The Depletion Region and the Characteristic Depletion Radius

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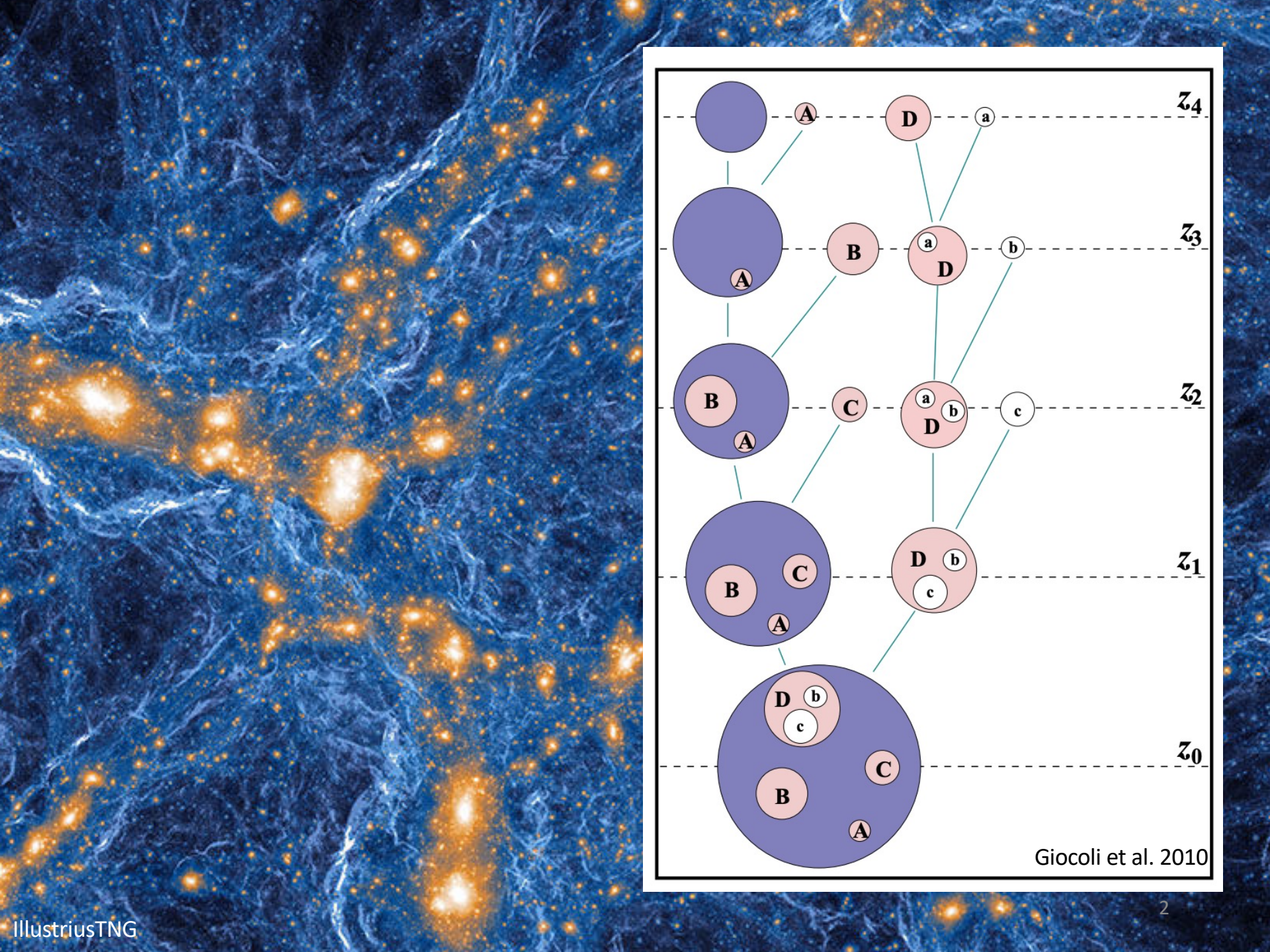
Advisor: Jiaxin Han
Shanghai Jiao Tong University
Cosmology From Home 2021


z4
z3
z2
z1
z0
A
D
a
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a
D
b
A
B
C
a
b
D
c
B
A
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D
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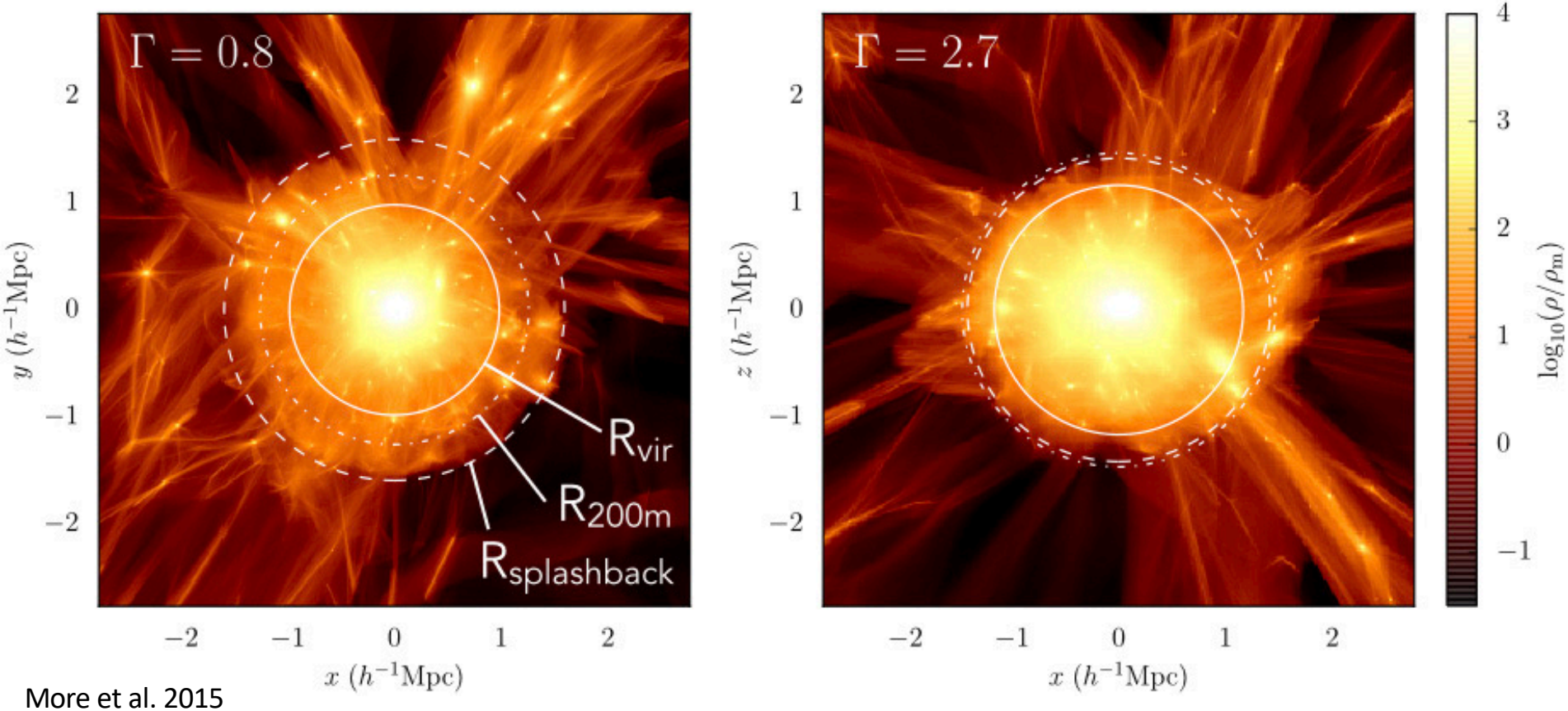
c
D
b
c
B
C
A
Giocoli et al. 2010
IllustriusTNG

Halo boundaries



More et al. 2015

Halo Bias

$$b(r) = \frac{\xi_{\mathrm{hm}}(r)}{\xi_{\mathrm{mm}}(r)} = \frac{\langle \delta(r) \rangle}{\xi_{\mathrm{mm}}(r)}$$

$$\delta(r) = \frac{\rho(r)}{\rho_m} - 1$$

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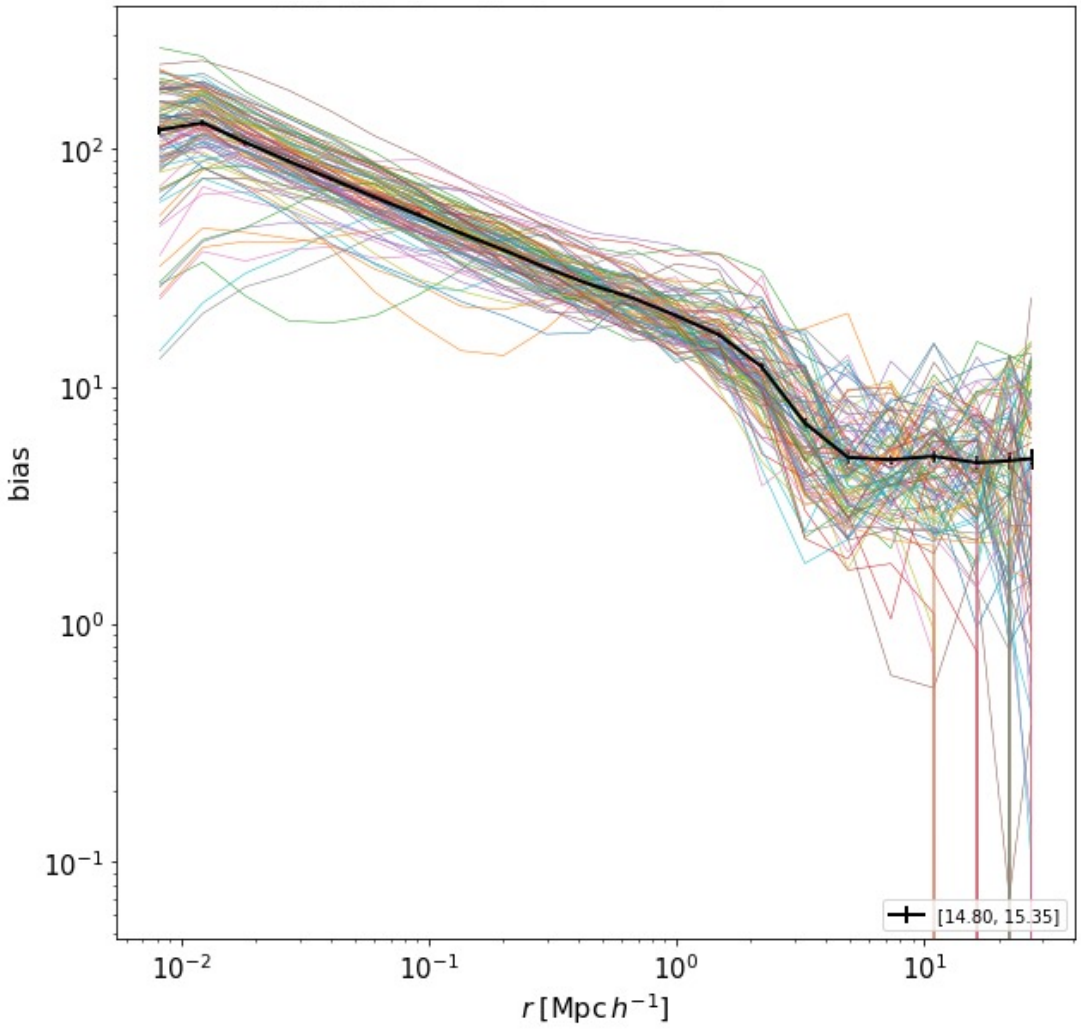

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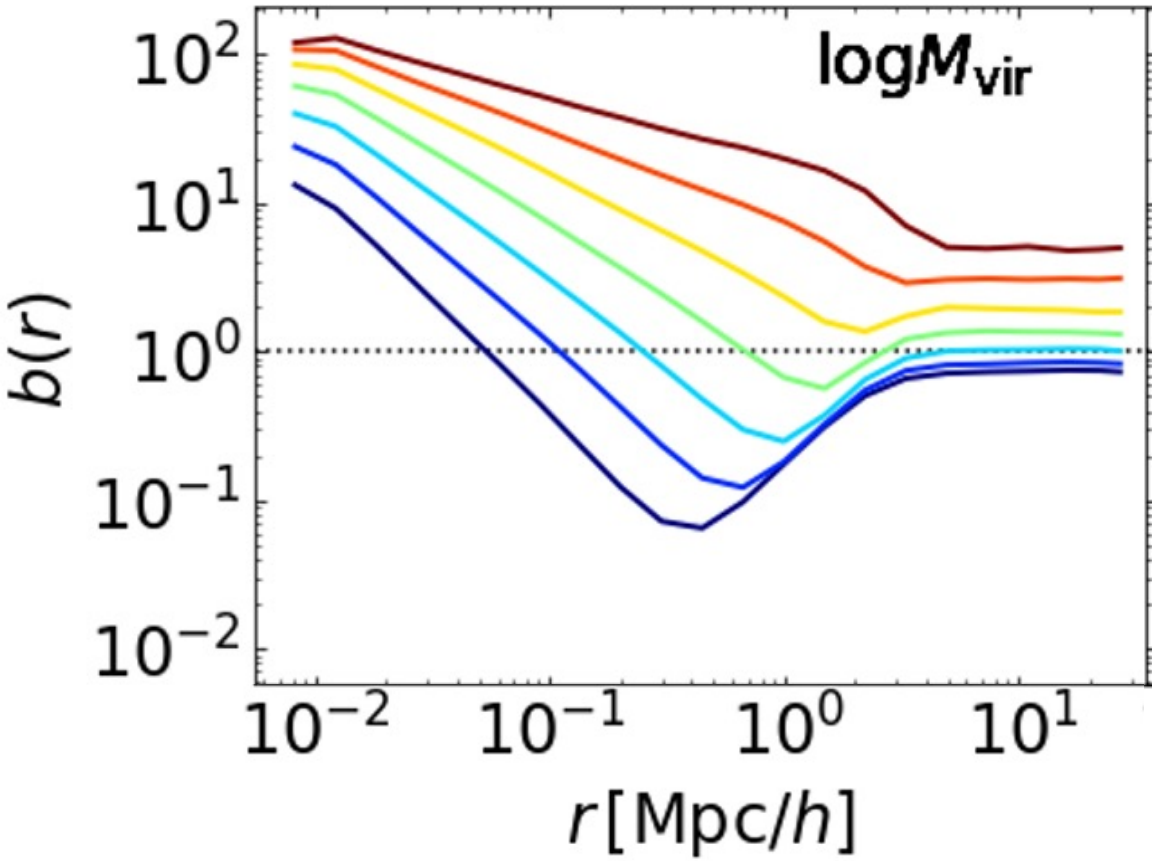

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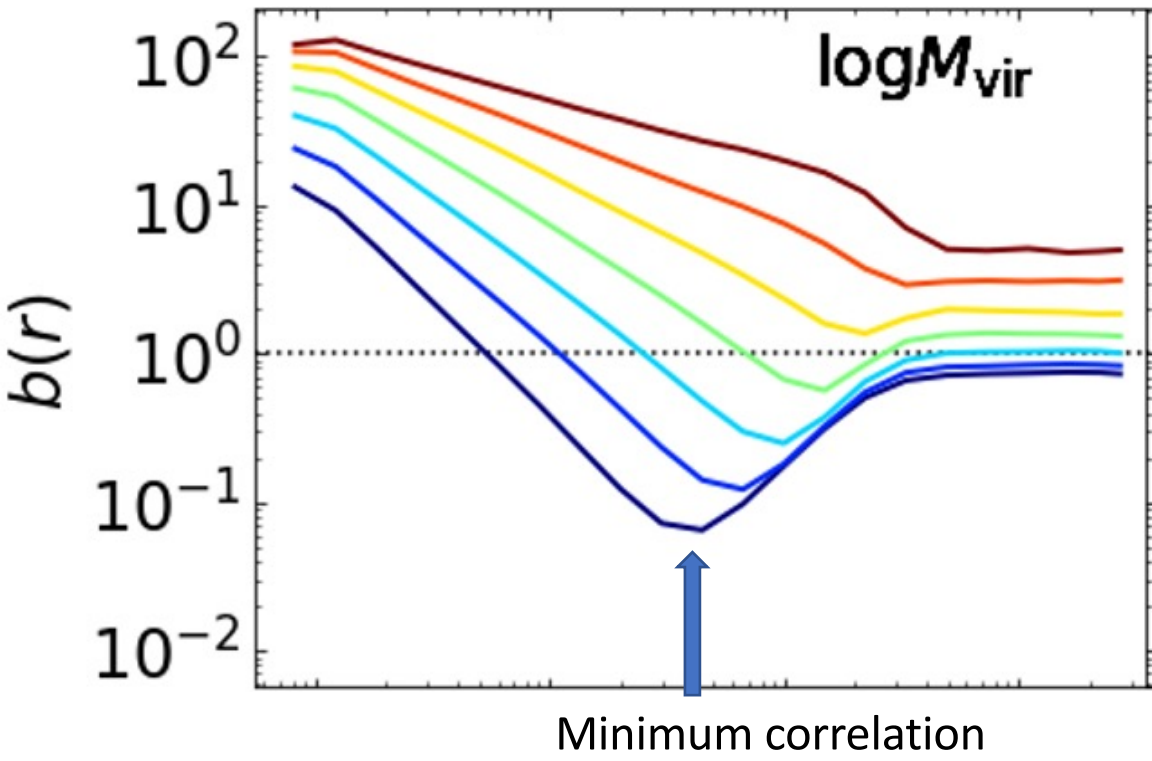
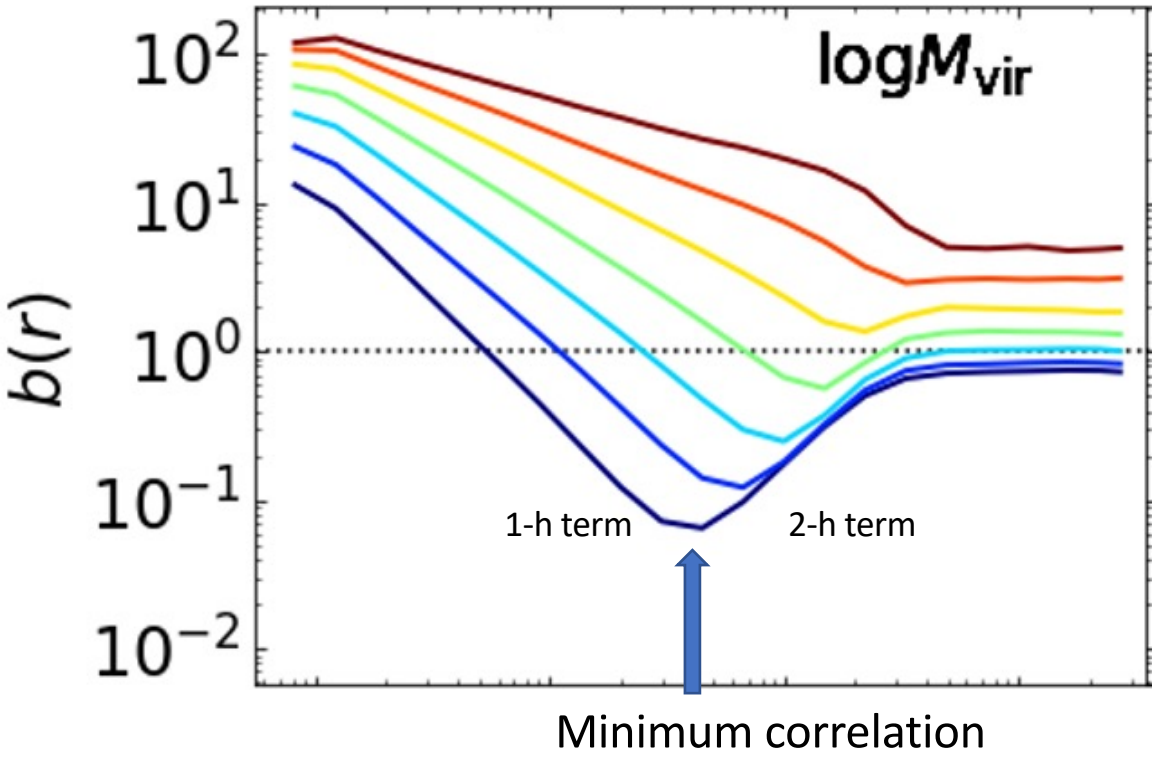


Minimum correlation

Halo Bias

$$b(r) = \frac{\xi_{\rm hm}(r)}{\xi_{\rm mm}(r)} = \frac{\langle \delta(r) \rangle}{\xi_{\rm mm}(r)}$$

$$\delta(r) = \frac{\rho(r)}{\rho_m} - 1$$



$$b(r) = \frac{\xi_{\rm hm}(r)}{\xi_{\rm mm}(r)} = \frac{\langle \delta(r) \rangle}{\xi_{\rm mm}(r)}$$

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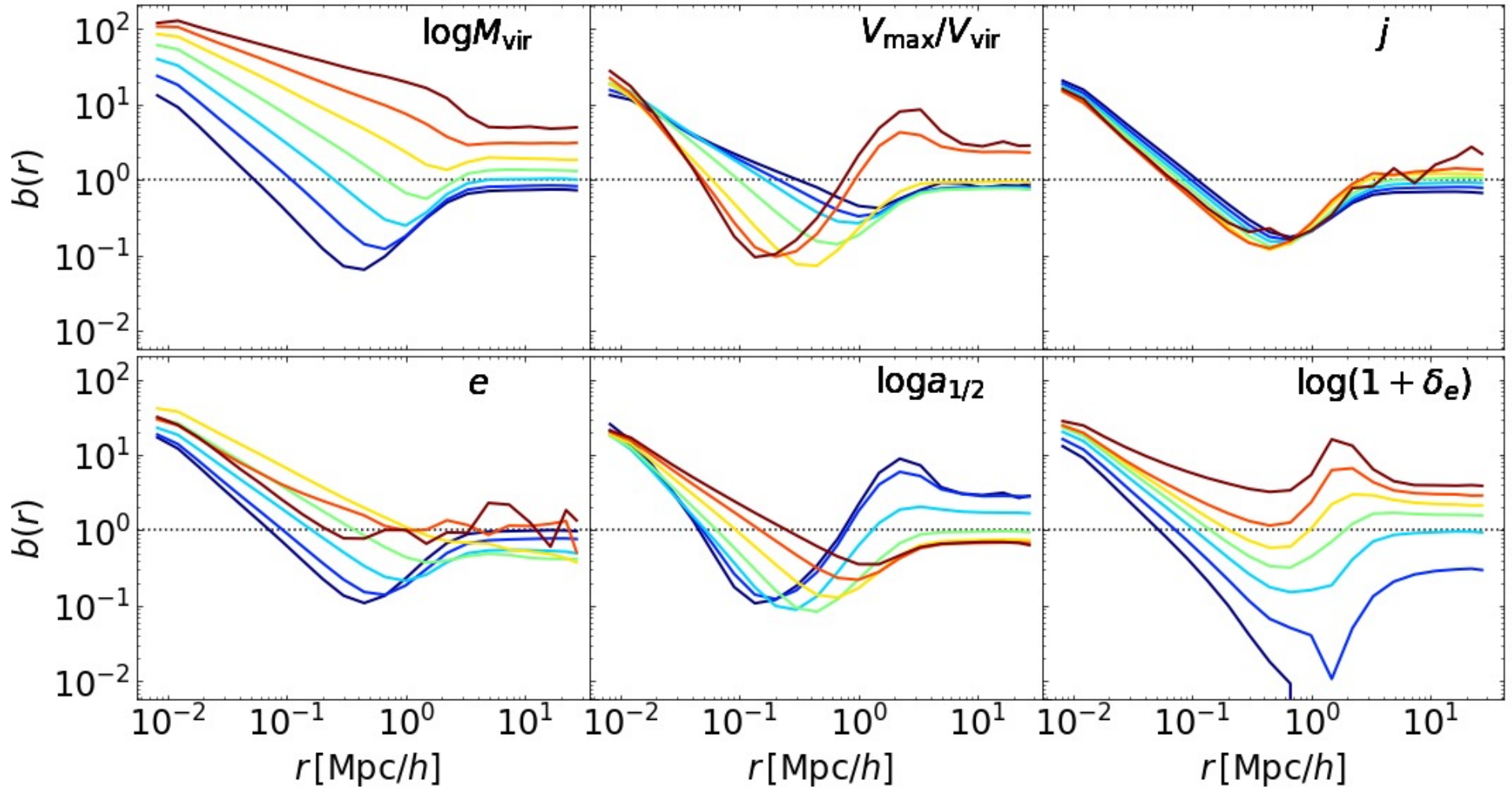

The depletion radius

$$b(r) = \frac{\xi_{\rm hm}(r)}{\xi_{\rm mm}(r)} = \frac{\langle \delta(r) \rangle}{\xi_{\rm mm}(r)}$$

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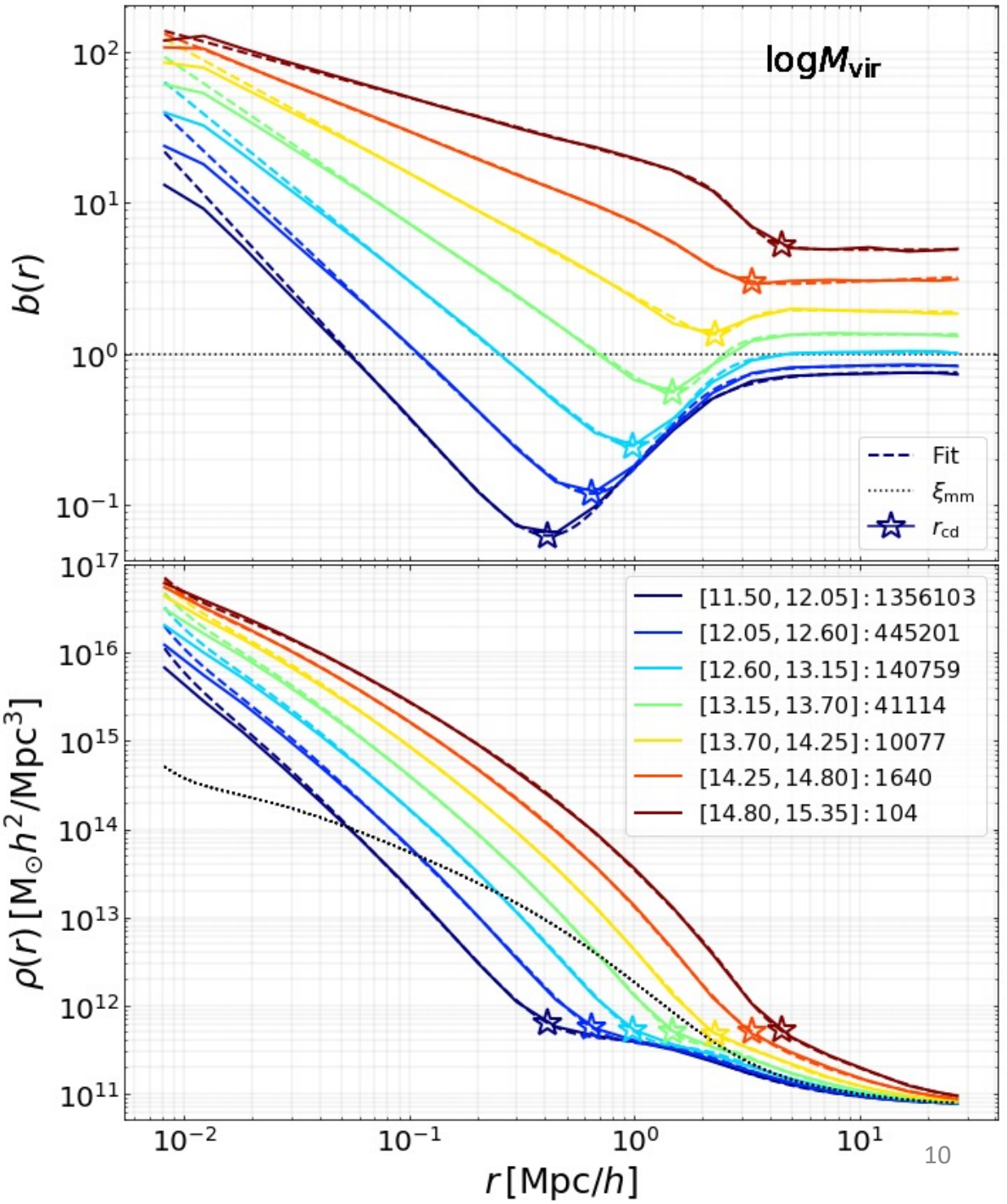

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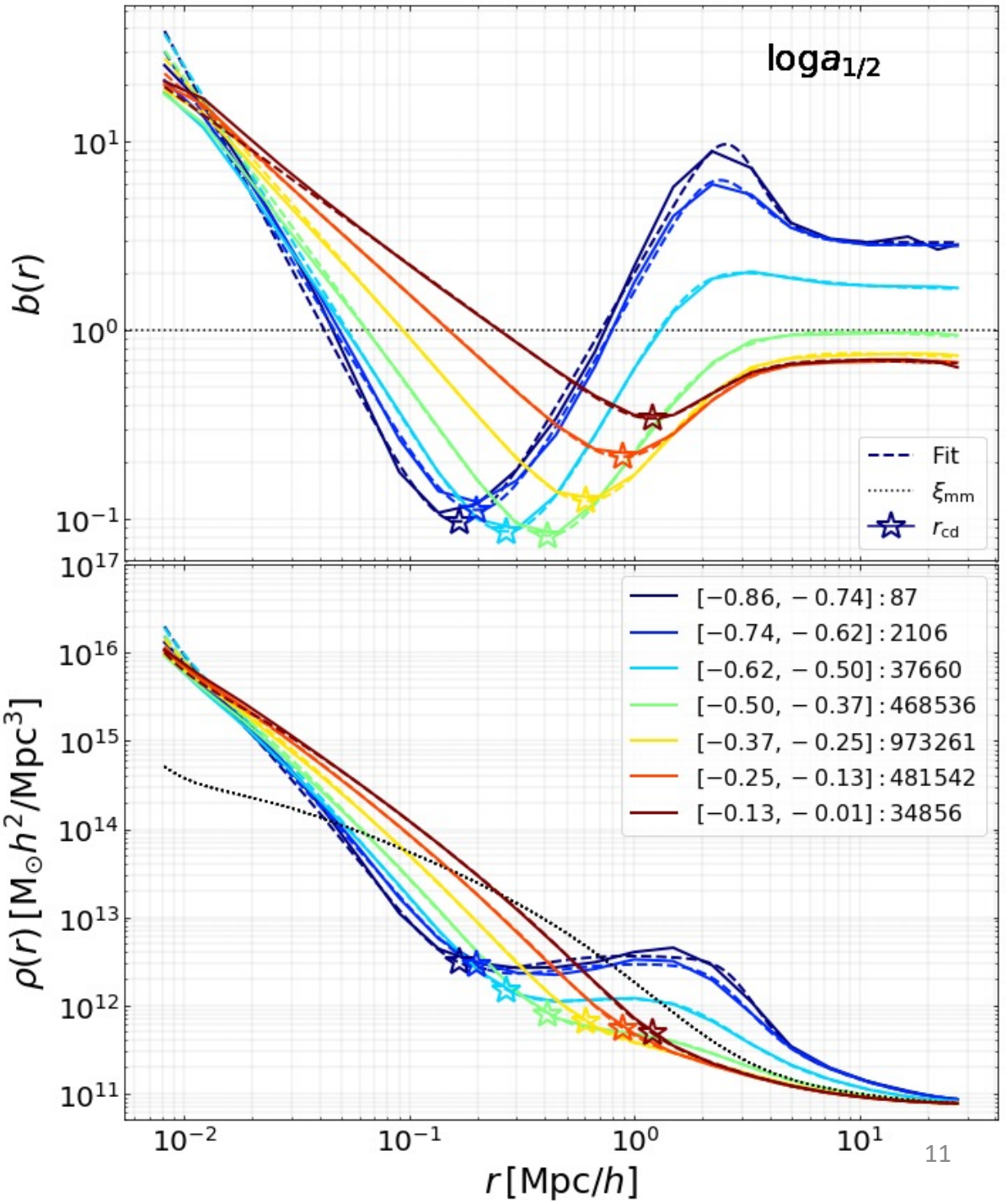
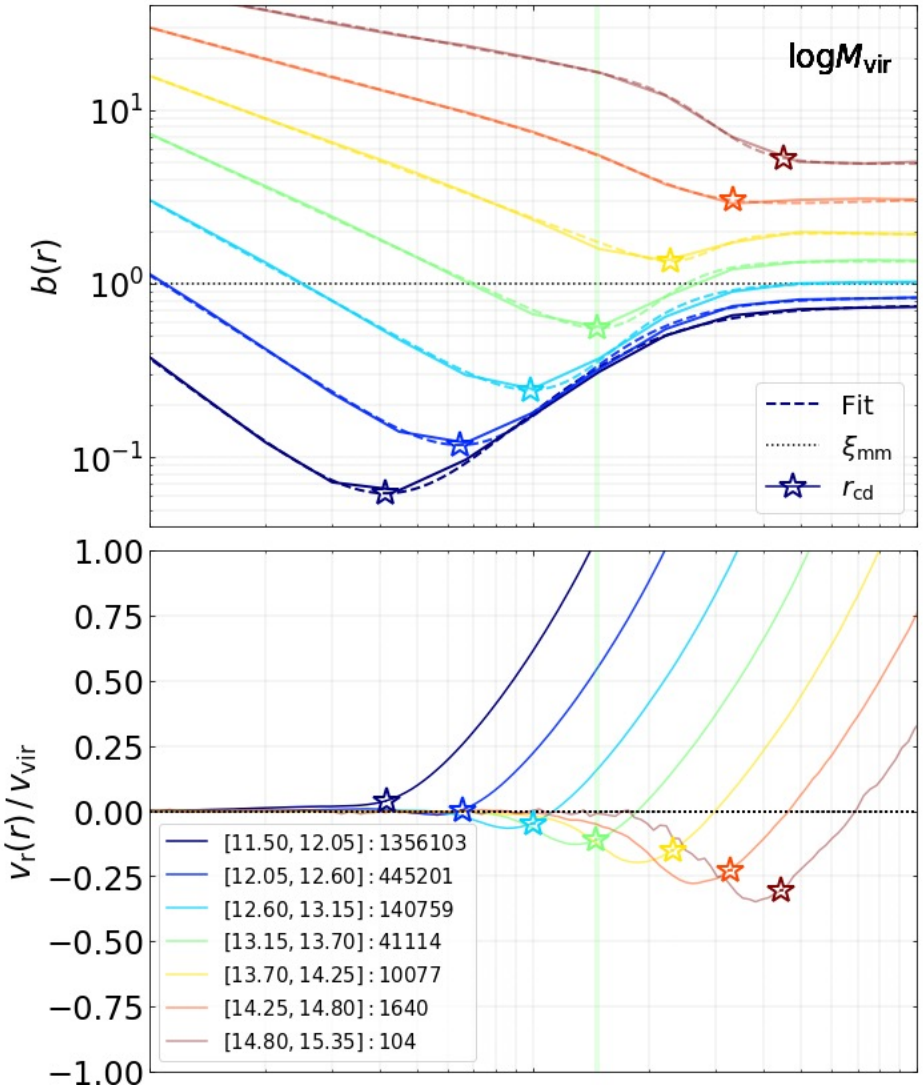
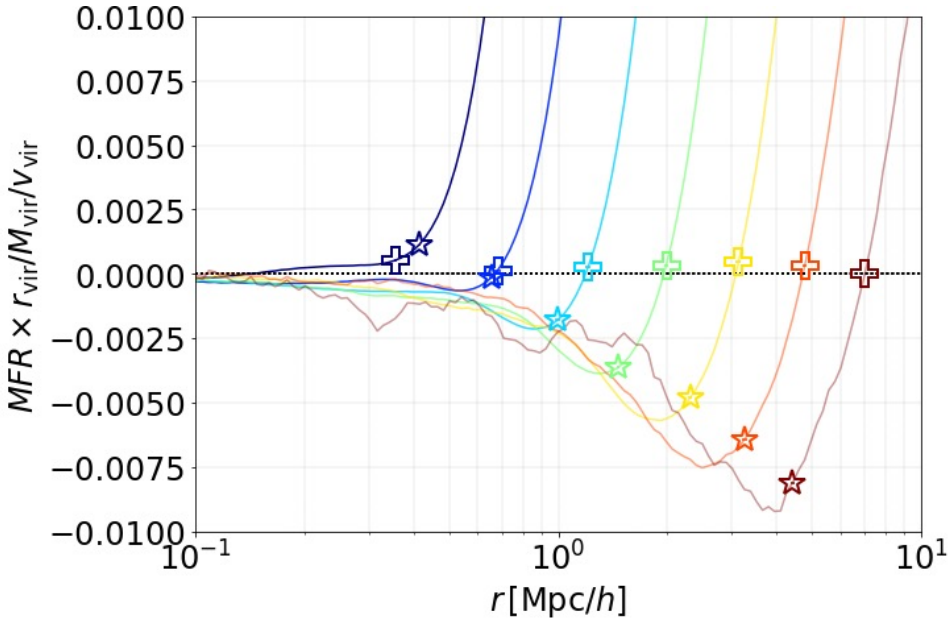




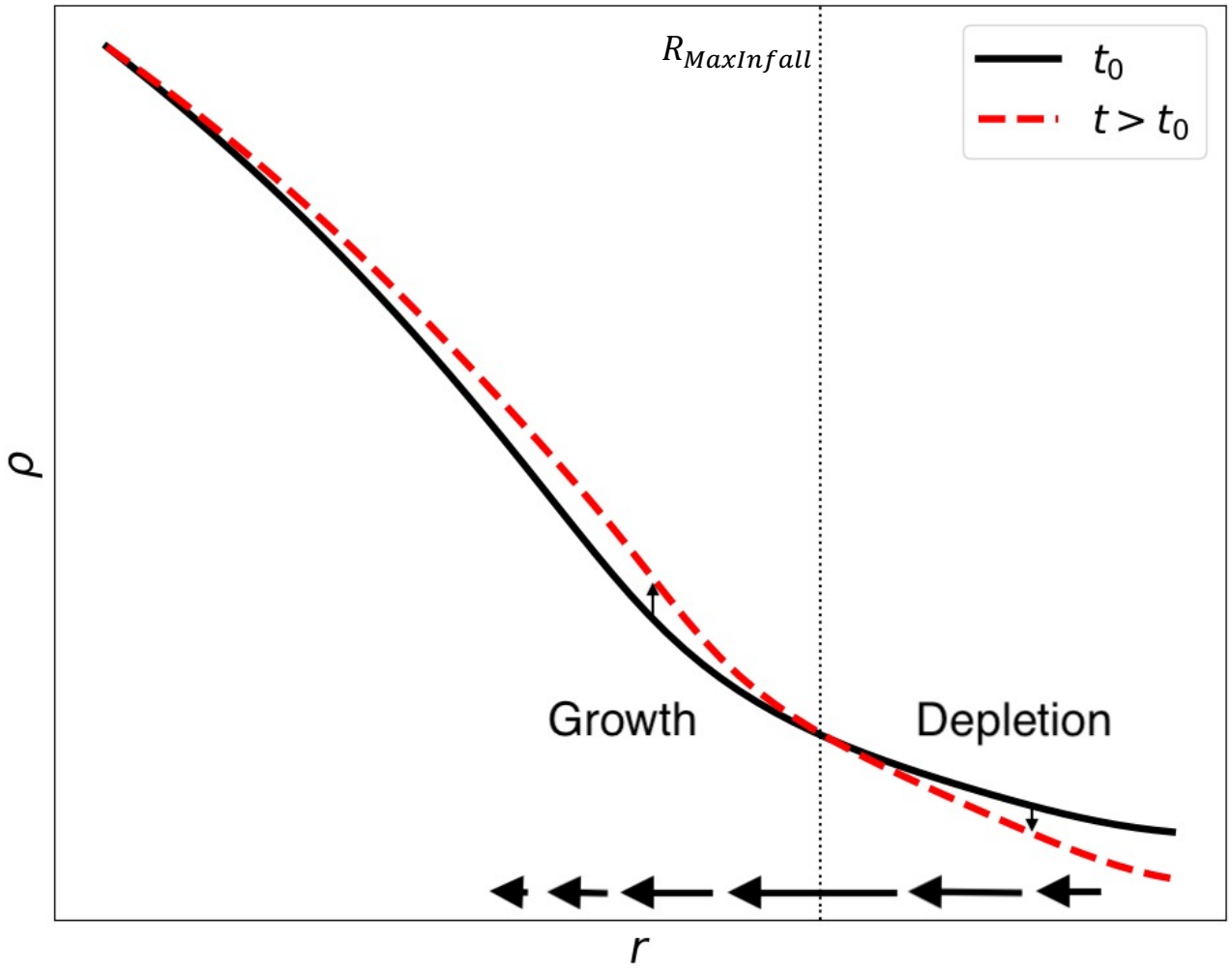
The depletion region



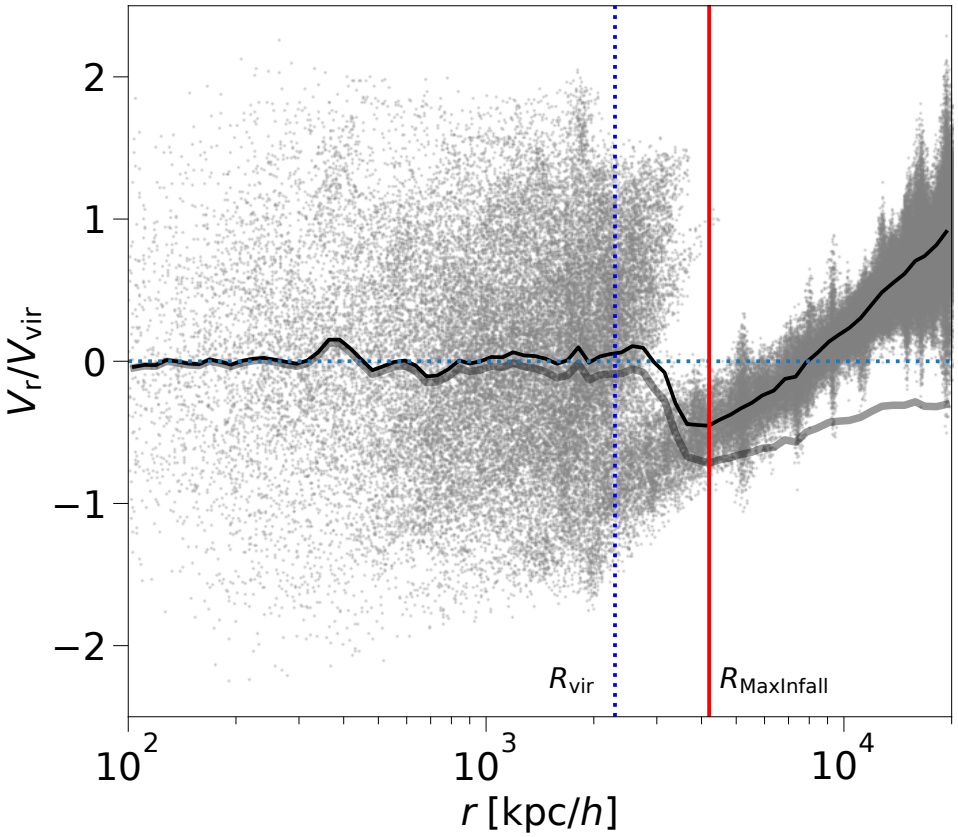
The locations of maximum inflow and infall are roughly the same

Depletion region

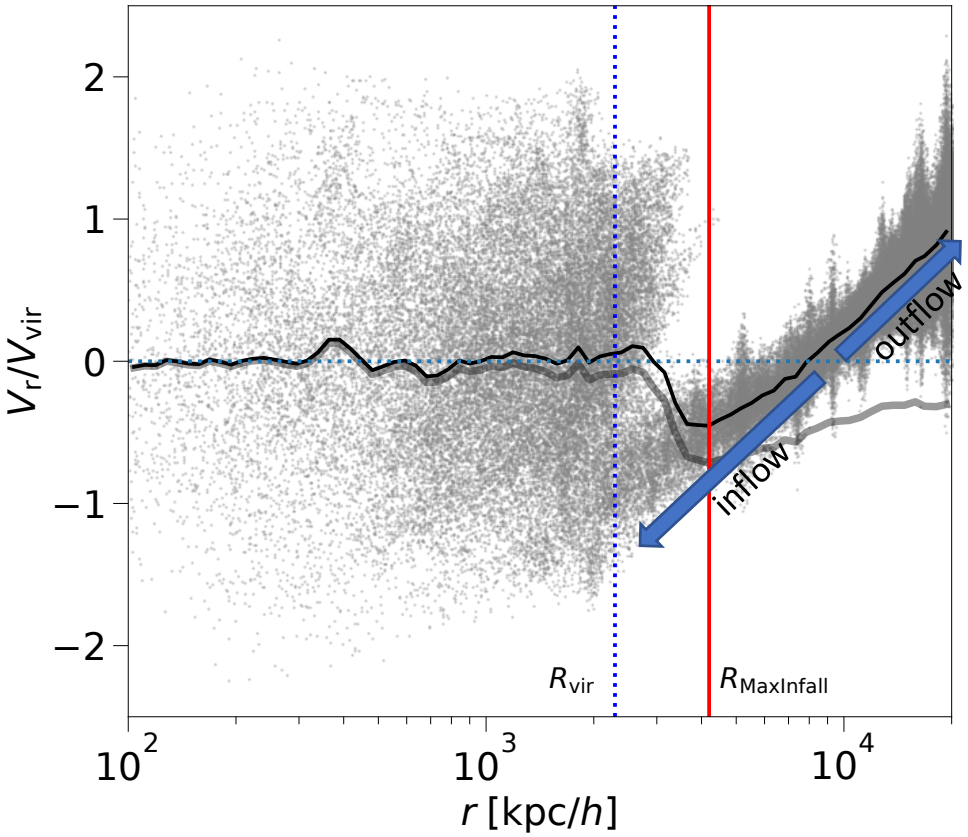
In the context of the depletion region, the location of maximum inflow or infall can be thought of as the inner depletion radius, r_{id}. Inside r_{id} the halo is growing and outside mass is being depleted from the halo's environment.



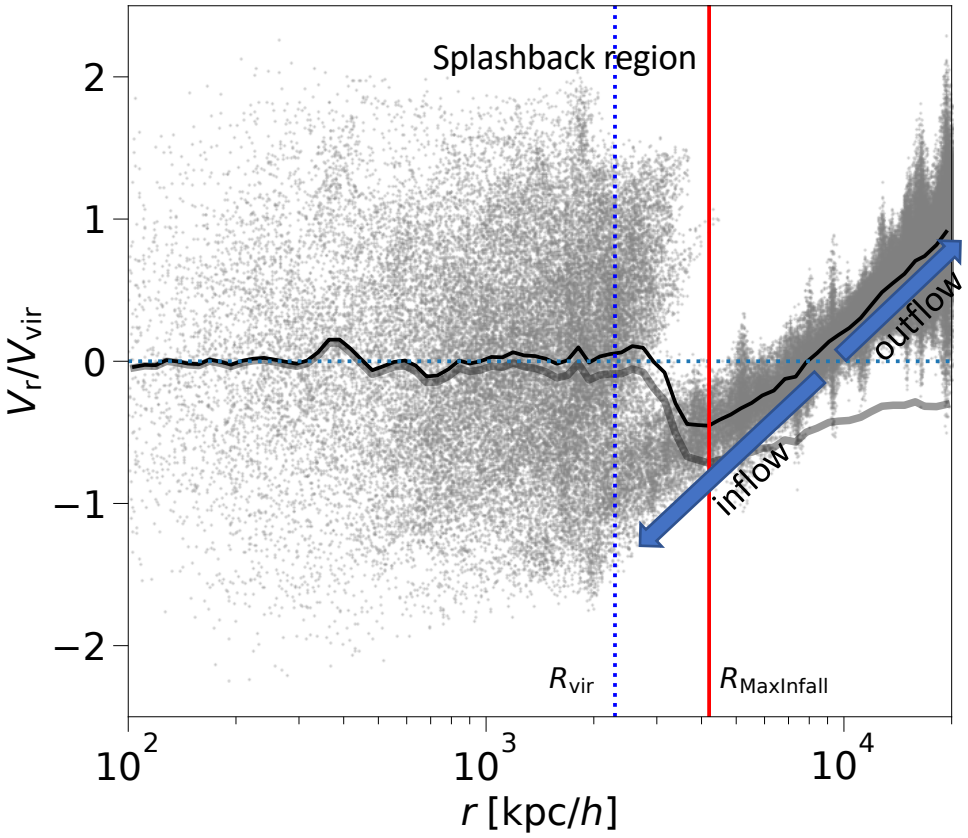
Depletion region



Depletion region



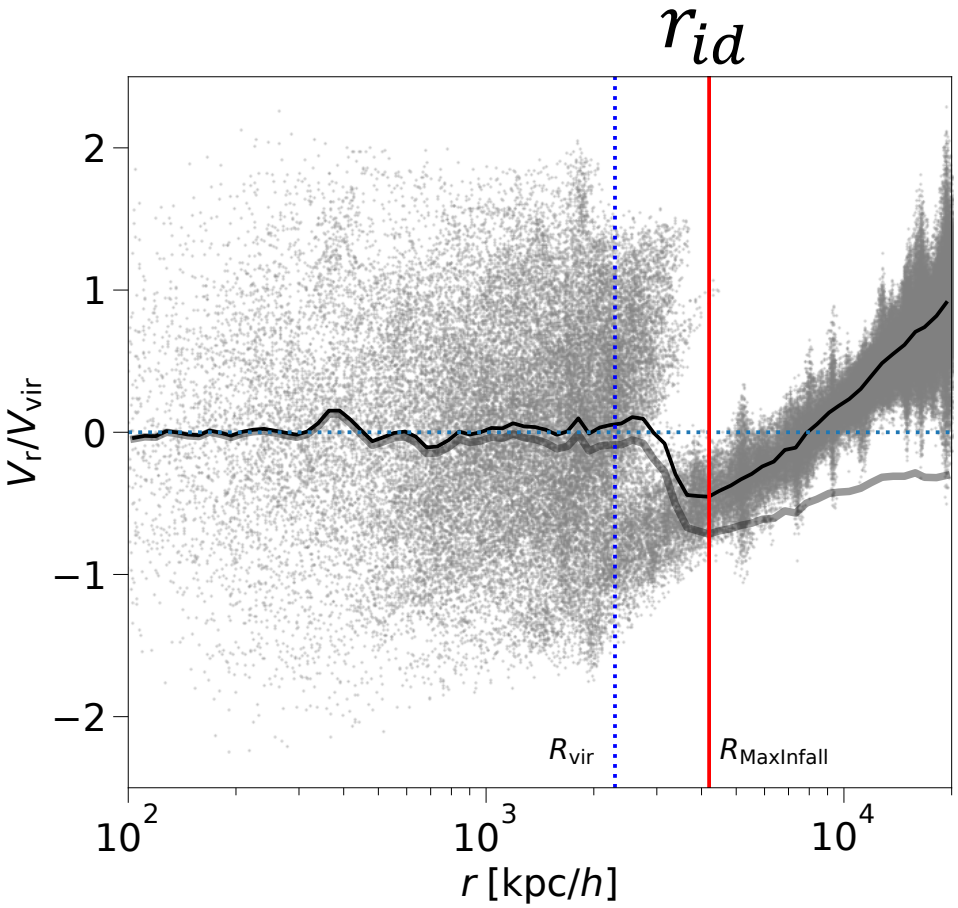
Depletion region

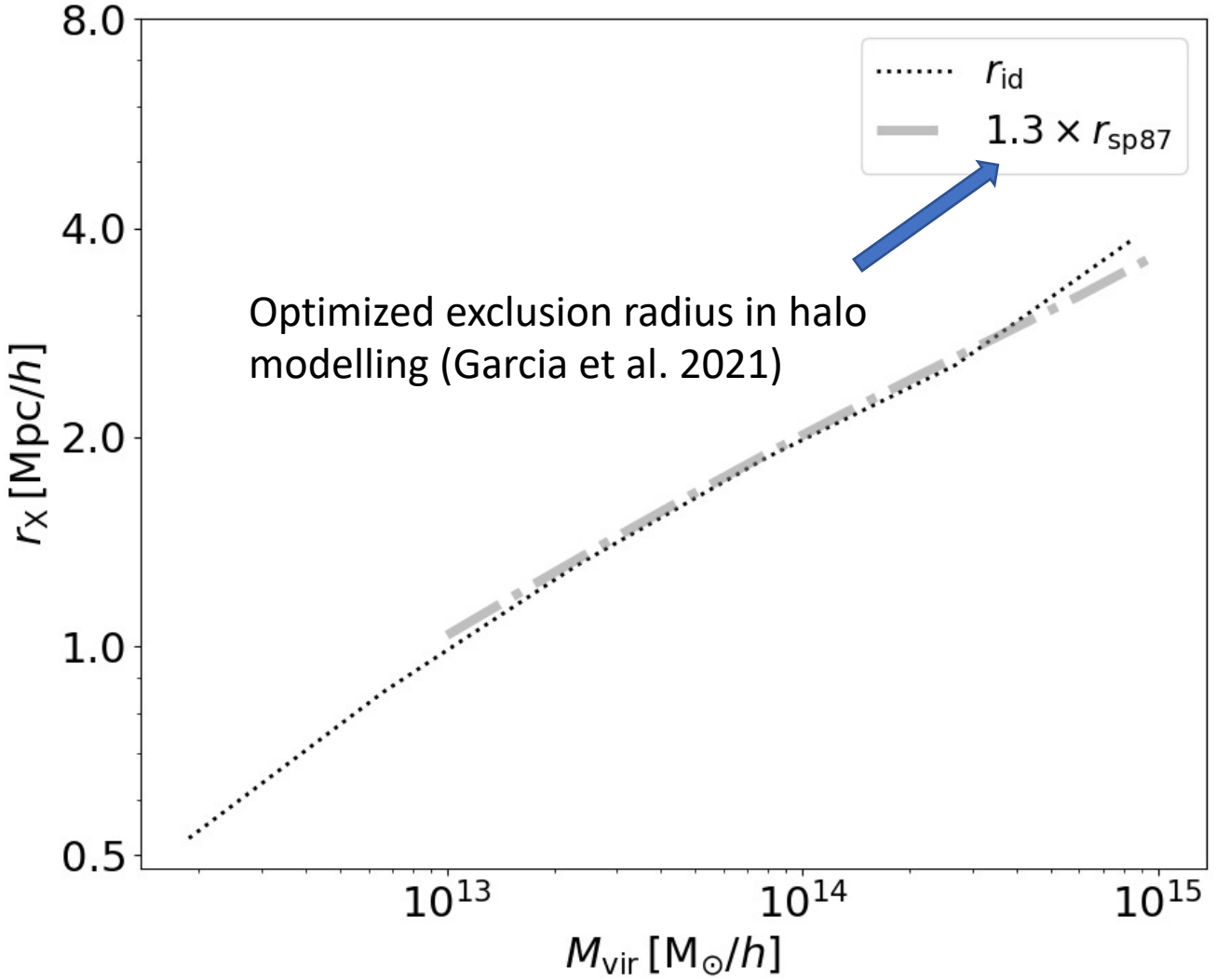


Depletion region

The depletion region can be characterized by three radii:

- The inner depletion radius r_{id}, or the maximum inflow (or outermost splashback) location




8.0
4.0
2.0
1.0
0.5
r_X [Mpc/h]
10^{13}
10^{14}
10^{15}
M_{vir} [$M_\odot/h$]
r_{id}
$1.3 \times r_{sp87}$
Optimized exclusion radius in halo modelling (Garcia et al. 2021)

Depletion region

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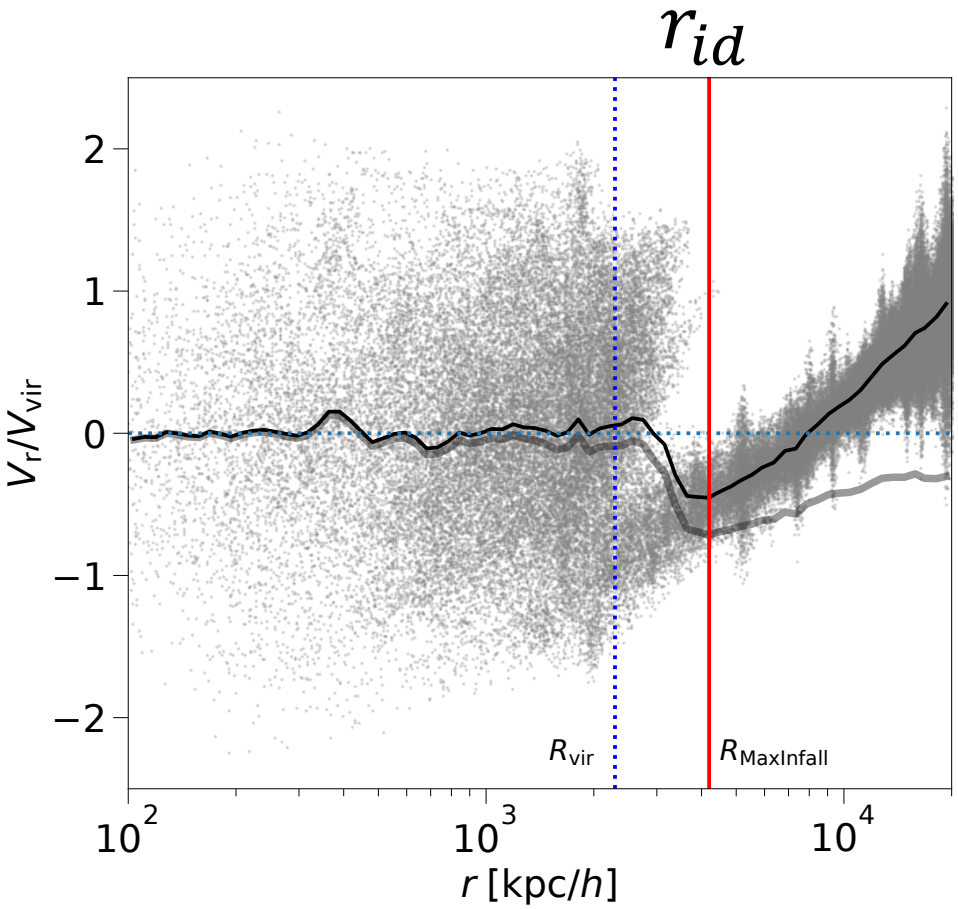
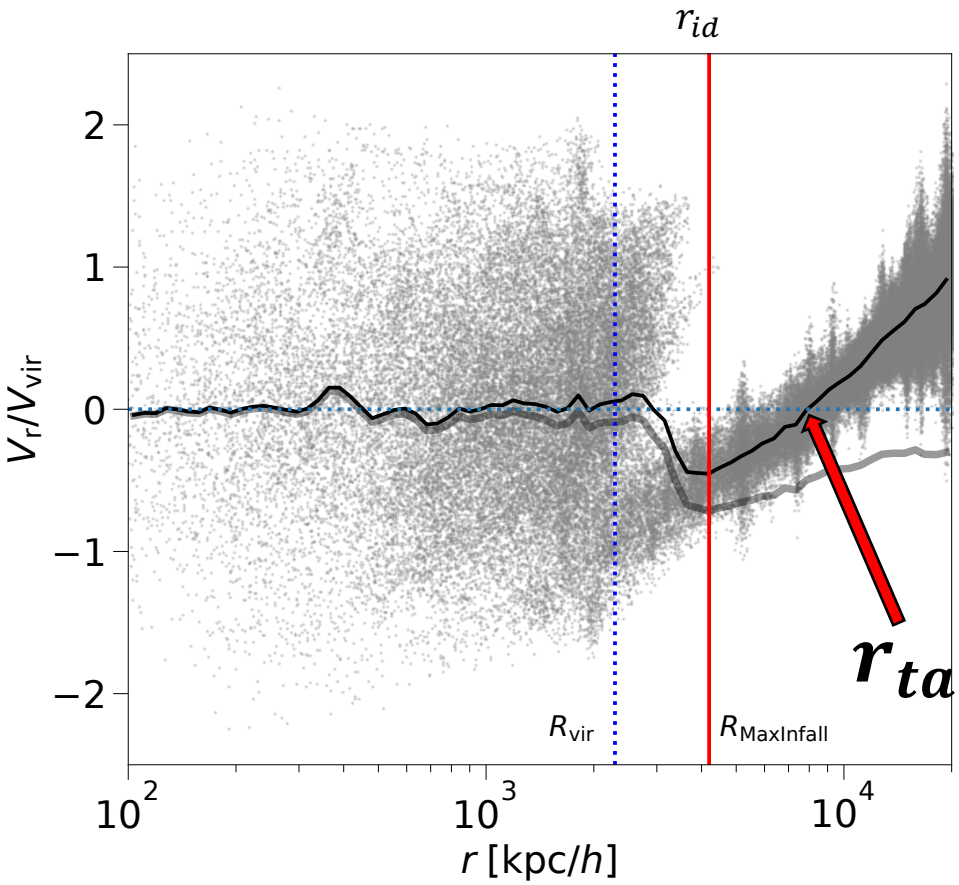


Depletion region

The depletion region can be characterized by three radii:

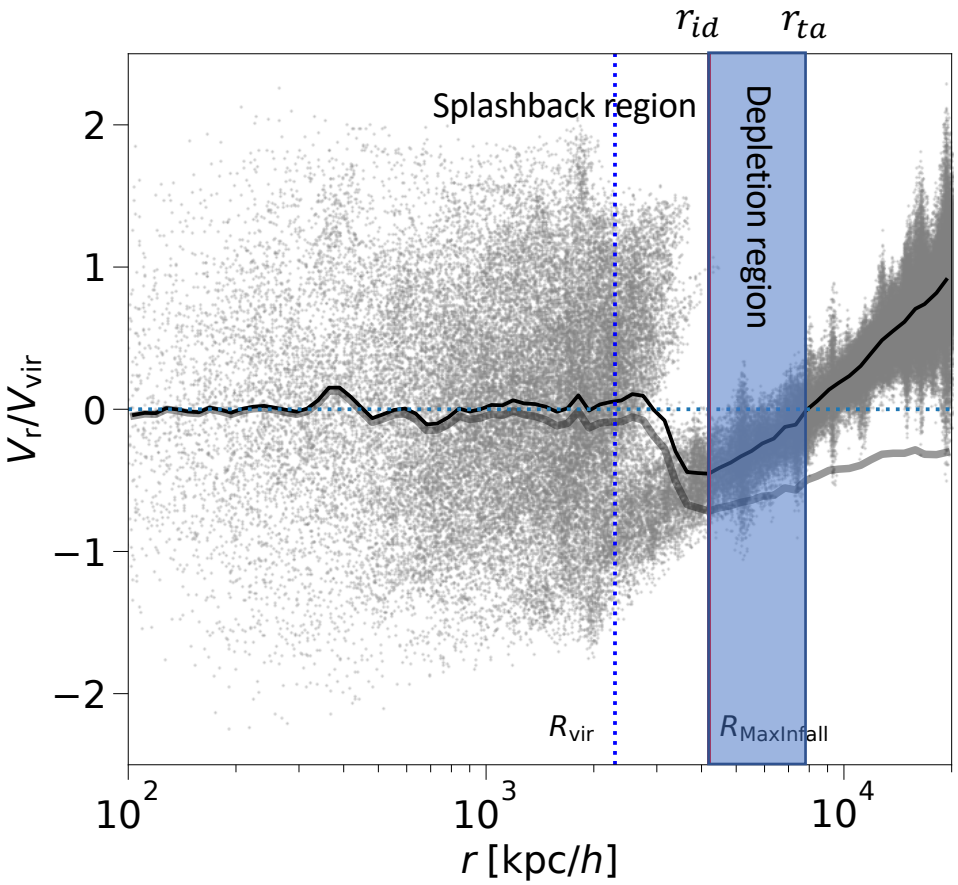
- The inner depletion radius r_{id}, or the maximum inflow (or outermost splashback) location
- The outer depletion edge is the turn around radius, r_{ta}



Depletion region

The depletion region can be characterized by three radii:

- The inner depletion radius r_{id}, or the maximum inflow (or outermost splashback) location
- The outer depletion radius is the turn around location, r_{ta}
- The characteristic depletion radius r_{cd}, or the minimum of the bias, bound by the inner and outer depletion radii



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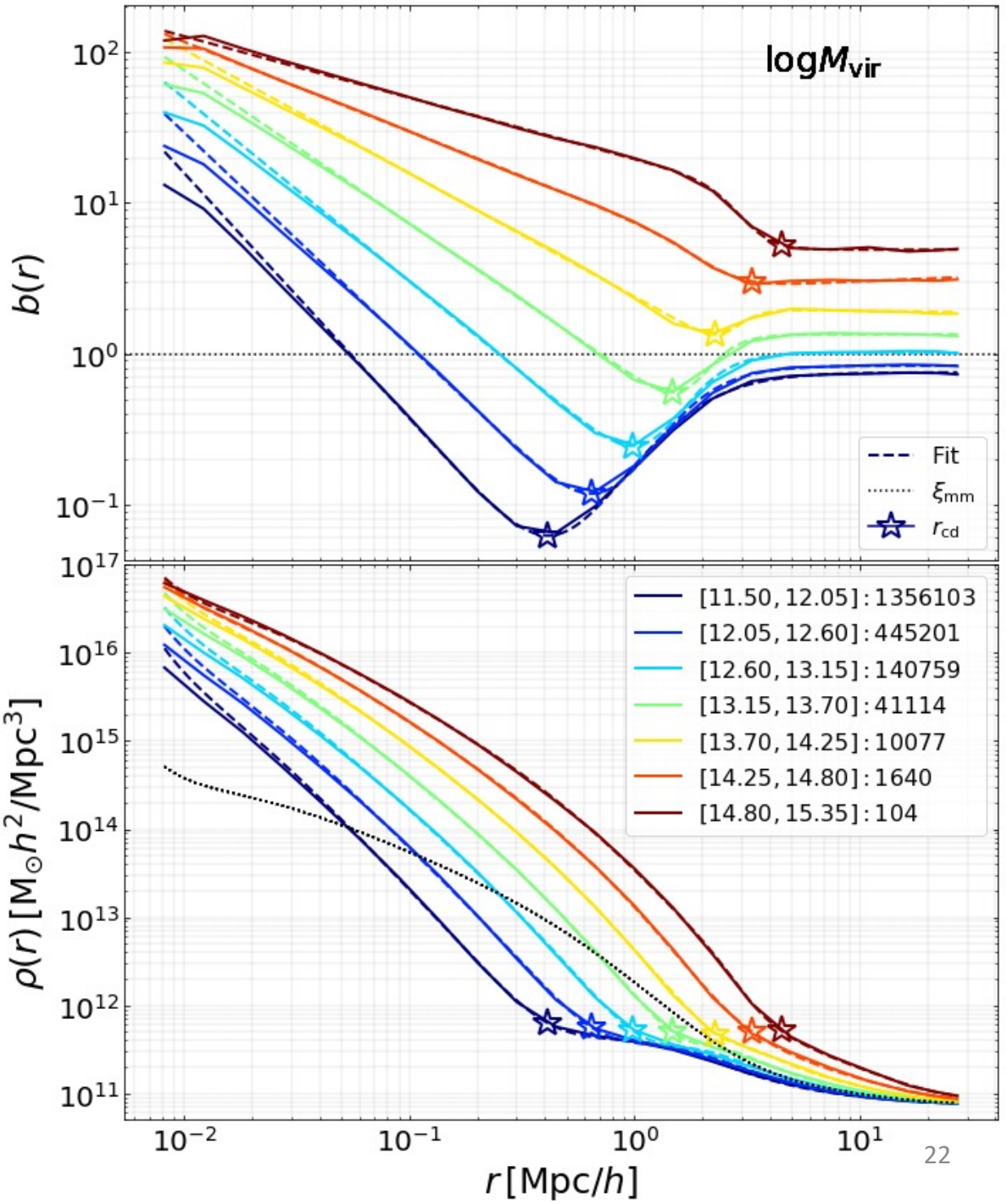
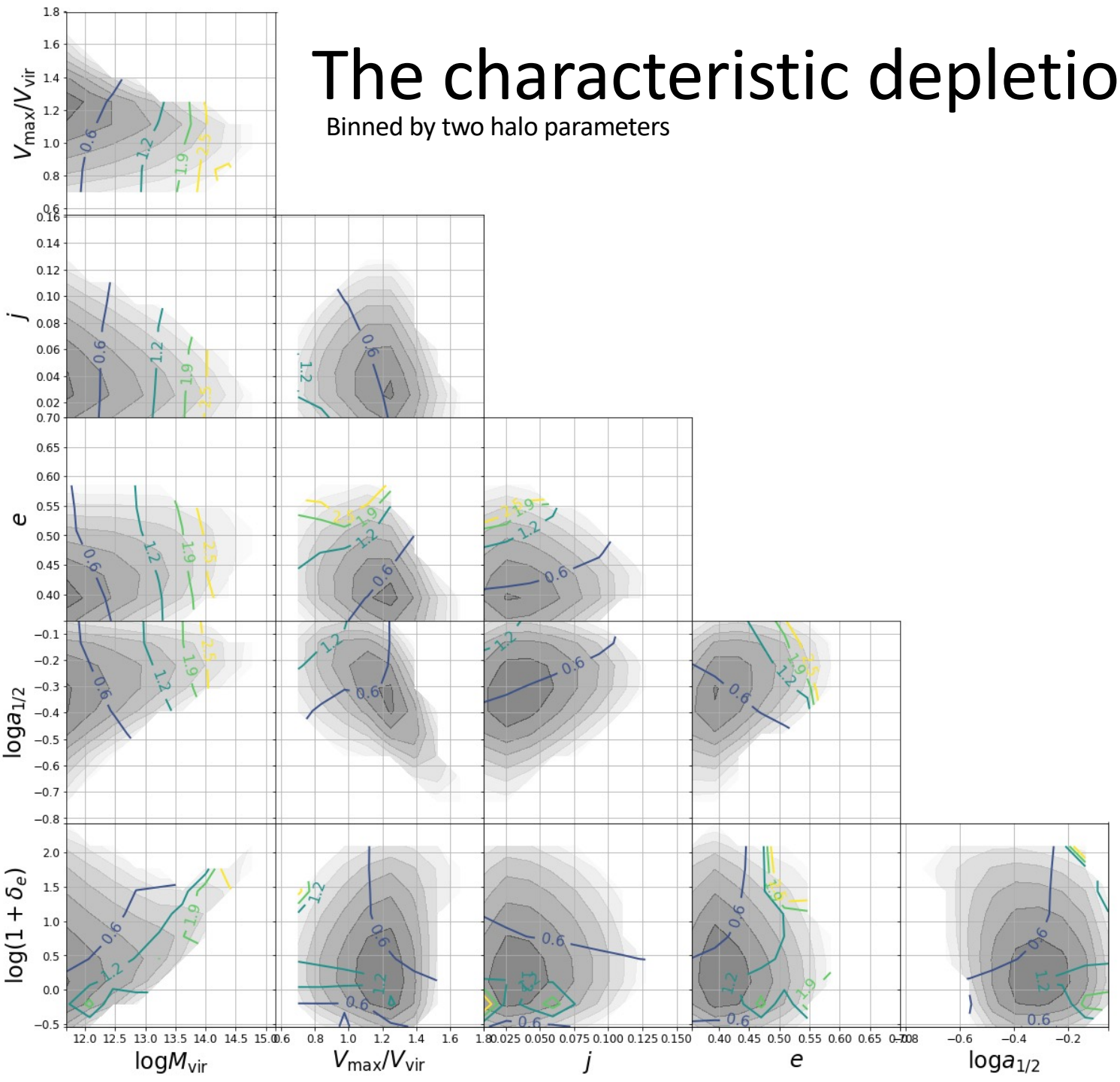


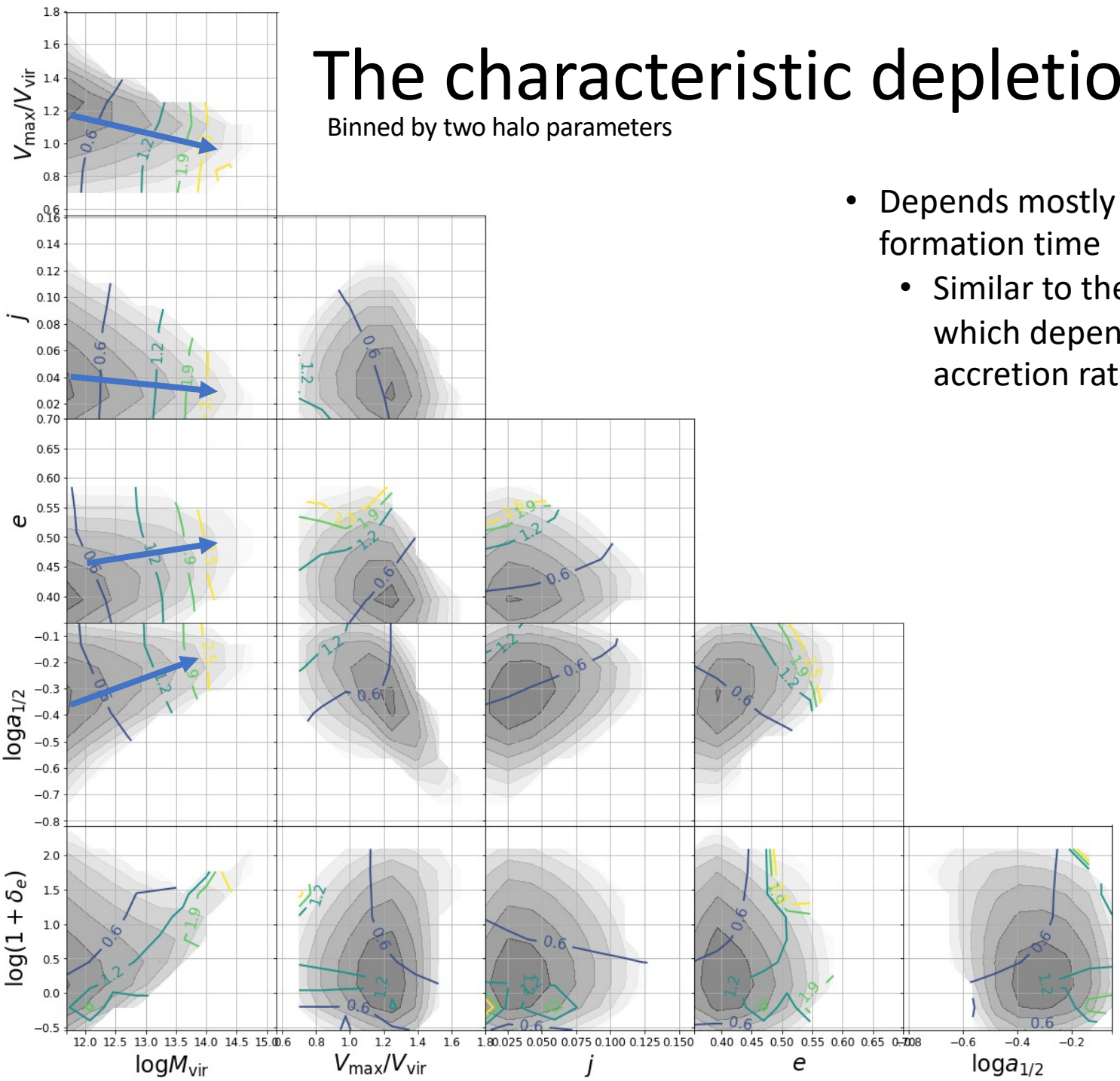
The characteristic depletion radius

Binned by two halo parameters

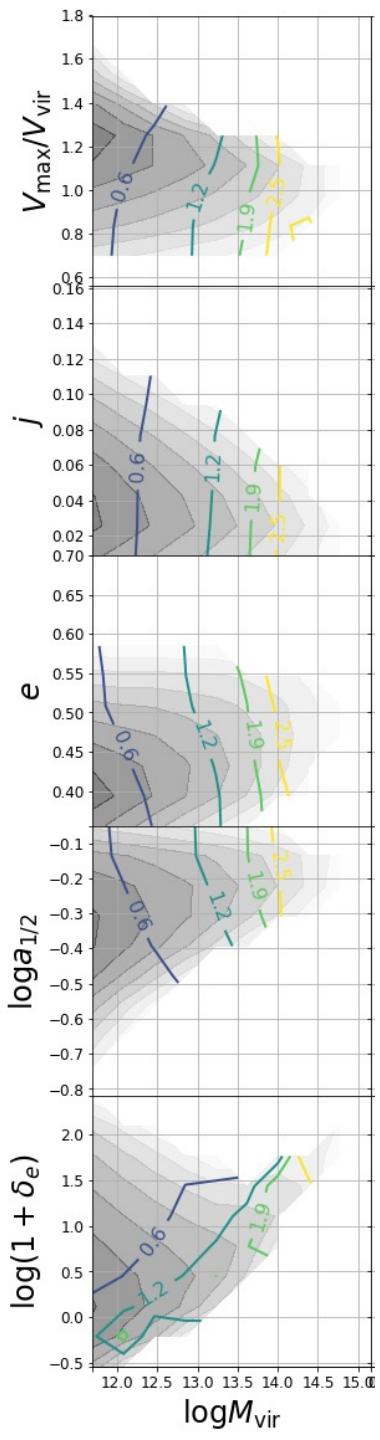


The characteristic depletion radius

Binned by two halo parameters



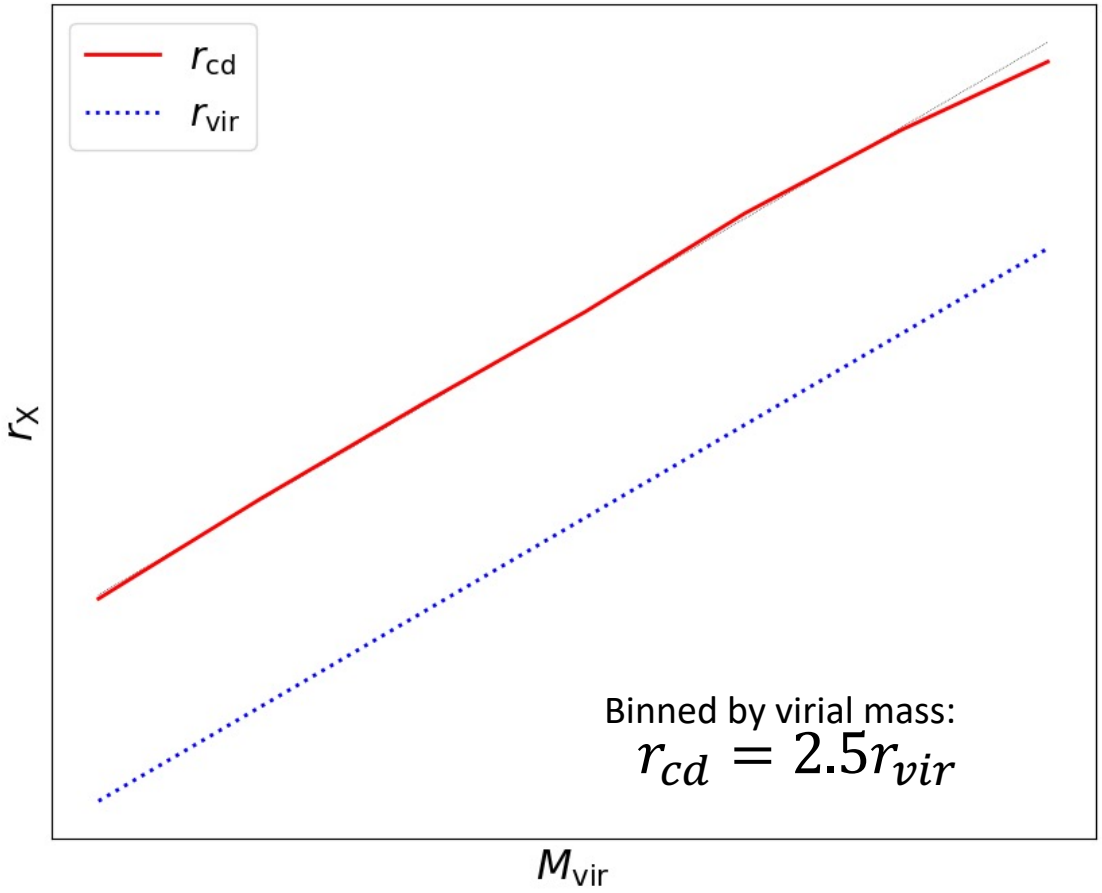
- Depends mostly on mass and formation time
  - Similar to the splashback radius, which depends on mass and accretion rate



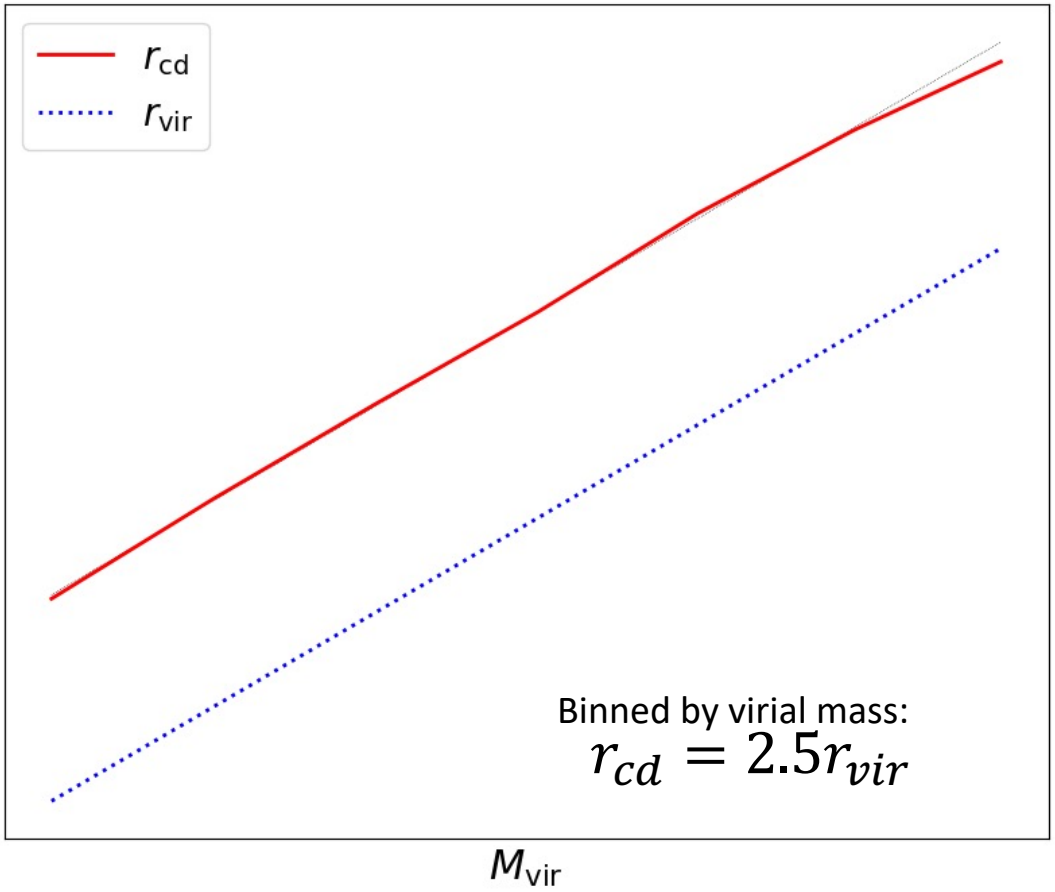
The characteristic depletion radius and the assembly bias

Binned by mass and a secondary halo parameter

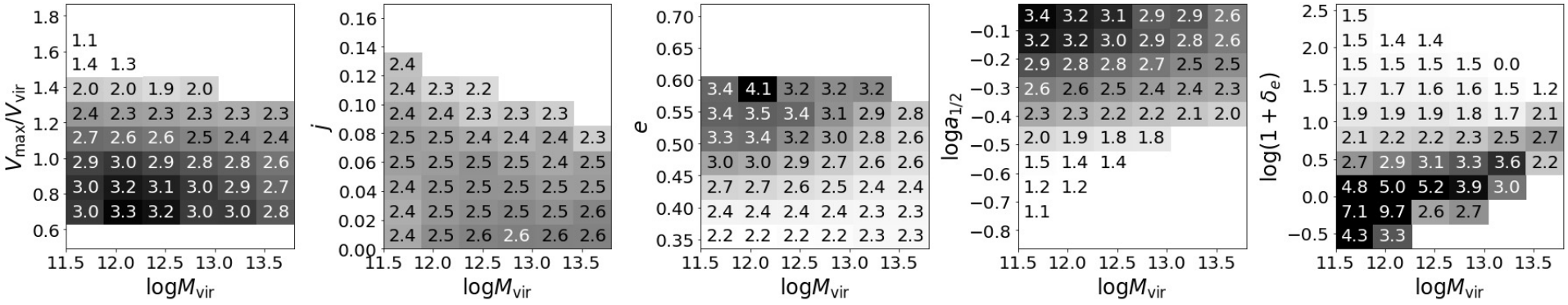
Depletion radius and virial radius

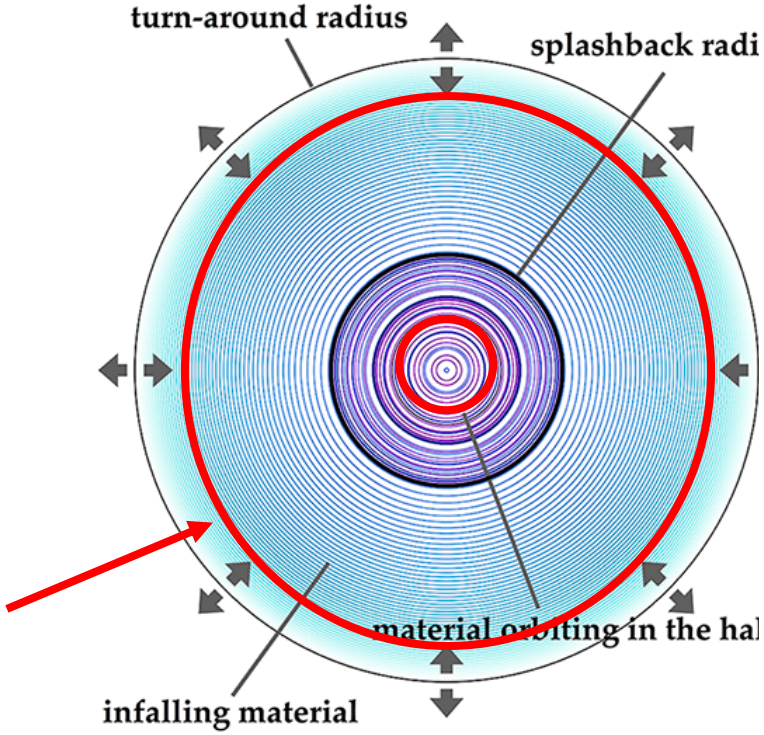


Depletion radius and virial radius

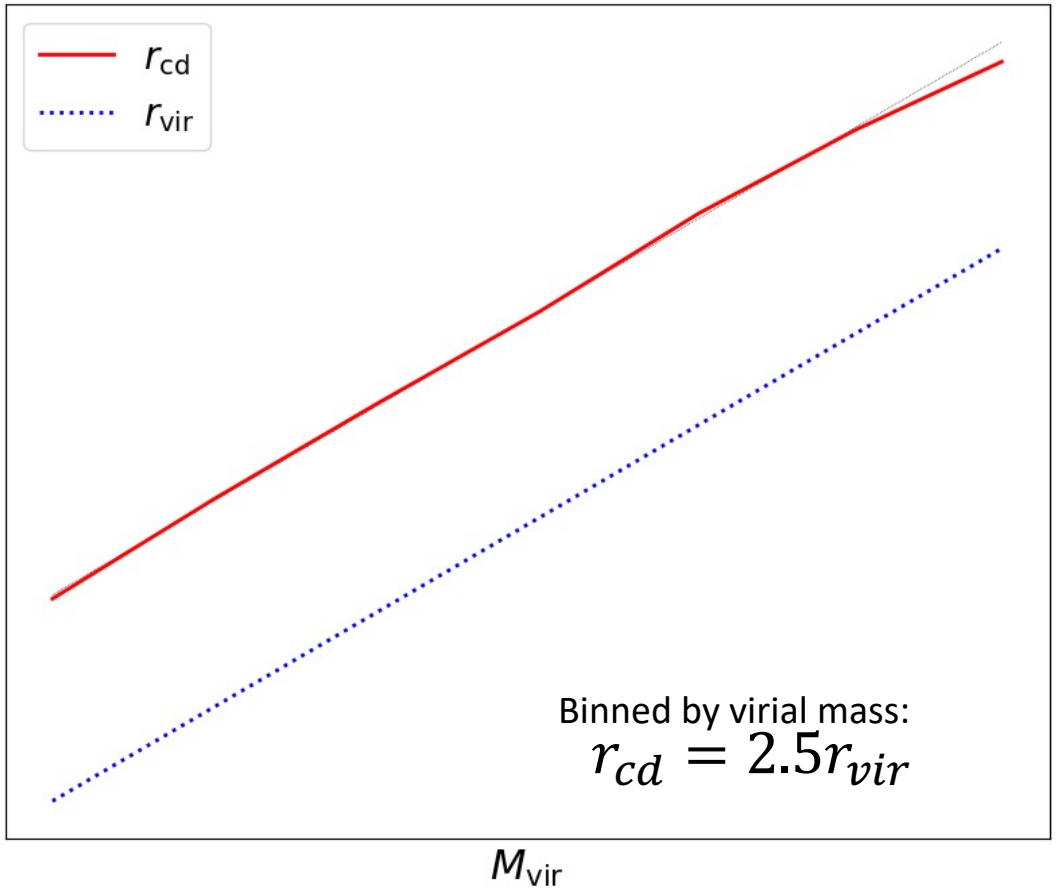


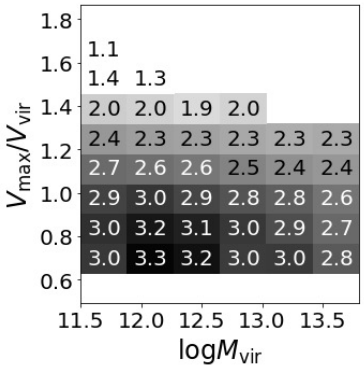
r_{cd}/r_{vir}

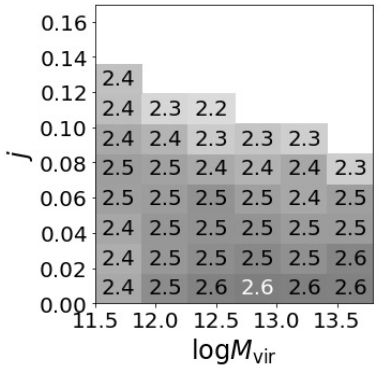


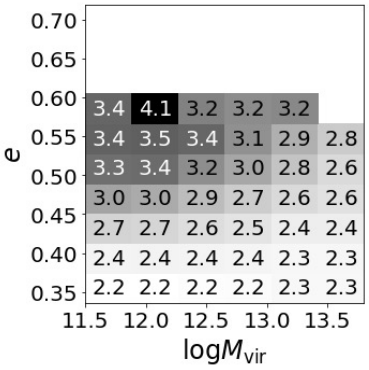

turn-around radius
splashback radi
material orbiting in the hal
infalling material

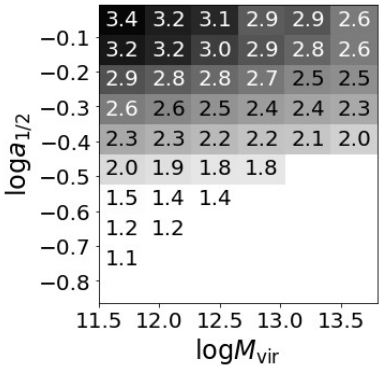
r_{cd}/r_{vir}

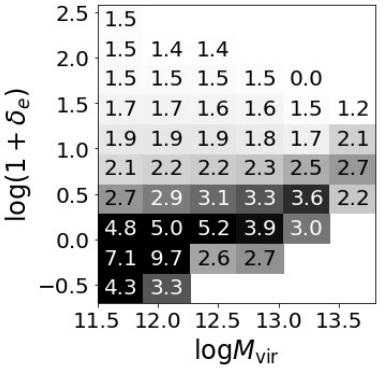

r_{cd}
r_{vir}
r_X
M_{vir}
Binned by virial mass:
$r_{cd} = 2.5 r_{vir}$


V_{max}/V_{vir}
logM_{vir}


j
logM_{vir}

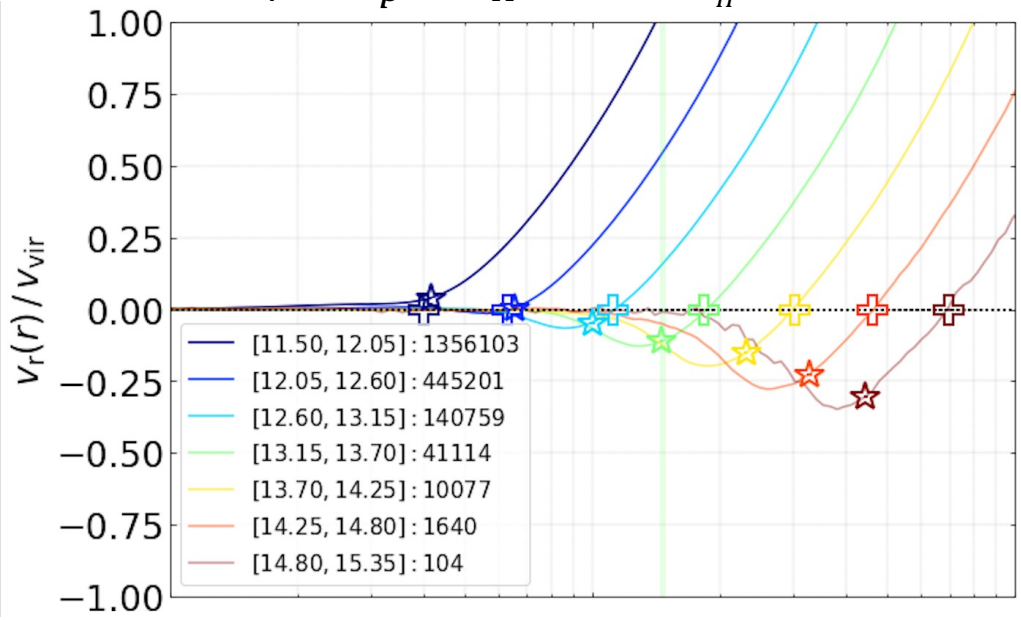

e
logM_{vir}

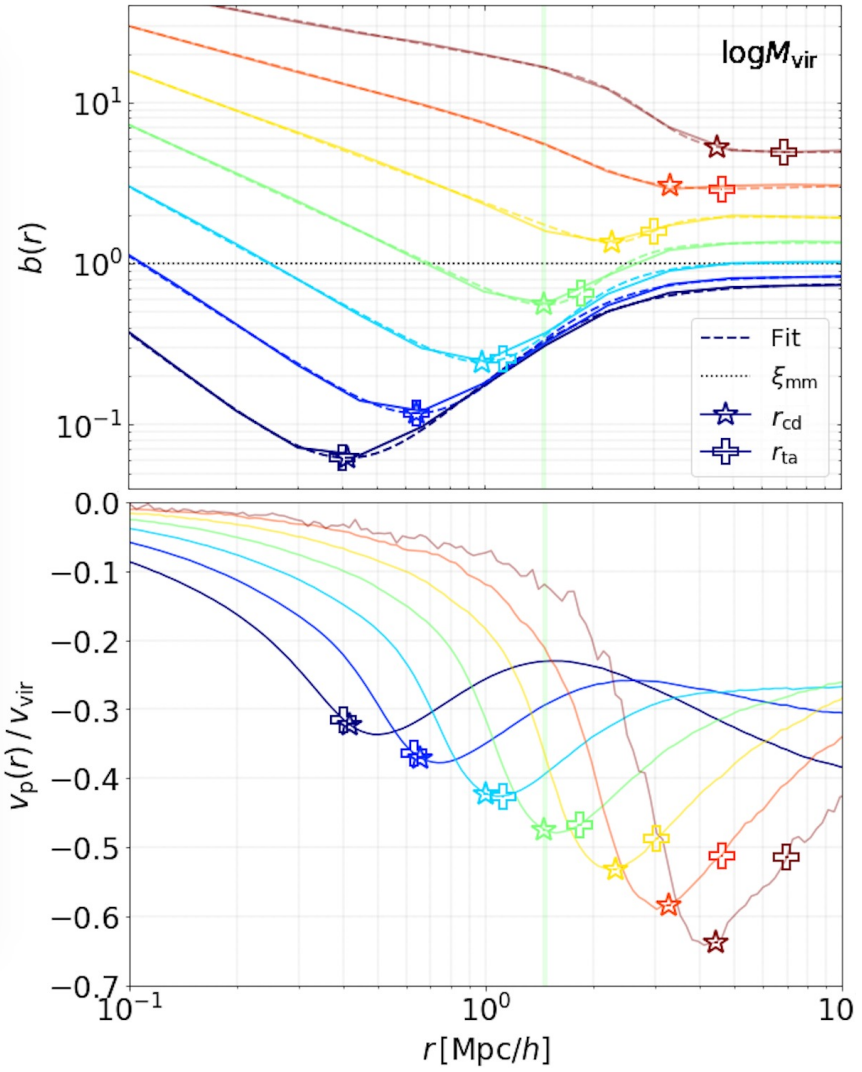

log$a_{1/2}$
logM_{vir}


log$(1+\delta_e)$
logM_{vir}

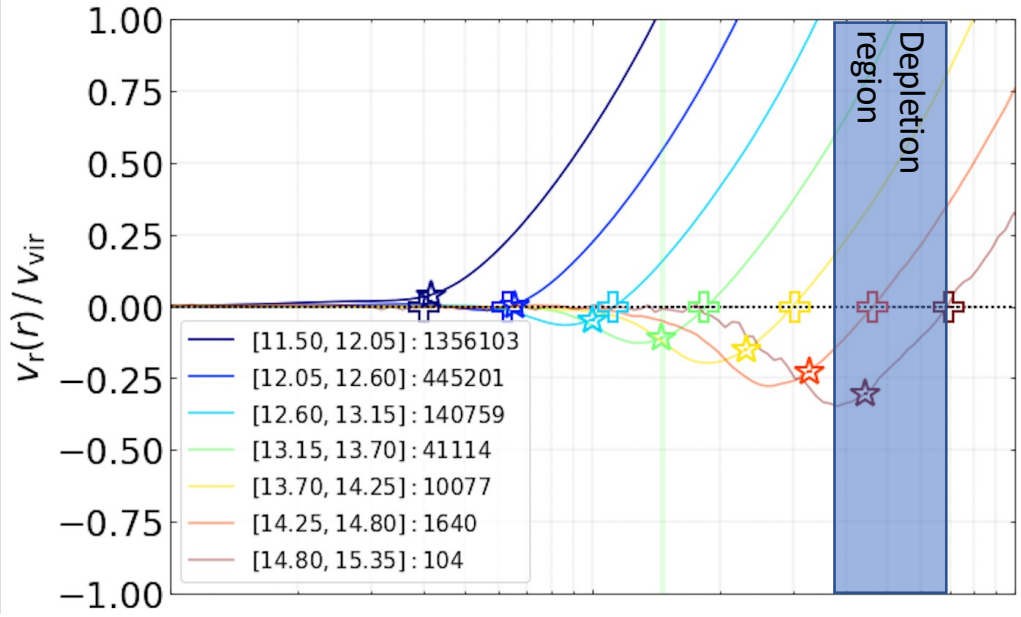
Depletion radius and Turnaround radius

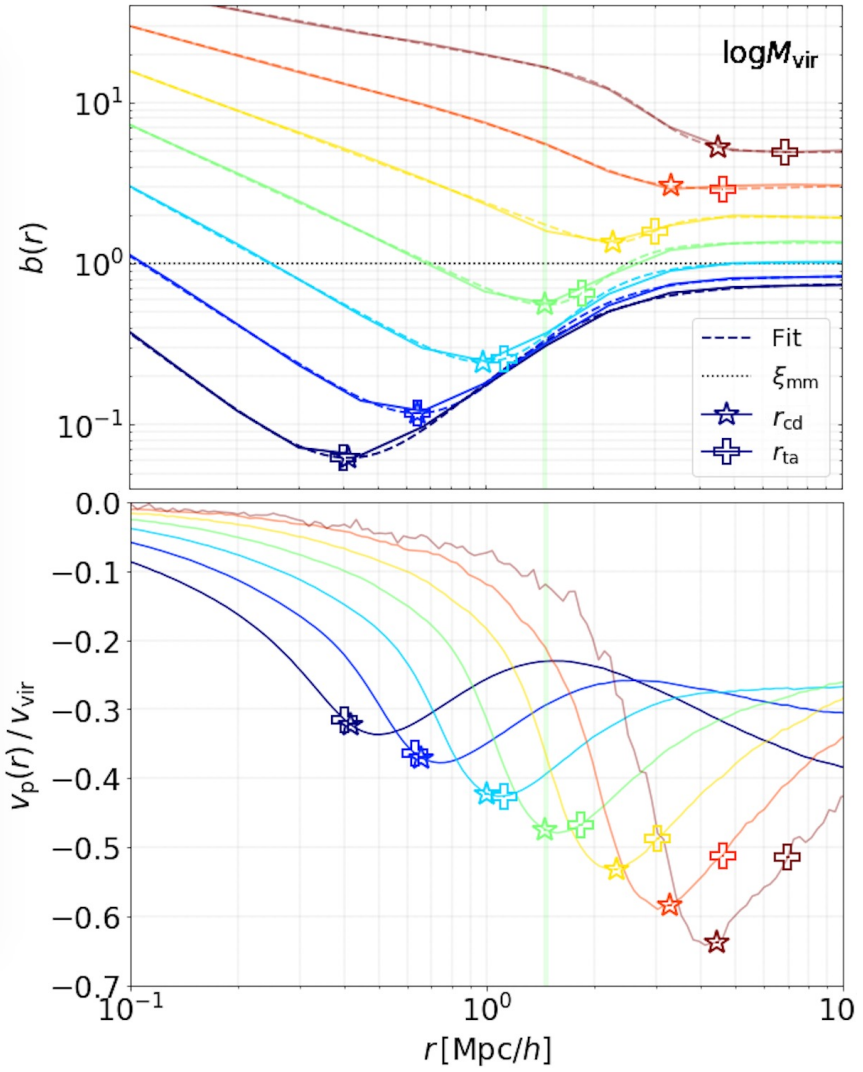
$v_r = v_p + v_H$ v_H = Hubble Flow





Depletion radius and Turnaround radius





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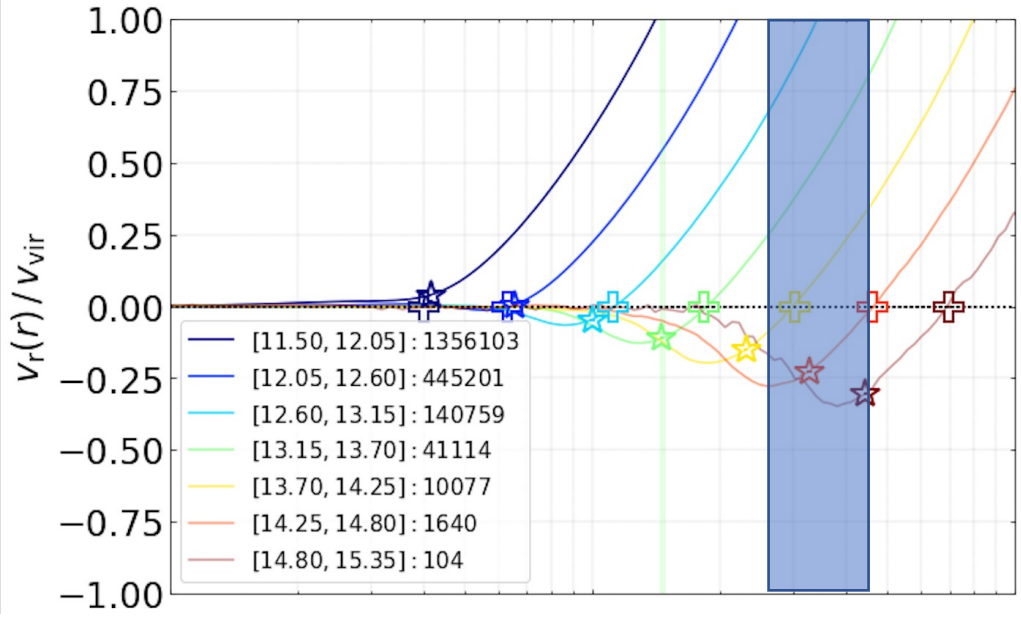
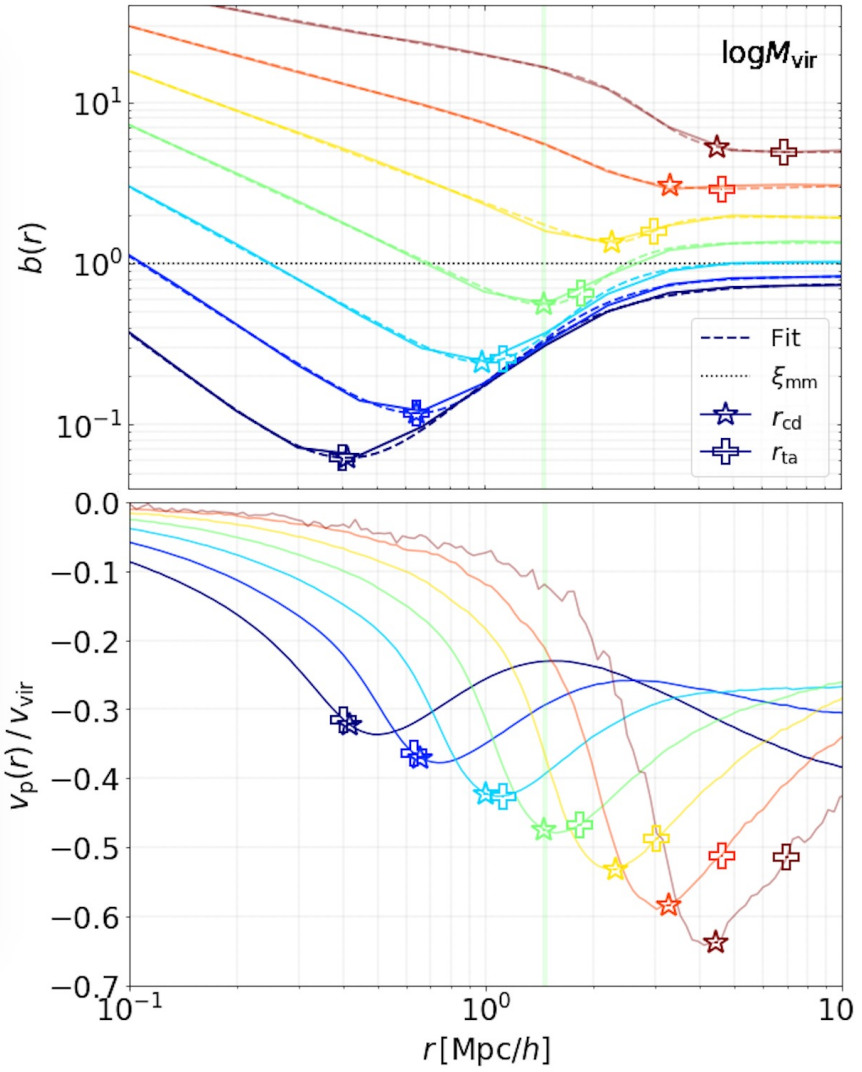
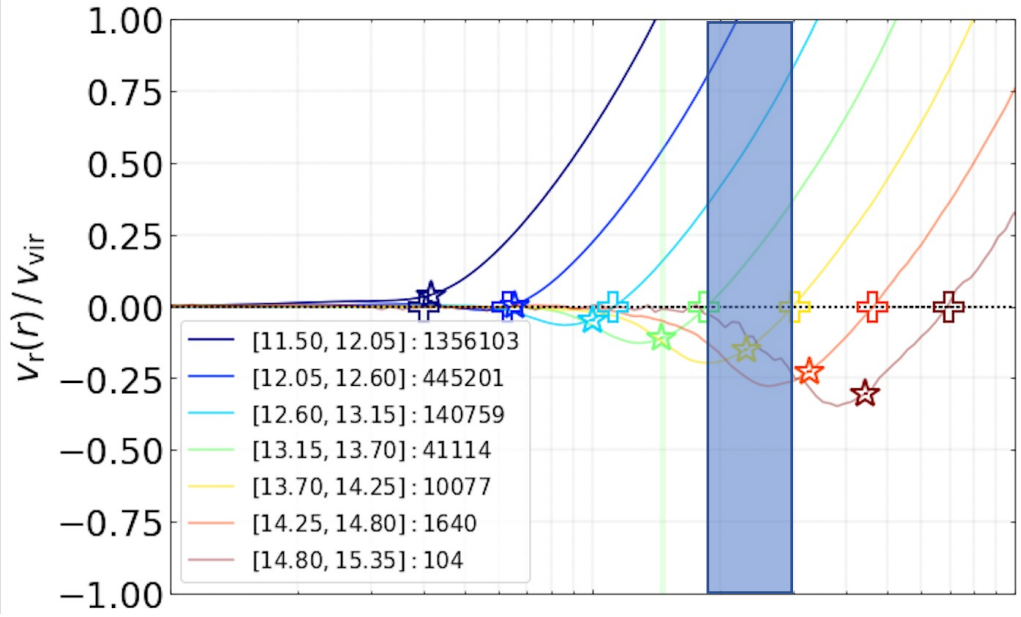
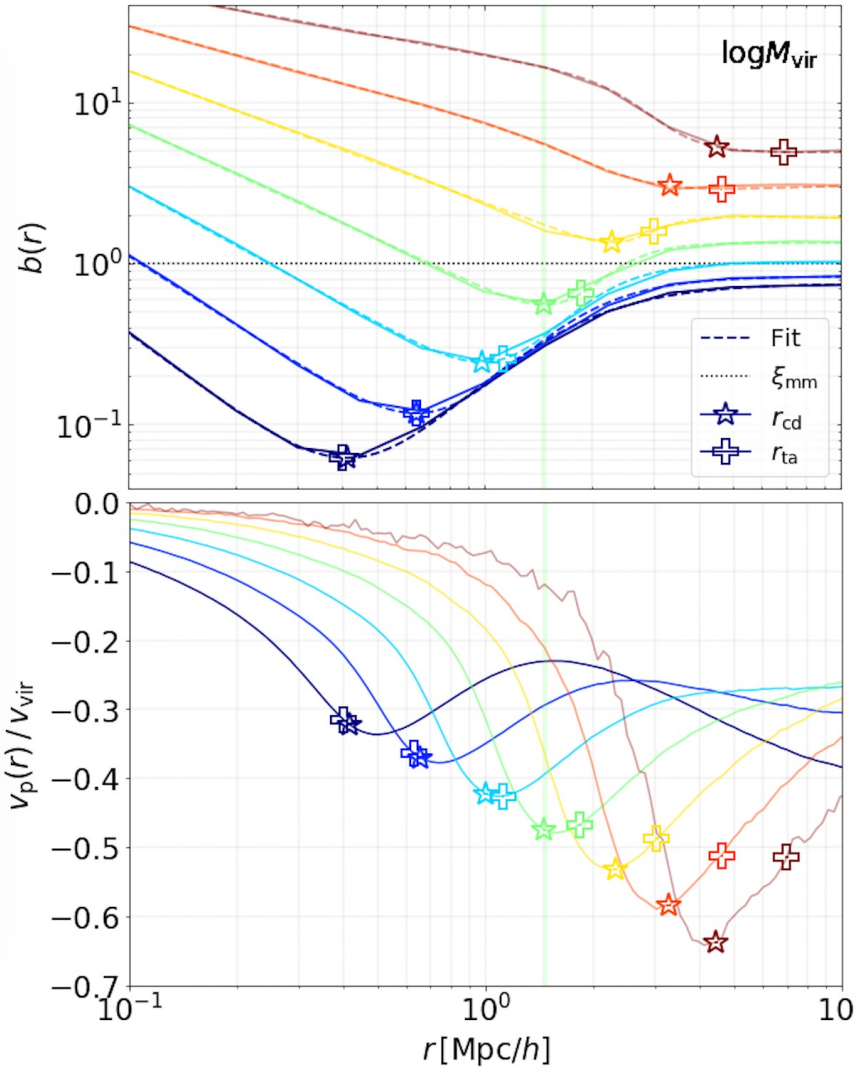


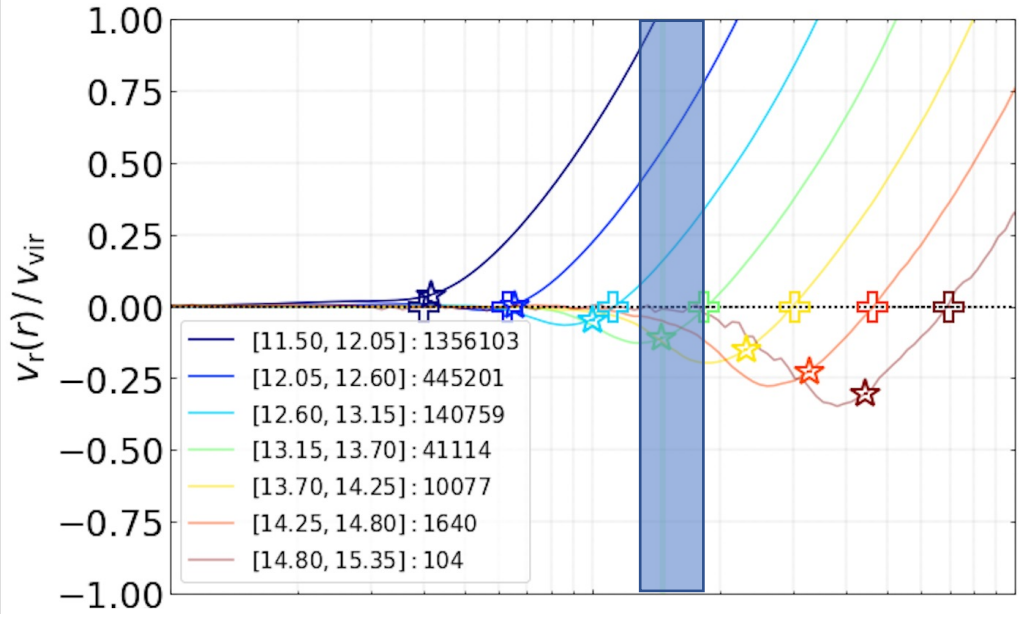


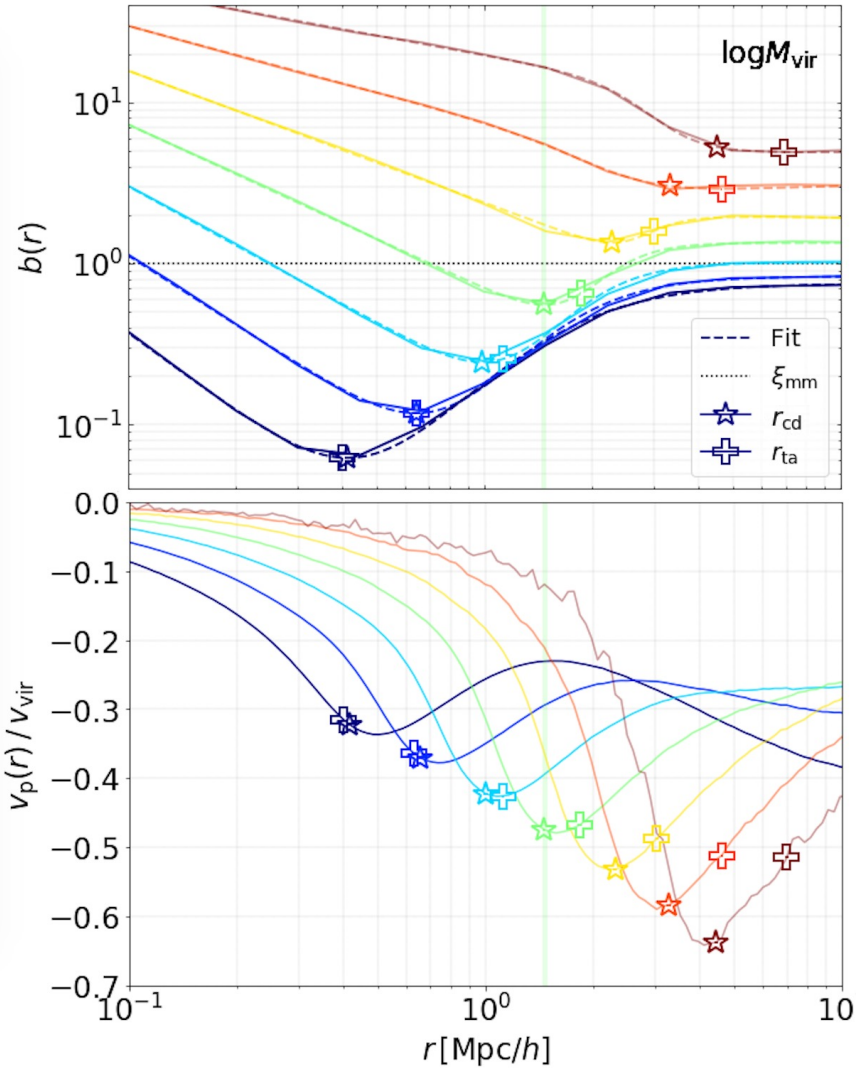
Depletion radius and Turnaround radius



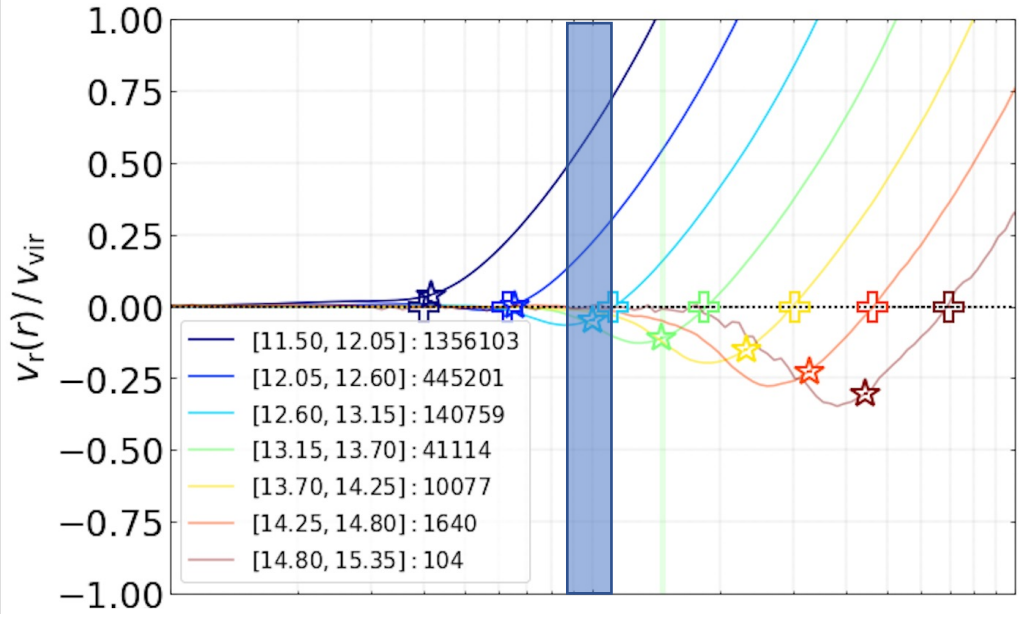


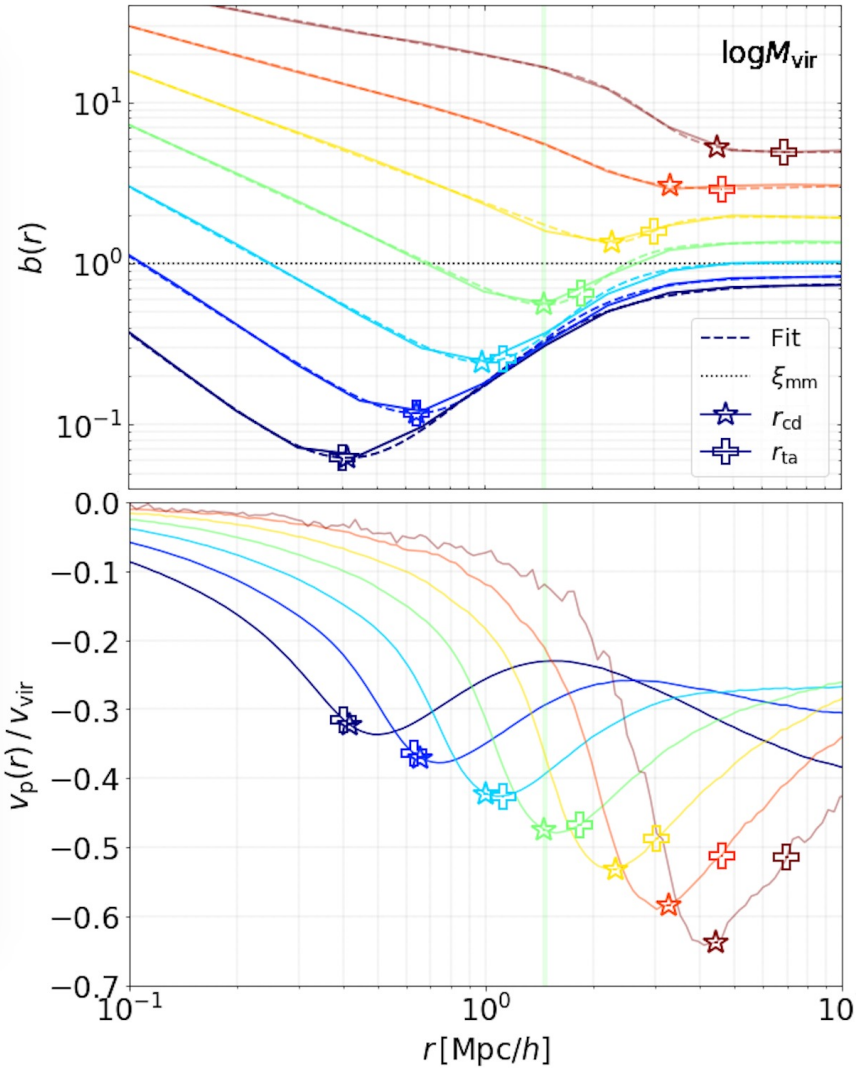
Depletion radius and Turnaround radius



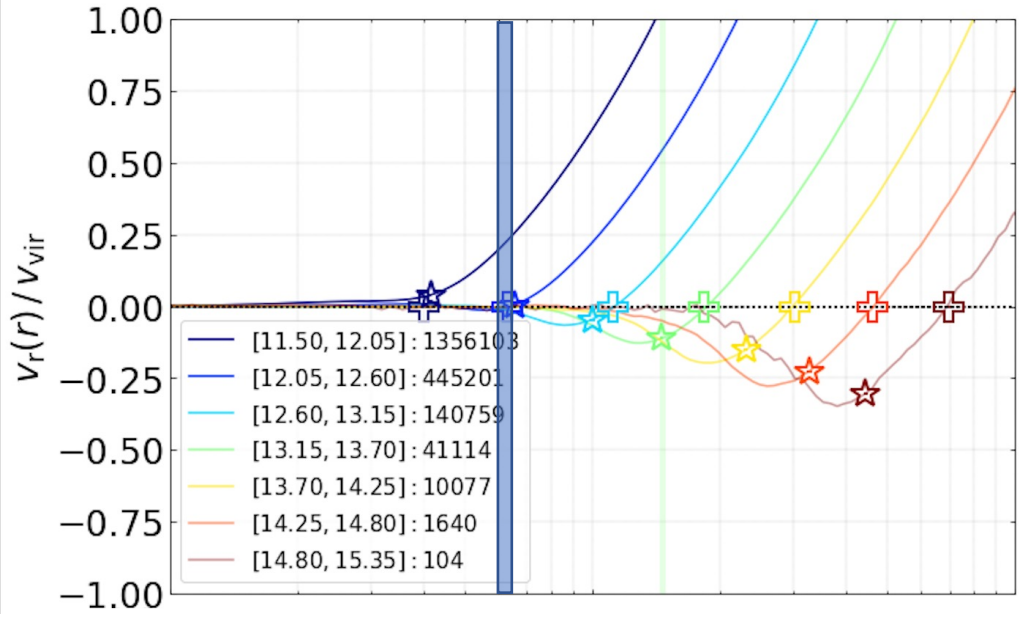


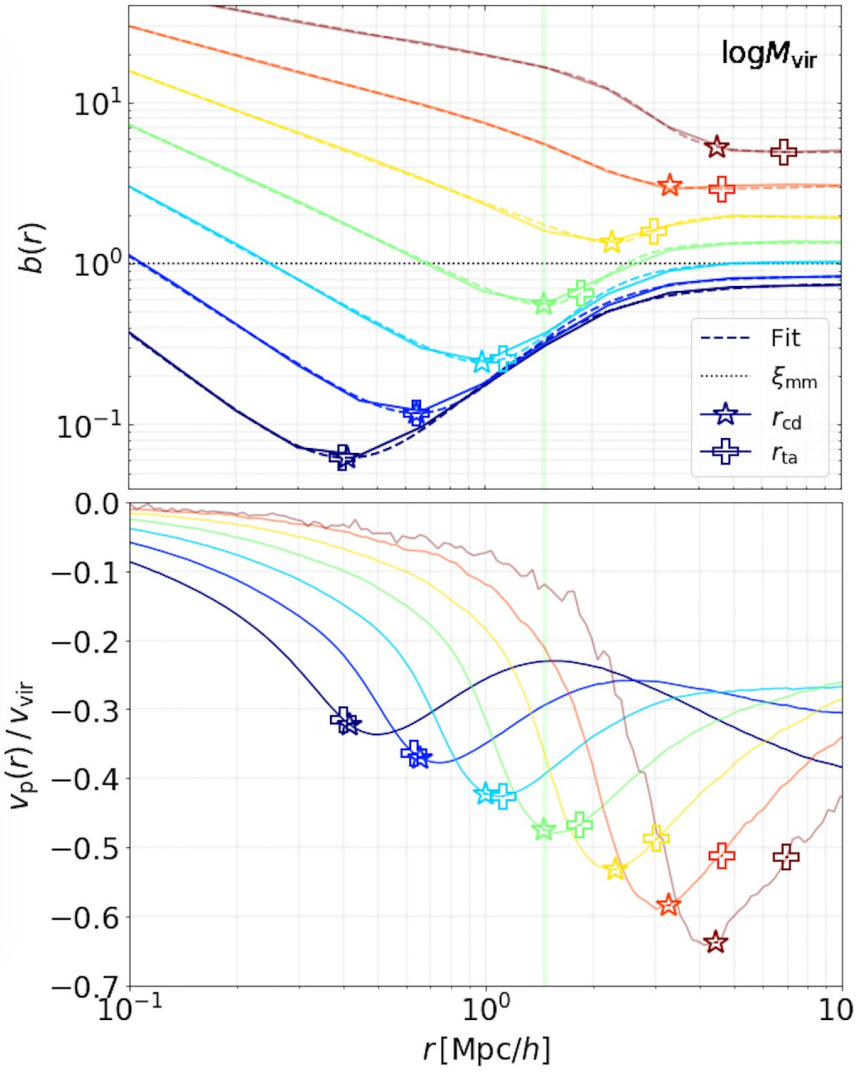
Depletion radius and Turnaround radius





Depletion radius and Turnaround radius





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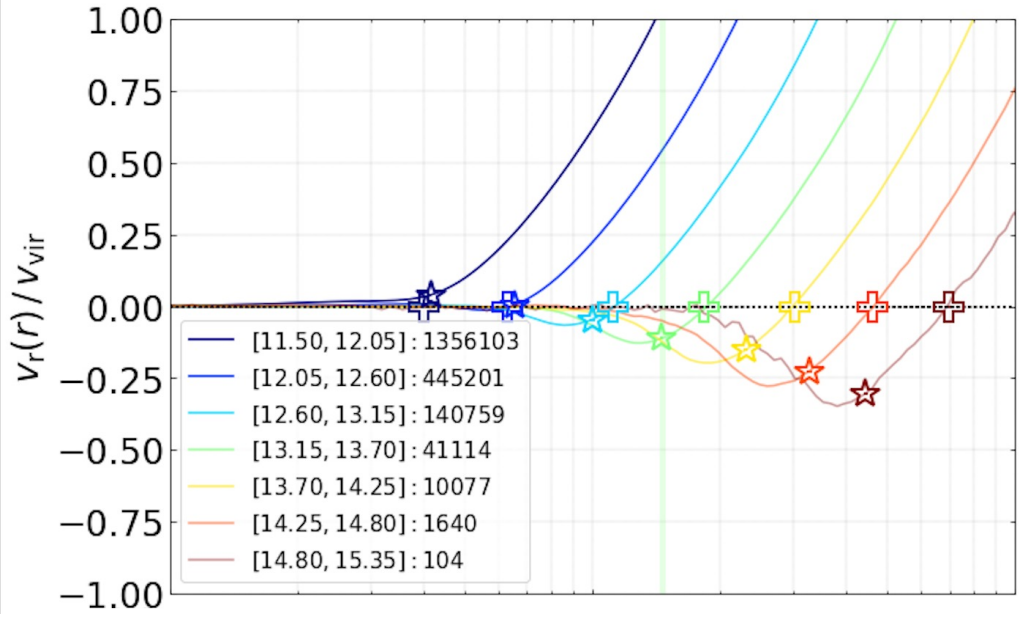
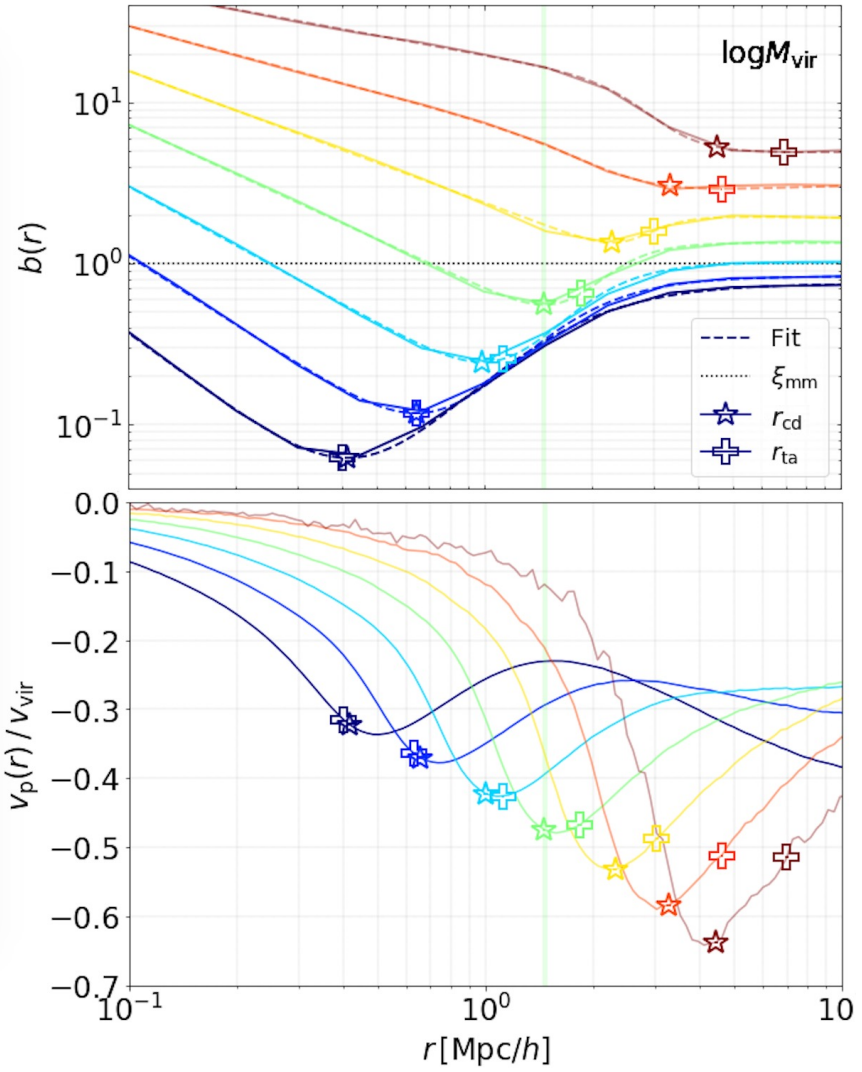
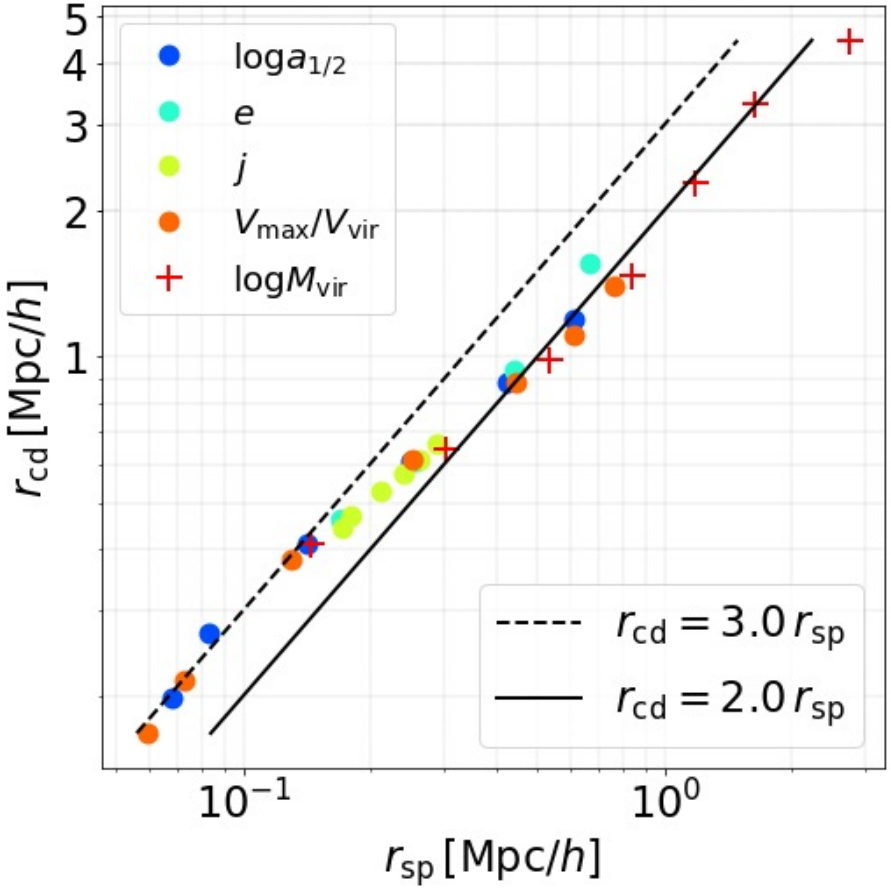
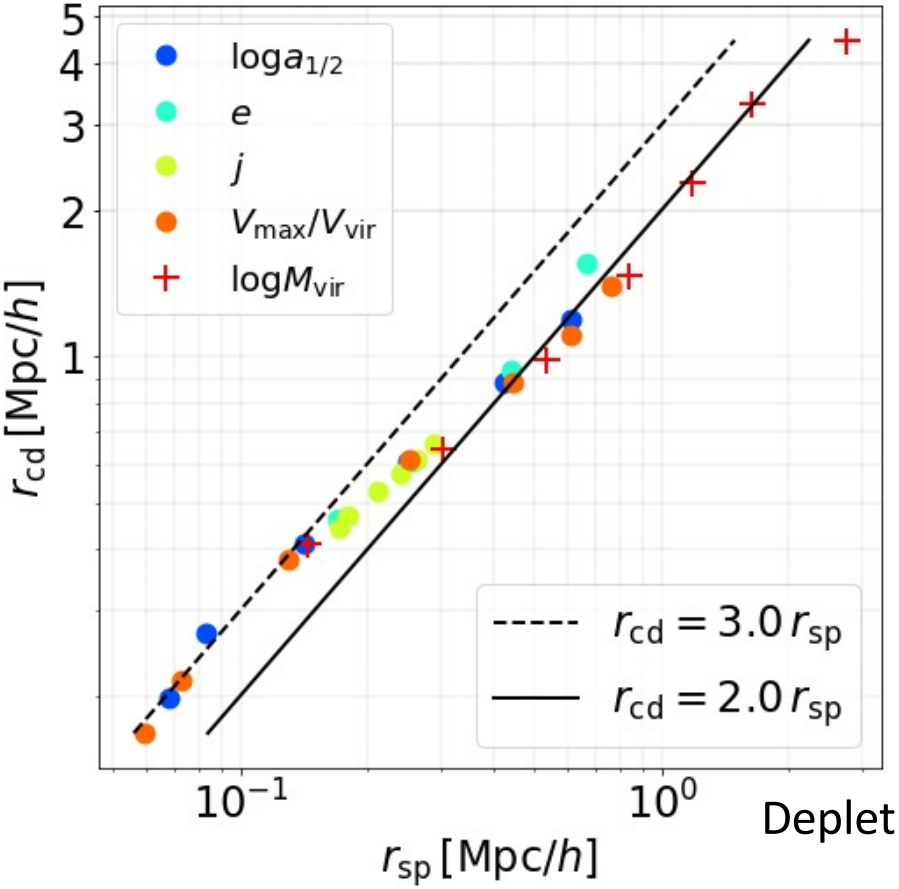


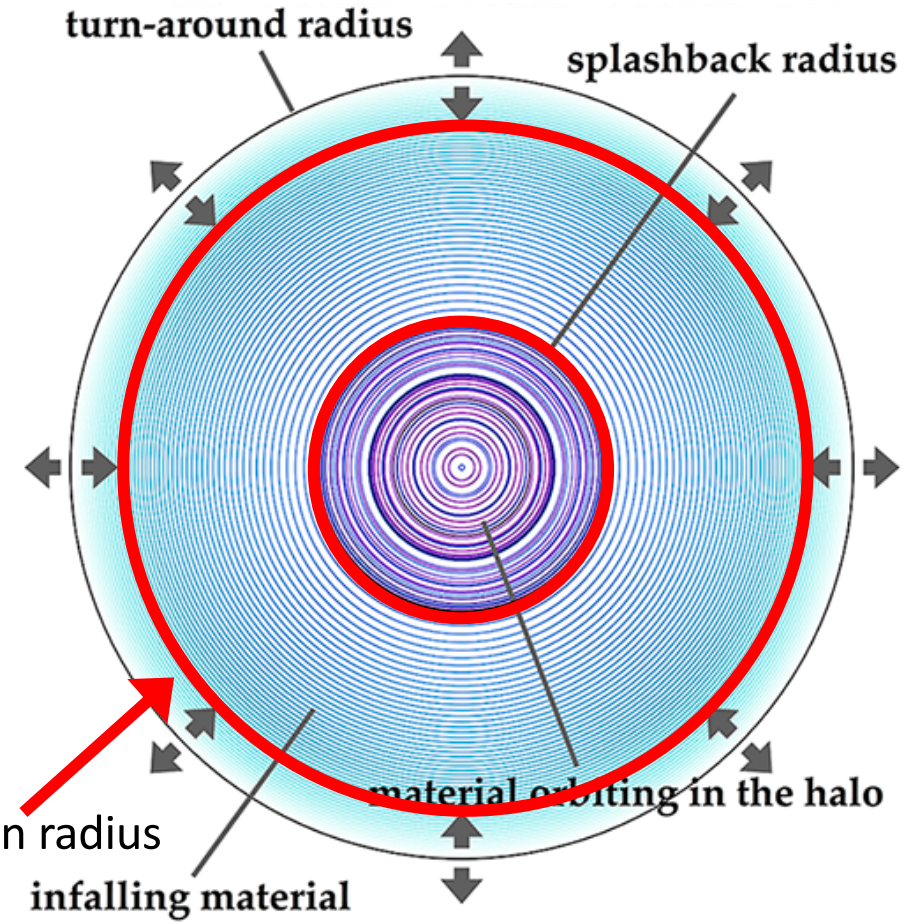


Depletion radius and Splashback radius



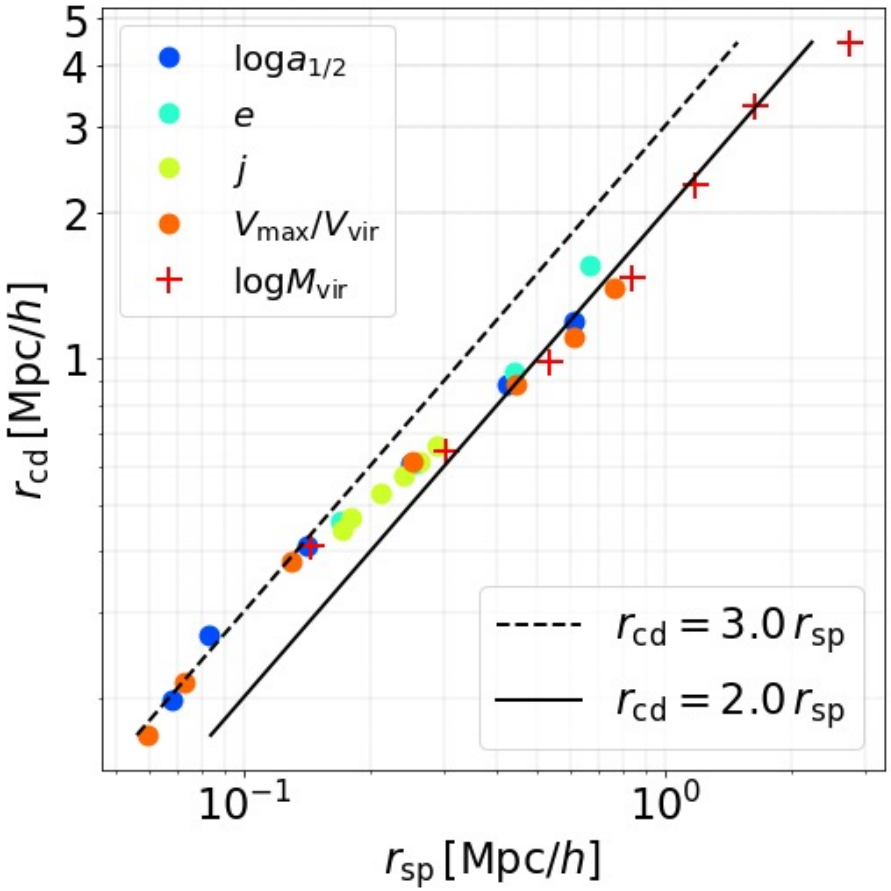
Depletion radius and Splashback radius

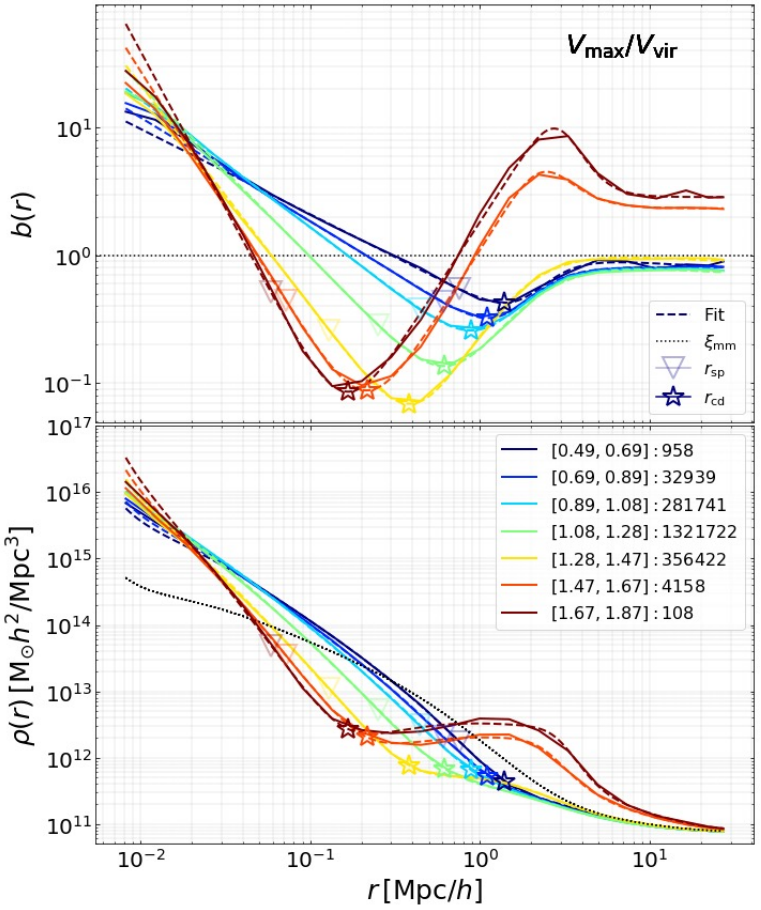




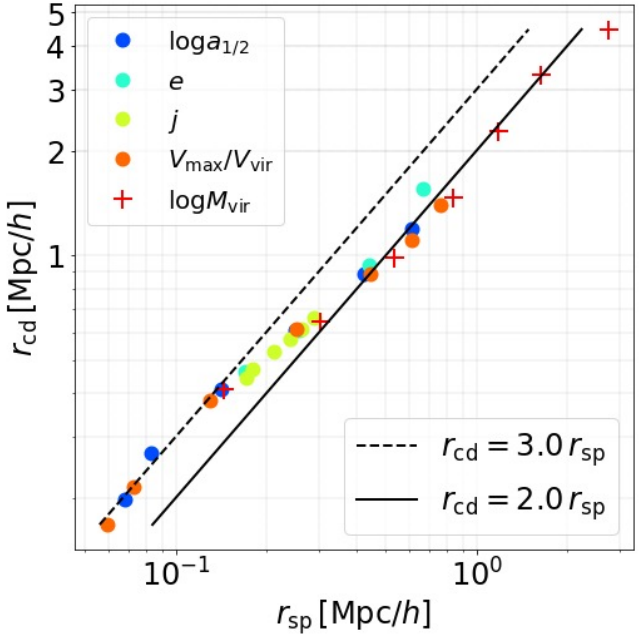
Depletion radius

Depletion radius and Splashback radius

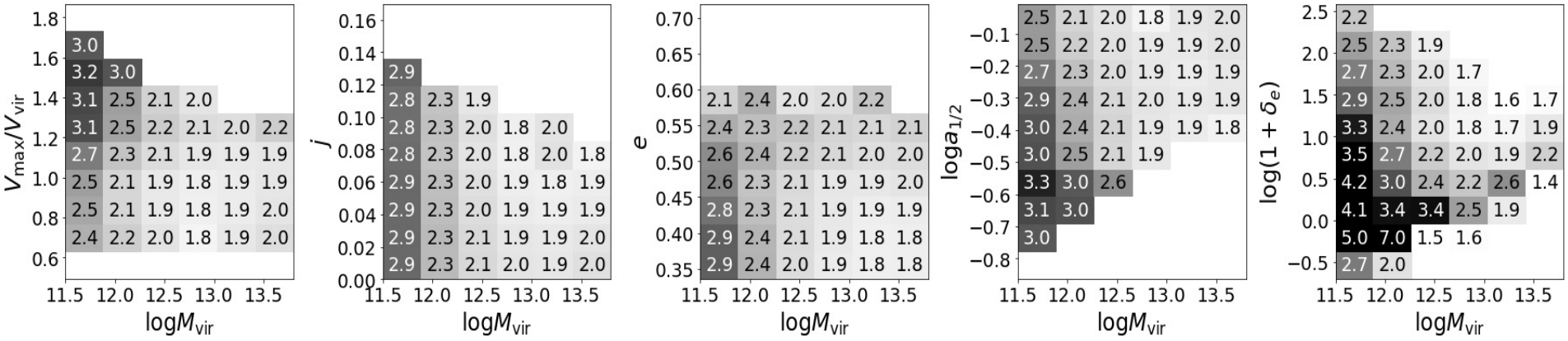




Depletion radius and Splashback radius



r_{cd}/r_{sp}



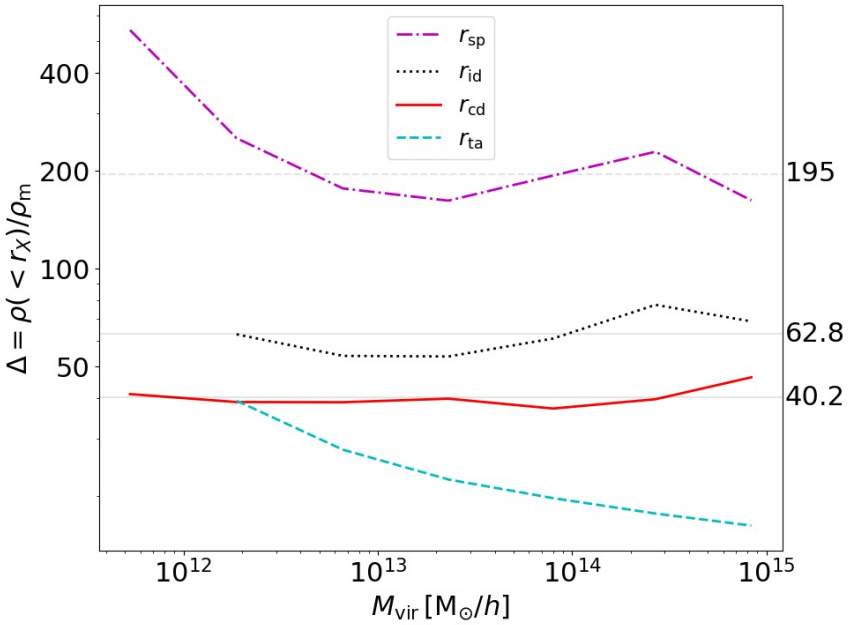
Density Contrast and Depletion radius

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

Binned by mass:

$$M_{cd} = 40\rho_m\frac{4\pi}{3}{r_{cd}}^3$$

$$\rho(< r_{cd}) = 40\rho_m$$



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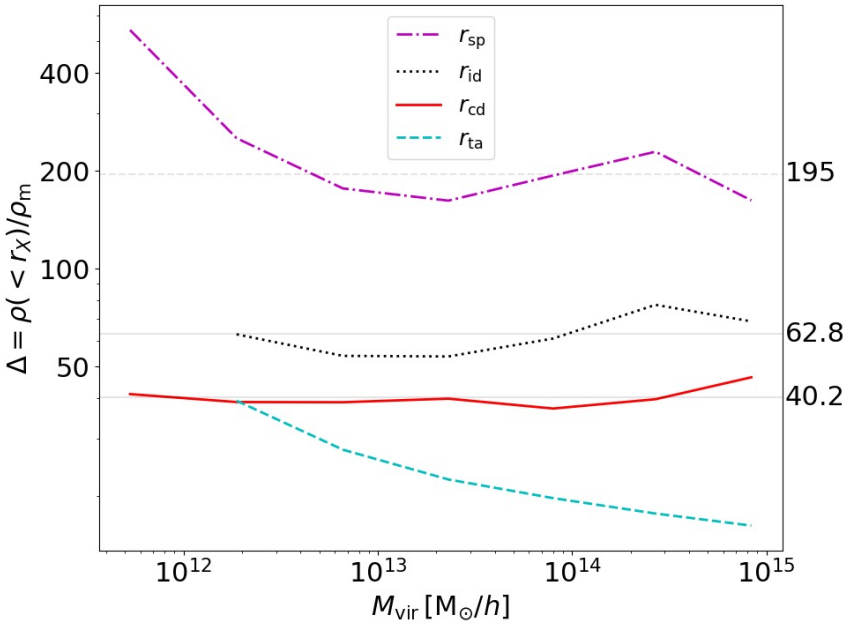
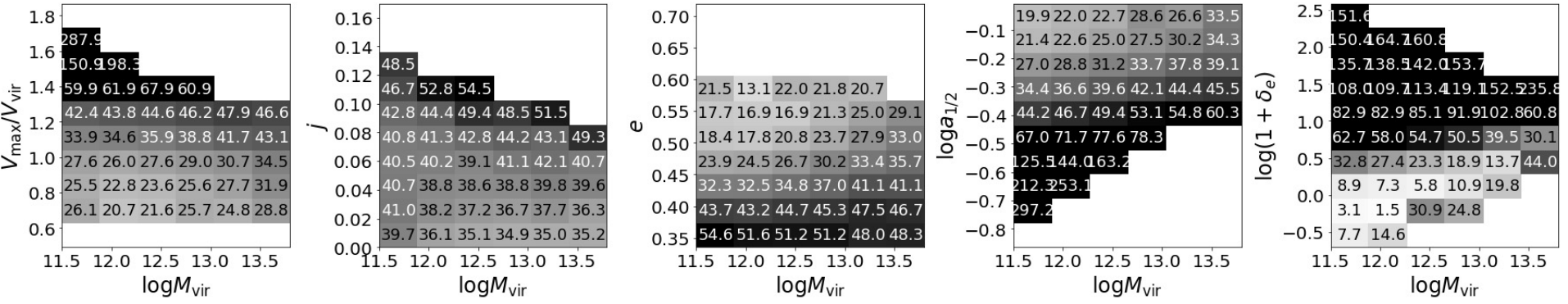
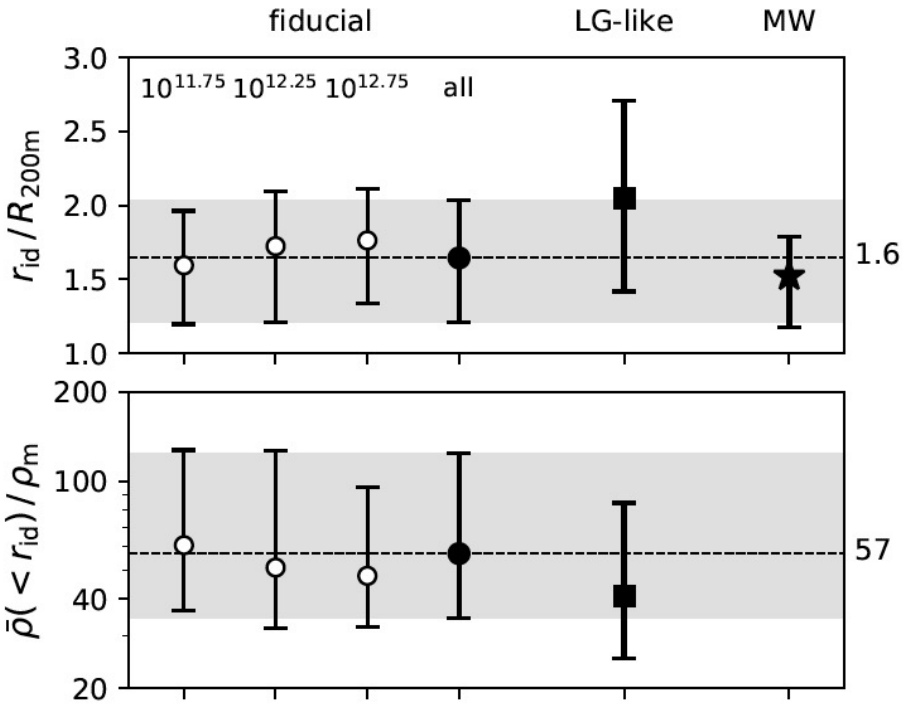
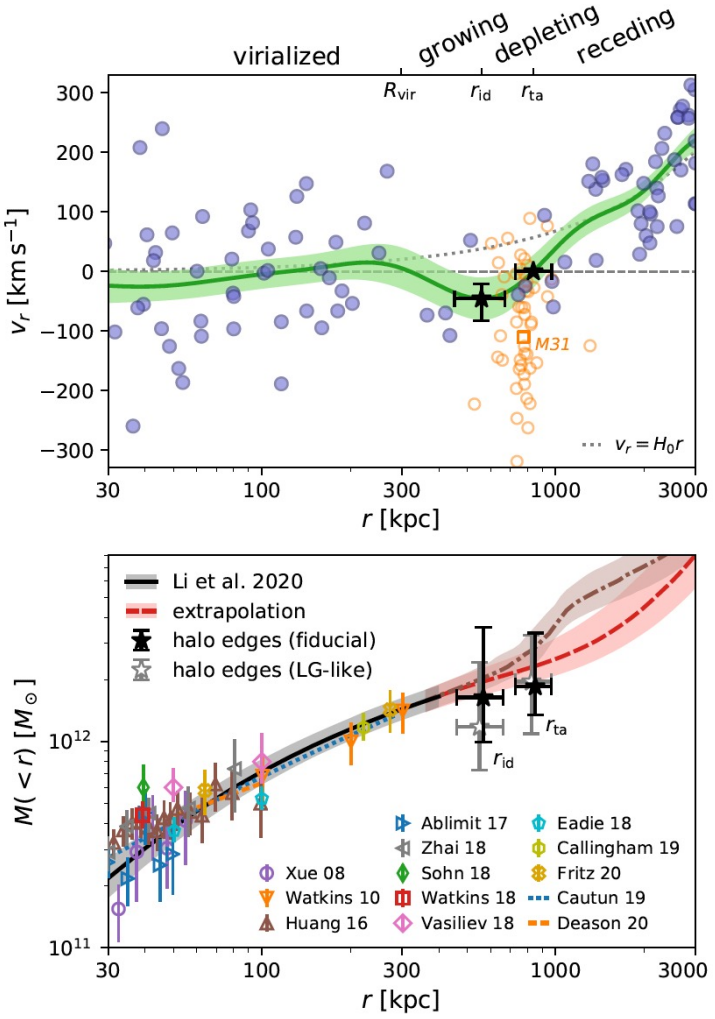




First measurement of inner depletion radius around the Milky Way (Li & Han 2021)





Ongoing detection of the characteristic depletion radius using weak lensing

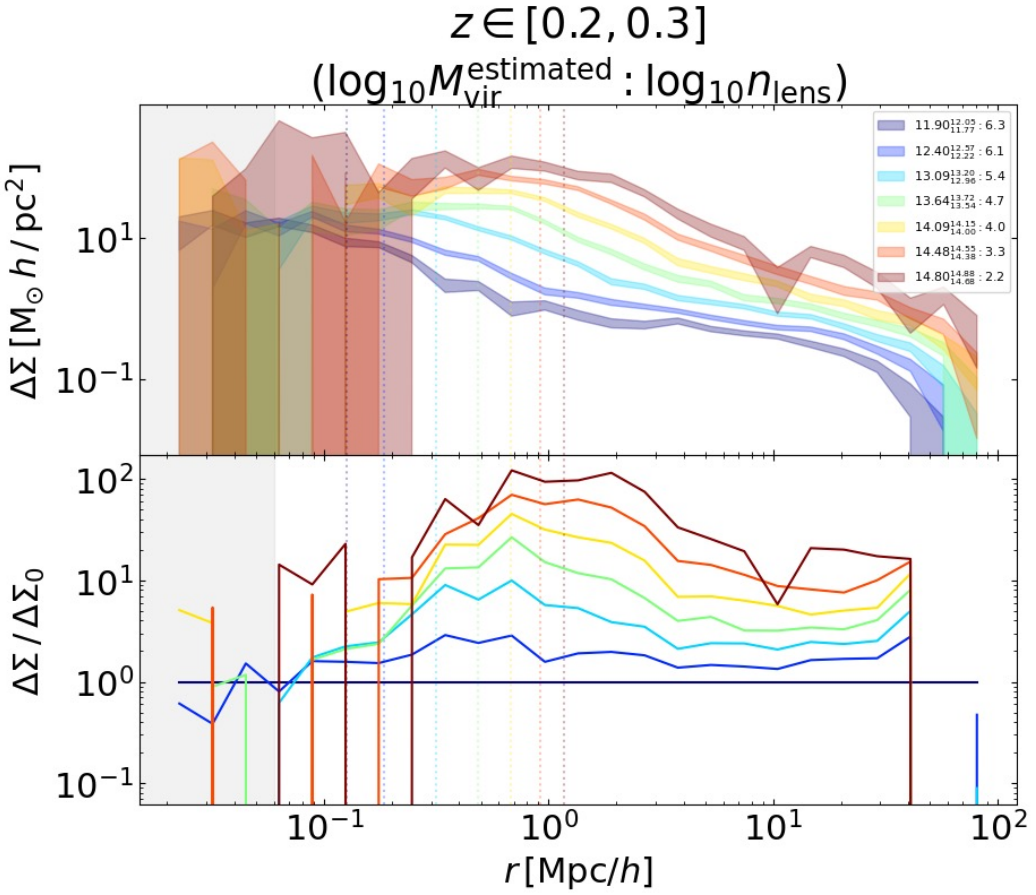
$$b^{\mathrm{Fit}}(r) = \frac{1 + \left(\frac{r}{r_0}\right)^{-(\alpha+\beta)}}{1 + \left(\frac{r}{r_1}\right)^{-(\beta+\gamma)}} \times \left(b_0 + \left(\frac{r}{r_2}\right)^{-\gamma}\right)$$

$$\rho(r) = \rho_{\mathrm{m}} \times (\xi_{\mathrm{mm}}(r) \times b(r) + 1)$$

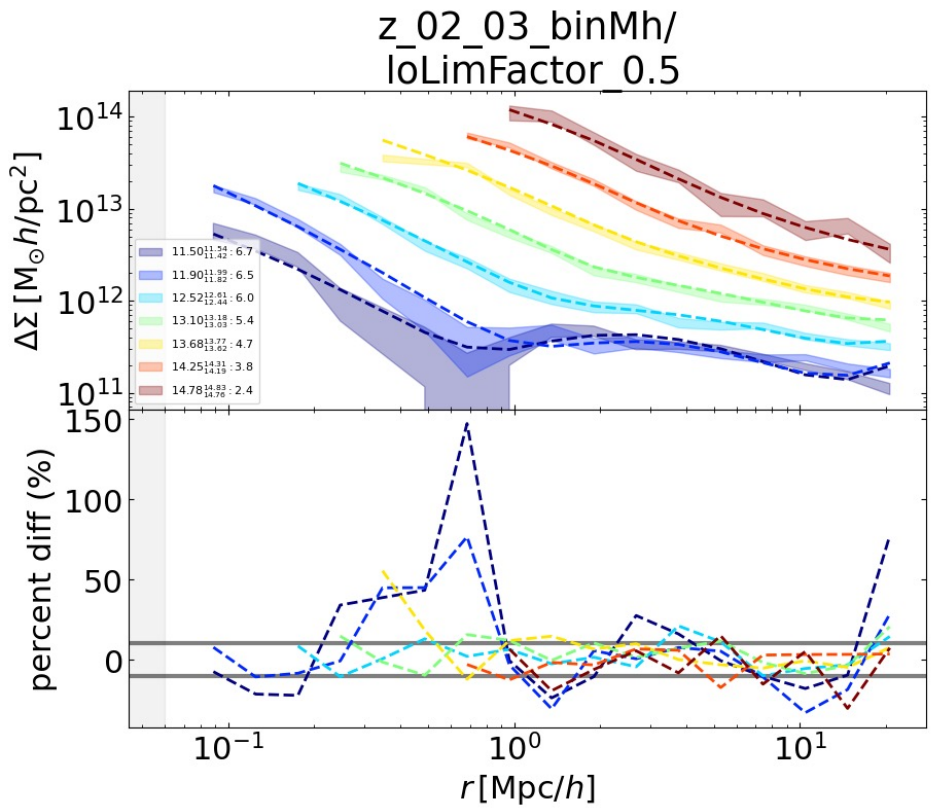
$$\Sigma(R) = 2\int_0^{\infty} \rho(R,z)dz = 2\int_R^{\infty} \frac{\rho(r)\,r}{\sqrt{r^2 - R^2}}\,dr$$

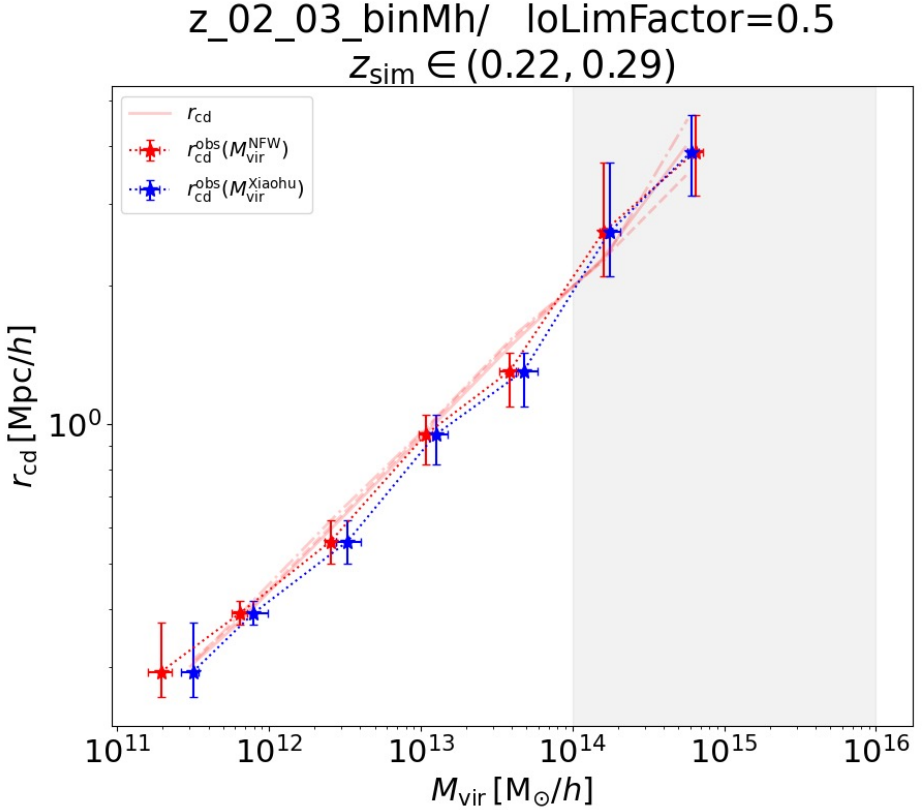
$$\overline{\Sigma}(R) = \frac{2}{R^2}\int_0^R R'\Sigma(R')dR'$$

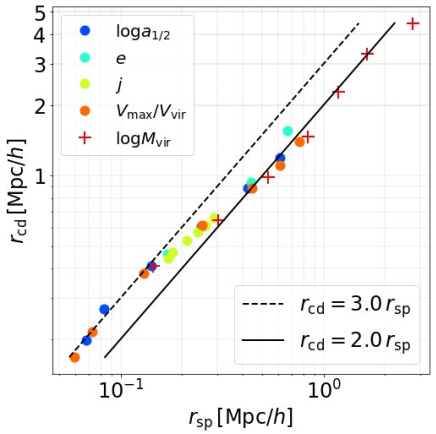
$$\Delta\Sigma(R) = \overline{\Sigma}(R) - \Sigma(R)$$

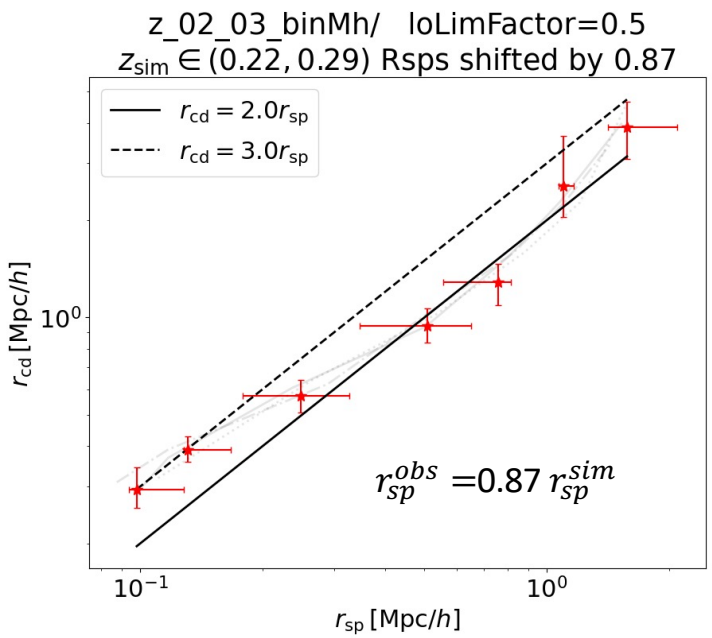


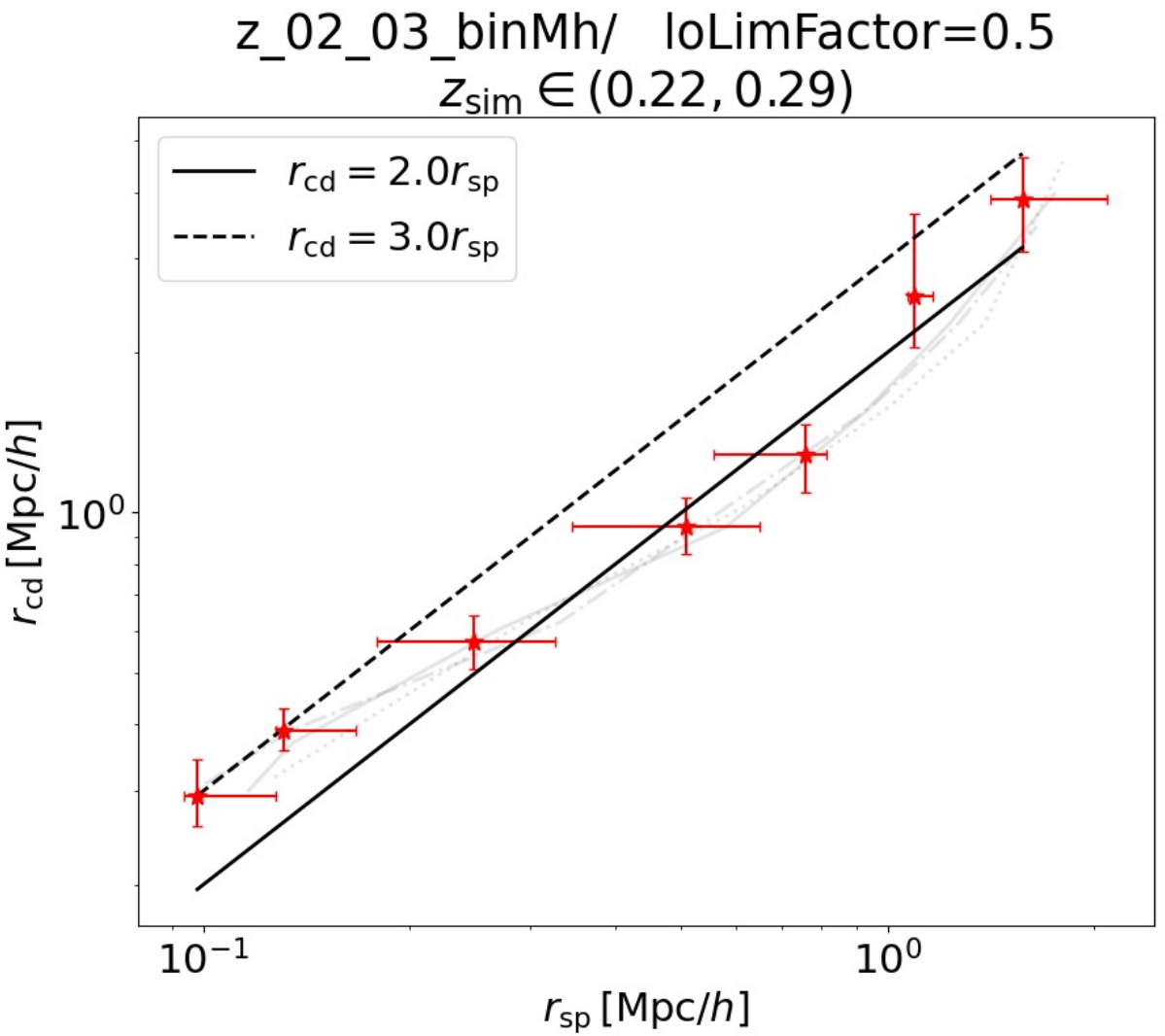
Ongoing detection of the characteristic depletion radius using weak lensing

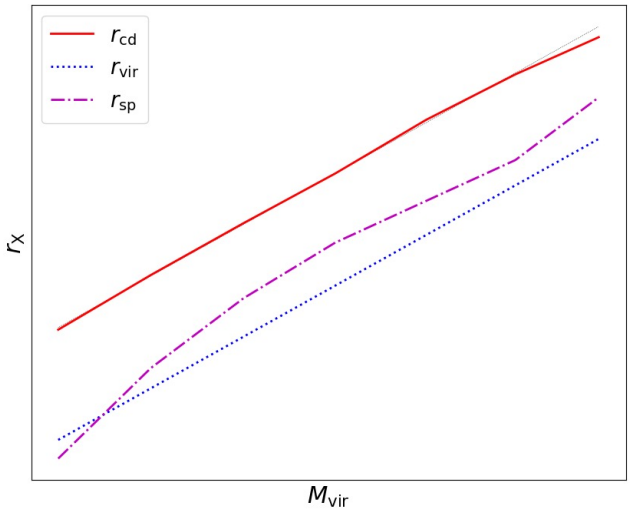


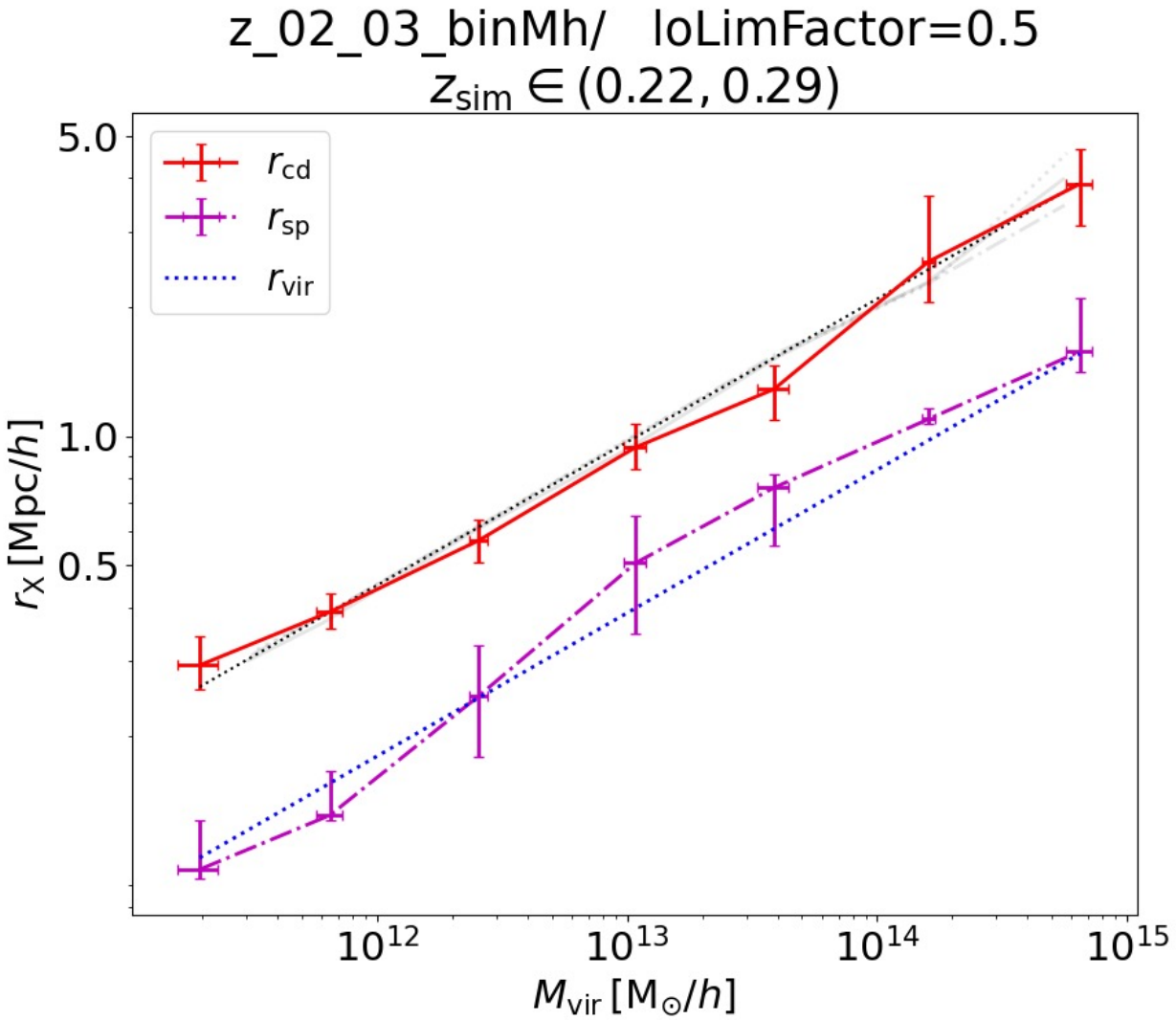


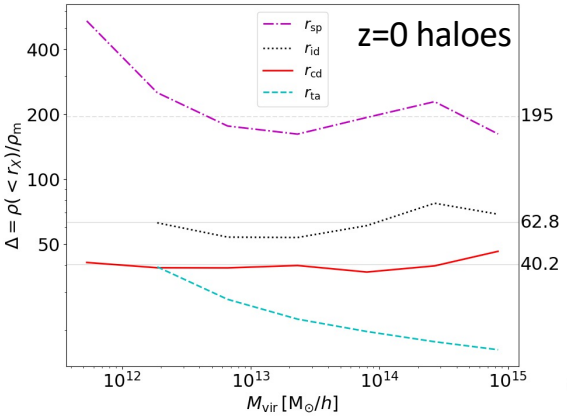

$\log a_{1/2}$
e
j
V_{max}/V_{vir}
$\log M_{vir}$
$r_{cd} = 3.0\, r_{sp}$
$r_{cd} = 2.0\, r_{sp}$
r_{cd} [Mpc/h]
r_{sp} [Mpc/h]


z_02_03_binMh/ loLimFactor=0.5
$z_{sim} \in (0.22, 0.29)$ Rsps shifted by 0.87
$r_{cd} = 2.0 r_{sp}$
$r_{cd} = 3.0 r_{sp}$
$r_{sp}^{obs} = 0.87\, r_{sp}^{sim}$
r_{cd} [Mpc/h]
r_{sp} [Mpc/h]


z_02_03_binMh/ loLimFactor=0.5
$z_{sim} \in (0.22, 0.29)$
$r_{cd} = 2.0 r_{sp}$
$r_{cd} = 3.0 r_{sp}$
r_{cd} [Mpc/h]
r_{sp} [Mpc/h]


r_{cd}
r_{vir}
r_{sp}
r_X
M_{vir}

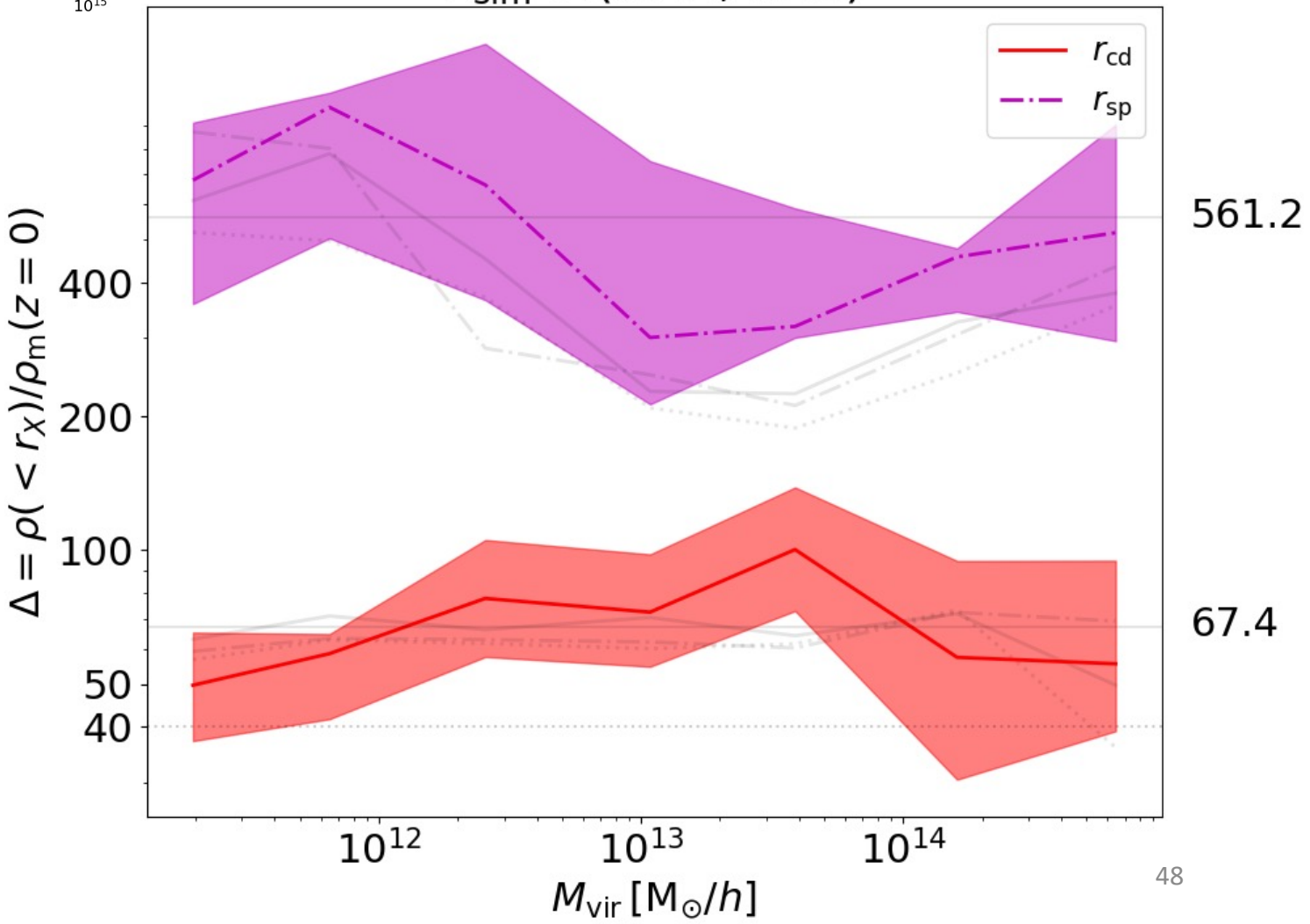

z_02_03_binMh/ loLimFactor=0.5
$z_{sim} \in (0.22, 0.29)$
r_{cd}
r_{sp}
r_{vir}
5.0
1.0
0.5
r_X [Mpc/h]
10^{12}
10^{13}
10^{14}
10^{15}
M_{vir} [$M_\odot/h$]



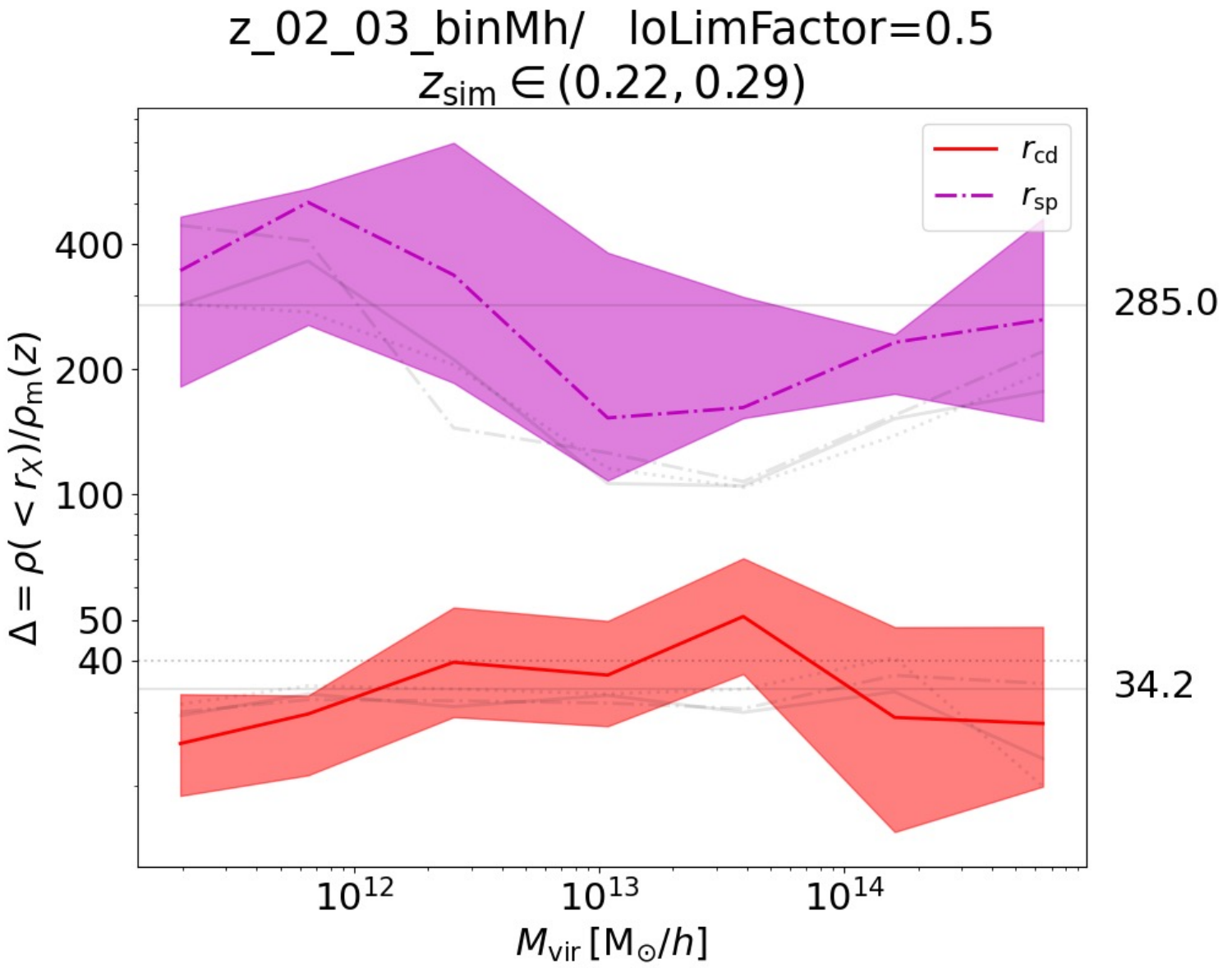
$$\rho_m(z=0)$$

z_02_03_binMh/ loLimFactor=0.5

$z_{sim} \in (0.22, 0.29)$



$\rho_m(z)$


z_02_03_binMh/ loLimFactor=0.5
$z_{sim} \in (0.22, 0.29)$
r_{cd}
r_{sp}
400
200
100
50
40
285.0
34.2
$\Delta = \rho(< r_X)/\rho_m(z)$
10^{12}
10^{13}
10^{14}
$M_{vir}\,[M_\odot/h]$

Summary

arXiv:2008.03477

- We define a depletion region around halos that can be described by three radii: the maximum inflow and turnaround locations bounding the region, and the characteristic depletion radius located between them
- The inner depletion radius r_{id} separates a growing halo from the depleting environment and can be interpreted as an outer splashback radius that encompasses a highly complete percent of splashback particles, and is thus a candidate for the exclusion radius that can help improve halo modelling.
- We emphasize the characteristic depletion radius. As it is easily identifiable through the bias, we are able to study how r_{cd} is related to halo properties. We show that it is located where we expect that the 1-halo term transitions to the 2-halo term and is sensitive to halo parameters beyond mass and accretion history
- r_{cd} can tell us about the structure of halos. A few examples:
  - When binning by virial mass, $r_{cd} = 2.5 r_{vir}$ and $\rho(< r_{cd}) = 40\rho_m$, or $M_{cd} = 40\rho_m \frac{4\pi}{3} {r_{cd}}^3$
  - Can inform when halos have completed their accretion phase, on characteristic depletion scales, when compared to the turnaround radius
  - Implies a universal outer density profile for halos when compared to the splashback radius
- The radii characterizing the depletion region can be determined by either the dynamics or distribution of matter
  - r_{id}, defined at the maximum infall location, has been found by Li & Han 2021
  - r_{cd}, defined at the minimum of the bias, is likely to be found in weak lensing: ongoing work