Non-universality of halo profiles and their scaling with the “virial” radius

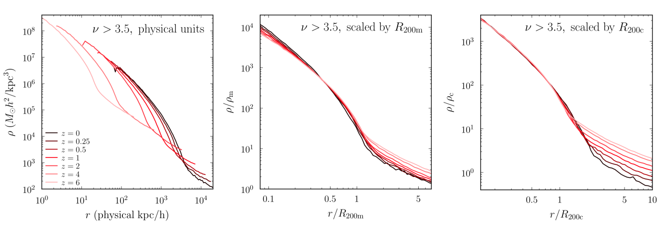
Benedikt Diemer[1,2], Andrey V. Kravtsov[1,2,3]

arXiv: 1401.1216

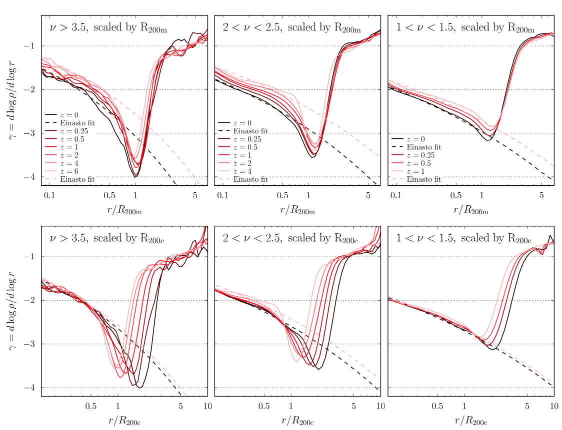
Abstract

The inner regions of halo density profiles have been studied extensively. Here, we focus on the median outer profiles. We find that the outer profiles are non-universal in the sense that, at a fixed peak height, they depend on the mass accretion rate of halos. High mass accretion rates lead to a steepening between $\approx 0.5 R_{200c}$ and R_{200m}, causing logarithmic slopes of up to -4 and steeper. Such signatures of high accretion rates are potentially observable through weak lensing. Furthermore, we find that halo samples binned by their peak height have median profiles which are remarkably self-similar across redshift when radii and densities are expressed in units of R_{200c} and ρ_c for the inner profiles, and R_{200m} and ρ_m for the outer profiles. Thus, the choice of “virial” radius and mass definition is critical when describing quantities that evolve with redshift, such as concentration.

Self-similarity of the density profiles

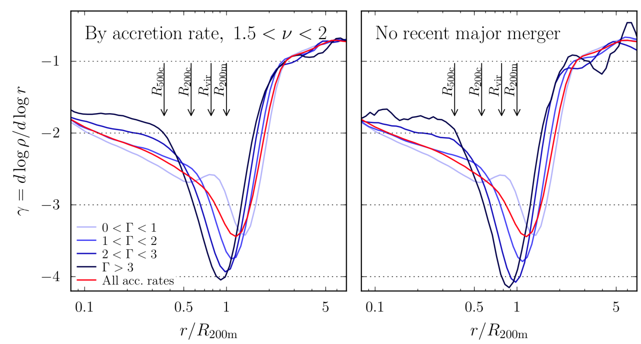


The median density profiles of high peak height halos at different redshifts. In physical units (left), the profiles vary across redshifts. When radii are re-scaled by some spherical overdensity radius, R_Δ, and the corresponding reference density, ρ_m or ρ_c, the profiles become universal in redshift. The inner region ($r < R_{200c}$) is most self-similar in units of R_{200c}, whereas the outer region ($r > R_{200m}$) is most self-similar in units of R_{200m}. Scaling with R_{vir} and ρ_{vir} gives intermediate results.

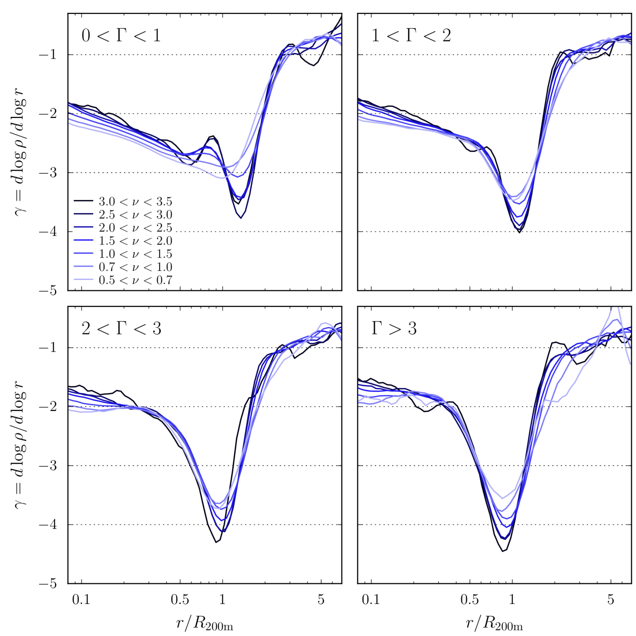


Profiles of the logarithmic slope for three bins in peak height, corresponding to very massive clusters ($M>10^{15}\ M_\odot/h$, left), more common clusters ($M\sim10^{14}\ M_\odot/h$, center), and galaxy to group scale halos ($M\sim10^{12-13}\ M_\odot/h$, right). The radii are scaled by R_{200m} in the top row and by R_{200c} in the bottom row. The self-similarity of the inner (outer) regions in units of R_{200c} (R_{200m}) holds for all halo masses.

Dependence on the mass accretion rate



The median slope profile of group to cluster sized halos (left panel, red line), and the profiles of halos from the same sample, but split by their accretion rate, $\Gamma = d\log(M_{vir}) / d\log(a)$. The profiles of fast-accreting halos (dark blue) have a distinct shape and reach much steeper slopes than their slowly accreting counterparts (light blue). In the right panel, halos with recent major mergers are excluded, but the median profiles remain almost unchanged. Thus, the steeper profiles are caused by the smooth accretion of matter rather than by major mergers.



The median slope profiles of halos of different peak heights, grouped by their mass accretion rate (with the lowest rate in the top left panel, and the highest at the bottom right). The shape of the outer profile is very similar for samples with the same mass accretion rate, even though the halo masses span five orders of magnitude. This plot demonstrates that mass accretion rate, in addition to halo mass, is a factor controlling the shape of the density profile.

THE UNIVERSITY OF CHICAGO
KICP Kavli Institute for Cosmological Physics at The University of Chicago
THE KAVLI FOUNDATION

1 Department of Astronomy and Astrophysics, The University of Chicago, Chicago IL 60637
2 Kavli Institute for Cosmological Physics, Chicago IL 60637
3 Enrico Fermi Institute, The University of Chicago, Chicago IL 60637

References

B. Diemer, A. Kravtsov, *Dependence of the outer density profiles of halos on their mass accretion rate*, 2014, arXiv:1401:1216