Dark matter gamma-ray signals in the Milky Way: brightest dark satellites versus diffuse galactic emission

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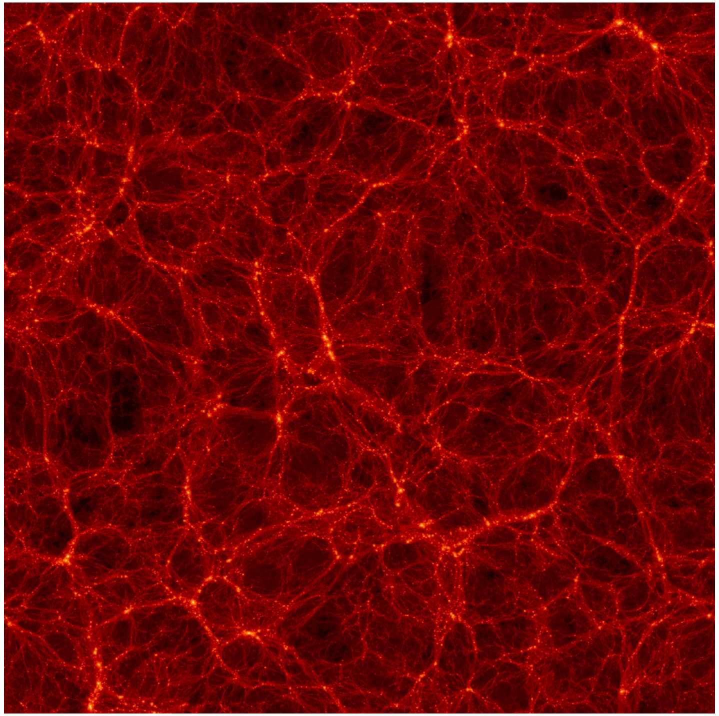
Dark matter halos and subhalos

- Filamentary structure at large scales.
- Halos are gravitationally bound structures.
- In the standard ΛCDM cosmology, small halos are created first and then combine to create bigger ones.
- Small halos merge constantly into larger ones, giving a configuration of many ‘subhalos’ inside a host.
- Halos have universal DM density profiles.
- If (sub)halos are made of WIMPs they would shine in gamma-rays.



Bolshoi simulation (*K. Riebe et al., 2013*)

Characterization of a system

$$\frac{\mathrm{d}N}{\mathrm{d}V\,\mathrm{d}m\,\mathrm{d}c}(\vec{r},m,c) \propto \frac{\mathrm{d}\mathcal{P}_v}{\mathrm{d}V}(\vec{r}) \times \frac{\mathrm{d}\mathcal{P}_m}{\mathrm{d}m}(m) \times \frac{\mathrm{d}\mathcal{P}_c}{\mathrm{d}c}(c,m)$$

- Subhalo Radial Distribution (SRD) – dP/dV – number of subhalos depending on the volume or distance to the galaxy center D_{GC} .
- SubHalo Mass/Velocity Function (SHMF/SHVF) – dP/dm or dP/dV_{max} – number of subhalos within a certain mass/V_{max} range.
  - V_{max} is the maximum circular velocity of particles inside a subhalo.
  - R_{max} is the distance to the subhalo center at which V_{max} happens.
- Velocity-concentration relation (c_V) – dP/dc – how concentrated the matter is inside a subhalo. Higher concentration equals steeper densities in the center for the same amount of total mass/V_{max}.

Methodology

Current simulations have mass and spatial resolution limits, which overlook small structures/subhalos. We have a code to repopulate systems below these resolution limits (*Coronado-Blázquez+19a,19b*).

1) Study a repopulation of DMO subhalos using an already constructed characterization.
2) Calculate and compare J-factors of repopulated subhalos.
3) Characterize the subhalo population (abundance, distribution and internal structure) for hydrodynamical and DMO simulations (more detail later), study their differences.

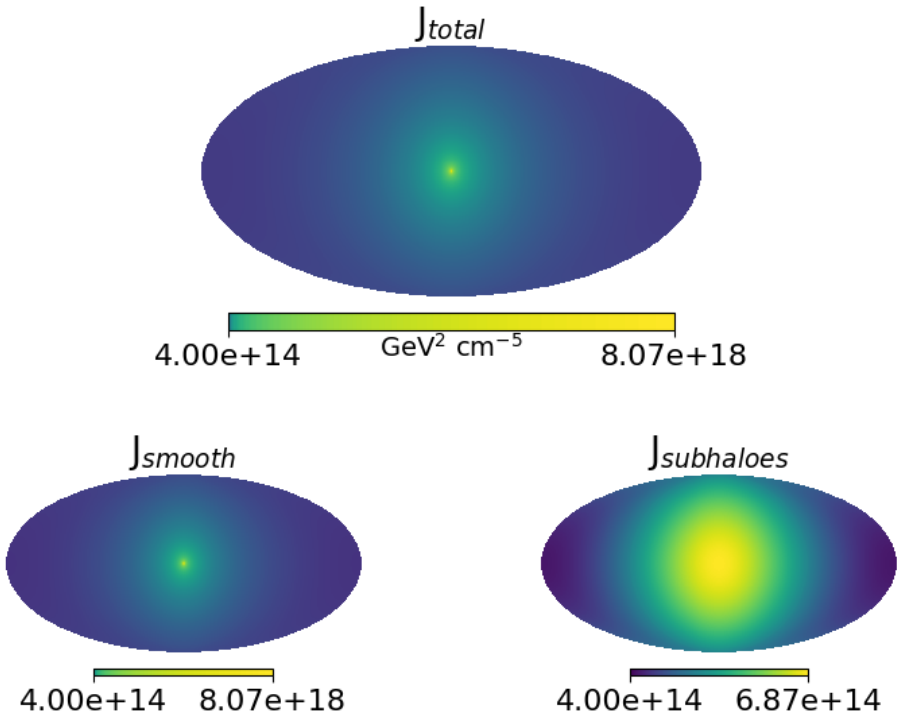
$$Flux = \underbrace{\frac{1}{Dist^2_{Subh-Earth}} \int_{\Delta\Omega} d\Omega \int_{l.o.s.} dl \cdot [\rho_{DM}]^2}_{J-factor} \cdot \underbrace{\frac{1}{4\pi} \frac{<\sigma v>}{2m_\chi^2} \sum_f B_f \int \frac{dN_f}{dE} dE}_{f_{PP}}$$

Diffuse annihilation flux in our galaxy

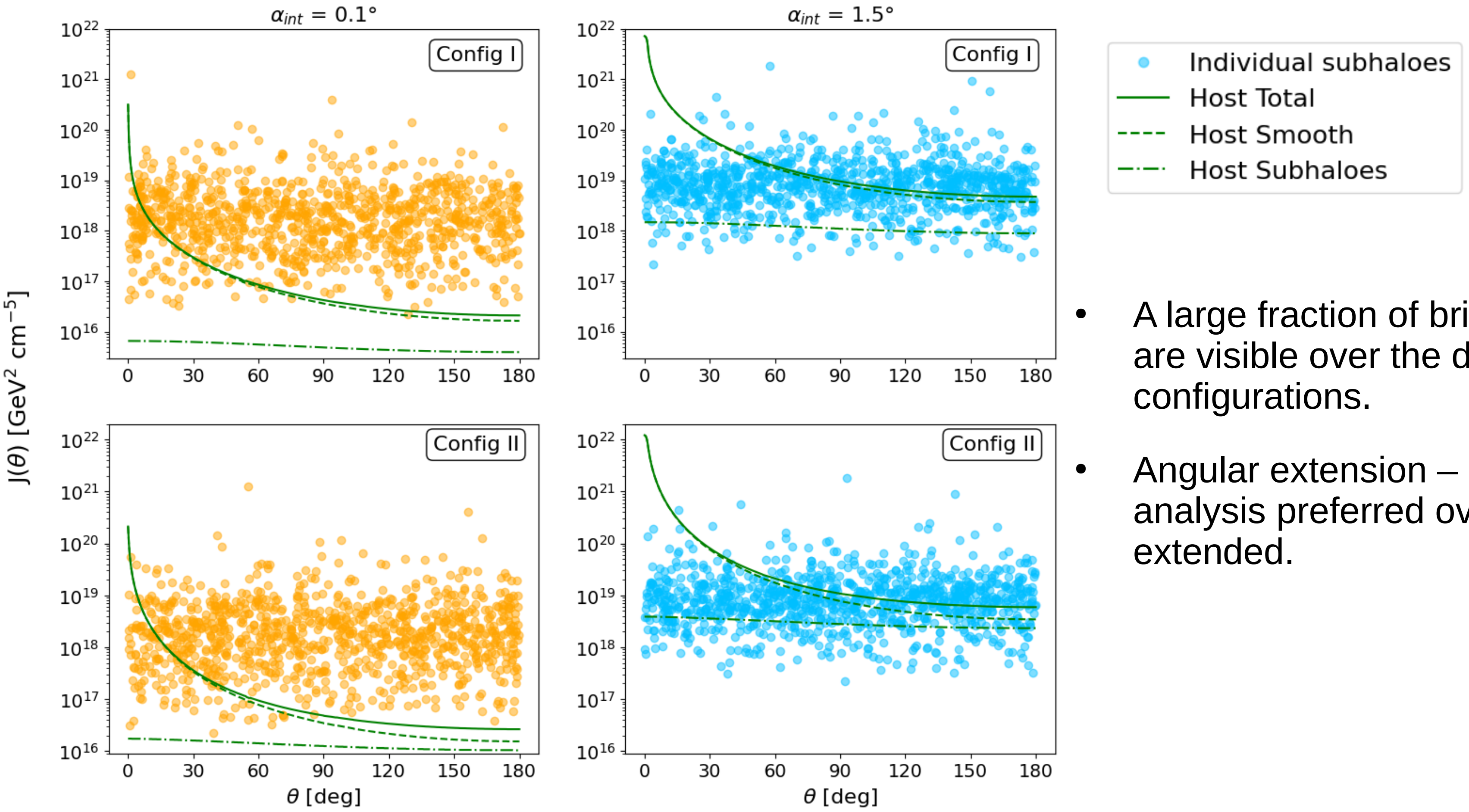
Two diffuse components:
- Smooth density profile of the host
- Unresolved subhalos

Ingredient	**Config I**	**Config II**
Host DM density profile	NFW	Einasto, α=0.17
Mass-concentration model of subhaloes	Moline et al.(2017)	
SRD	Anti-biased NFW	Einasto, α=0.69
SHMF	Power law, α=1.9	

Skymaps for Config I created with CLUMPY for this project.

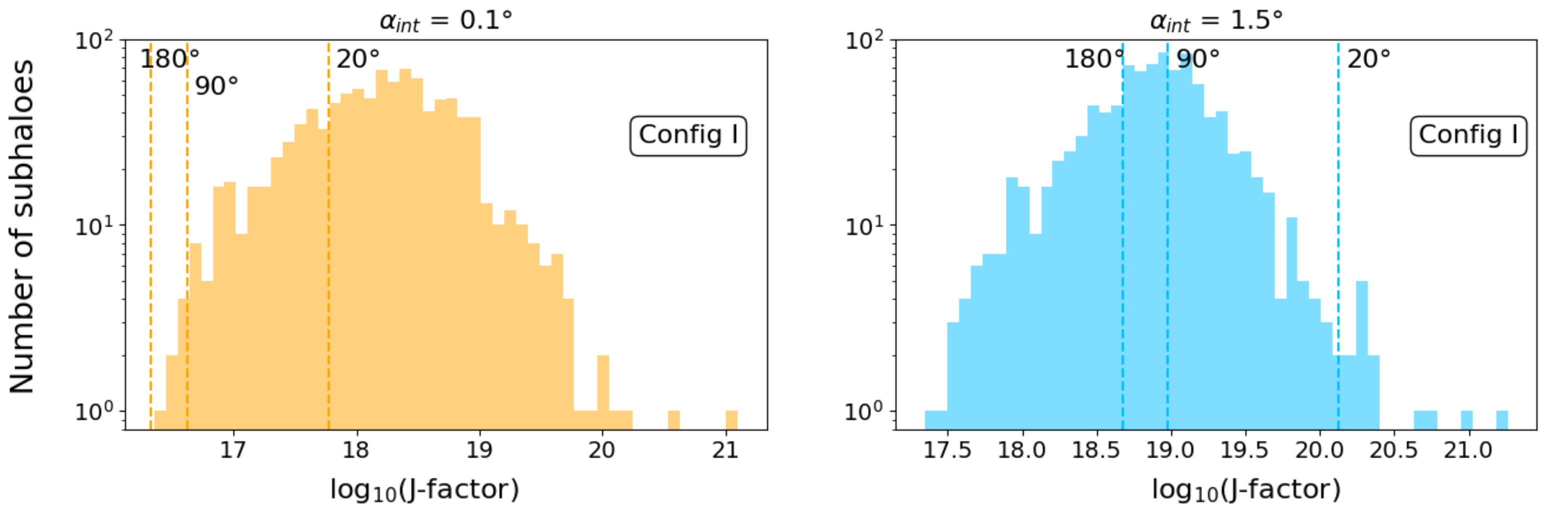


Diffuse flux vs resolved subhalos



- A large fraction of bright subhalos are visible over the diffuse in all configurations.
- Angular extension – point-like analysis preferred over spatially-extended.

Diffuse flux vs resolved subhalos



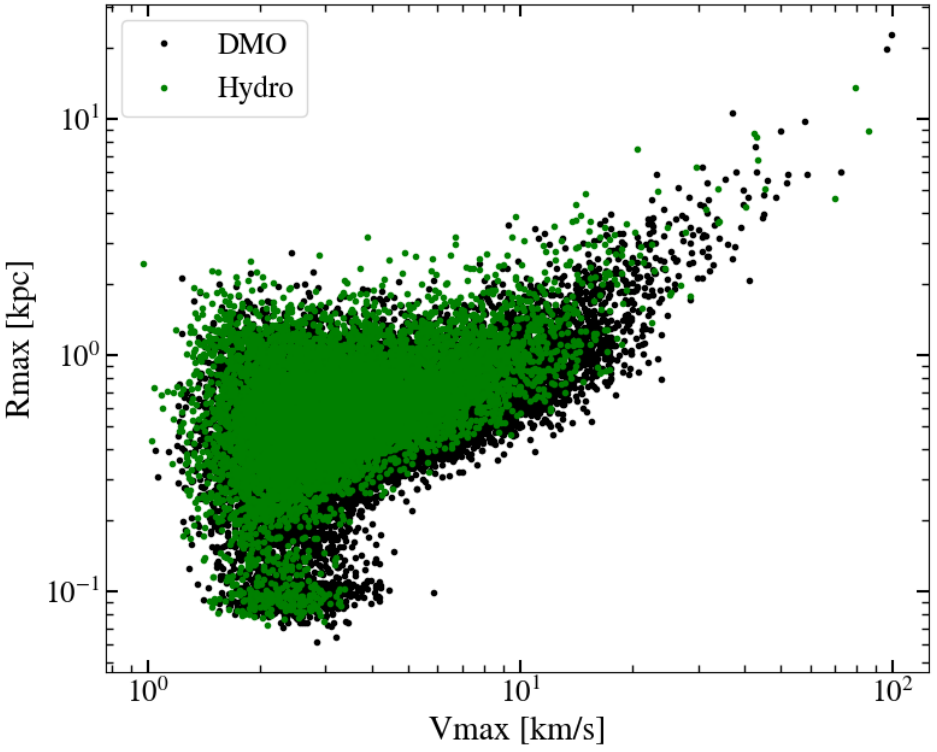
Percentage of subhalos with J-factor larger than the diffuse one

		Config I		Config II	
		$\alpha_{int} = 0.1°$	$\alpha_{int} = 1.5°$	$\alpha_{int} = 0.1°$	$\alpha_{int} = 1.5°$
θ [deg]	20°	74.6	1.4	69.4	1.1
	90°	99.4	41.9	98.9	37.7
	180°	100.0	70.6	99.9	62.4

Baryon party

APOSTLE: DMO + hydrodynamical

- We use data from APOSTLE, a set of of zoom-in simulations of MW systems in AURIGA original simulations.
- We asked for APOSTLE data to the APOSTLE/AURIGA team, and currently work with it in order to characterize our systems.
- Data we have: V_{max}, R_{max}, D_{GC} (*Grand&White20, Grand+21*).

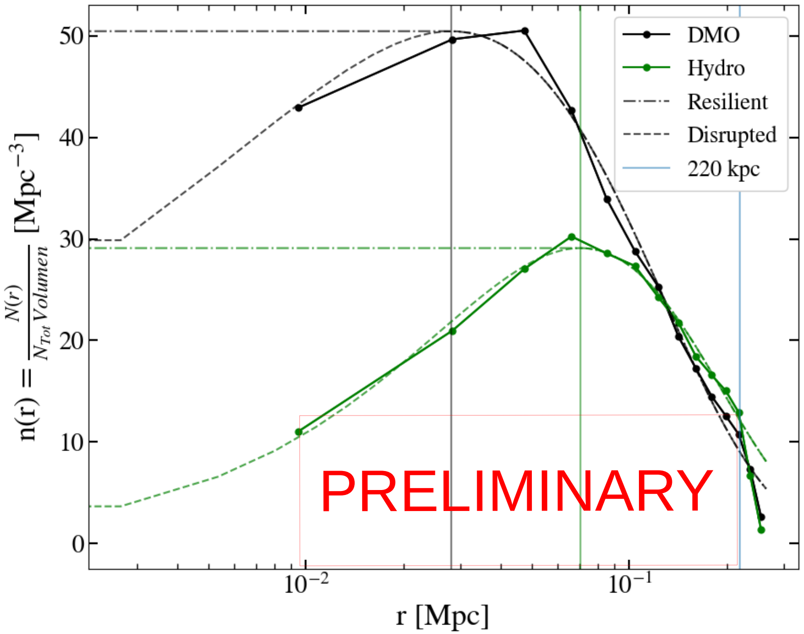


Subhalo characterization: SRD

- Ongoing debate in the literature about subhalo survival: do subhalos survive in the center of halos or get disrupted? What is the actual SRD? Is it a matter of numerical resolution?

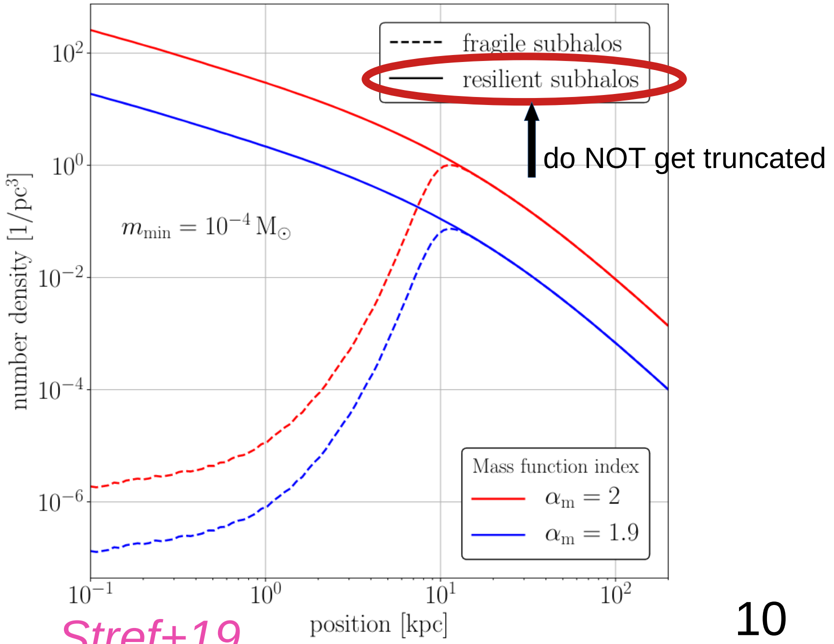
See Alejandra's talk tomorrow!

- We will keep agnostic about this debate by adopting two different scenarios:
  1) Disrupted subhalos, as found in our numerical APOSTLE data.
  2) Resilient subhalos, just assuming that the SRD does get truncated down to the inner galaxy.
- Ongoing work to obtain resilient case.



SRD obtained from APOSTLE

(m_{min} ~ $10^7 M_\odot$)



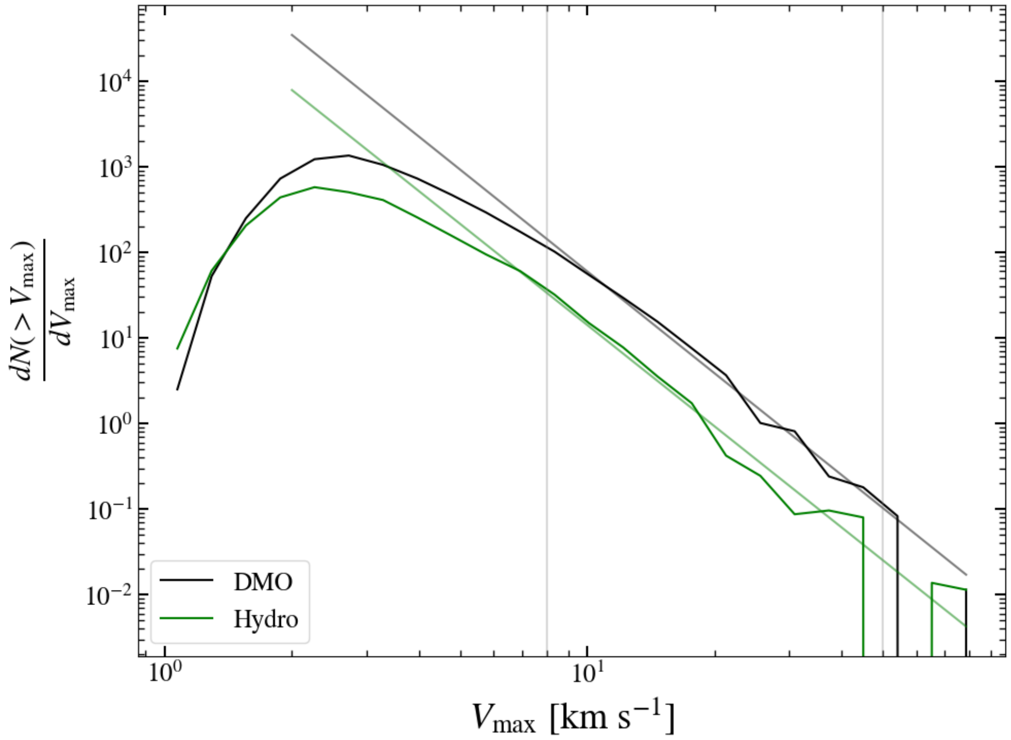
Stref+19

Subhalo characterization: SHVF

- Low V_{max}: resolution limit.

  m_{DMO} = -3.96

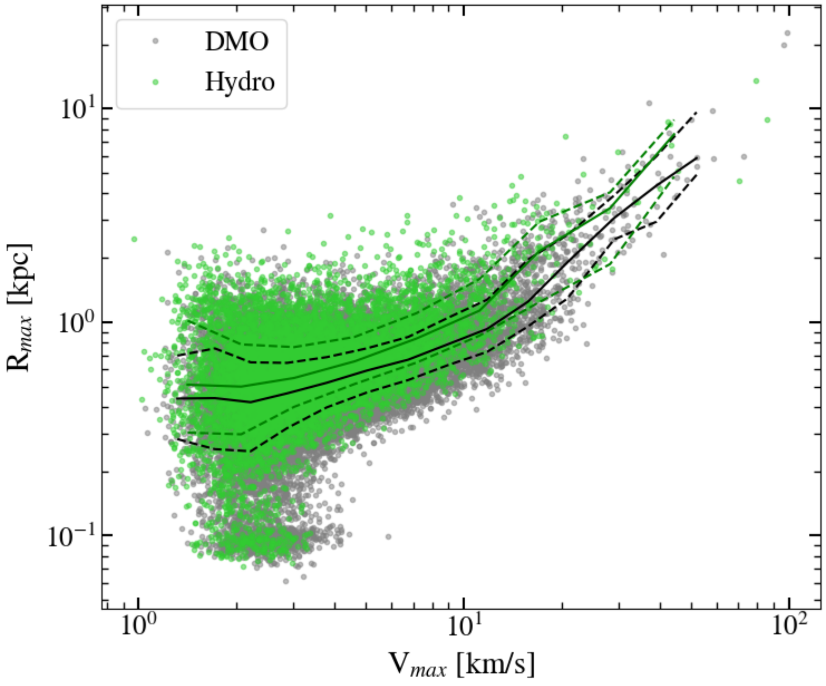
  m_{hydro} = -3.93
- These slopes are consistent with state-of-the-art DMO simulations.
- We seem to have a lower number of subhalos compared to other works (ie *Moliné+21* aka Uchuu, DMO).

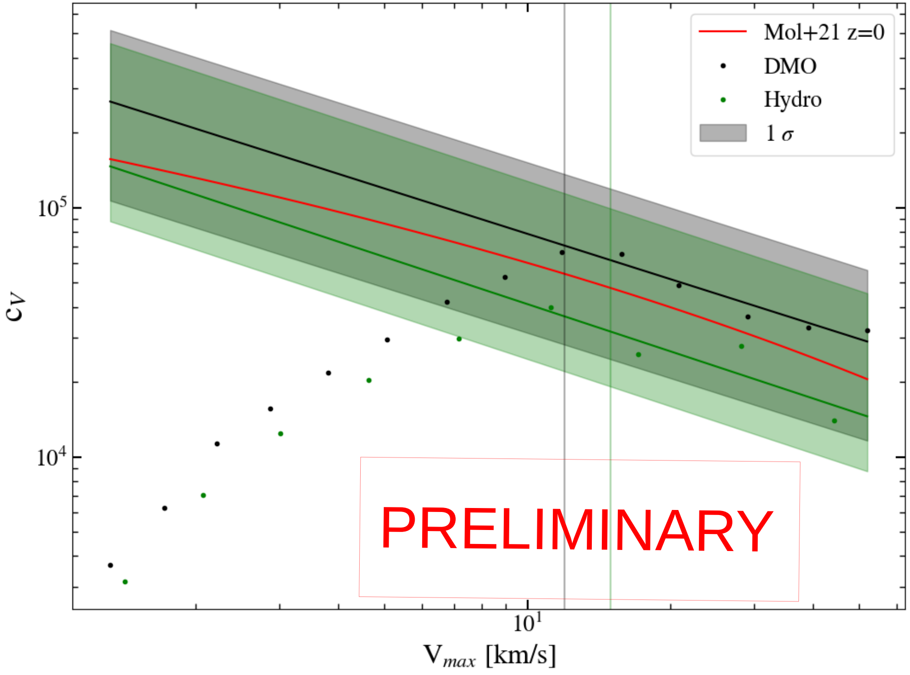


Subhalo characterization: c_V

- Median data with calculated scatter.

$$c_V = 2\left(\frac{V_{max}}{H(z)\, R_{max}}\right)^2$$





Next steps

- Finish the ongoing work of characterizing our ingredients of hydro/DMO systems.
- Repopulate the MW-like system with subhalos with masses/V_{max} below the resolution limits with our code, compute and compare J-factors in the DMO and hydro cases.
- Check the detection rate of these subhalos against the diffuse background of the systems.
- If we still have time left, calculate annihilation fluxes and telescope sensitivity predictions.

Thank you for your attention