Fake it 'til you make it:

Embedding galaxies in cosmological simulations

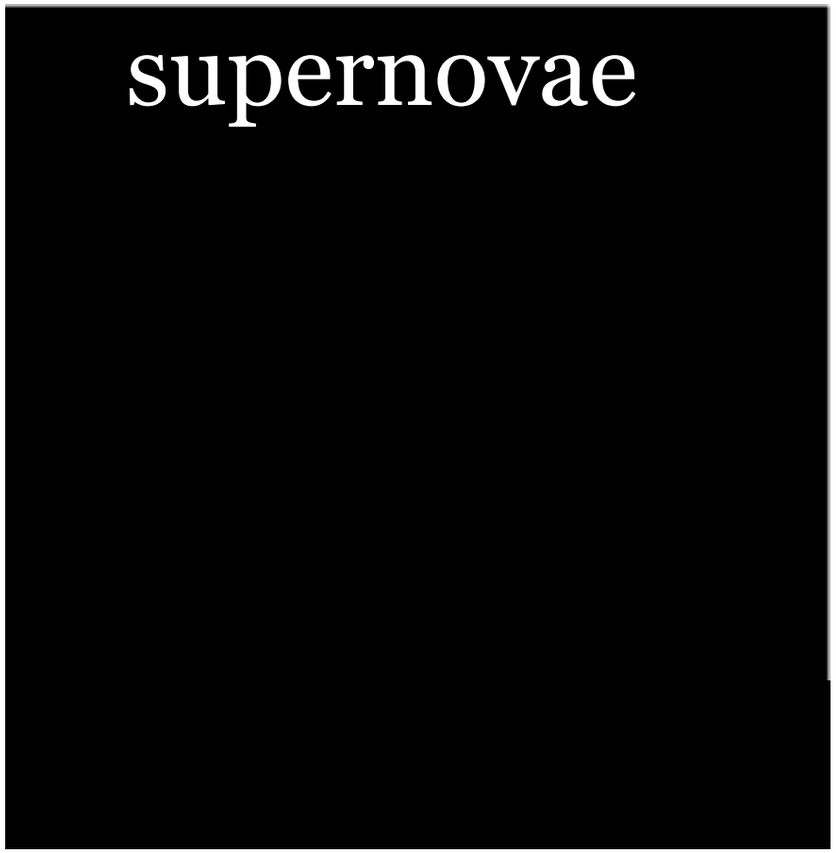
Shea Garrison-Kimmel (Caltech)
with Andrew Wetzel, James Bullock, Phil Hopkins,
Mike Boylan-Kolchin, Robyn Sanderson, and Tyler Kelley

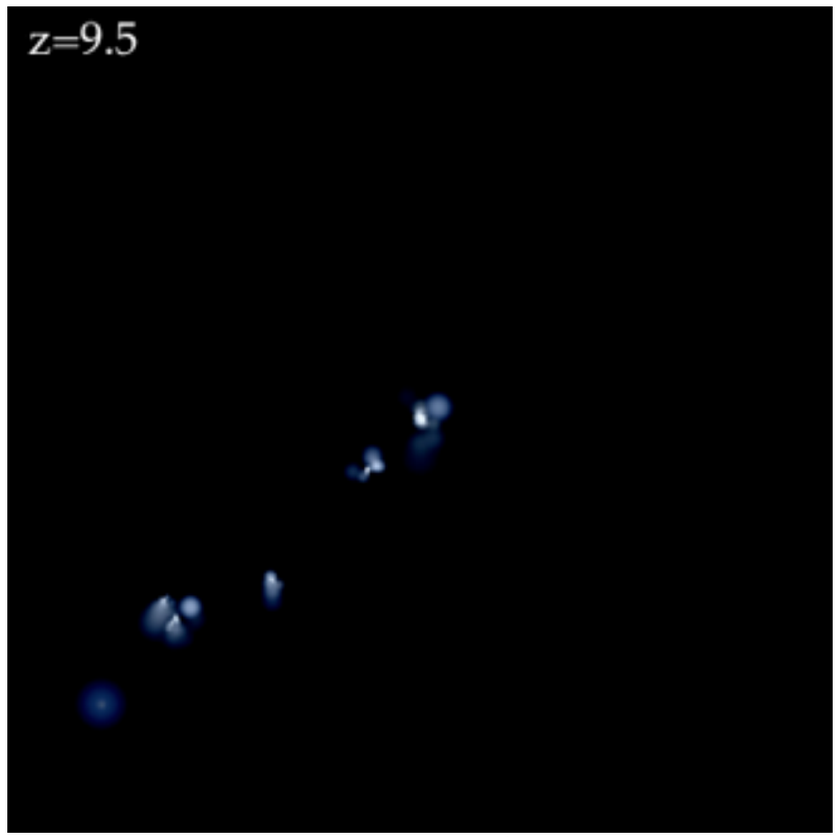
Hydro sims are great!

Movies mostly from P. Hopkins, J. Oñorbe

They include, e.g.,:

supernovae





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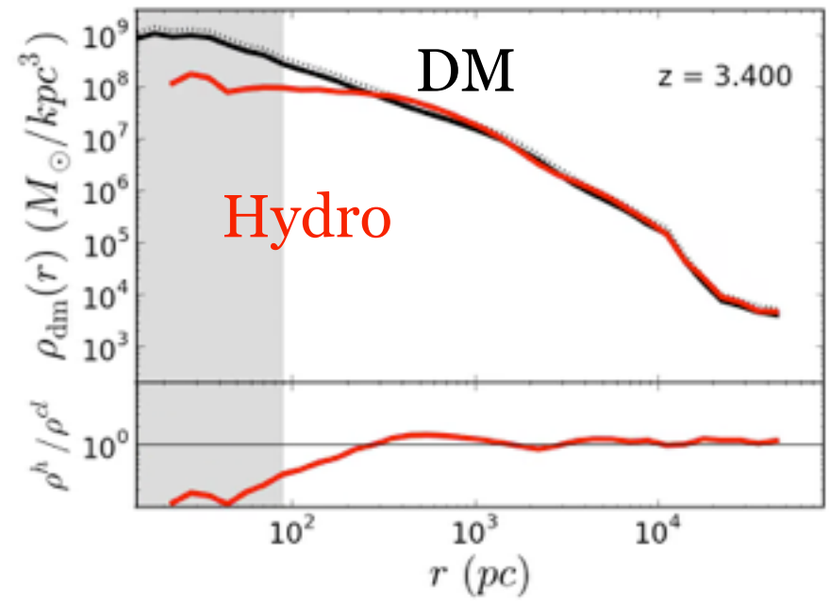
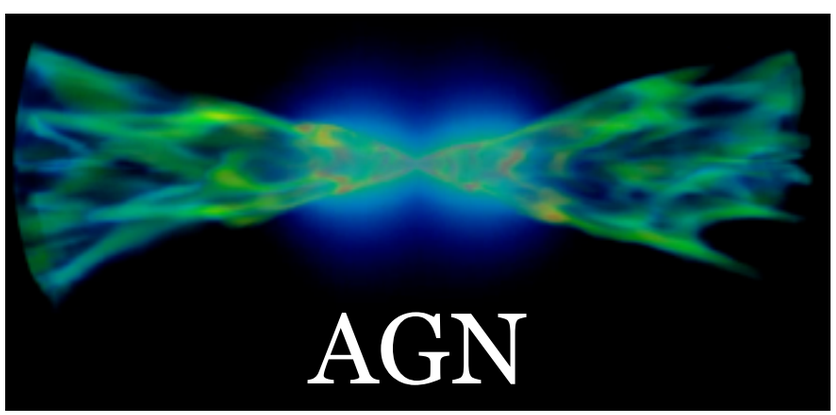


baryon-DM interactions



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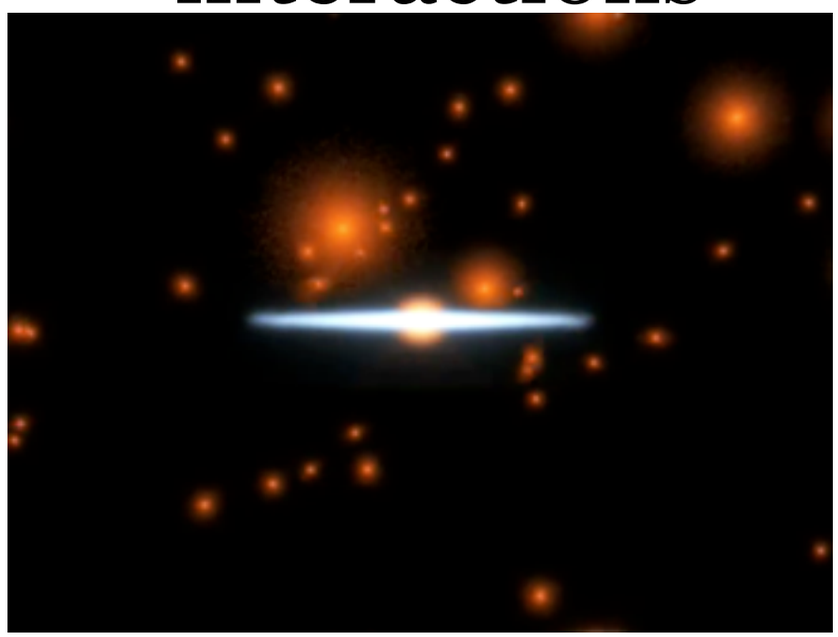
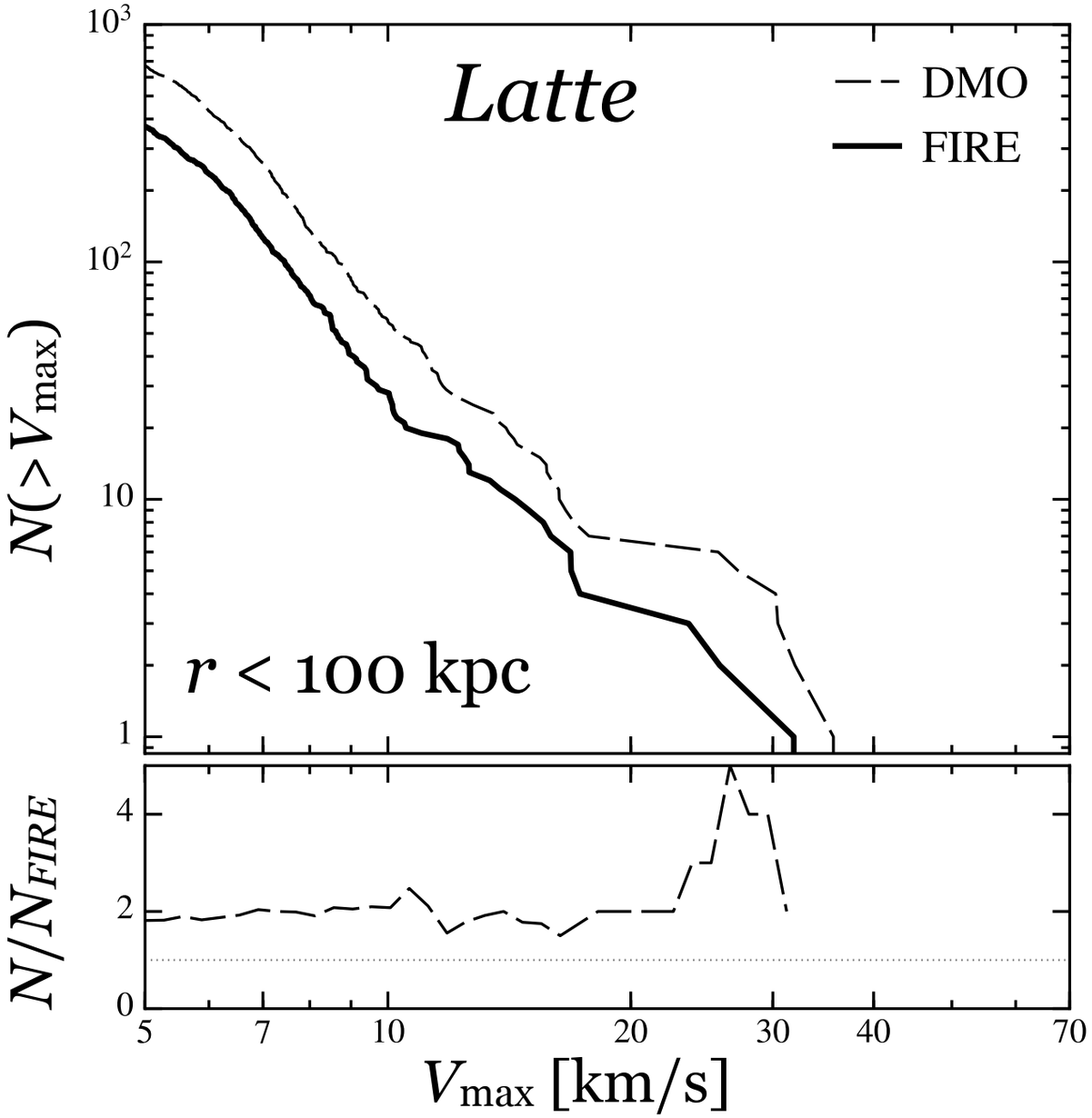


Compare directly to data...and (more) correct!

Baryons affect subhalo populations

*Particle masses in DMO simulations reduced by (1-f_b)



Wetzel+2016

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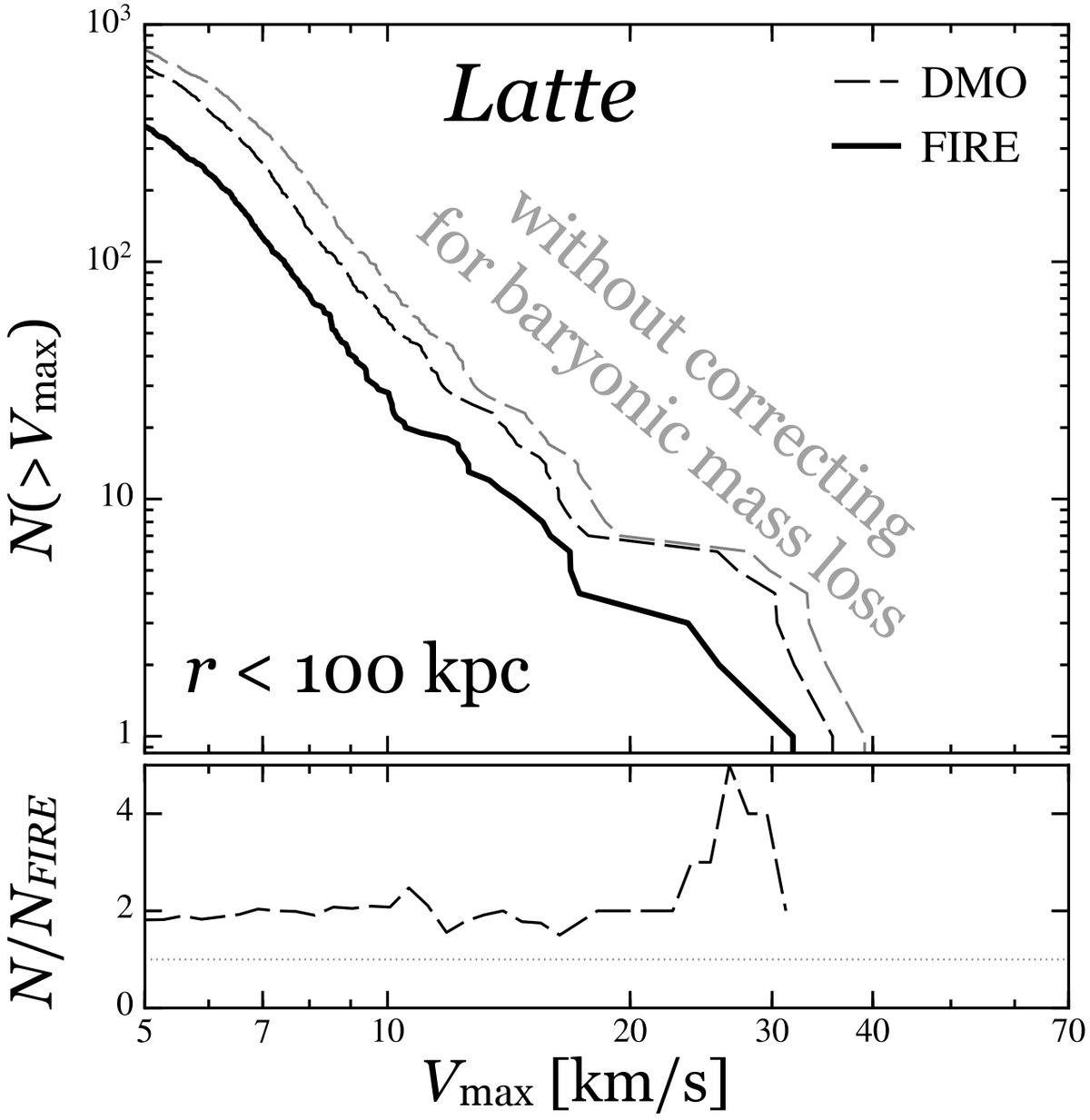

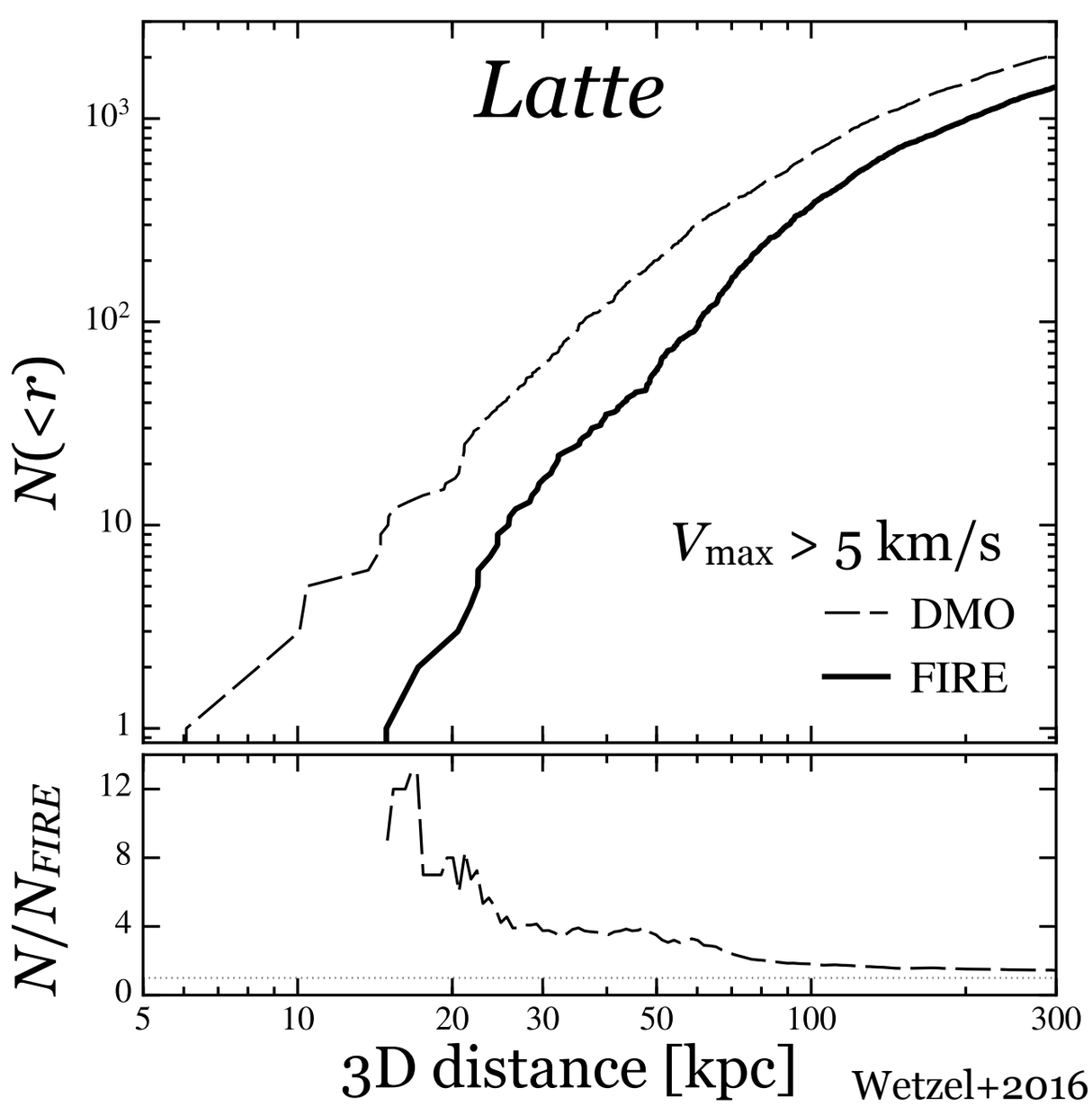

Wetzel+2016

DMO over predicts by a factor of 2 within 100 kpc and a

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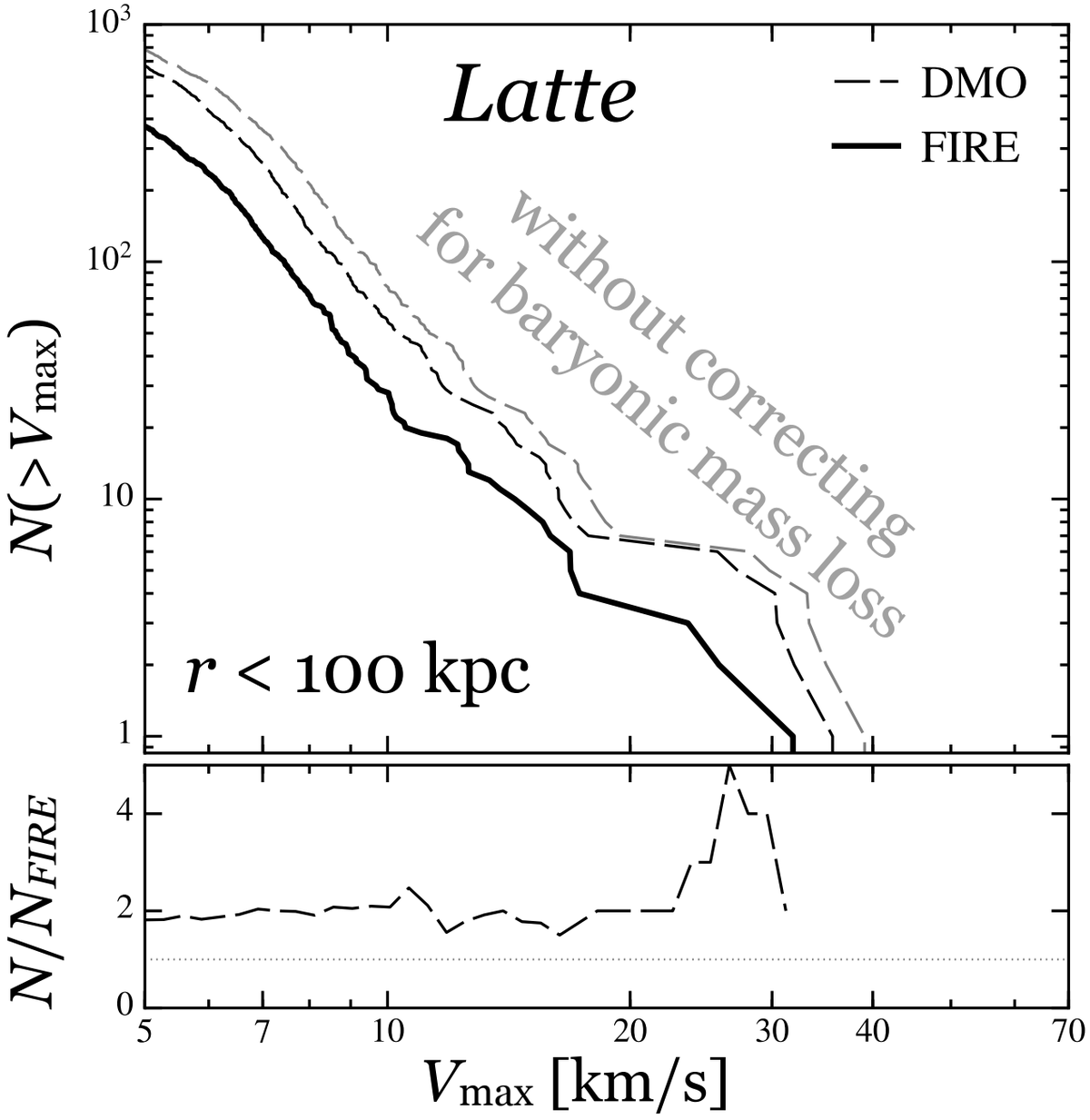

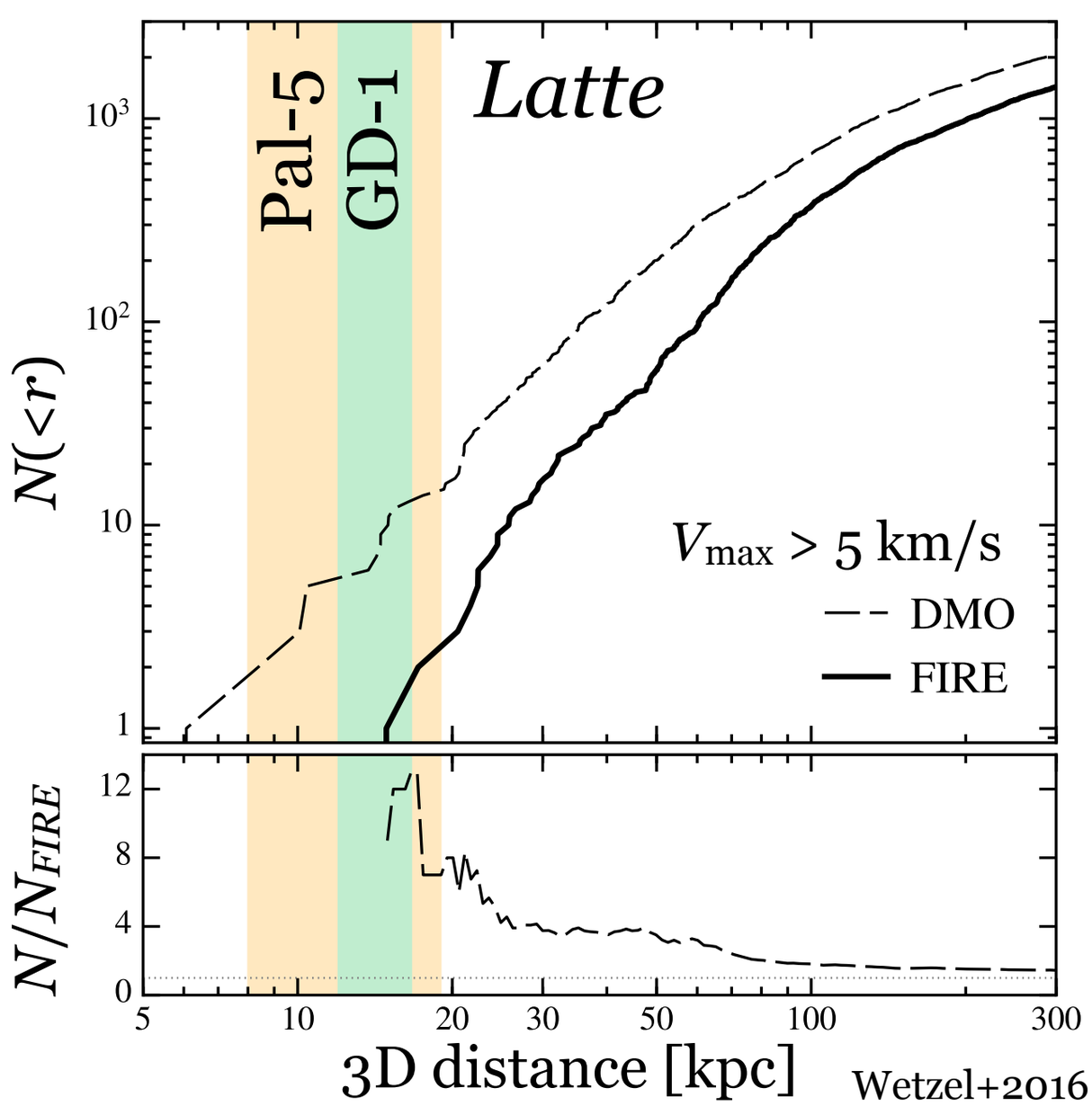

Wetzel+2016

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	Baryonic simulations	DMO simulations
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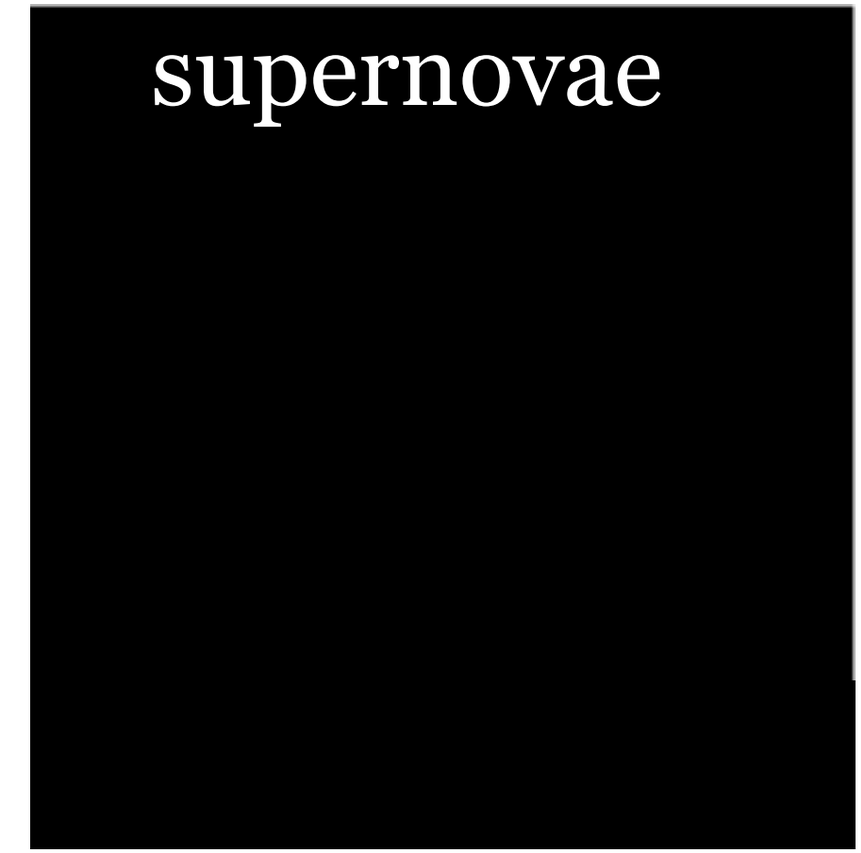

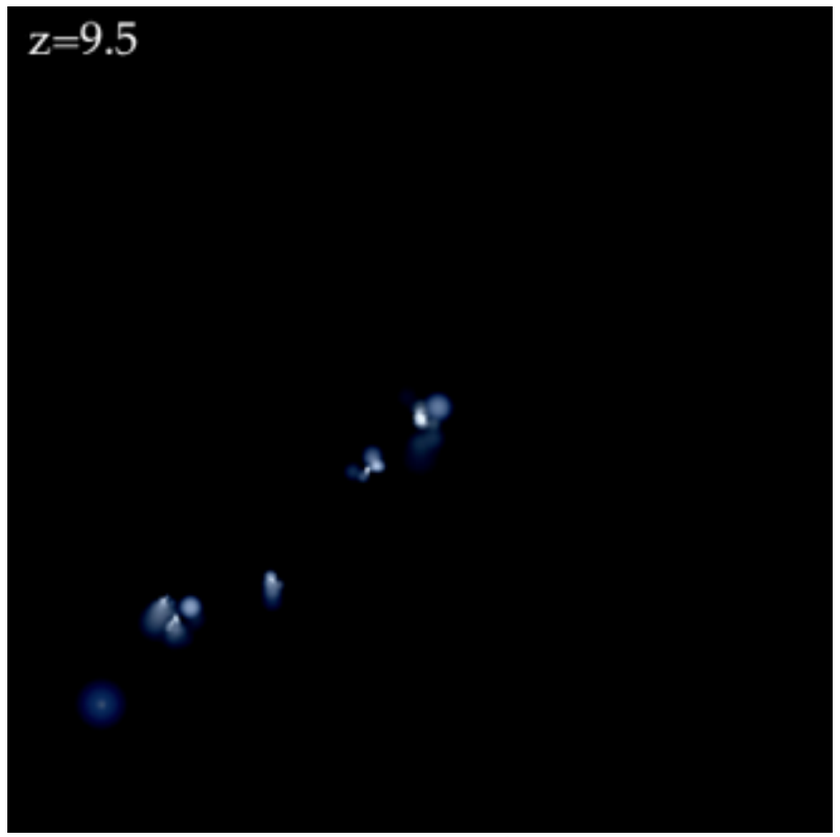

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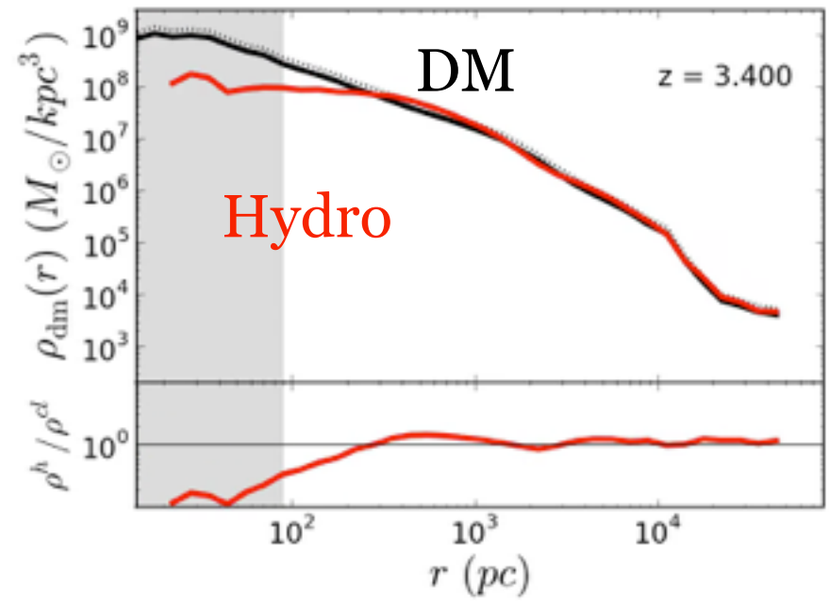

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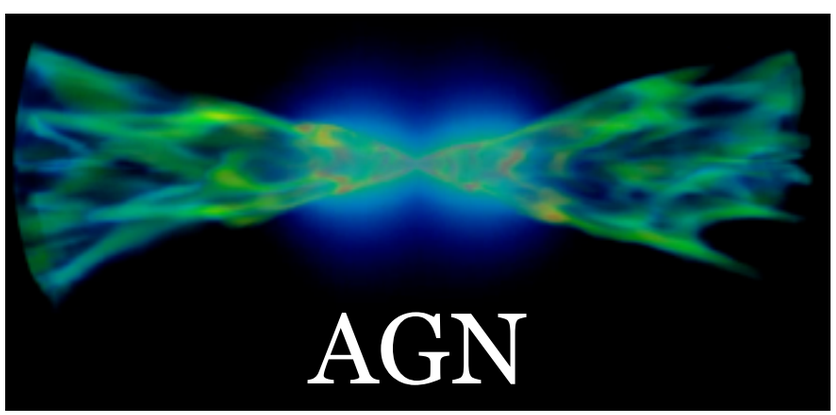

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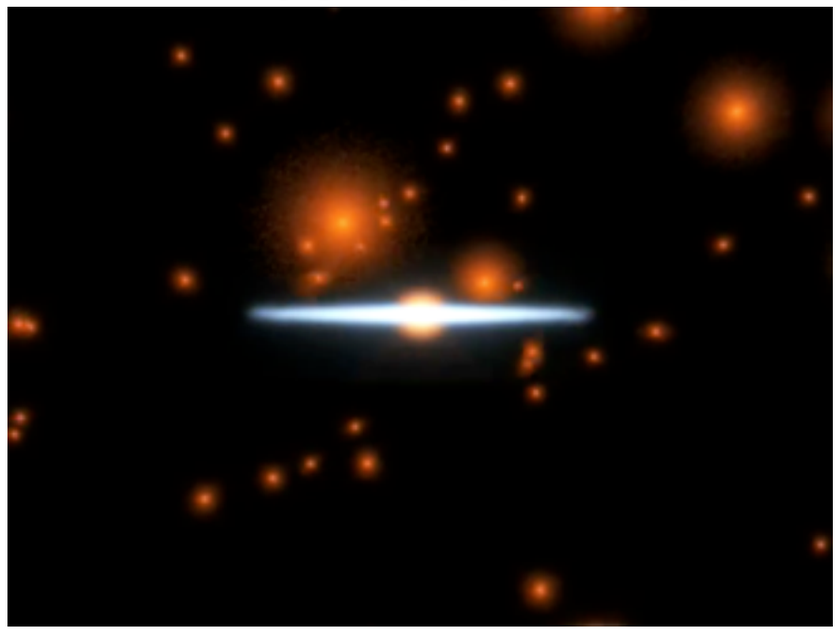

Adding all of this (plus hydro) is very expensive!

Hydro sims are ***costly!***

	Baryonic simulations	DMO simulations
Accurate?	✔	***X***
Cheap?	*Latte* FIRE: 720,000 CPU hours	*Latte* DMO: 6326 CPU hours

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Could simulate 100+ halos in the same CPU time

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Statistical samples?	***X***	✔

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Statistical samples?	***X***	✔

Can’t broadly sample distribution of halo and subhalo properties

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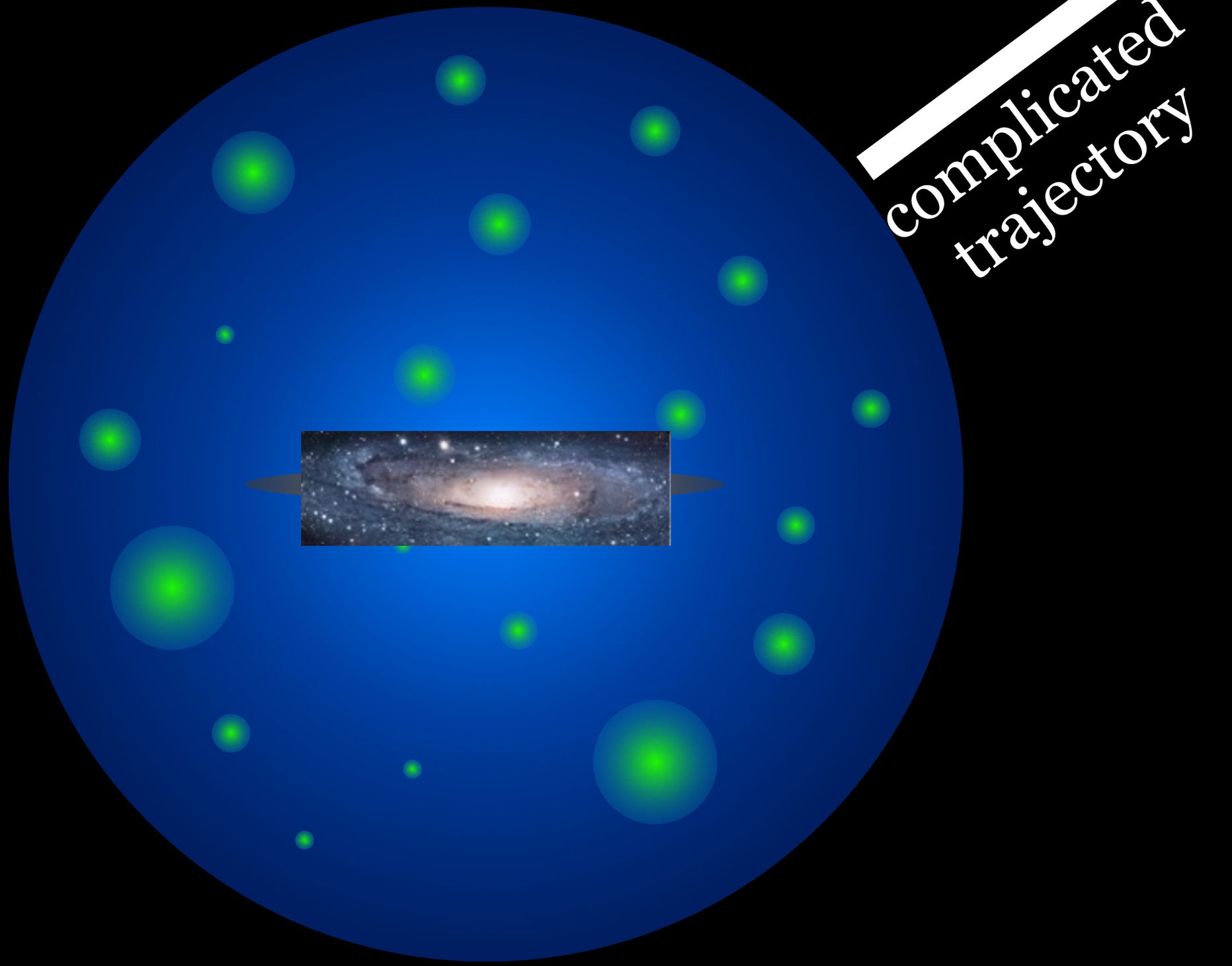
	Baryonic simulations	DMO simulations	Embedded disk
Accurate?	✔	***X***	
Statistical samples?	***X***	✔	



Insert massive particle to track halo center
Add acceleration from a disk *that matches FIRE*

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Accurate?	✔	***X***	
Statistical samples?	***X***	✔	~2x DMO

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	Baryonic simulations	DMO simulations	Embedded disk
Accurate?	✔	***X***	
Statistical samples?	***X***	✔	✔

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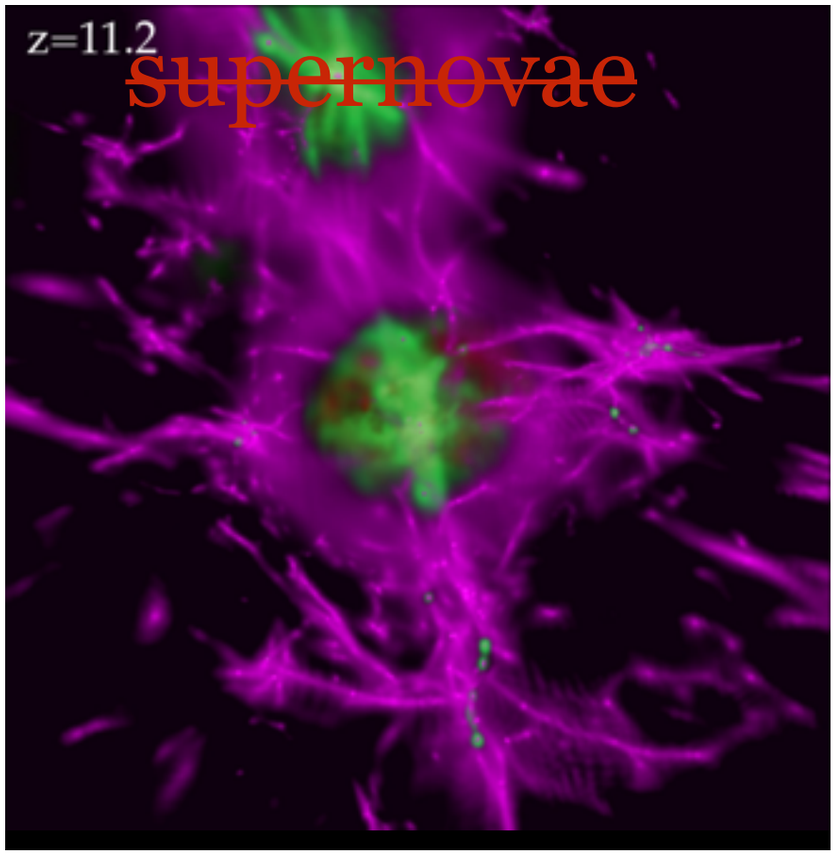

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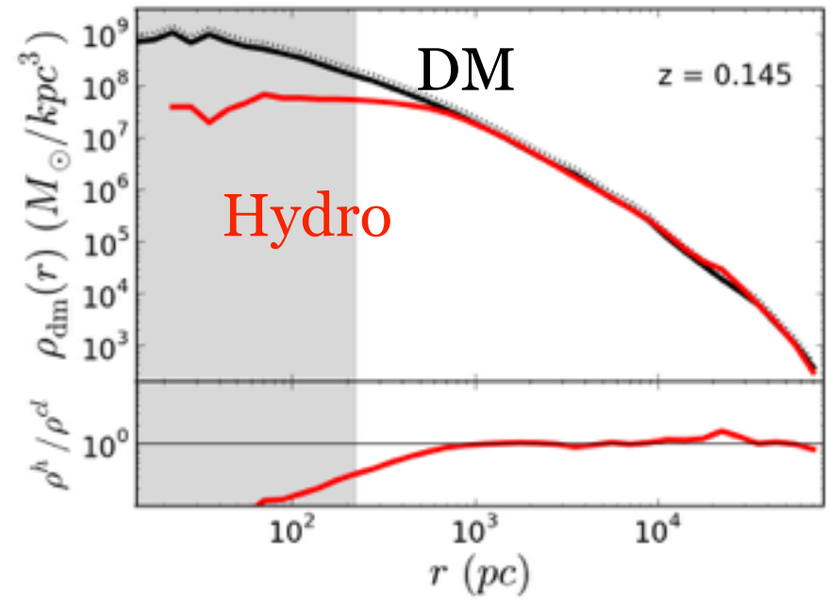

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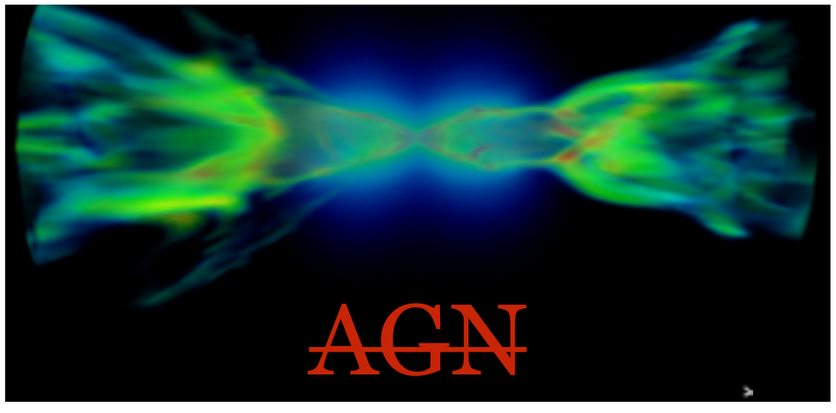

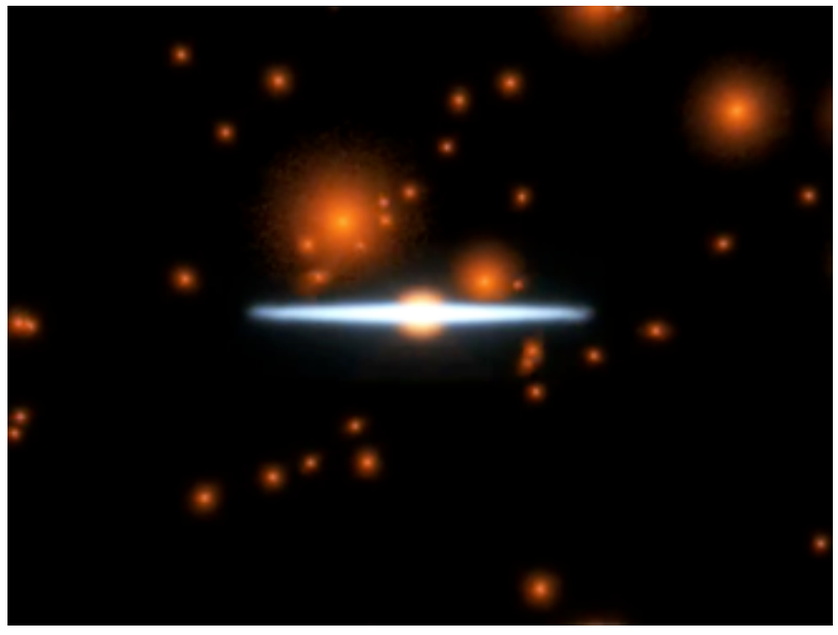

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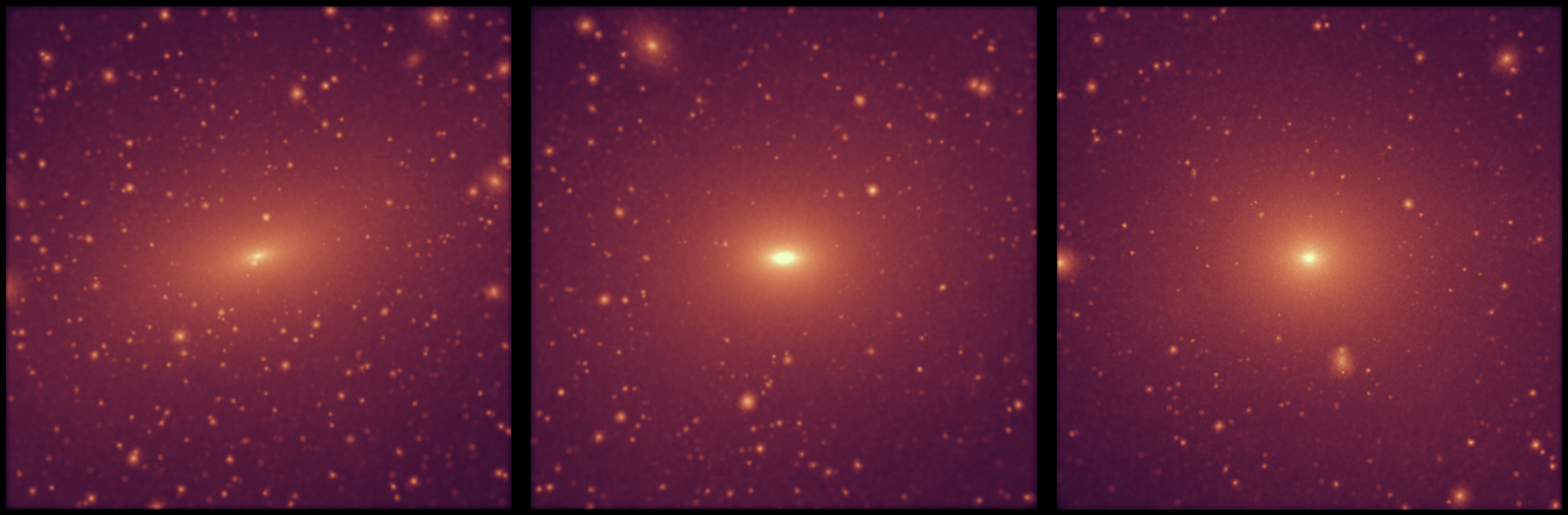
	Baryonic simulations	DMO simulations	Embedded disk
Accurate?	✔	***X***	✔
Statistical samples?	***X***	✔	✔

How effective is the disk?

Visualizing the local *DM* density



GK+, in prep

100 kpc

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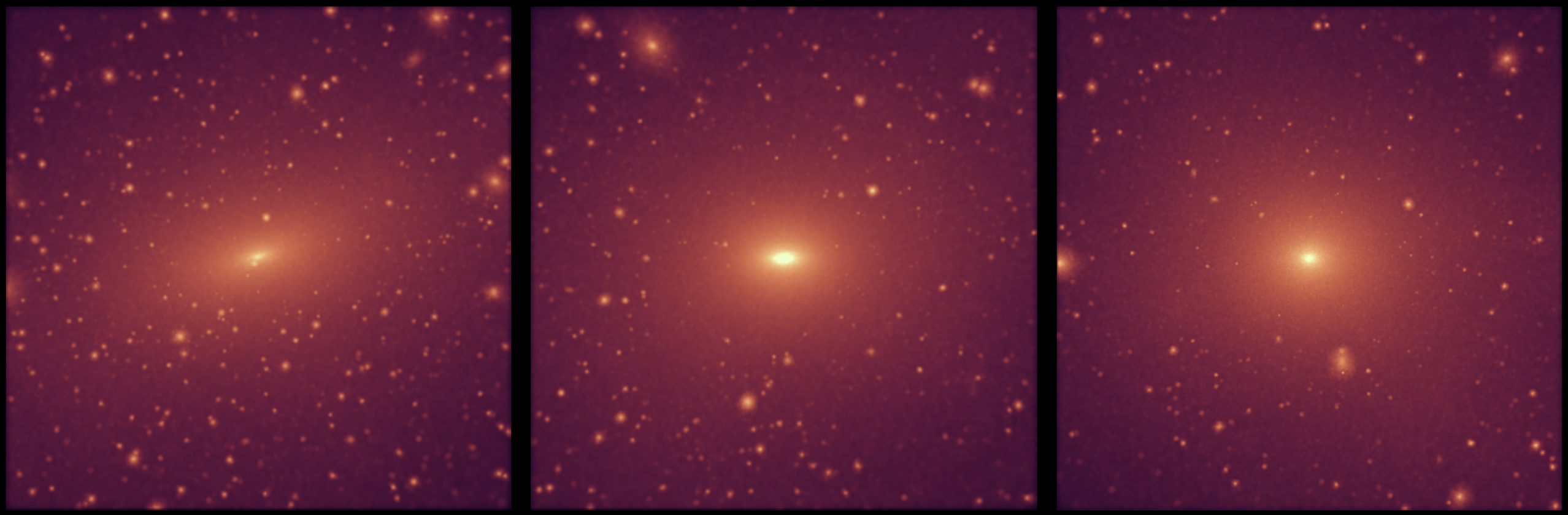
Visualizing the local *DM* density

DMO

??

??



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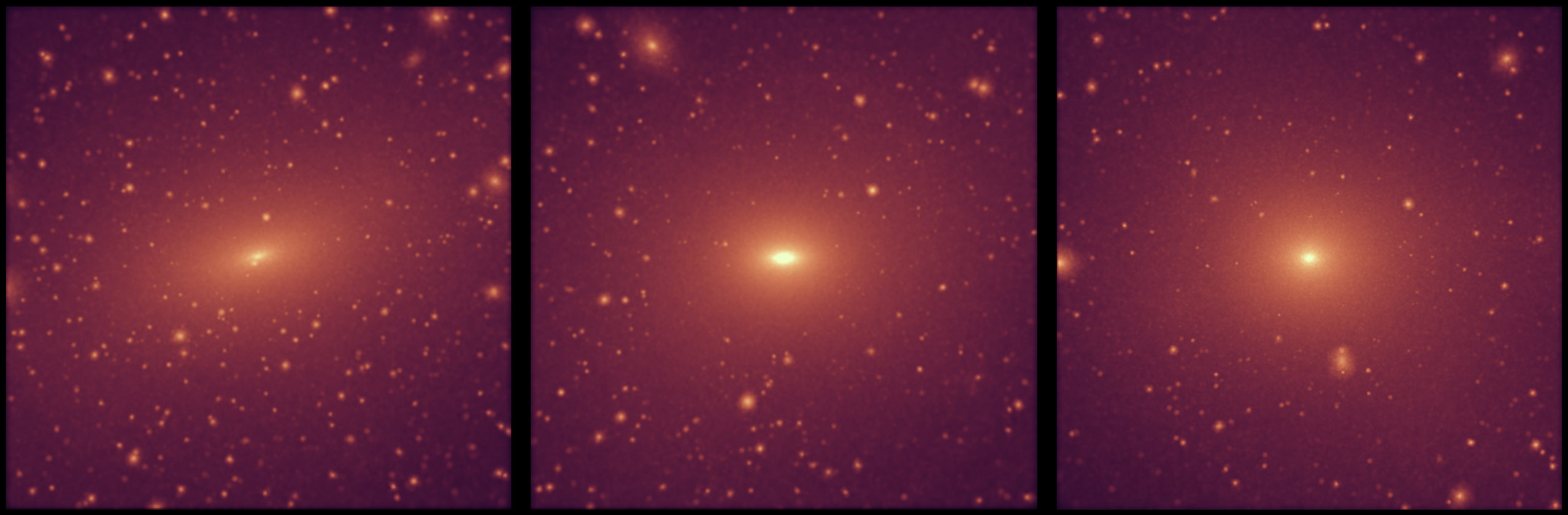
FIRE



GK+, in prep

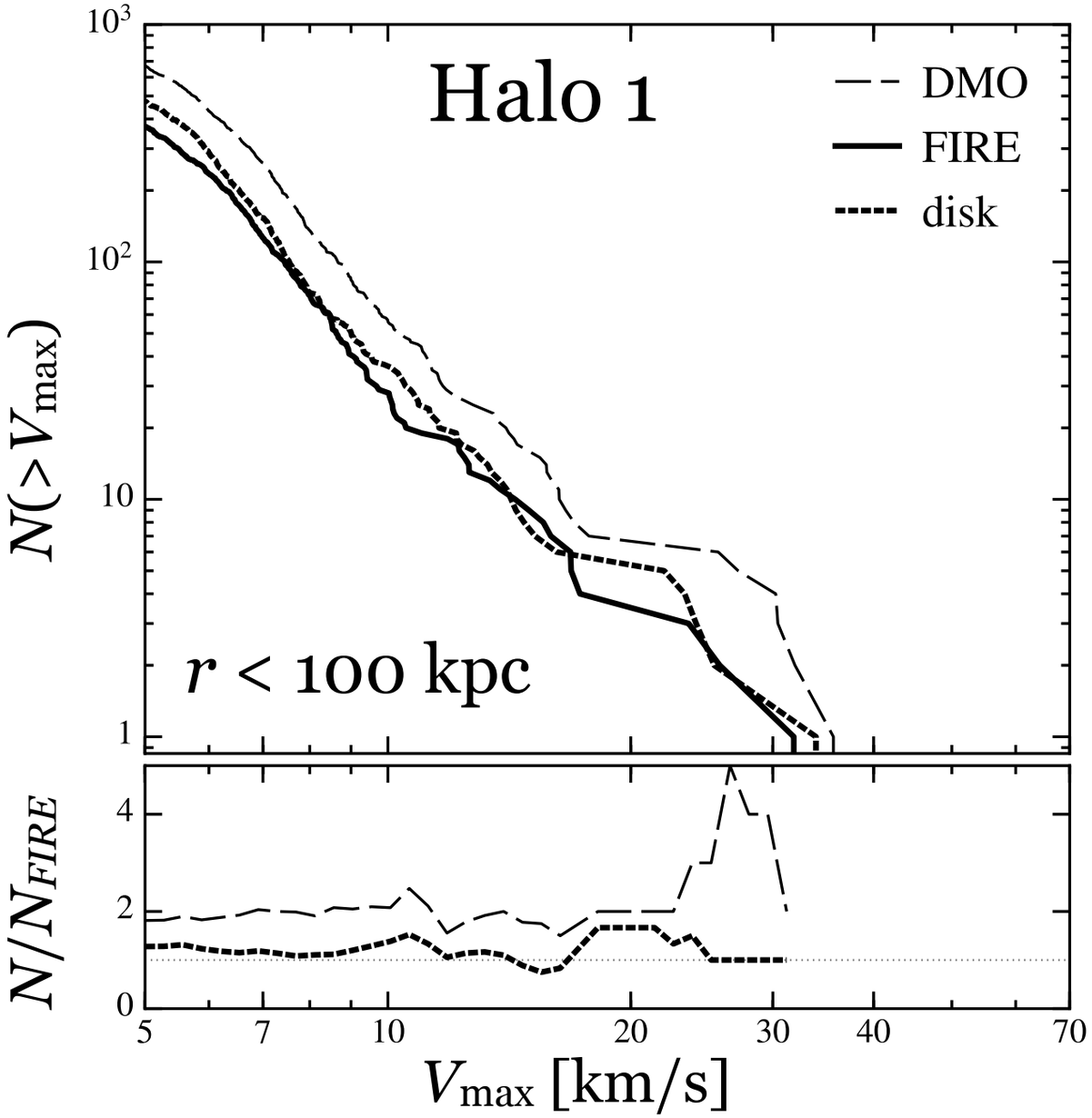
100 kpc

How much of the stripping/destruction is due to the galaxy?
How well do we reproduce FIRE with the potential?

Mass functions

GK+, in prep

*Particle masses in DMO simulations reduced by (1-f_b)



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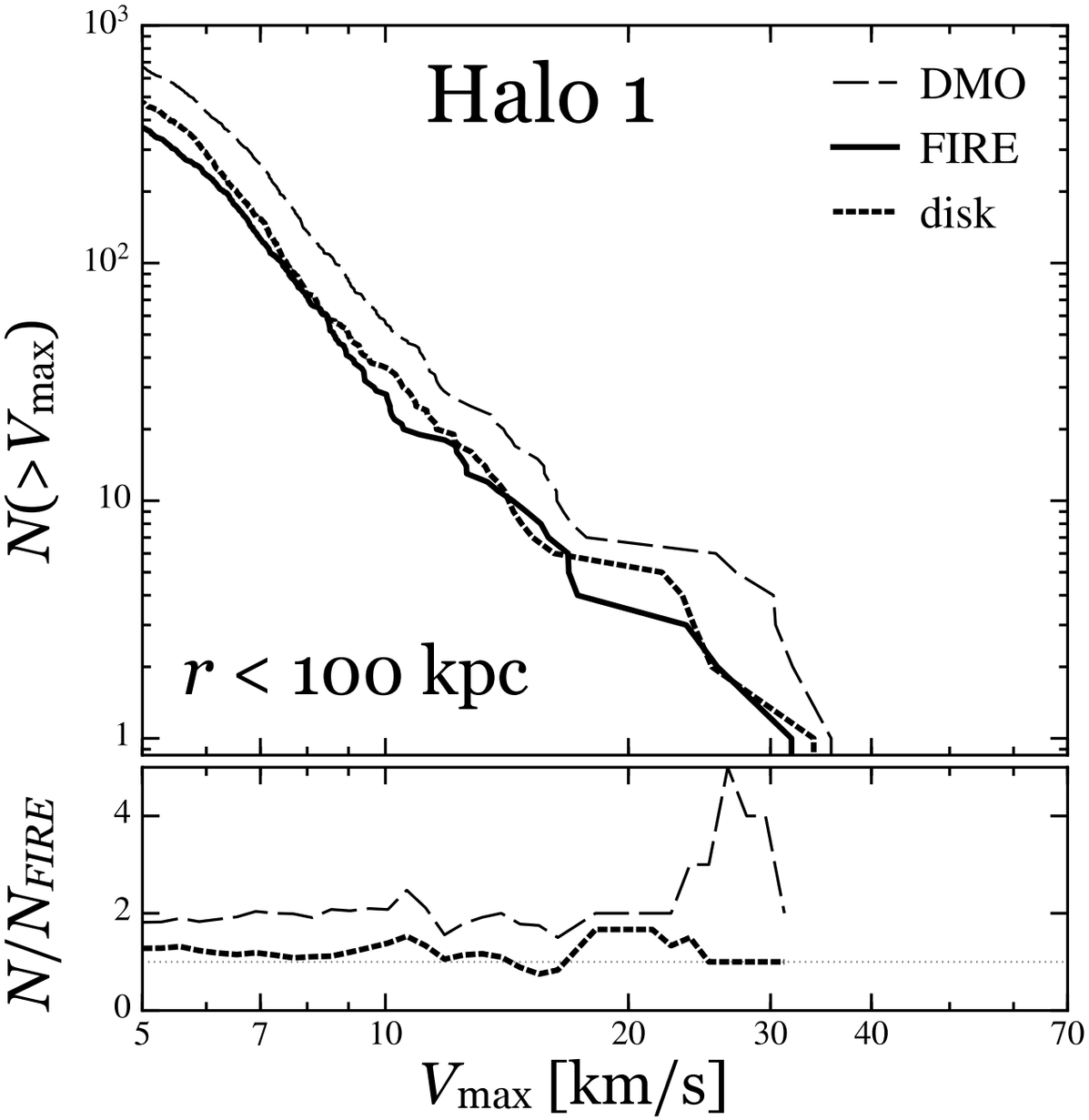

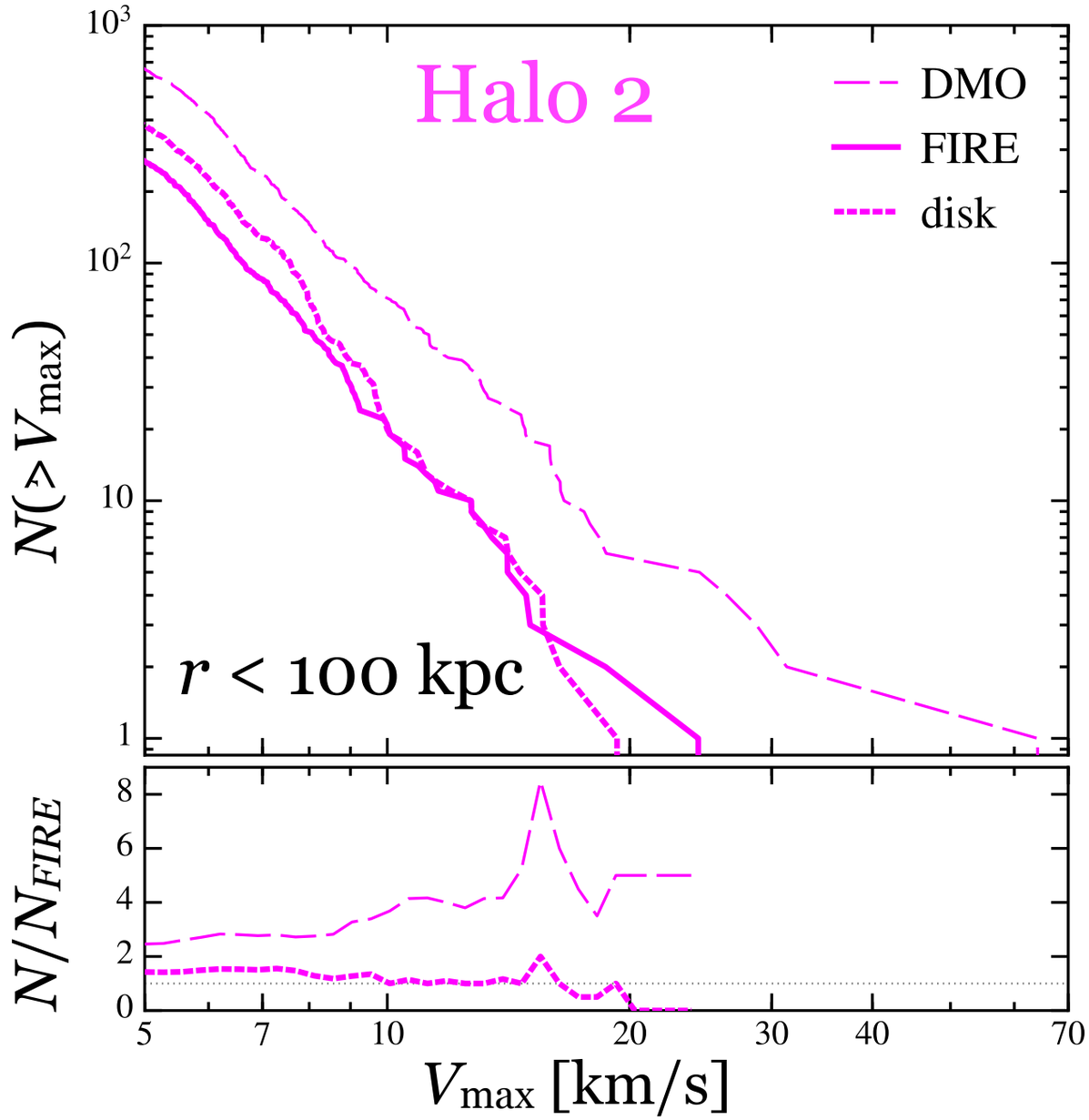

Only including the disk brings the DMO simulations into agreement at 25% level

Mass functions

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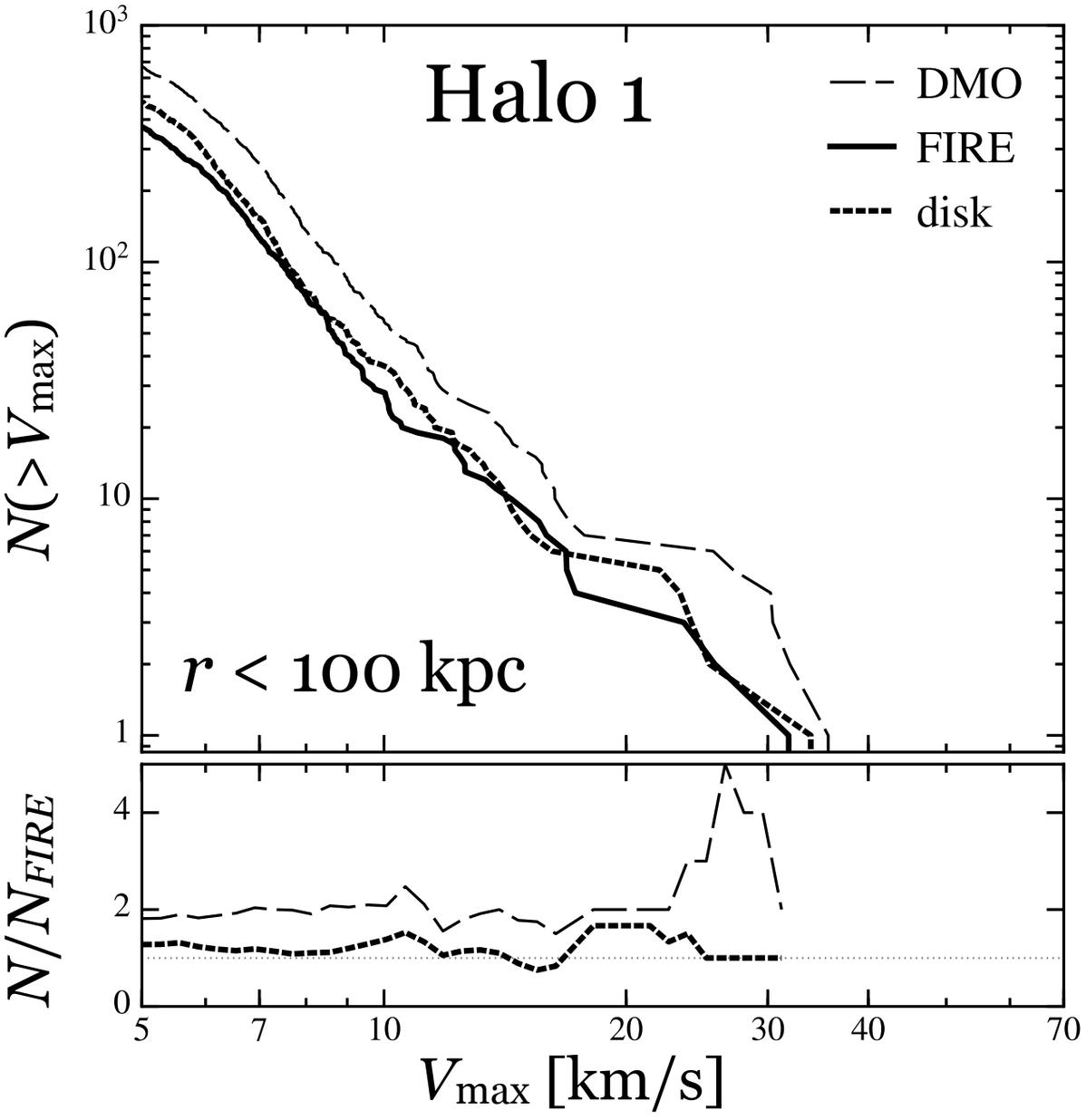

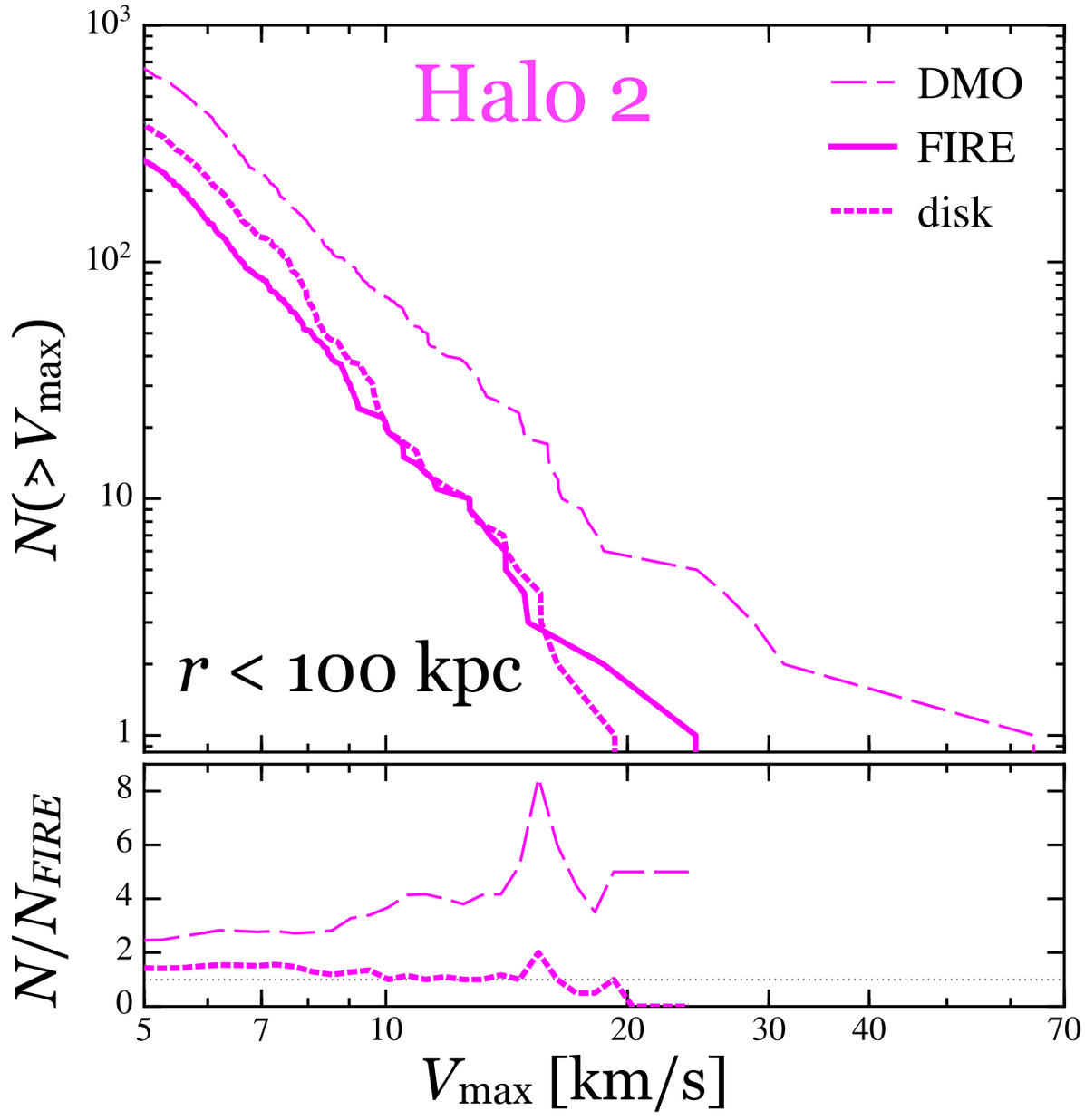

The central galaxy is responsible for 2/3 - 3/4 of the substructure stripping/destruction for r < 100 kpc

Radial distributions

GK+, in prep

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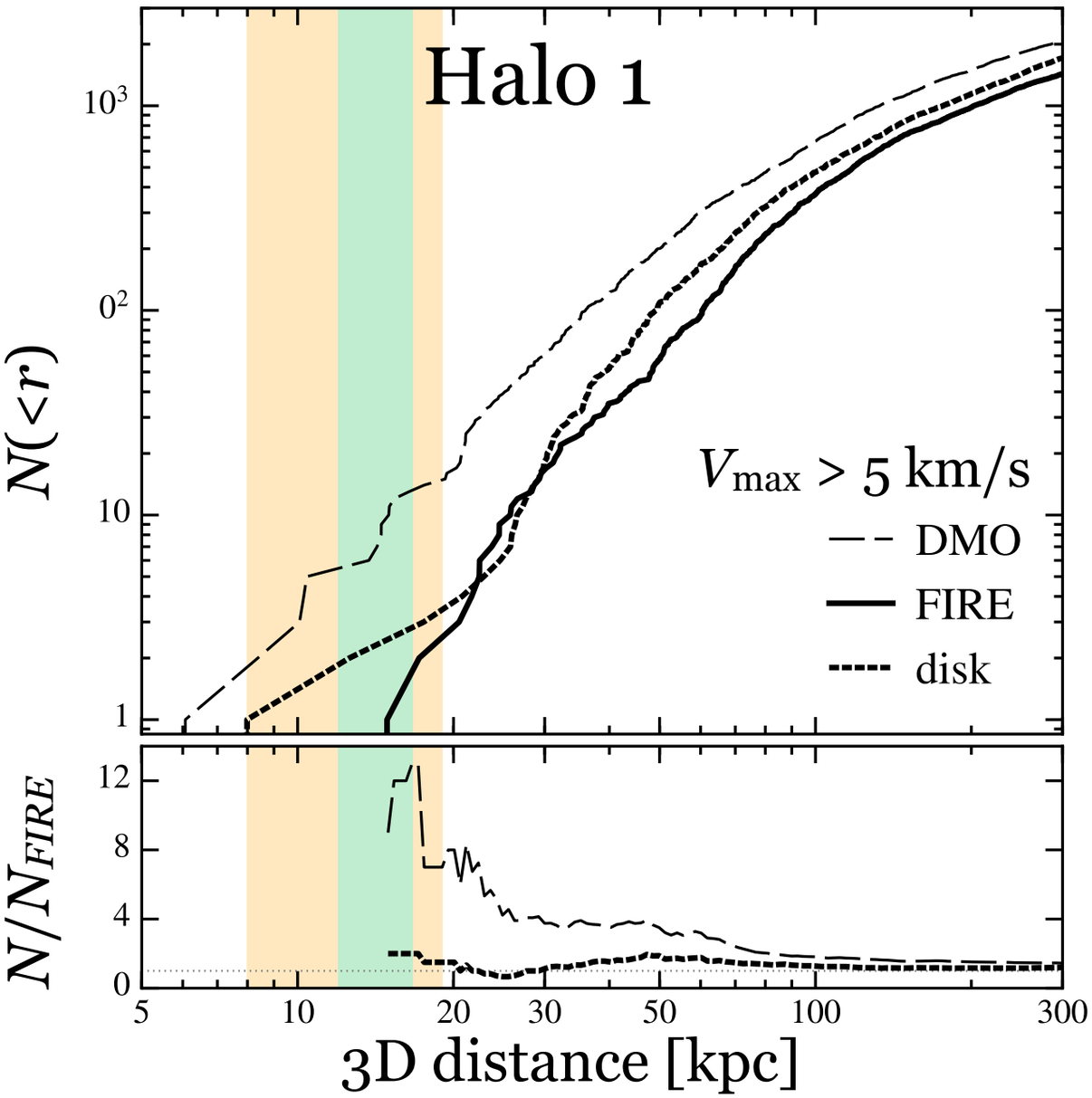

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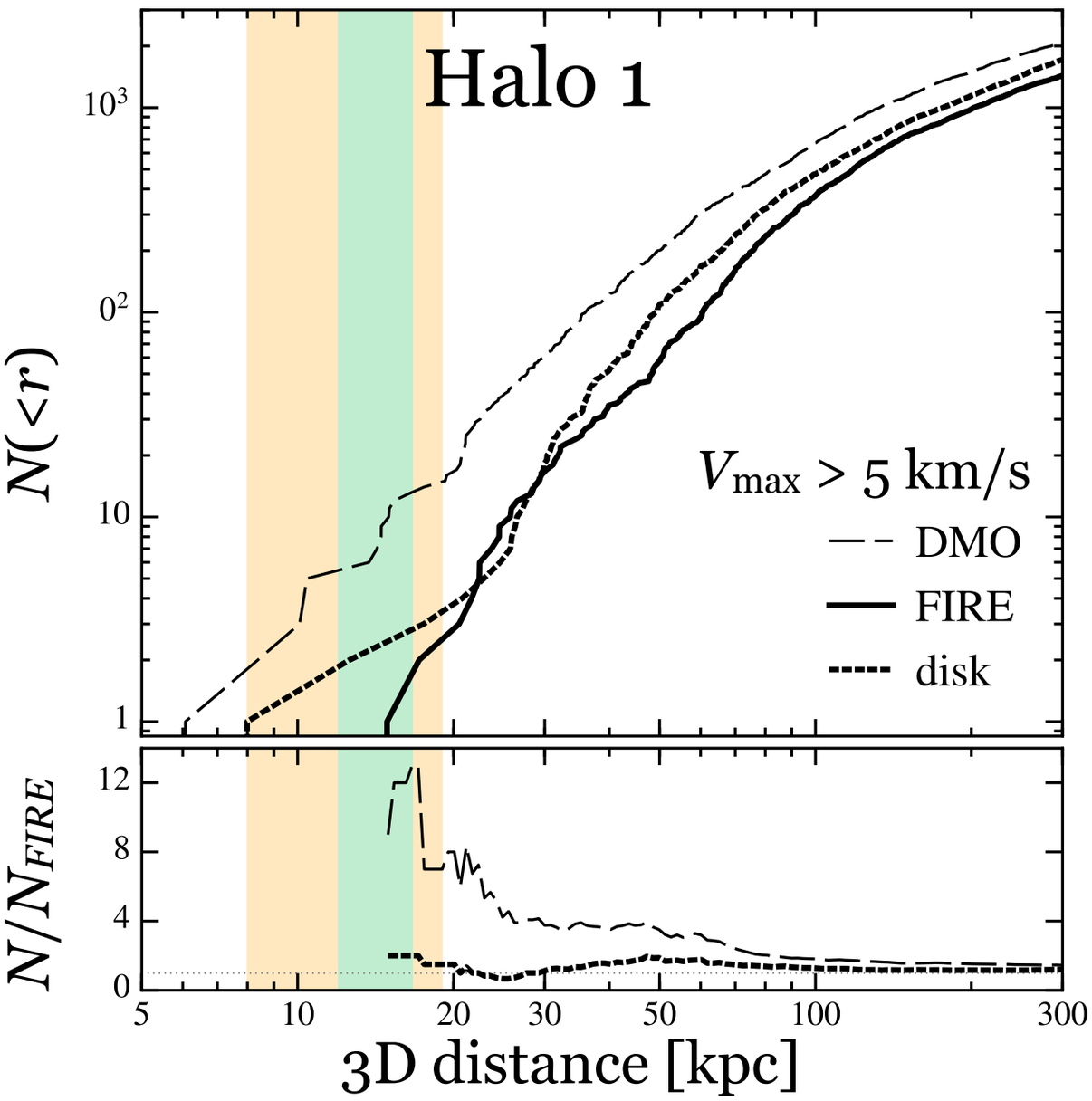

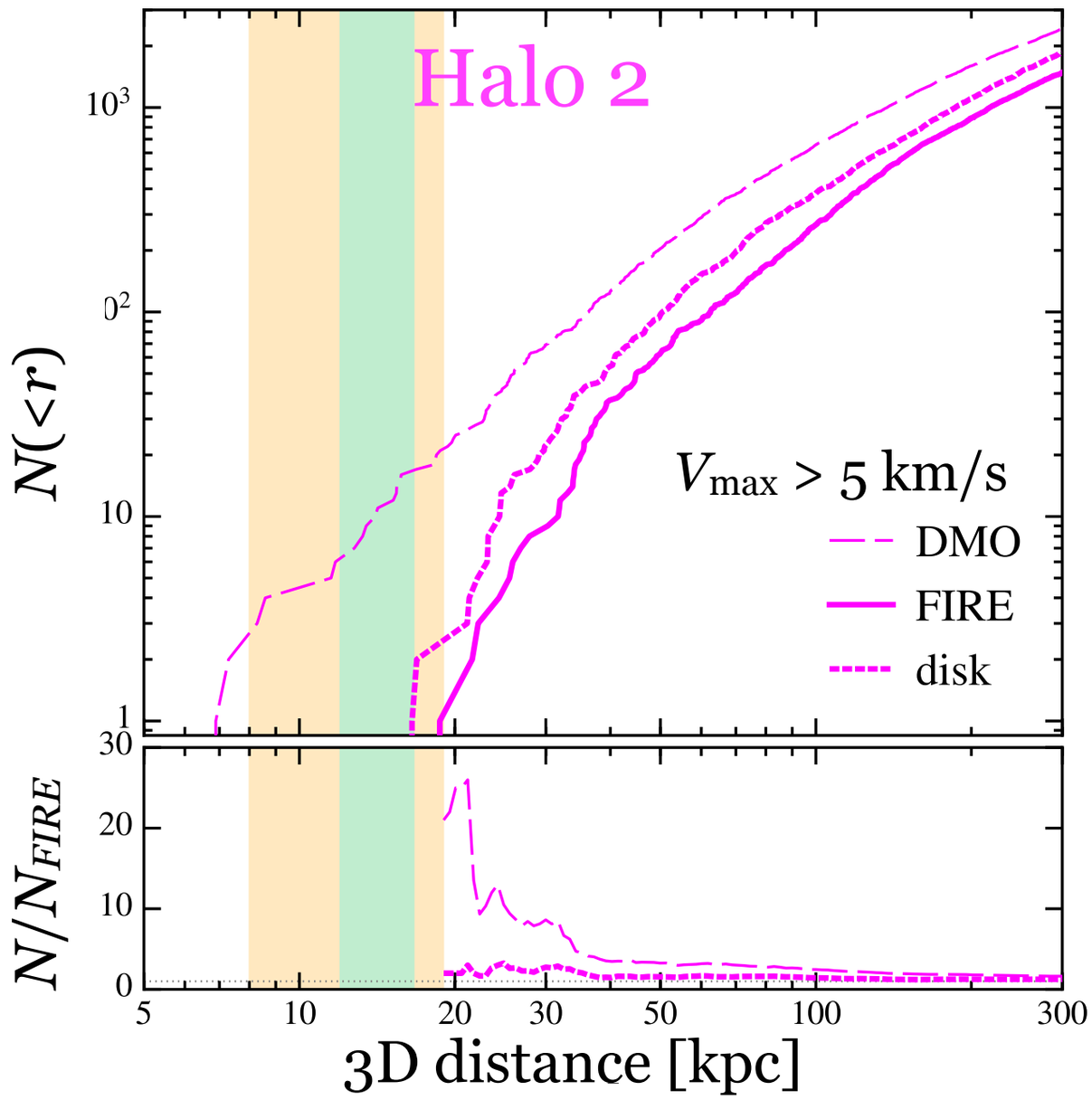

Destruction is greatest at small radii: DMO over predicts by a factor of at least 5-10 at r < 30 kpc

Radial distributions

GK+, in prep

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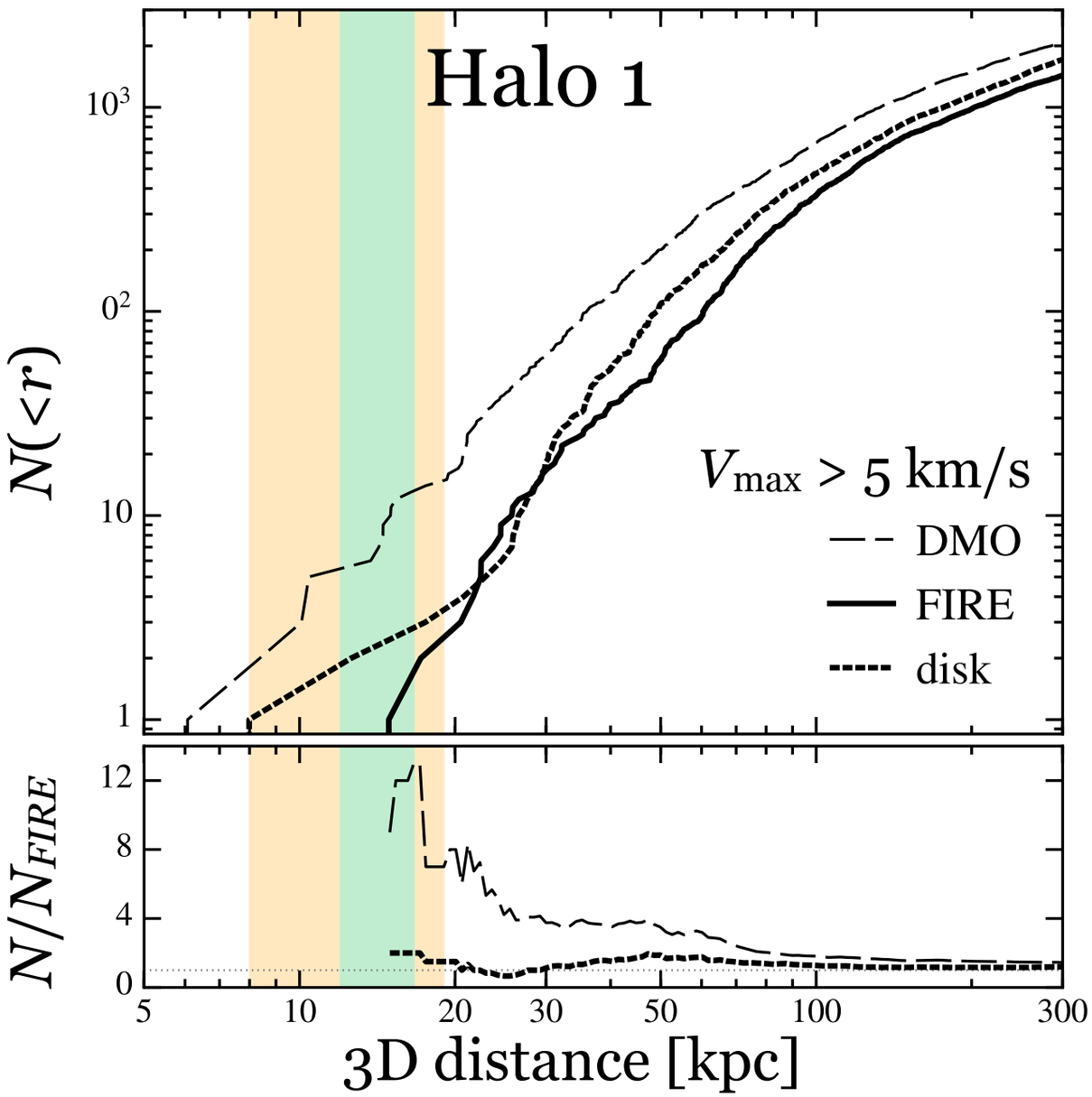

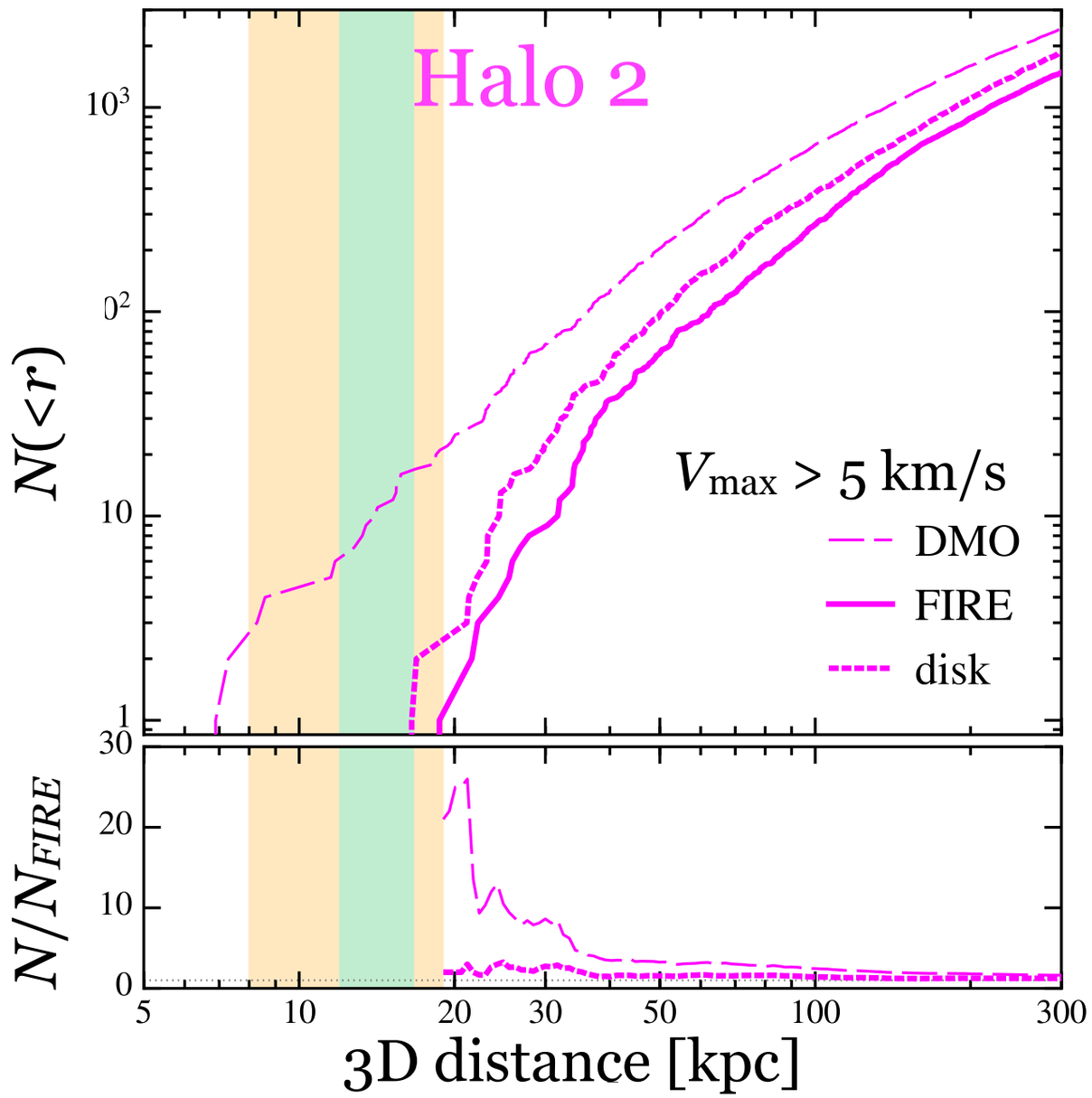

The embedded potential is responsible for at least 75% of that destruction

Radial distributions

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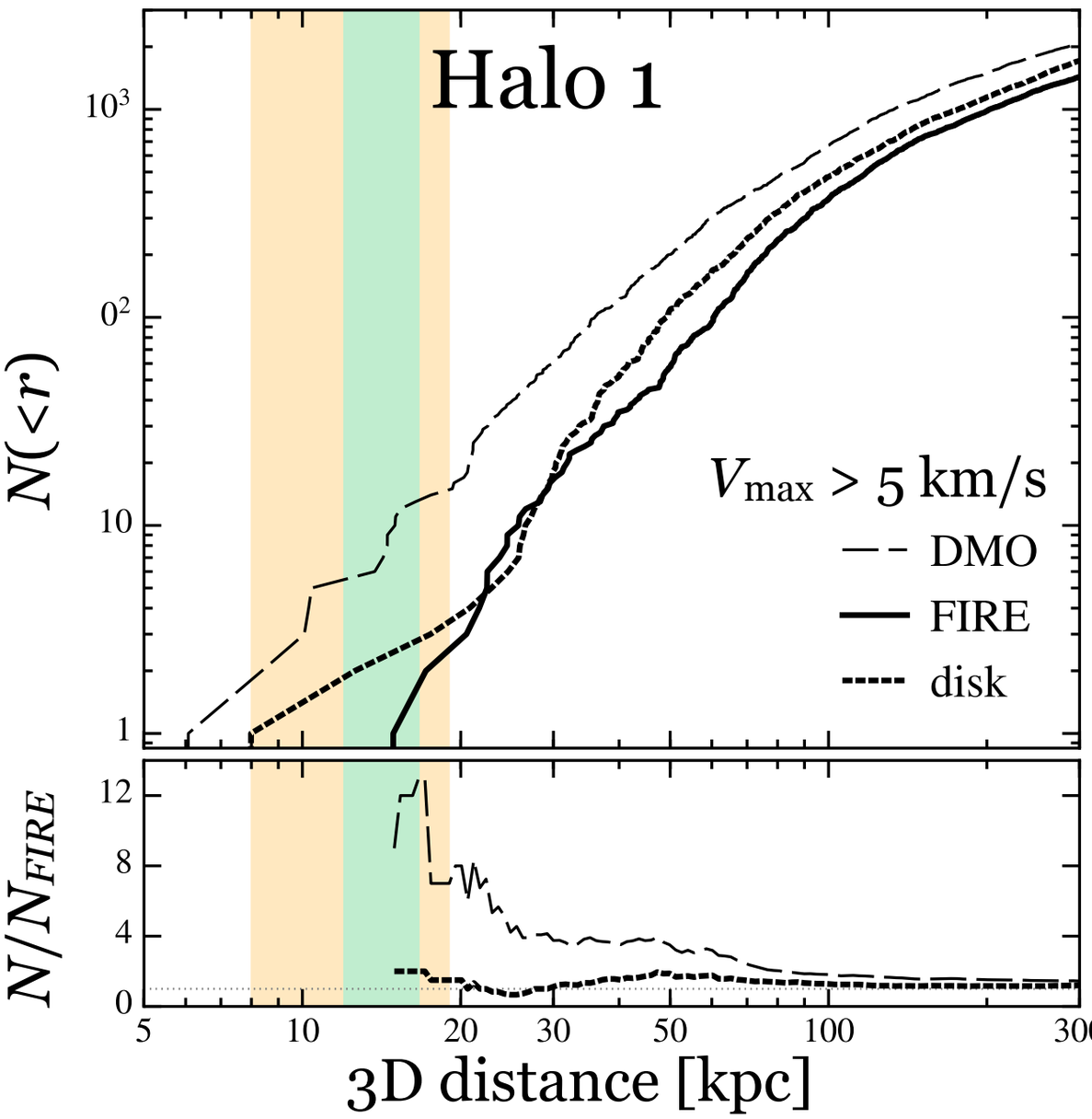
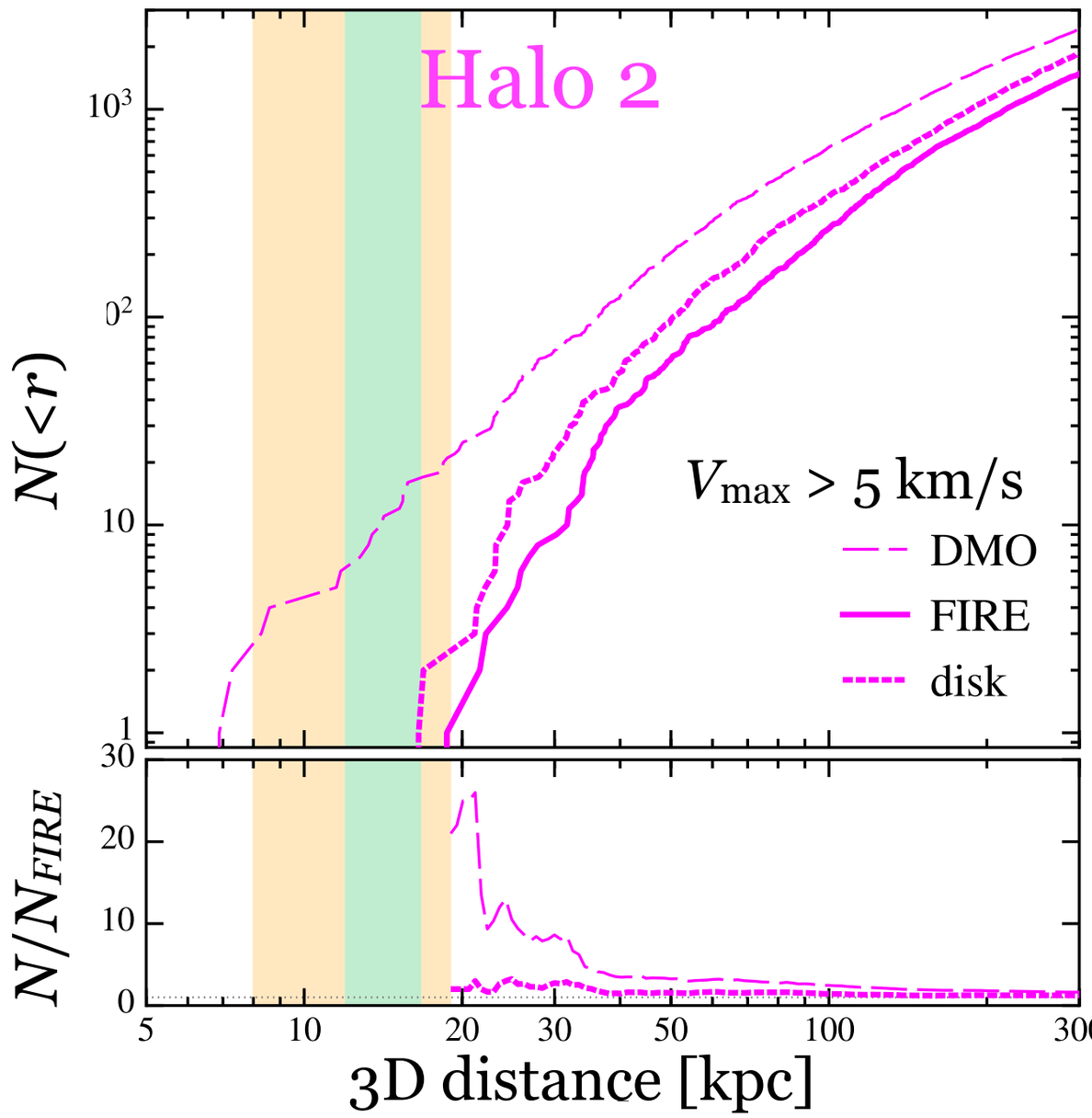




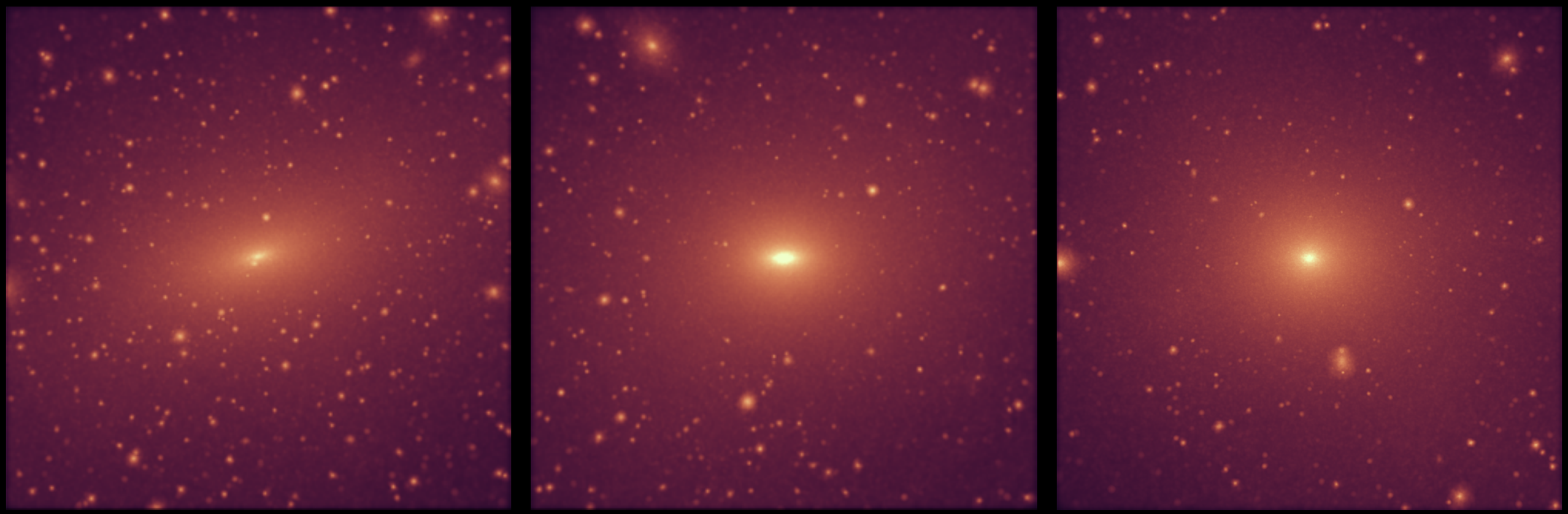
Null results from stellar streams within 20 kpc are in line with predictions from LCDM

e.g., Ibata+201

How effective is the disk?

Visualizing the local *DM* density

DMO | embedded disk | FIRE



GK+, in prep

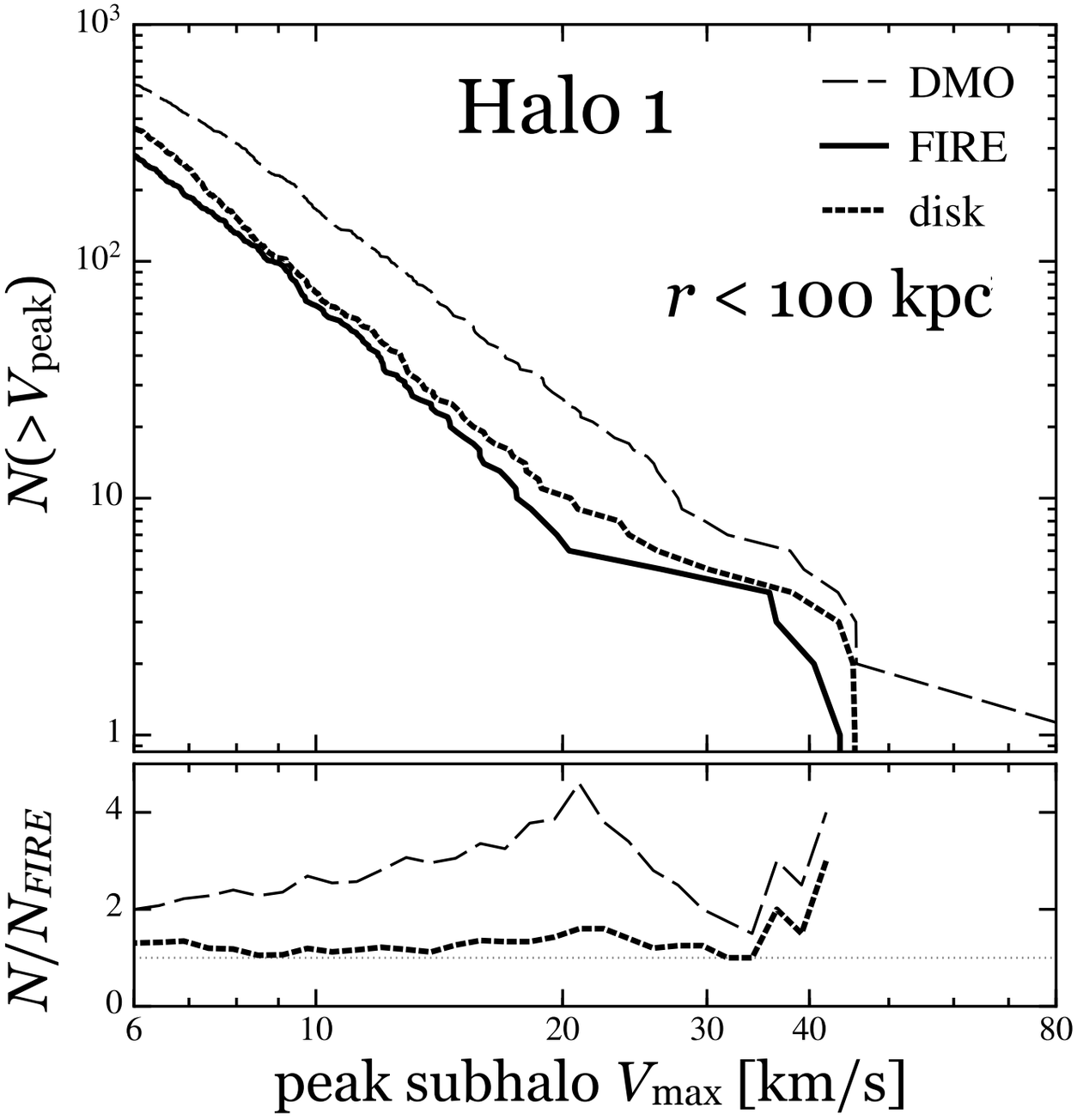
100 kpc

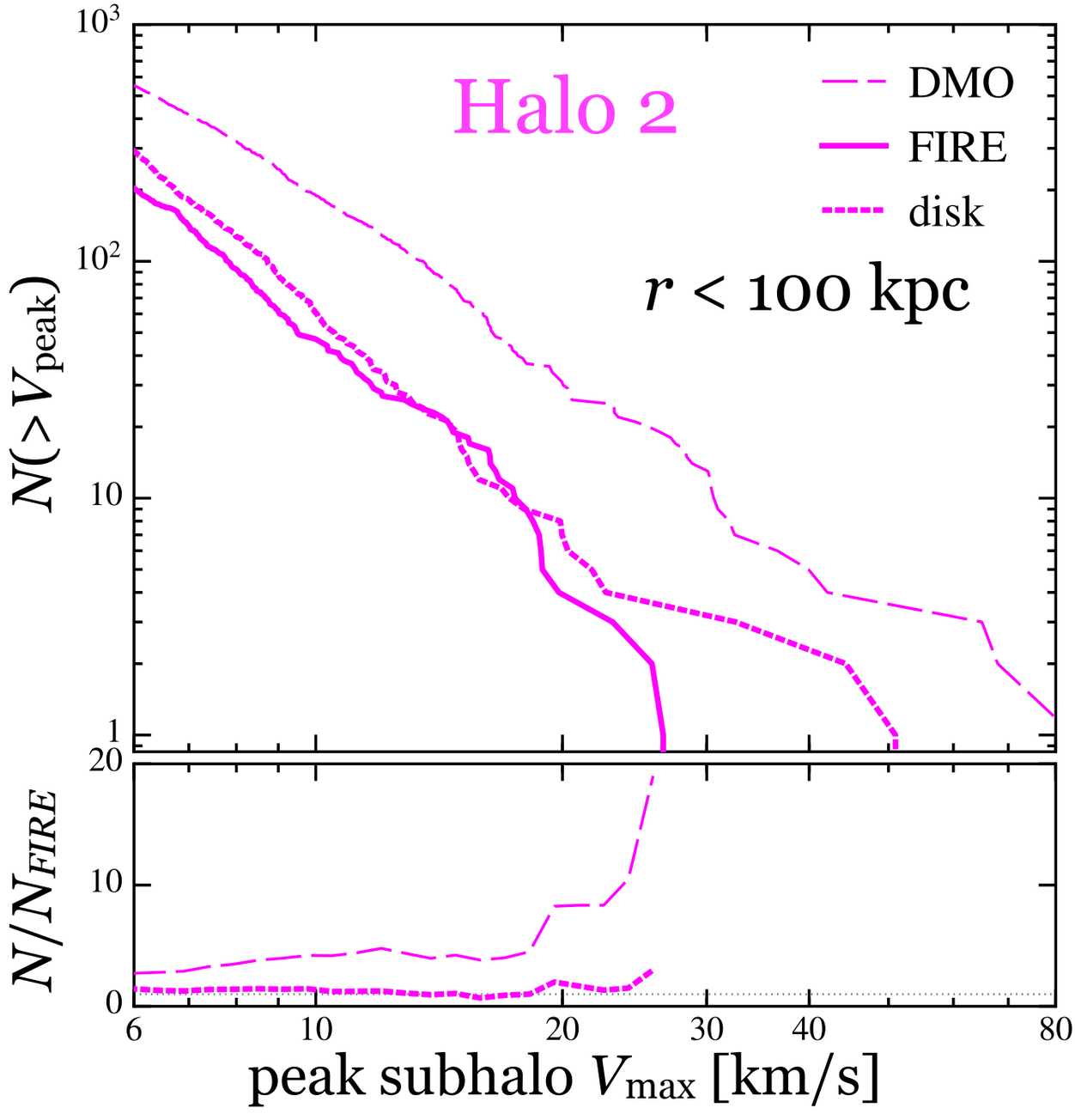
Simple model matches mass function and radial profiles
within ~25% *vs* 100-500% errors in pure DMO

Stripping or destruction?

GK+, in prep

*Particle masses in DMO simulations reduced by $(1\text{-}f_b)$





No trend in V_{peak}: destroys subhalos at all masses

Captures destruction better than stripping

Stripping or destruction?

GK+, in prep

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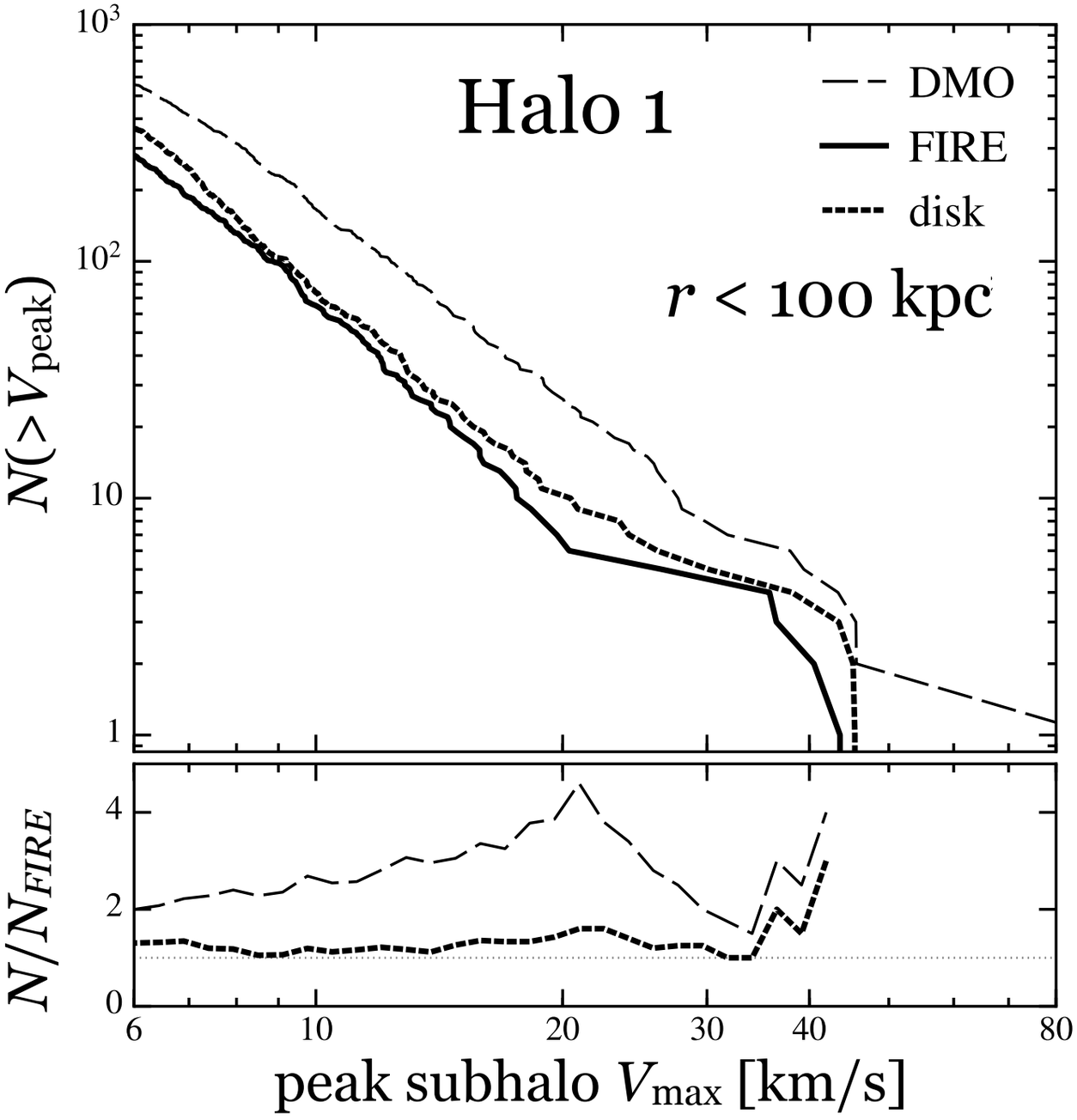

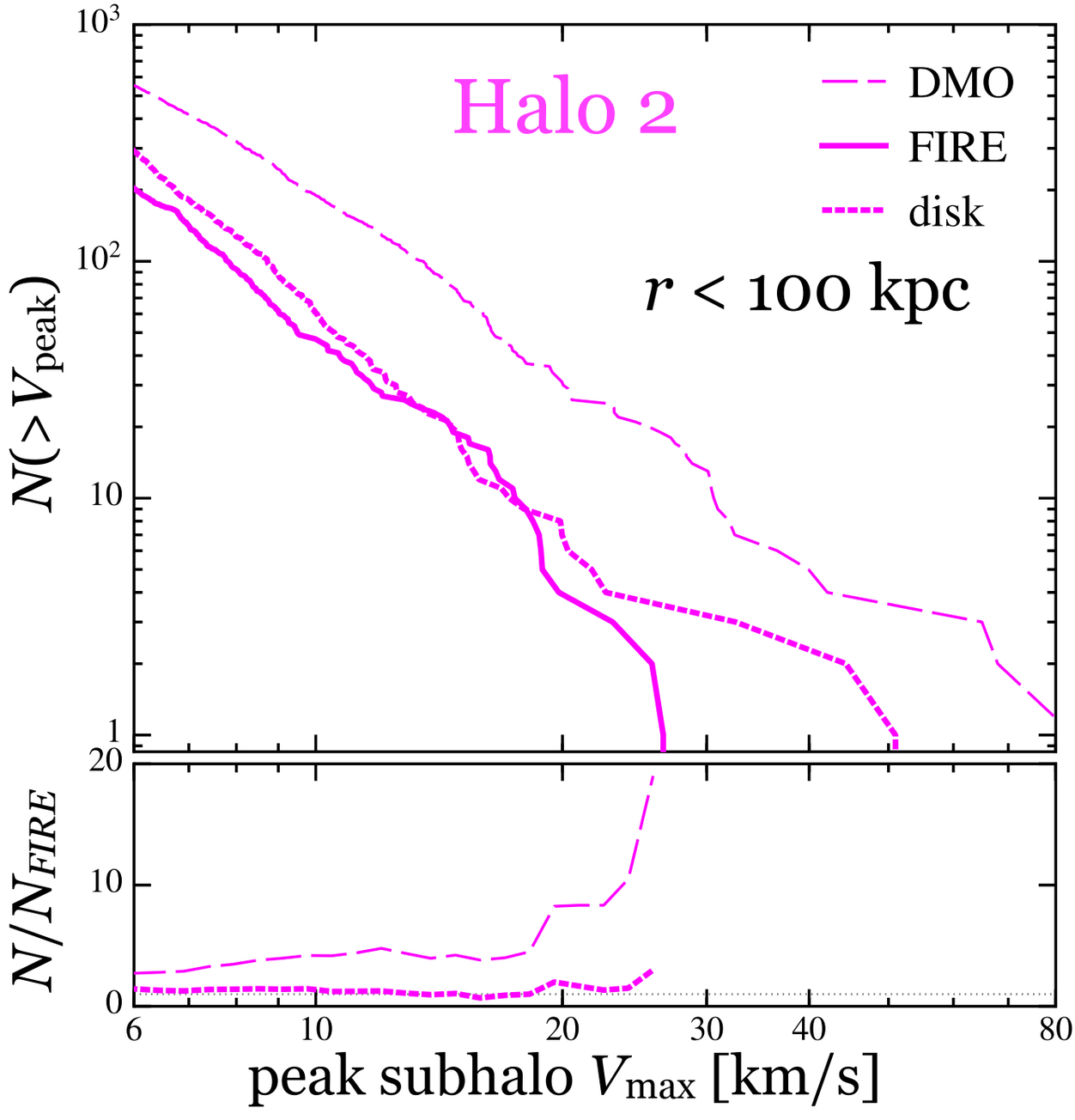

Central galaxy responsible for nearly all of the destruction within 100 kpc

Which subhalos are destroyed?

GK+, in prep

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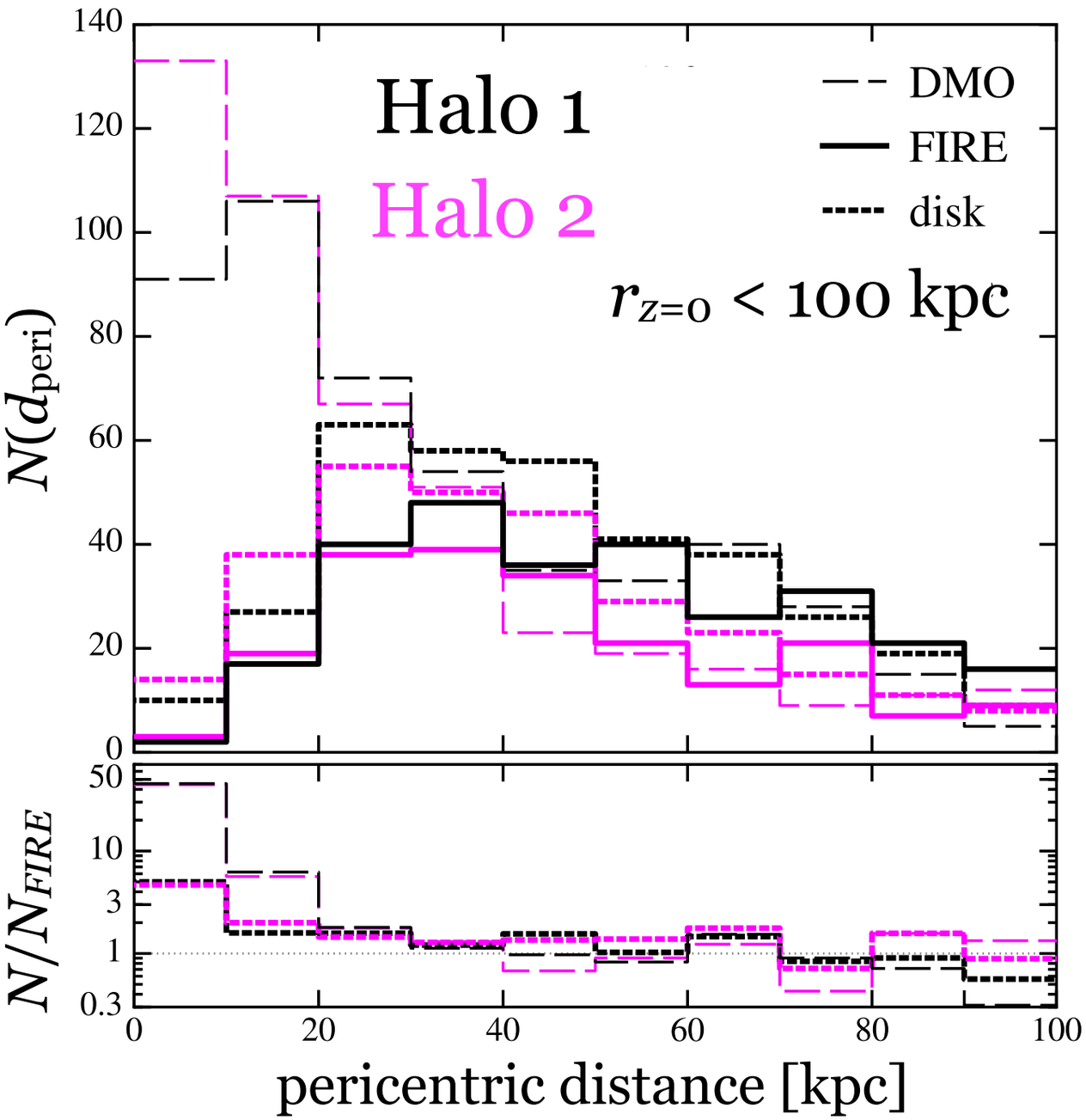

>95% of subhalos that pass within 20 kpc are destroyed by the central galaxy

Which subhalos are destroyed?

GK+, in prep

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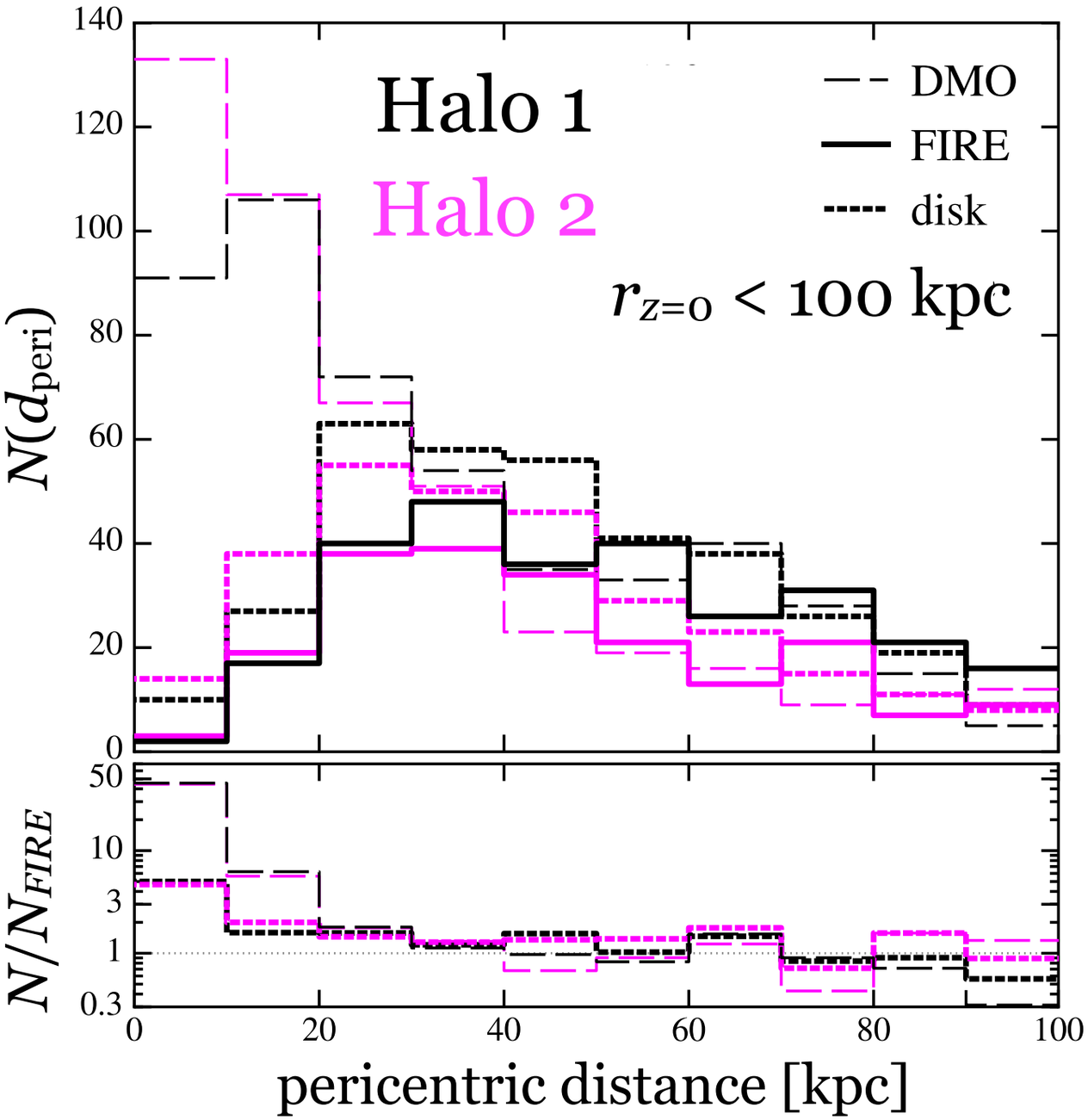

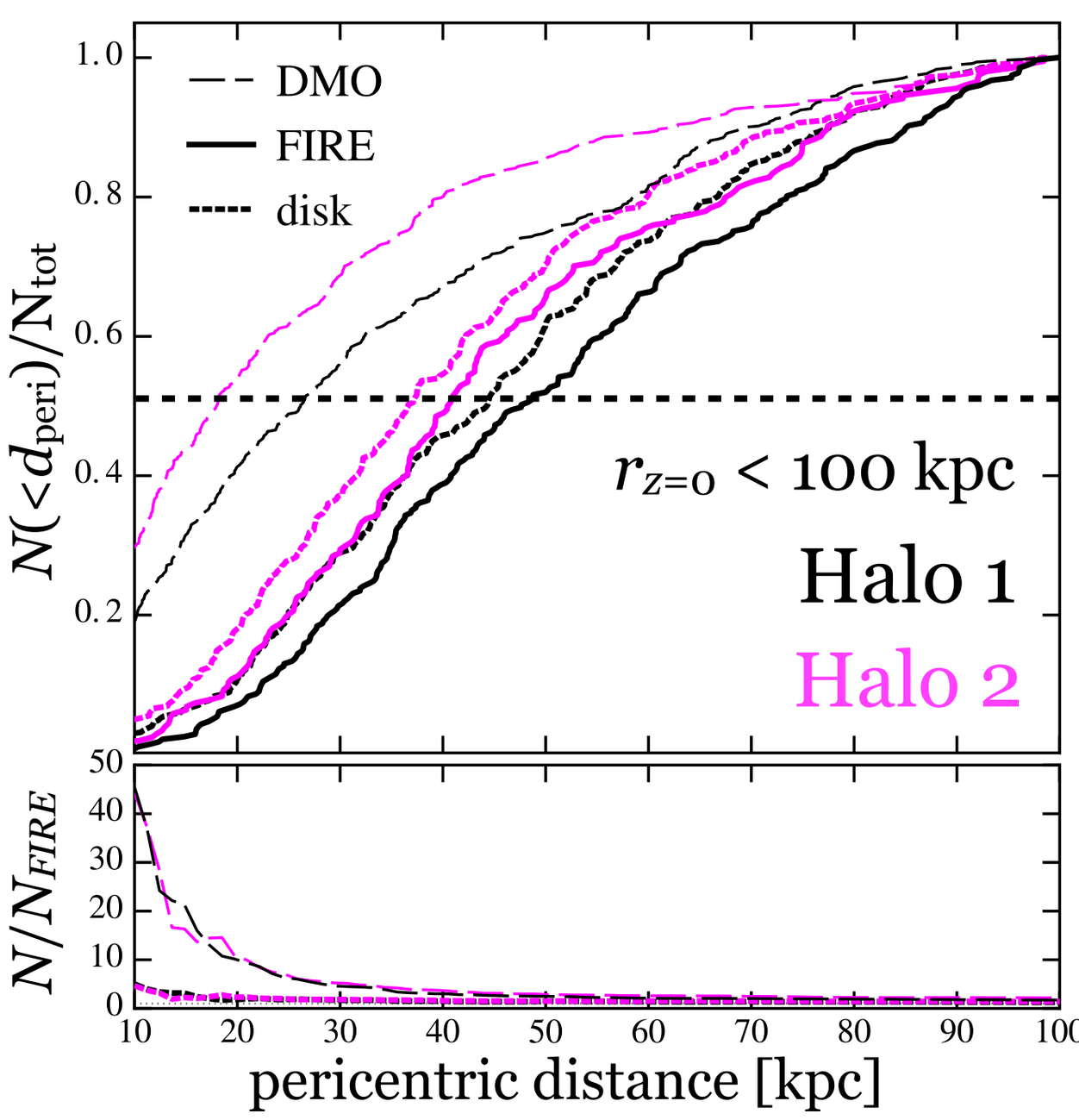

Median pericenter more than doubled!

Anisotropic subhalo orbits

GK+, in prep

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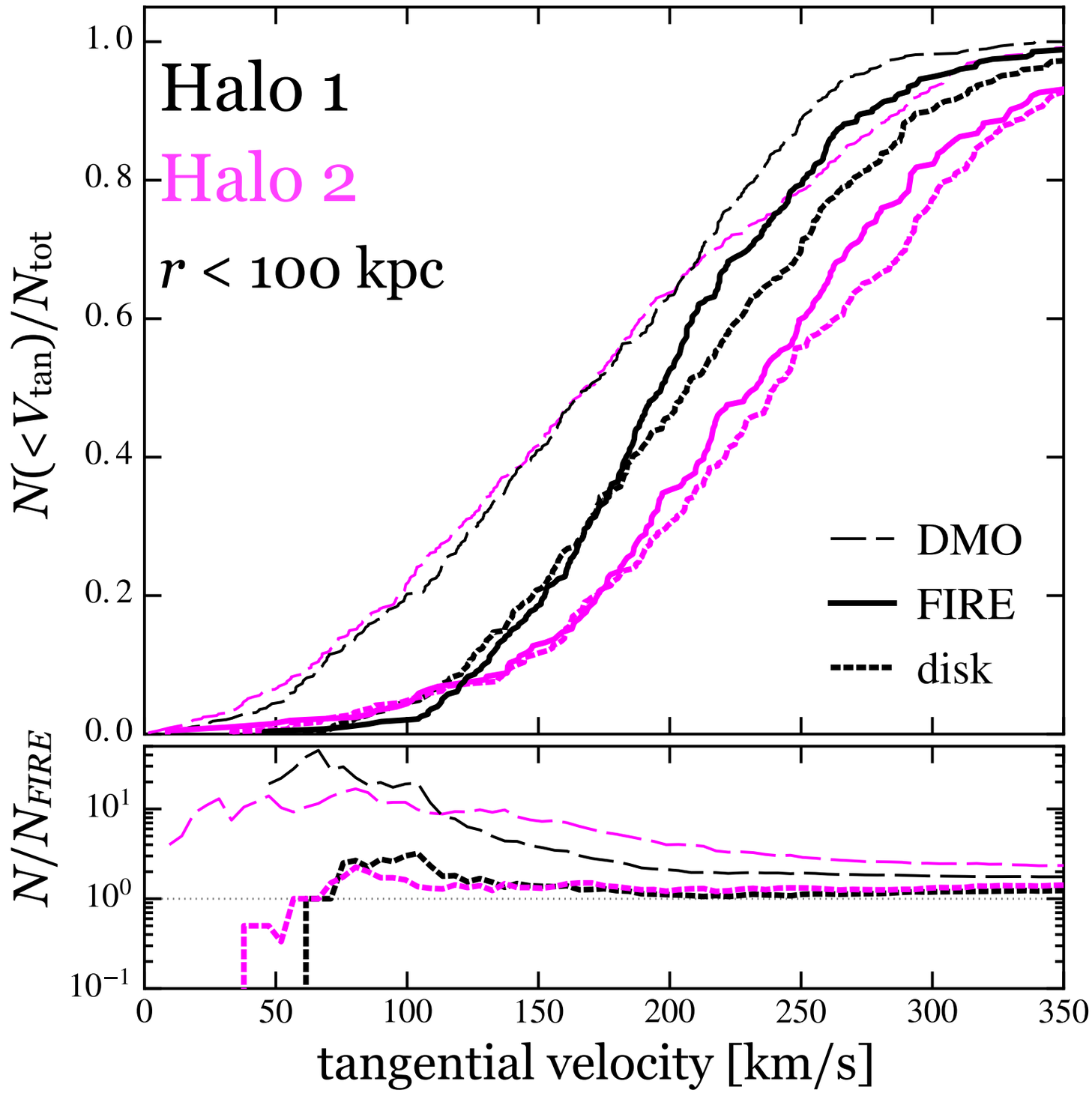

Surviving subhalos are tangentially biased

Anisotropic subhalo orbits

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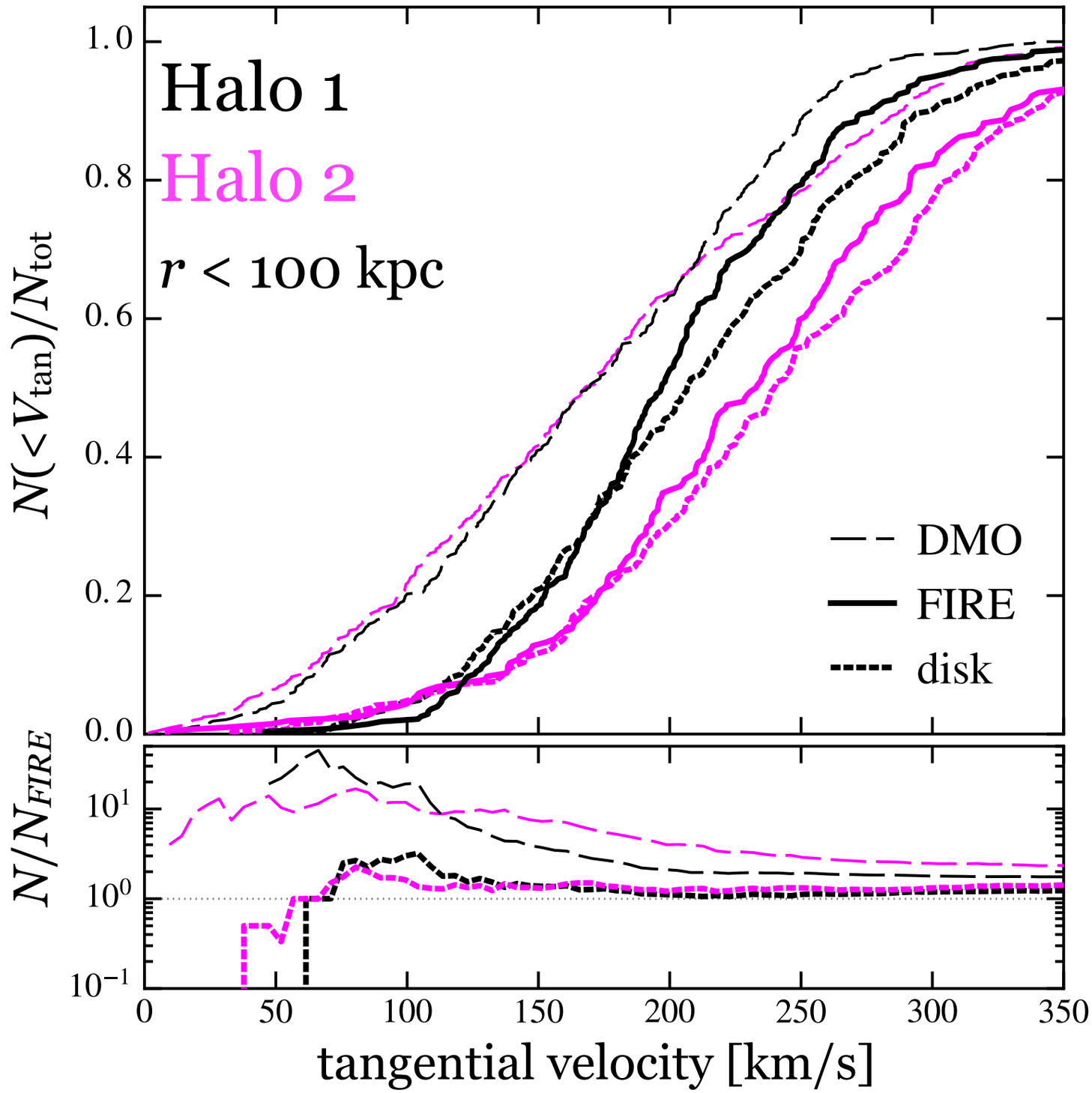

DMO overpredicts low V_{tan} subhalos by a factor of 30

Anisotropic subhalo orbits

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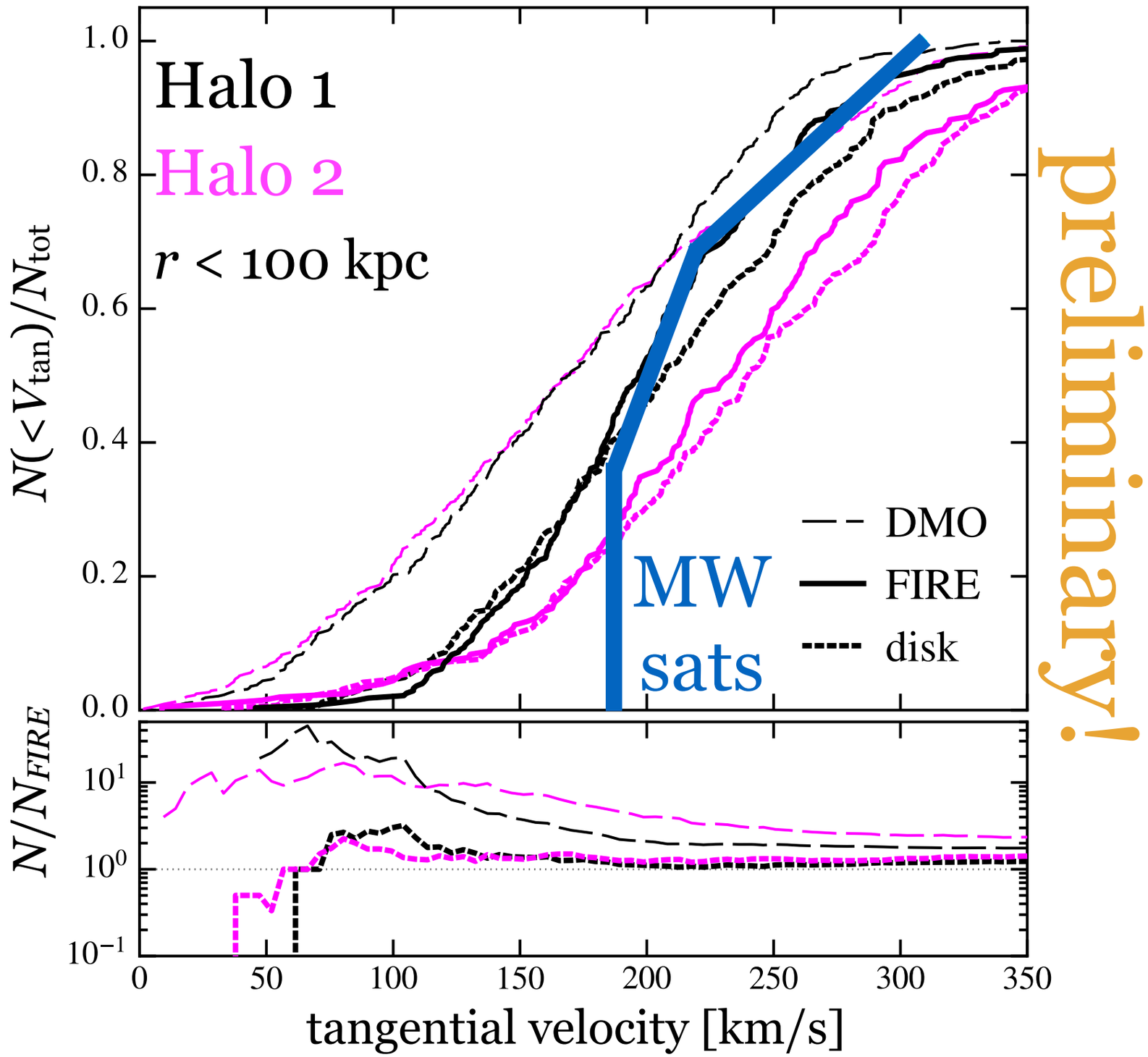

Reproduces lack of low V_{tan} satellites

Conclusions

Only DMO sims can provide the statistical samples needed to interpret future observations (GAIA, WFIRST, etc.)

But, DMO sims ignore galaxies at halo centers and vastly over predict subhalo counts relative to hydro simulations

Embedding galactic potentials bring substructure populations to within ~25% of predictions from FIRE simulations

Galaxy *alone* accounts for ≳75% of substructure depletion

Subhalos on radial orbits are preferentially destroyed

Substructure predictions can be significantly improved ***at minimal CPU cost*** with embedded potentials

Upcoming: Statistical samples of MW-size and group-like zooms with embedded potentials (Tyler Kelley+, in prep)

Thanks!