BLOODHOUND: TRACKING THE EVOLUTION OF SUBSTRUCTURE

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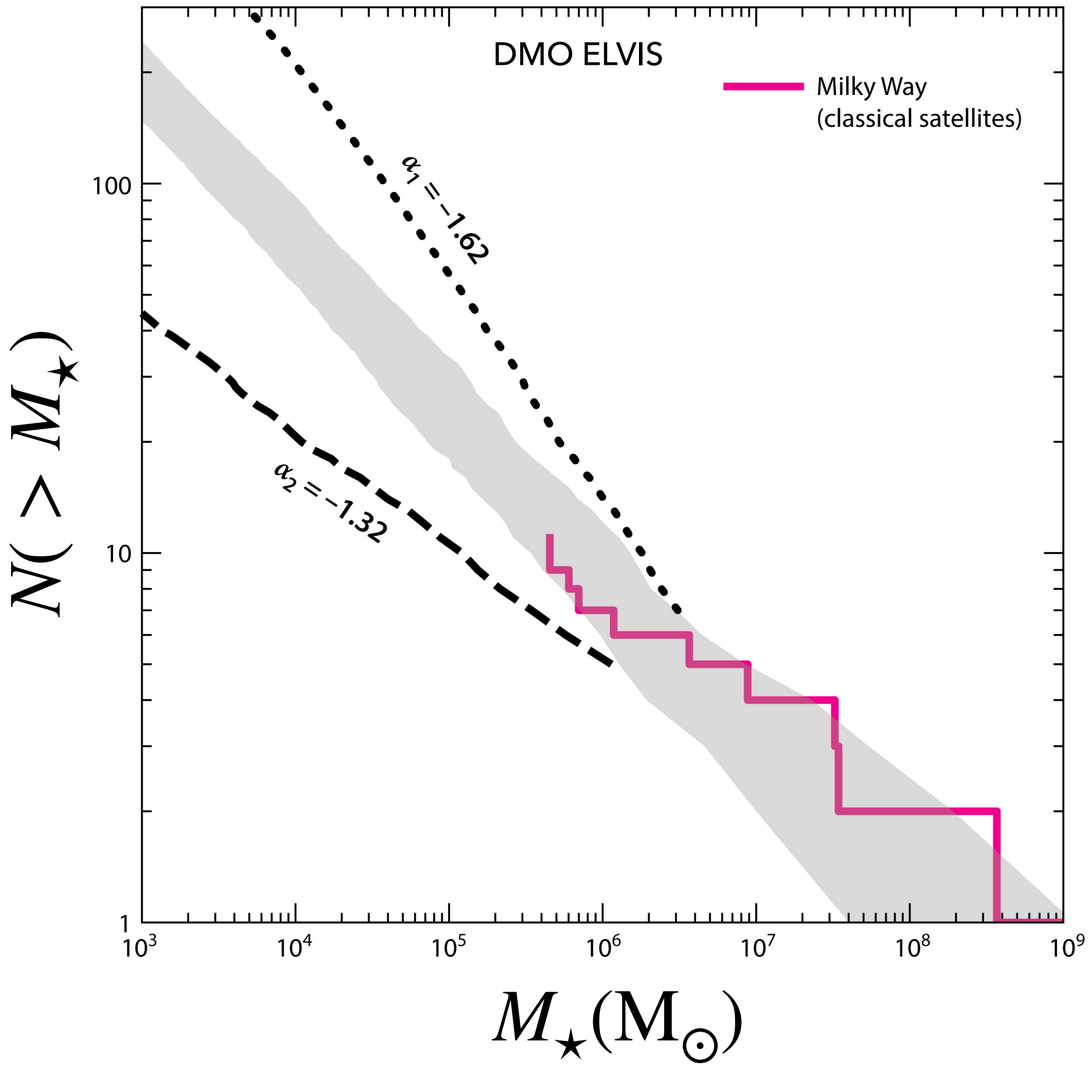
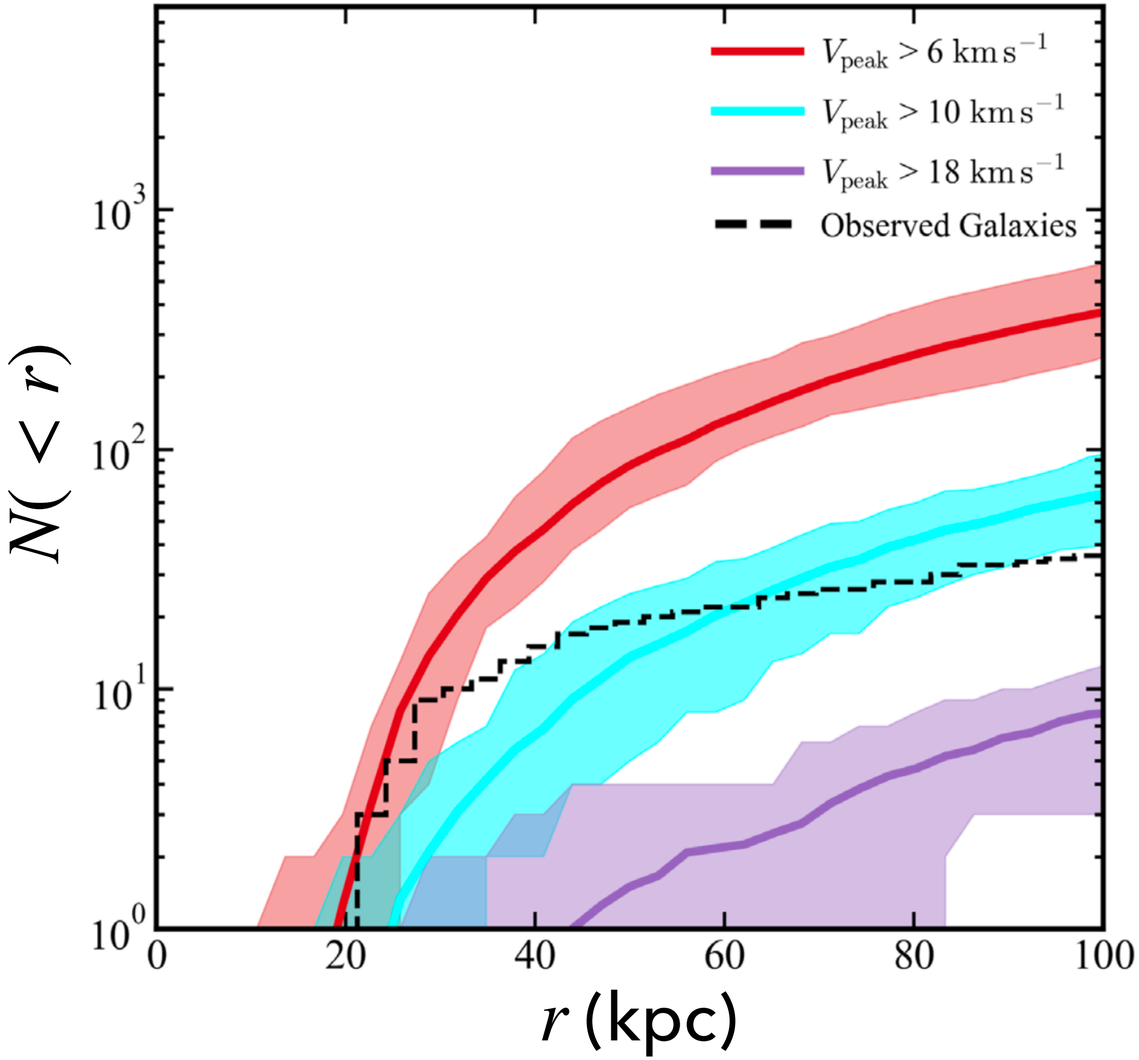
MW SATELLITE COUNTS



Bullock & Boylan-Kolchin 2017



Graus et al. 2019

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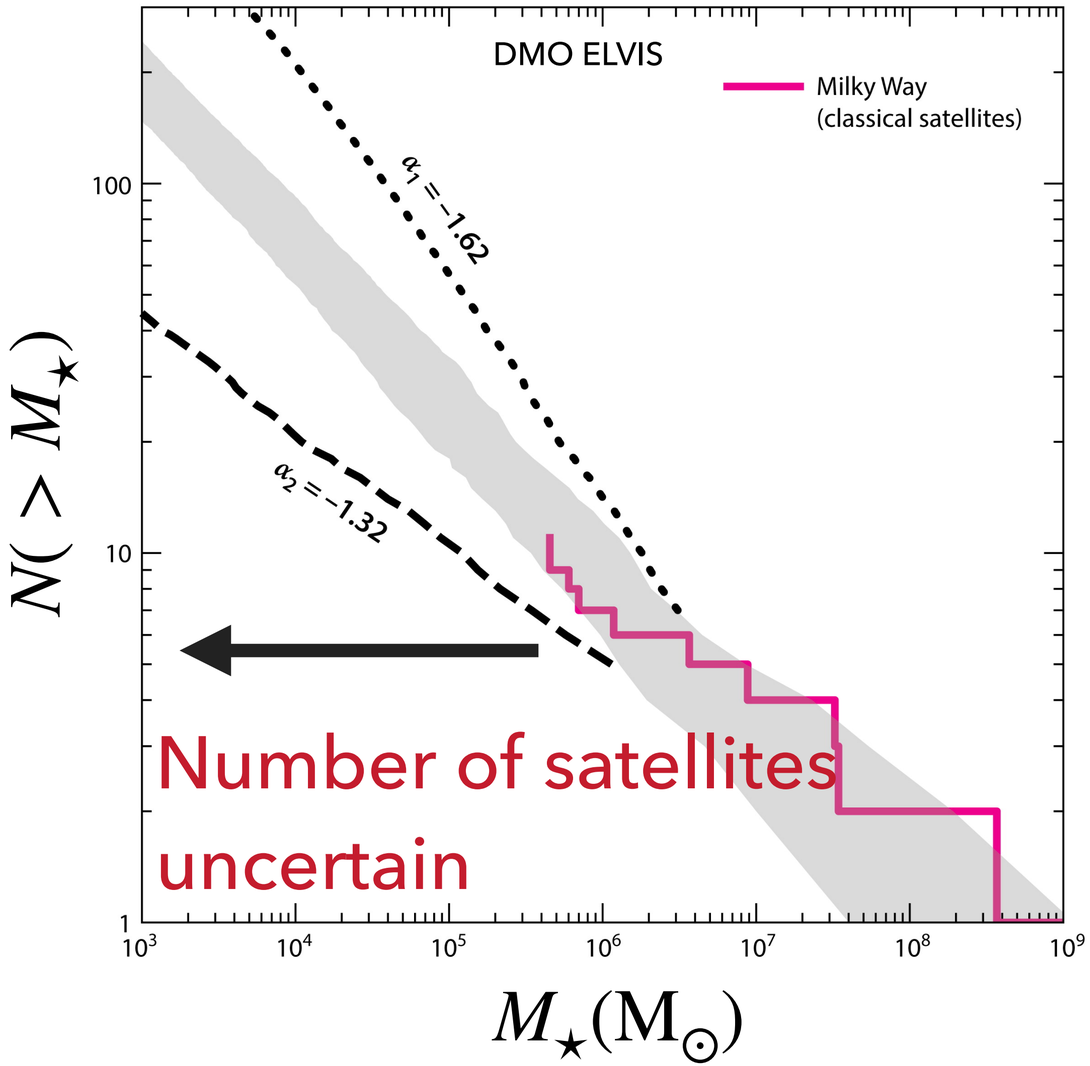

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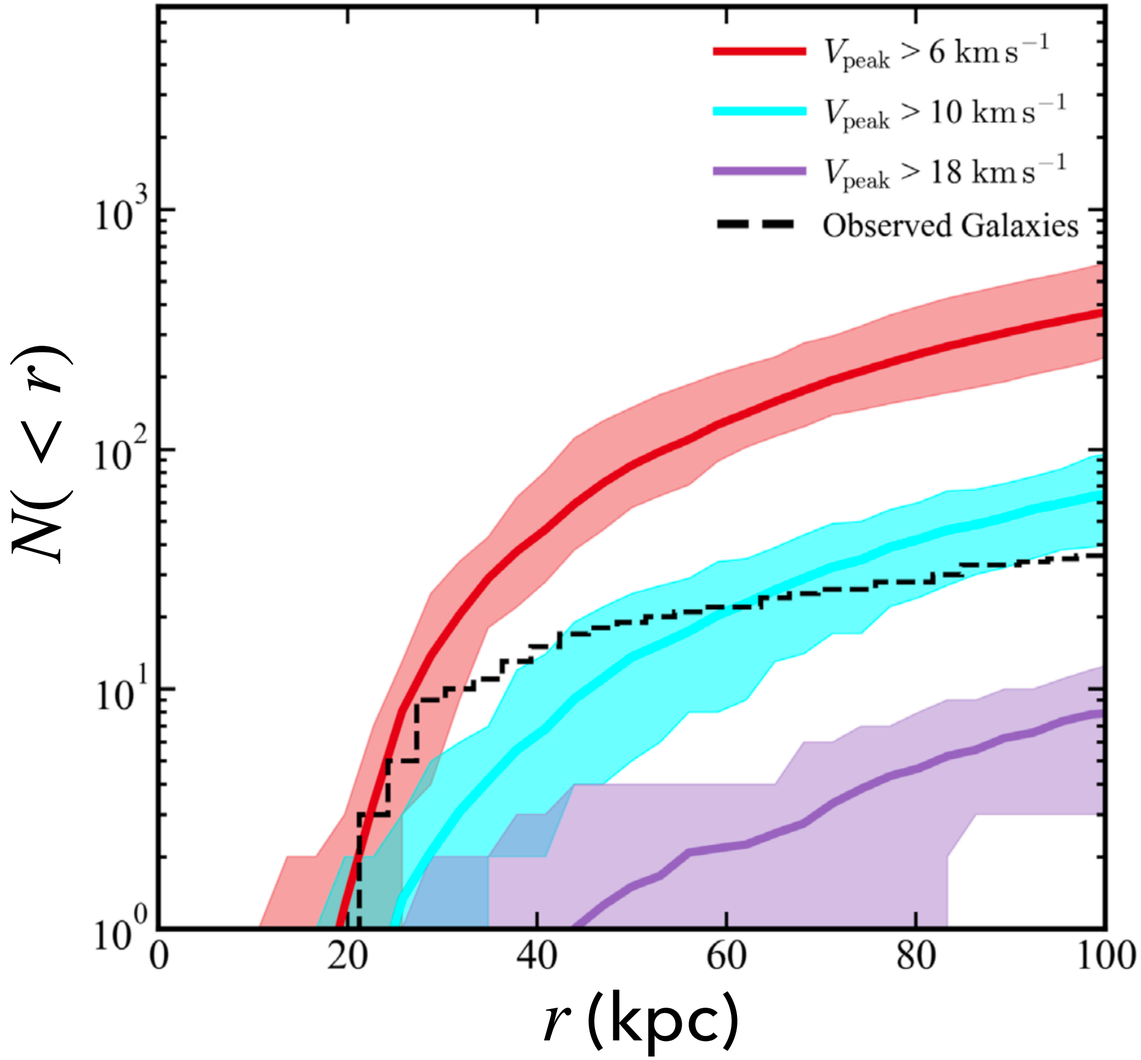

Graus et al. 2019

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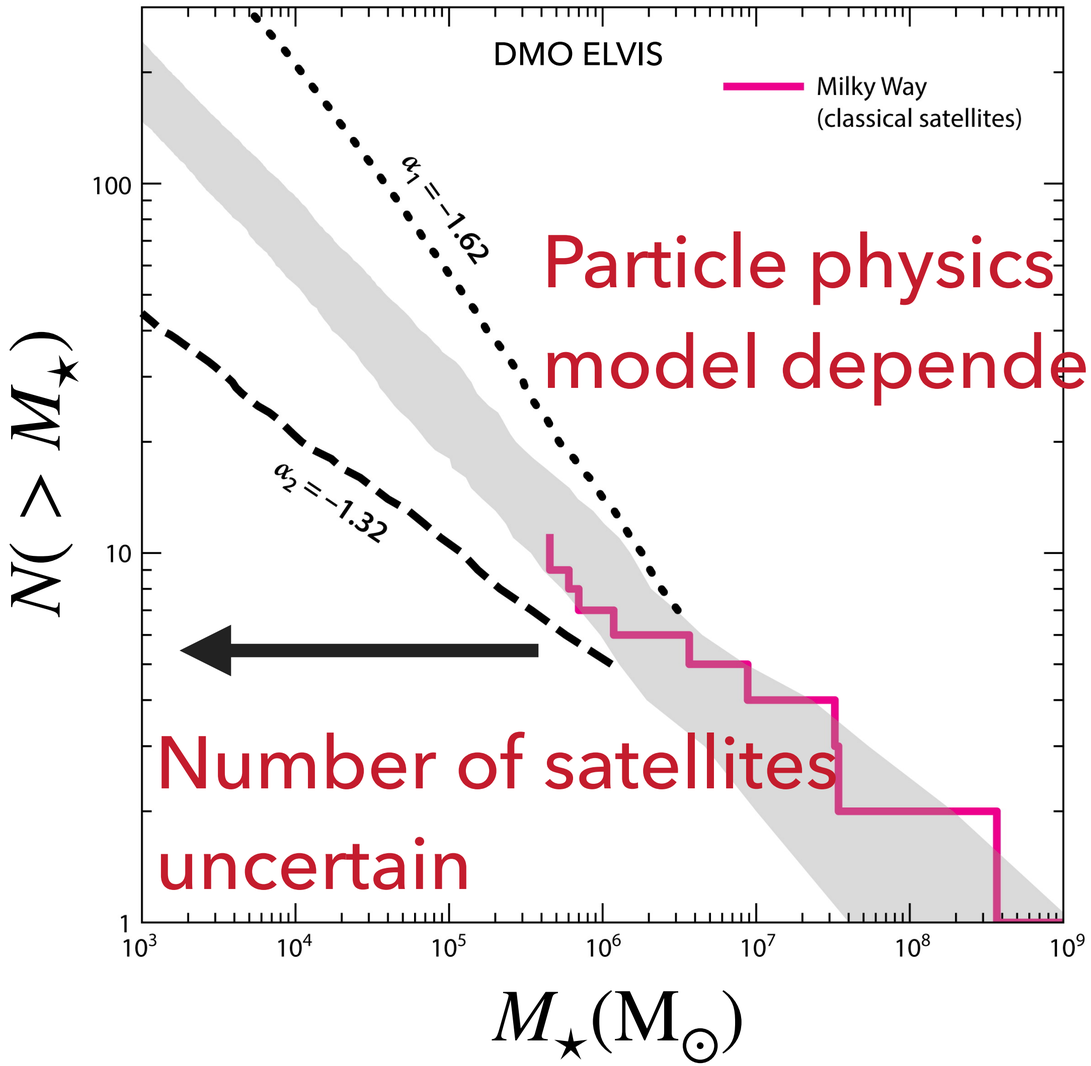
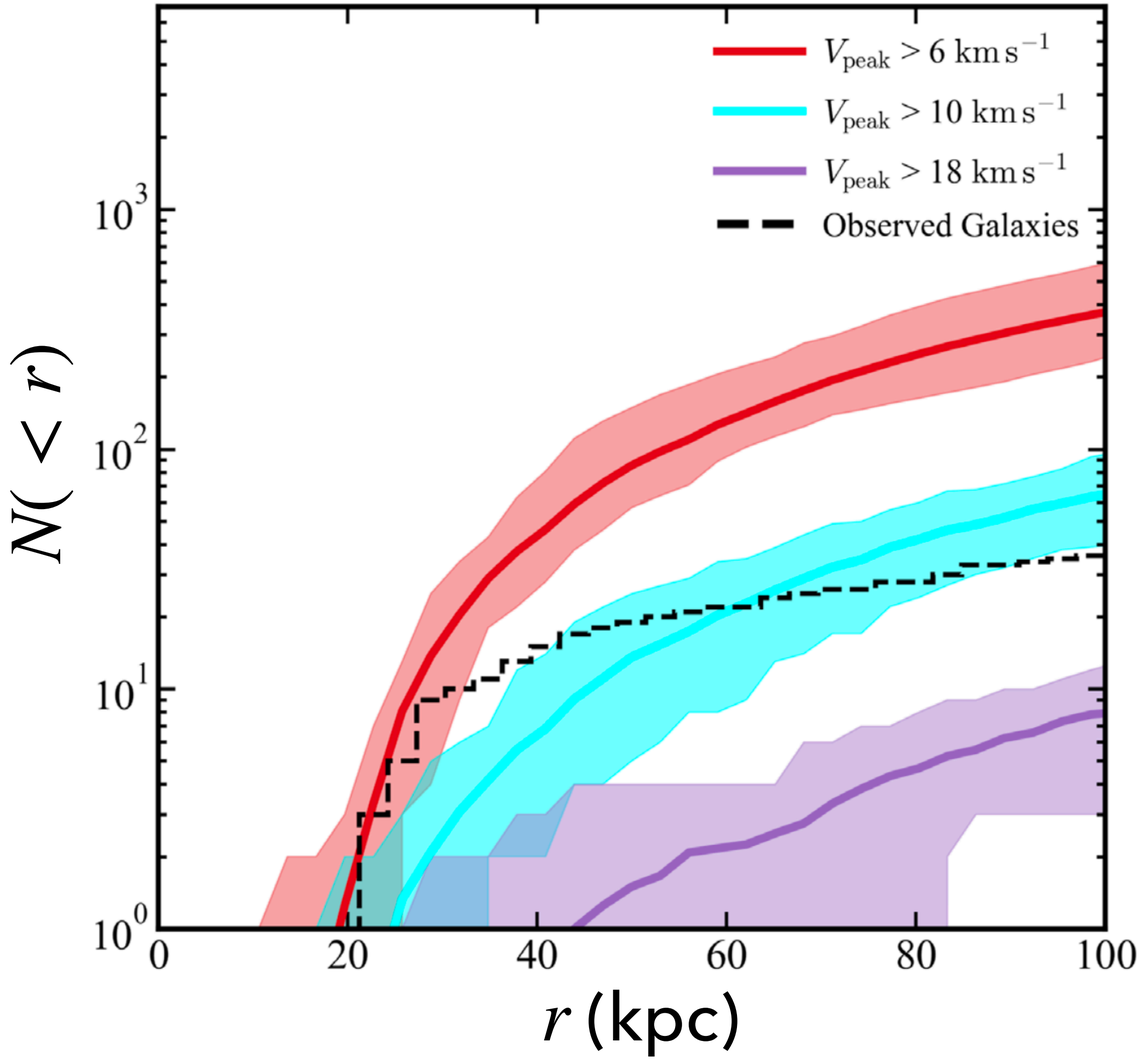


Particle physics model dependent

Number of satellites uncertain

Bullock & Boylan-Kolchin 2017



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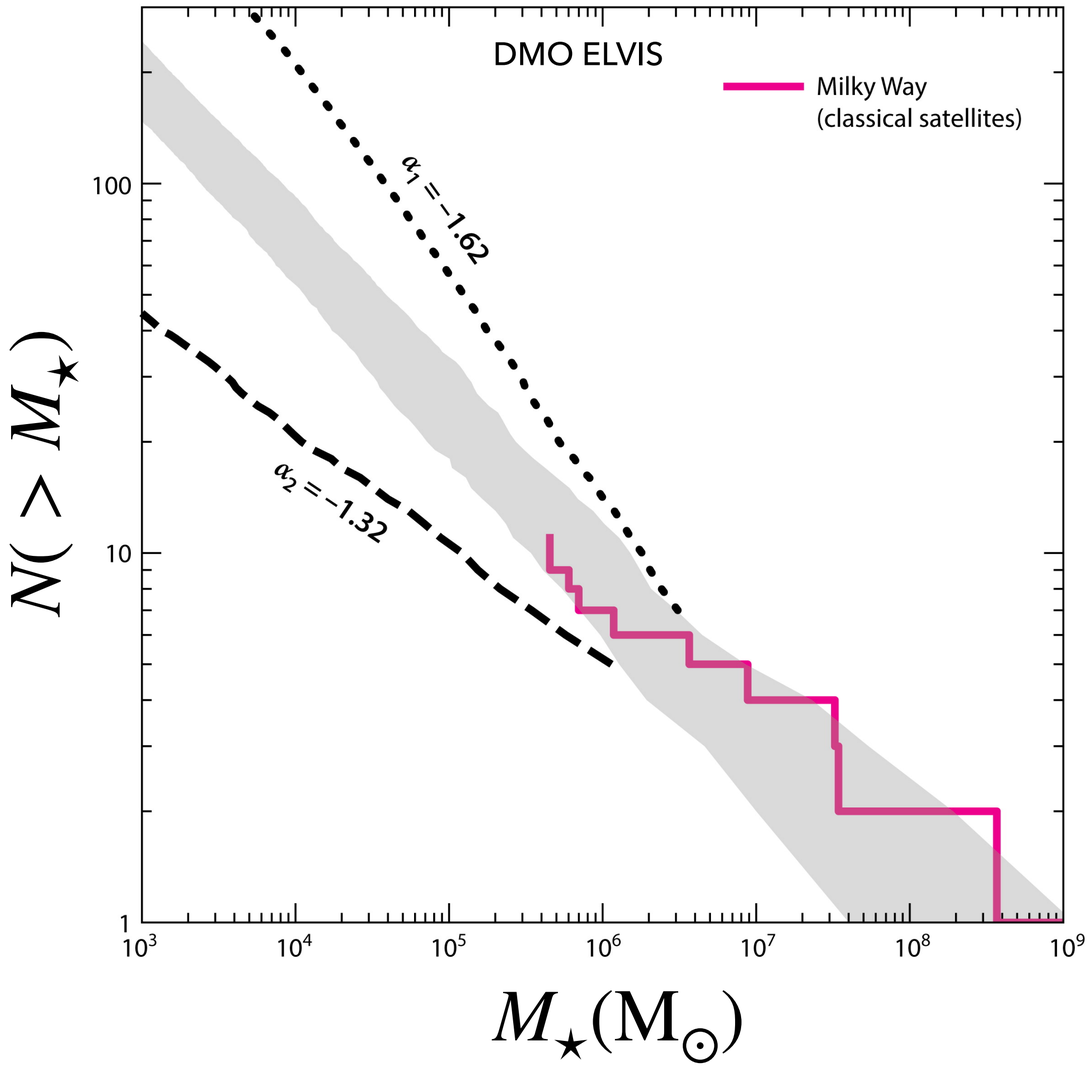
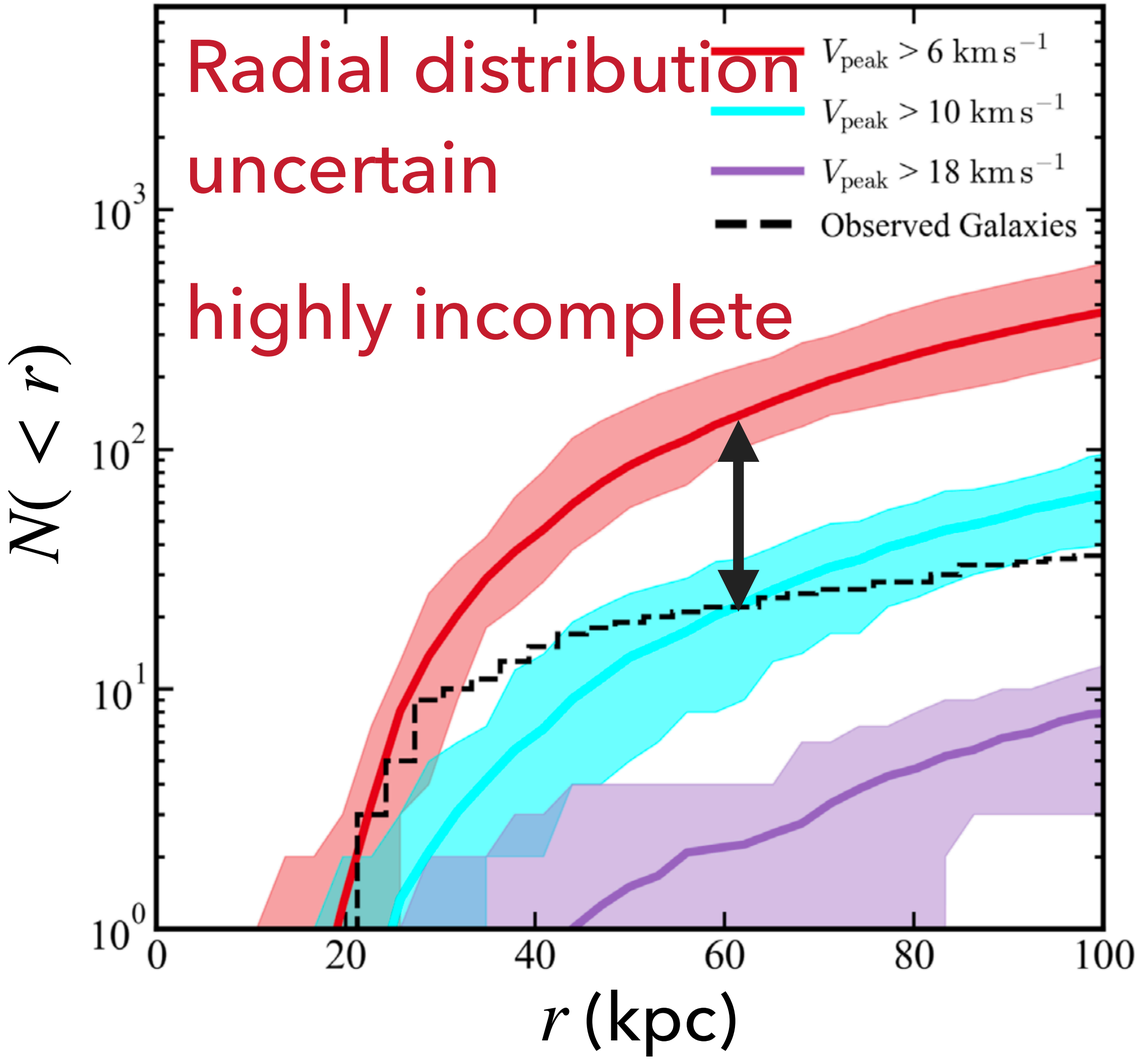


Bullock & Boylan-Kolchin 2017



Graus et al. 2019

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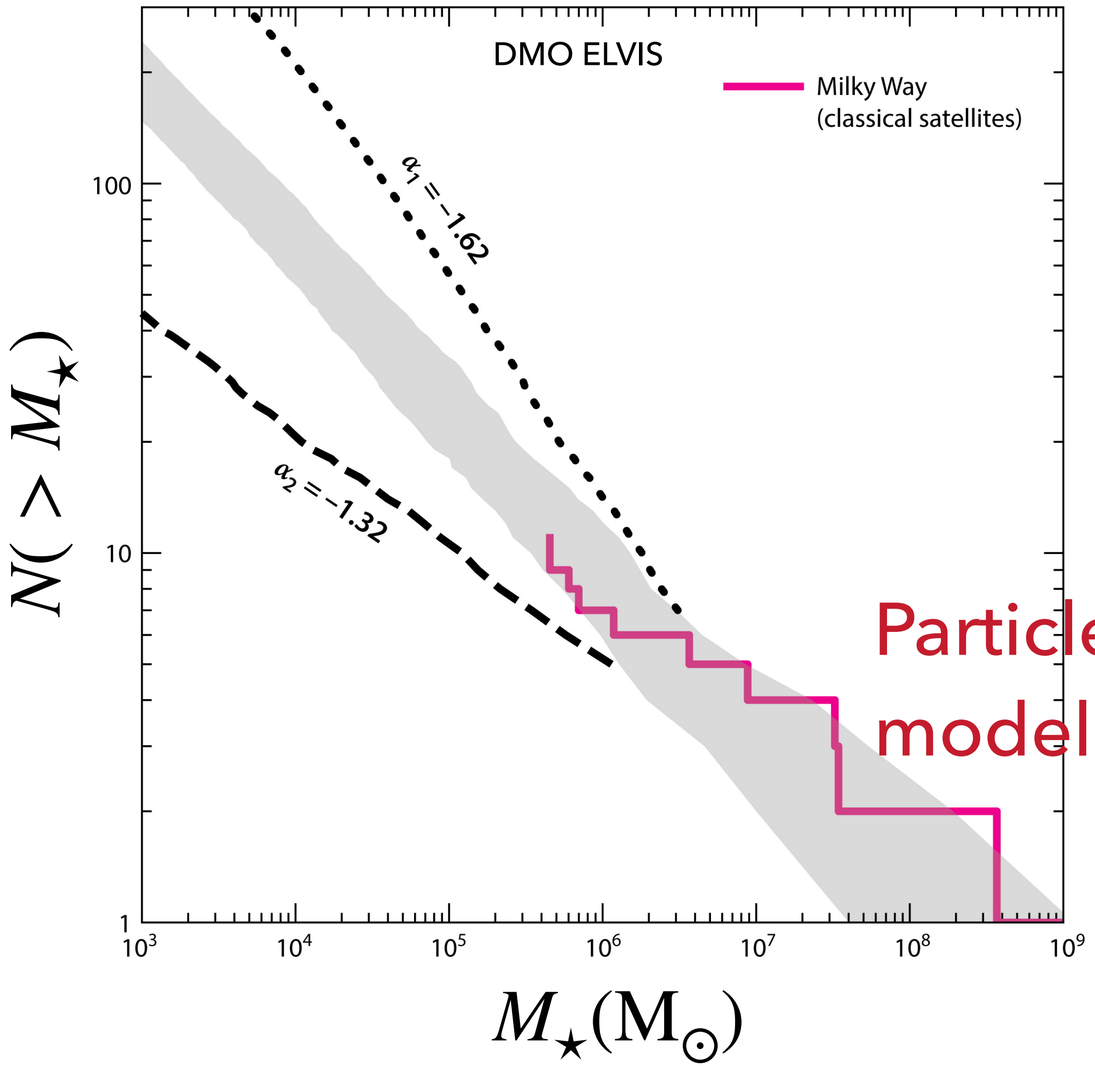
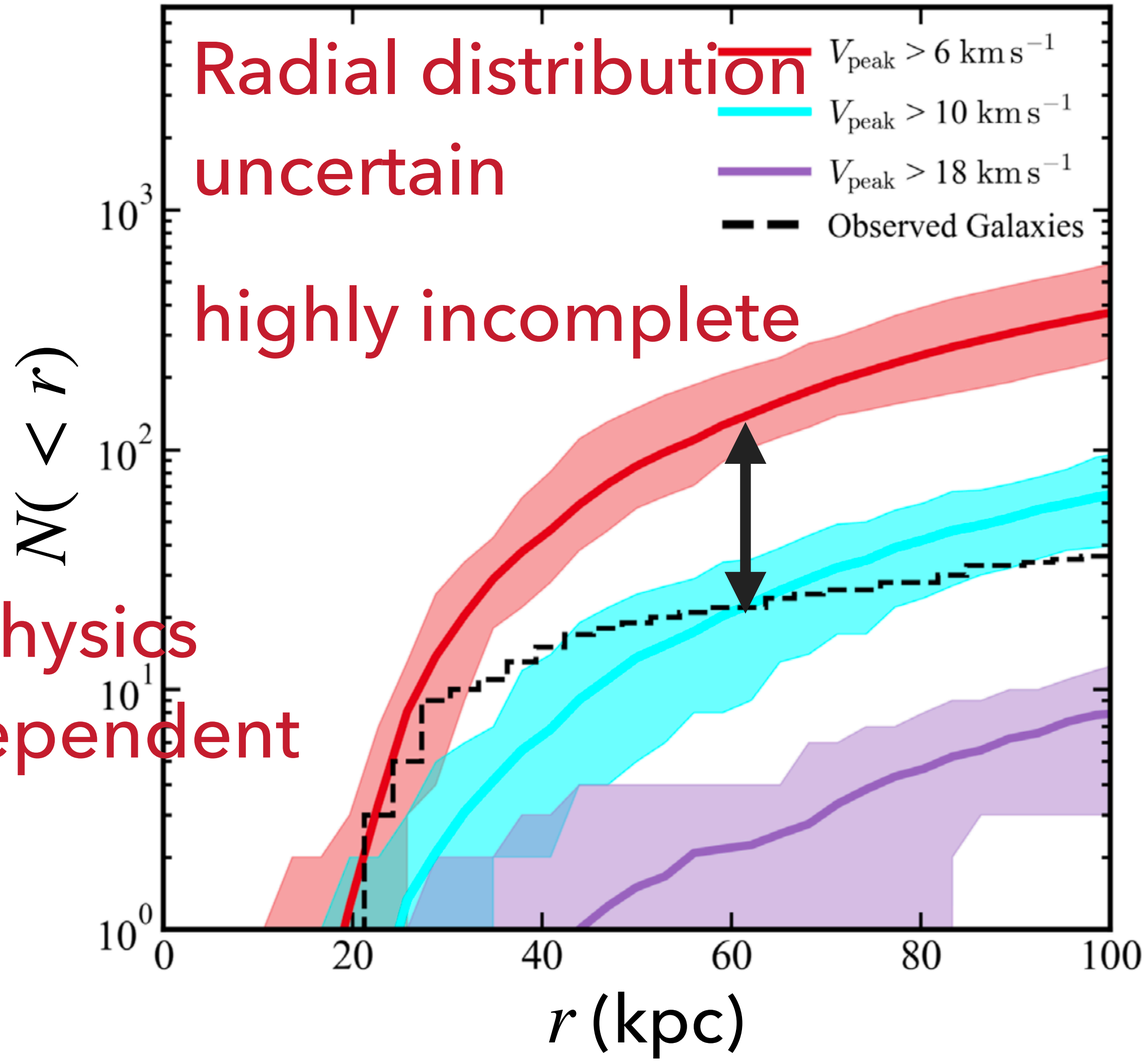


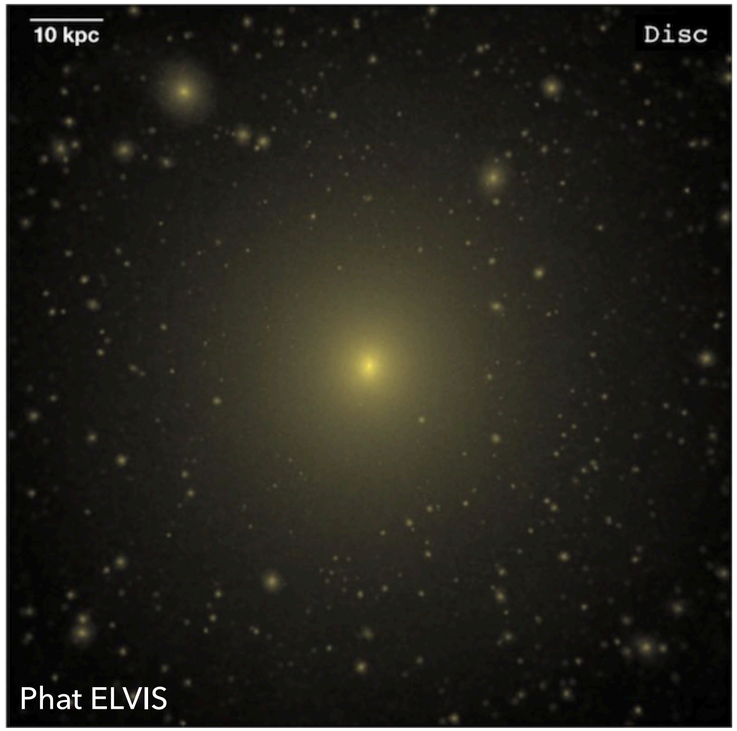
Bullock & Boylan-Kolchin 2017

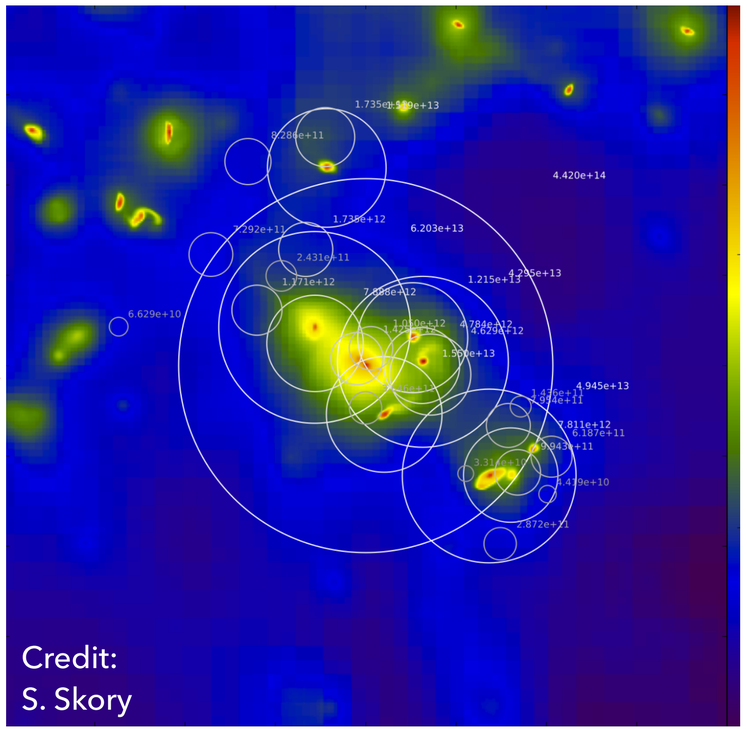
Particle physics
model dependent

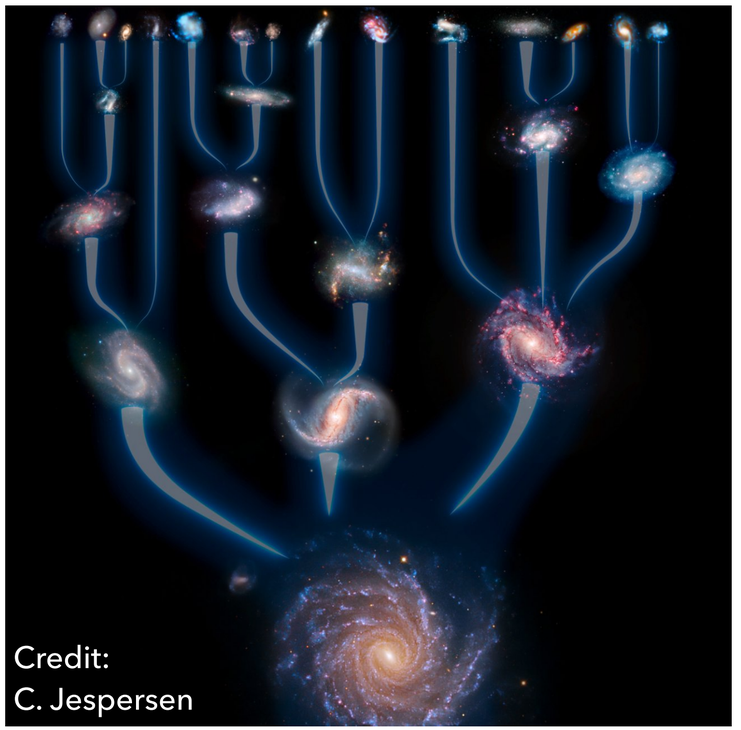


Graus et al. 2019

FLAWED TOOLS





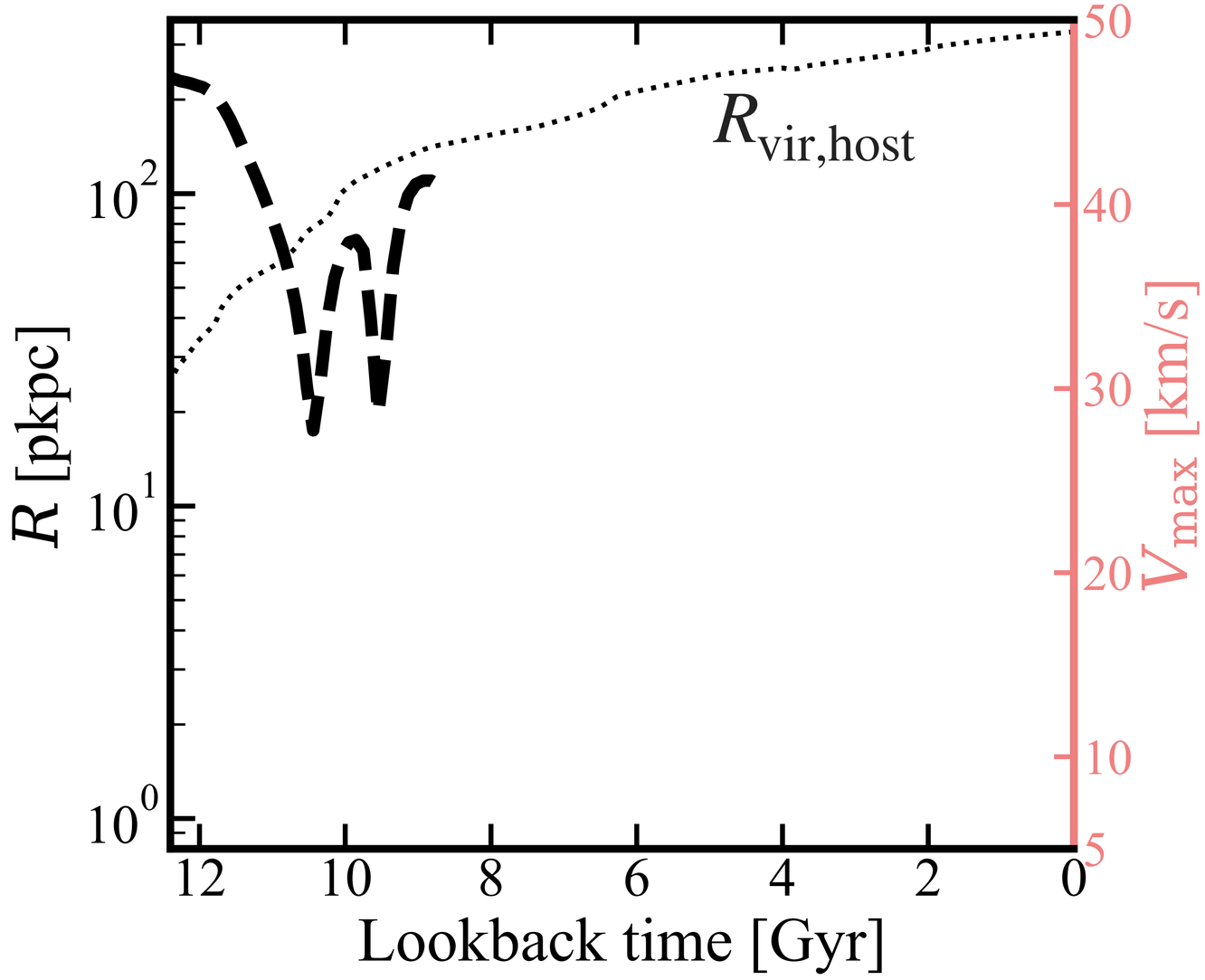


Simulation

Halo finder

Merger tree

MERGER-TREE VS. PARTICLES



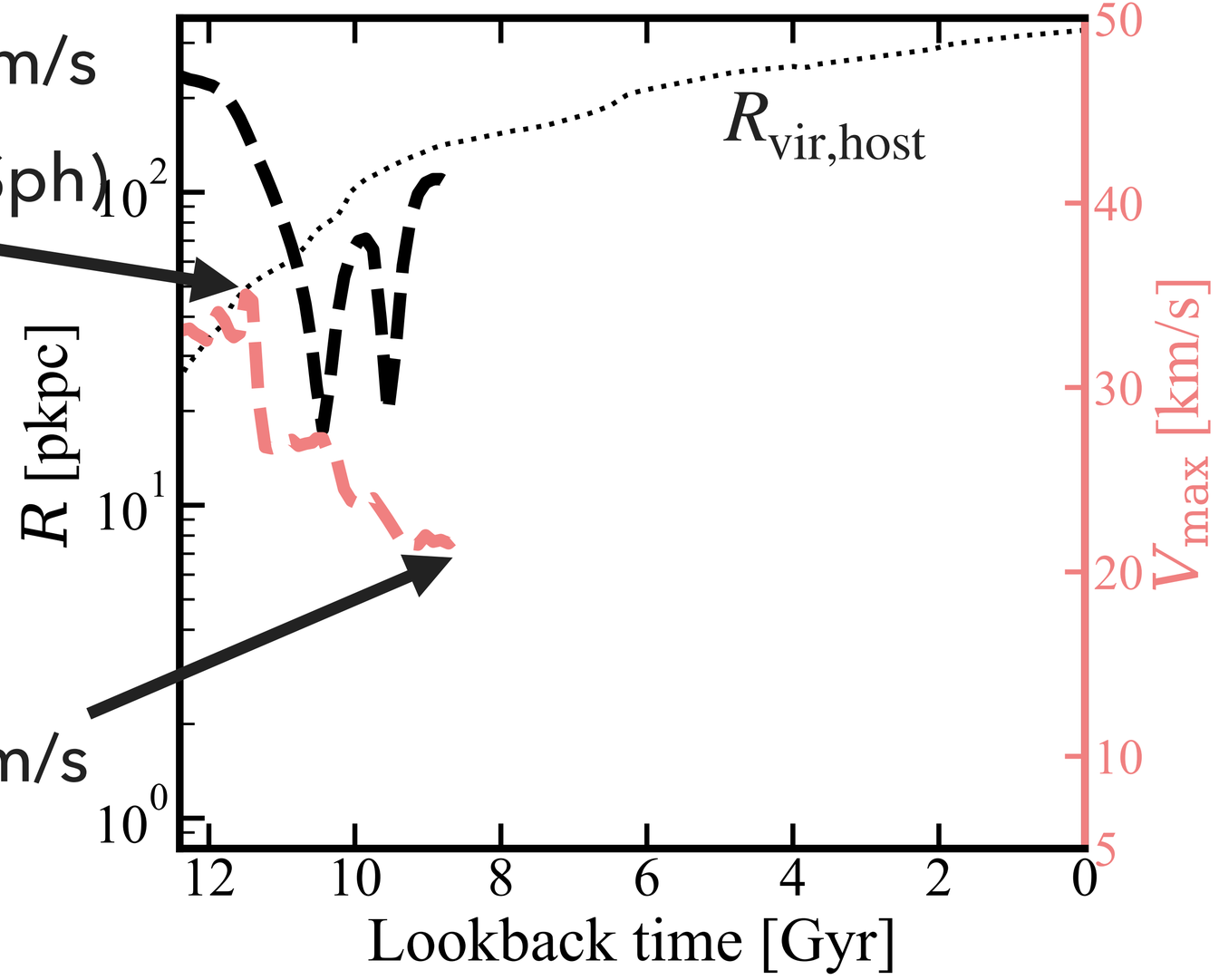
MERGER-TREE VS. PARTICLES

$V_{\rm peak} \sim 35$ km/s

(Classical dSph)

Lost at

$V_{\rm max} = 20$ km/s



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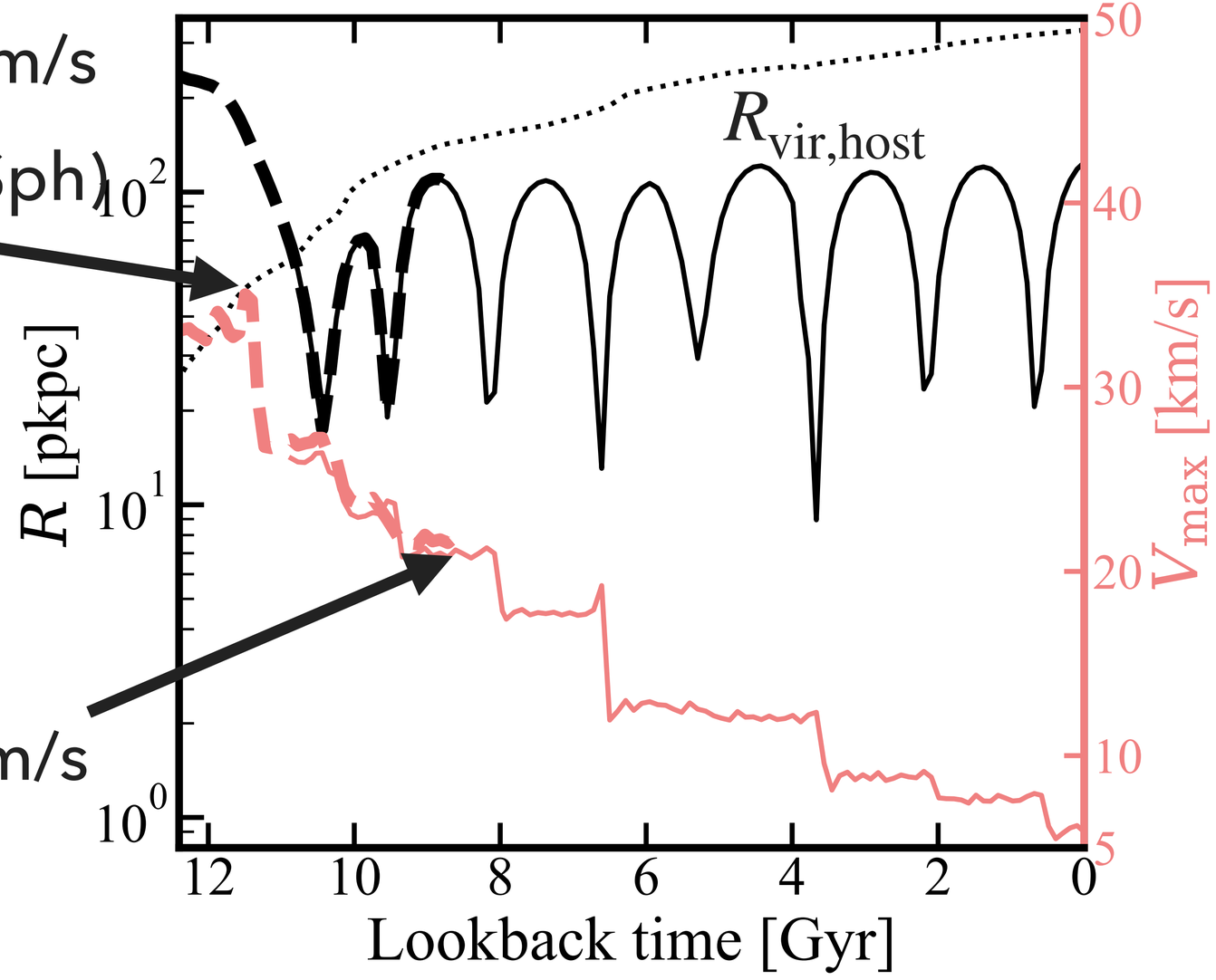
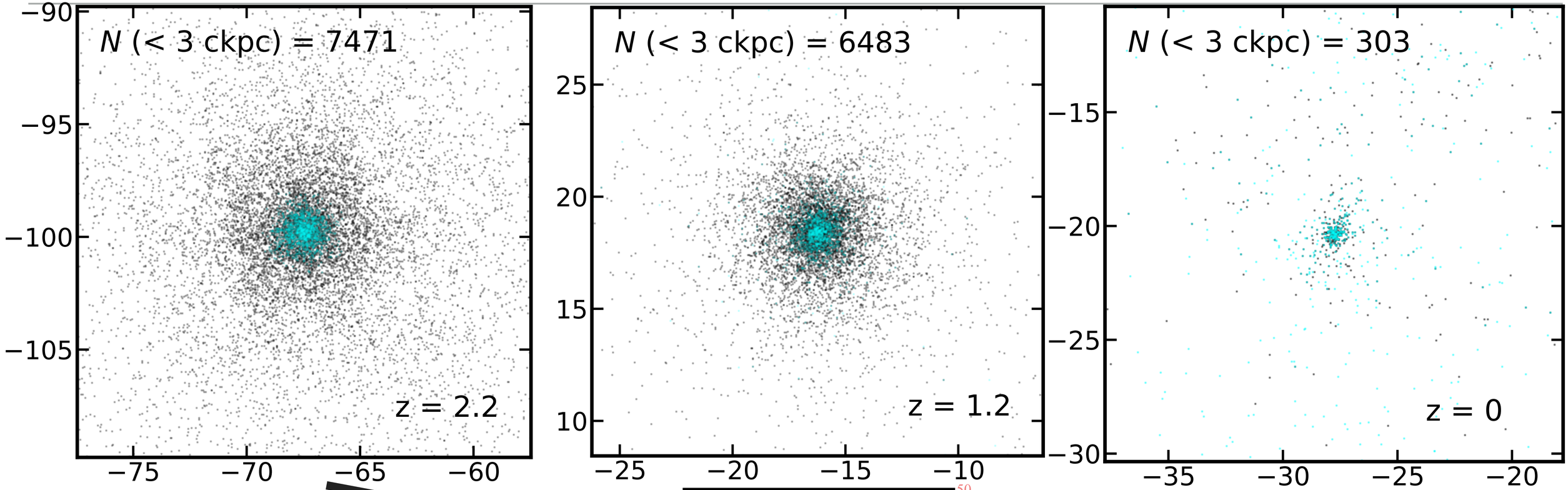


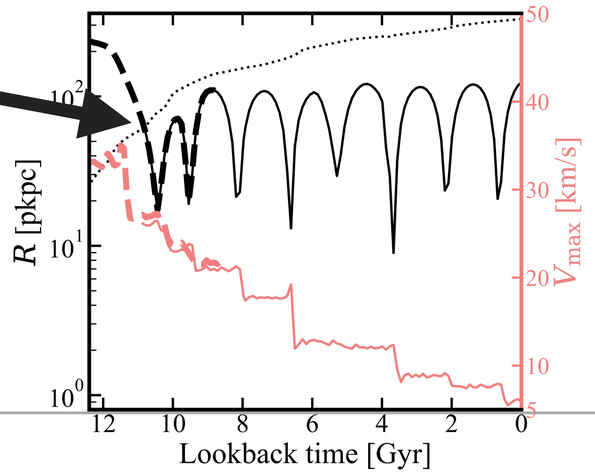
Bloodhound:

- Tracked all the way to z=0
- ~ 9 Gyr longer
- 6 additional pericenters
- $V_{\rm max} = 5$ km/s

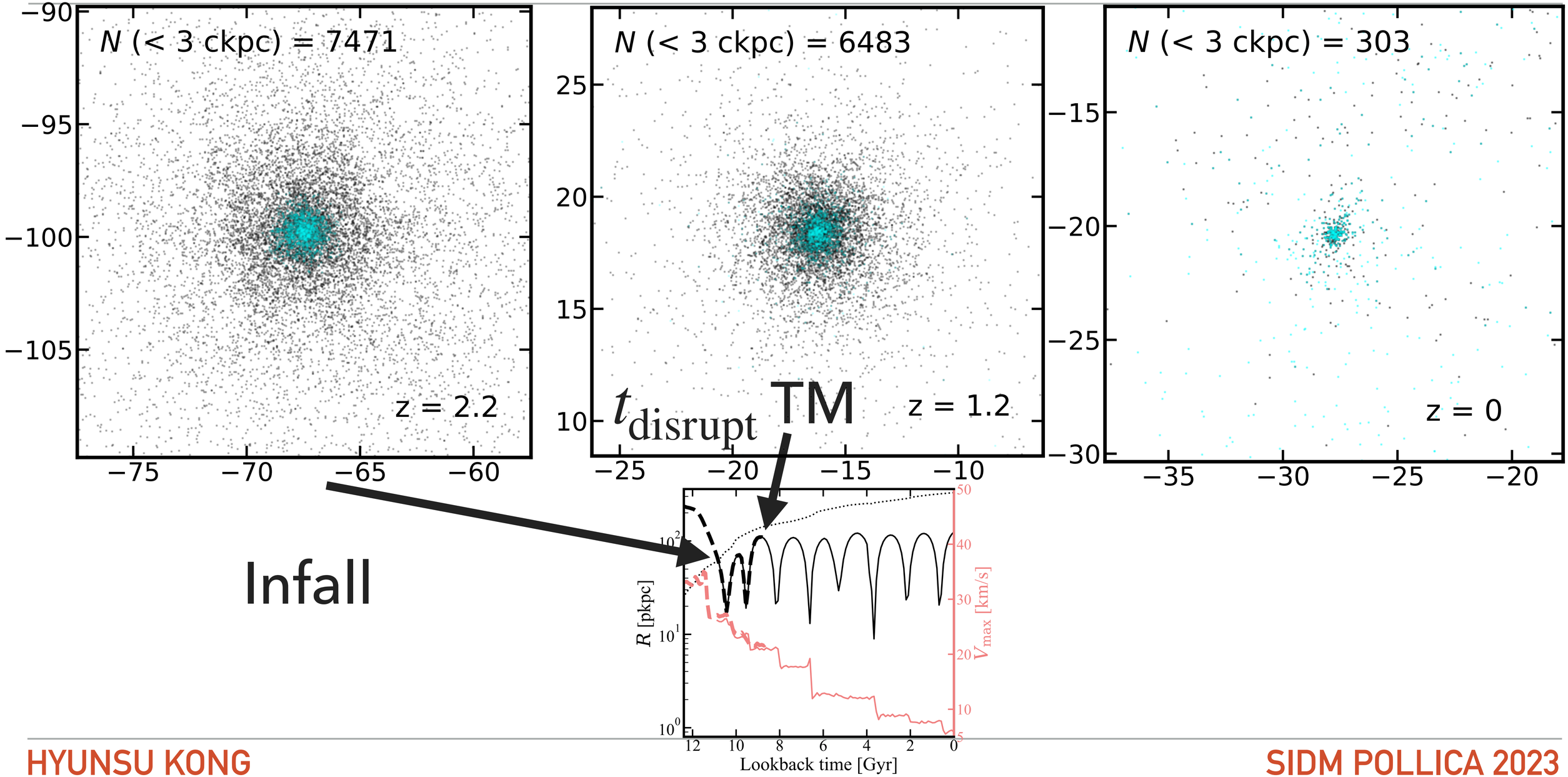
BLOODHOUND



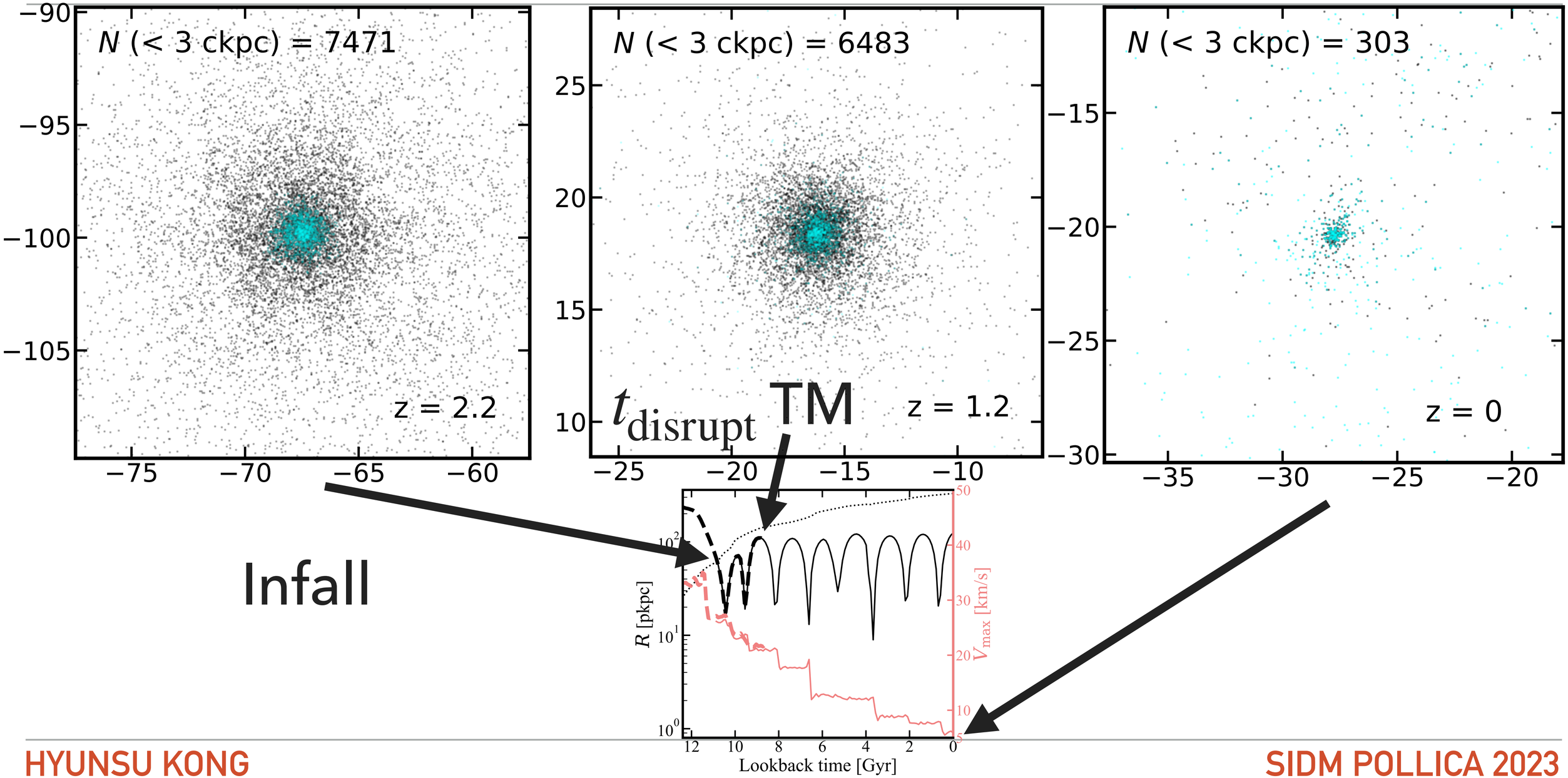
Infall



BLOODHOUND


N (< 3 ckpc) = 7471
z = 2.2
N (< 3 ckpc) = 6483
z = 1.2
N (< 3 ckpc) = 303
z = 0
$t_{\rm disrupt}$
TM
Infall
R [pkpc]
$V_{\rm max}$ [km/s]
Lookback time [Gyr]

BLOODHOUND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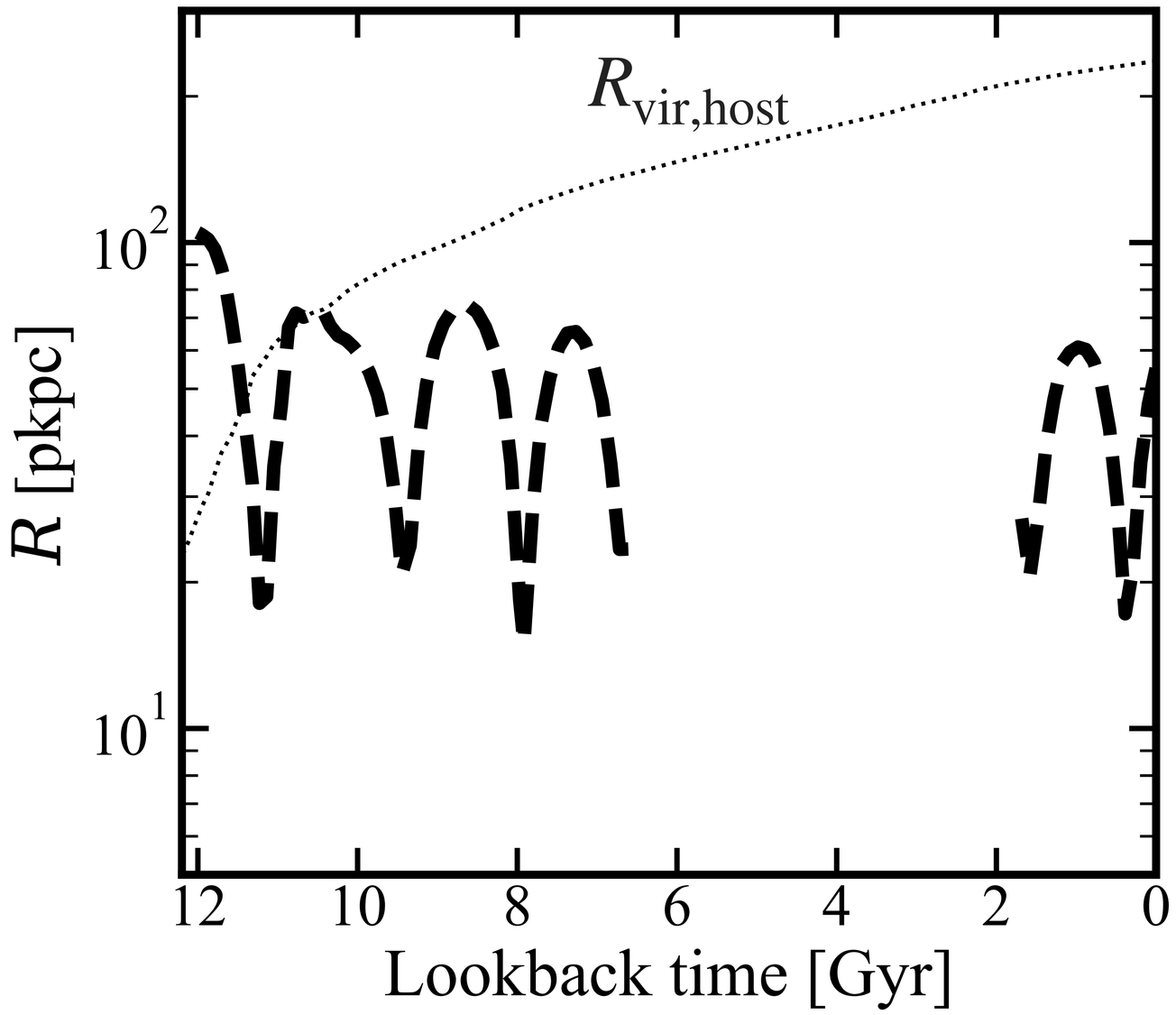
MISSING-LINK TREES



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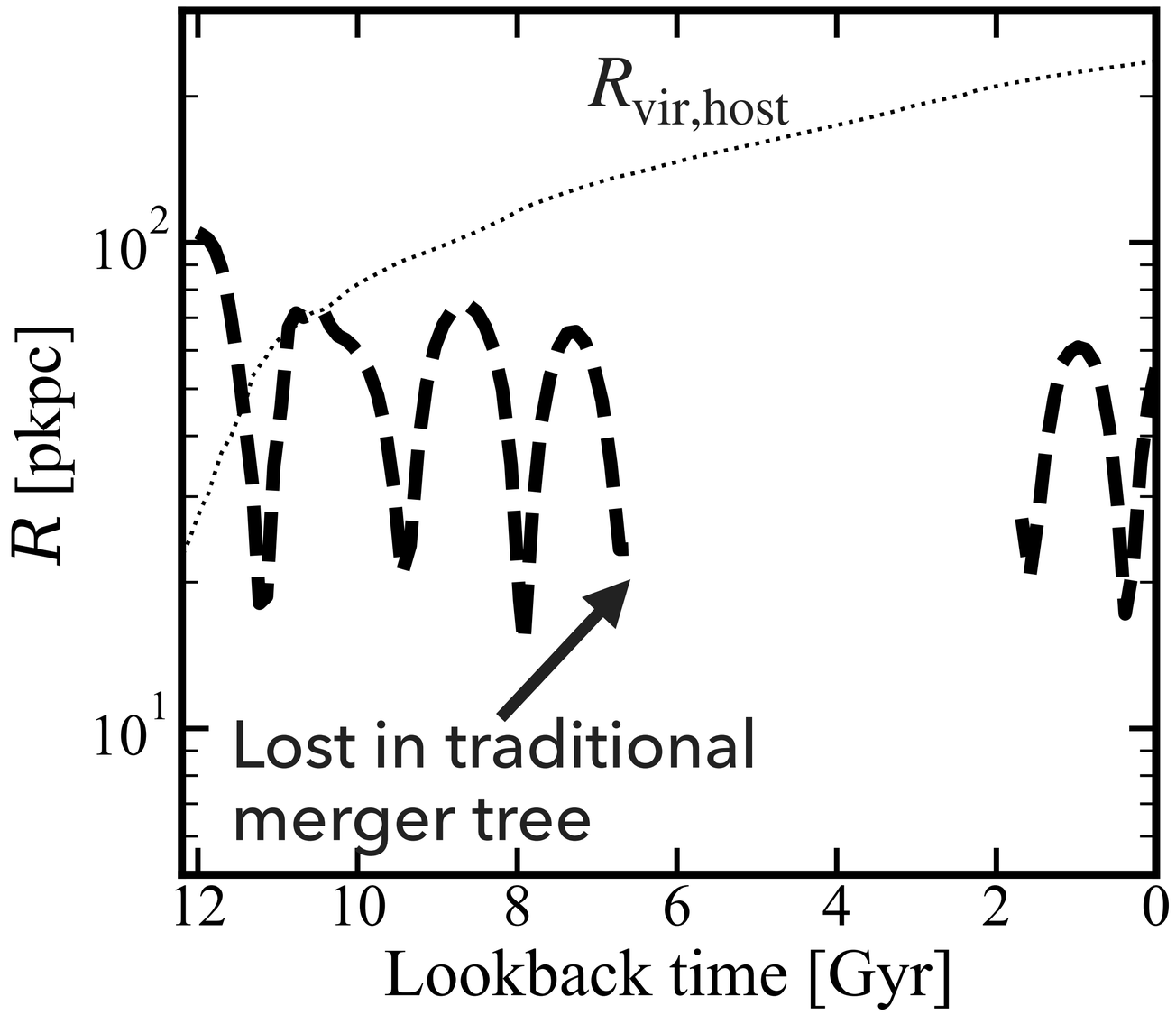

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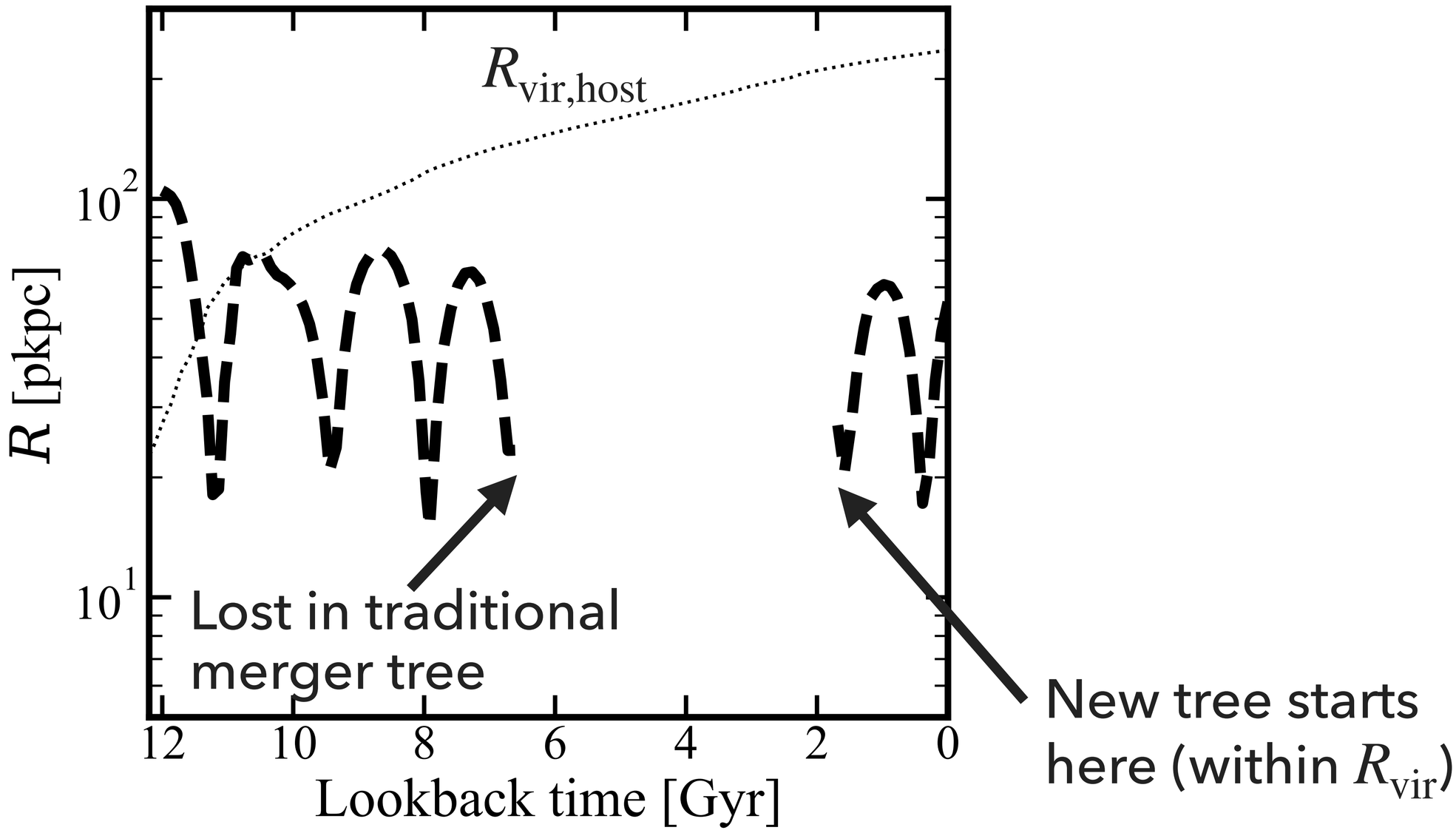

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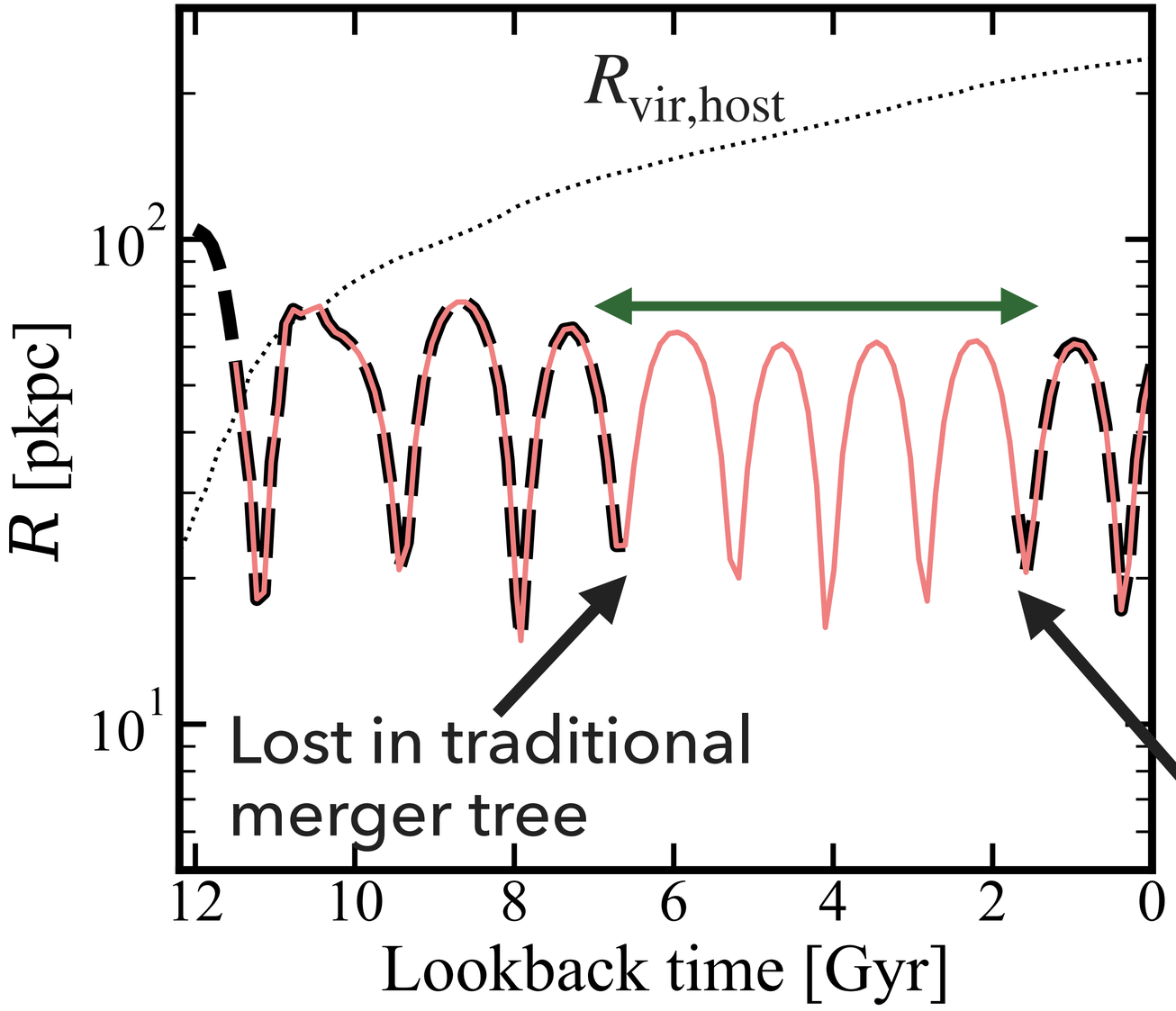
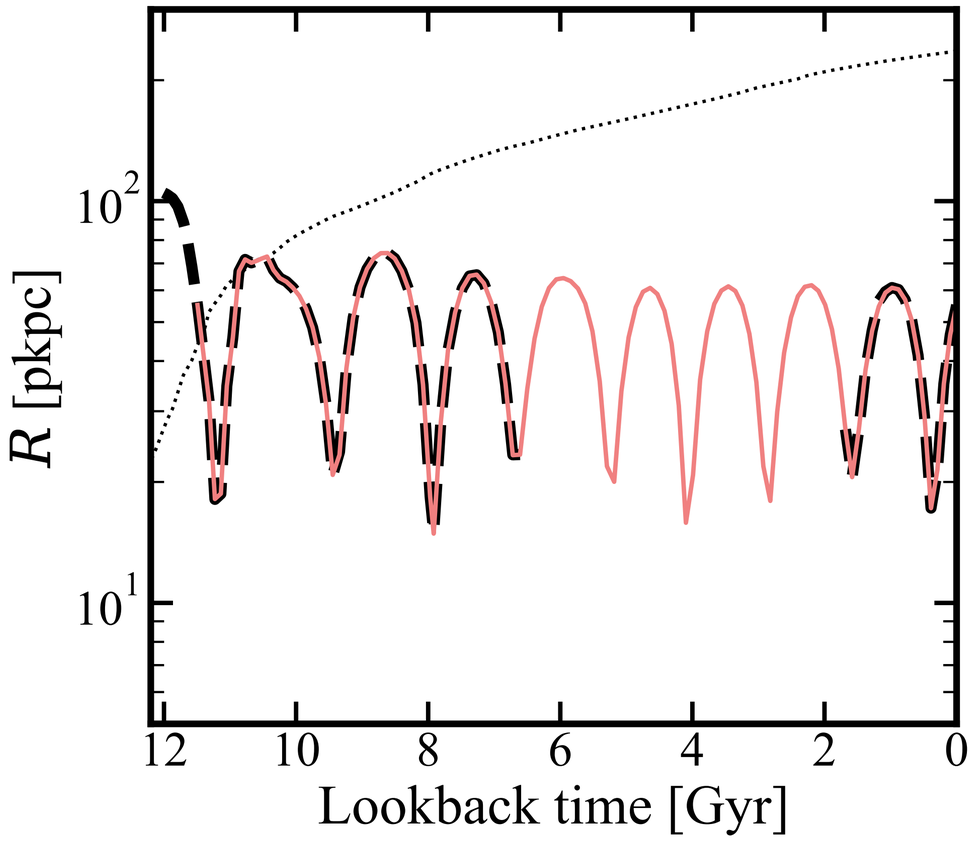
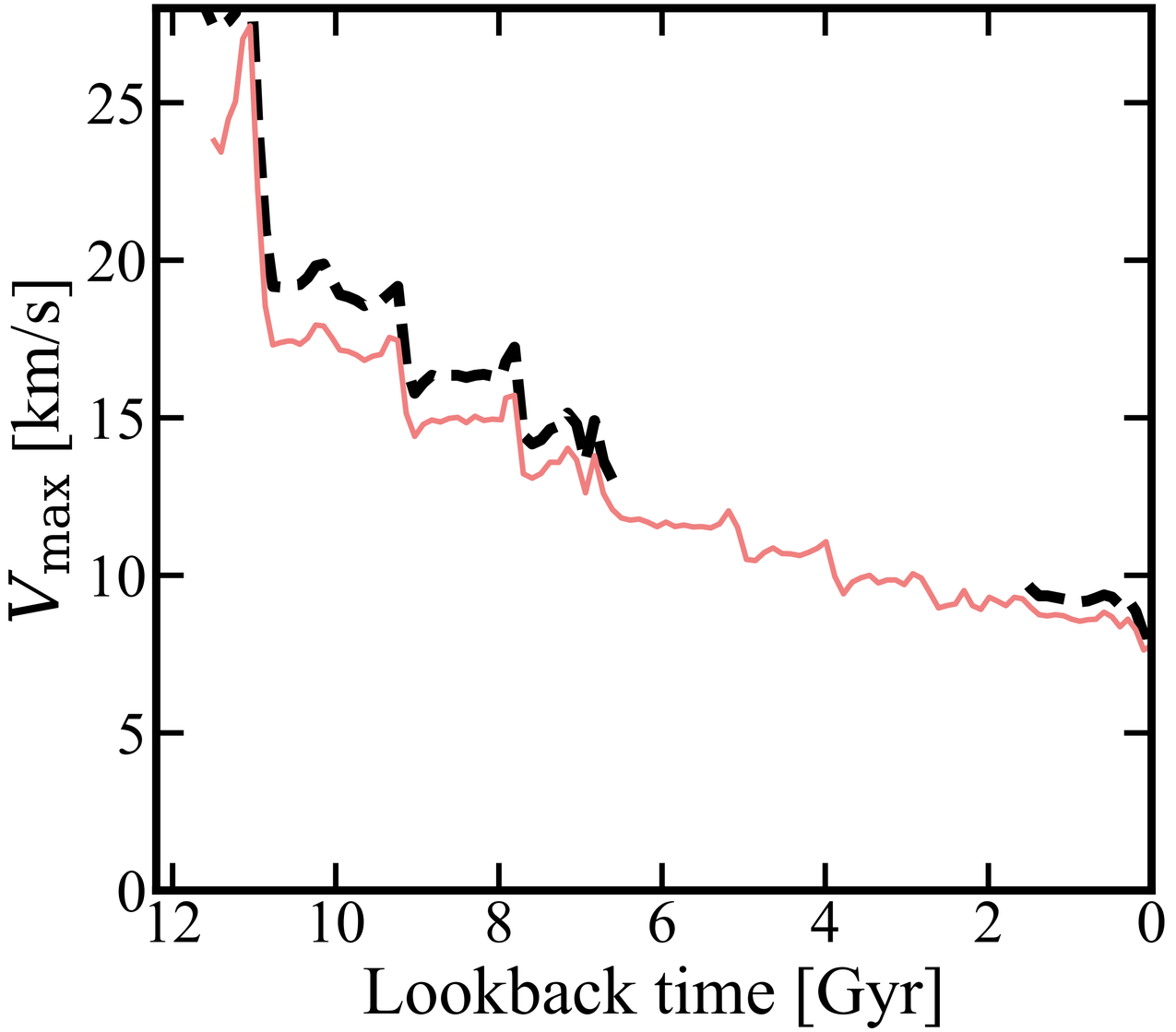


Bloodhound continuously tracks it as 1 halo, never lost

New tree starts here (within $R_{\rm vir}$)

MISSING-LINK TREES





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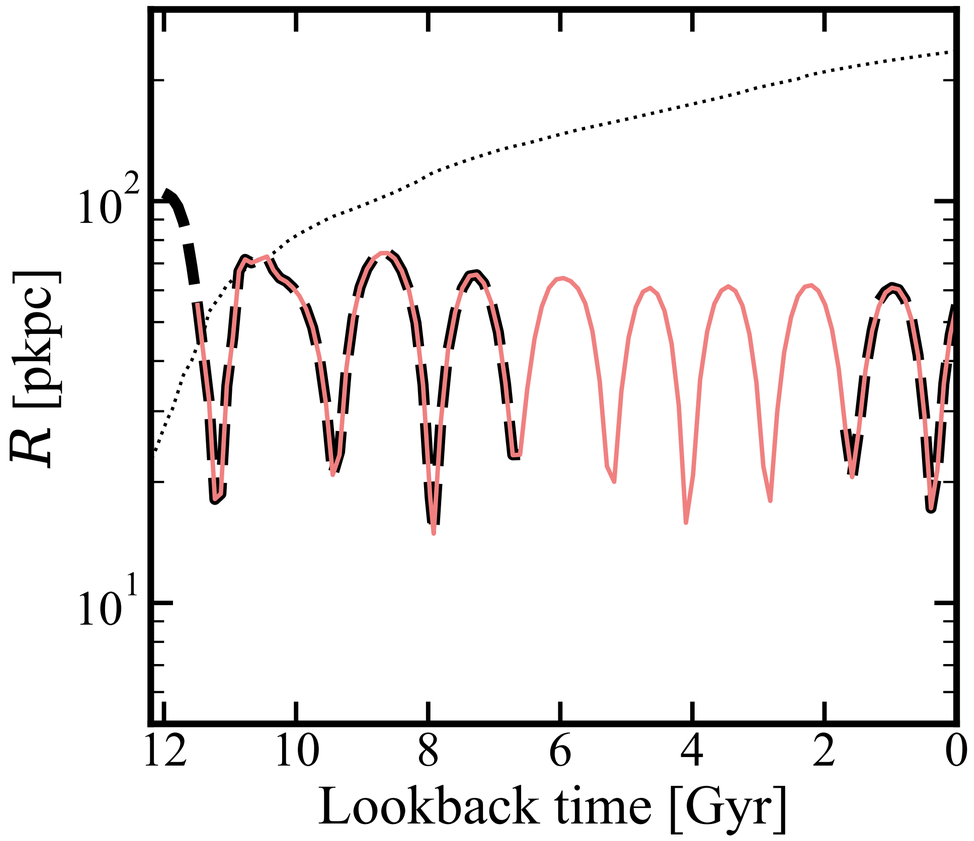
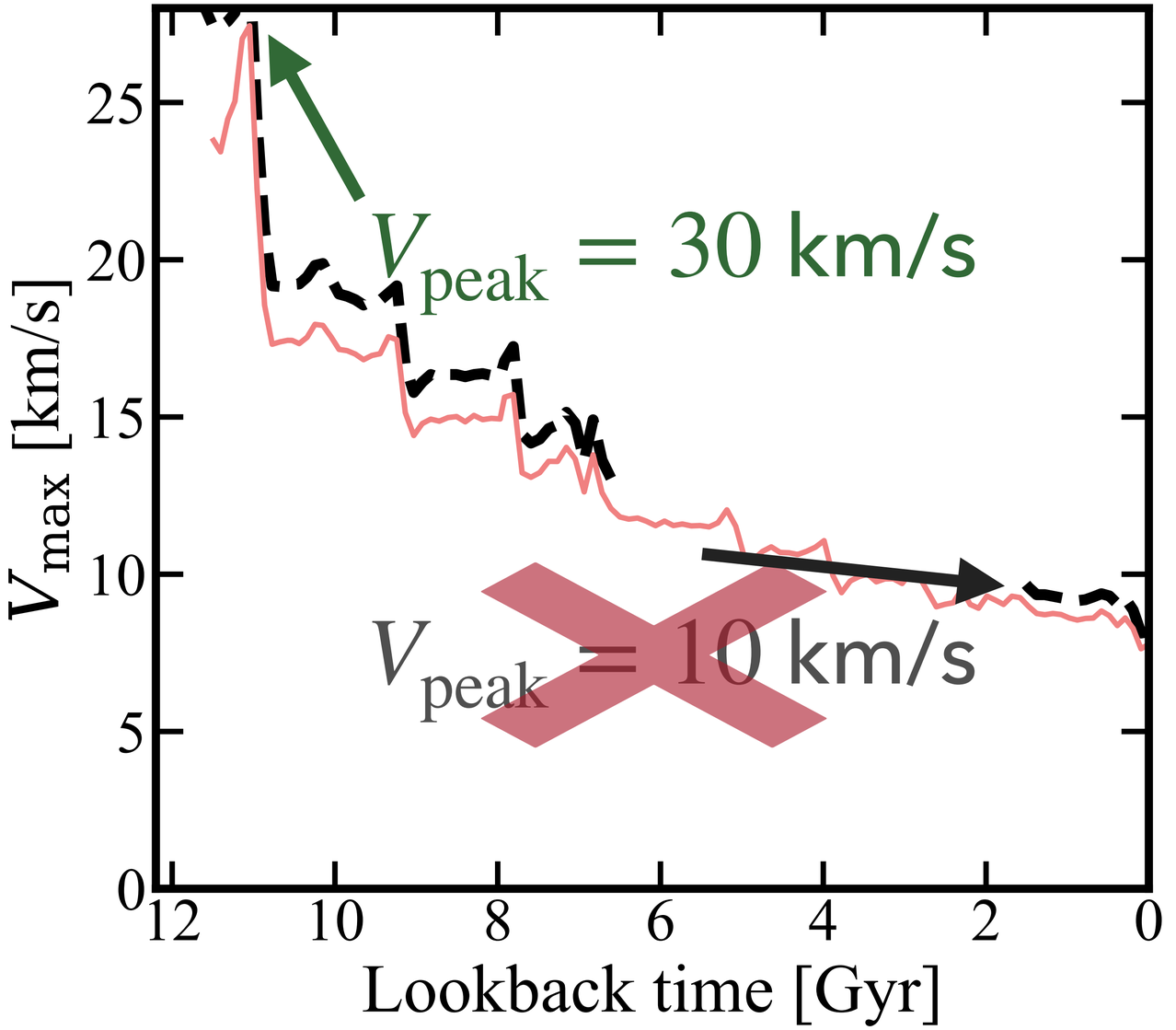
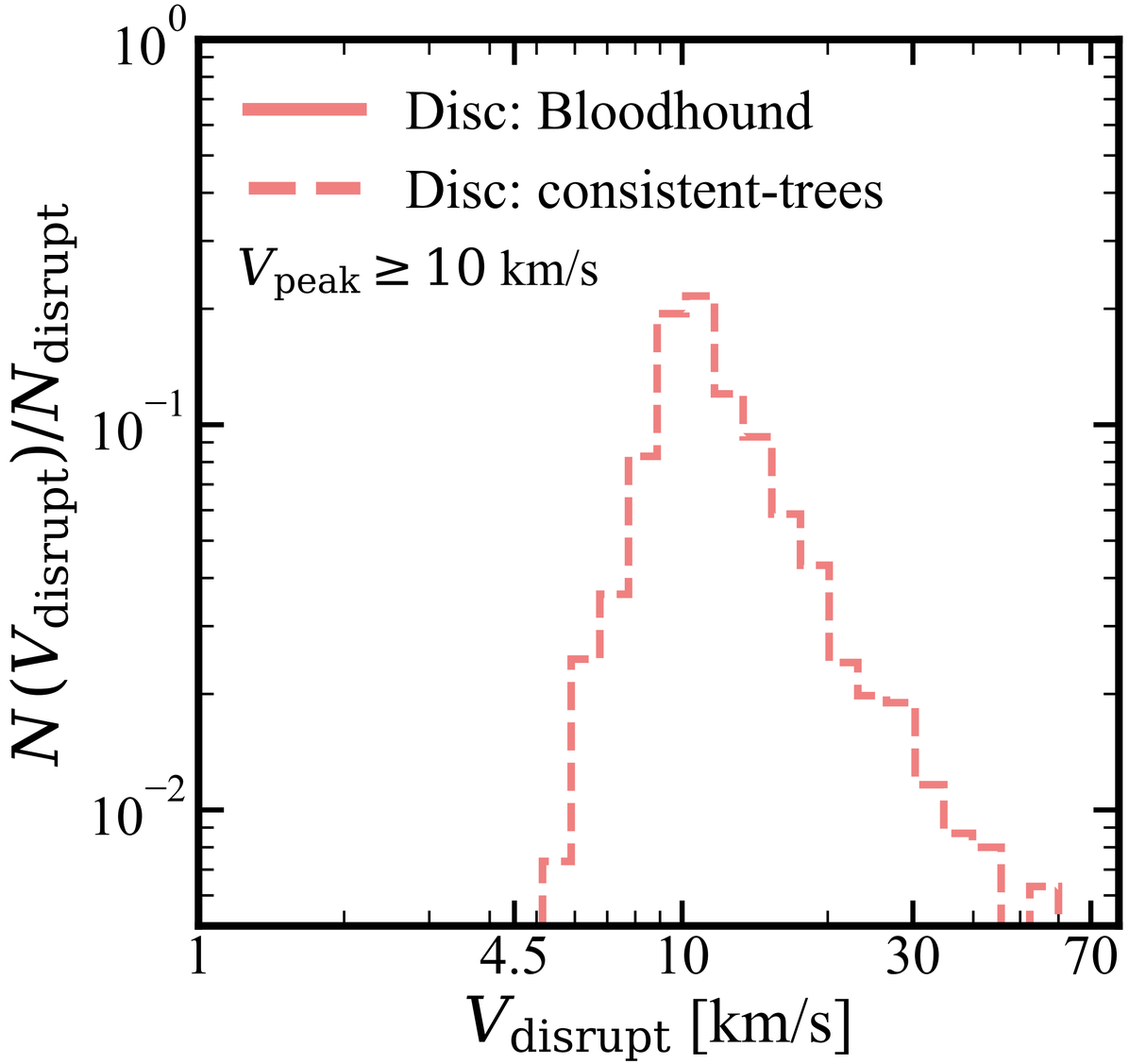




SUBHALO TRACKING IMPROVEMENTS



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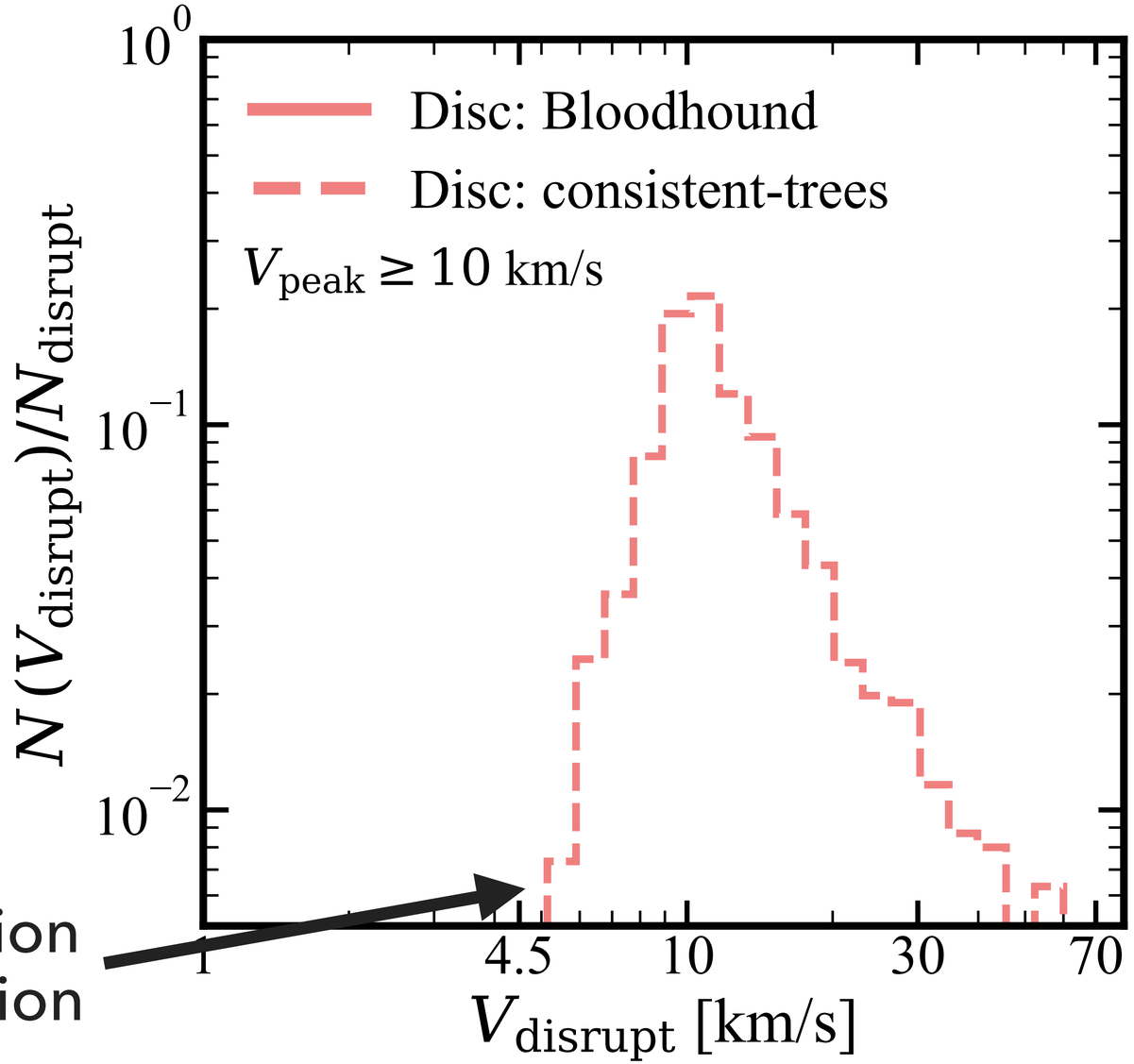
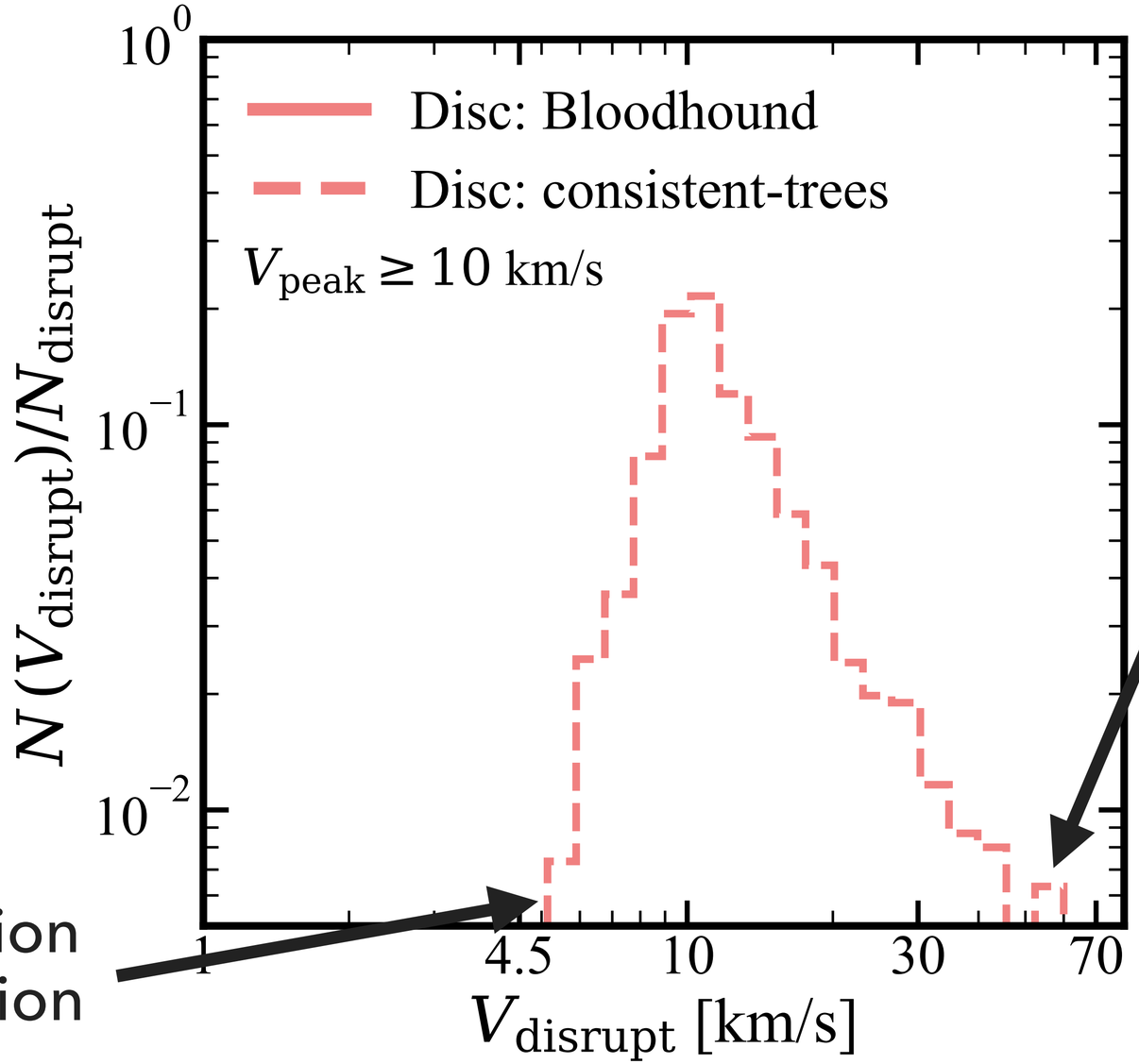


All above simulation halo mass resolution

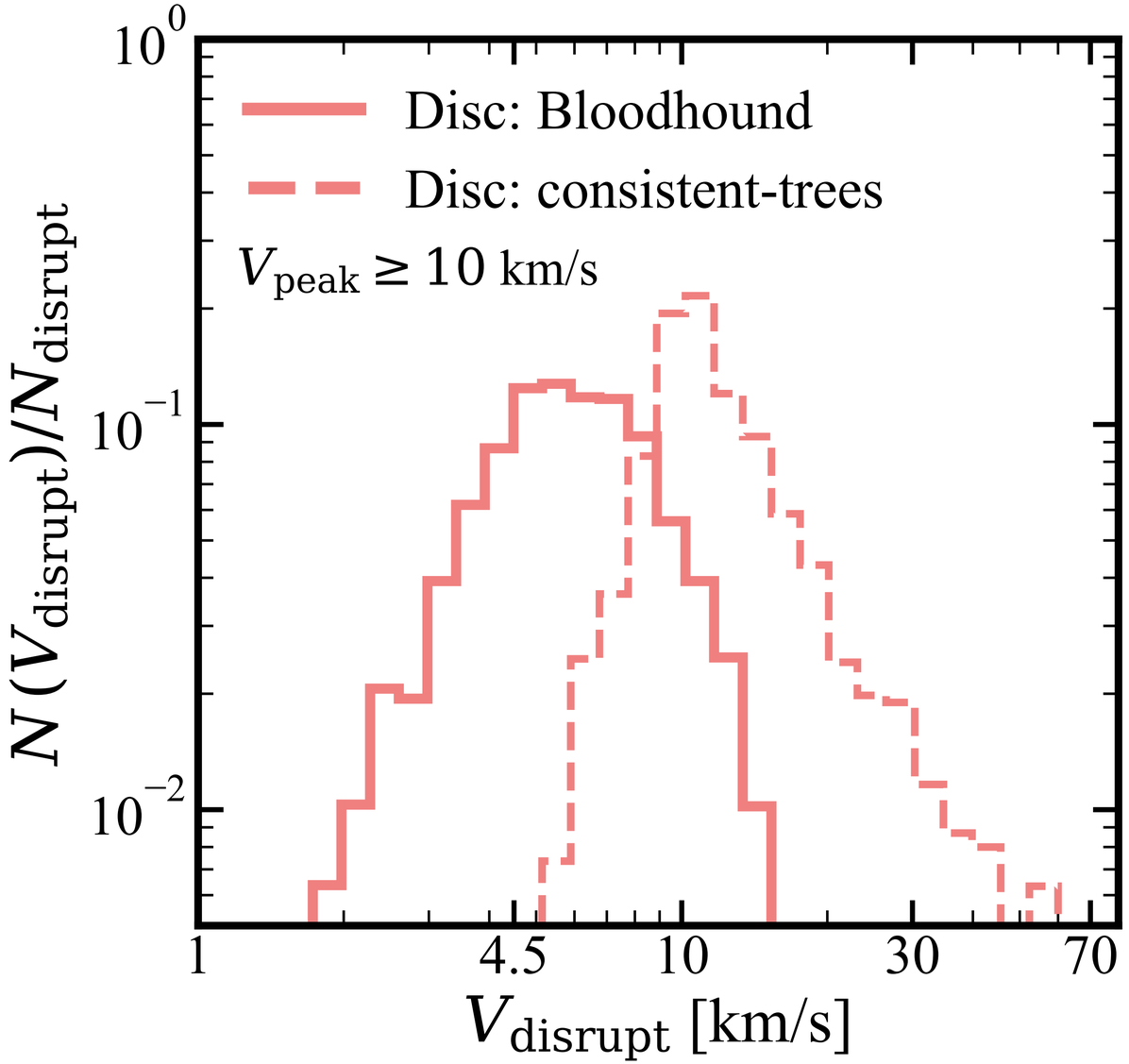
SUBHALO TRACKING IMPROVEMENTS



"Disruption" at very large (LMC) masses

All above simulation halo mass resolution

SUBHALO TRACKING IMPROVEMENTS



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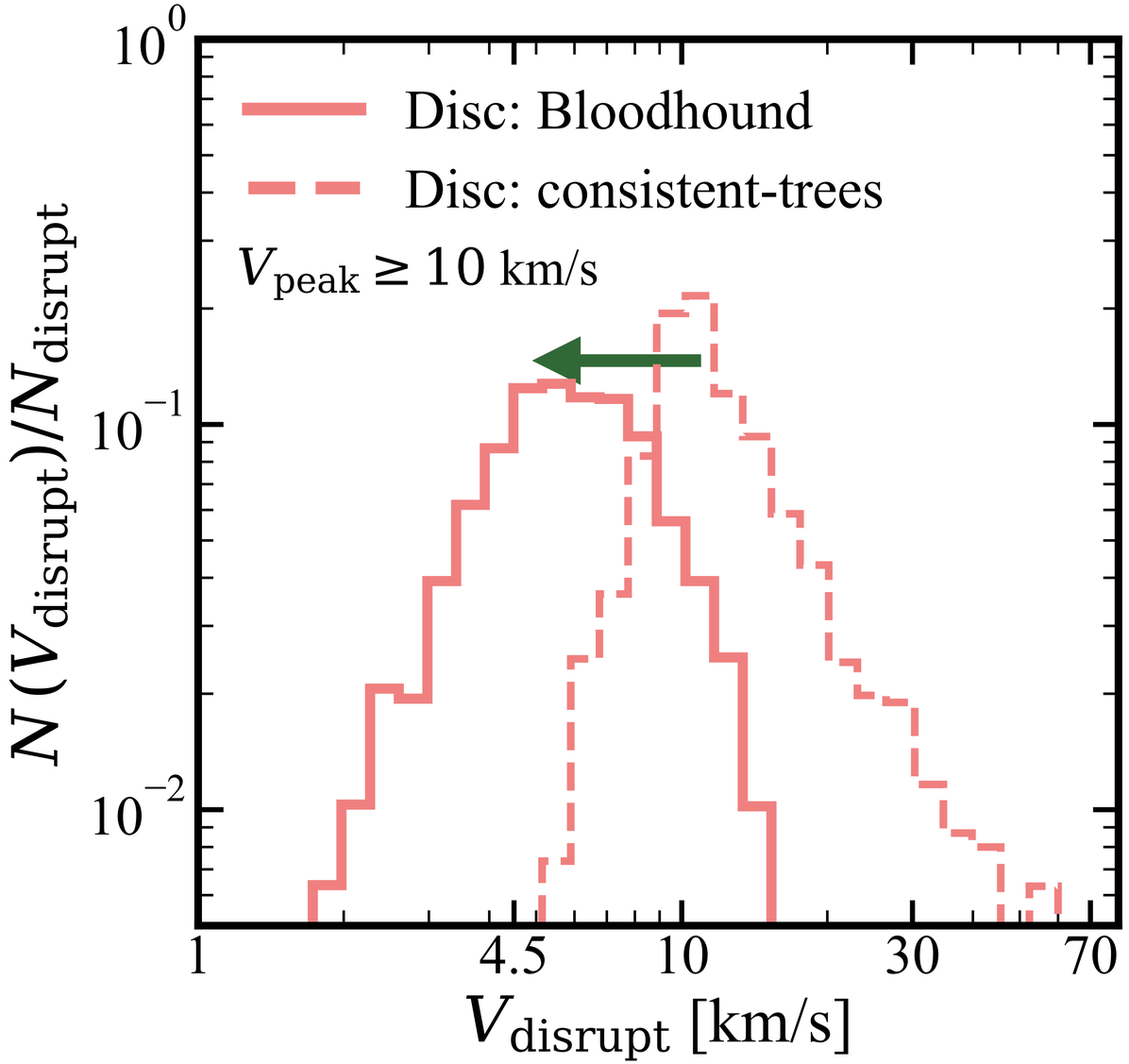

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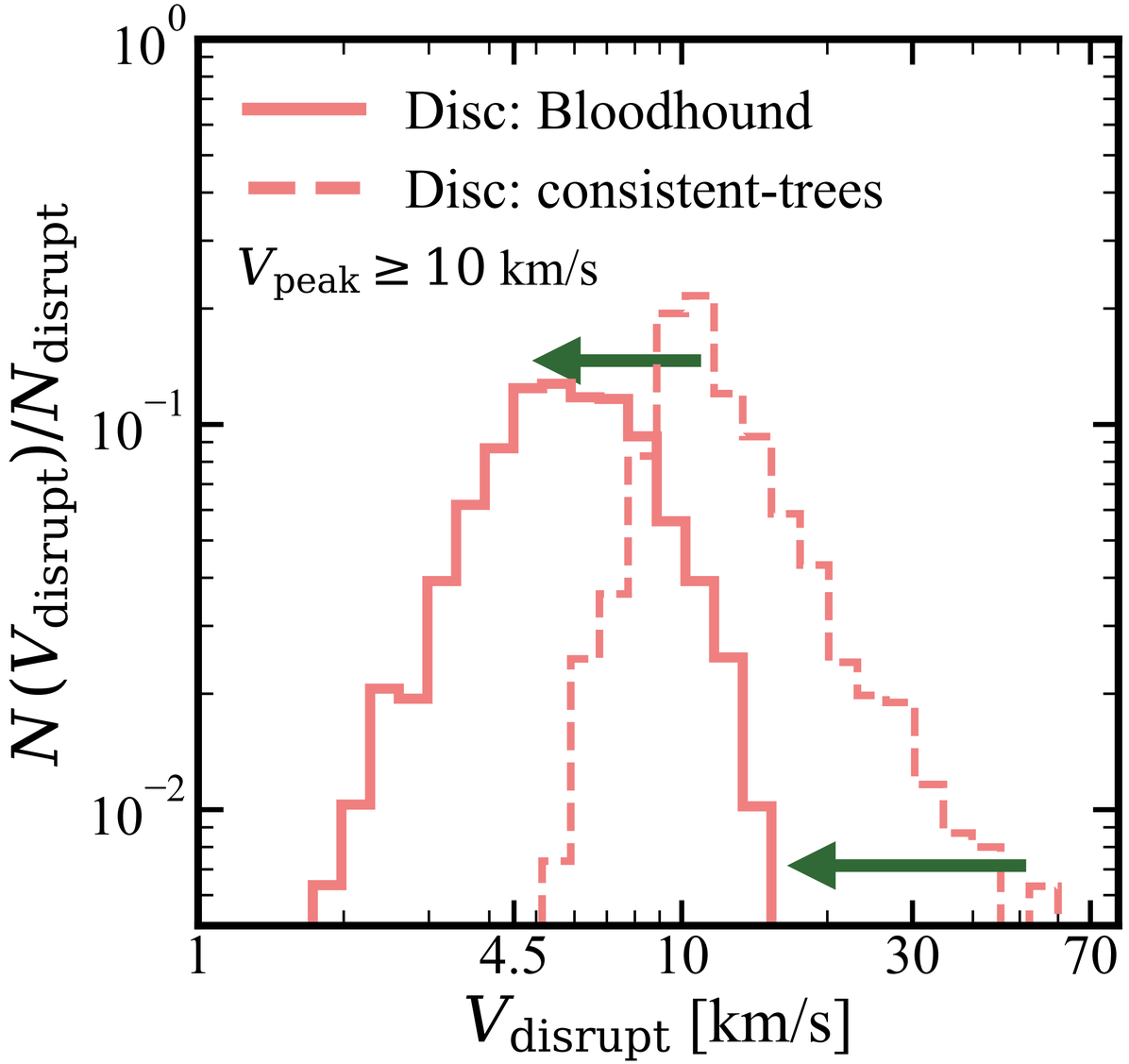
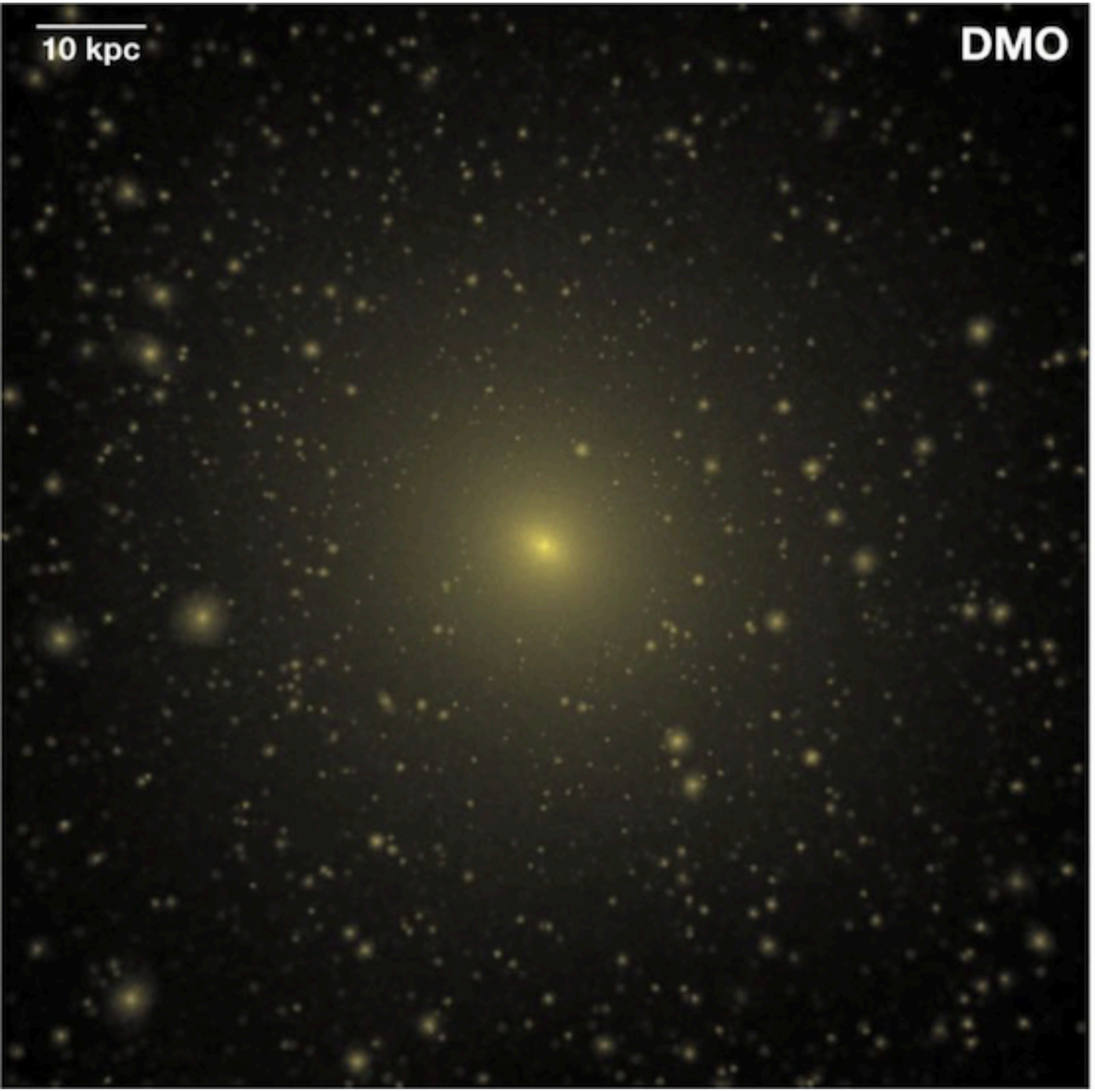


PHAT ELVIS: DMO VS. DISC



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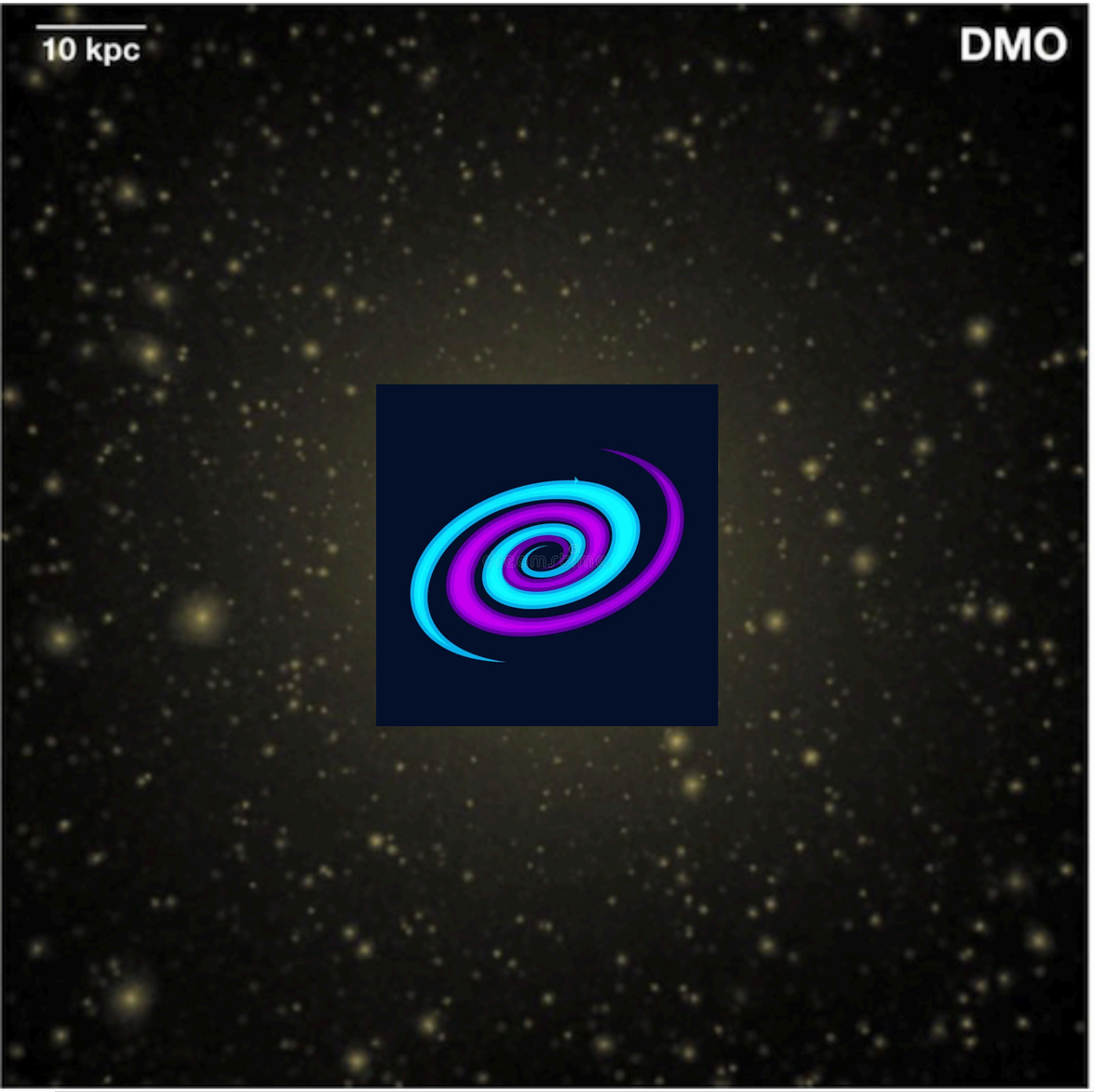

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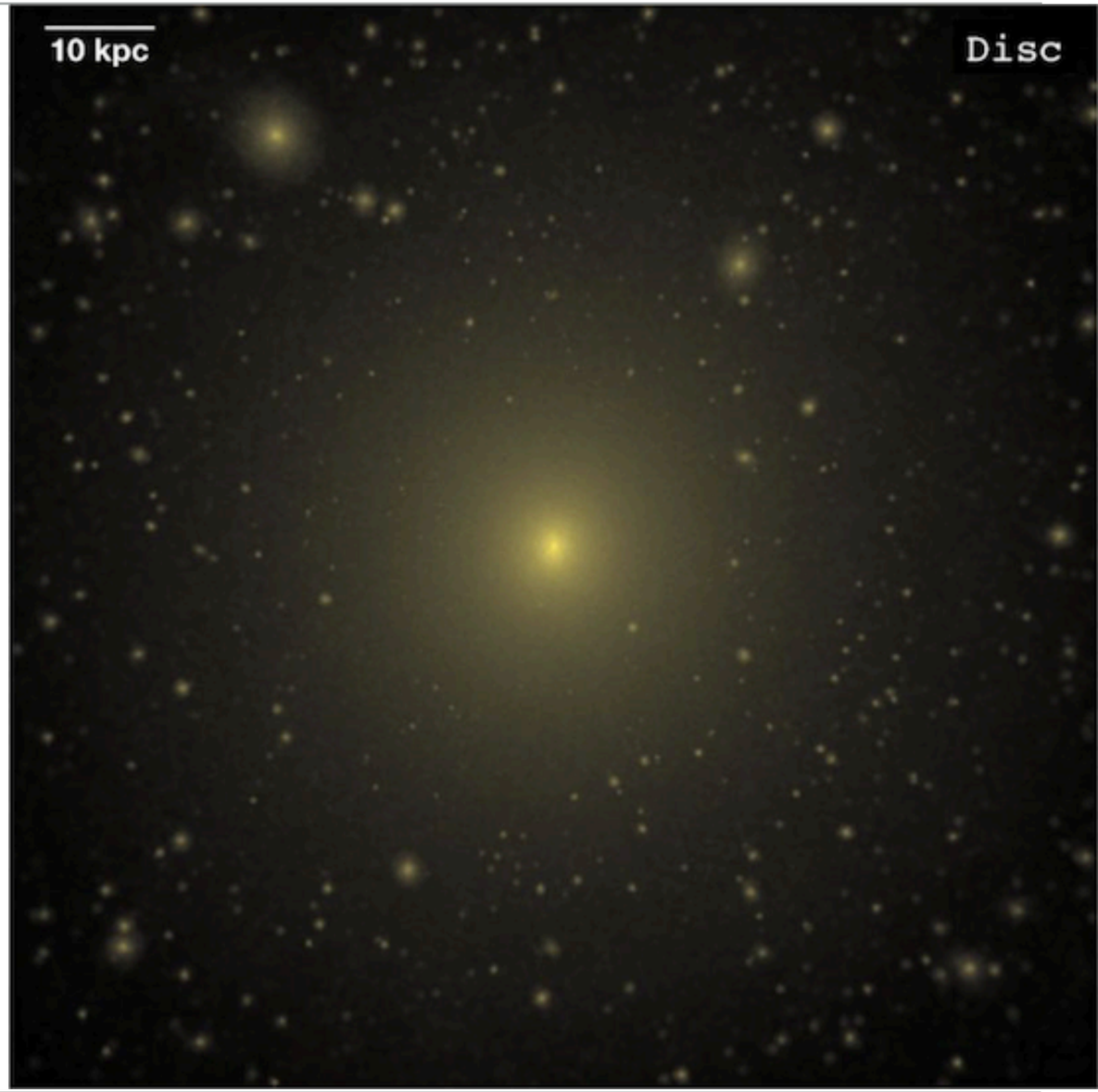

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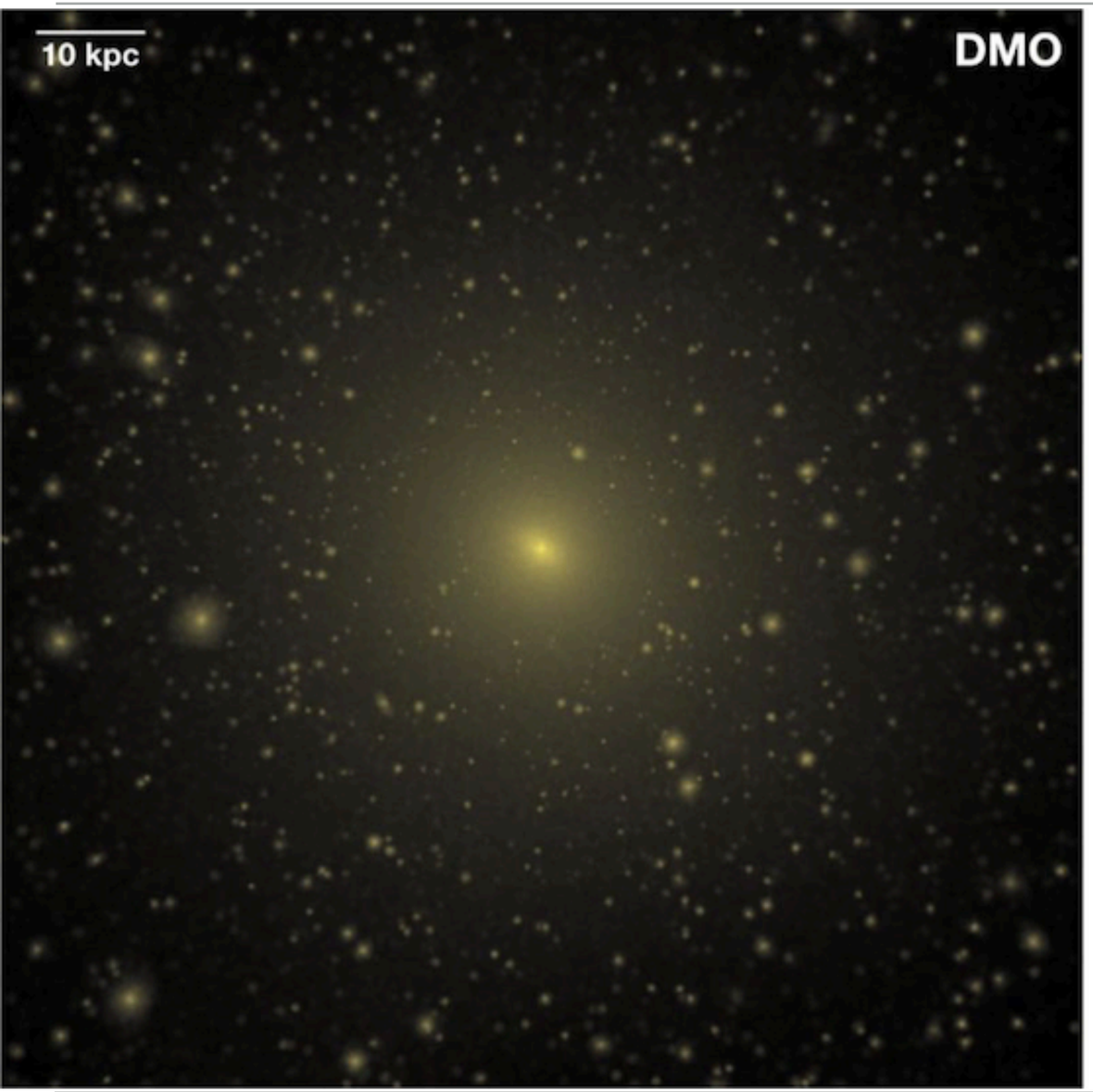
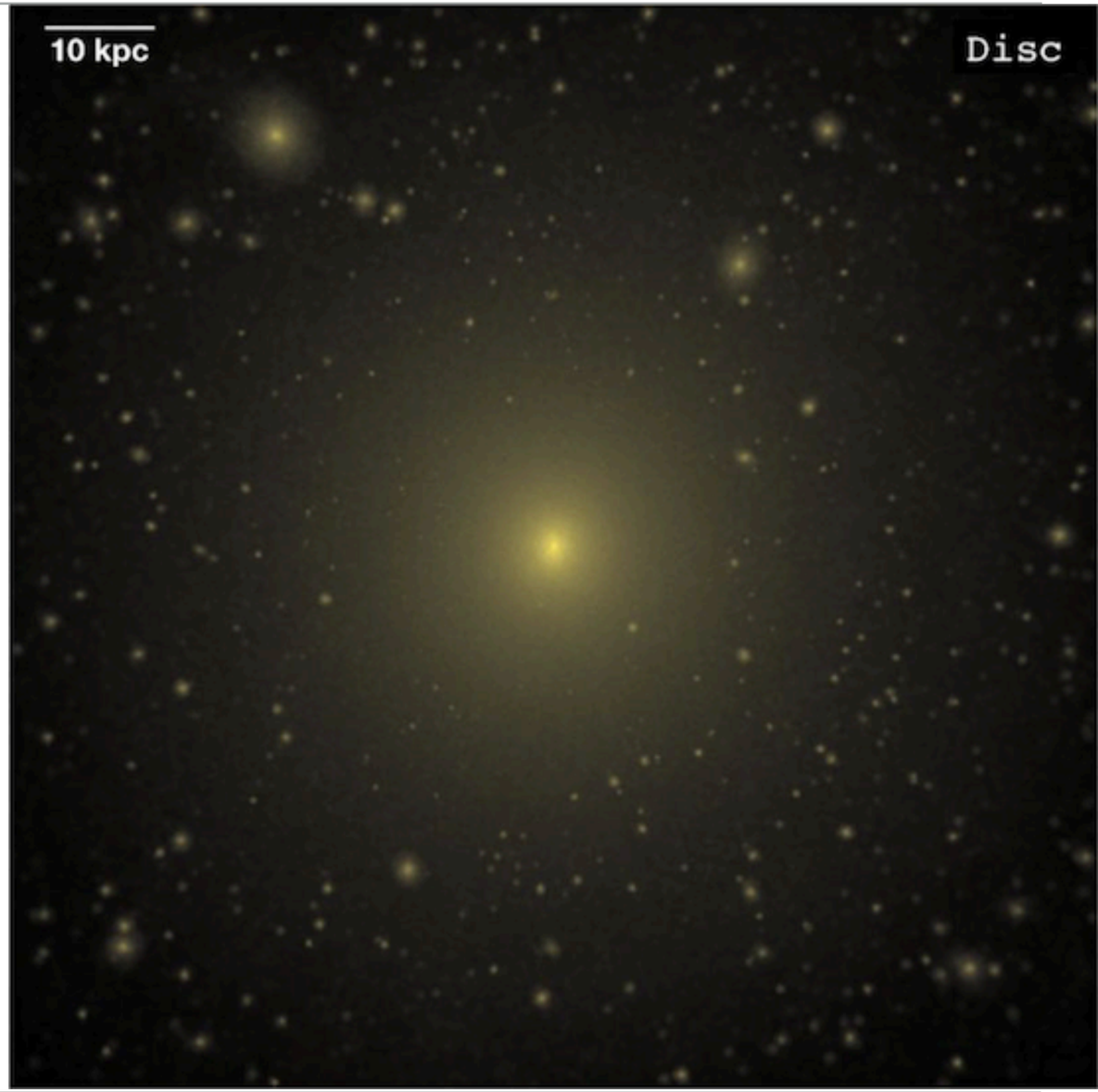
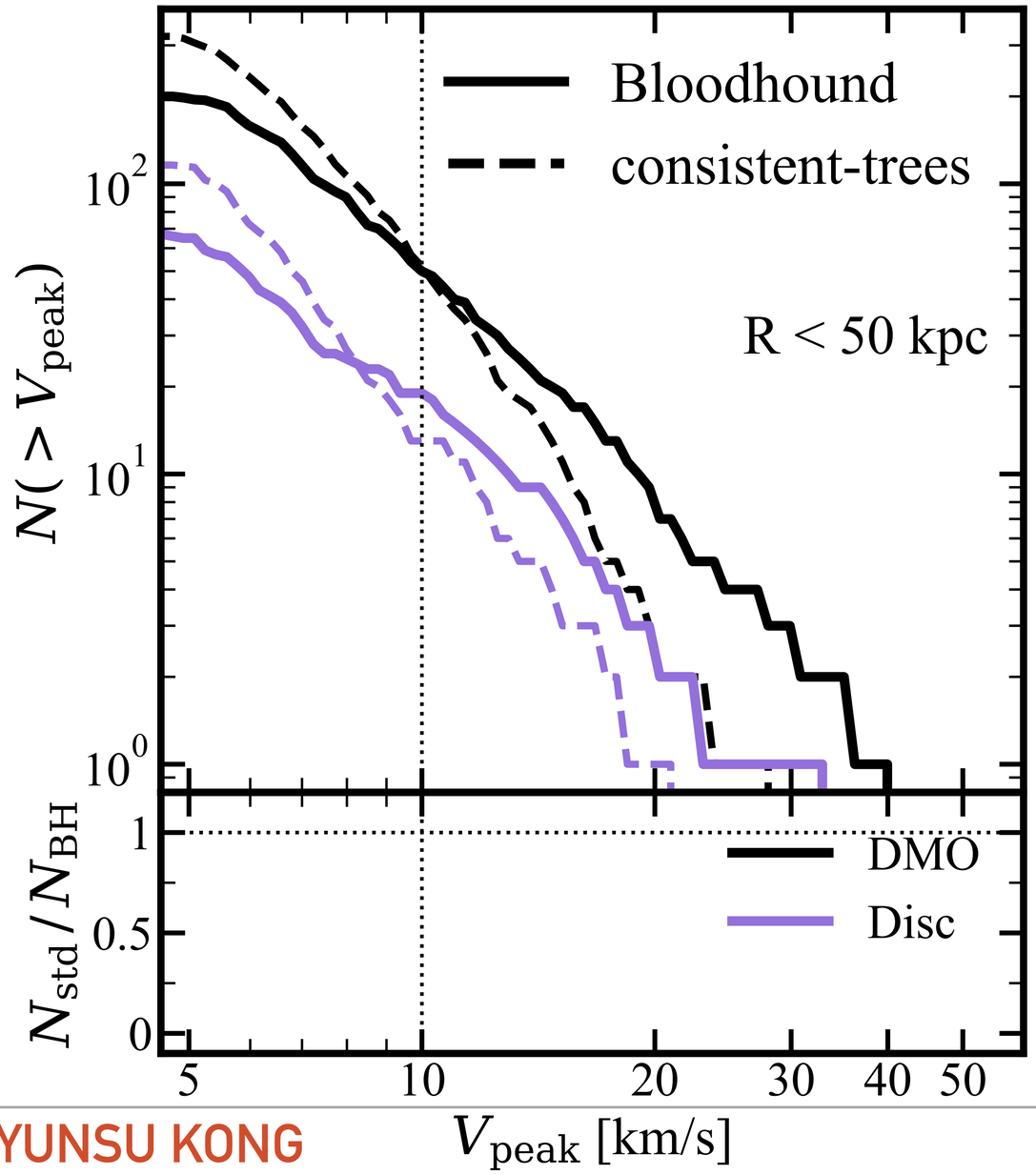




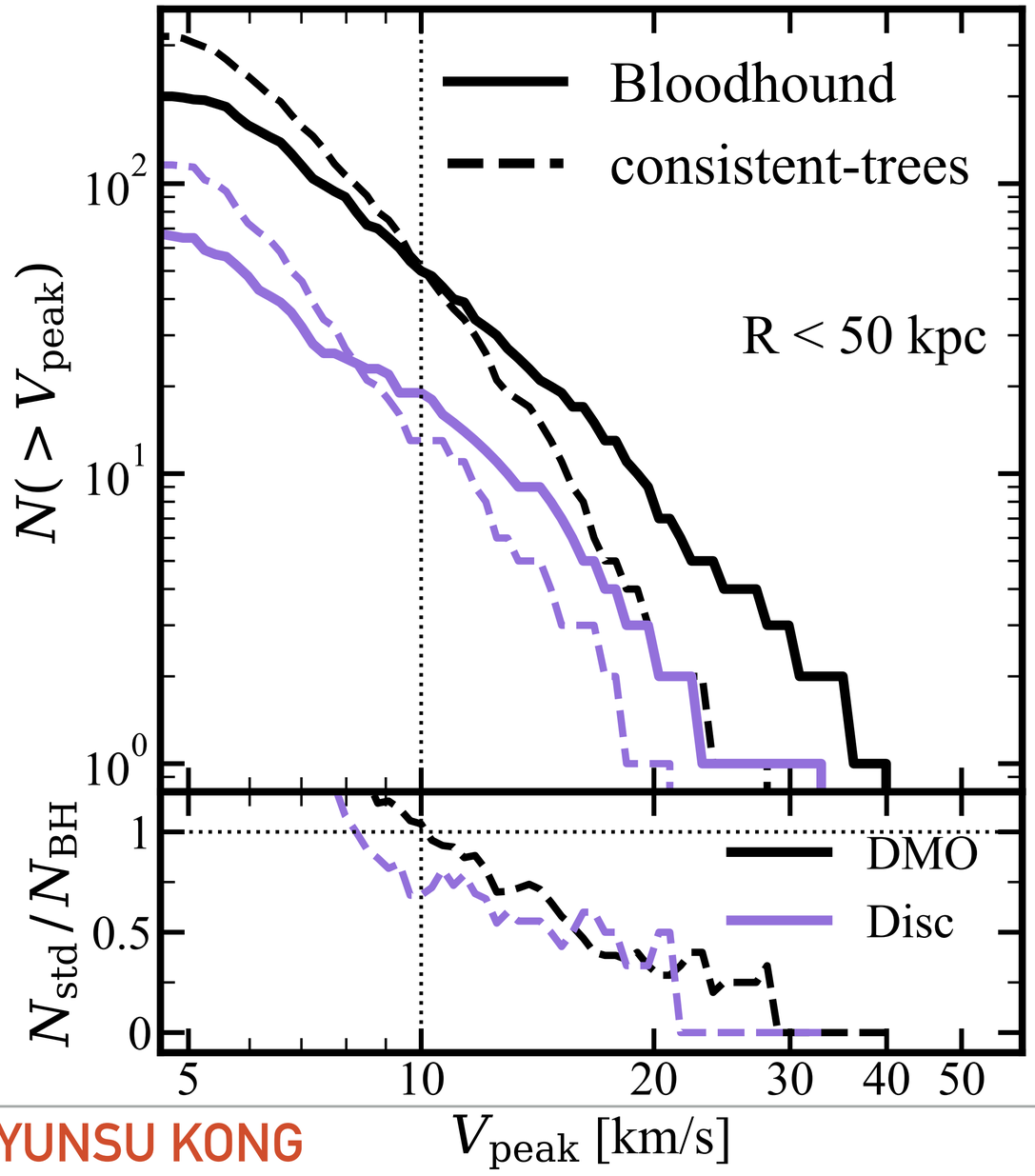
VELOCITY FUNCTIONS



DMO

Disc

VELOCITY FUNCTIONS



DMO

Disc

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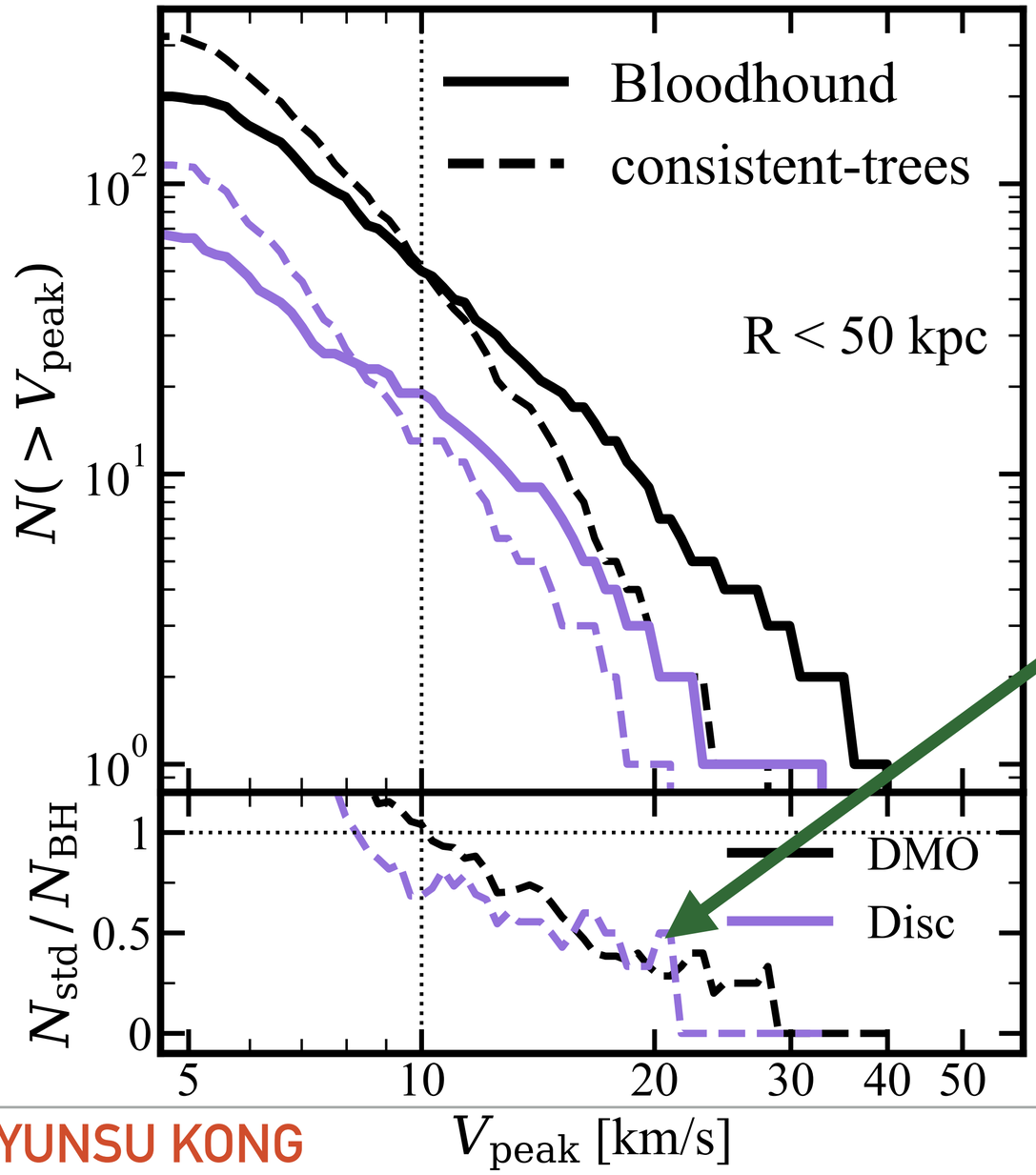
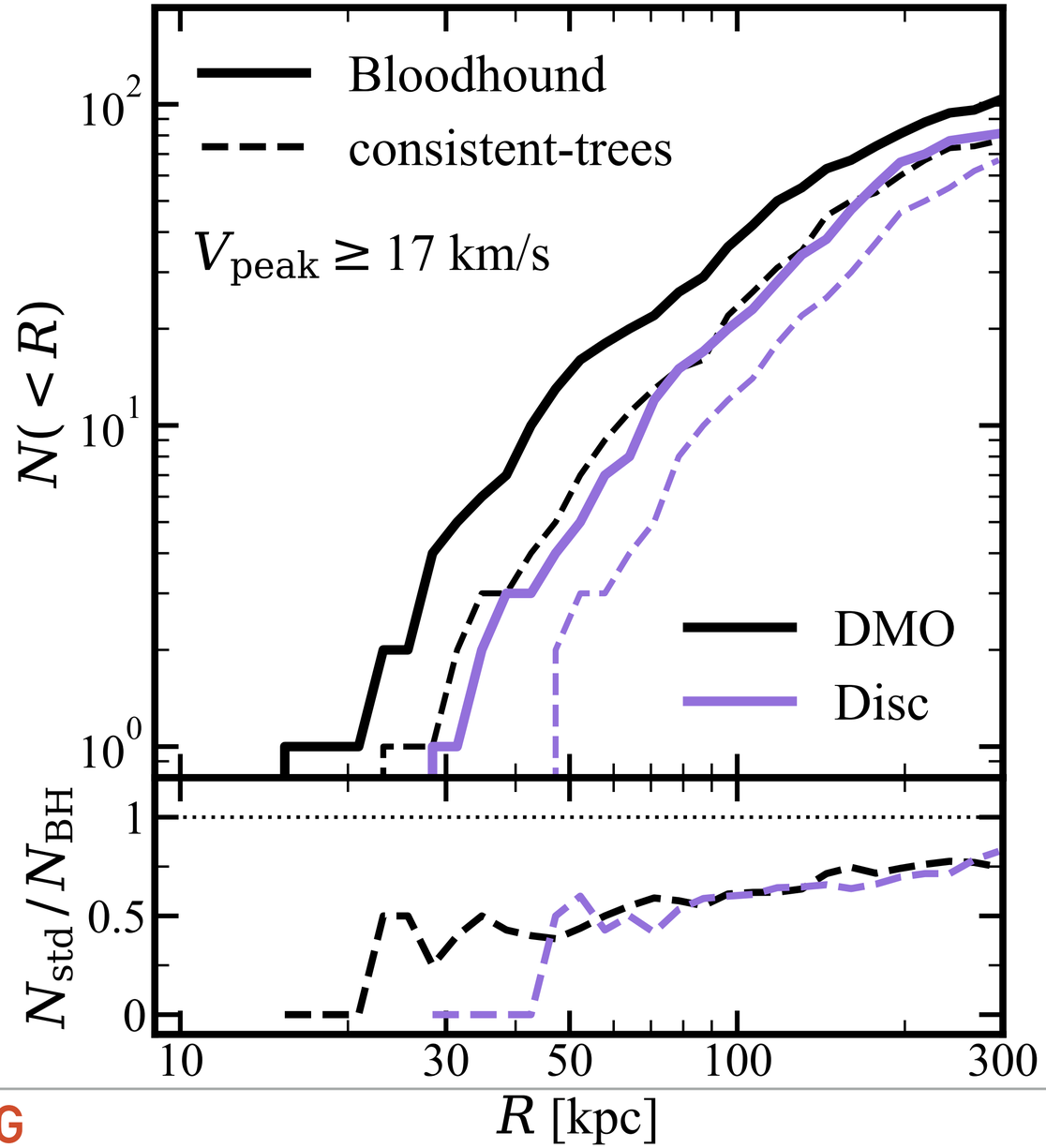


DMO

Disc

2x more surviving subhalos of $V_{peak} > 20$ km/s (atomic cooling limit) within 50 kpc

RADIAL DISTRIBUTIONS



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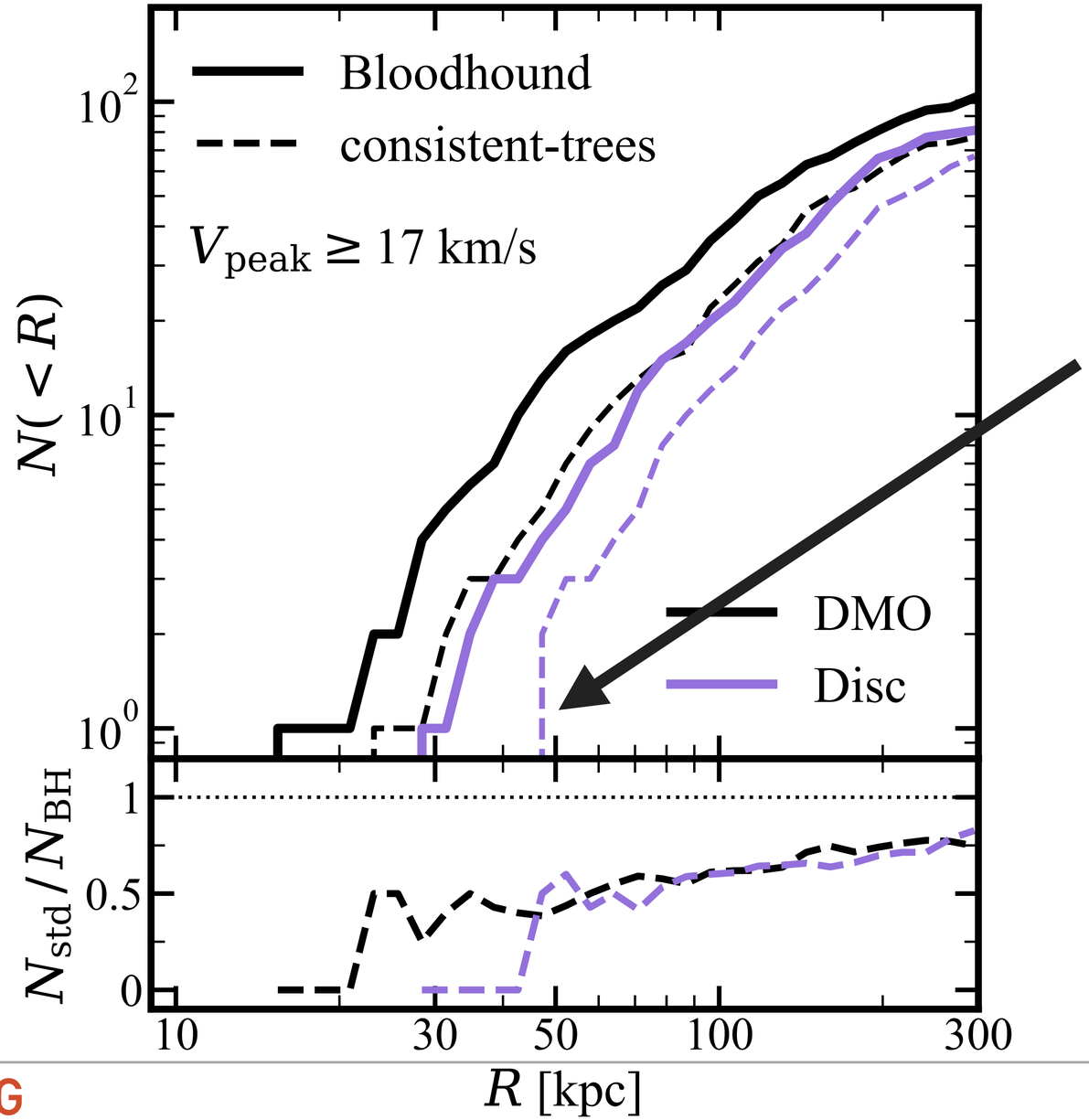
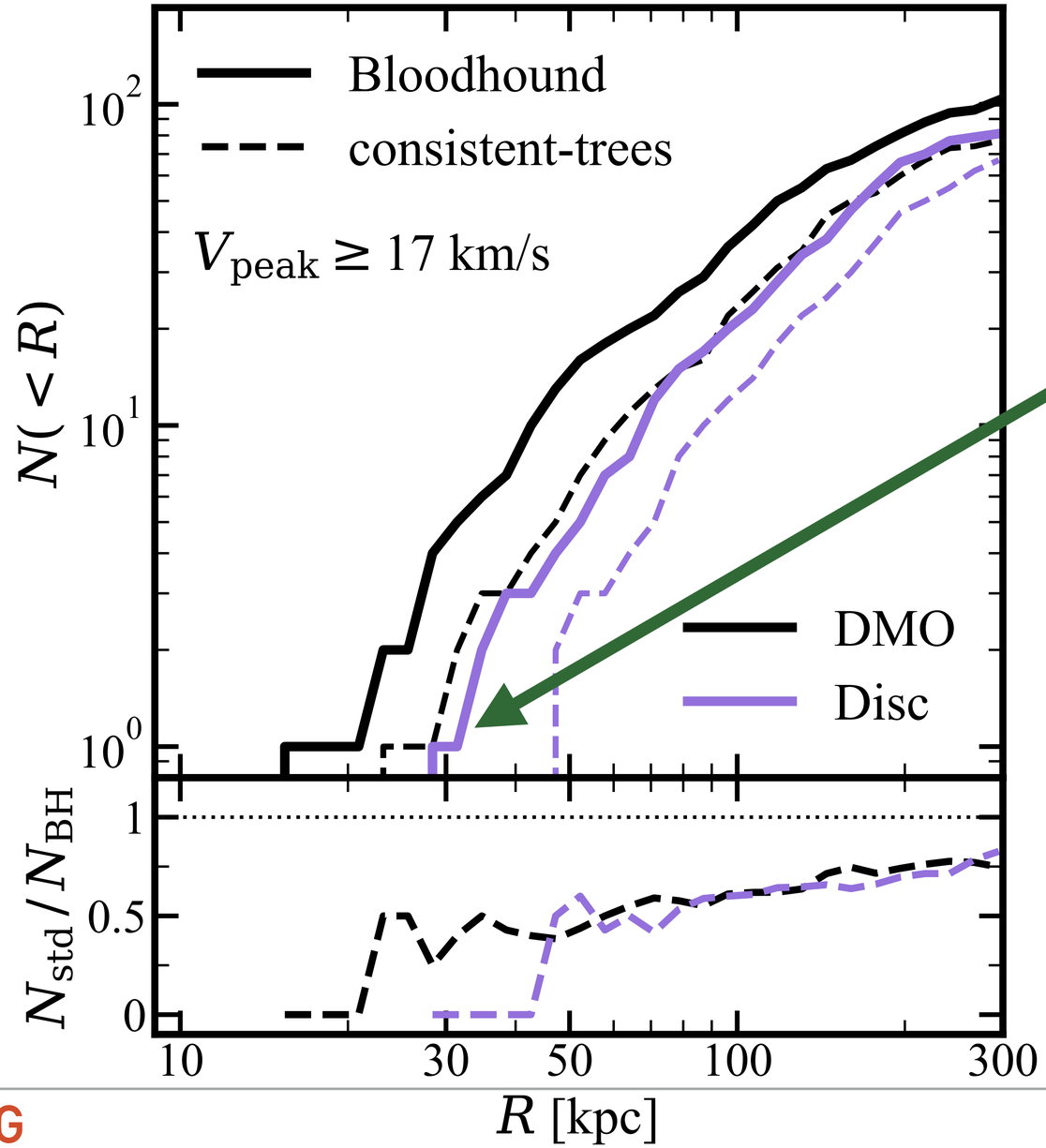


Depleted R < 50 kpc
in traditional method

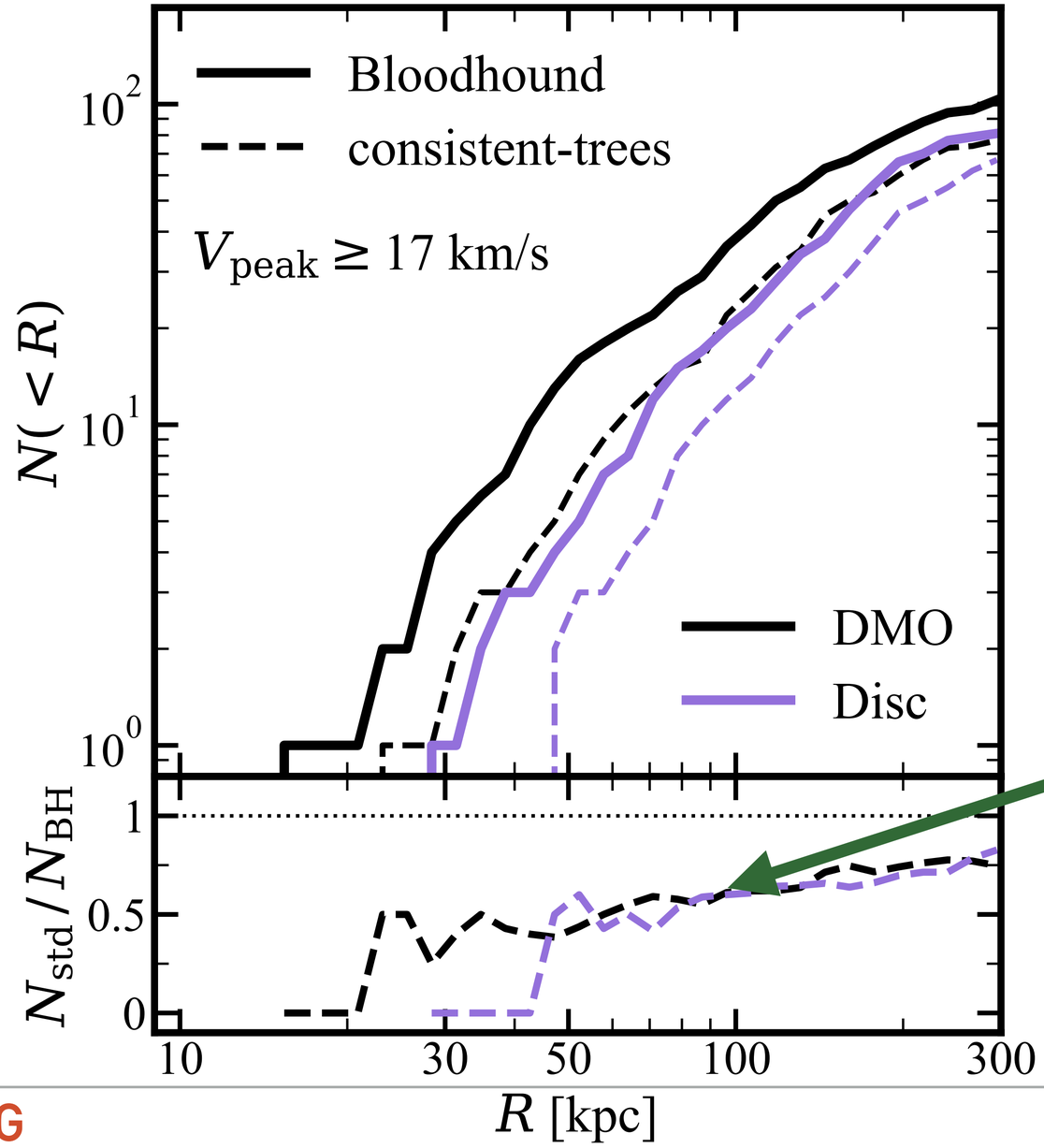
RADIAL DISTRIBUTIONS



Bloodhound:

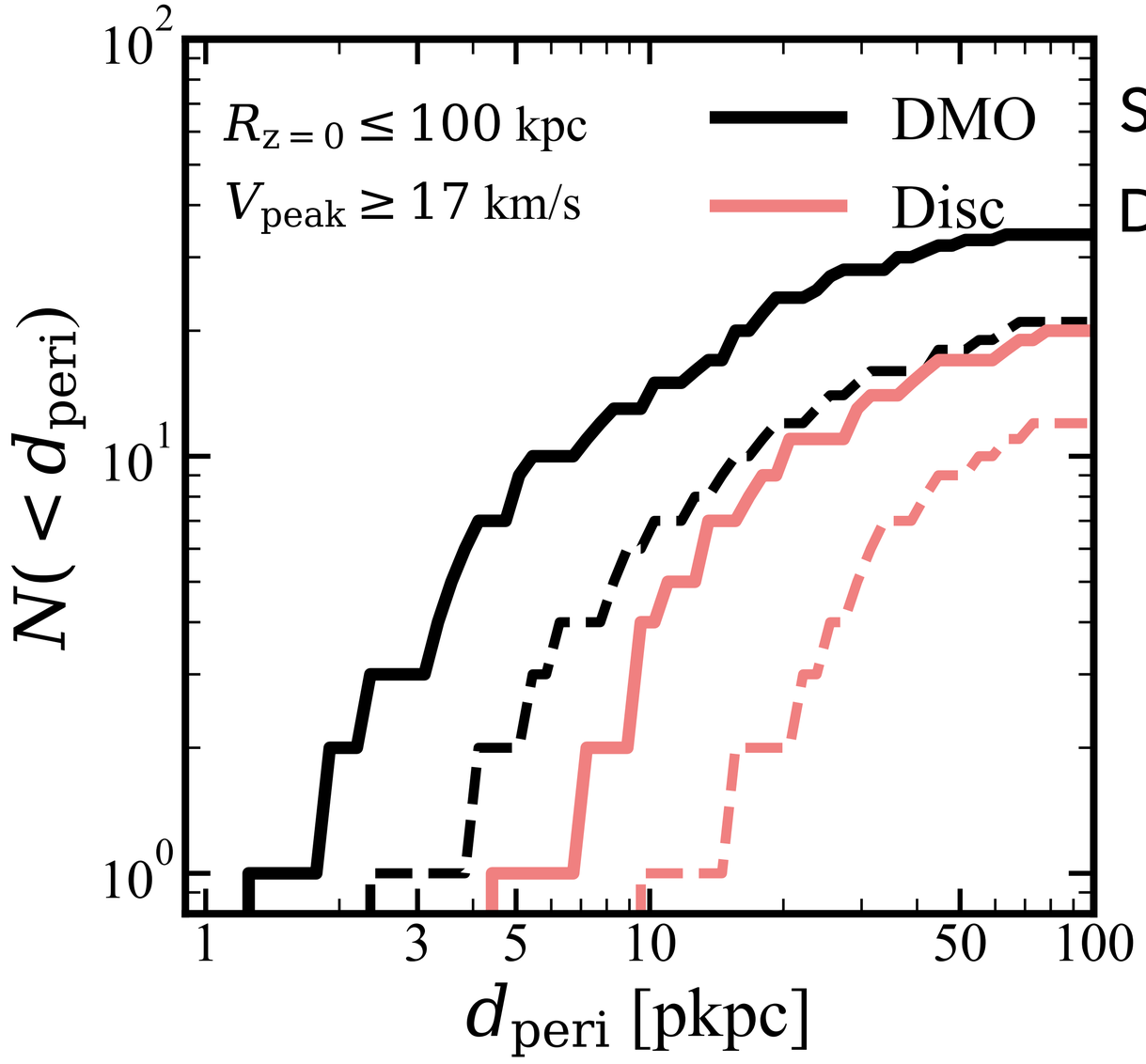
As close as 30 kpc

RADIAL DISTRIBUTIONS



2x more subhalos with $V_{\rm peak} > 17$ km/s out to 100 kpc

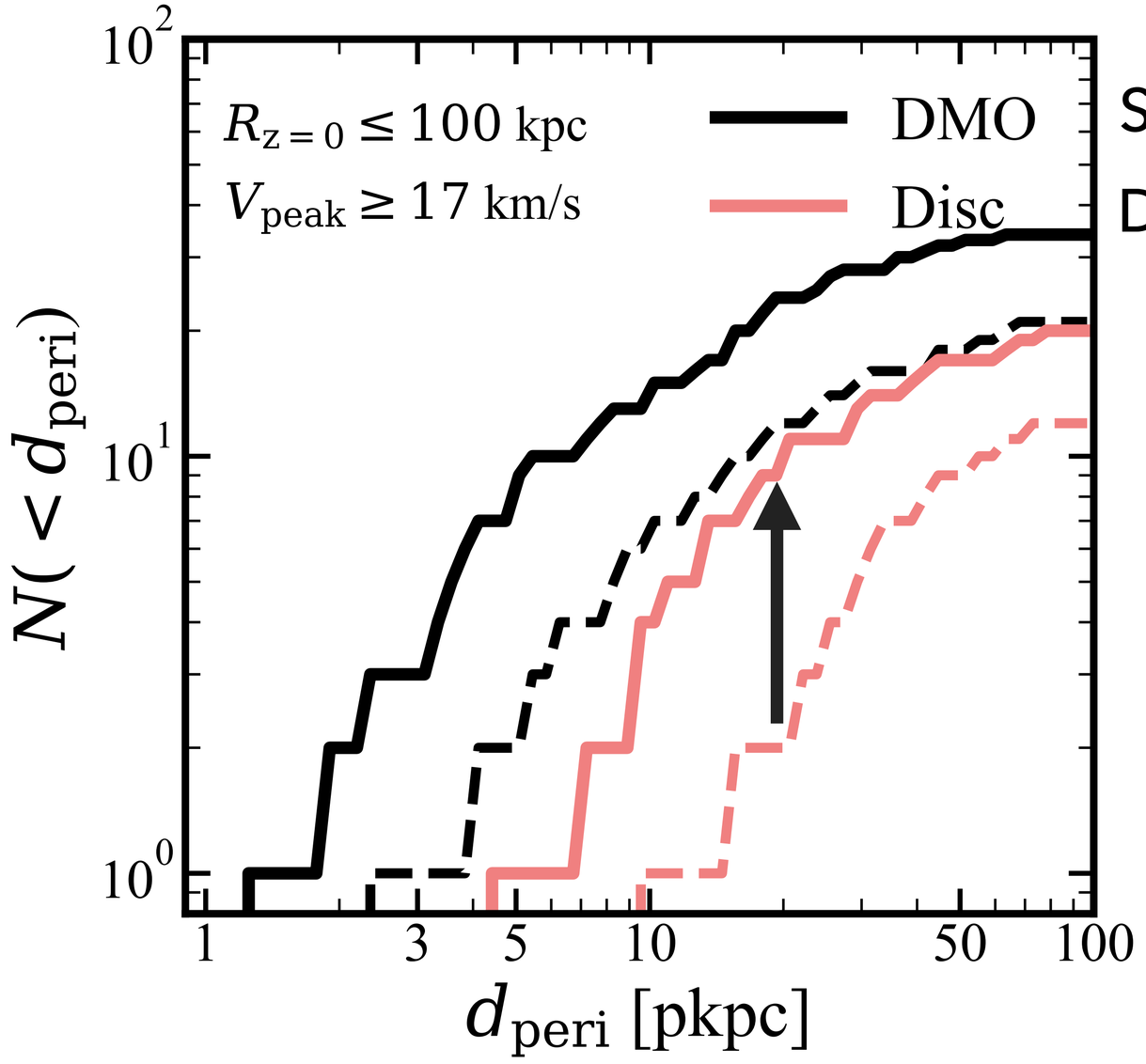
PERICENTER DISTRIBUTION



Solid: Bloodhound

Dashed: traditional method

PERICENTER DISTRIBUTION



Solid: Bloodhound

Dashed: traditional method

$\times 3$ more surviving subhalos with $d_{\rm peri} < 20$ kpc found in Bloodhound

SUMMARY

- Missing a lot of low-mass things, Gyrs of information
- DM substructure detection: MW stellar streams, subhalo lensing anomalies
- Tidal disruption due to the host galaxy
- Galaxy formation:
  - UDG: FIRE II, Jenna Samuel and Courtney Reed (Summer NSF REU)
  - Ultra-faint galaxies, completeness correction
- Making a prediction requires a statistical sample of subhalos with sufficient resolution and **faithful tracking**
- Applying to alternative DM models, higher-res simulations

ADDITIONAL FIGURES

SUMMARY

- Missing a lot of low-mass things: implications - predicting detectability of things, maybe threshold of galaxy formation
- Ultra-diffuse galaxies: simulations have trouble producing the same variety of things we observe, this could be because we are losing them, Courtney's research note.
- Better estimates of tidal disruption due to the host disc
- We are losing Gyrs of information about dynamical evolution of low-mass objects
- Applying to new DM models, higher resolution simulations
- DM detectability

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DM SUBSTRUCTURE DETECTION

- Gravitational effects of DM substructure
- Subhalos' effect on MW stellar streams
- DM substructure lensing anomalies
- Making a prediction requires a statistical sample of subhalos with sufficient resolution and **faithful tracking**

You can just say that thin streams may be sensitive to low-mass subhalos (and same for lensing), but current predictions don't have correct estimates of frequency of subhalo-stream interactions because subhalos aren't tracked well

GALAXY FORMATION

- Stripped/disrupted galaxies: Ultra-diffuse satellite galaxies
  - With FIRE II simulations, in progress
- Threshold of galaxy formation: Ultra-faint galaxies
- Completeness correction: we only see ones close to us

SUMMARY

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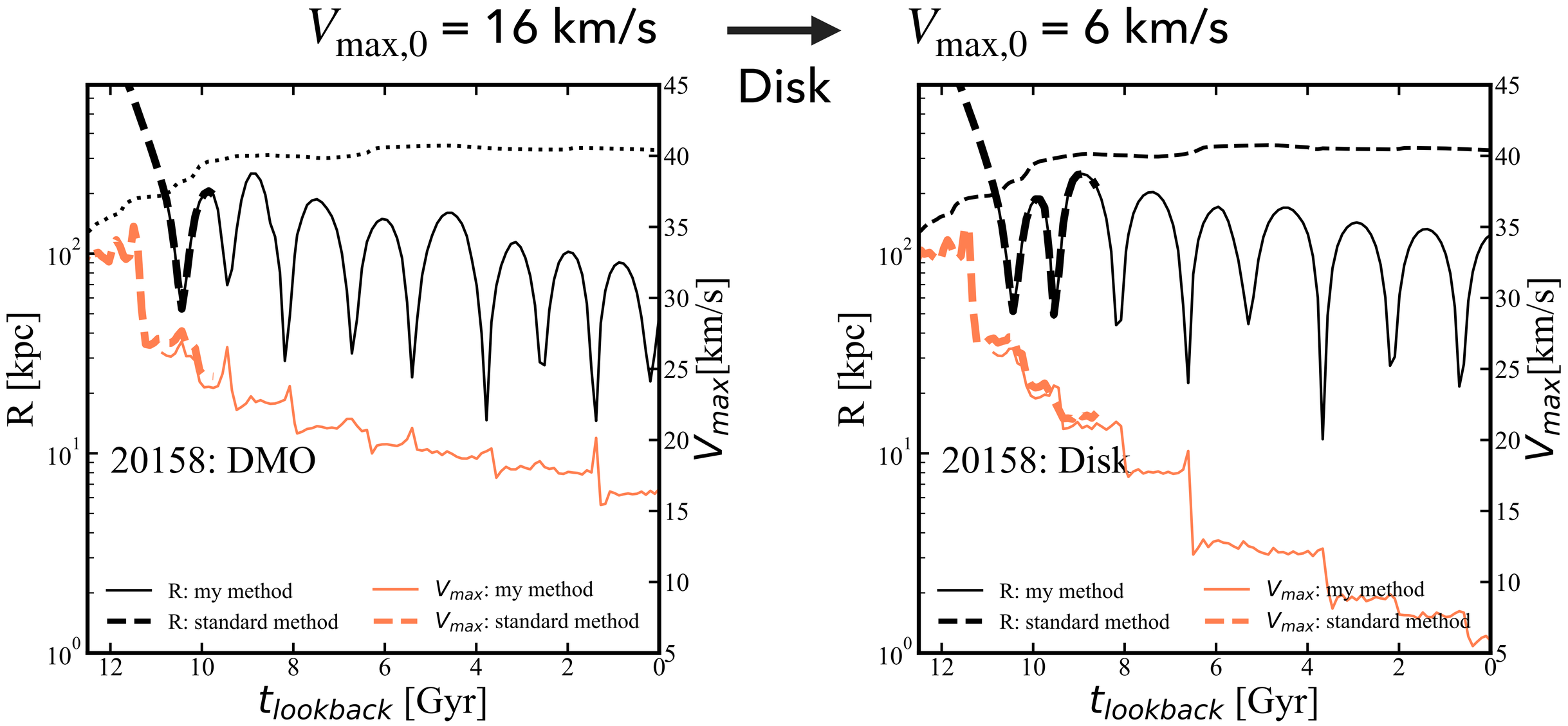
hyunsukong@utexas.edu

MERGER-TREE VS. PARTICLES



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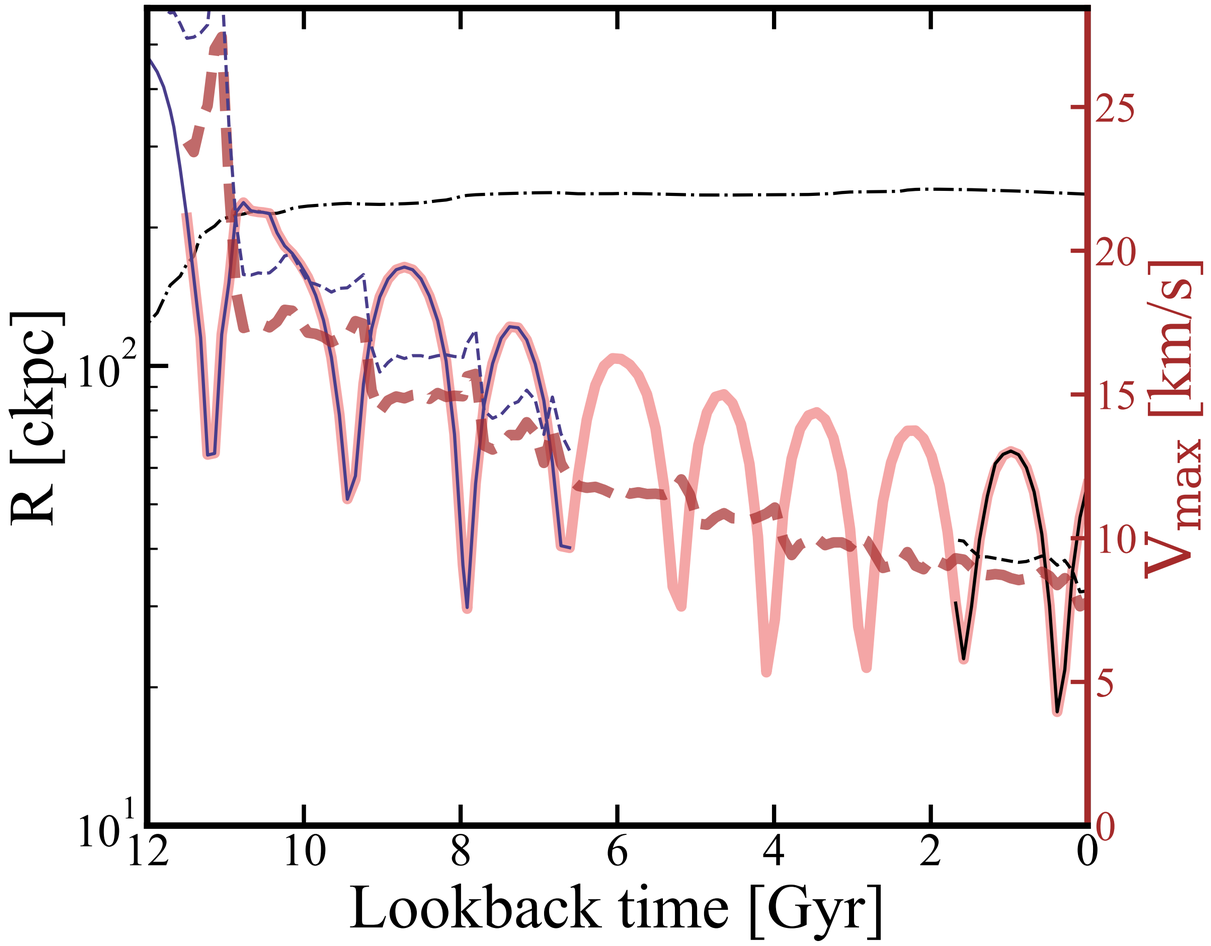

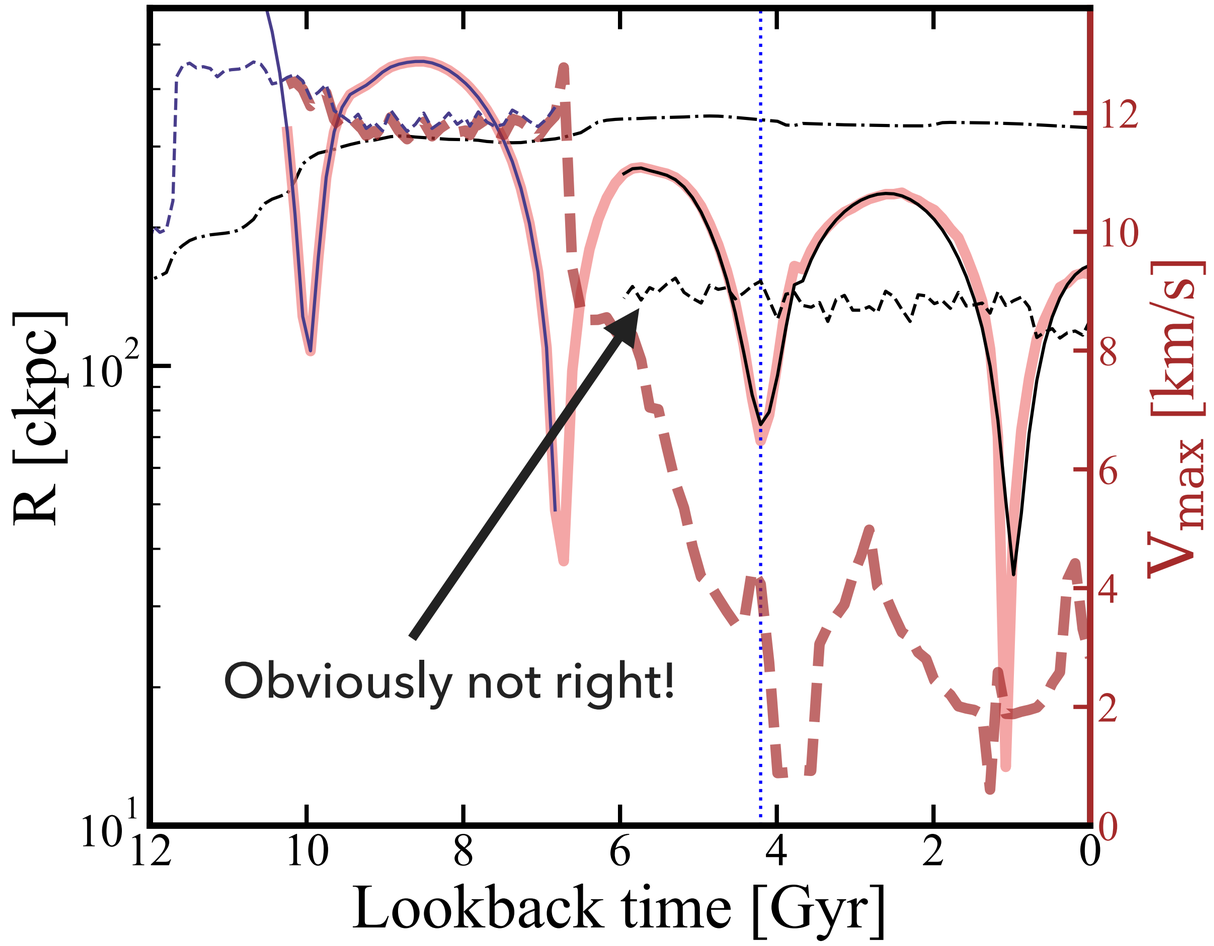

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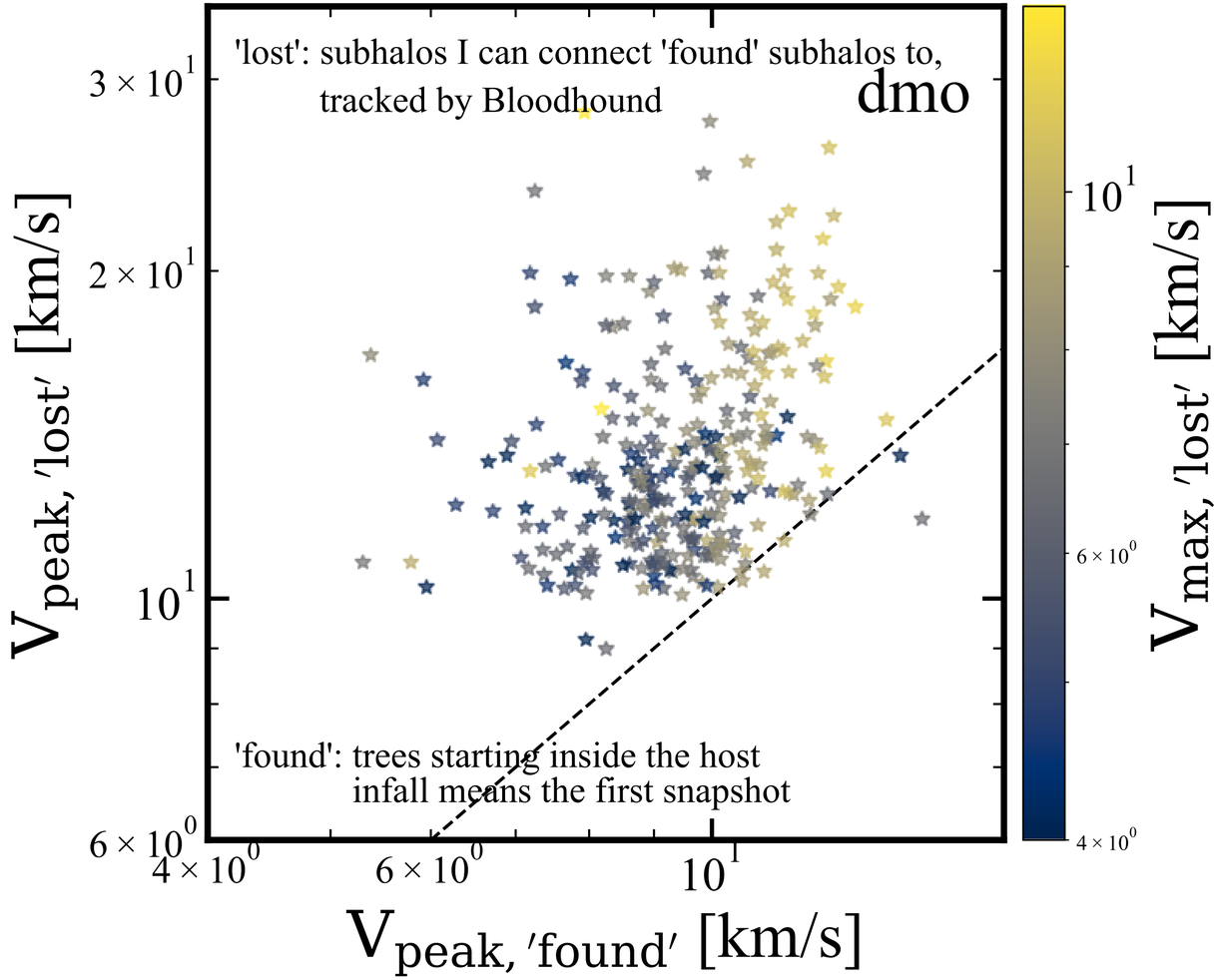

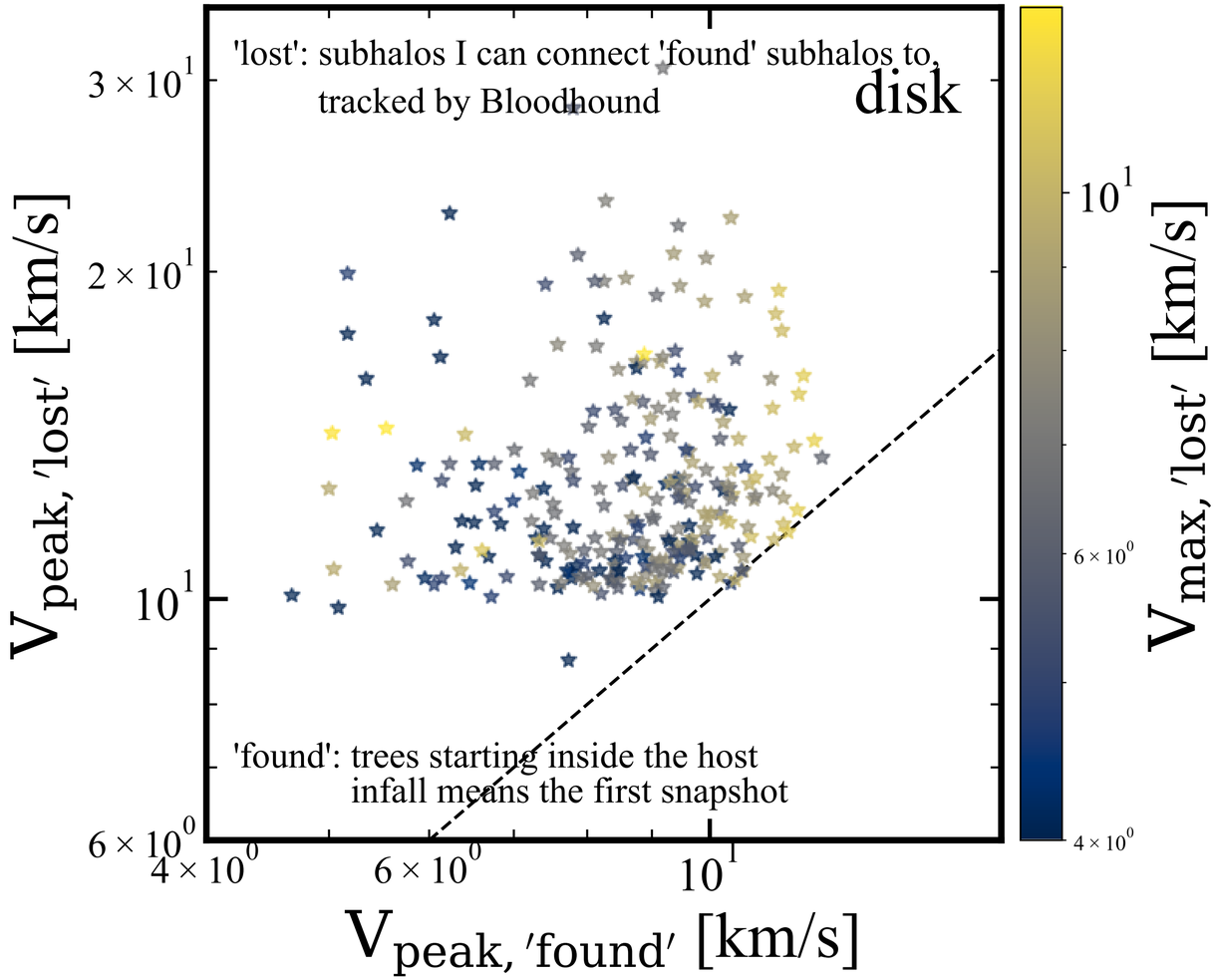

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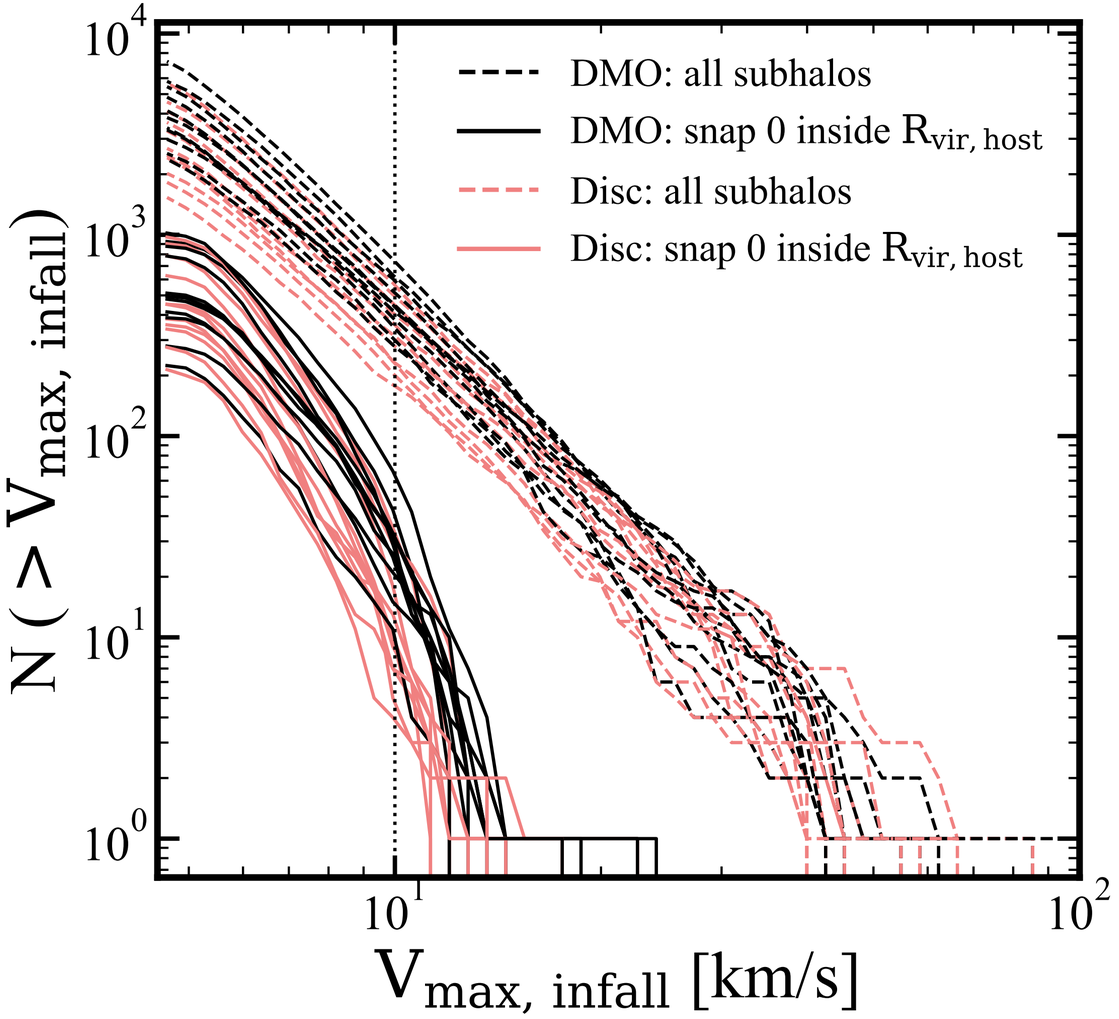
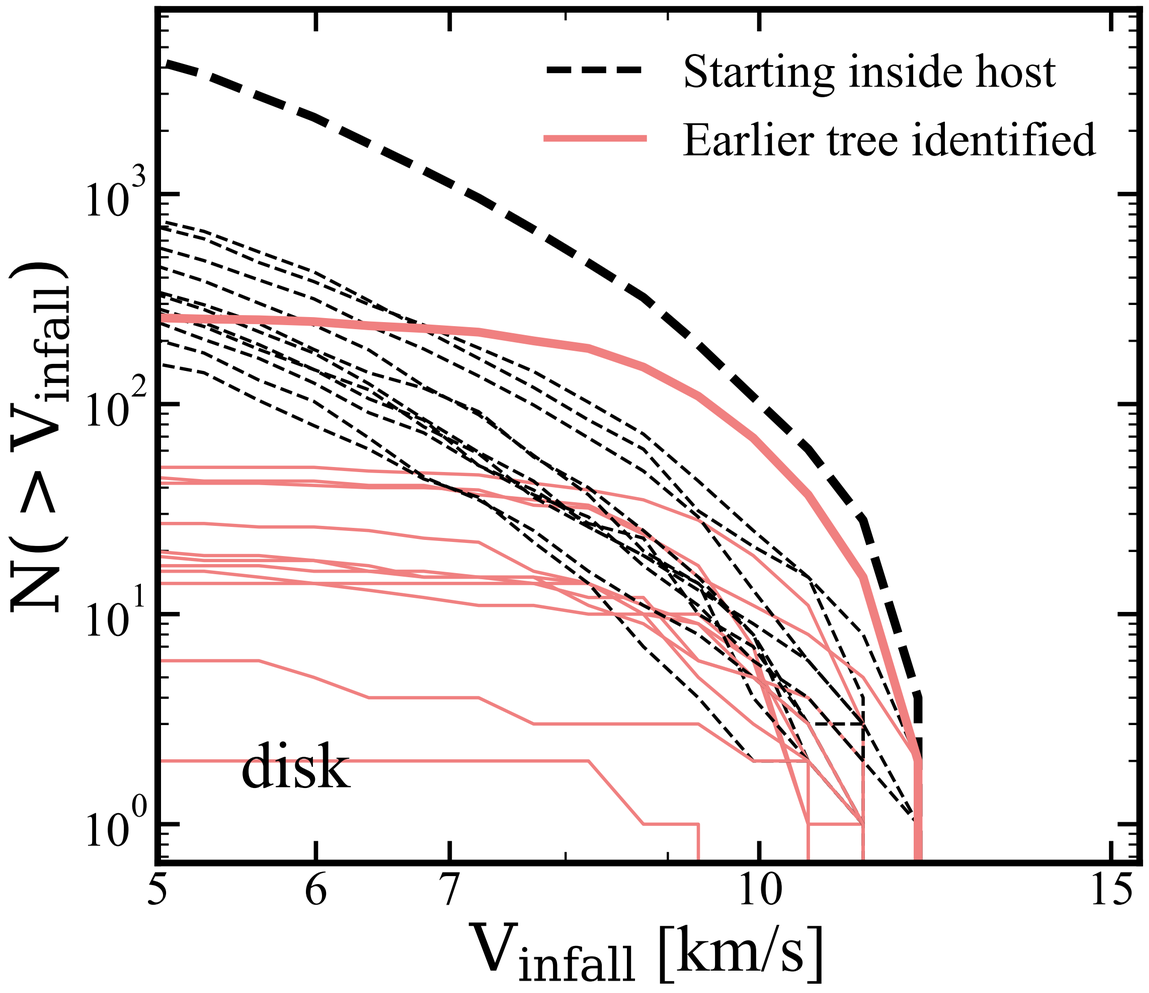
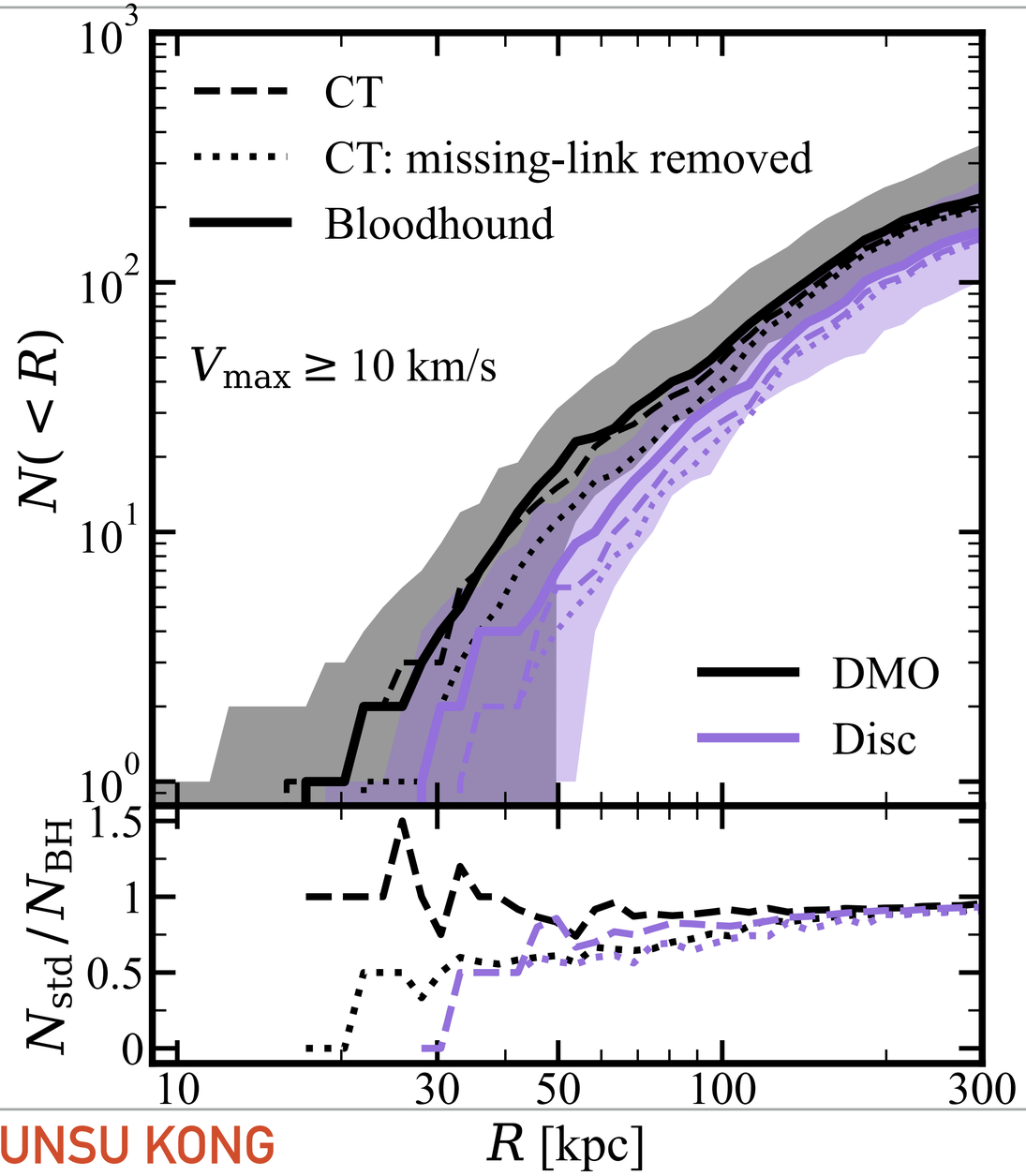
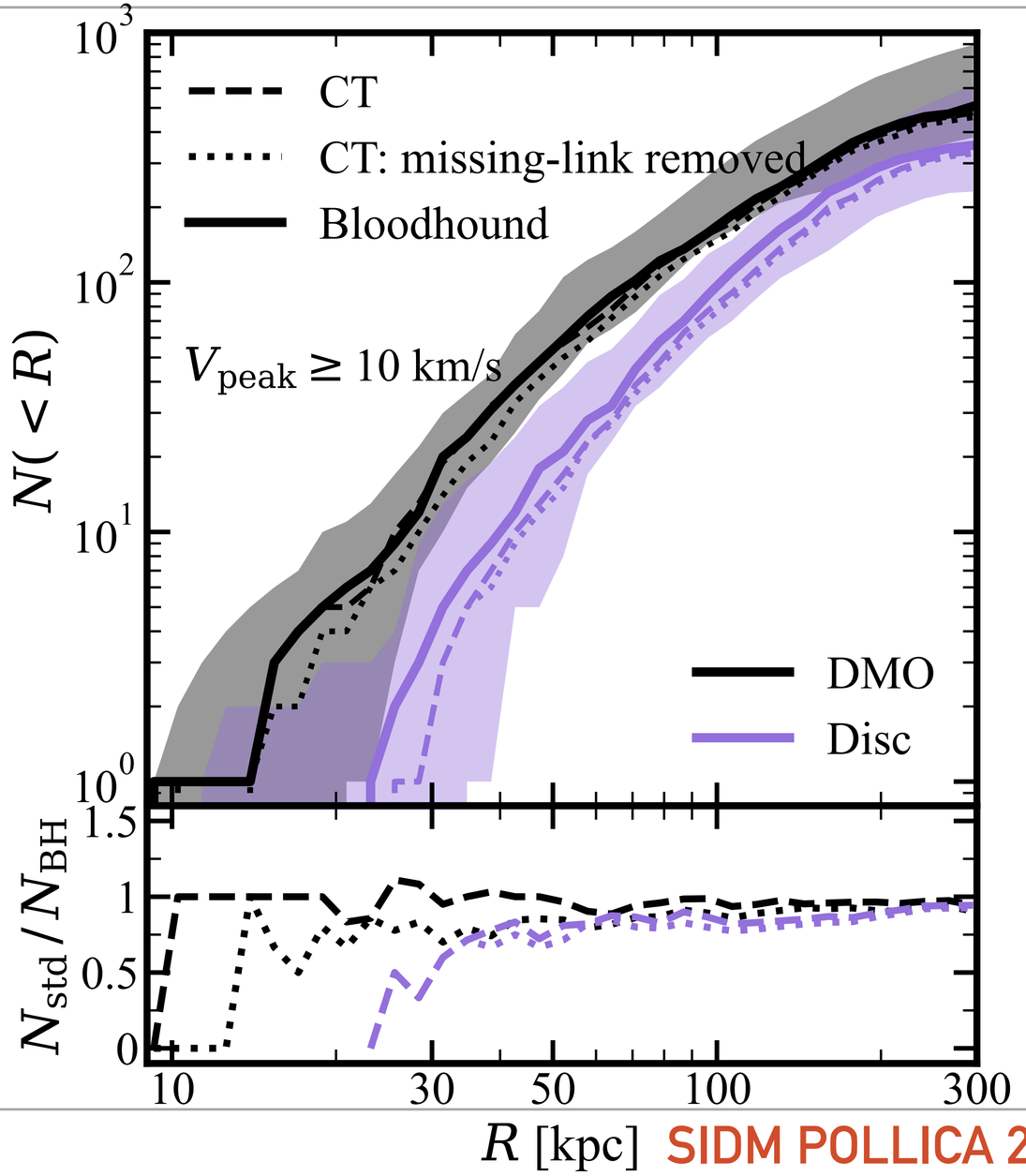


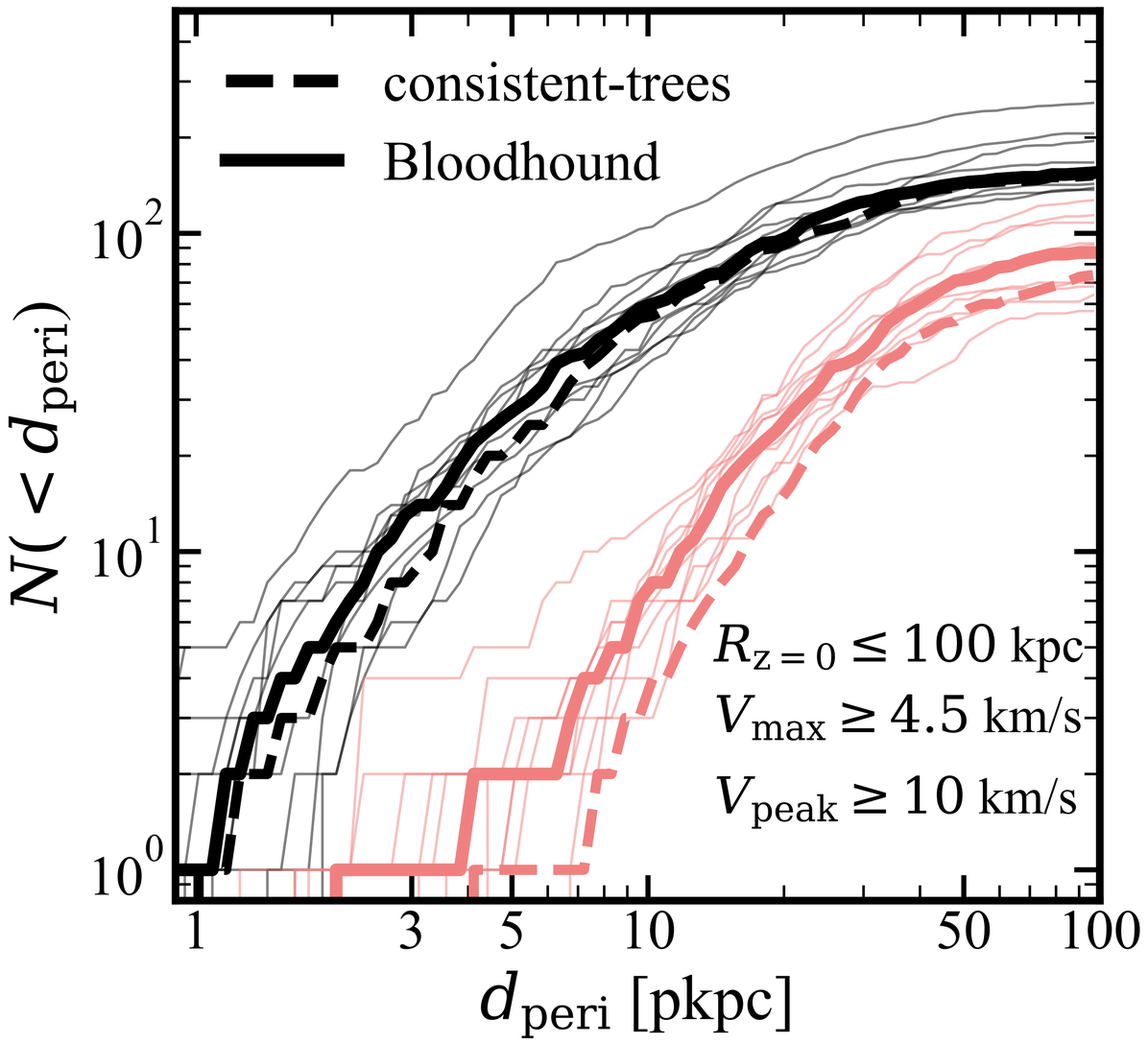


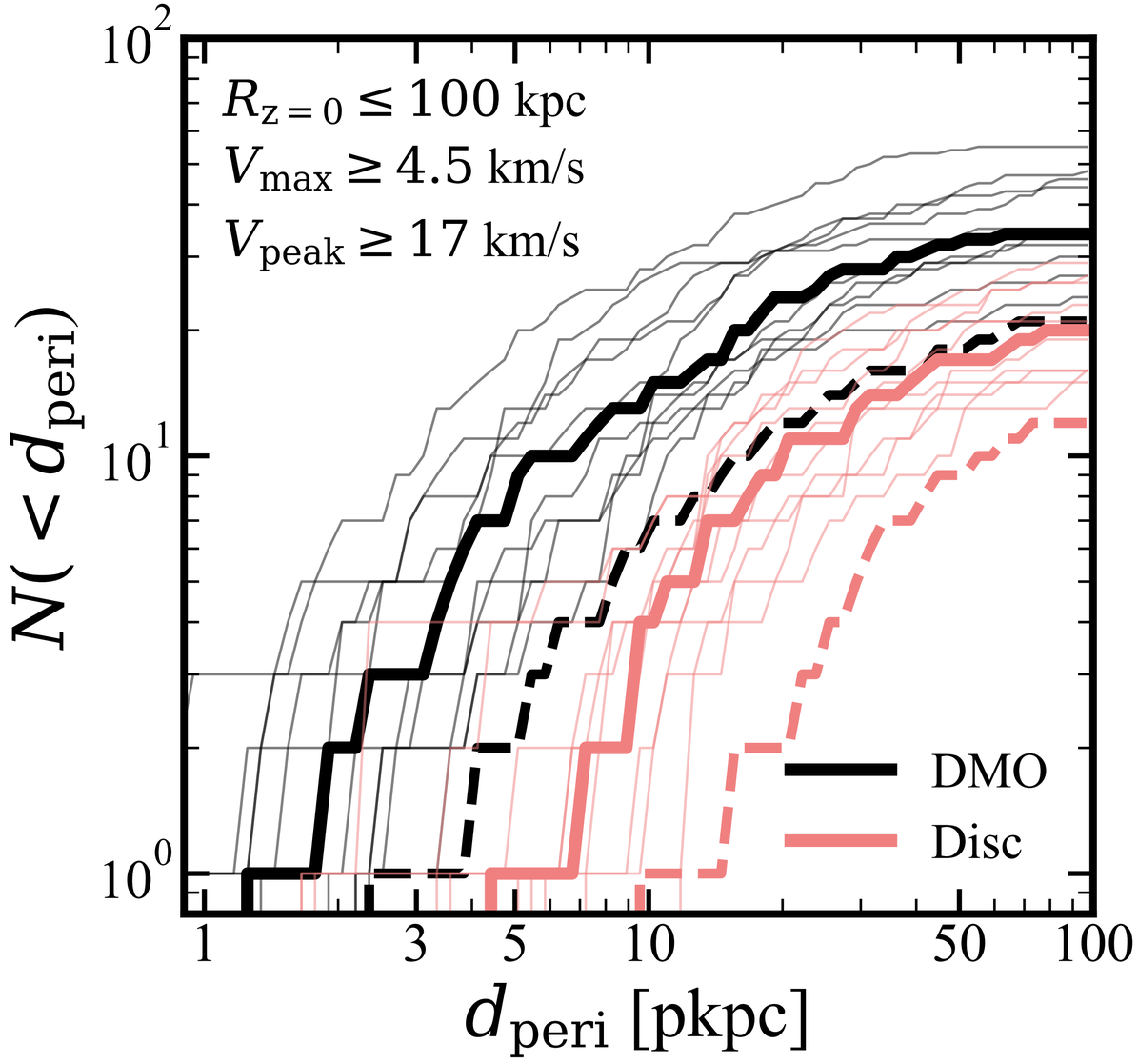
RADIAL DISTRIBUTIONS





PERICENTER DISTRIBUTION

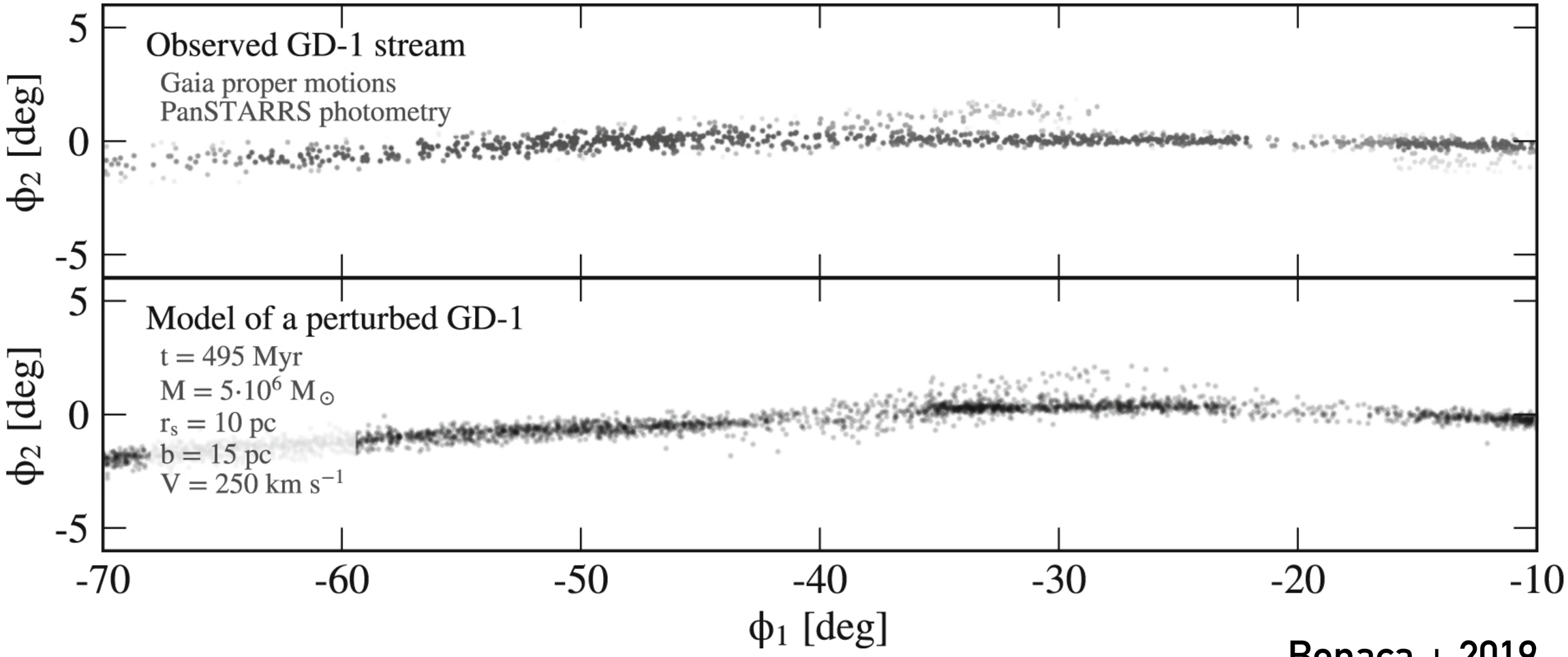




FLAWED TOOLS

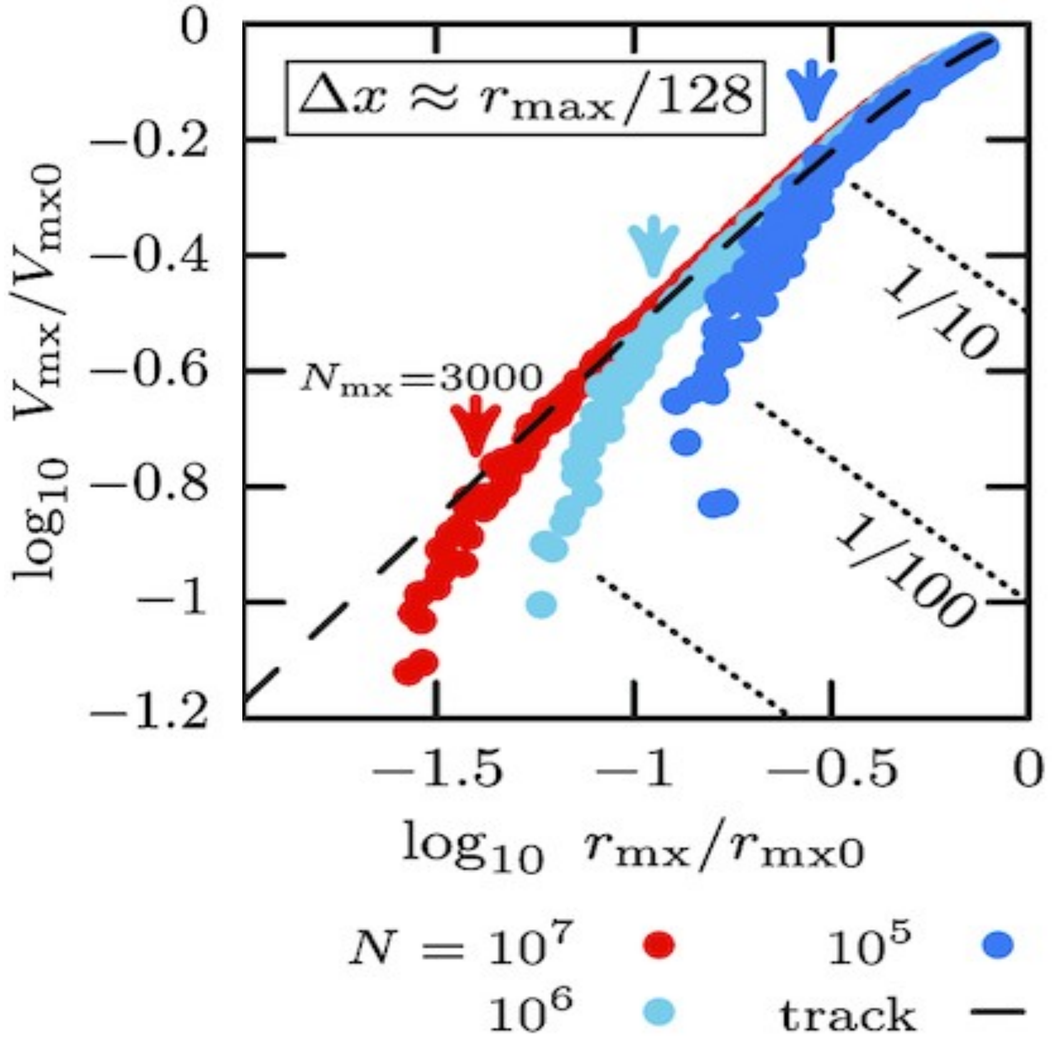
- People start right from the halo catalog/merger tree side, assuming they are correct, but there's a nuance.
- At each step, we lose something.
- And that something is very important for what I am are interested in.

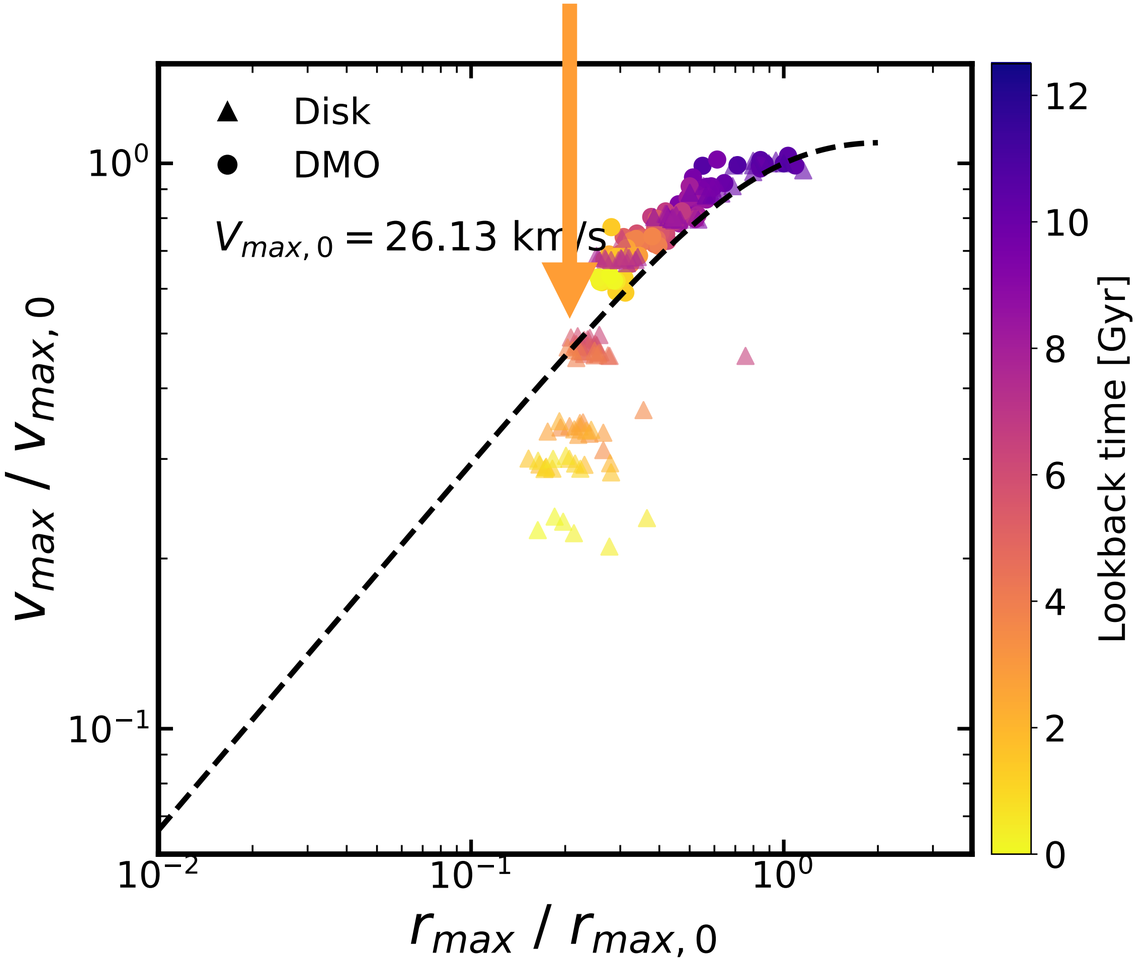
DM SUBSTRUCTURE DETECTION



Bonaca + 2019

FUTURE PLANS: HIGHER RESOLUTION





Errani & Navarro 2021