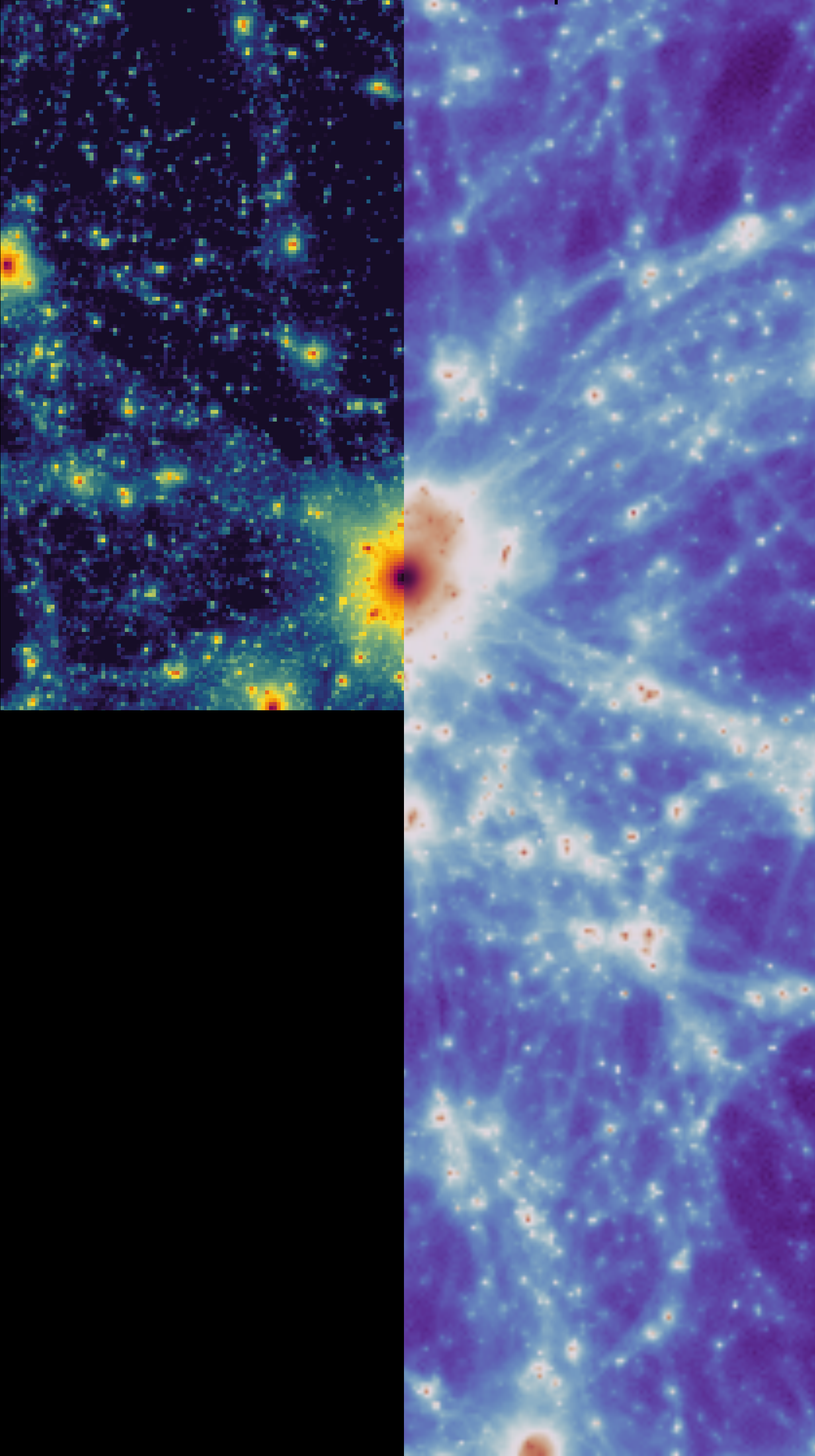


A vertical strip on the left side of the slide shows a cosmic web visualization. It features a dense field of small, bright yellow and orange spots (galaxies) against a dark blue background, transitioning into a more diffuse, filamentary structure of blue and purple with scattered white points.

THE AIDA PROJECT:

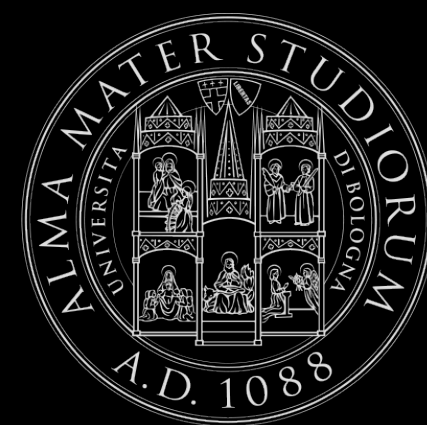
GALAXY FORMATION

IN ALTERNATIVE DARK MATTER

MODELS

Giulia Despali

Department of Physics and Astronomy
University of Bologna



ALMA MATER STUDIORUM
UNIVERSITÀ DI BOLOGNA

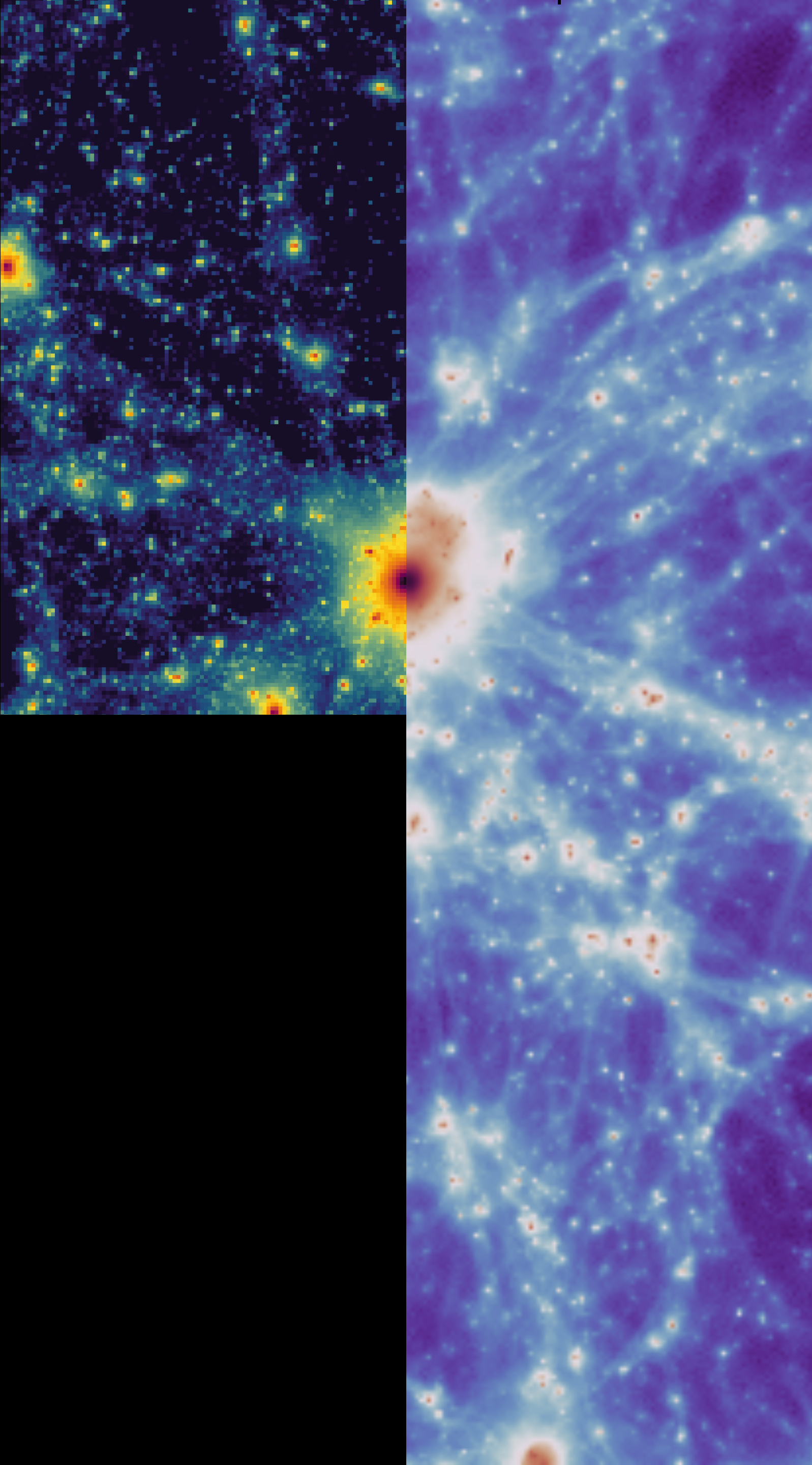
LAURO MOSCARDINI
DYLAN NELSON
ANNALISA PILLEPICH
MARK VOGELSBERGER
VOLKER SPRINGEL



EuroHPC
Joint Undertaking

AIDA-TNG SIMULATIONS

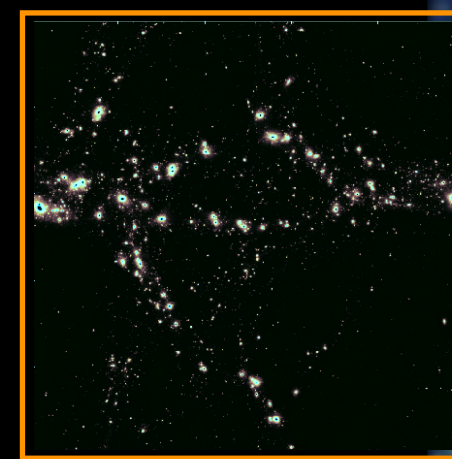
- ✓ three cosmological boxes
- ✓ AREPO - moving mesh
- ✓ TNG galaxy formation model
- ✓ CDM, WDM, SIDM
- ✓ multiple resolution levels



100 Mpc

50 Mpc

new
20 Mpc



$(2 \times 1080)^3$

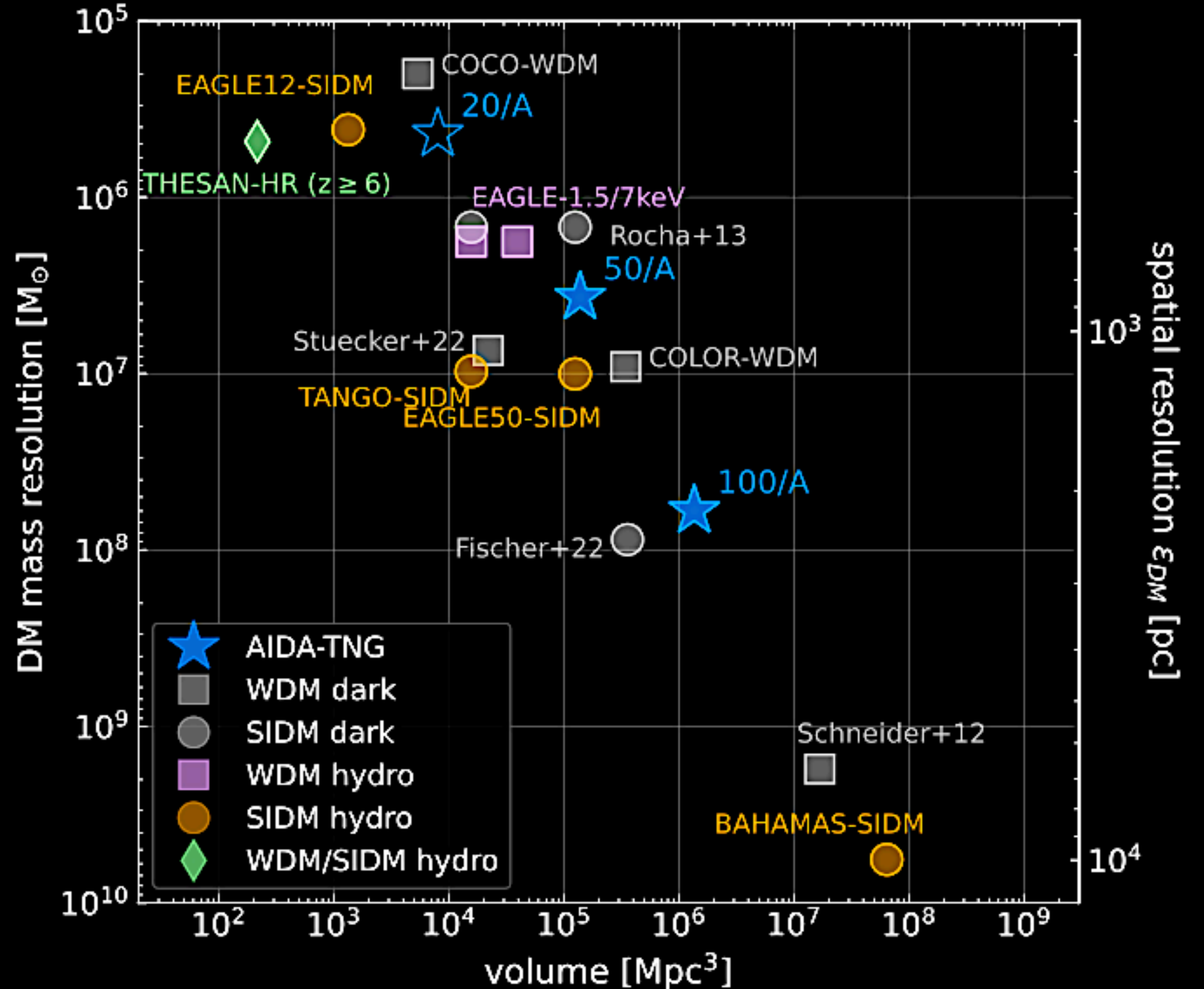
50 Mpc

$(2 \times 910)^3$

max resolution:
~280 pc

WDM/SIDM SIMULATIONS

Many zoom-in
simulations with
ADM+baryons



Clusters: *Shen et al. 2022, ...*
Galaxies: *Apostle WDM/SIDM, Despali et al. 2020,*
Rose et al. 2022, Robles et al. 2019,
MAGICC-WDM....
Dwarfs: *SIDM on Fire, Zavala et al.,*
Vogelsberger et al...

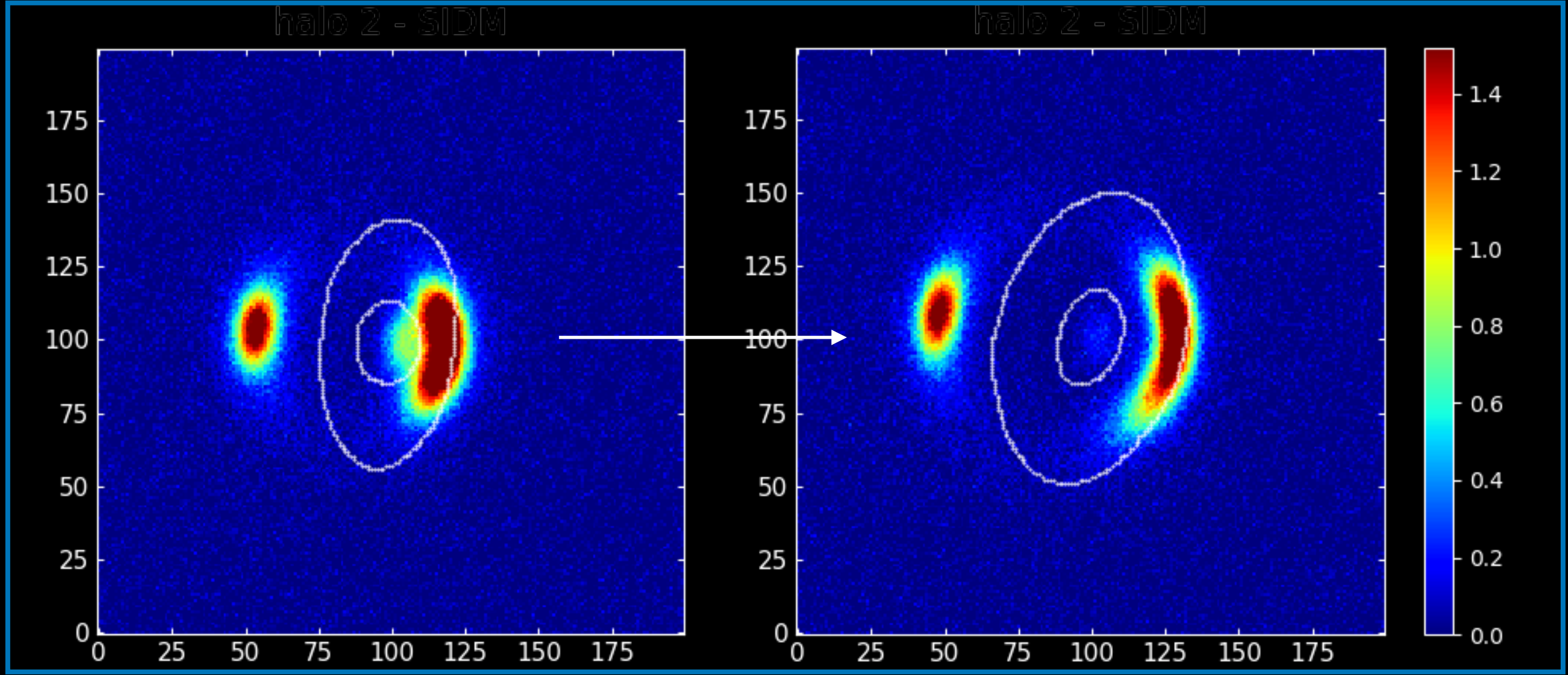
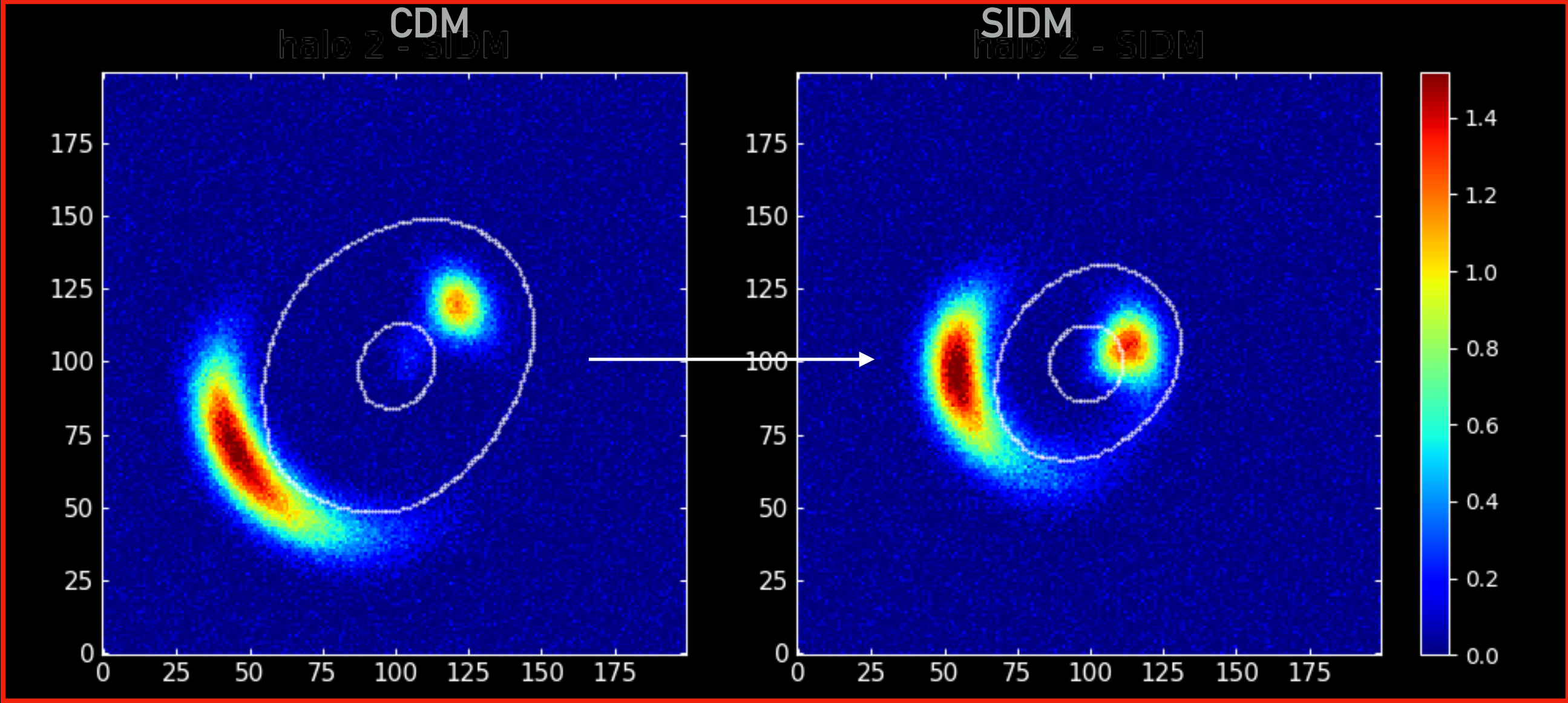
Current cosmological uniform-box simulations of galaxies

Metadata			Resolution							References and Data			
Simulation Name	Year	Code	Box Size [cMpc]	$N_{\text{baryon}}^{\dagger}$	N_{DM}	$M_{\text{baryon}}^{\dagger} [\text{M}_{\odot}]$	$M_{\text{DM}} [\text{M}_{\odot}]$	$\epsilon_{\text{DM}} [\text{kpc}]$	$\Delta x_{\text{gas,SF}} [\text{kpc}]$	Simulation Reference(s)	Methods Reference(s)	Website	Public Data?
Illustris	2014	AREPO	106.5	1820^3	1820^3	1.3×10^6	6.3×10^6	0.7	0.7	Vogelsberger+14 Genel+14 Sijacki+15	 		
Magneticum 4uhr	2014	GADGET-3	68.2	576^3	576^3	1.4×10^7	5.1×10^7	2.0	?	Hirschmann+14	?		
Eagle	2015	GADGET-3	100	1504^3	1504^3	1.8×10^6	9.7×10^6	0.7	1.1	Schaye+15			
MassiveBlack-II	2015	GADGET-3	142.7	1792^3	1792^3	3.1×10^6	1.6×10^7	2.6	?	Khandai+15	?		
HorizonAGN	2015	RAMSES	142	?	1024^3	—	8.0×10^7	?	1.0	Dubois+14	?		
Romulus25	2016	ChaNGa	25	$\sim 1100^3$	$\sim 1100^3$	2.1×10^5	3.4×10^5	0.25	?	Tremmel+16	?		
MUFASA	2016	GIZMO	73.5	512^3	512^3	1.8×10^7	9.6×10^7	0.74	?	Dave+16	?		
TNG100	2017	AREPO	110.7	1820^3	1820^3	1.4×10^6	7.5×10^6	0.74	0.7	Springel+18, Pillepich+18, Nelson+18, Marinacci+18, Naiman+18	 		
TNG300	2017	AREPO	302.6	2500^3	2500^3	1.1×10^7	5.9×10^7	1.5	1.4	Springel+18, Pillepich+18, Nelson+18, Marinacci+18, Naiman+18	 		
FABLE	2018	AREPO	58.9	512^3	512^3	9.4×10^6	5.0×10^7	3.5	?	Henden+18	?		
Simba100	2019	GIZMO	147.1	1024^3	1024^3	1.8×10^7	9.6×10^7	0.74	?	Dave+19	?		
TNG50	2019	AREPO	51.7	2160^3	2160^3	8.5×10^4	4.5×10^5	0.29	0.28	Nelson+19, Pillepich+19	 		
NewHorizon	2020	RAMSES	16	?	$\sim 470^3$	—	1.2×10^4	?	0.04	Dubois+21	?		
FIREbox	2022	GIZMO	22.1	1024^3	1024^3	6.3×10^4	3.4×10^5	0.08	0.01	Feldmann+22			

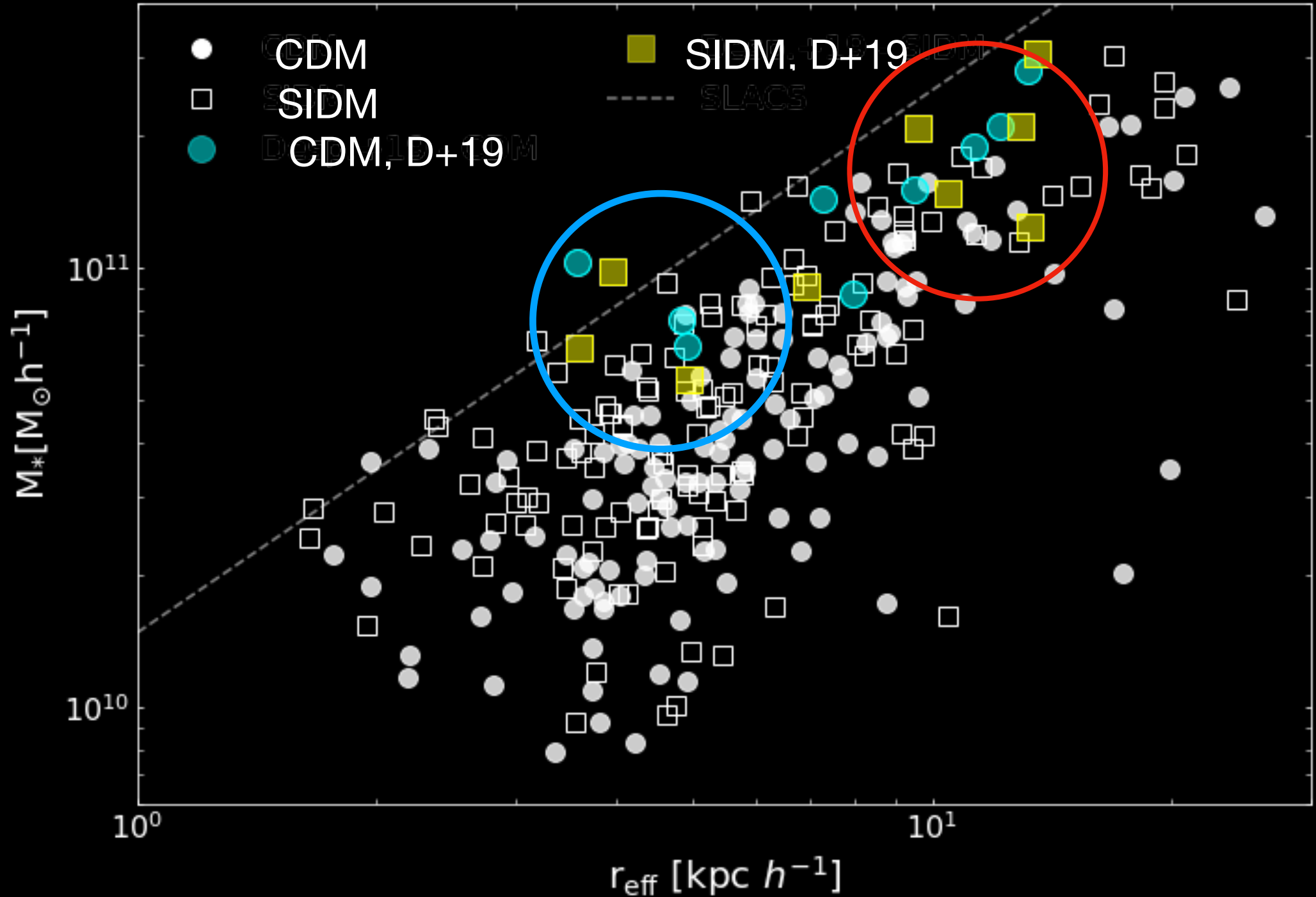
Credits: D. Nelson:
<https://www.tng-project.org/data/landscape/>

!!! All with different details in the implementation of the galaxy-formation models, e.g. feedback !!!

SIDM + BARYONS: ZOOM-IN RUNS



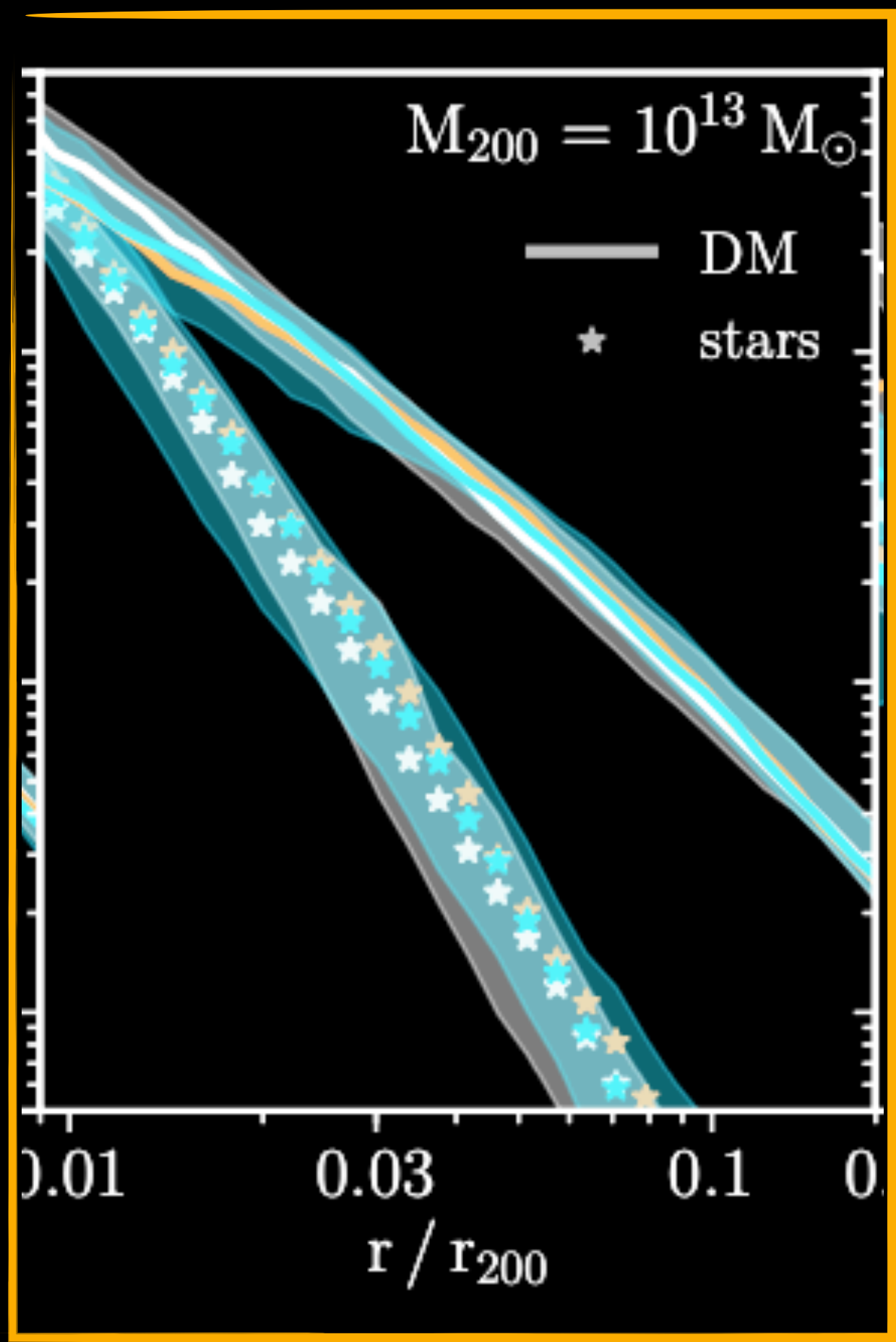
Elliptical galaxies $M \sim 10^{13} M_\odot$



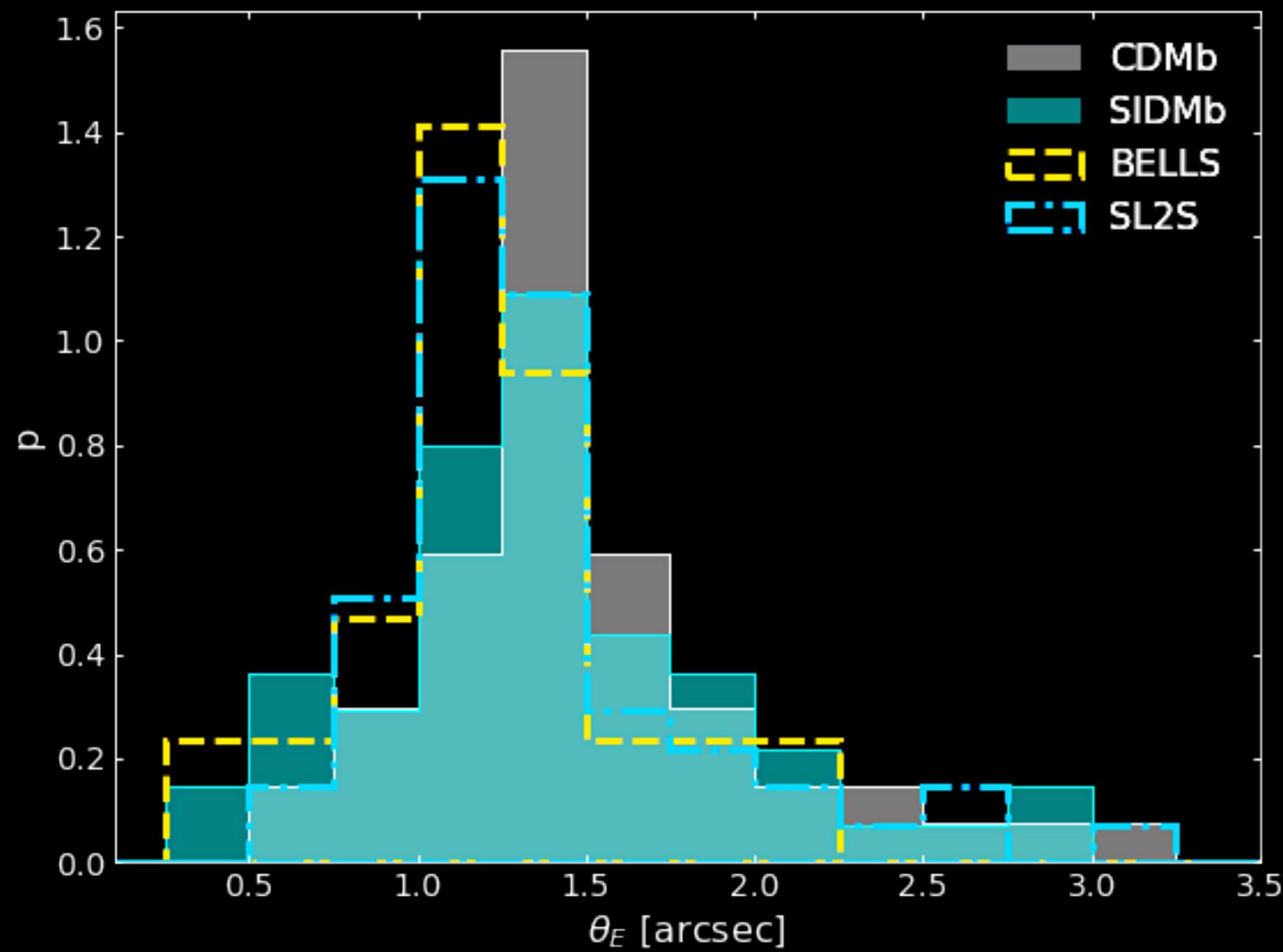
Zoom-in TNG+SIDM $\sigma=1$
(Despali+20,22)

SIDM + BARYONS: EAGLE50 BOX

EAGLE50-SIDM (*Robertson et al. 2021*)

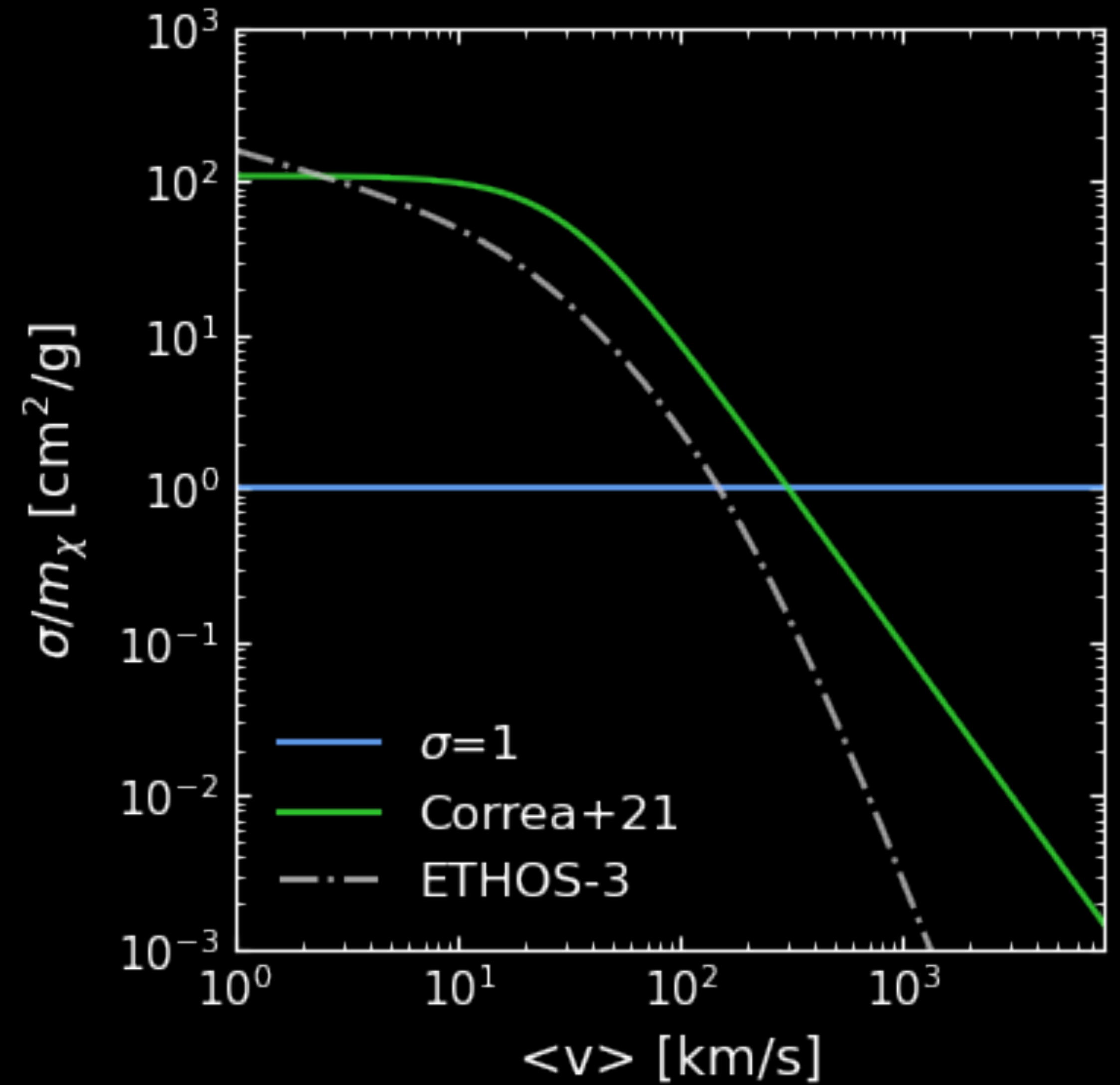
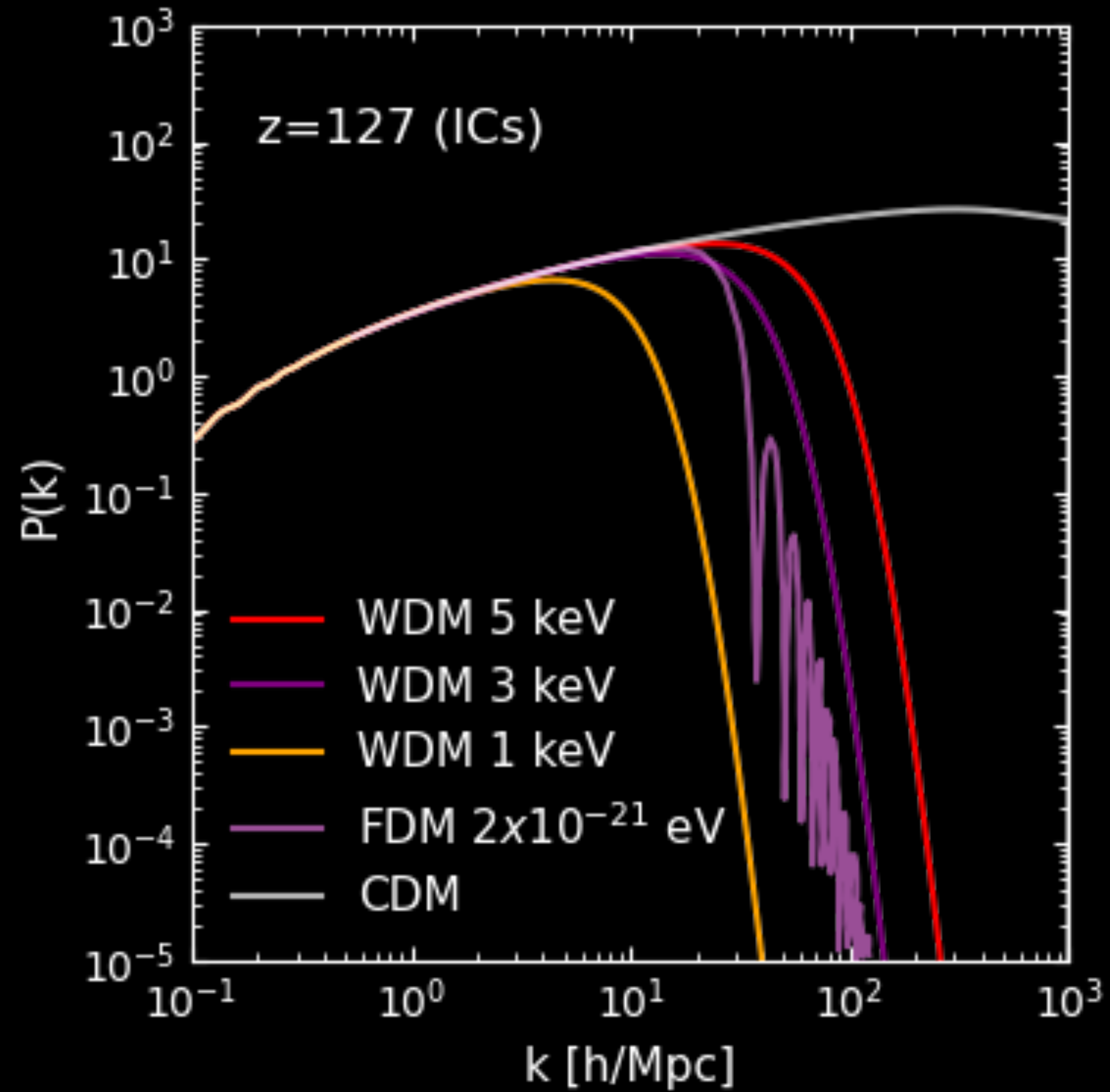


similar distribution of Einstein radii

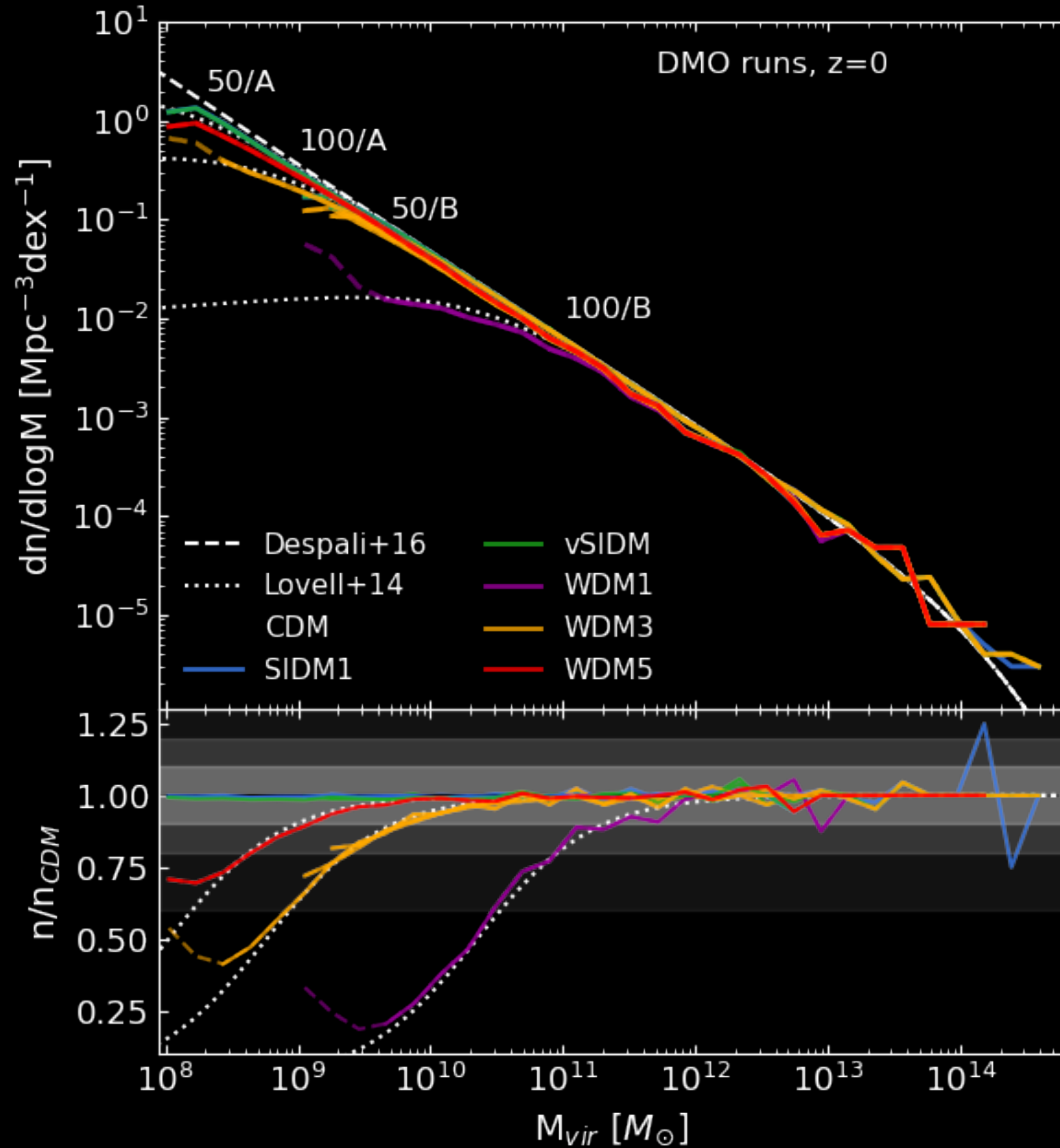


(*Mastromarino, Despali et al. 2023*)

AIDA MODELS

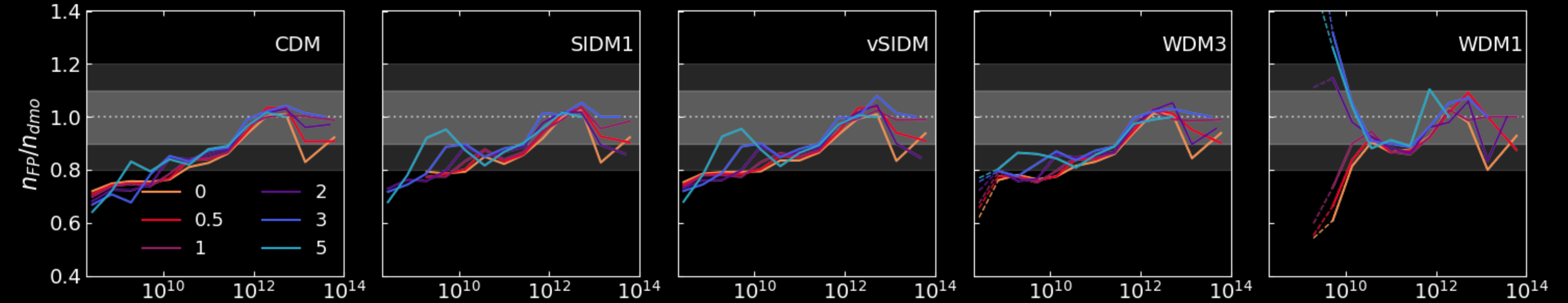


HALO MASS FUNCTIONS

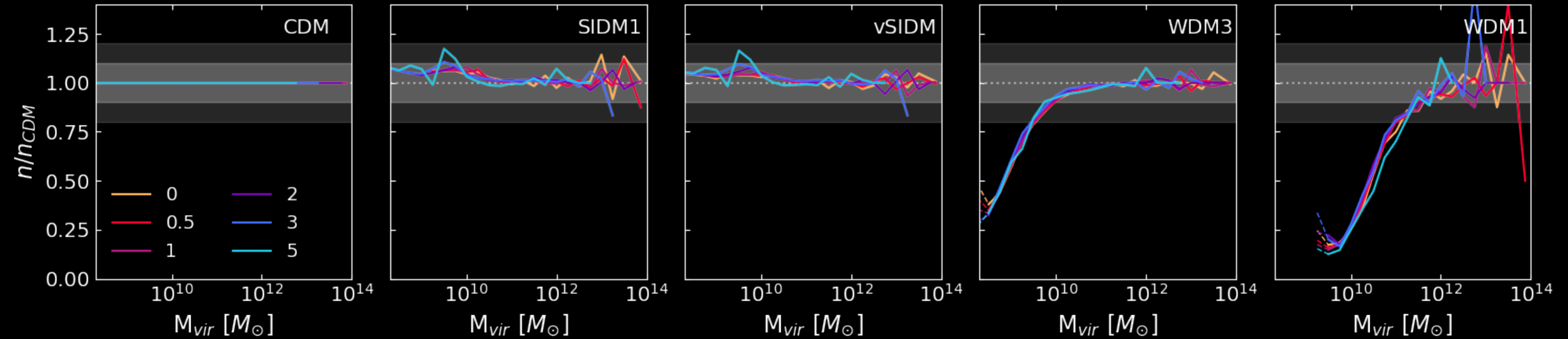


HALO MASS FUNCTIONS

Effect of baryons (TNG)

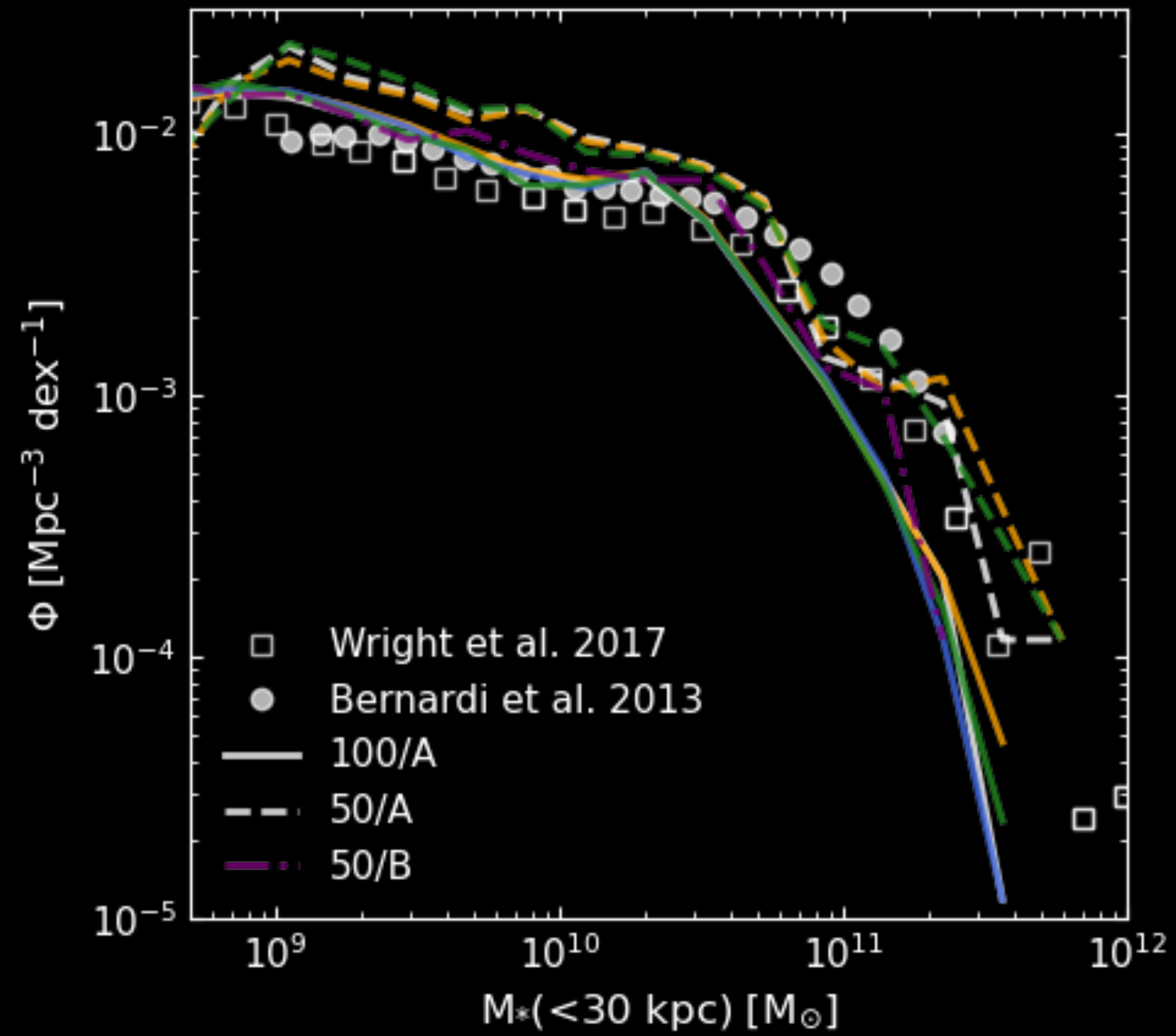


Effect of dark matter physics

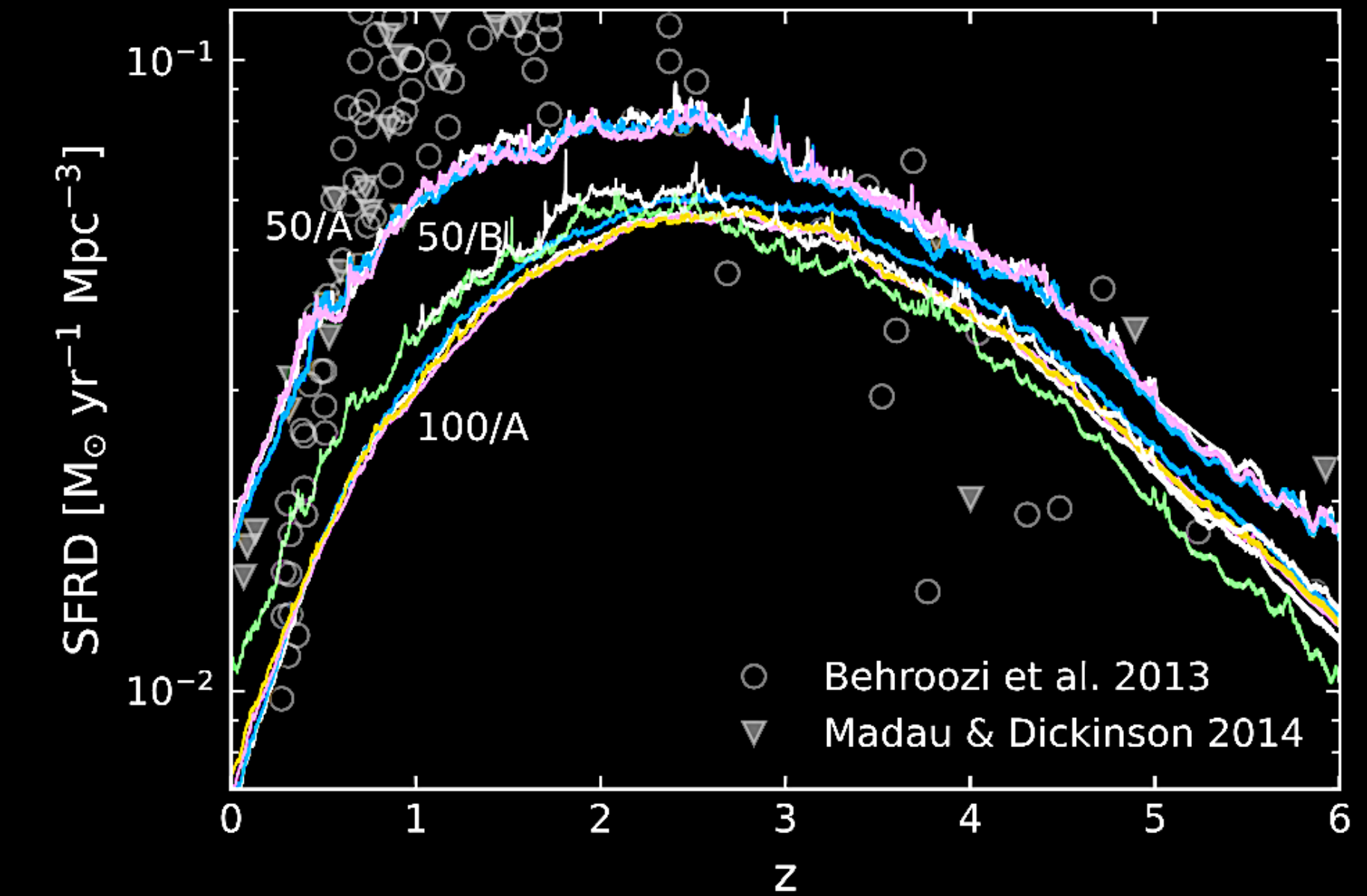
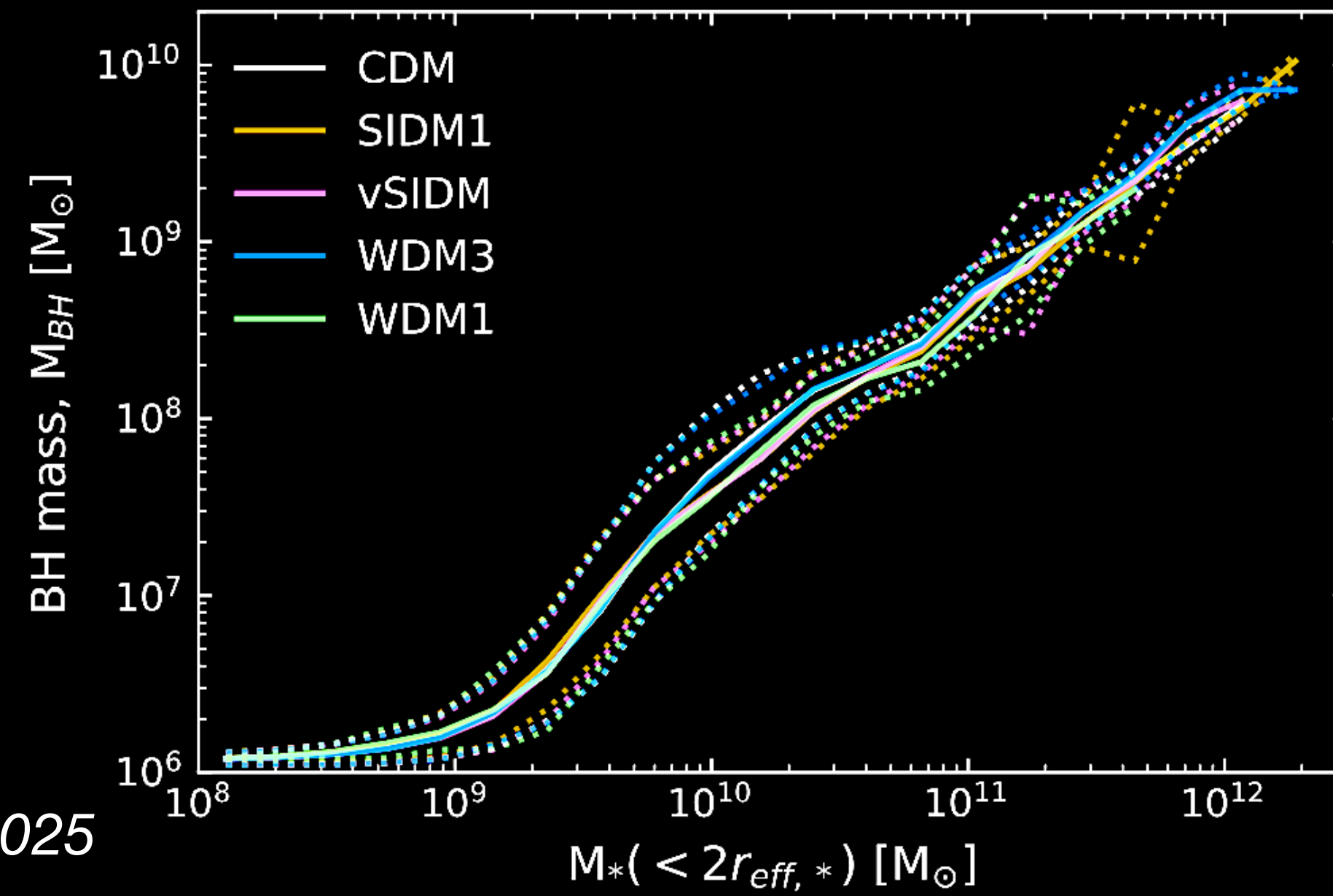
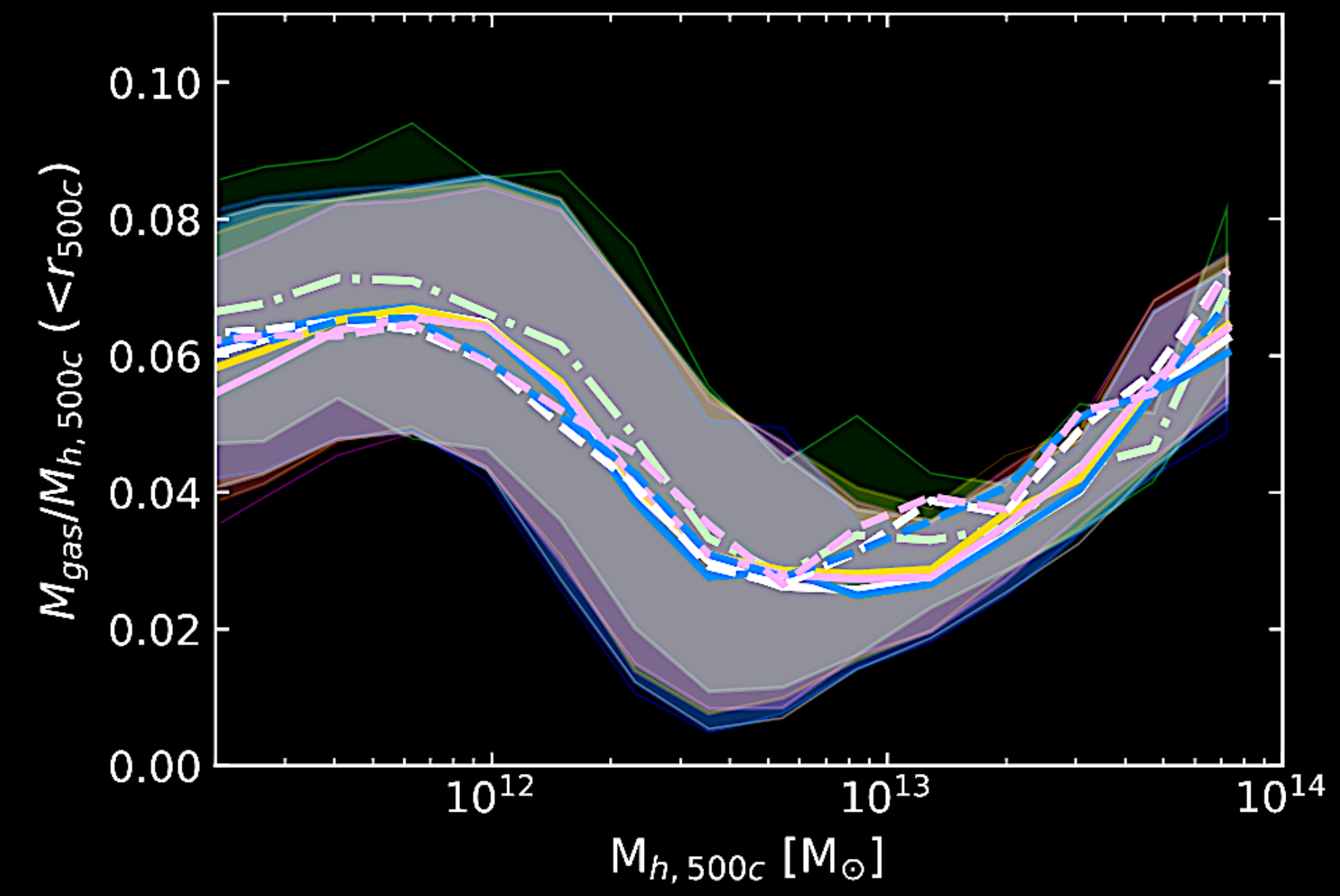
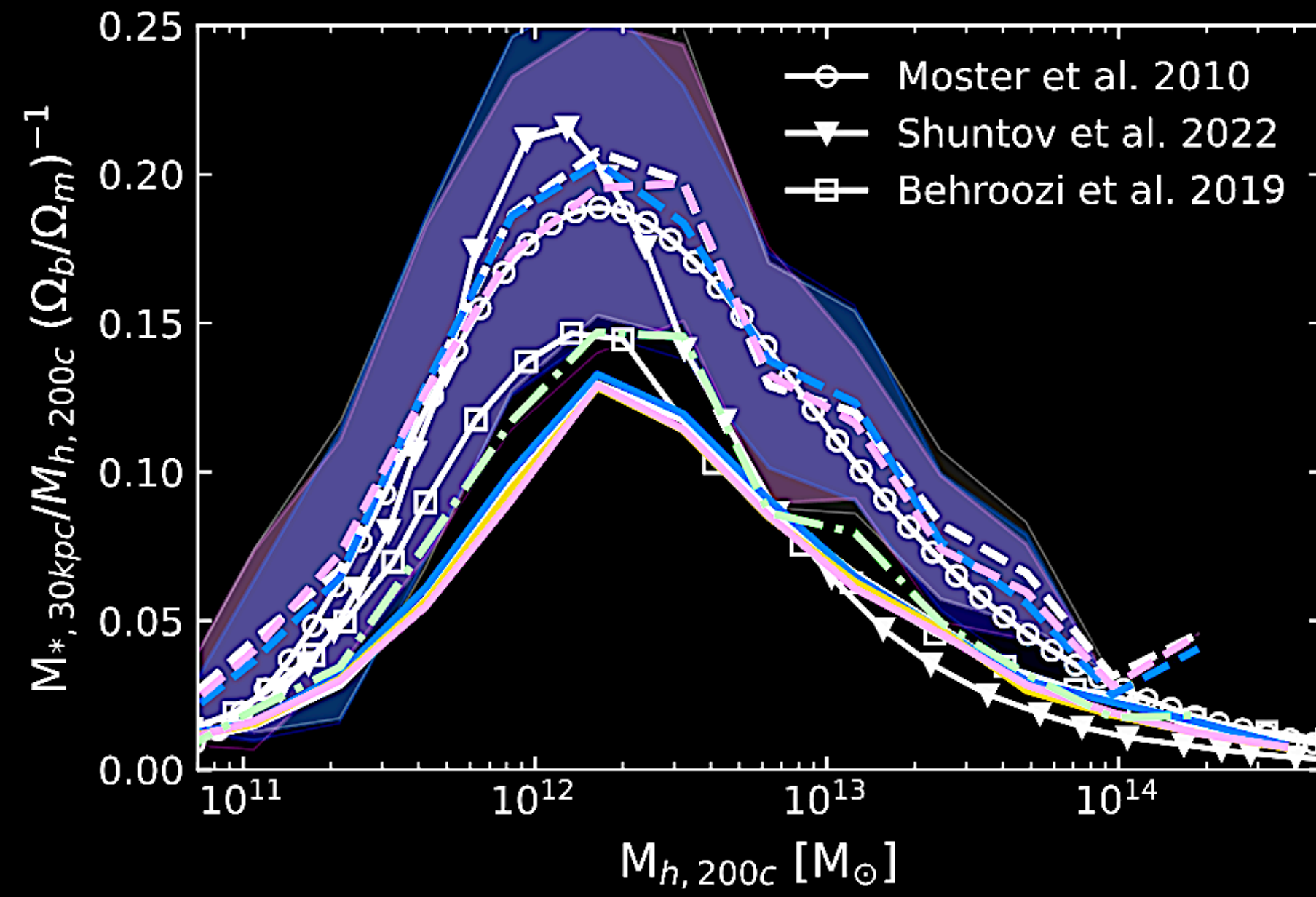


Full Physics runs from $z=0$ to $z=5$

stellar mass function

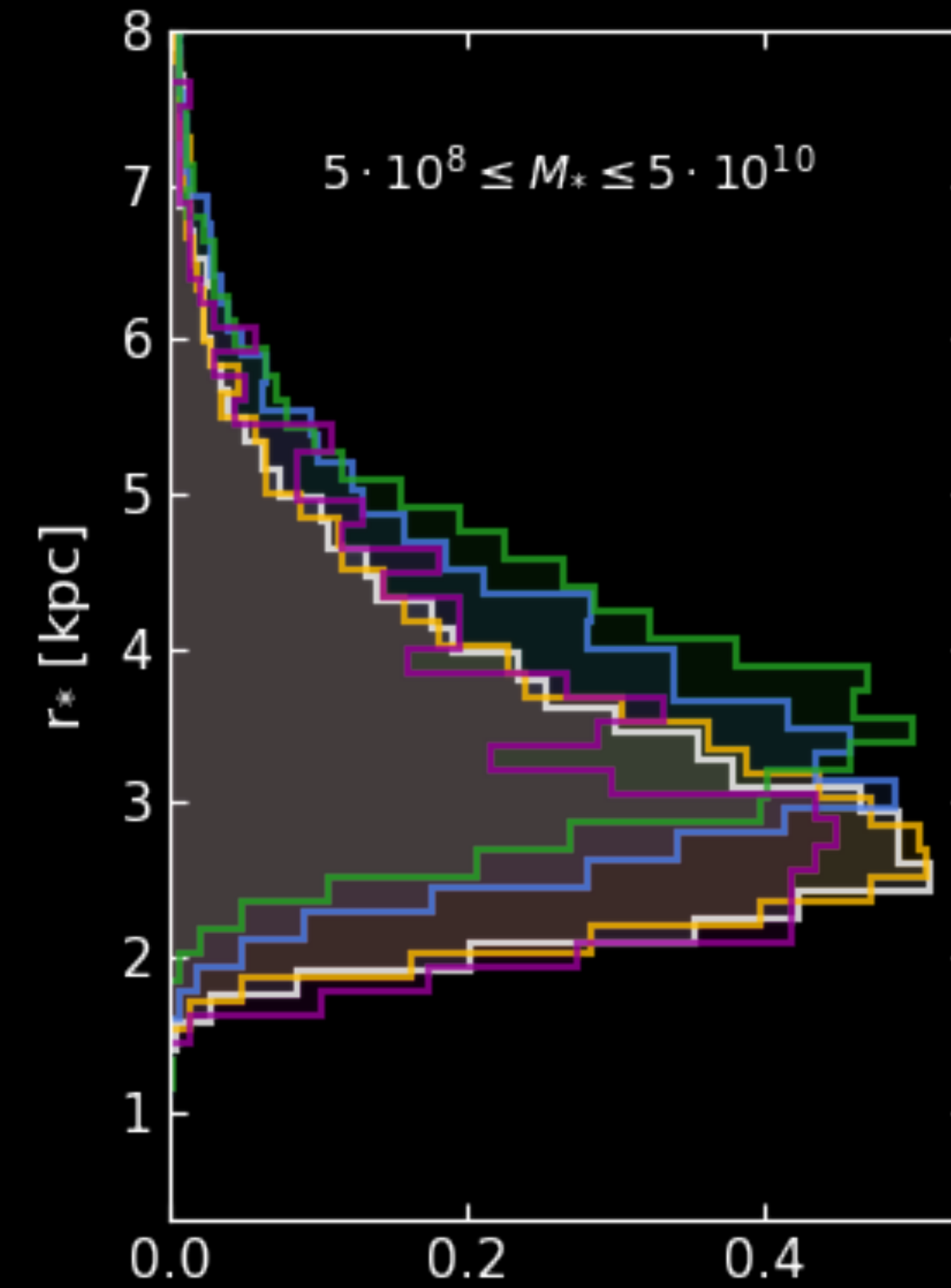
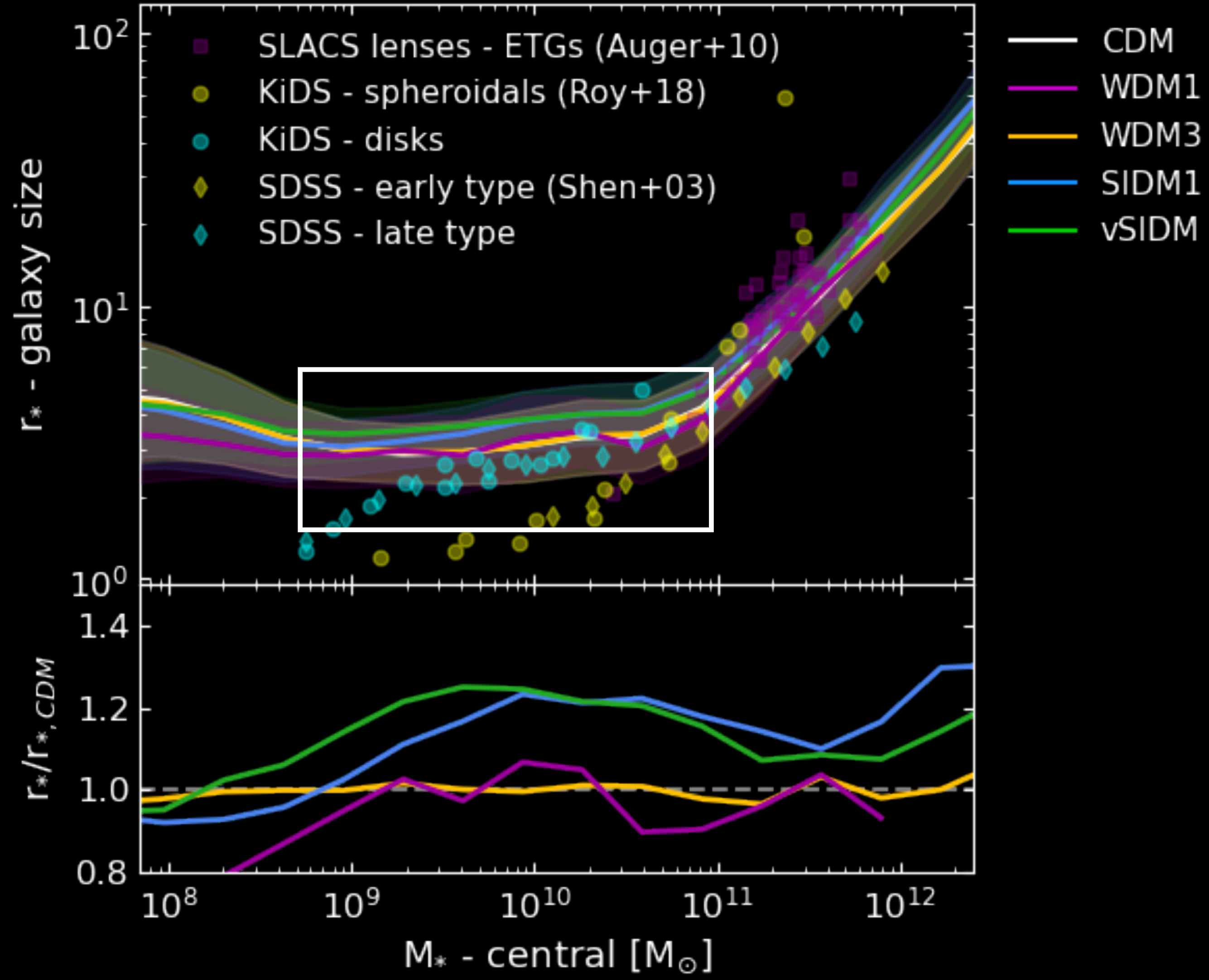


GALAXY PROPERTIES

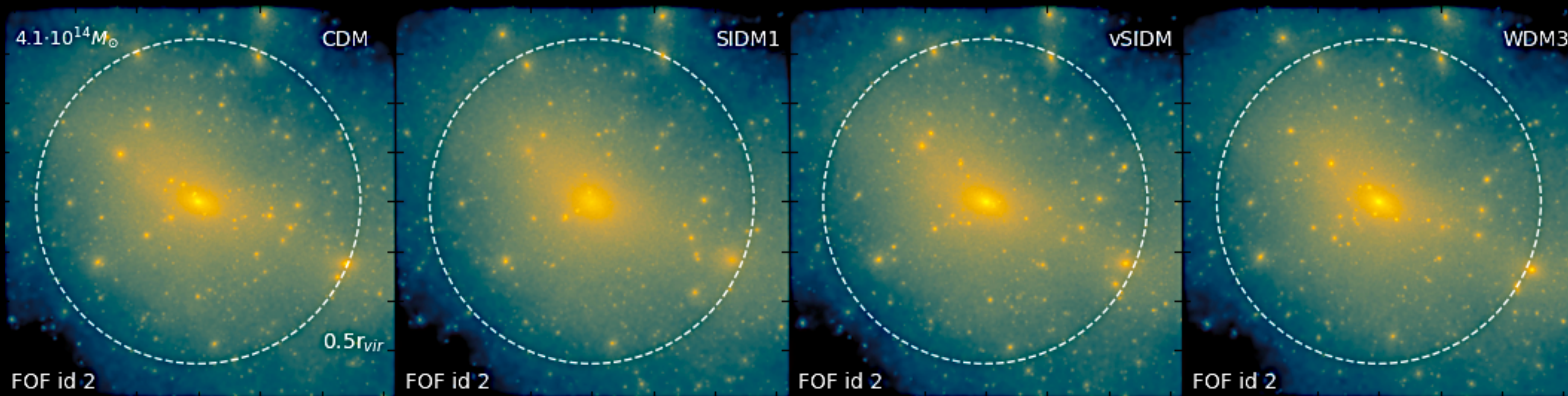


GALAXY PROPERTIES

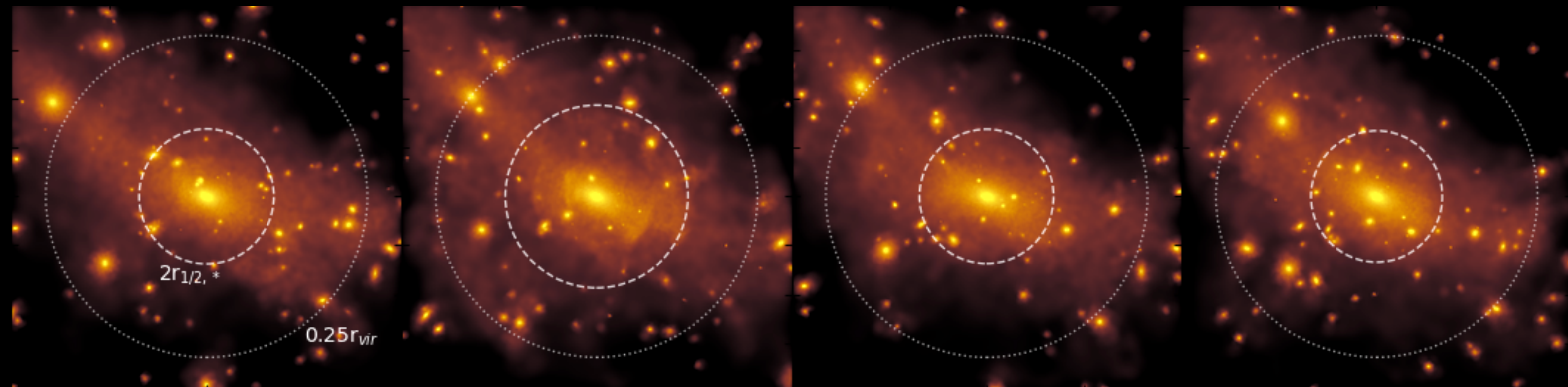
galaxy sizes

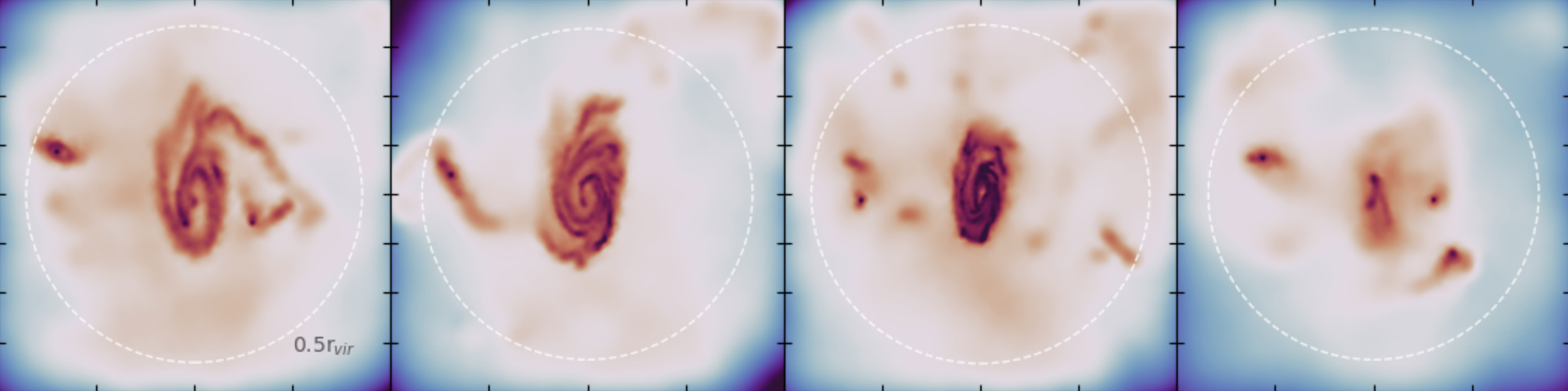
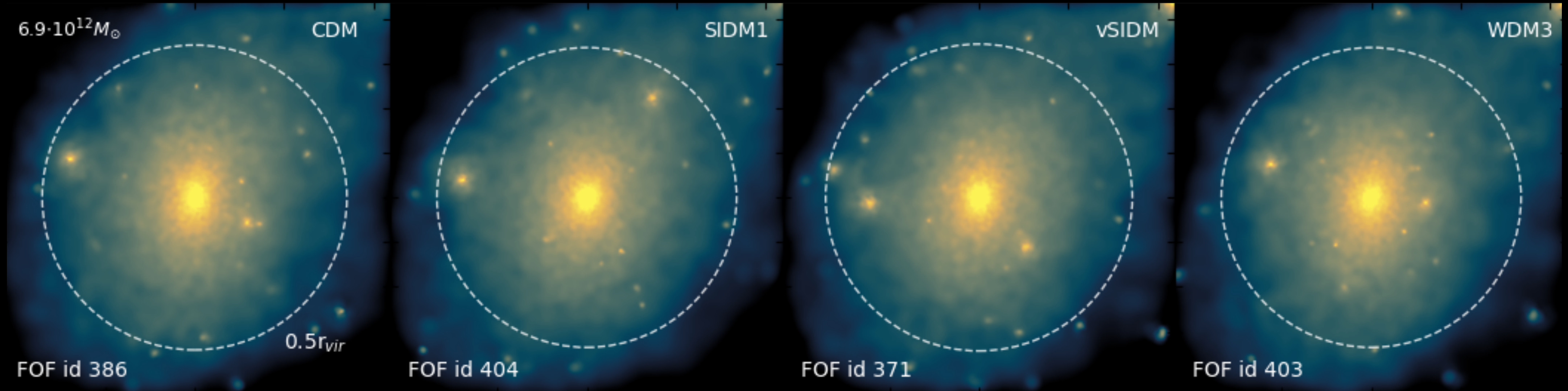


dark matter

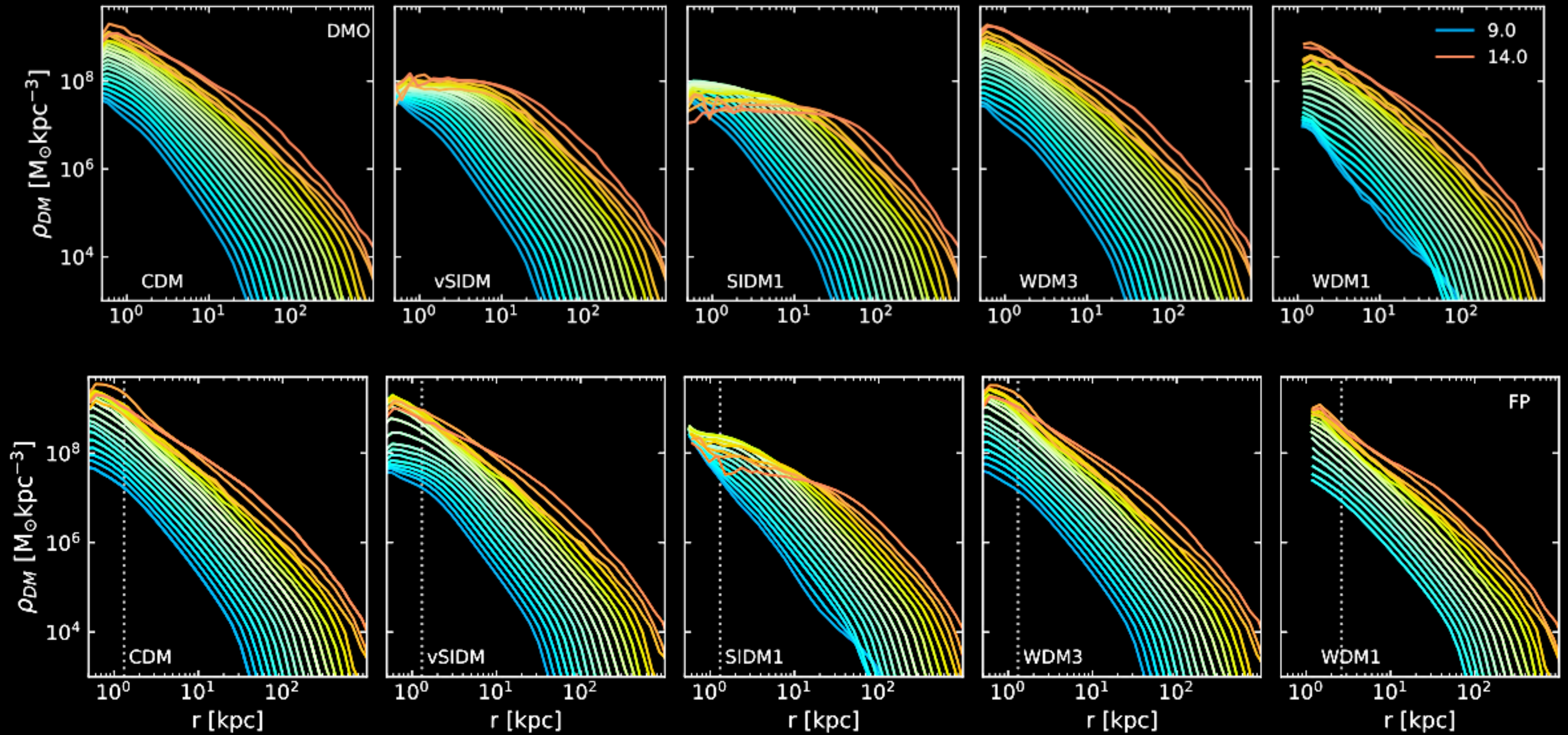


stars

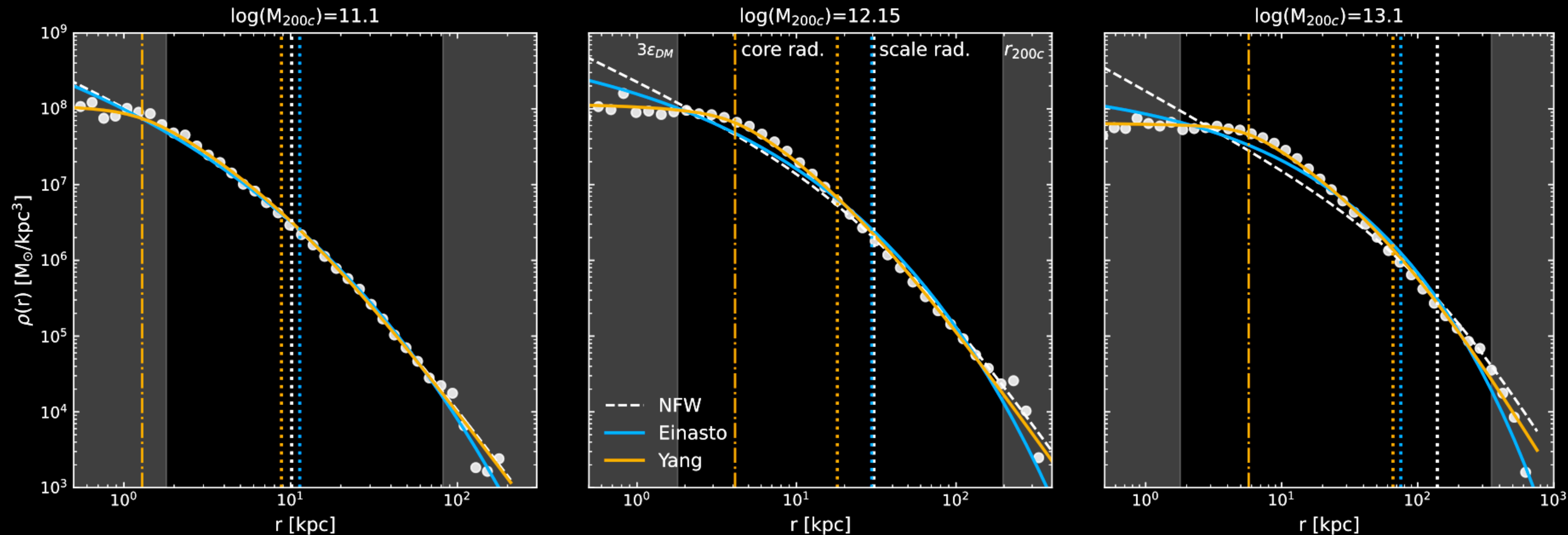




HALO PROFILES



HALO PROFILES



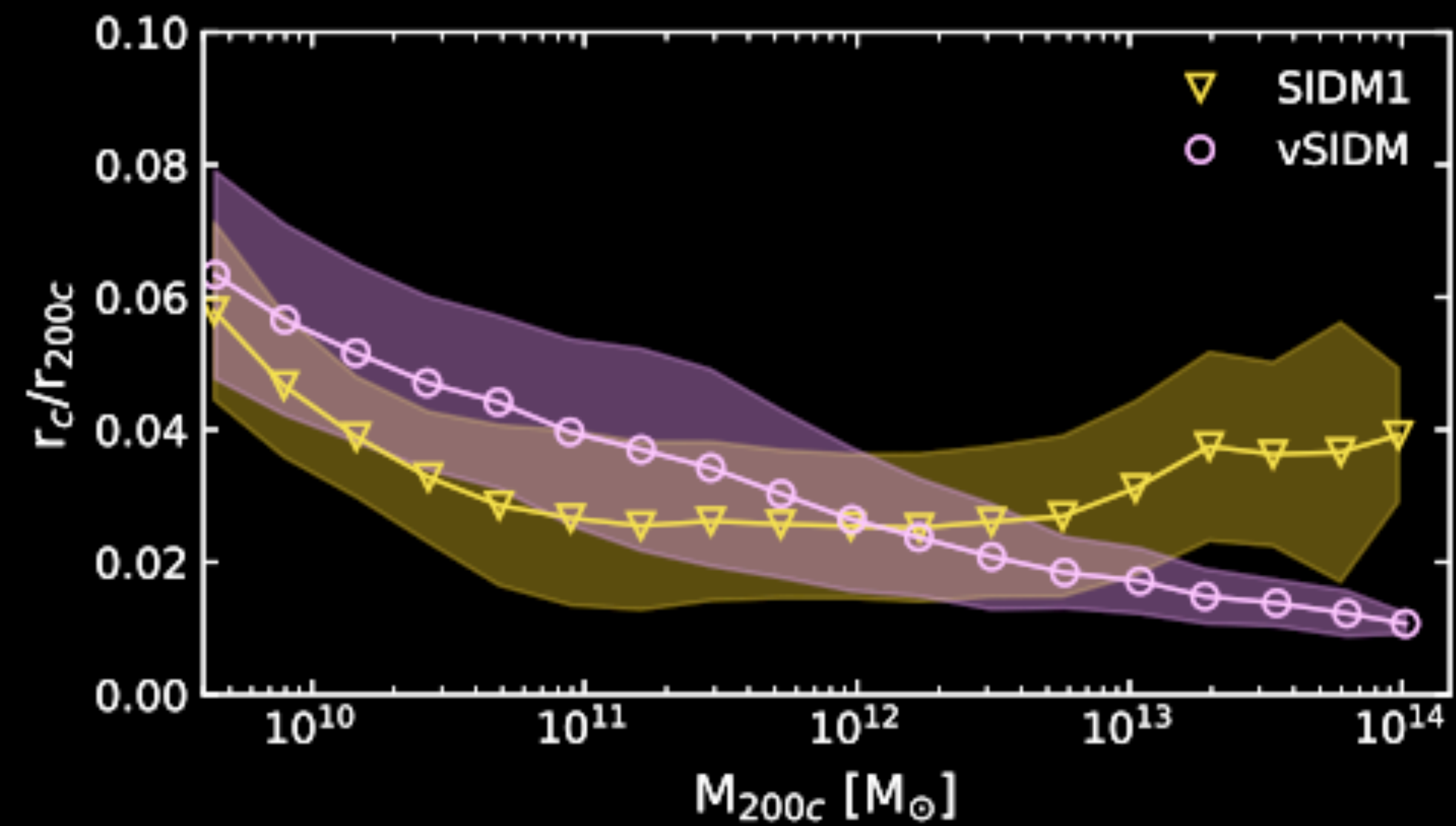
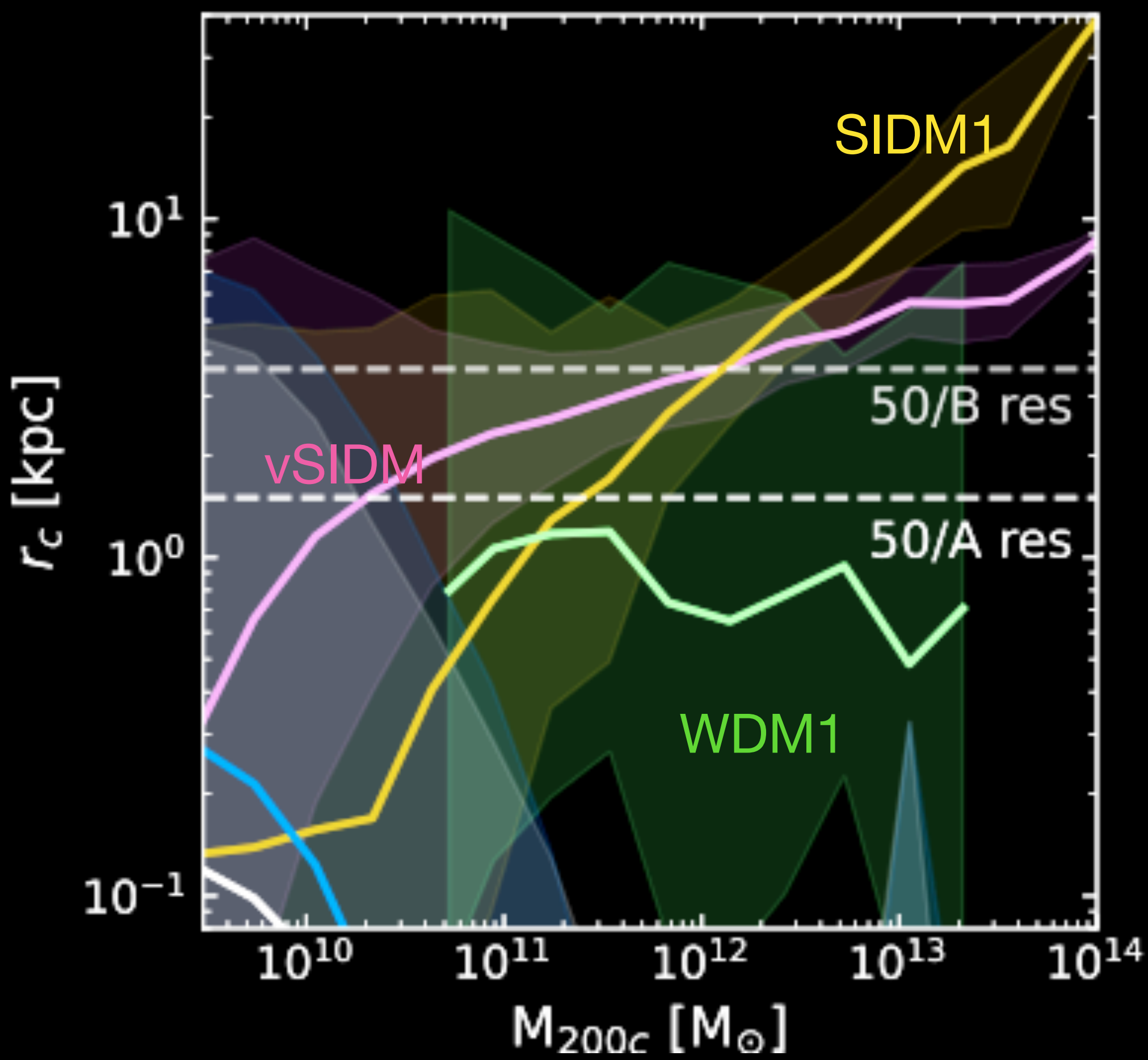
Einasto

Cored profile

(Yang et al. 2024)

$$\rho_Y(r) = \frac{\rho_Y}{[(r^\beta + r_c^\beta)^{1/\beta} / r_Y] \left(1 + \frac{r}{r_Y}\right)^2}$$

HALO PROFILES

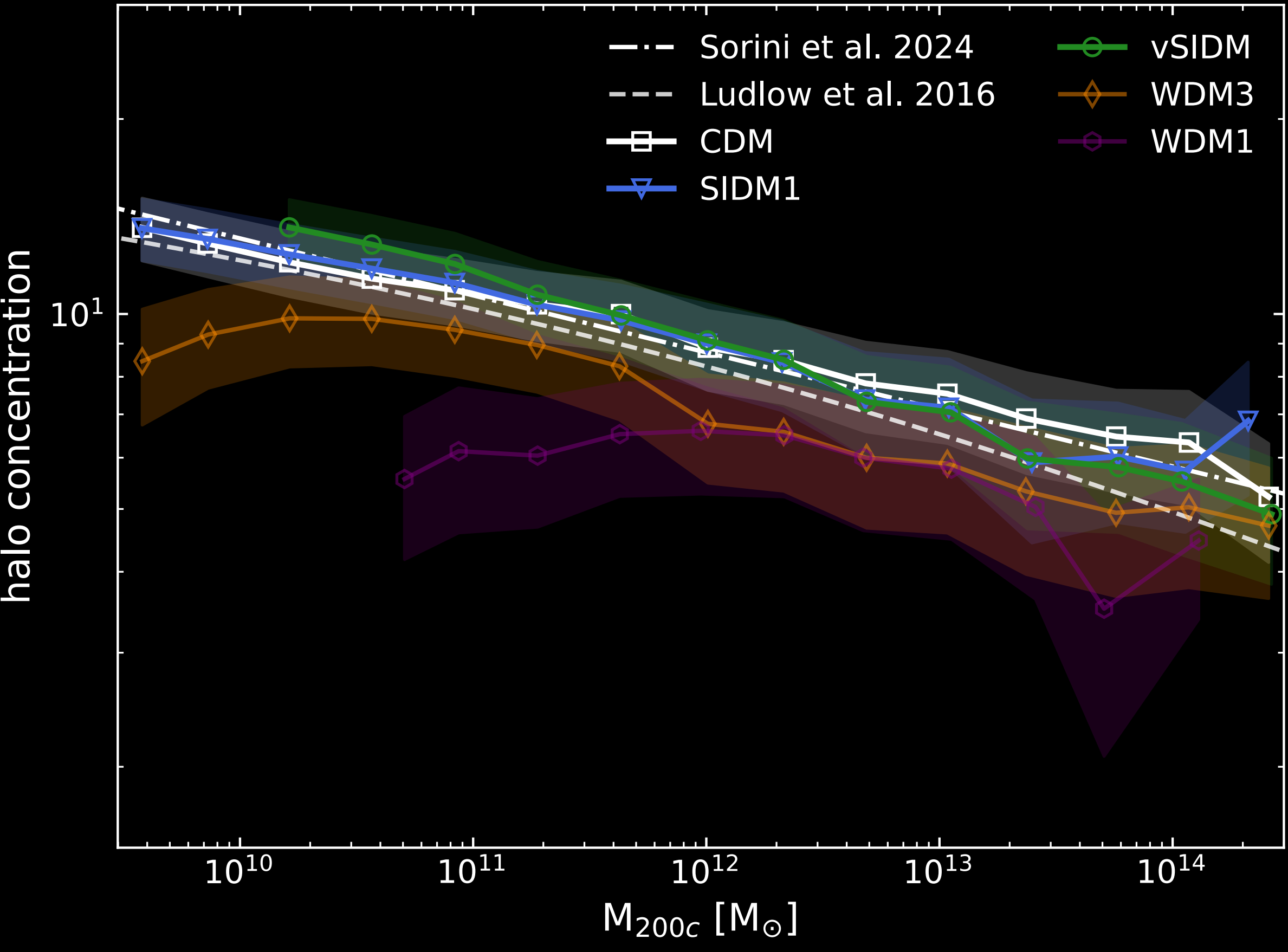
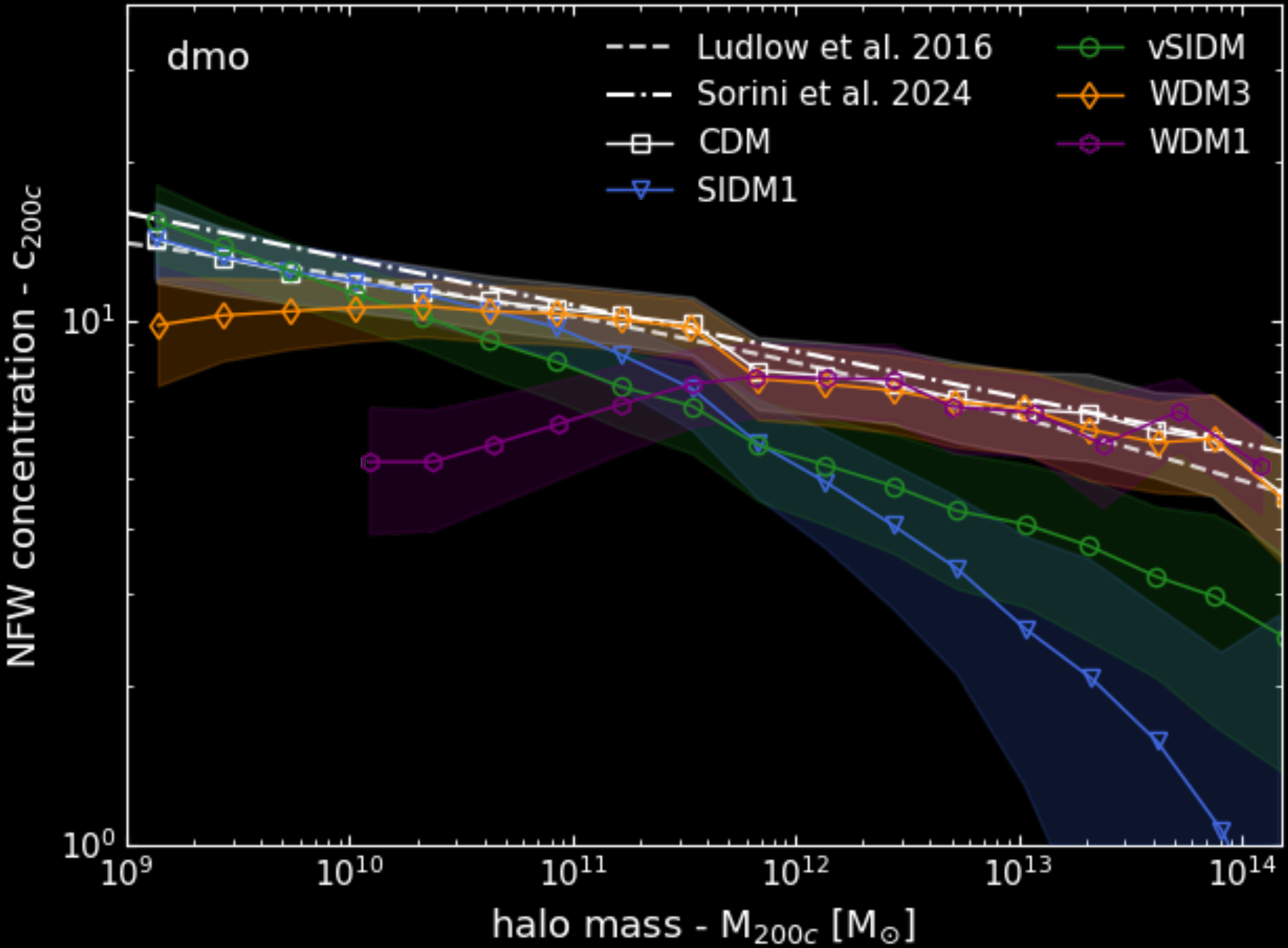


Cored profile

(Yang et al. 2024)

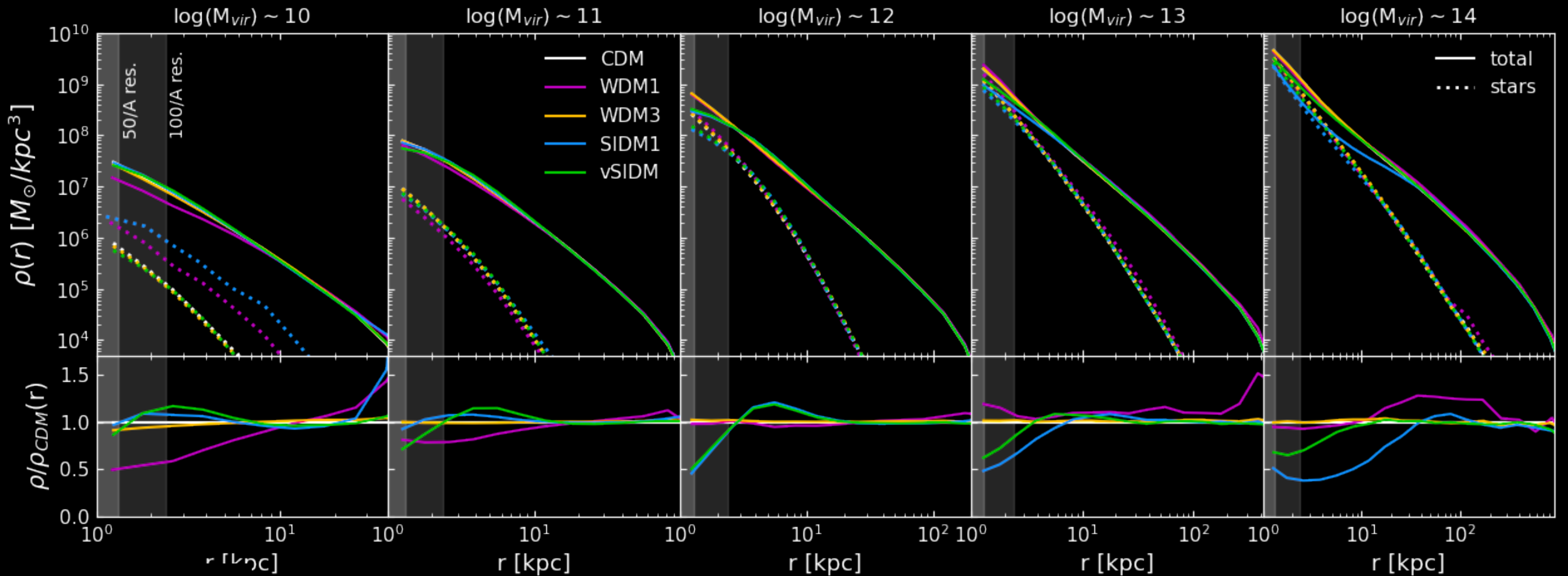
$$\rho_Y(r) = \frac{\rho_Y}{[(r^\beta + r_c^\beta)^{1/\beta}/r_Y] \left(1 + \frac{r}{r_Y}\right)^2},$$

HALO CONCENTRATIONS

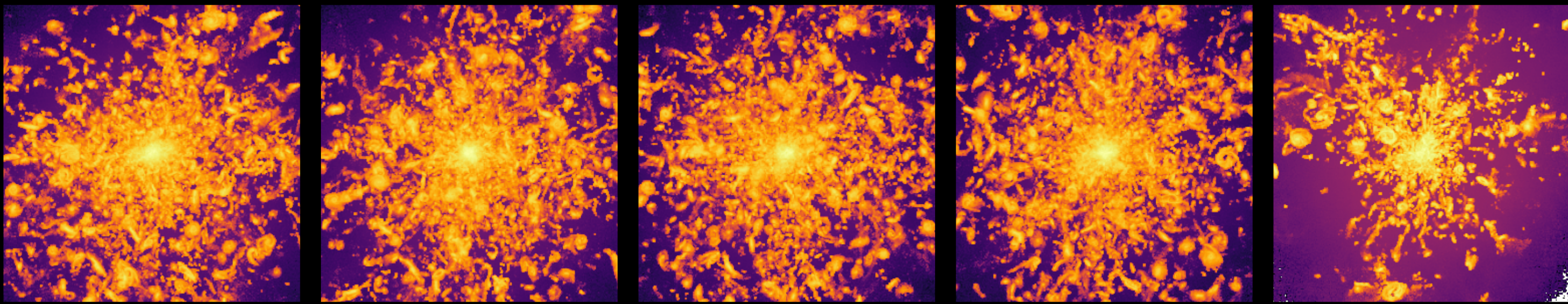


HALO PROFILES

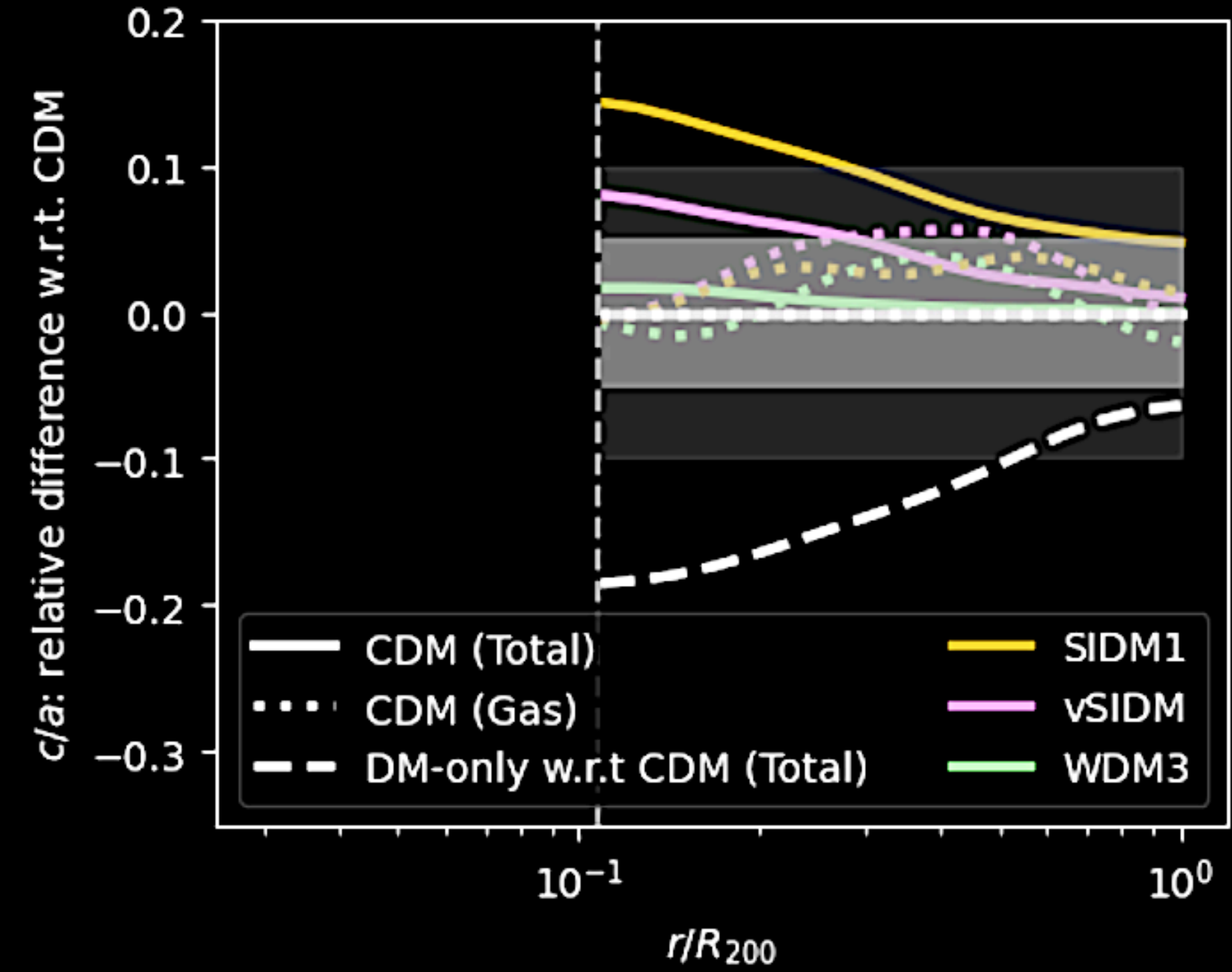
not only the DM profile is affected, but also the total density



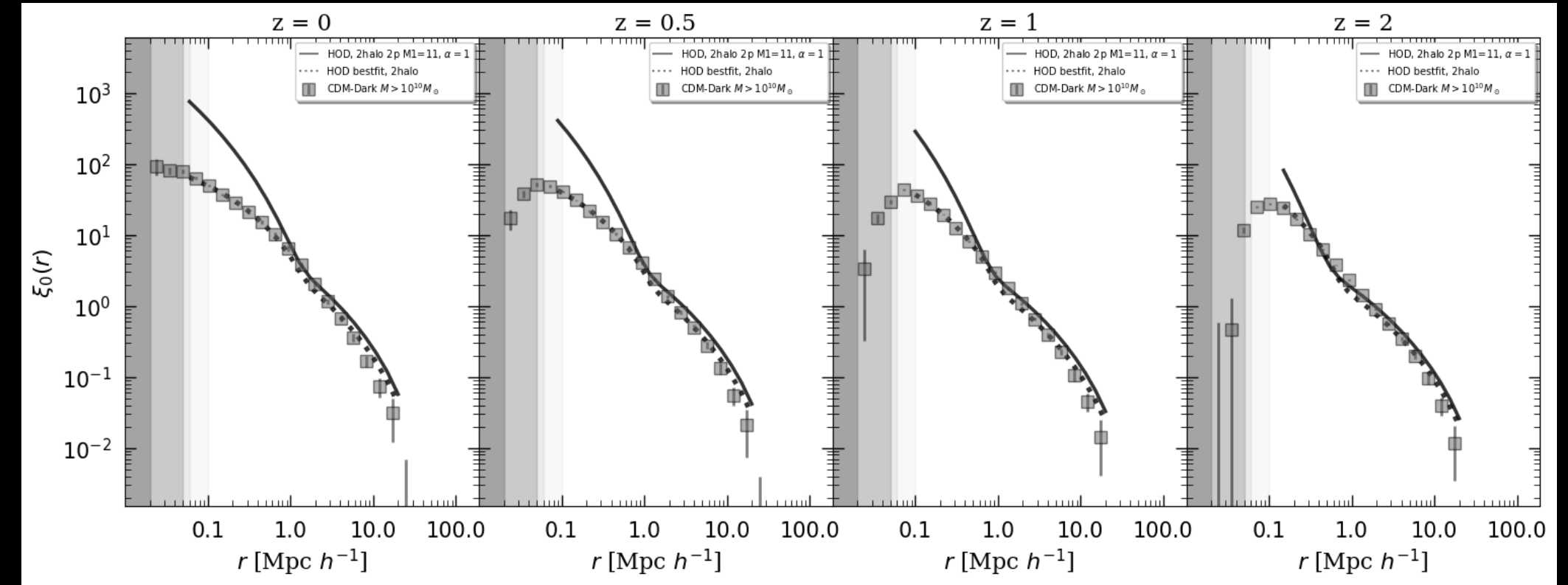
HI and Lyman- α (Zhang et al. in prep)



Halo shapes (Giocoli et al. in prep)



Subhalo distribution & clustering (Romanello et al. in prep)



Evolution of subhalo profiles (core-collapse?)

Properties of disk galaxies

new AIDA-TNG simulations

- ✓ three cosmological boxes
- ✓ AREPO - moving mesh
- ✓ TNG galaxy formation model
- ✓ CDM, WDM, SIDM
- ✓ multiple resolution levels
- ✓ large statistics of galaxies

SUMMARY

