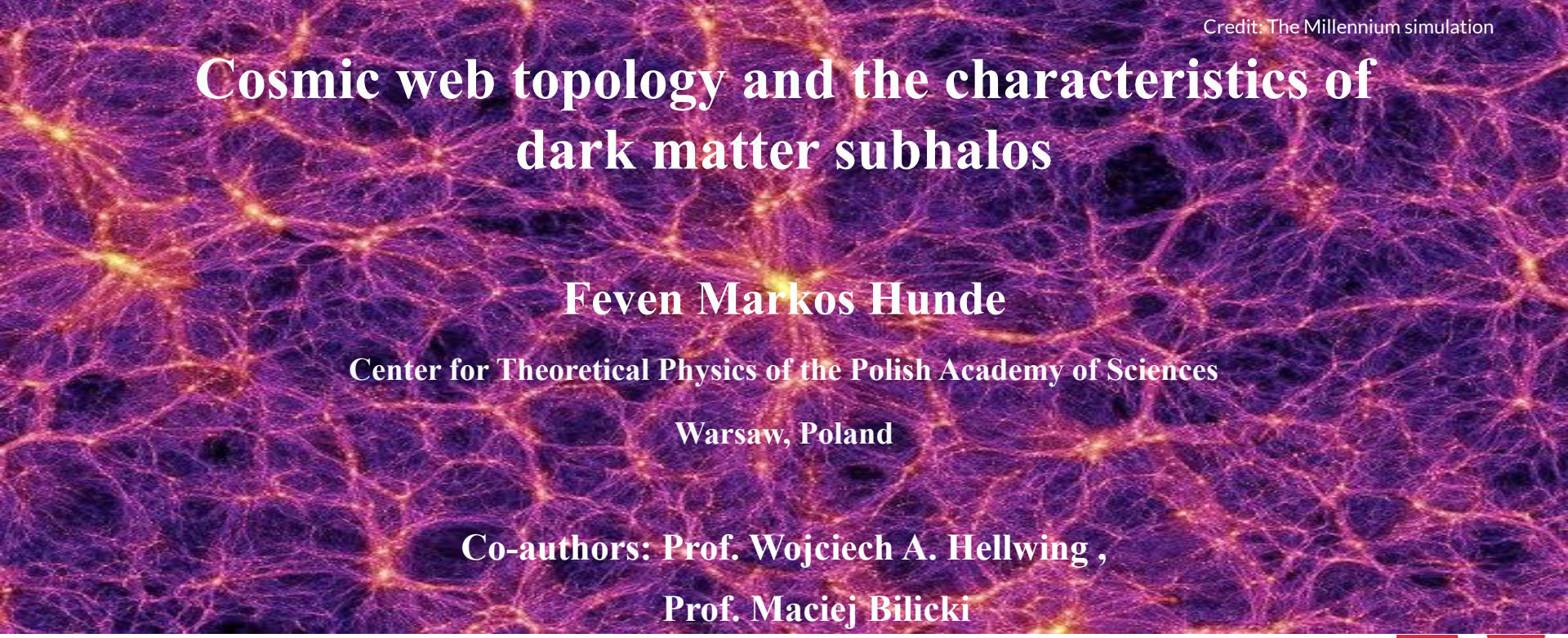

Cosmic web topology and the characteristics of dark matter subhalos

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3rd African Conference on Fundamental and Applied Physics, ACP2023

George, South Africa,

September 25-29, 2023

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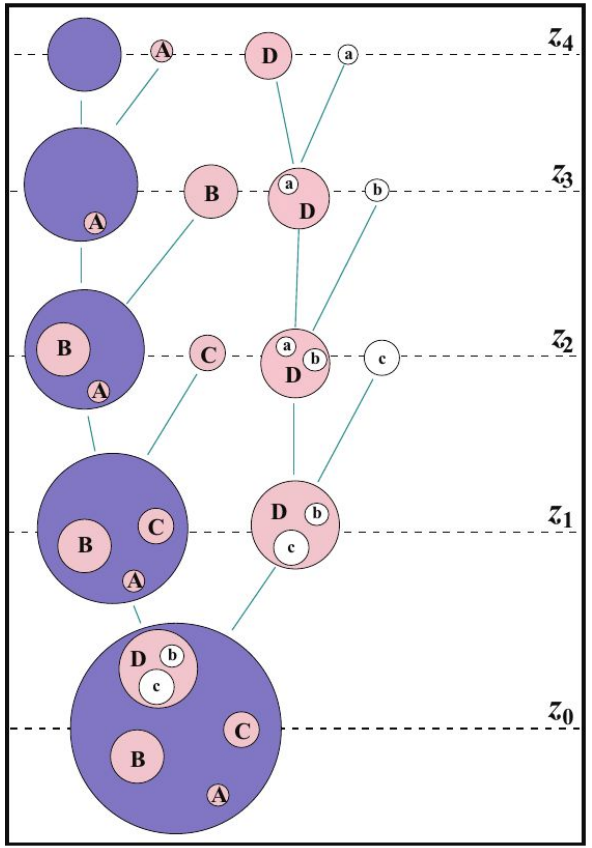
The large-scale structure of the Universe

★ Hierarchical structure formation.

★ **Subhalos**: Their centers are within the virial radii of larger “parent” halos.



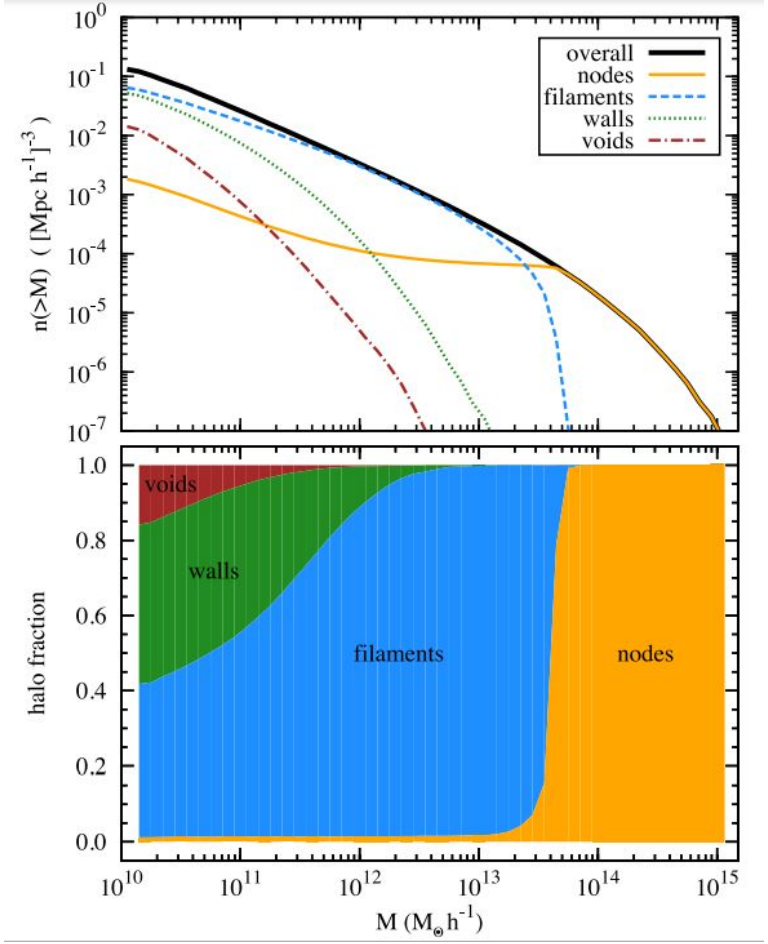
Zavala et al. 2019

Environmental dependence of halo properties

Cosmic web:

- Filaments, nodes/knots, walls and voids

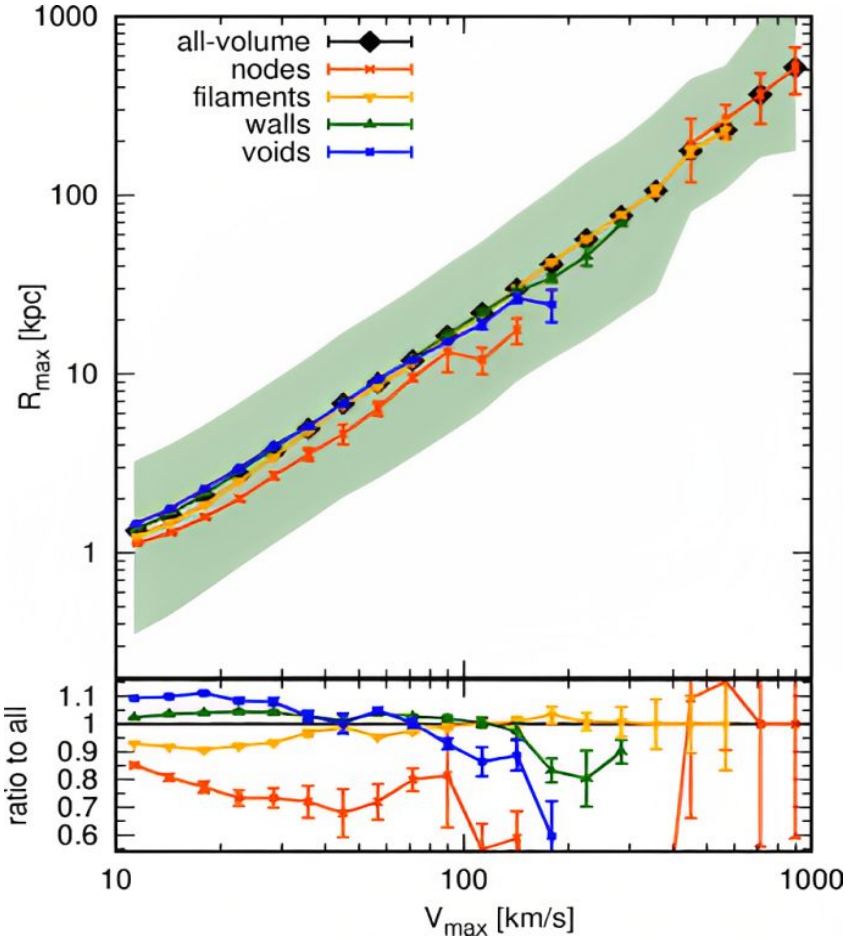
★ The population of halos in nodes dominates the highest mass range and walls becomes significant only for lower masses below 10^{10} $h^{-1}M_{\odot}$.



Cautun et al. (2014)

Environmental dependence of halo properties

★ Node and filament halos have the lowest R_{max} values, and voids have the largest R_{max} values for the fixed V_{max} values.



Hellwing et al. (2021)

Copernicus Complexio Simulation

COpernicus complexio LOw Resolution (COLOR), "zoom-in" simulations.

- ★ 1620^3 DM particles
- ★ $M_p = 6.19\times10^6 M_\odot h^{-1}$
- ★ $V_{box} = 3.5\times105 h^{-3} Mpc^3$
- ★ CDM and WDM flavors.
- ★ Initial cosmology parameters WMAP7
- ★ Dark matter halos, and their self-bound subhalos were identified using the SUBFIND algorithm.
- ★ NEXUS+ algorithm was used for the segmentation of the cosmic web.

Hellwing et al. (2021)

Motivation

Why?

The study of DM subhalos

★ Examines the dependence of subhalo properties on the properties of their host halos
★ Provides a deeper understanding of the nature and properties of dark matter
★ To explore the cosmic web impact on hierarchical structure formation of DM halos
★ Contributes for understanding of formation and evolution of galaxies

Goal

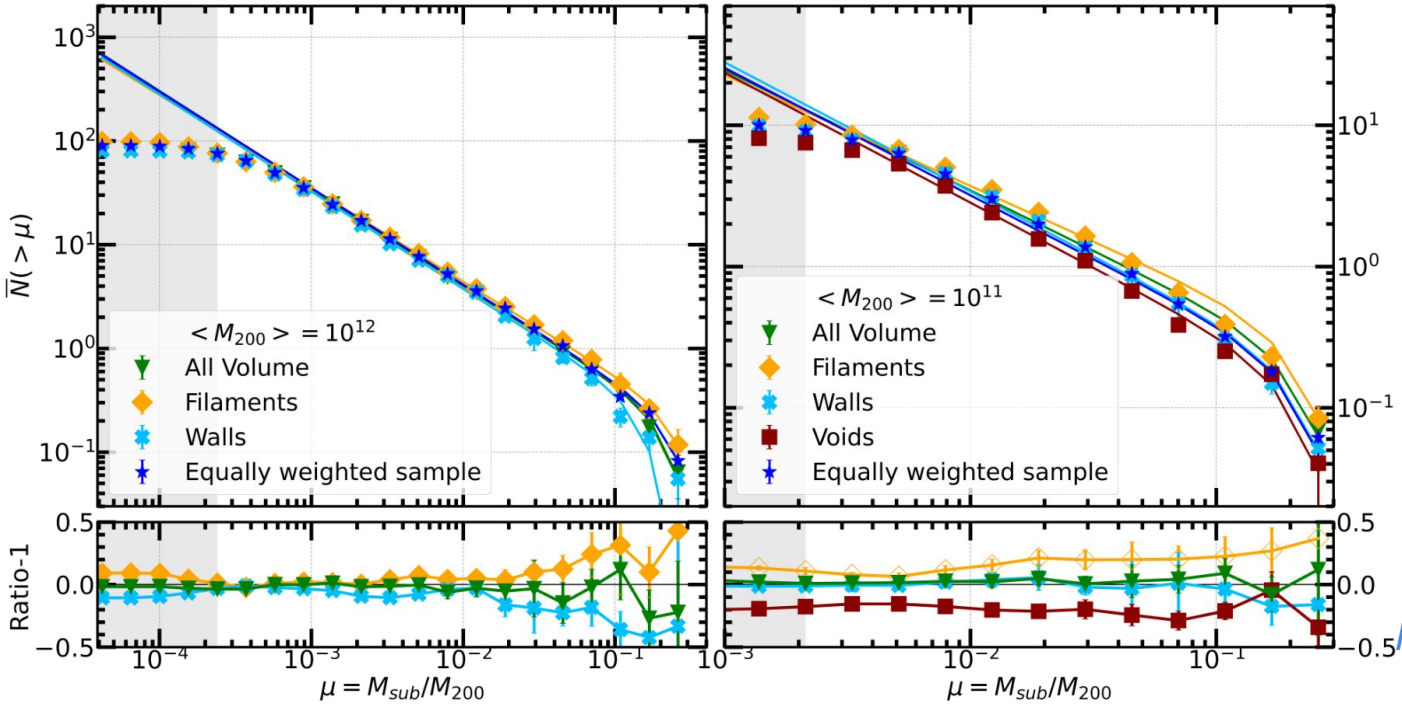
★ Study the detailed DM subhalo properties of different cosmic web environments
  - Mass function, density profile, concentration and radial distribution
★ Investigate the subhalo properties dependence on host halo properties

Subhalo mass function

★ For MW-like halos in COLOR simulation: ~95% in filaments and ~5% in walls.

★ The equally weighted sample is obtained by selecting an equal number of host halos from each environment, determined by the environment with the fewest number of halos.

$$N_{fit}(>\mu) = a\mu^{-s}exp^{(-\beta\mu^3)}$$ .....Giocoli et al. 2008a

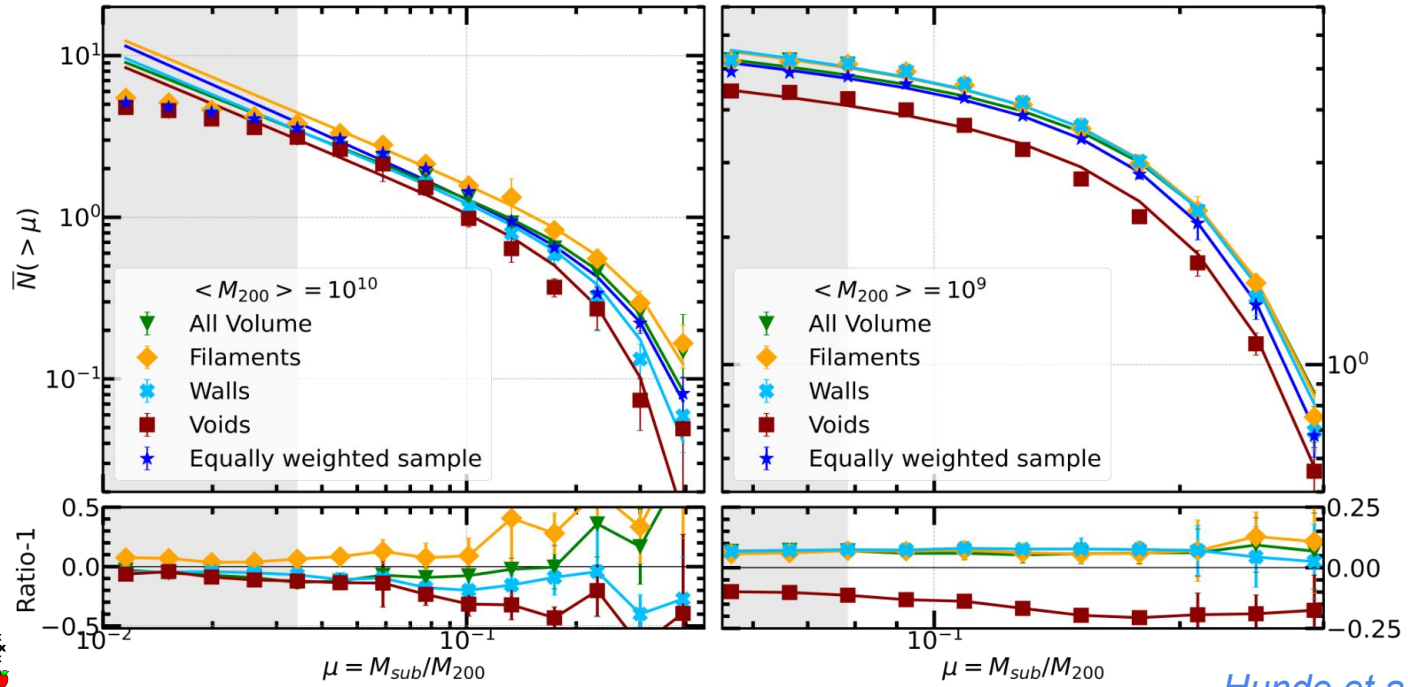


Hunde et al. (in prep.)

Subhalo mass function...

★ We excluded subhalos with less than 100 particles.

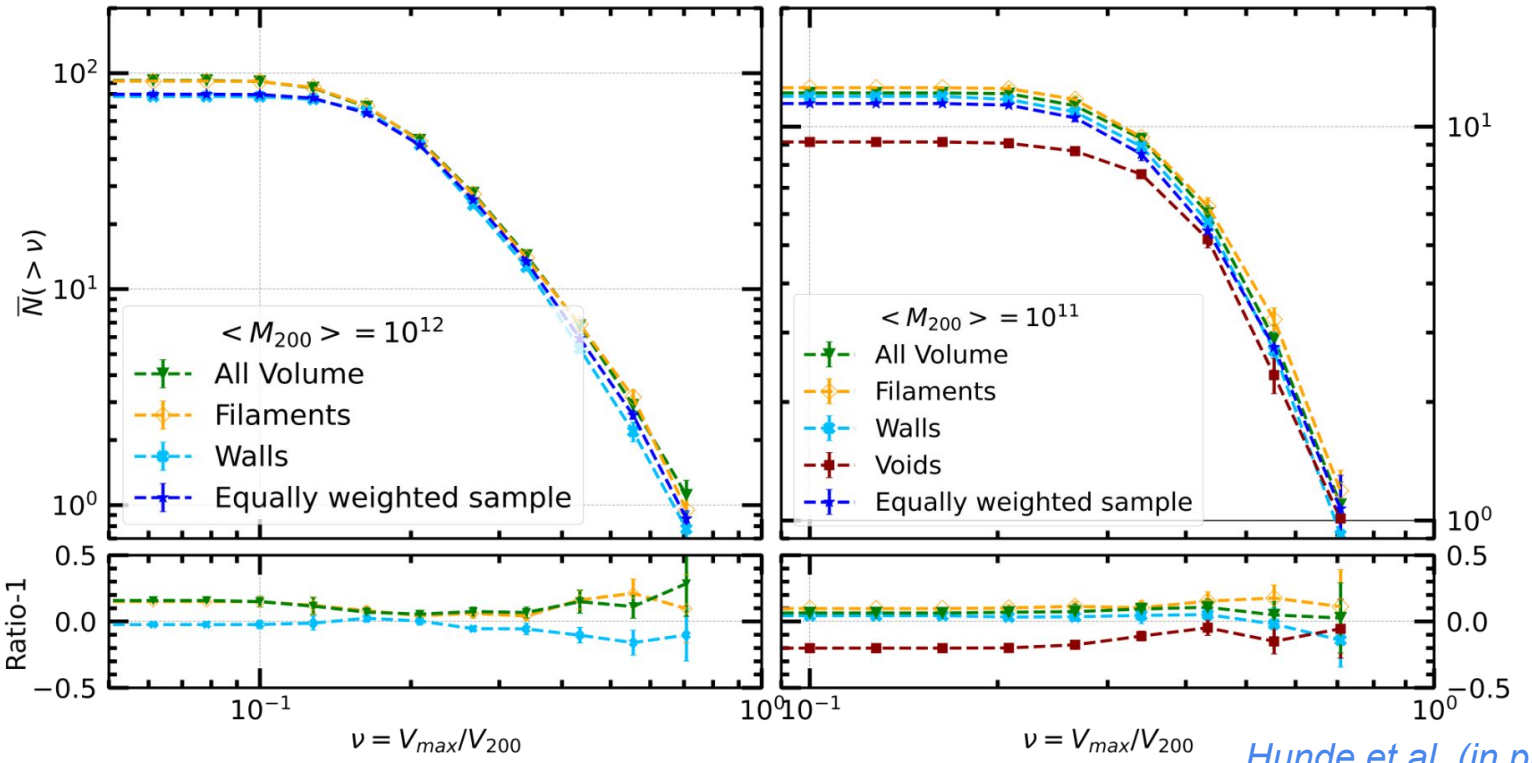
★ The region of the lightest gray shading corresponds to values below the cutoff mean (μ_{cut}) that were excluded from the fitting model.



Hunde et al. (in prep.)

Subhalo velocity function

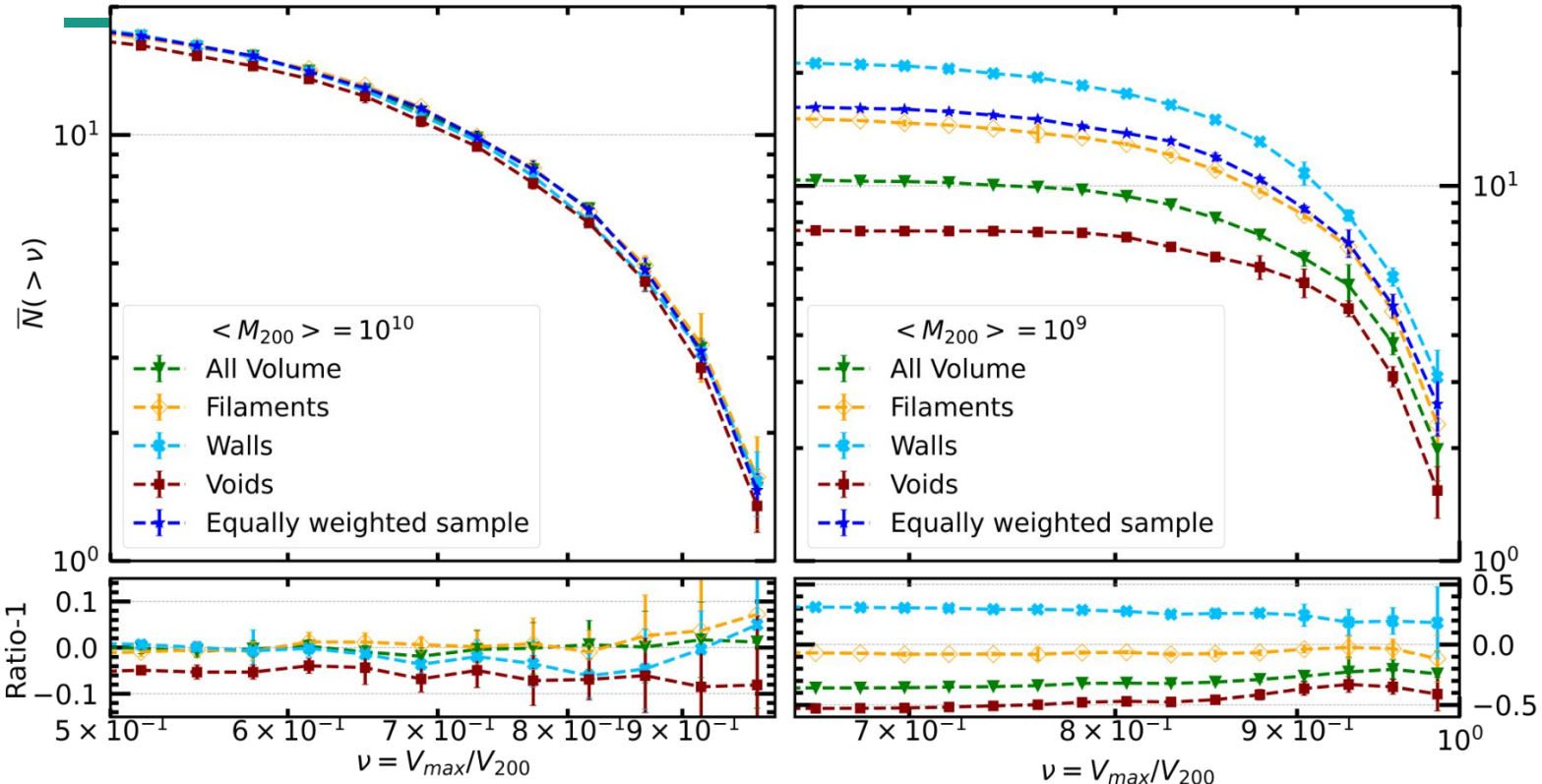
★ Subhalo velocity function used as a stable measure of a subhalo's bound particles due to its less dependence on subhalo definition compared to subhalo mass.



Hunde et al. (in prep.)

Subhalo velocity function....

$$V'_{max} = V_{max}[1 + (\epsilon/R_{max})^2]^{1/2}$$ .....Springel et al. (2008)

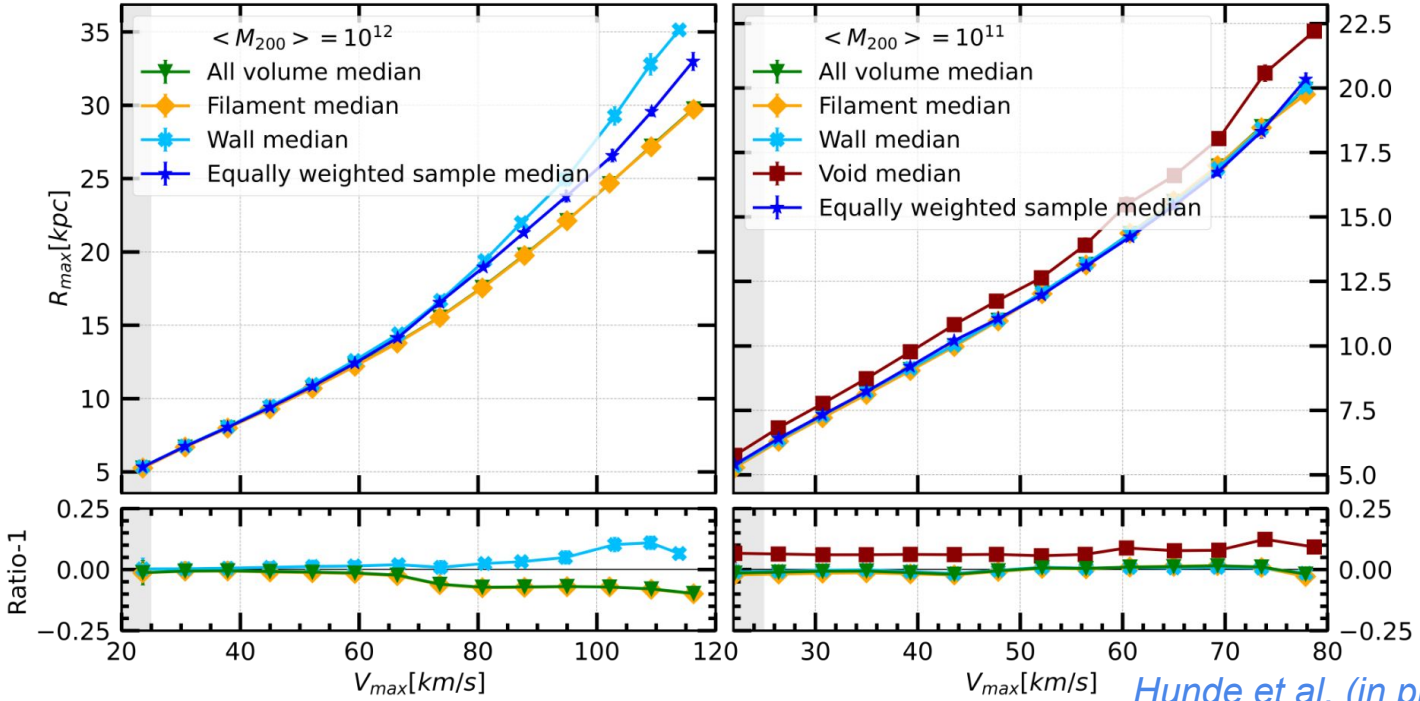


Hunde et al. (in prep.)

The V_{max} -R_{max} relation

★ The relation of the maximum circular velocity (Vmax) and the associated radius (Rmax) of subhalos.

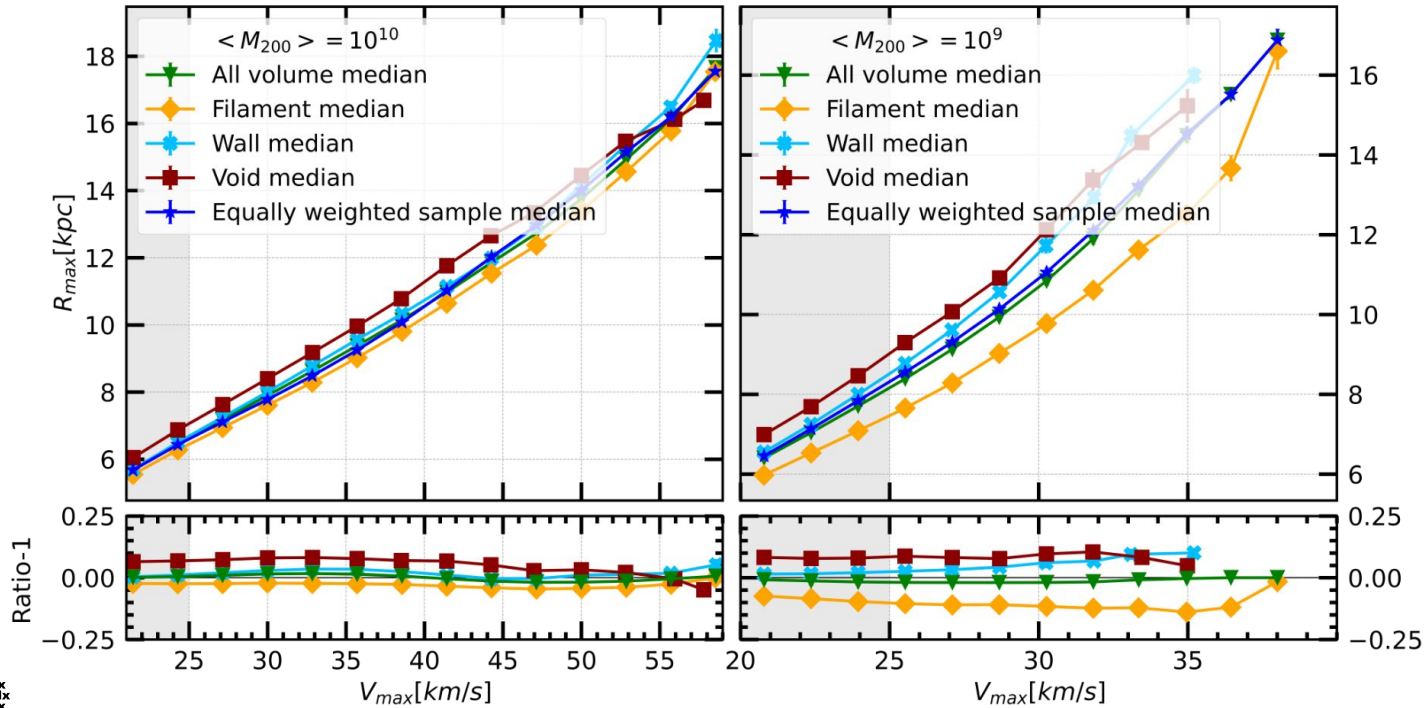
★ The gray shaded region corresponds to values below the resolution limit, $V_{max} = 25\ kms^{-1}$.



Hunde et al. (in prep.)

The V_{max} -R_{max} relation...

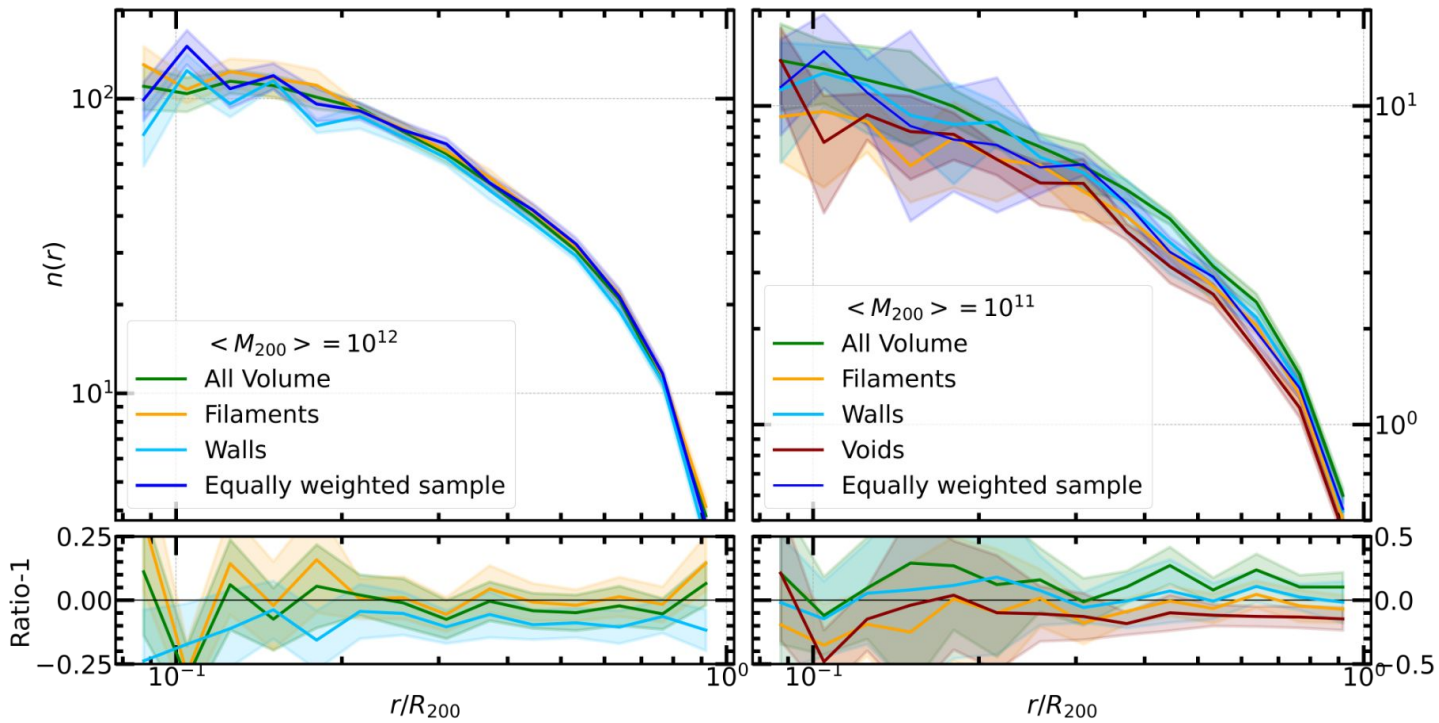
★ The errors are the bootstrap errors on the median.



Hunde et al. (in prep.)

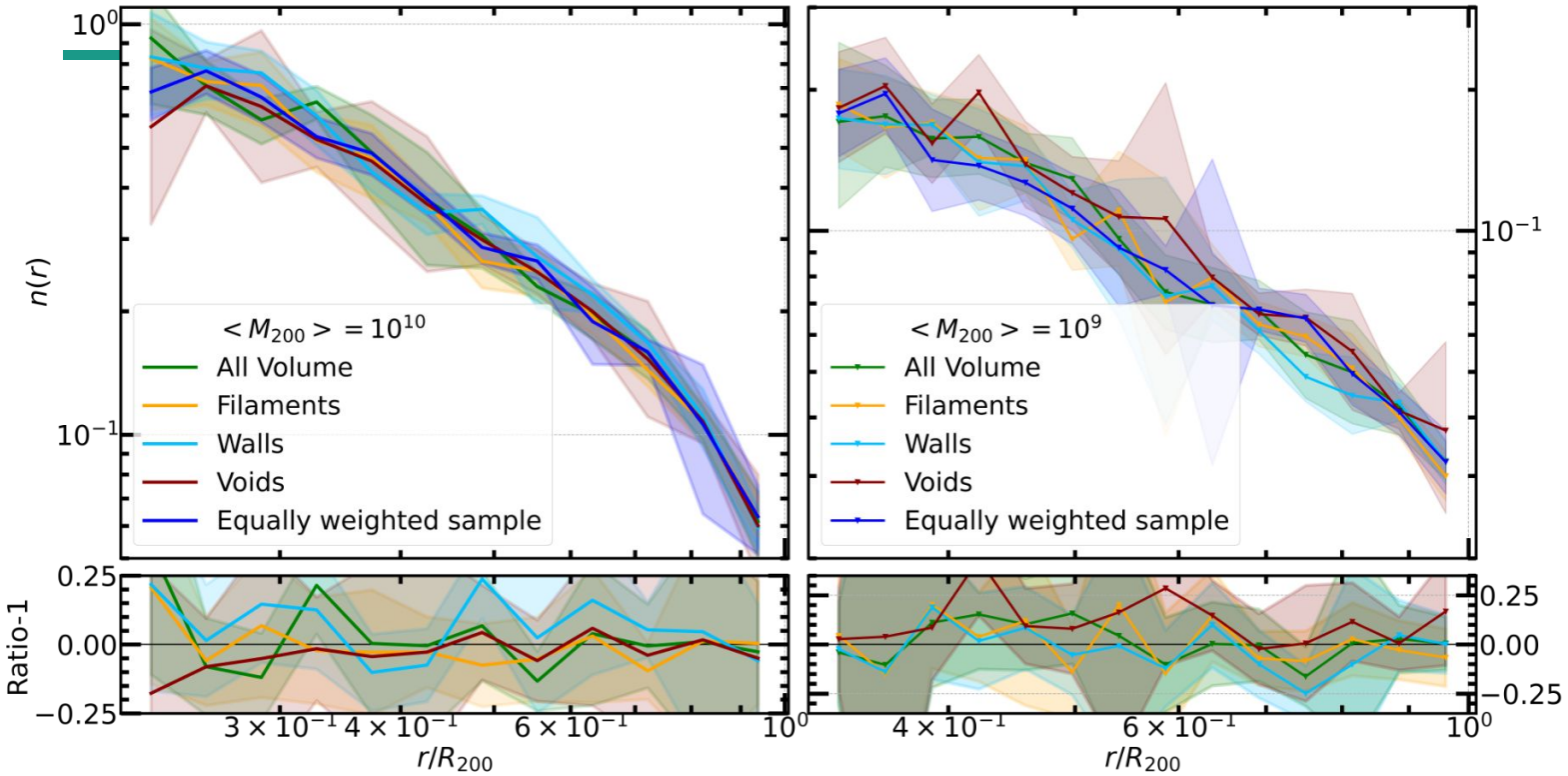
The radial distribution of subhalos

★ The number density of subhalos used to show the spatial distribution.



Hunde et al. (in prep.)

The radial distribution of subhalos…



Hunde et al. (in prep.)

Summary

- ★ Subhalos hosted by halos located in filaments dominate the mass function in the majority of host halo mass ranges
- ★ The abundance of subhalos is generally higher in high-mass halos, suggesting a correlation between host halo mass and subhalo population
- ★ Subhalo mass function follows an exponential power-law fitting that extends to a rescaled subhalo mass value of $\mu = 10^{-5}$ and characterizes the higher μ values better than any fit
- ★ Subhalos found in filament halos exhibit the lowest R_{max} values while the ones in void halos exhibit the largest values when V_{max} is fixed, showing subhalos in filaments are more concentrated toward the center of their host halos

Ongoing work: **time evolution** of these properties, **satellite galaxies** properties dependence on the cosmic web


thank you
danke
謝謝
ngiyabonga
شكراً جزيلاً
рахмат
teşekkür ederim
спасибо
Баярлалаа
gracias
dank je
tapadh leat
obrigado
dziękuję
bedankt
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go raibh maith agat
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Backup slides

The number of host halos

Table: The number of host halos in the specific mass ranges for each cosmic web environment.

$<M_{200}>$	**All volume**	**Filaments**	**Walls**	**Voids**
$\mathbf{10^{12}}$	100%	94.74%	5.21%	0.05%
$\mathbf{10^{11}}$	100%	56.38%	41.07%	2.54%
$\mathbf{10^{10}}$	100%	37.14%	48.02%	14.66%
$\mathbf{10^{9}}$	100%	35.50%	41.19%	23.31%

The M_{200} range values

Table: The range of M_{200} mass values that give the specific median value.

$<M_{200}>$	All volume ($logM_{200}$)	Filaments ($logM_{200}$)	Walls ($logM_{200}$)	Voids ($logM_{200}$)
10^{14}	[13.75 - 14.70]	-	-	-
10^{13}	[12.72 - 13.75]	[12.72 - 13.75]	-	-
10^{12}	[11.72 - 12.72]	[11.68 - 12.72]	[11.90- 12.70]	[11.93 - 12.10]
10^{11}	[10.72 - 11.72]	[10.66 - 11.68]	[10.74 - 11.90]	[10.86 - 11.93]
10^{10}	[9.72 - 10.72]	[9.72 - 10.66]	[9.70 - 10.74]	[9.77 - 10.86]
10^{9}	[8.72 - 9.72]	[8.71 - 9.72]	[8.71 - 9.70]	[8.73 - 9.77]