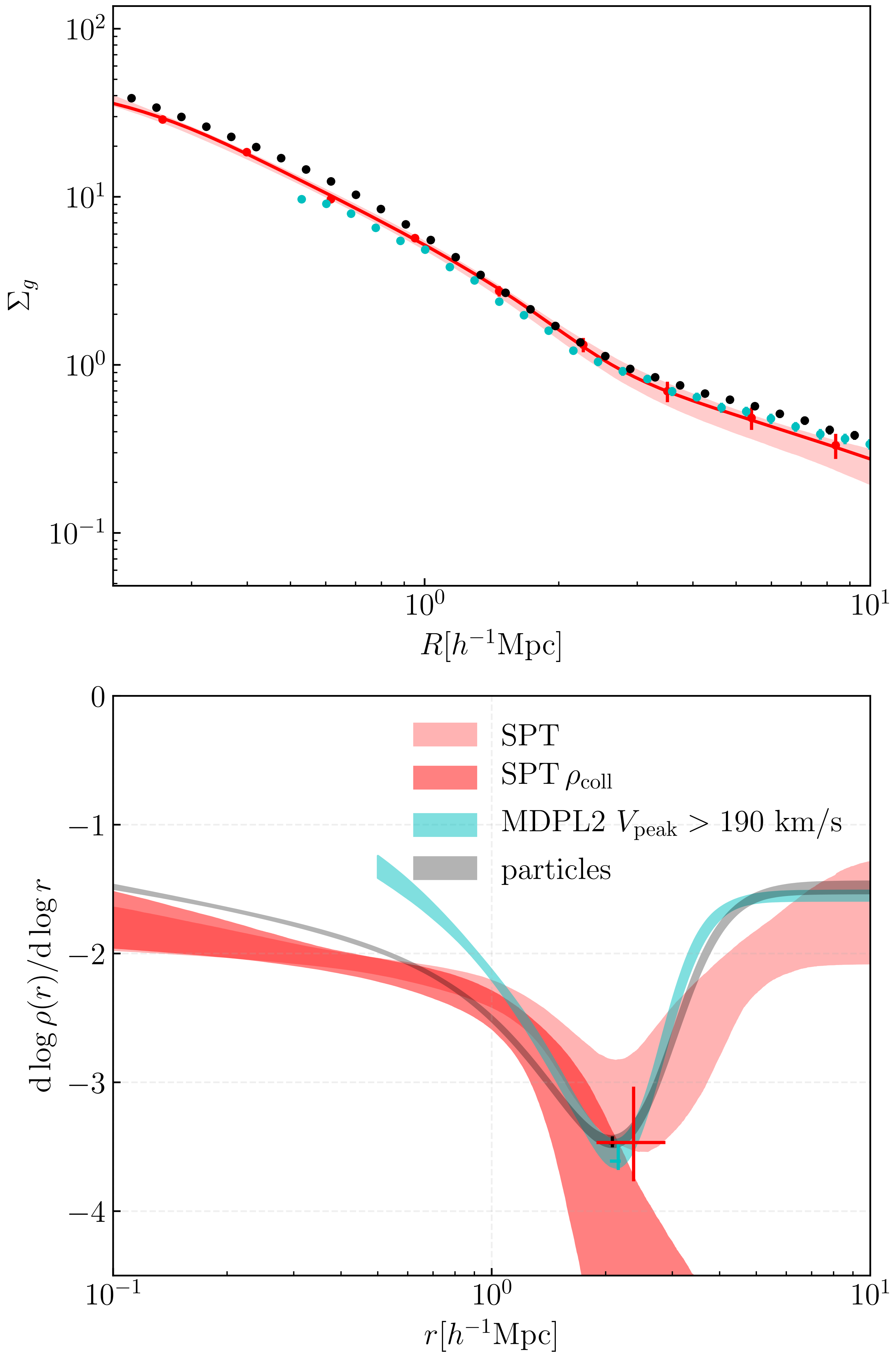
Galaxy number density

Weak lensing around clusters

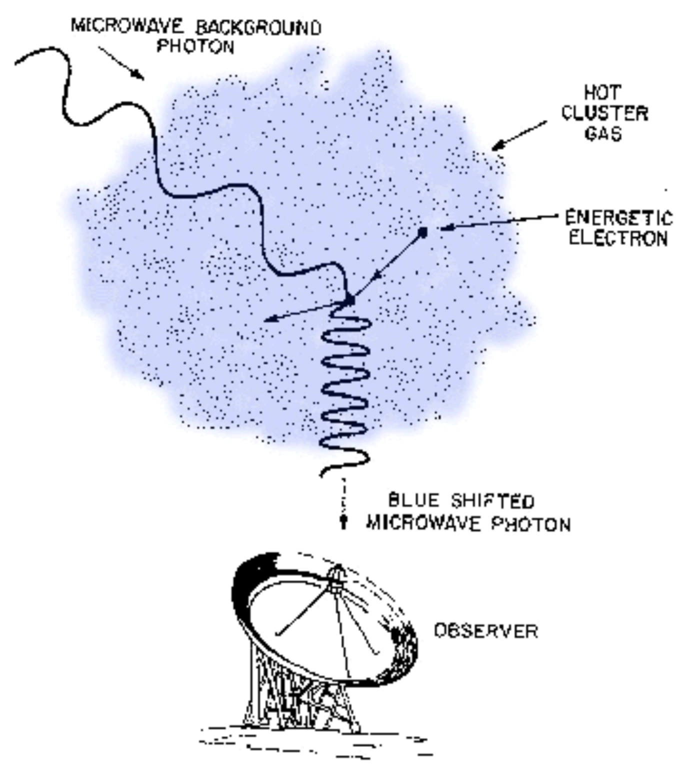
Chang et al.2017

Discrepancy persists in the lensing splashback radius as well

Splashback radius in SZ-selected clusters using DES galaxies



Hyeon-Shin, Adhikari et al. 2019

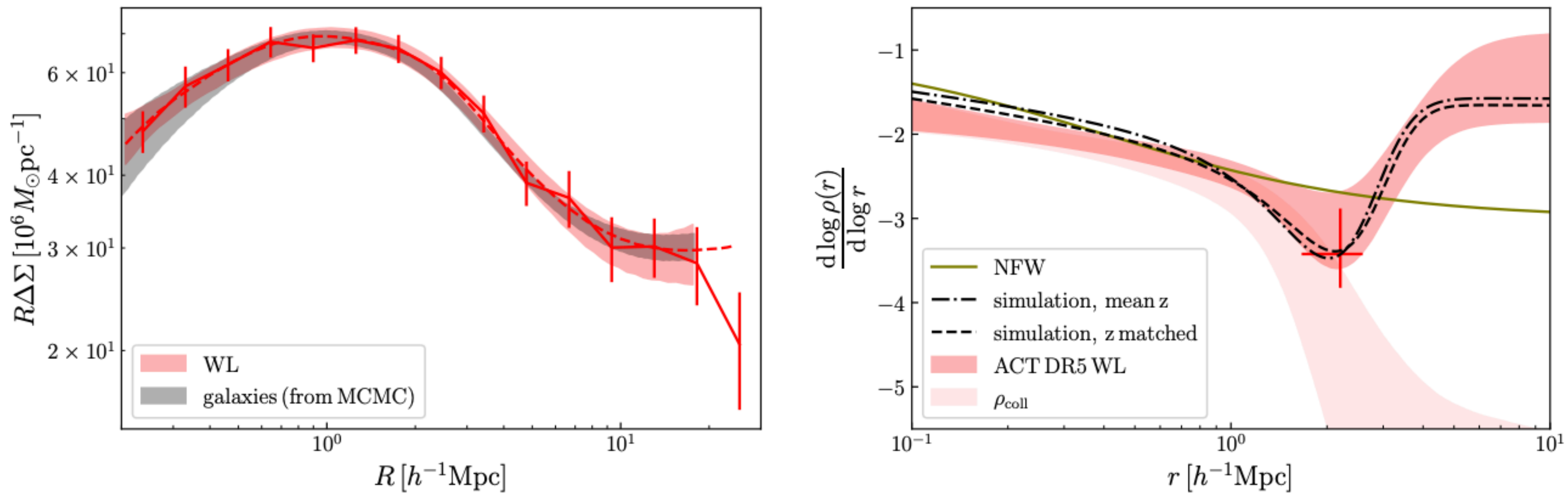


Splashback radius SZ clusters are statistically consistent with simulations

Pink - Slope of the fitted density profile
Black- Particles from MDPL2
Blue - Subhalos abundance matched

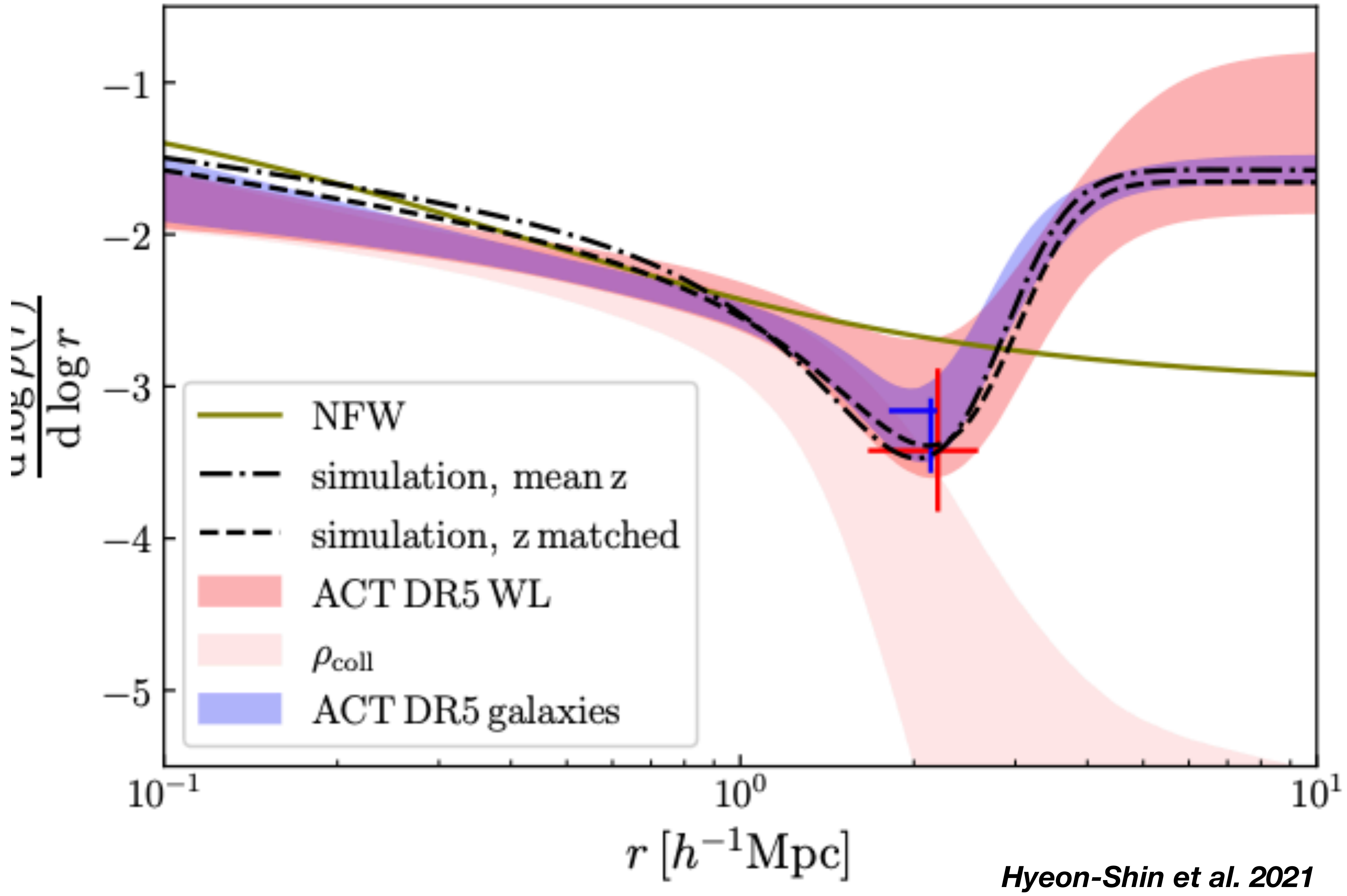
Consistent with Zuercher & More 2019 who did a similar analysis with Planck clusters

The Mass and Galaxy Distribution around ACT clusters using DES galaxies



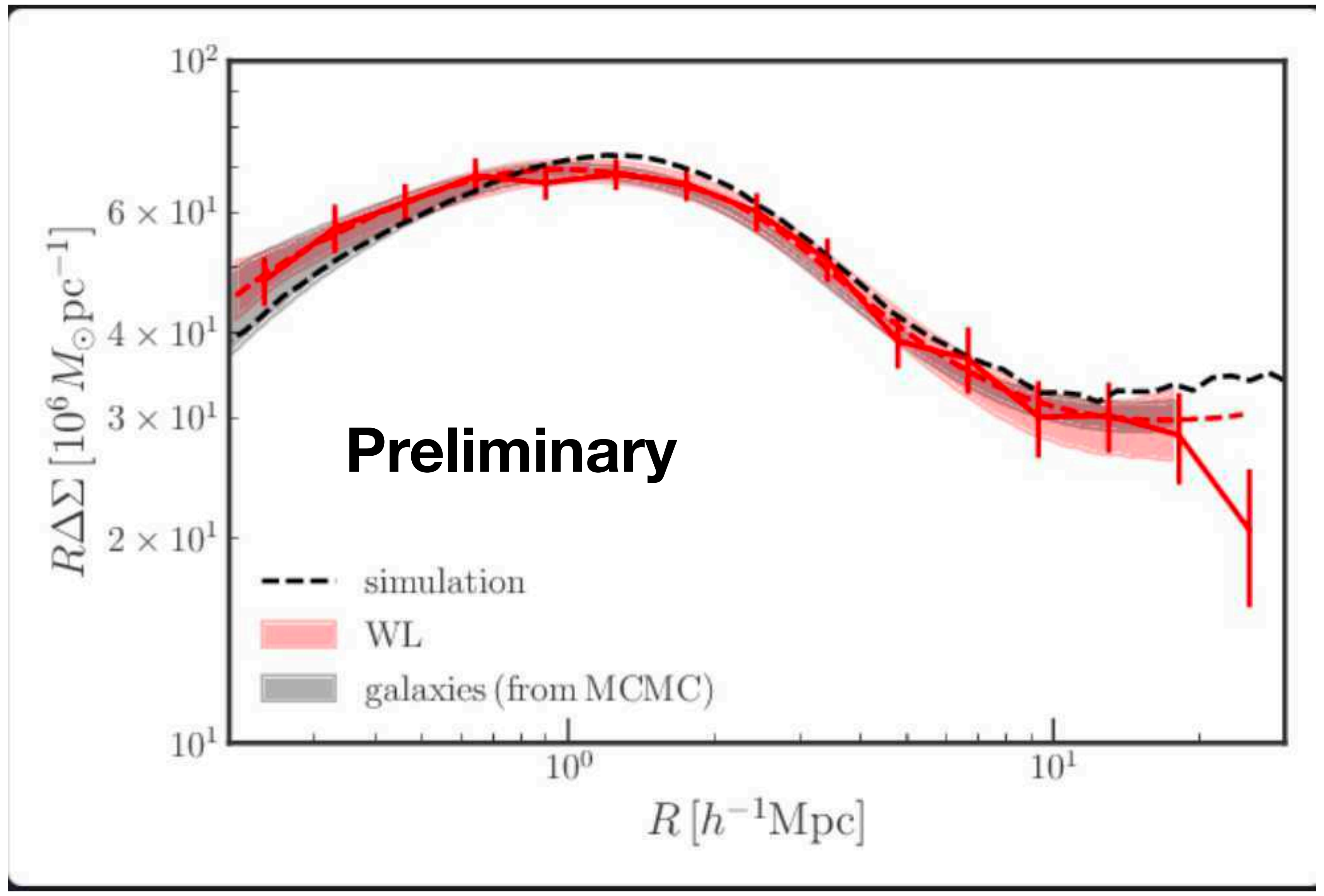
Hyeon-Shin et al. 2021

The Splashback radius of Dark Matter in massive galaxy clusters



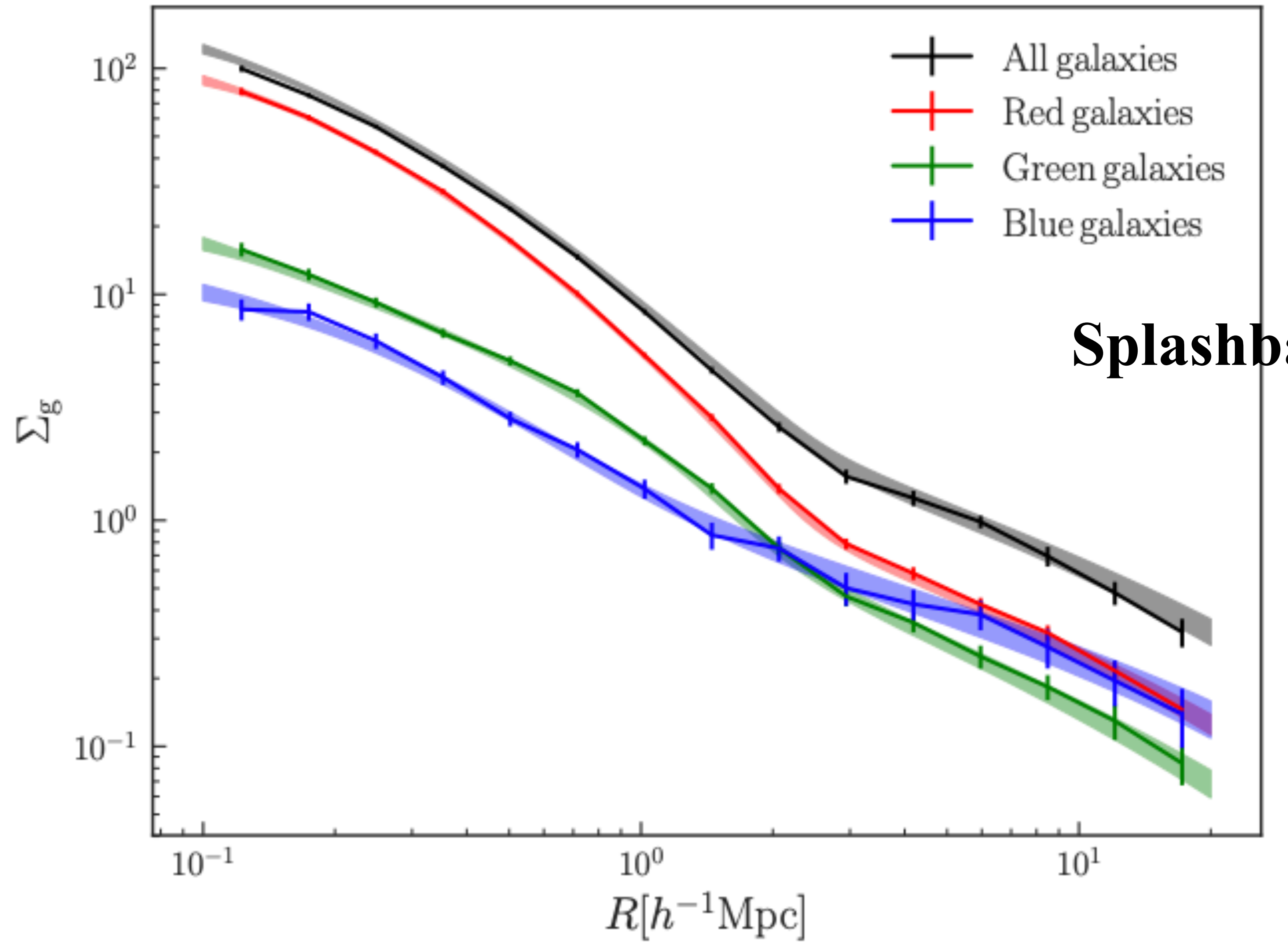
Hyeon-Shin et al. 2021

- **Galaxies and Dark Matter follow each other quite closely out to large distances**
- **Splash back radius agrees**
- **Lensing and galaxies are possibly steeper than CDM-only simulations**



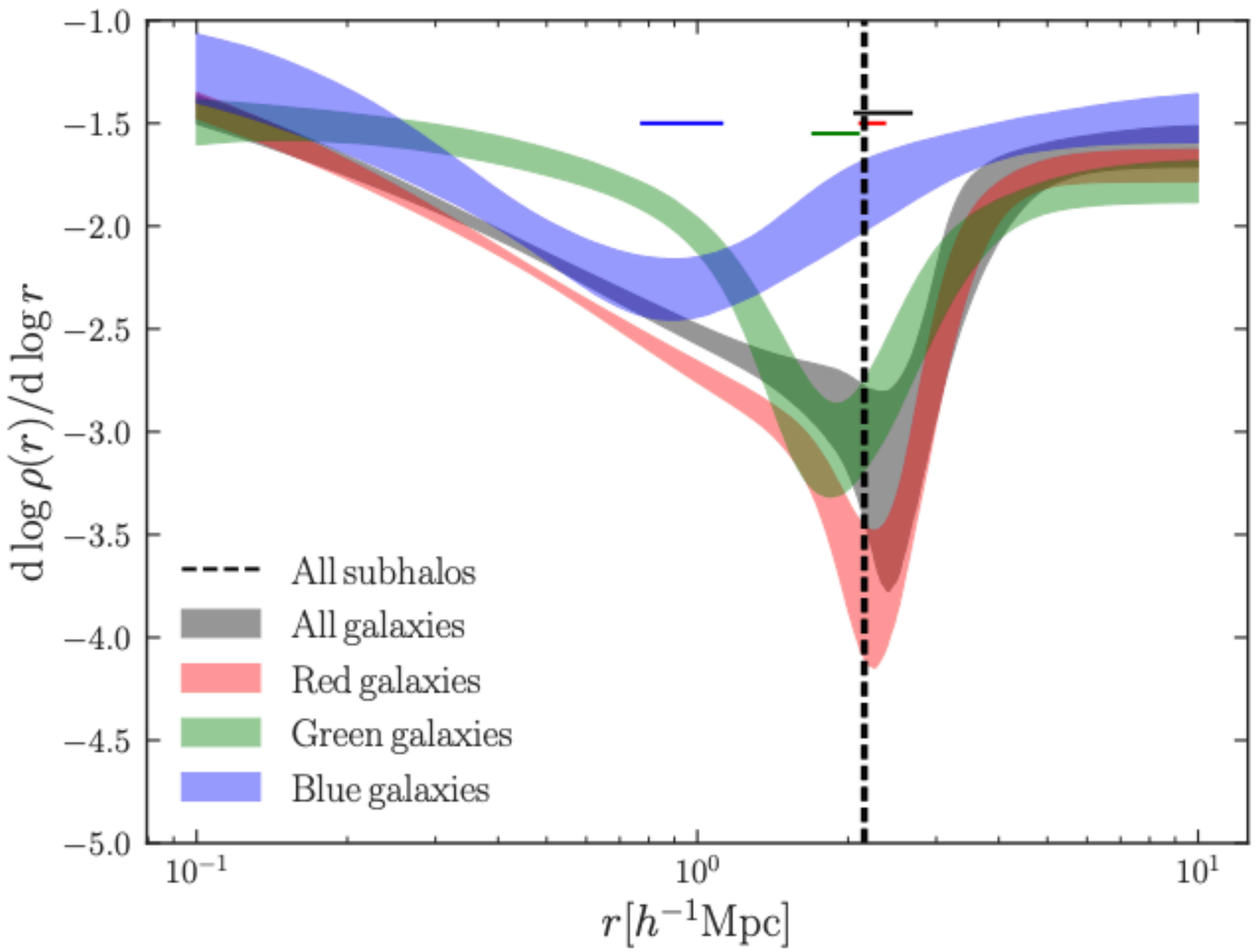
First measurement of both dark matter and galaxy distribution simultaneously

Distribution of galaxies of different galaxy color inside clusters



Adhikari et al. 2020

Splashback radius and the star-formation history of galaxies

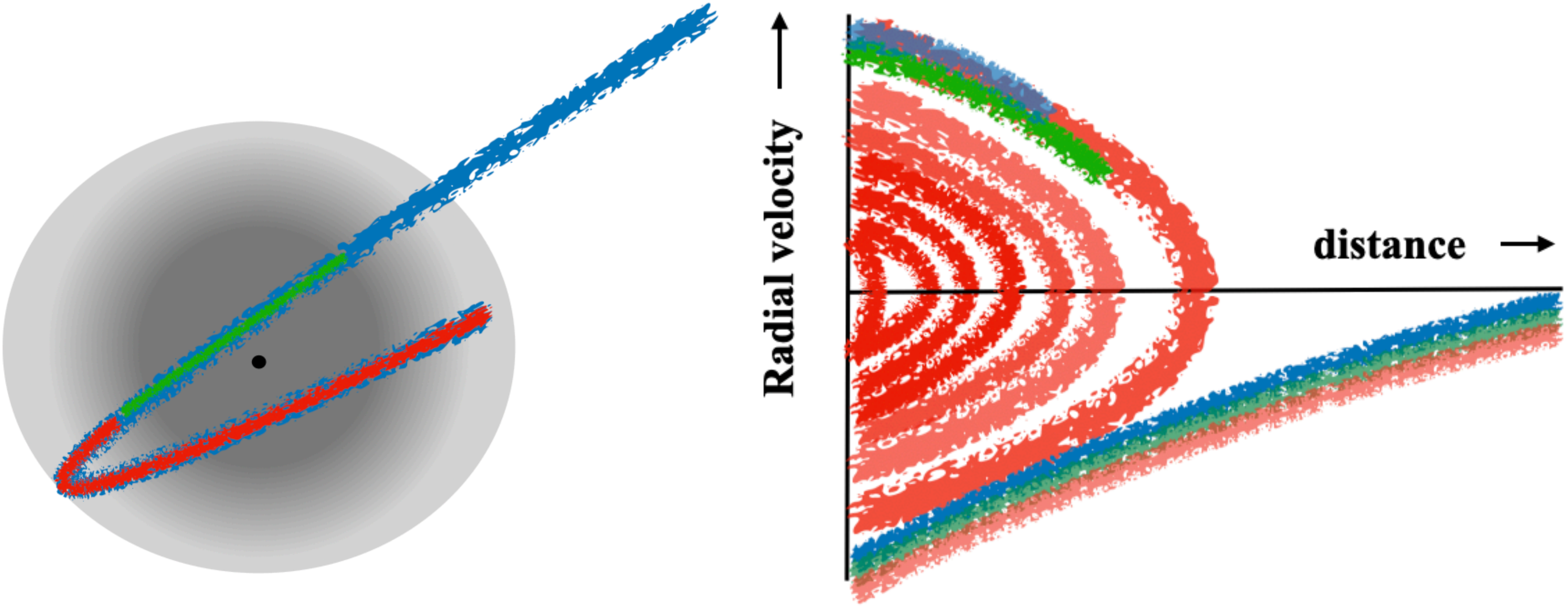


Adhikari et al. 2020

The splashback radius as a clock in the halo

Galaxies stop forming stars with time as they fall into a halo

Blue star-forming galaxies turn into red and dead galaxies

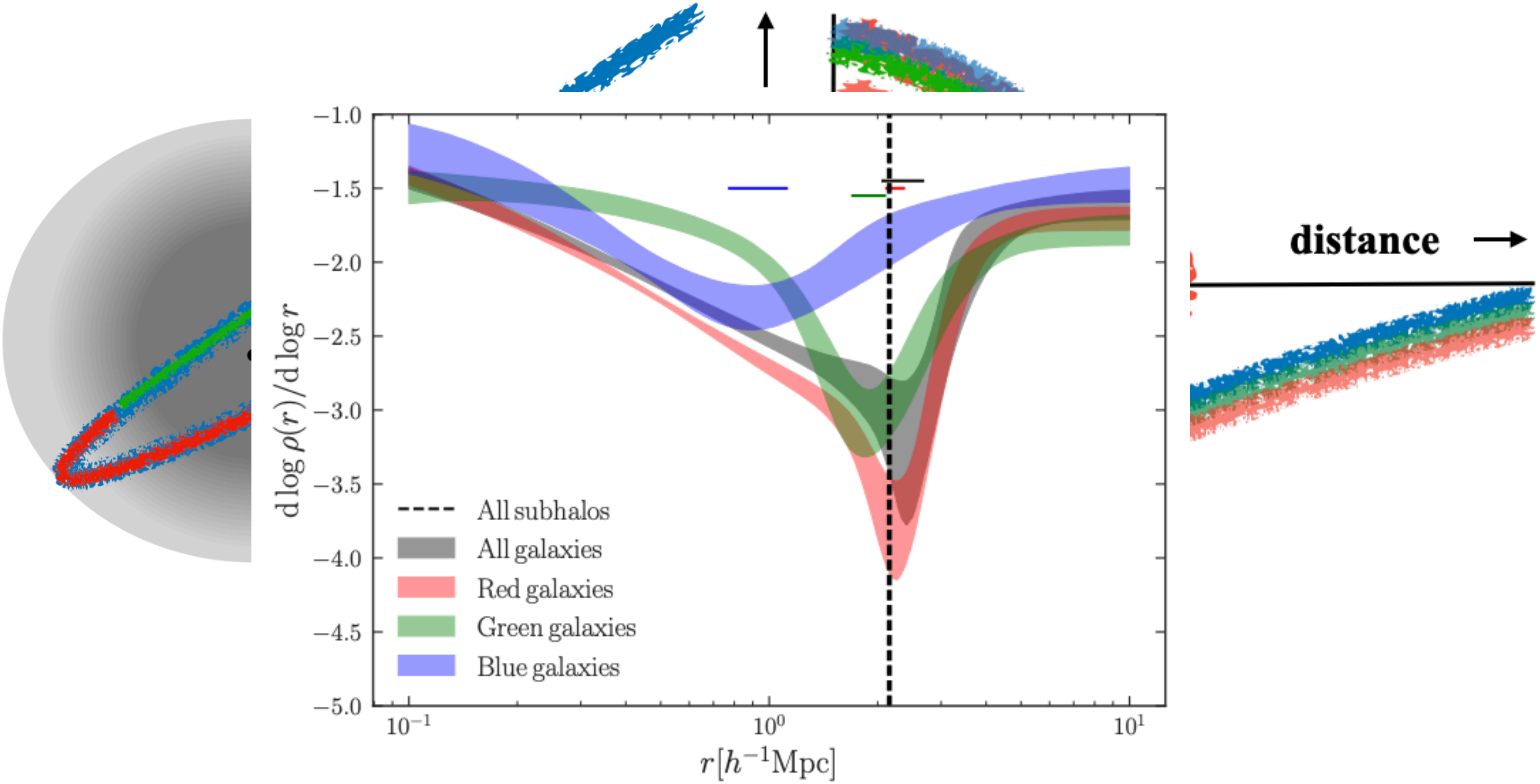


Minimum traces the time spent in the cluster by a population of galaxies

The splashback radius as a clock in the halo

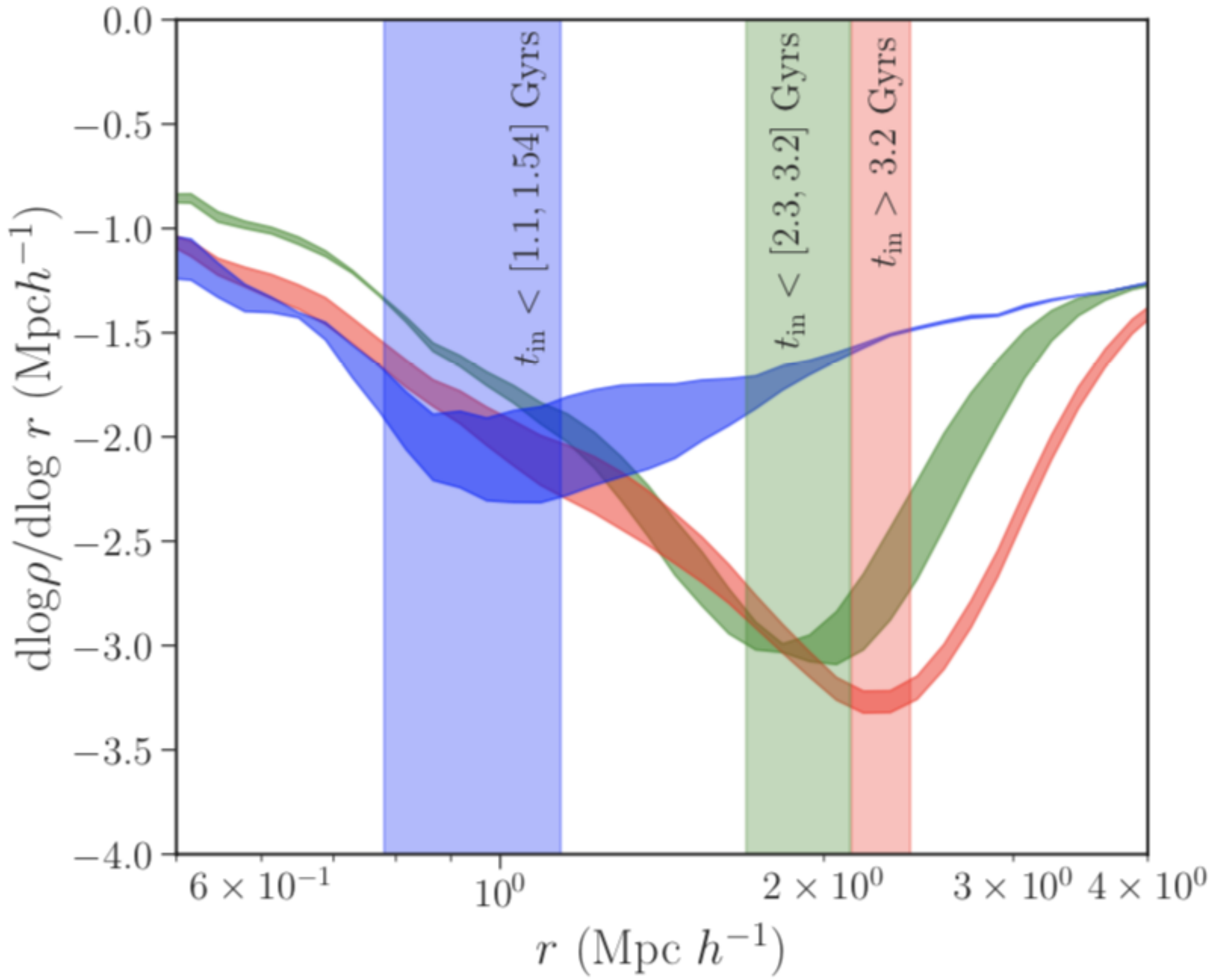
Galaxies stop forming stars with time as they fall into a halo

Blue star-forming galaxies turn into red and dead galaxies



Minimum traces the time spent in the cluster by a population of galaxies

Galaxy infall times from cluster profiles

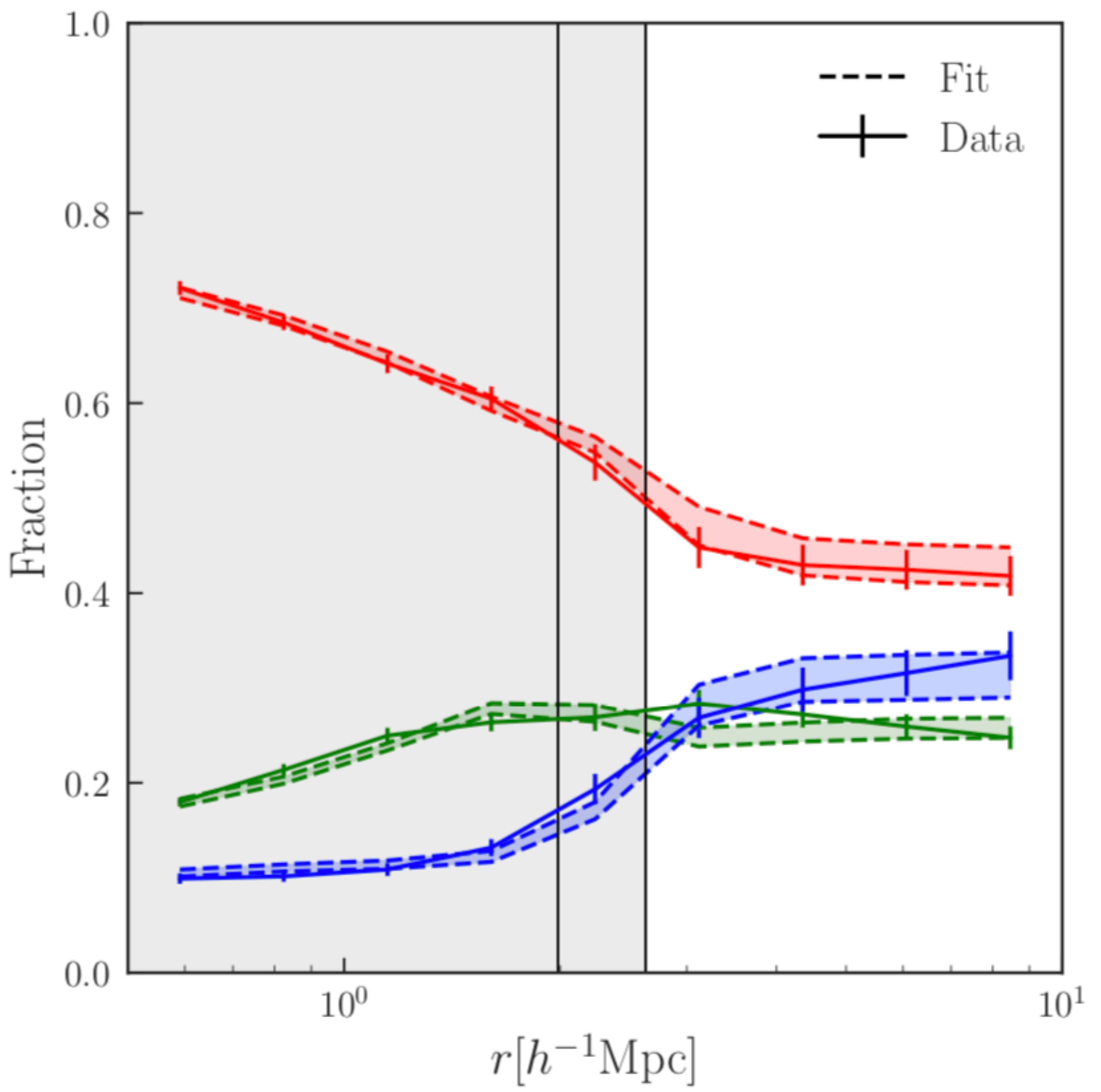


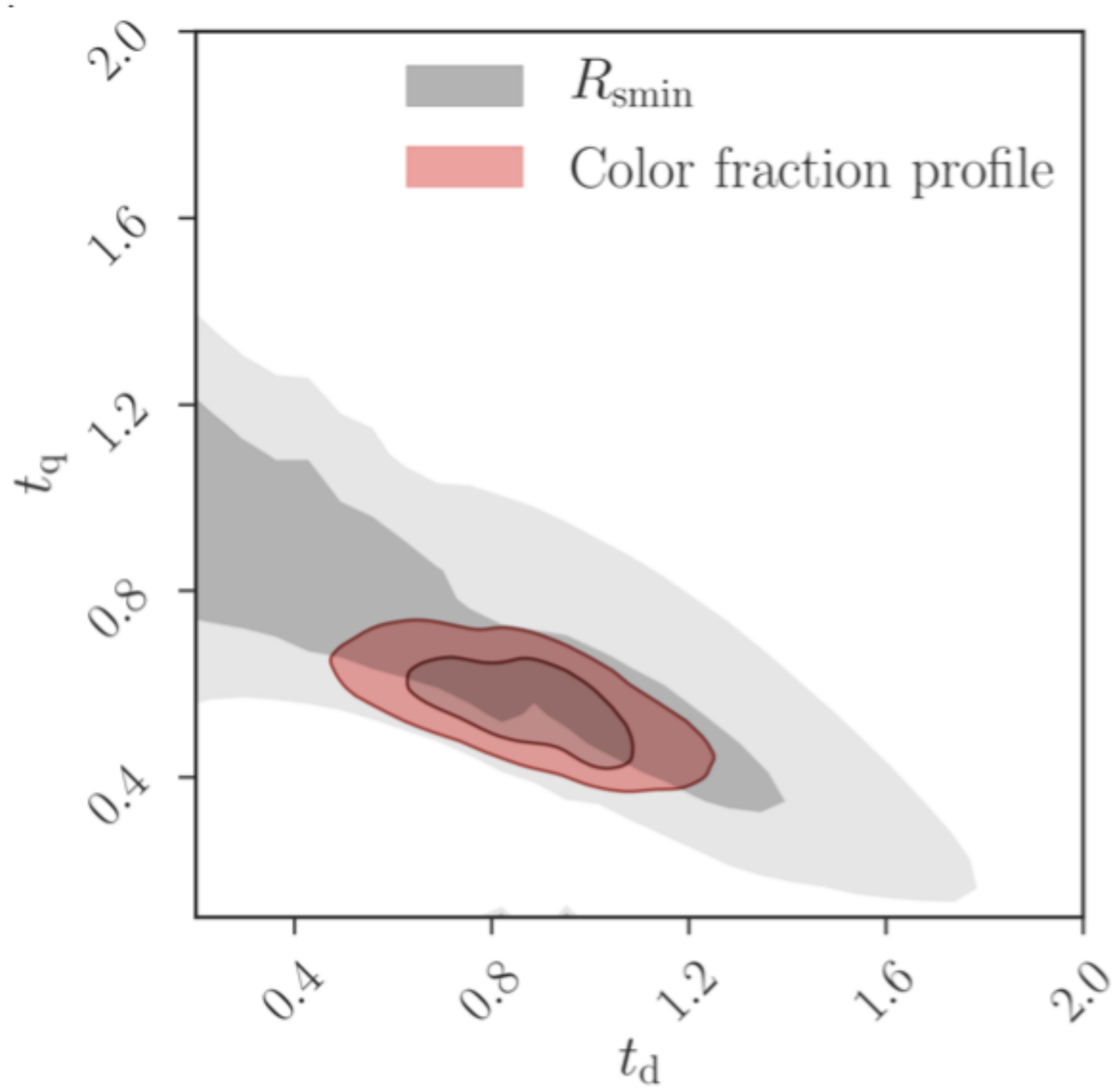
Red - contains galaxies accreted before 3.2 Gyrs

Green galaxies - accreted between [2.3-3.2] Gyrs

Blue galaxies have fallen in recently < 1.5 Gyrs

Constraints on the quenching timescales inside galaxy clusters





Exponential quenching time ~ 0.6 Gyrs

Delay time ~ 1 Gyr

Looking ahead at the future

Where is the boundary of the gas in the dark matter halo? (see Eric’s talk)

How does it relate to the splashback radius?

How does it relate to the boundary of galaxy quenching?

How does the distribution of Dark Matter relate to the distribution of gas?

Can we obtain better constraints on mass using the splashback radius and the galaxy distribution?