Can SIDM Compete with Baryonic Effects?

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SIDM Conference

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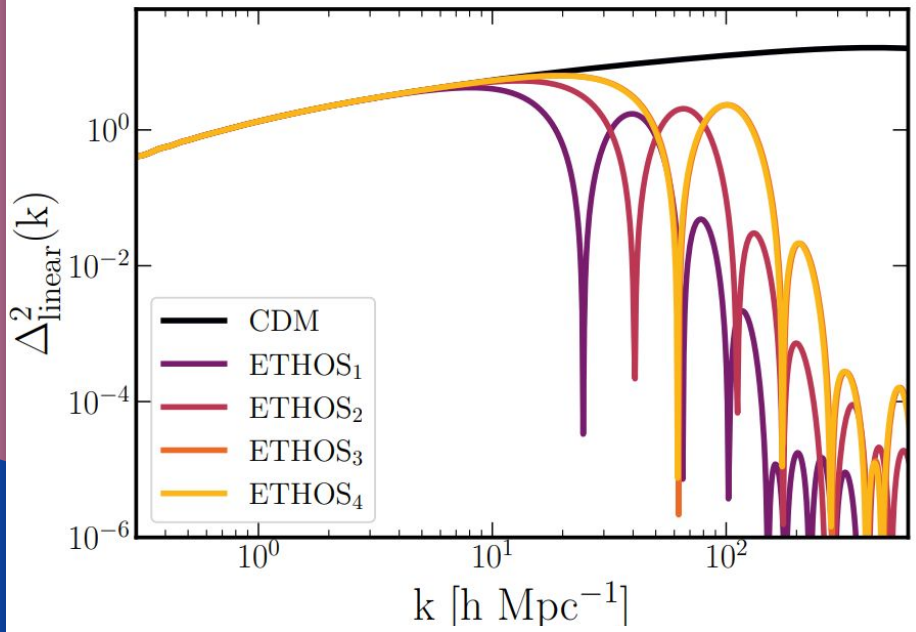
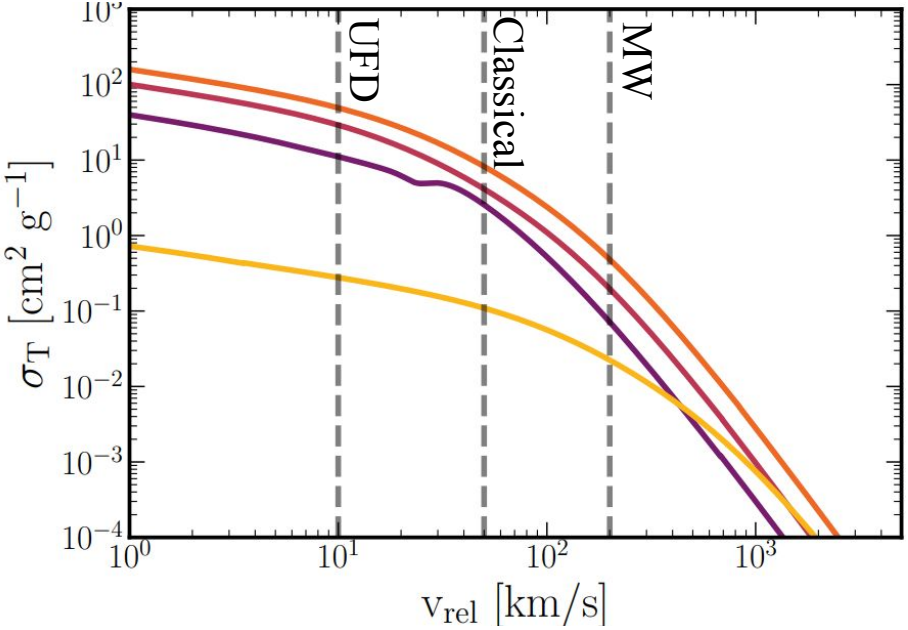
This Investigation

Most SIDM models are tested with N-body simulations, do these results hold when we include a comprehensive galaxy formation model?

The ETHOS Models

Max <σ> = 25 7 0.5





Name	α_χ	α_ν	m_ϕ (MeV c^{-2})	m_χ (GeV c^{-2})	$r_{\rm DAO}$ (h^{-1} Mpc)	$r_{\rm SD}$ (h^{-1} Mpc)	a_4 (h Mpc^{-1})	$\langle\sigma_T\rangle_{30}/m_\chi$ (cm^2 g^{-1})	$\langle\sigma_T\rangle_{200}/m_\chi$ (cm^2 g^{-1})	$\langle\sigma_T\rangle_{1000}/m_\chi$ (cm^2 g^{-1})
CDM	–	–	–	–	–	–	–	–	–	
ETHOS-1	0.071	0.123	0.723	2000	0.362	0.225	14 095.65	4.98	0.072	0.0030
ETHOS-2	0.016	0.03	0.83	500	0.217	0.113	1784.05	9.0	0.197	0.000 97
ETHOS-3	0.006	0.018	1.15	178	0.141	0.063	305.94	16.9	0.48	0.0028
ETHOS-4 (tuned)	0.5	1.5	5.0	3700	0.138	0.0615	286.09	0.16	0.022	0.000 75

Vogelsberger et al. 2016

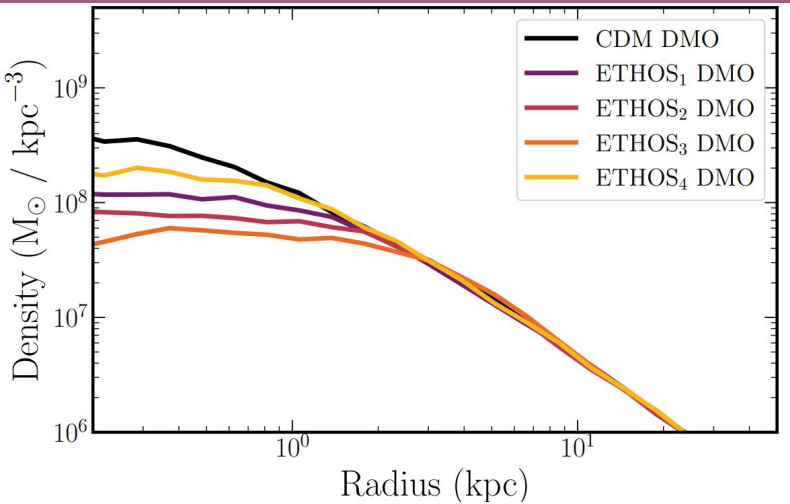
N-body Results

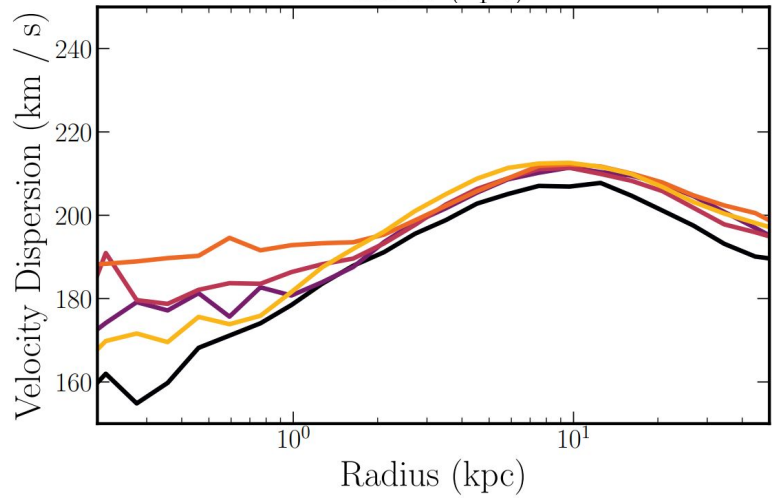
CDM | $ETHOS_1$ | $ETHOS_2$ | $ETHOS_3$ | $ETHOS_4$

- Zoom-in simulation of MW-mass galaxy and satellites
  - Initial conditions fixed for each simulation (same as Stephanie's)
  - Run with Arepo code

N-body Results - Central

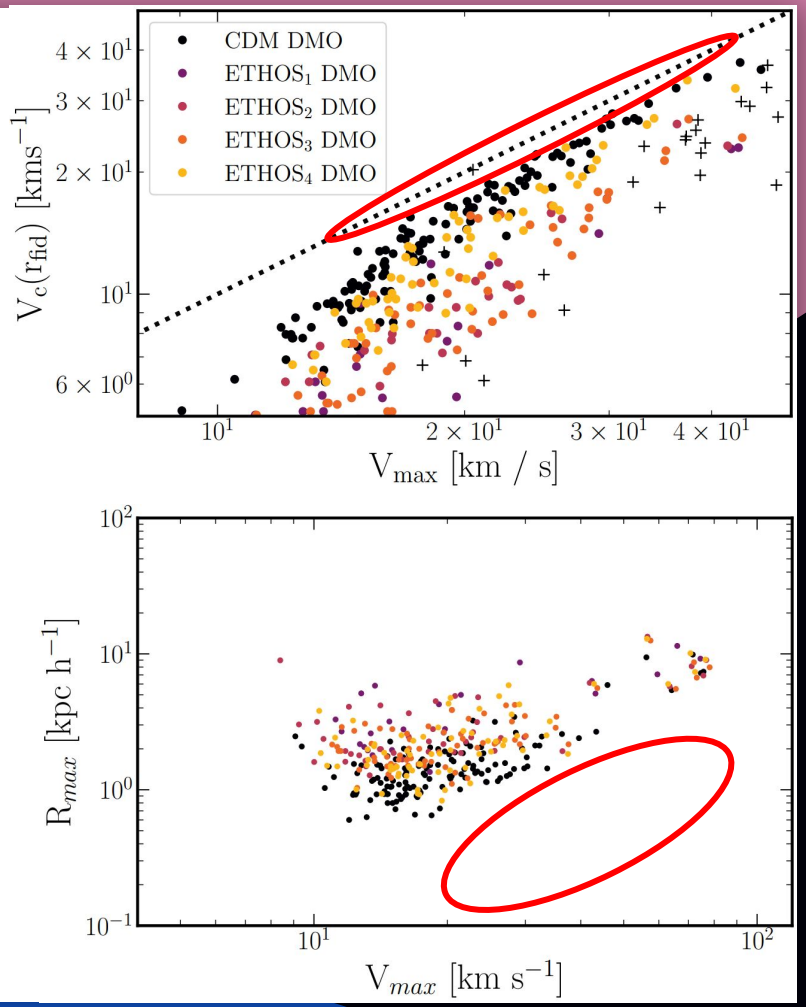
- Isothermal and isodensity cores for the central halo
  - Cores up to 3 kpc
  - Core sizes are proportional to magnitude of SIDM cross section



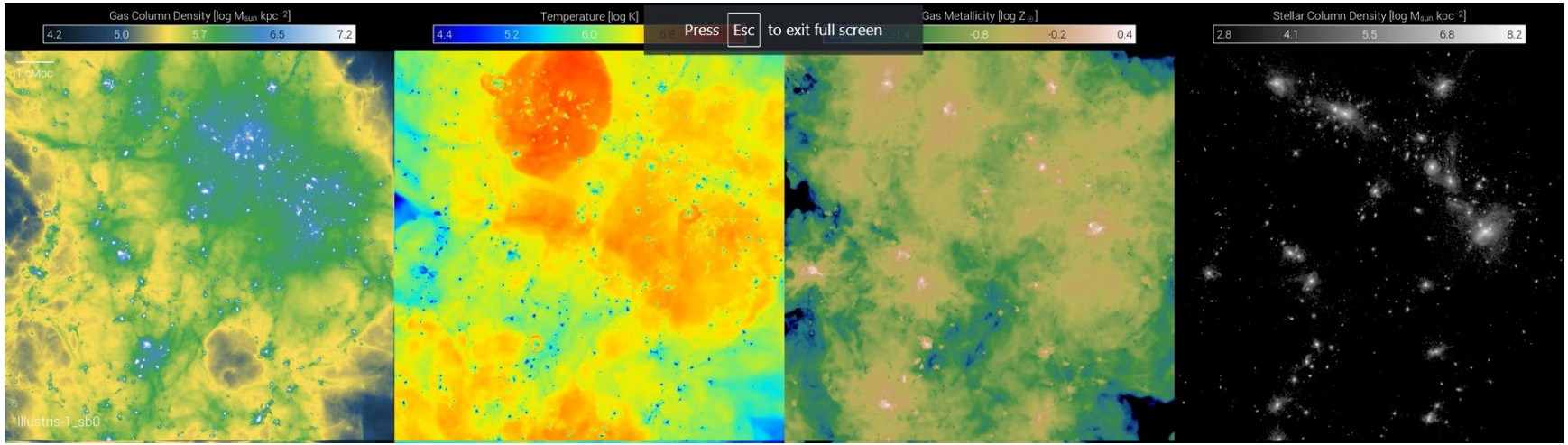


N-body Results - Gravothermal Collapse?

- No gravothermal collapse
  - Cross sections are not large enough
- CDM can also not reach these densities

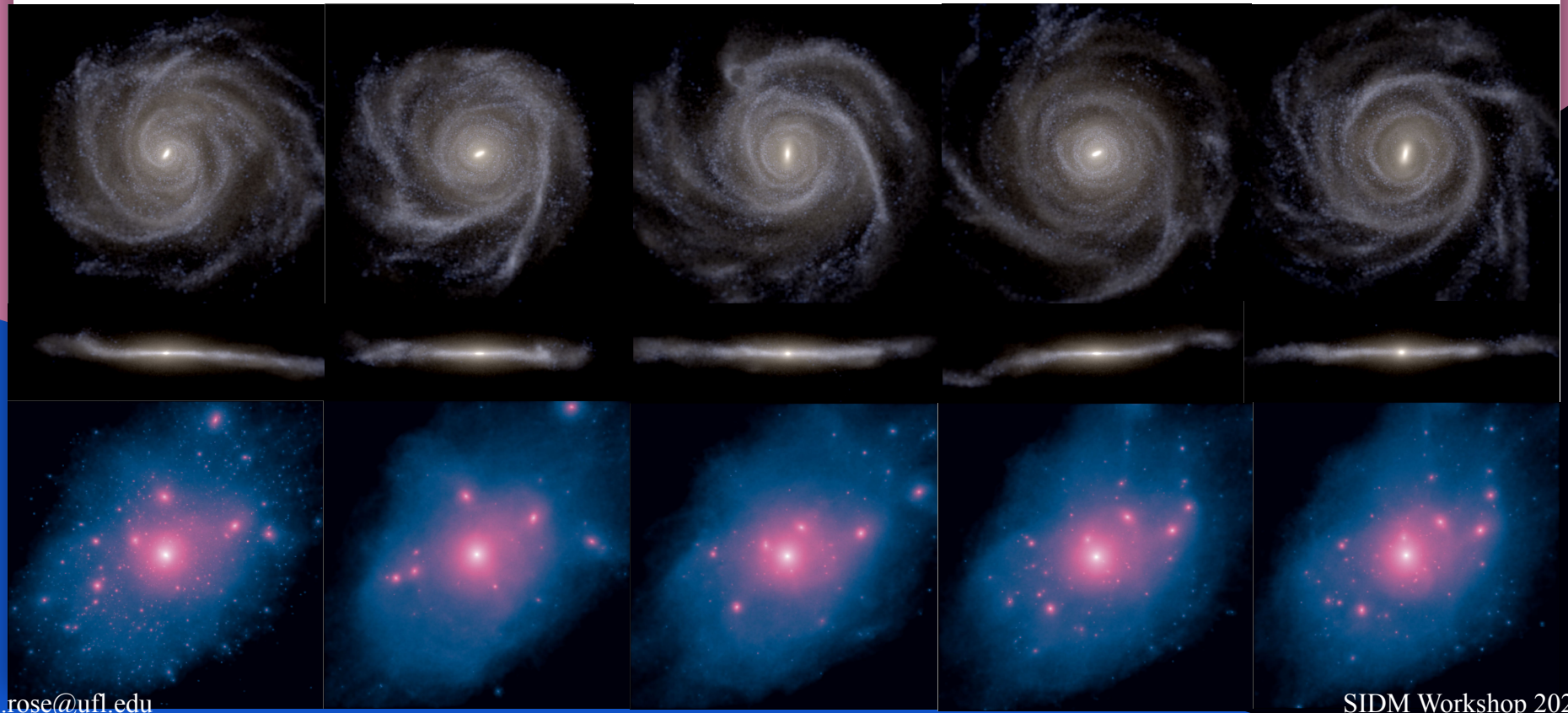


IllustrisTNG



MW Disks with SIDM and IllustrisTNG

CDM | ETHOS_1 | ETHOS_2 | ETHOS_3 | ETHOS_4



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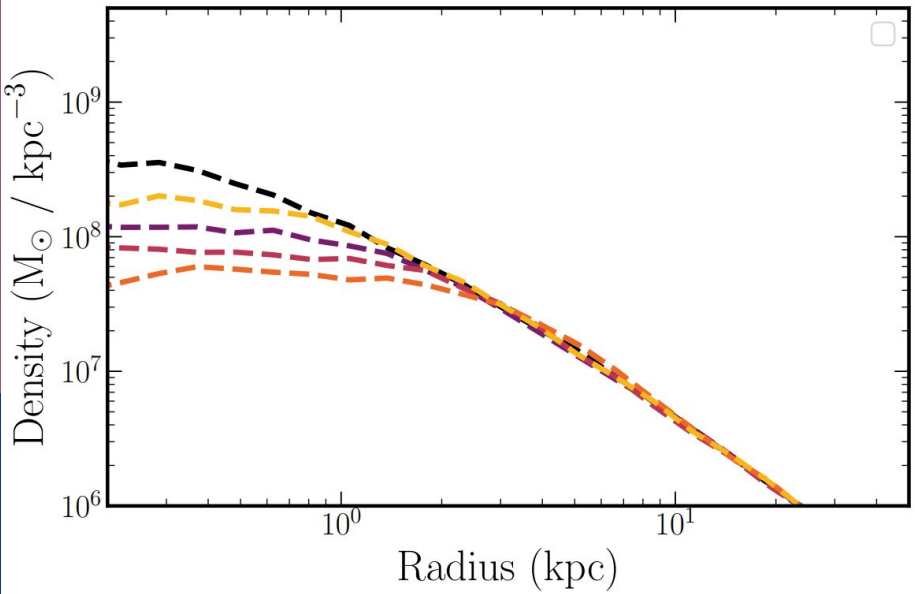
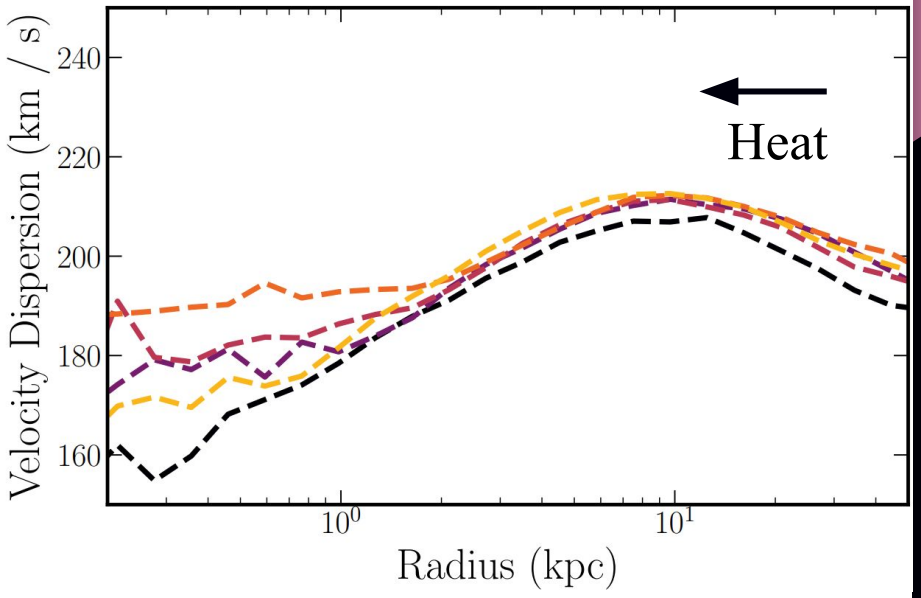
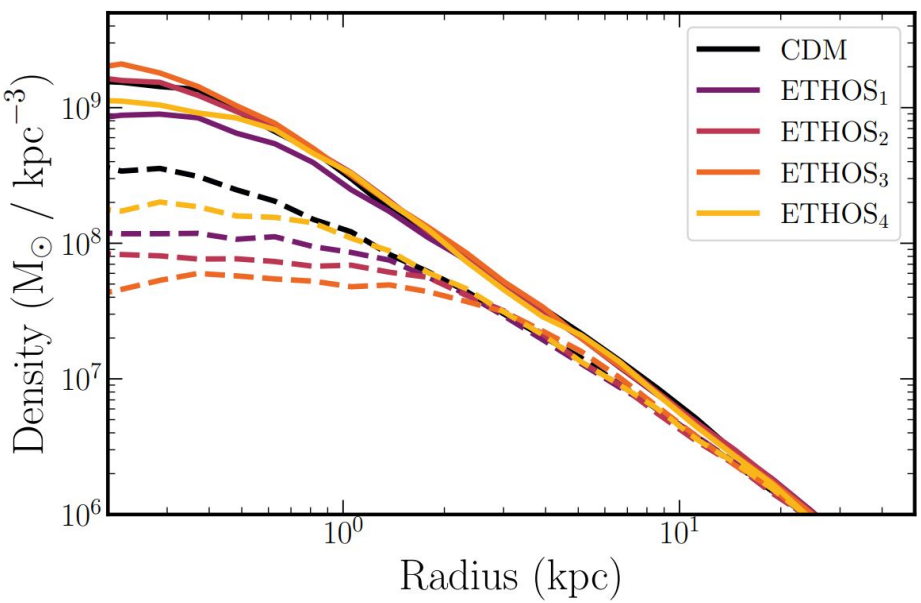
Comparison to N-body Simulations

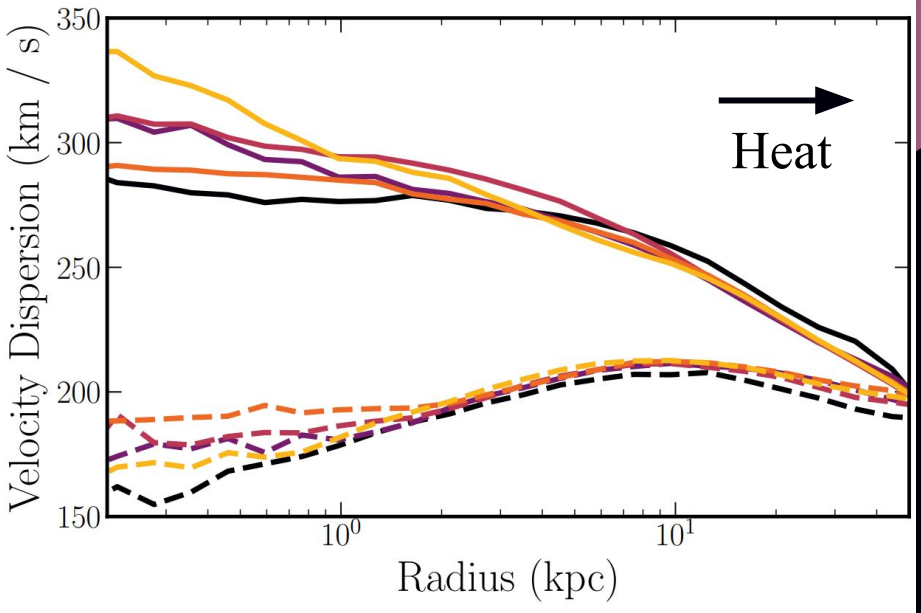




- Isothermal and isodensity cores for the central halo
  - Cores up to 3 kpc
  - Core sizes are proportional to magnitude of SIDM cross section

Comparison to N-body Simulations

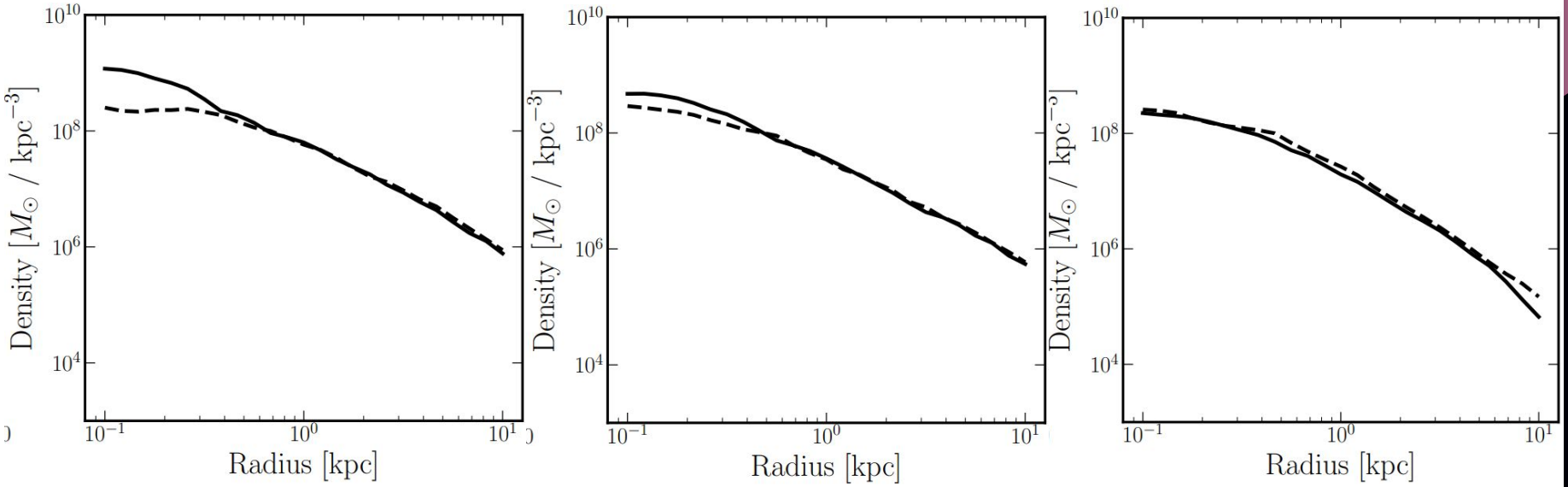




- All galaxies are now denser with no constant-density core
- There is little variation between SIDM models

Adiabatic Contraction in CDM

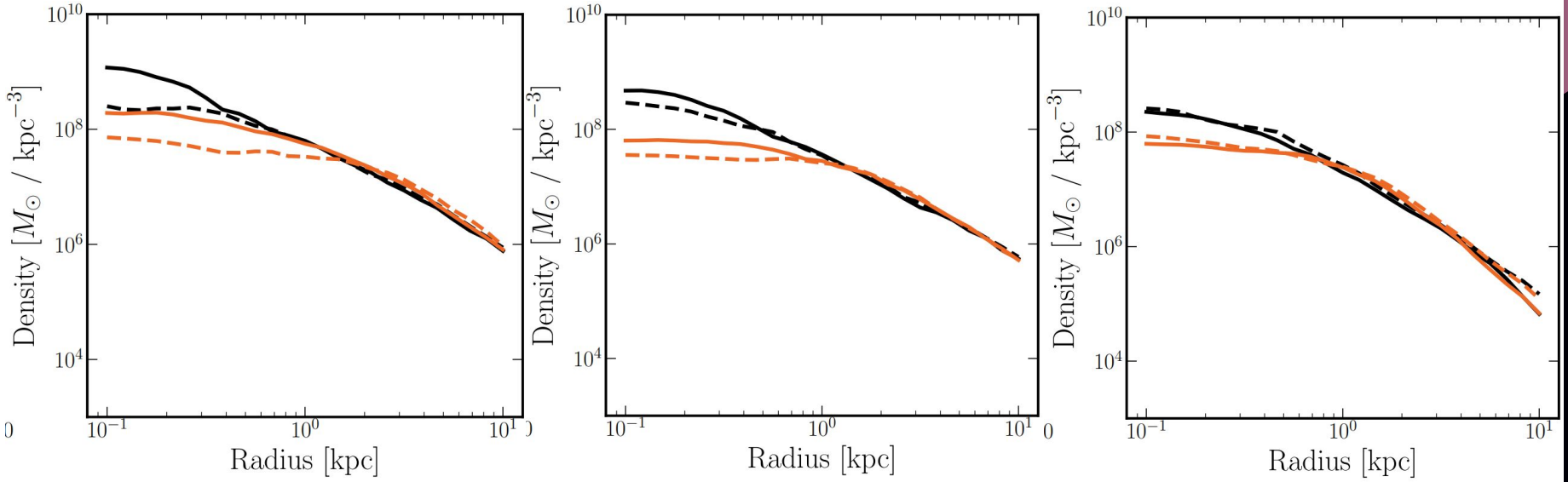
$M_* = 1.0 \times 10^9$ $M_* = 1.8 \times 10^8$ $M_* = 1.8 \times 10^7$



- Larger halos have higher DM densities in TNG simulations
- Increased density is from adiabatic contraction

Adiabatic Contraction in SIDM

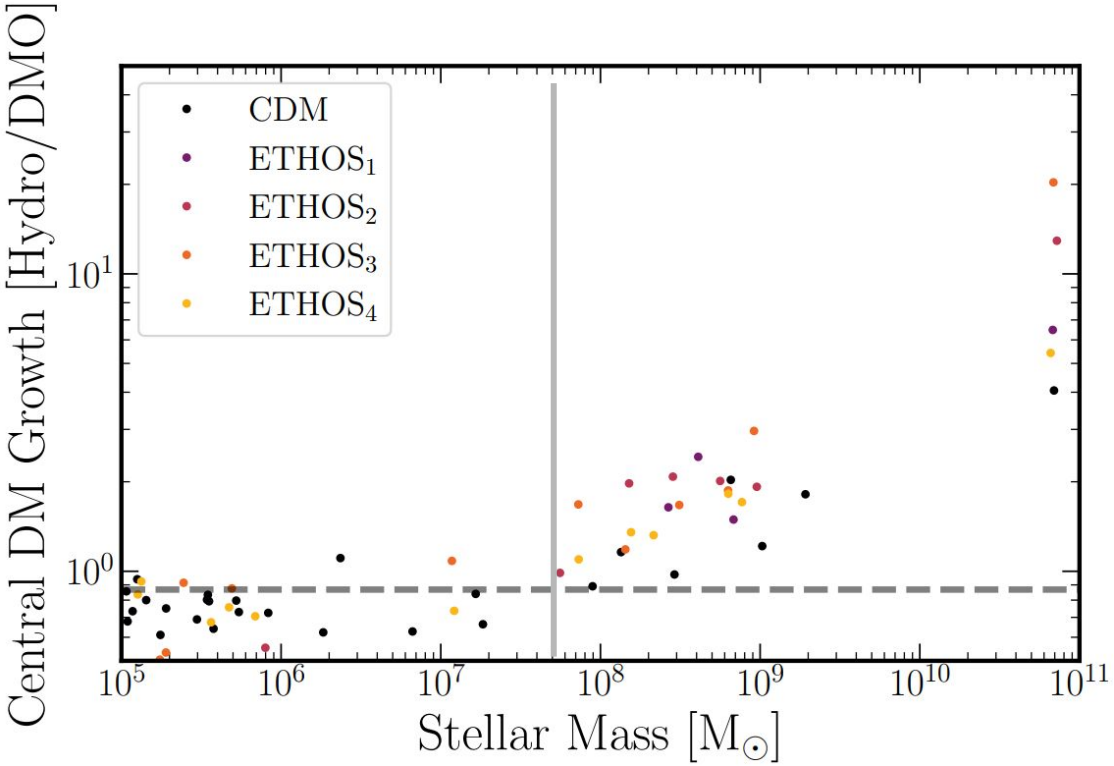
$M_* = 1.0 \times 10^9$ $M_* = 1.8 \times 10^8$ $M_* = 1.8 \times 10^7$



- Adiabatic contraction also affects SIDM satellites

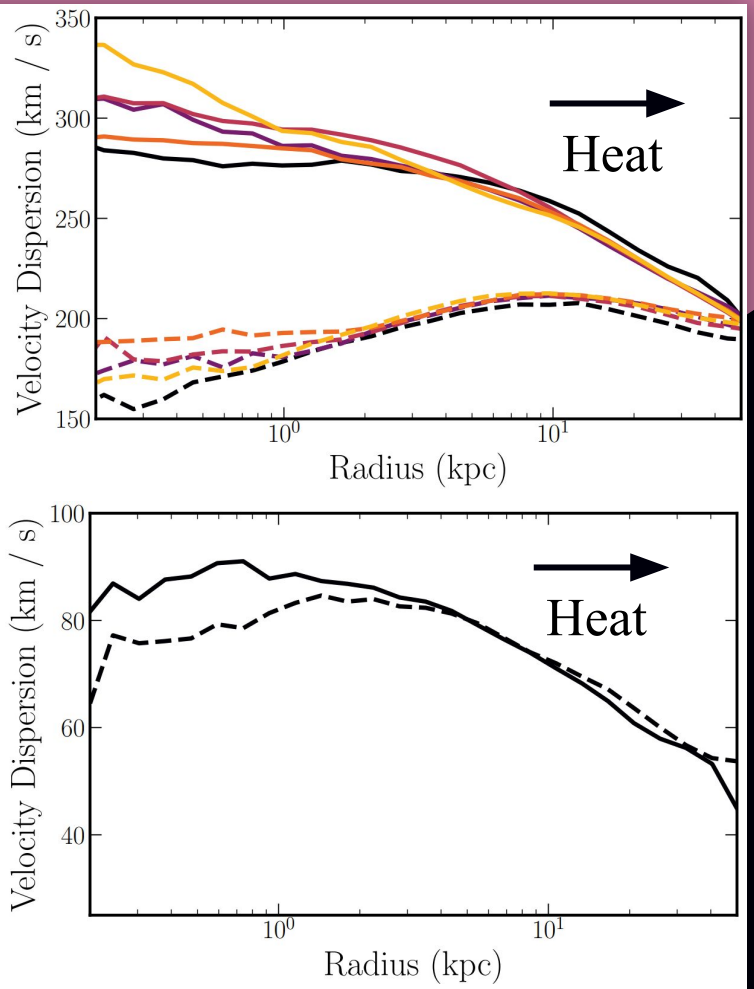
Adiabatic Contraction in Dwarfs

- Adiabatic contraction affects halos larger than ~10^8 stellar mass
  - ~ 10^{10} halo mass
- Smaller halos remain the same as N-body simulations



Implications for SIDM

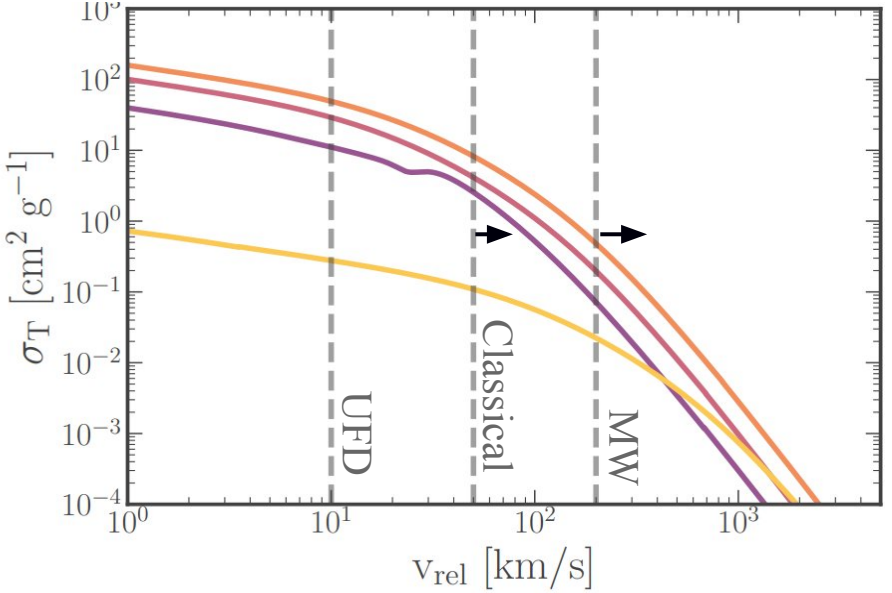
- Baryons heat the center of halos
  - Both centrals and satellites
- Can push galaxies into core collapse
  - Especially for very baryon-dominated galaxies, like MW



Implications for SIDM

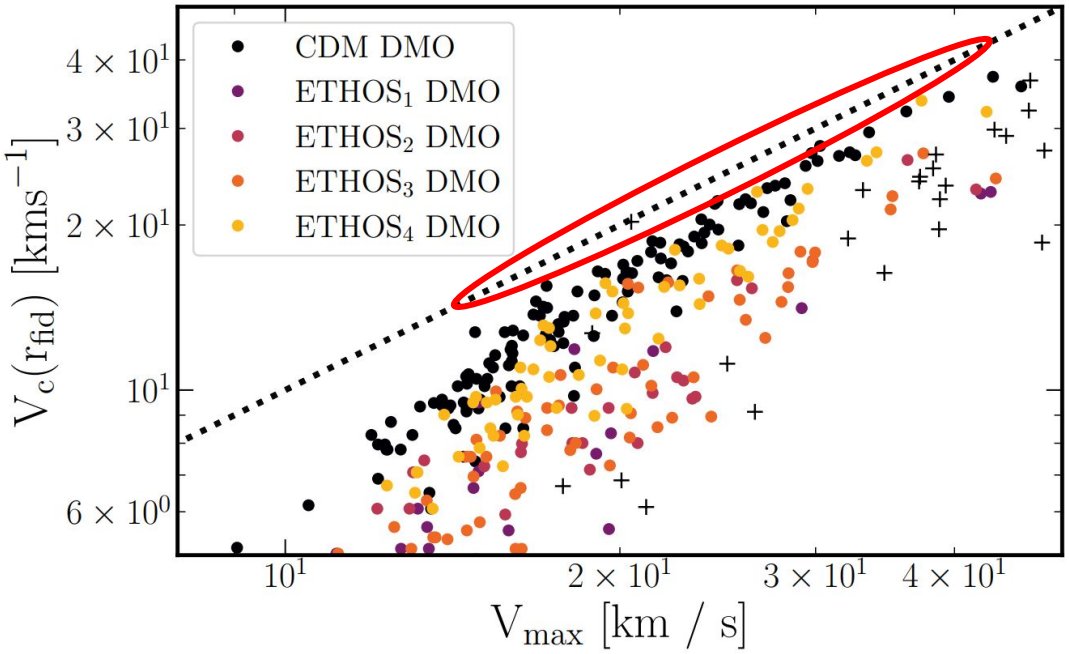
- Central velocities are higher
  - Can change SIDM cross section
- UFD cross sections are unchanged
- Classical change slightly
- MW change most

Old Max <σ> = 25 7 0.5
New Max <σ> = 25 5 0.1



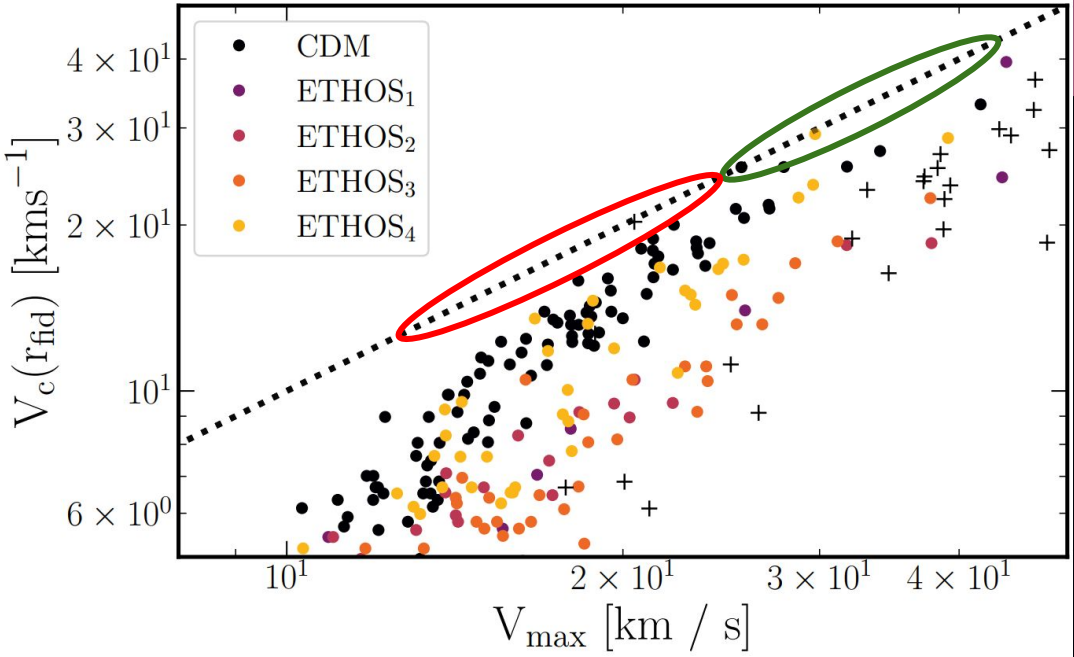
Gravothermal Collapse? (N-body)

- No gravothermal collapse
  - Cross sections are not large enough
- CDM can also not reach these densities



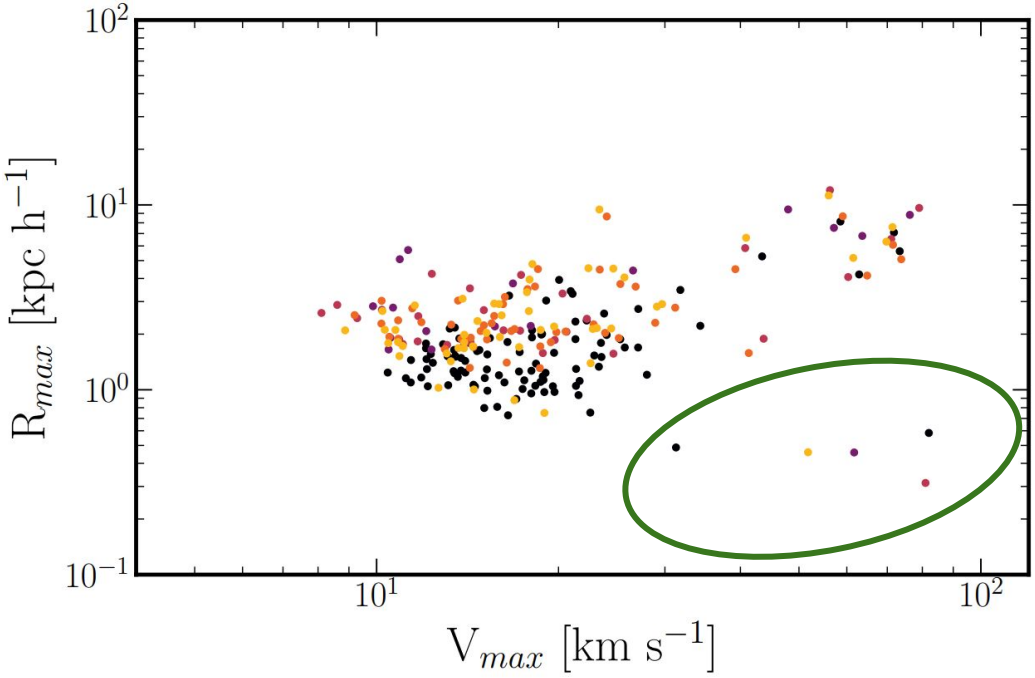
Gravothermal Collapse?

- Few dense halos despite isothermal cores.
  - Cross sections are too small?
- Core collapsed halos are at higher masses
- CDM also has very dense halos

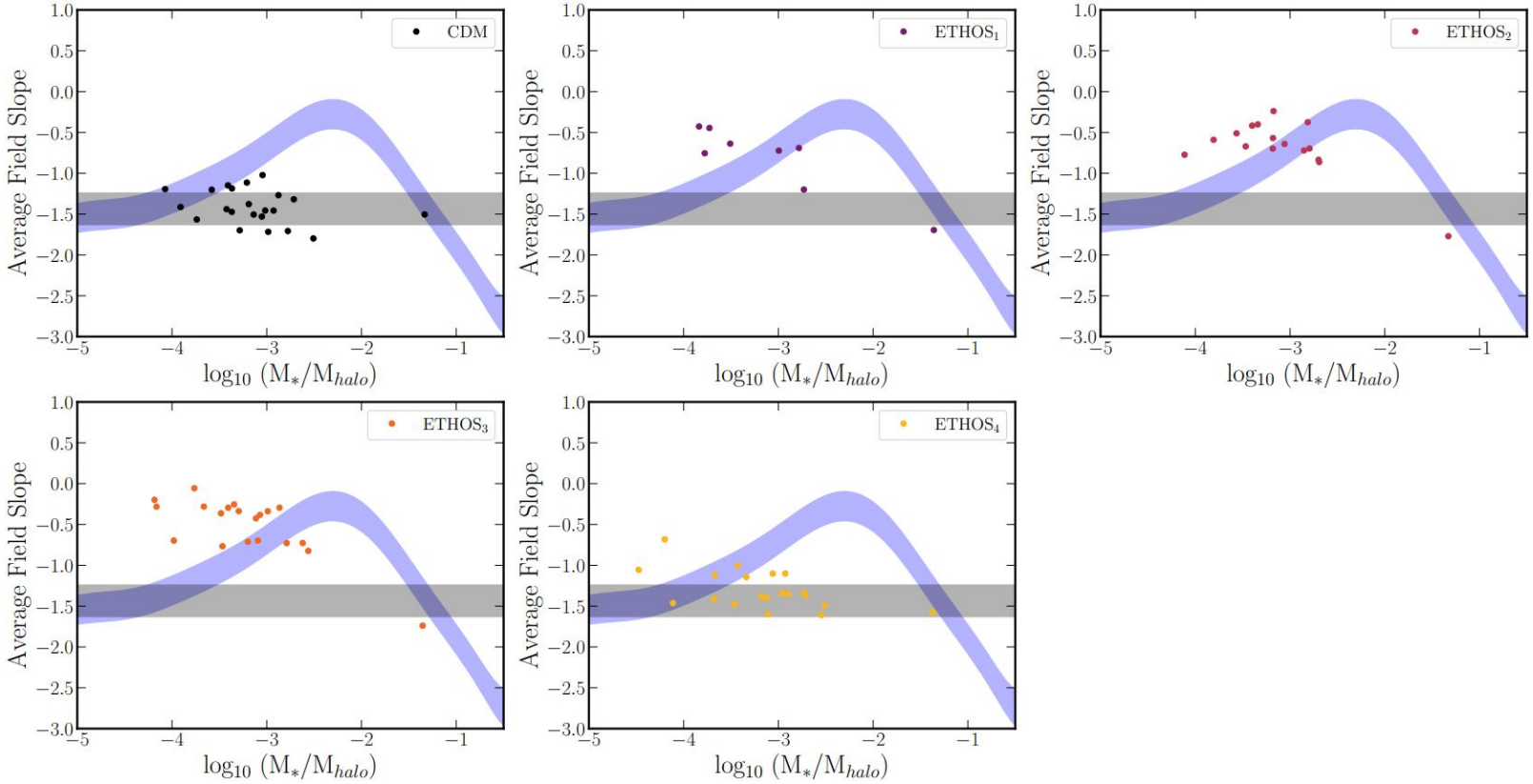


Gravothermal Collapse?

- Few dense halos despite isothermal cores
  - Cross sections are too small?
- CDM also has very dense halos
  - No separation between CDM and SIDM



Satellite Cores



Conclusions

Most SIDM models are tested with N-body simulations, do these results hold when we include a comprehensive galaxy formation model?

- With IllustrisTNG and ETHOS: Yes
  - Only for galaxies with stellar mass less than ~10^8 $M_\odot$ (Halo mass ~10^{10})

Other Results:

- Baryons heat the center of the DM halo during adiabatic contraction
  - Can create isothermal cores in larger halos (centrals and satellites)
  - Increases relative velocities for dark matter scatterings
- Low diversity in small dwarfs (UFD-classical) without large SIDM cross sections