The Last Journey. II. SMACC — Subhalo Mass-loss Analysis using Core Catalogs

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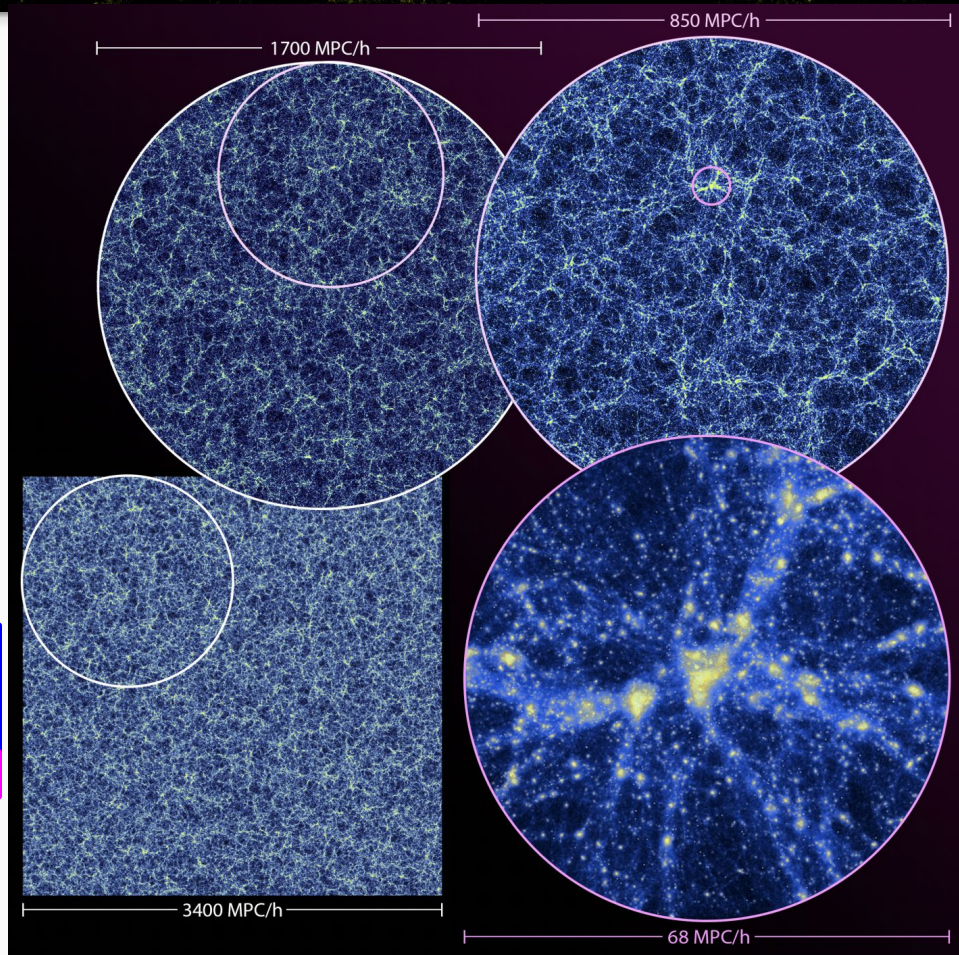
Extreme-scale gravity only simulations

Heitmann+20

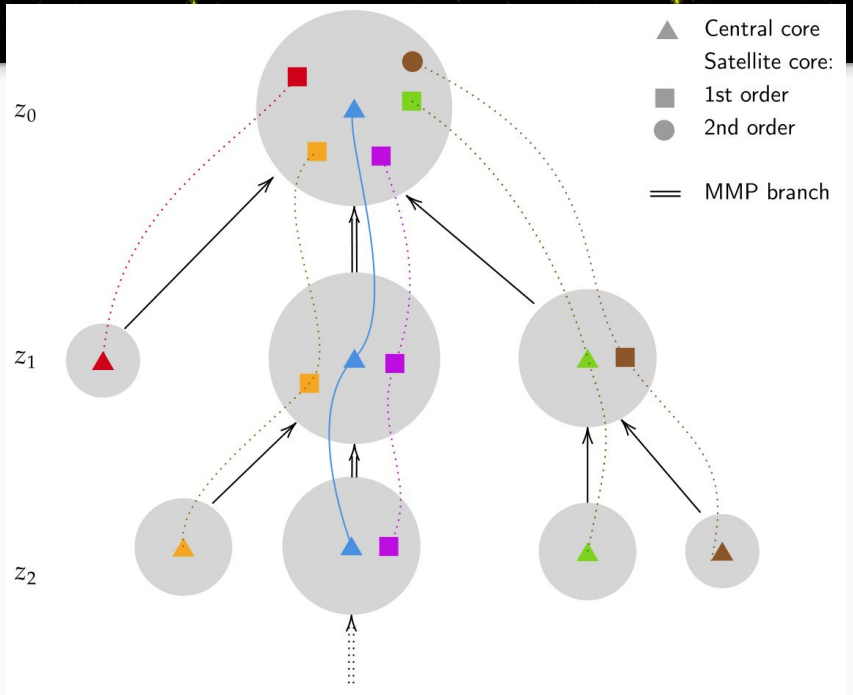
- N-body ΛCDM dark matter simulations with HACC
- Last Journey Simulation (Heitmann+20)
  - over 1.24 trillion particles in a $(3400h^{-1}\text{Mpc})^3$ volume
  - Planck-18 cosmology

Name	Simulation Volume $[(h^{-1}\text{Mpc})^3]$	Particle count	Particle mass $[h^{-1}\text{M}_\odot]$
Last Journey	3400^3	$10{,}752^3$	$\sim 2.7 \cdot 10^9$
Last Journey-SV	250^3	1024^3	$\sim 1.3 \cdot 10^9$
Last Journey-HM	250^3	3072^3	$\sim 4.6 \cdot 10^7$
AlphaQ	256^3	1024^3	$\sim 1.2 \cdot 10^9$



Tracking dark matter: Cores

- **Core**: central particles of a halo
- Position, velocity, etc. stored for all snapshots in **core catalogs**
- Halo merger into parent halo: Infall halo properties (e.g. **mass**) stored with “satellite” core



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Using cores as proxies for subhalos

- Korytov+20: cores as proxies for galaxies
- Advantages over using subhalos
  - “Orphan galaxies” and substructure near halo center
  - SH finding/SH merger tree construction computationally expensive
- Subhalo information needed for SAMs of galaxy formation
  - Position, velocity, evolution history
  - **Mass (need to model)**
- Model subhalo mass with SMACC

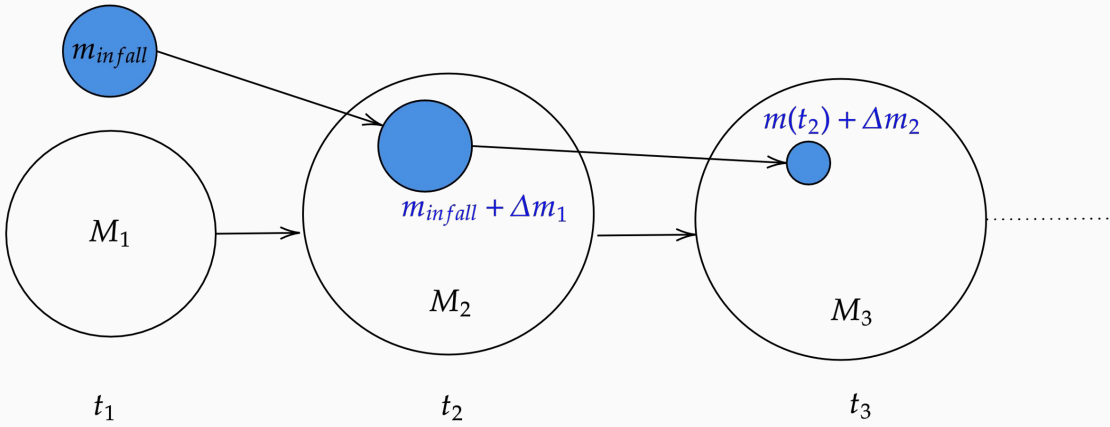
Subhalo mass loss model

$$\dot{m} = -A\frac{m}{\tau_{\rm dyn}}\left(\frac{m}{M}\right)^{\zeta}$$

van den Bosch+ 2005, Jiang & van den Bosch 2016

- Orbit-averaged
- m, M
- τ_{dyn}(z, cosmology)
- A, ζ free parameters

$\rightarrow \Delta m$

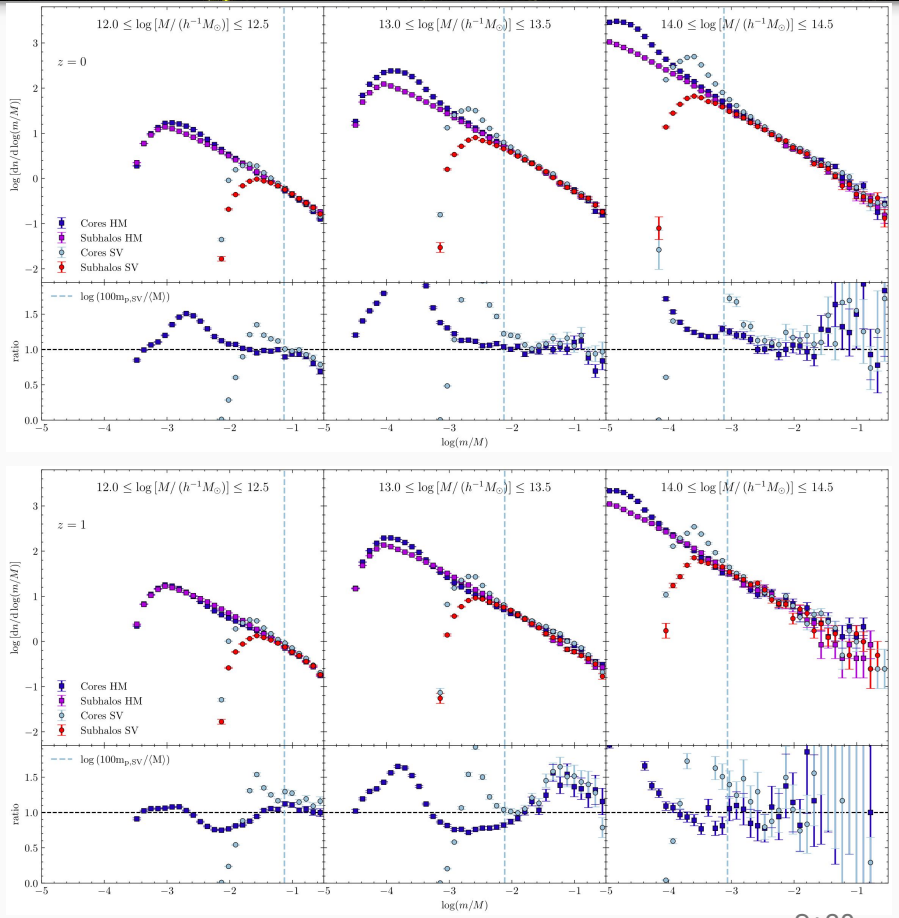


Tuning the model

- Parameter exploration
  - A = 0.4 to 2.4; ζ = 0.001 to 0.3
  - Compared SHMF to CMF in HM for three host halo mass bins at z=0 and z=1
  - **(A, ζ) = (1.1, 0.1)** provide good compromise across redshifts and host halo masses
- Mass resolution effects
  - HM and SV simulations enable exploration of different mass resolutions

Resolution tests

- Particle mass
  - Last Journey-HM: ~5×10^7 $h^{-1}M_\odot$
  - Last Journey-SV: ~10^9 $h^{-1}M_\odot$
- Results are converged above a **mass threshold of ~100 SV particles** (vertical dashed lines)



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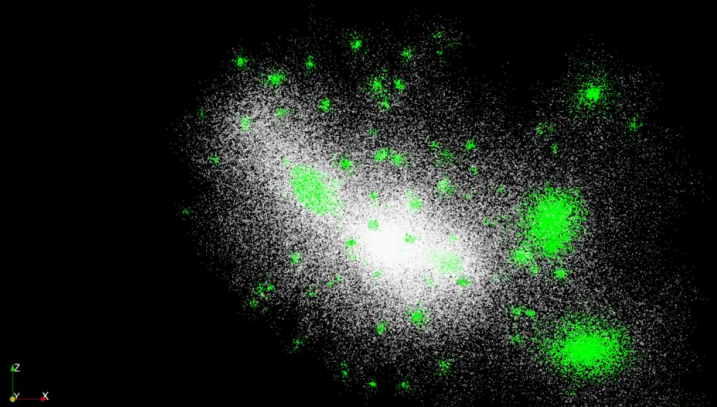
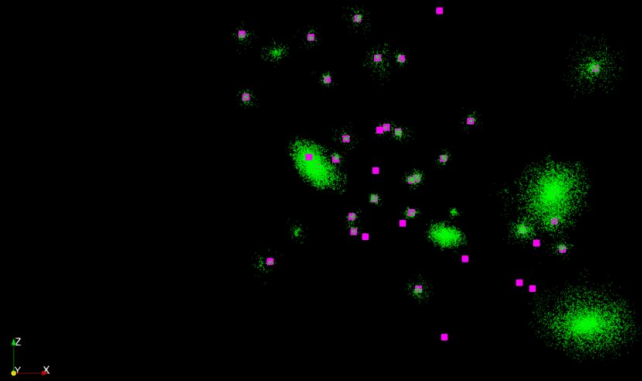
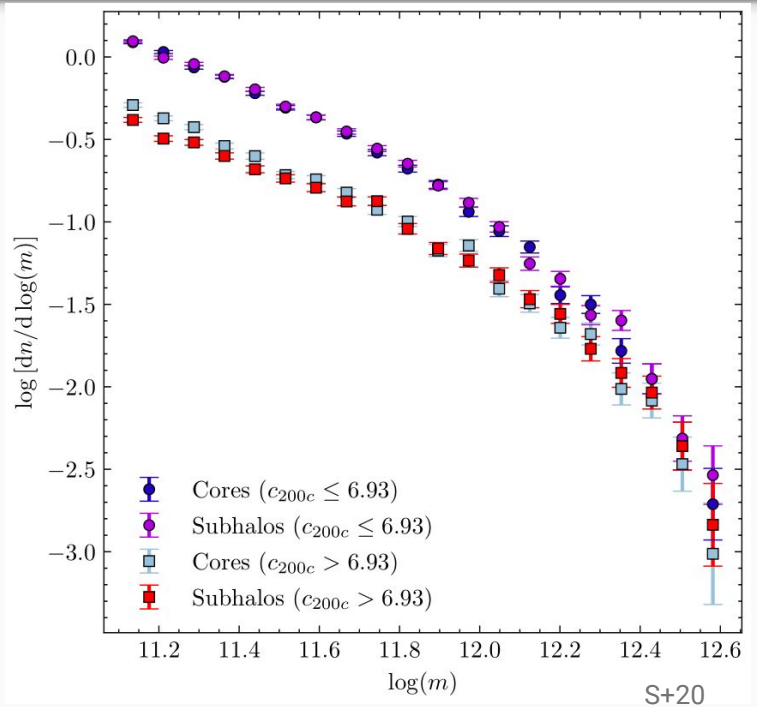

Z
Y
X


Z
Y
X

Model robustness

Host halo concentration effects

- Concentration as a proxy for environment effects and evolution history
- ~50,000 SV host halos with mass 10^{12} to 10^{13} $h^{-1}M_{\odot}$ split into two concentration bins
- Higher concentration subhalo mass functions suppressed
- **Excellent agreement between cores and subhalos (above resolution threshold)**



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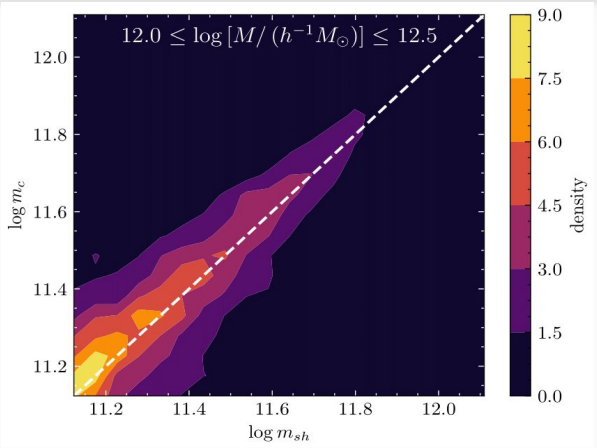
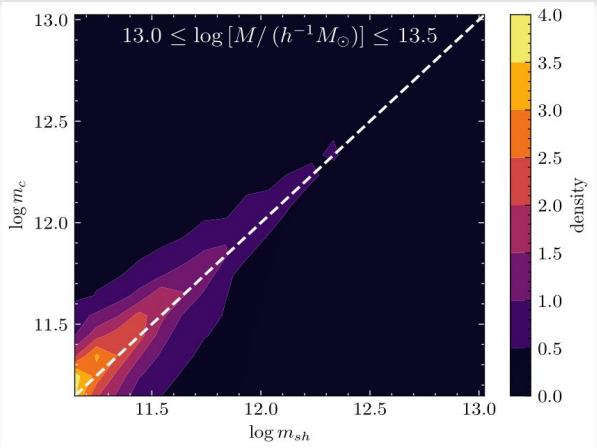
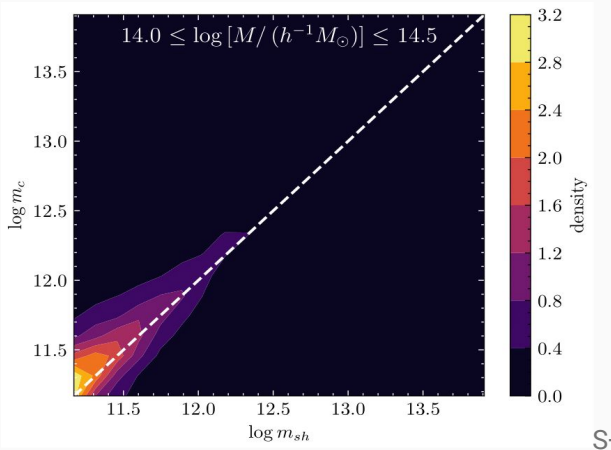
Subhalo–core spatial matching

- How well do the SV core and subhalo masses agree for individual objects (above our resolution threshold)?
- Match each subhalo to most massive “nearby” core







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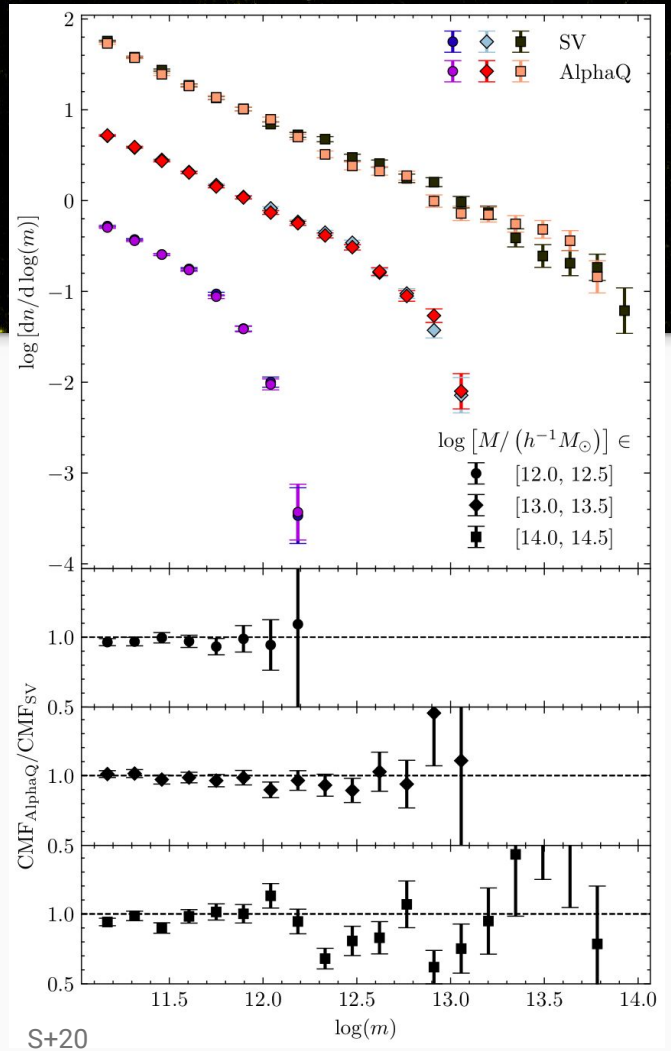
Cosmology effects

- Last Journey-SV: Planck-18
- AlphaQ: WMAP-7
- SMACC insensitive to cosmology (close to best-fit ΛCDM model)



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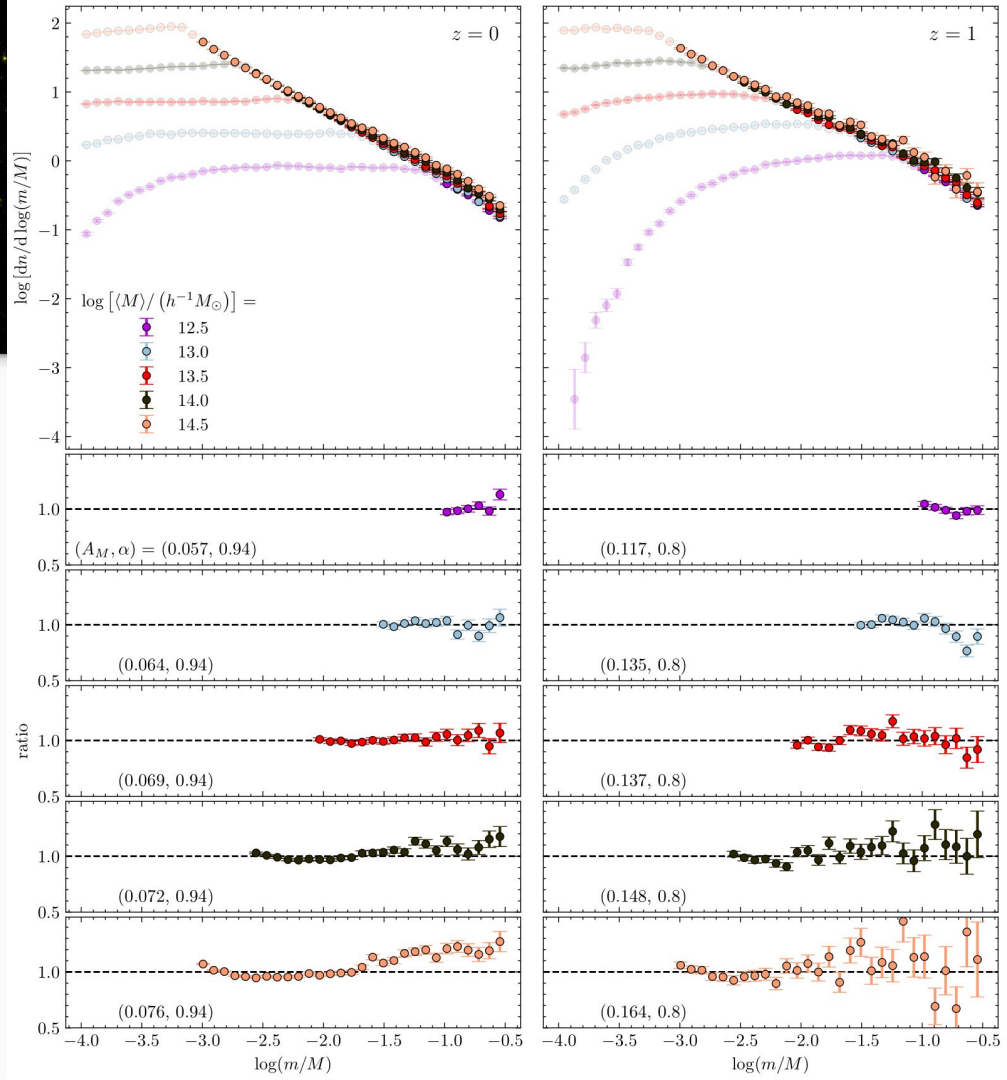
Last Journey core mass function

$$\frac{\mathrm{d}N}{\mathrm{d}\log(m/M)} = A_M \left(\frac{m}{M}\right)^{-\alpha} \exp\left[-50(m/M)^4\right]$$

van den Bosch & Jiang 2016

- Empirically selected α=0.94 (z=0) and α=0.8 (z=1)
  - Literature: slopes of 0.7 to 1.1 reported for N-body simulation SHMFs



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Summary and future work

- Cores as proxies for subhalos with **SMACC** (Subhalo Mass-loss Analysis using Core Catalogs)
- Demonstrated validity of SMACC with mass resolution and model robustness tests
- Future work: core mergers/disruption as proxies for **galaxy mergers/disruption**; **semi-analytic galaxy modeling** in Last Journey
- Goal: detailed synthetic sky maps for cosmological surveys

Thanks for your time!

Questions?

Backup slides

Subhalo mass function comparison

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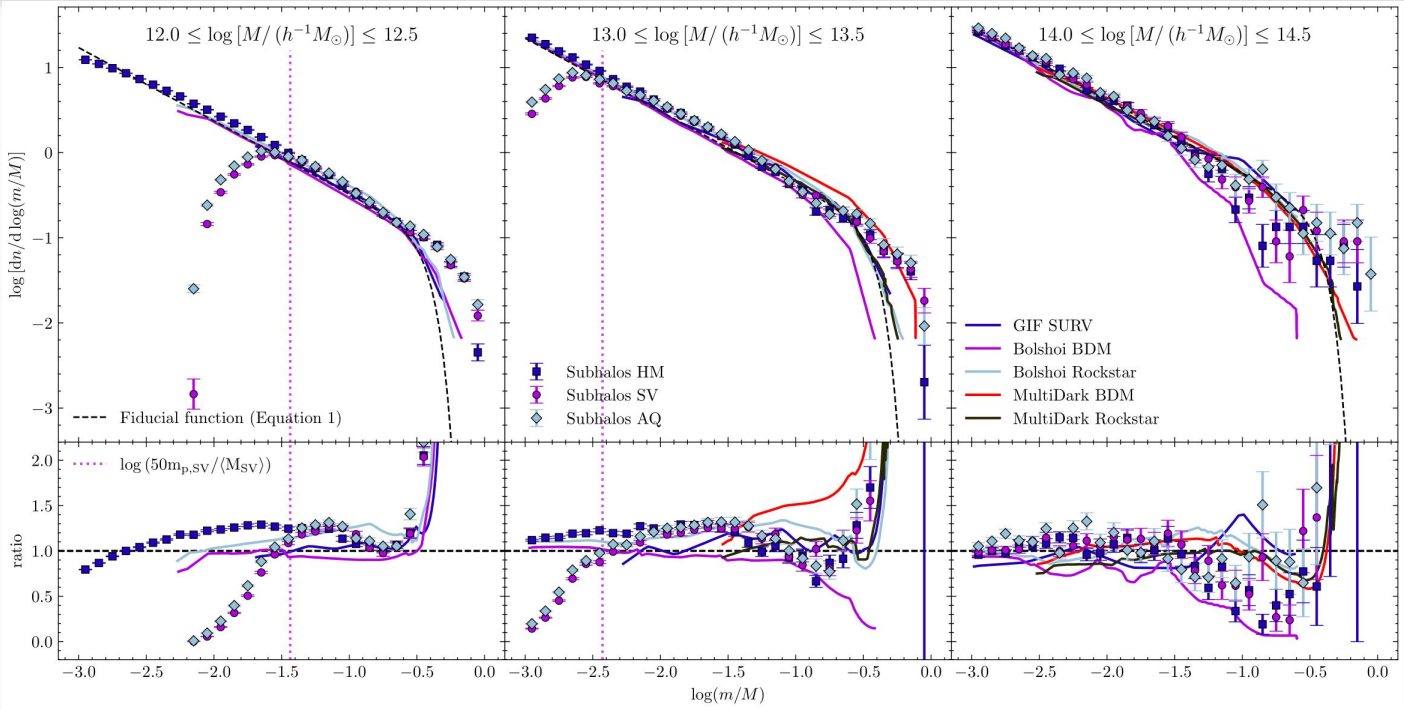
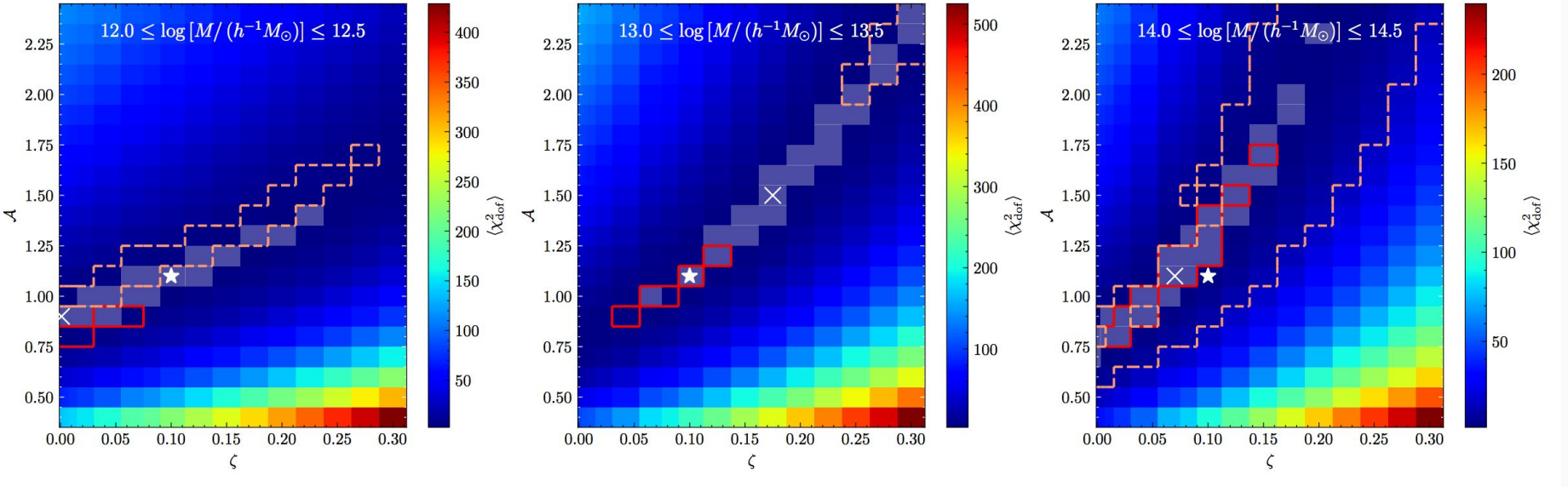


Parameter exploration (chi-squared)



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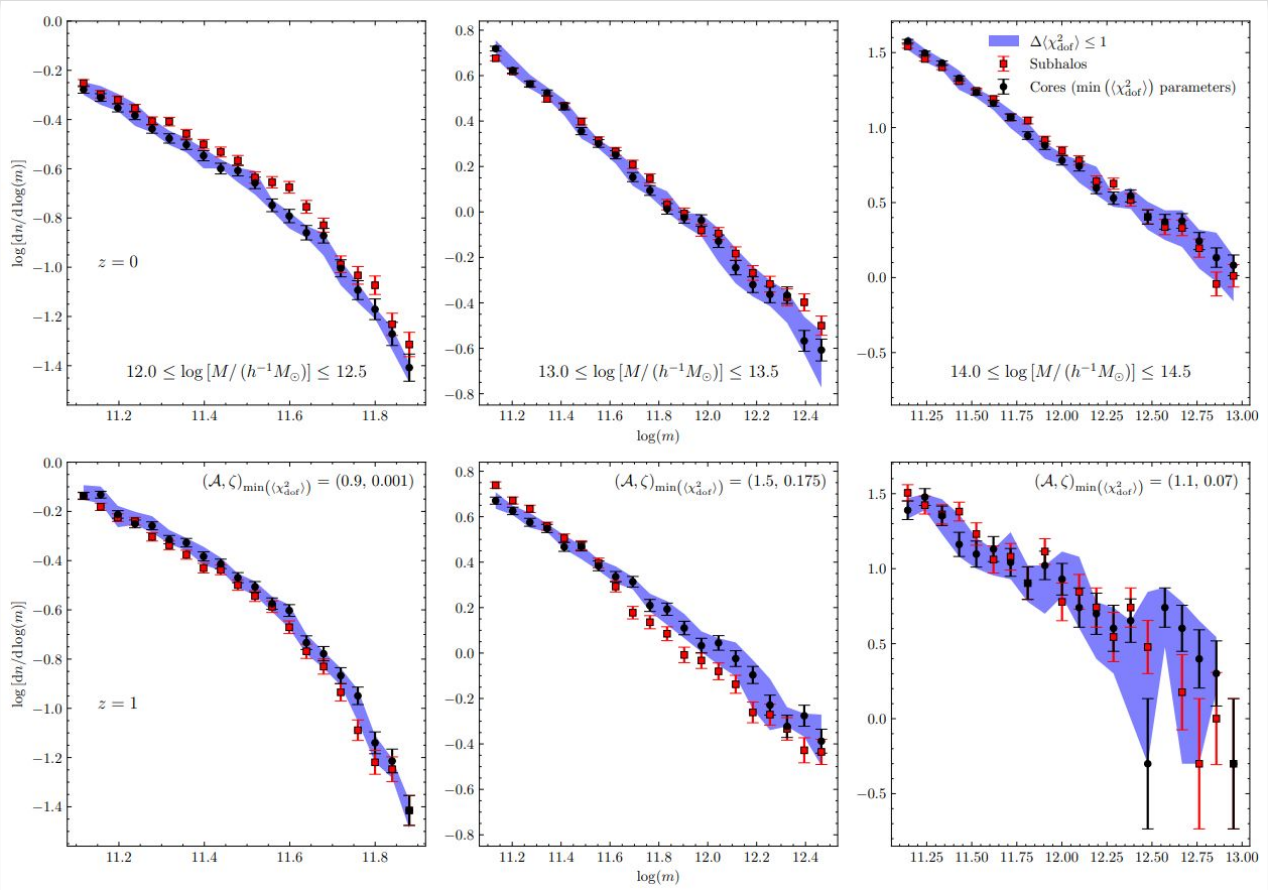
Parameter exploration (best-fit mass functions)



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Subhalo–core spatial matching
(infall and evolved mass distributions)

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