Collapse Timescales in Isolated Dwarfs

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Self-Interacting Dark Matter: Models, Simulations and Signals

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Milky Way-like N-Body Simulation with SIDM

Dark Matter + Baryonic Disk and Bulge

$$M_{\rm vir} = 10^{12} M_\odot$$

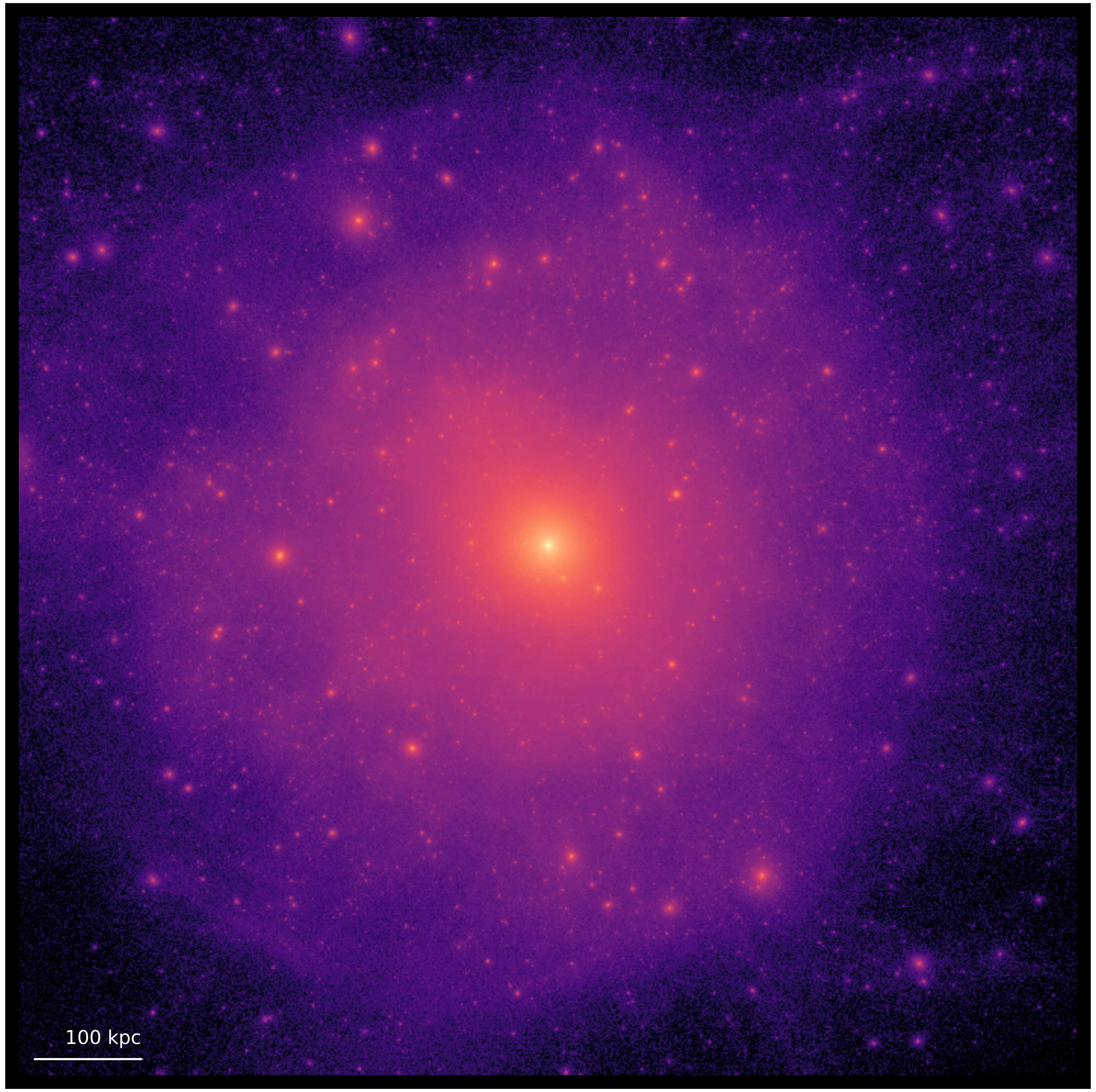
$$m_{\rm DM} = 3 \times 10^4 M_\odot$$

$$M_* = 4.1 \times 10^{10} M_\odot$$

$$\sigma/m = 1 \ \mathrm{cm^2/g}$$

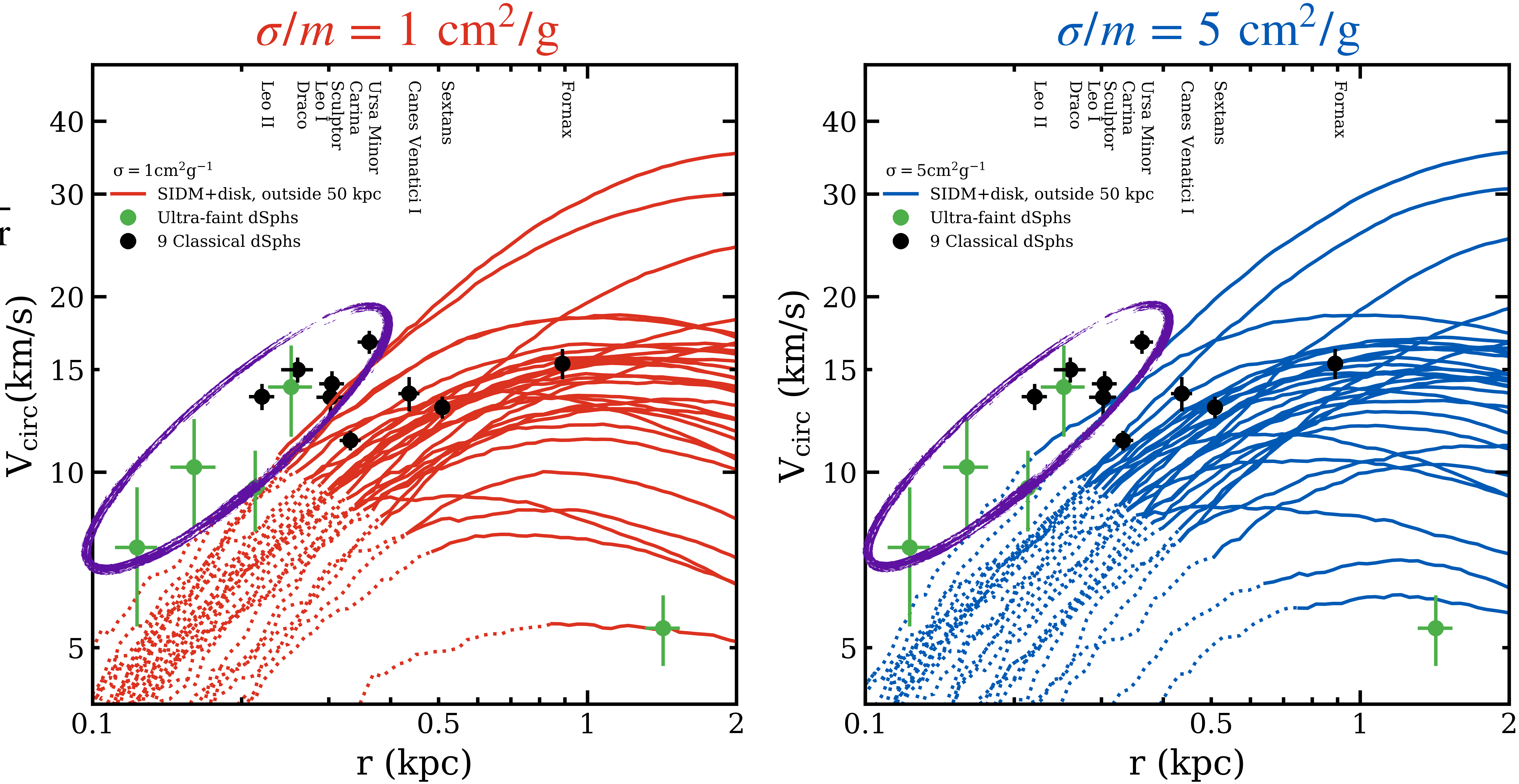
$$\sigma/m = 5 \ \mathrm{cm^2/g}$$

Proposed to solve diversity problem



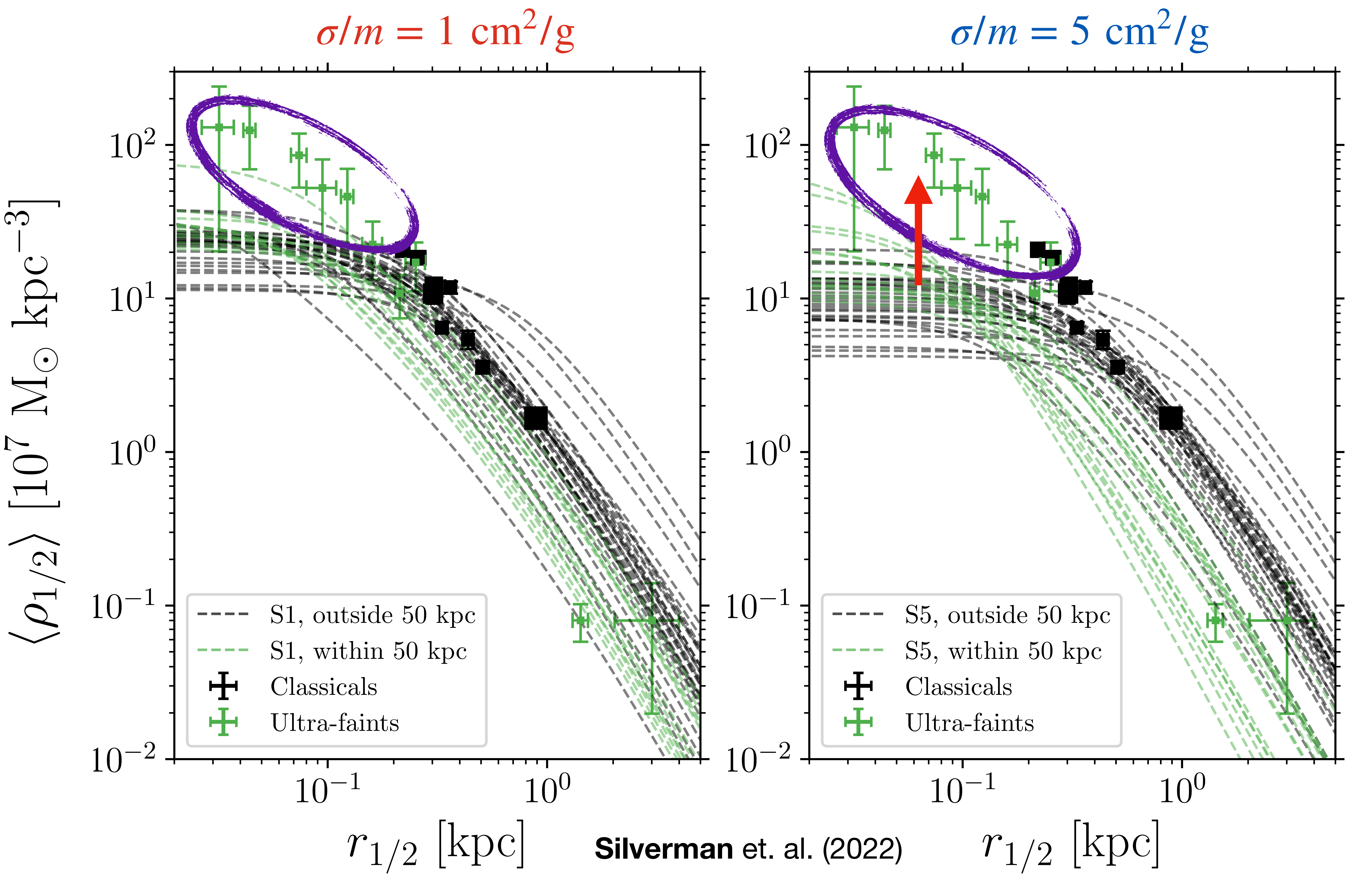
Subhalo Circular Velocity Profiles vs dSphs

$$V_{circ} = \sqrt{GM/r}$$



Silverman et. al. (2022)

Density Profiles vs dSphs



Silverman et. al. (2022)

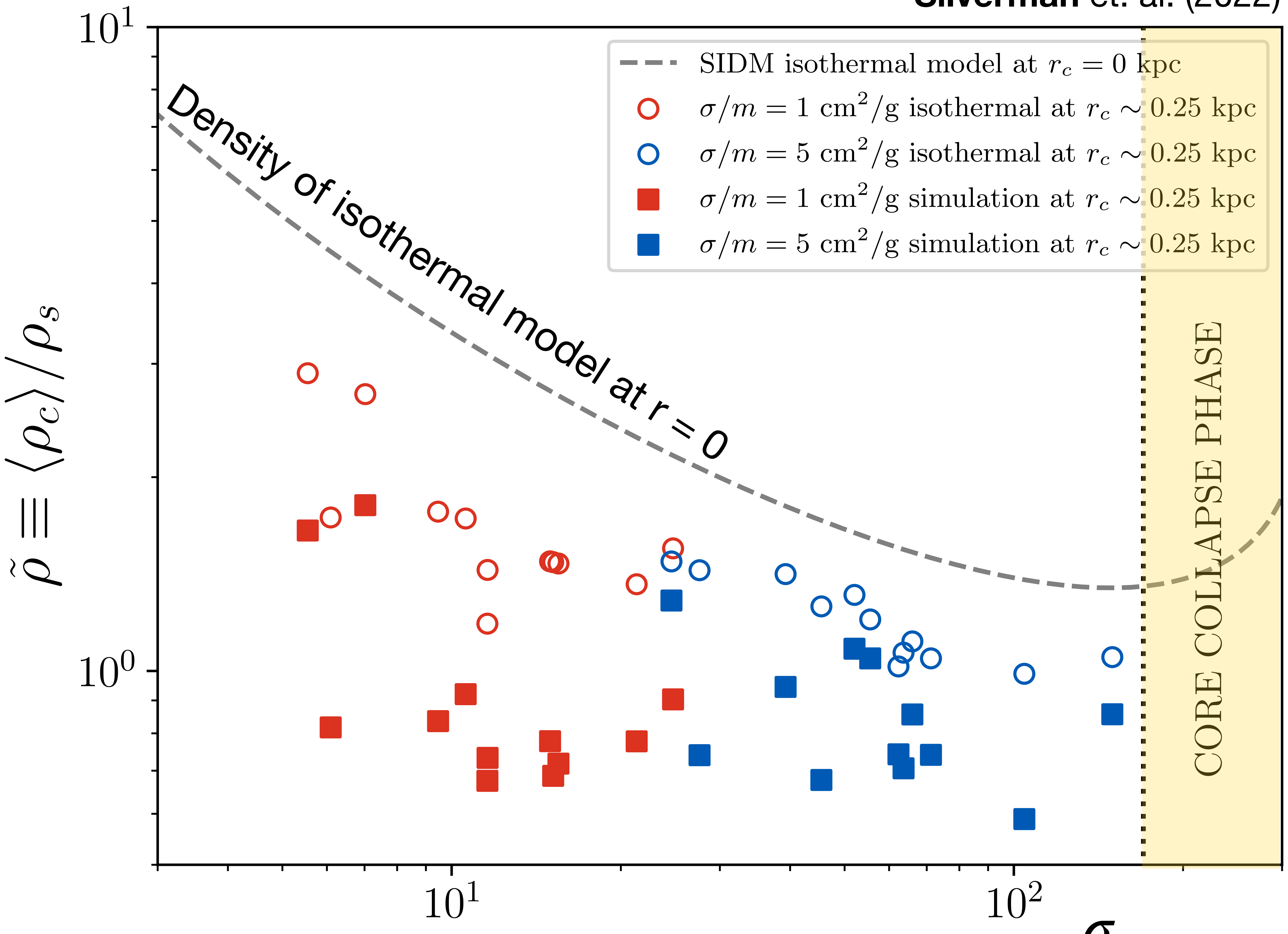
Core Collapse Timescale

- simulated subhalos
- isothermal model

$\sigma/m = 1\ \mathrm{cm}^2/\mathrm{g}$

$\sigma/m = 5\ \mathrm{cm}^2/\mathrm{g}$

Silverman et. al. (2022)

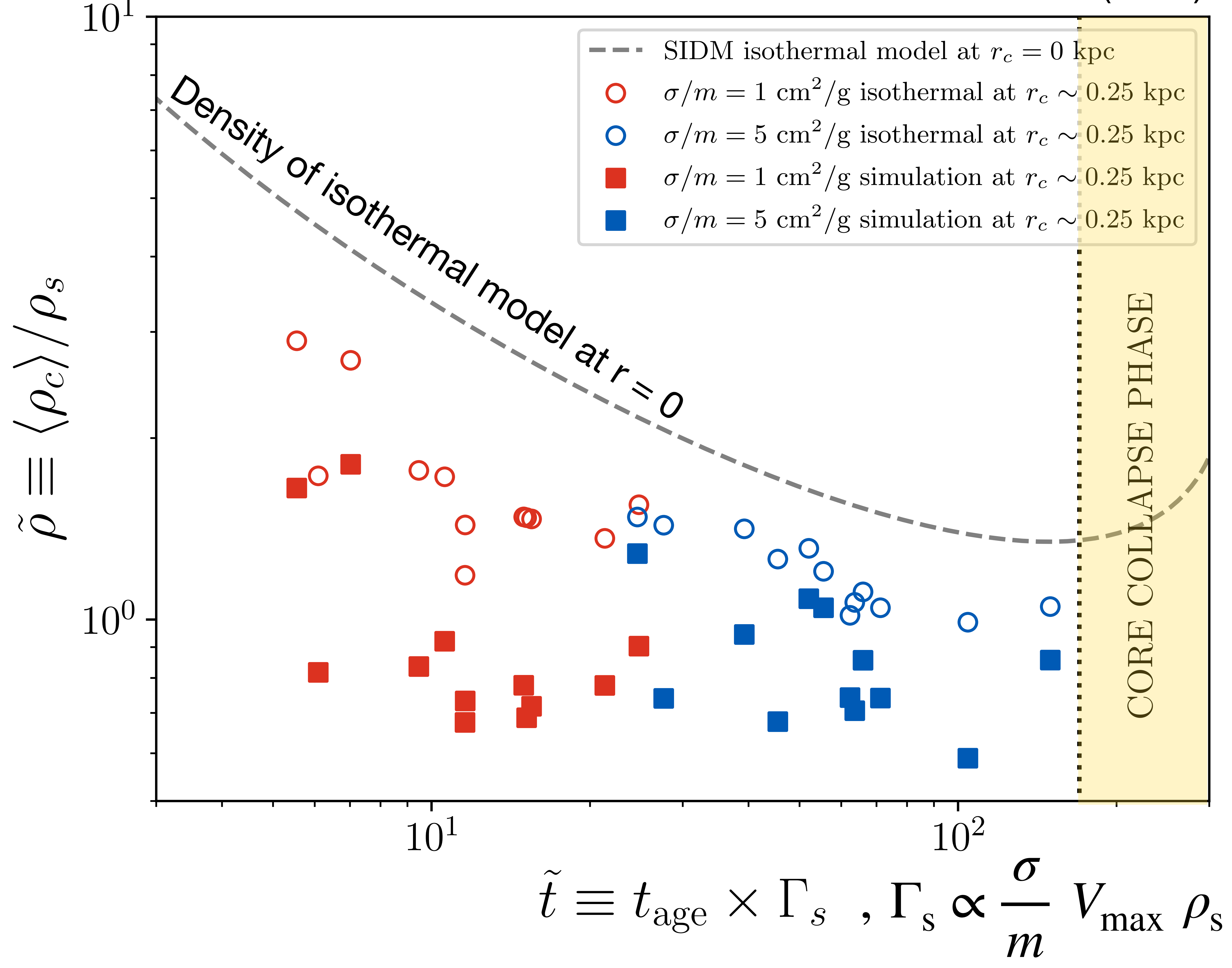


$$\tilde{t} \equiv t_{\mathrm{age}} / t_0 \quad , \quad t_0^{-1} \propto \frac{\sigma}{m} V_{\mathrm{max}}\, \rho_s$$

Conclusion: Moderate σ

- Need core collapse for SIDM to match observations
- No core collapse in simulation with $\sigma/m = 5\ \mathrm{cm}^2/\mathrm{g}$
- Next:
  - (Much) larger σ/m for low velocity scales (~10 km/s)
  - Velocity dependence
  - Baryonic feedback

Silverman et. al. (2022)



N-Body Simulations with SIDM: isolated dwarfs

Dark Matter Only

$$M_{\rm vir} = 10^{10} M_\odot$$

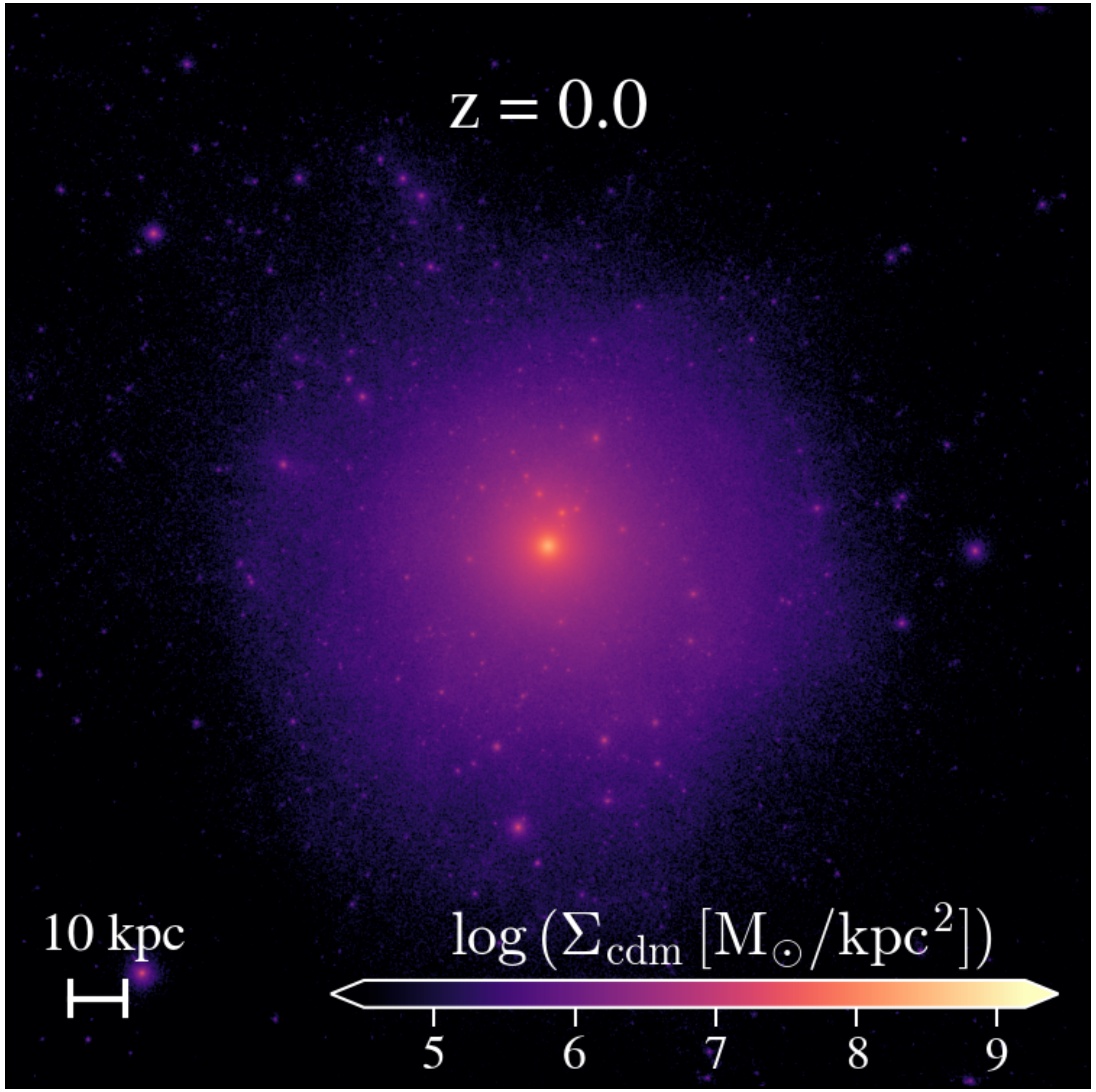
$$m_{\rm DM} = 1.5 \times 10^3 M_\odot$$

$$\sigma/m = 0,\ 5,\ 30,\ 70,\ 200\ {\rm cm}^2/{\rm g}$$

$$c = 18.3$$

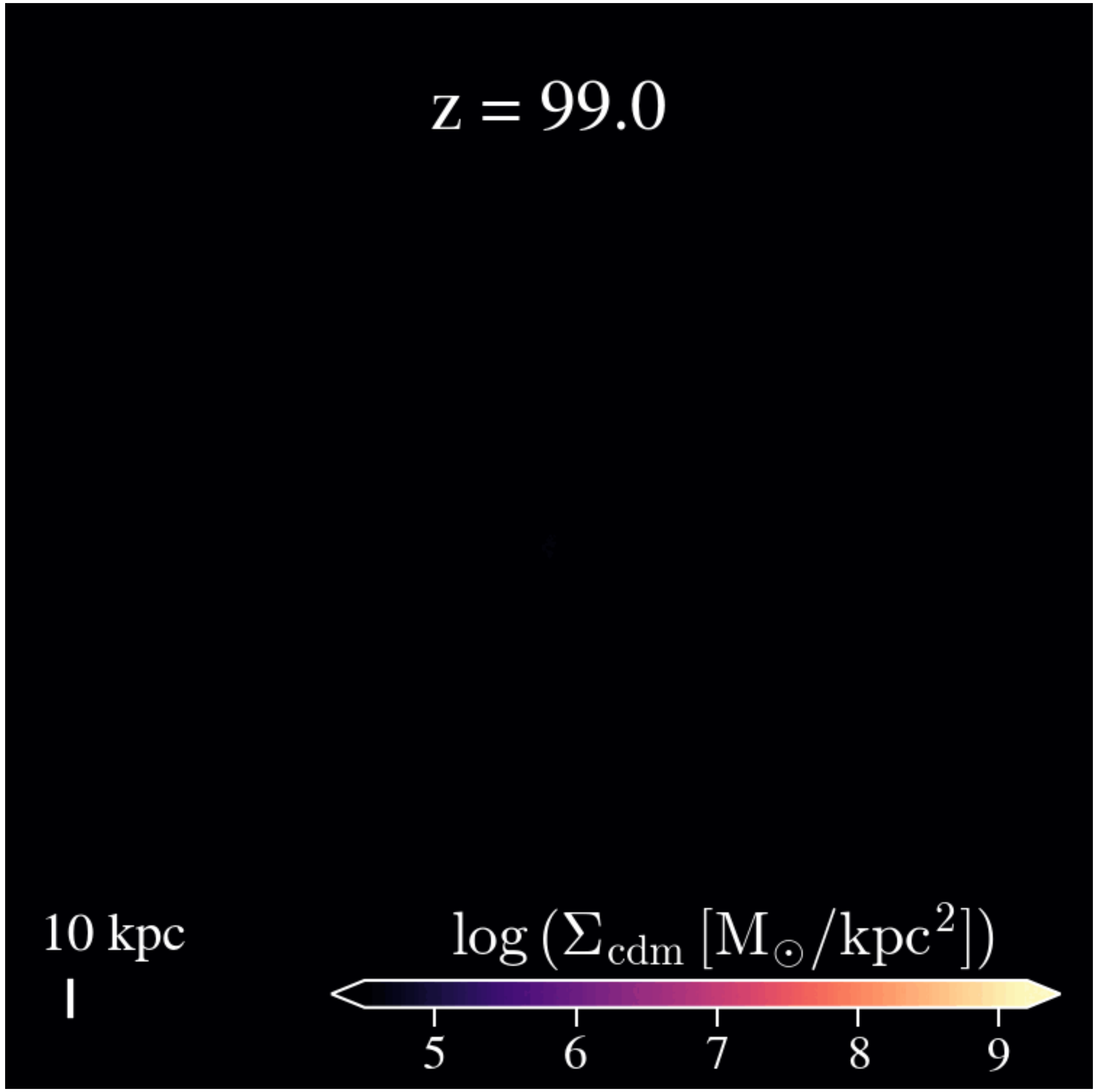
Using FIRE Initial Conditions

Hydro FIRE2 coming soon!

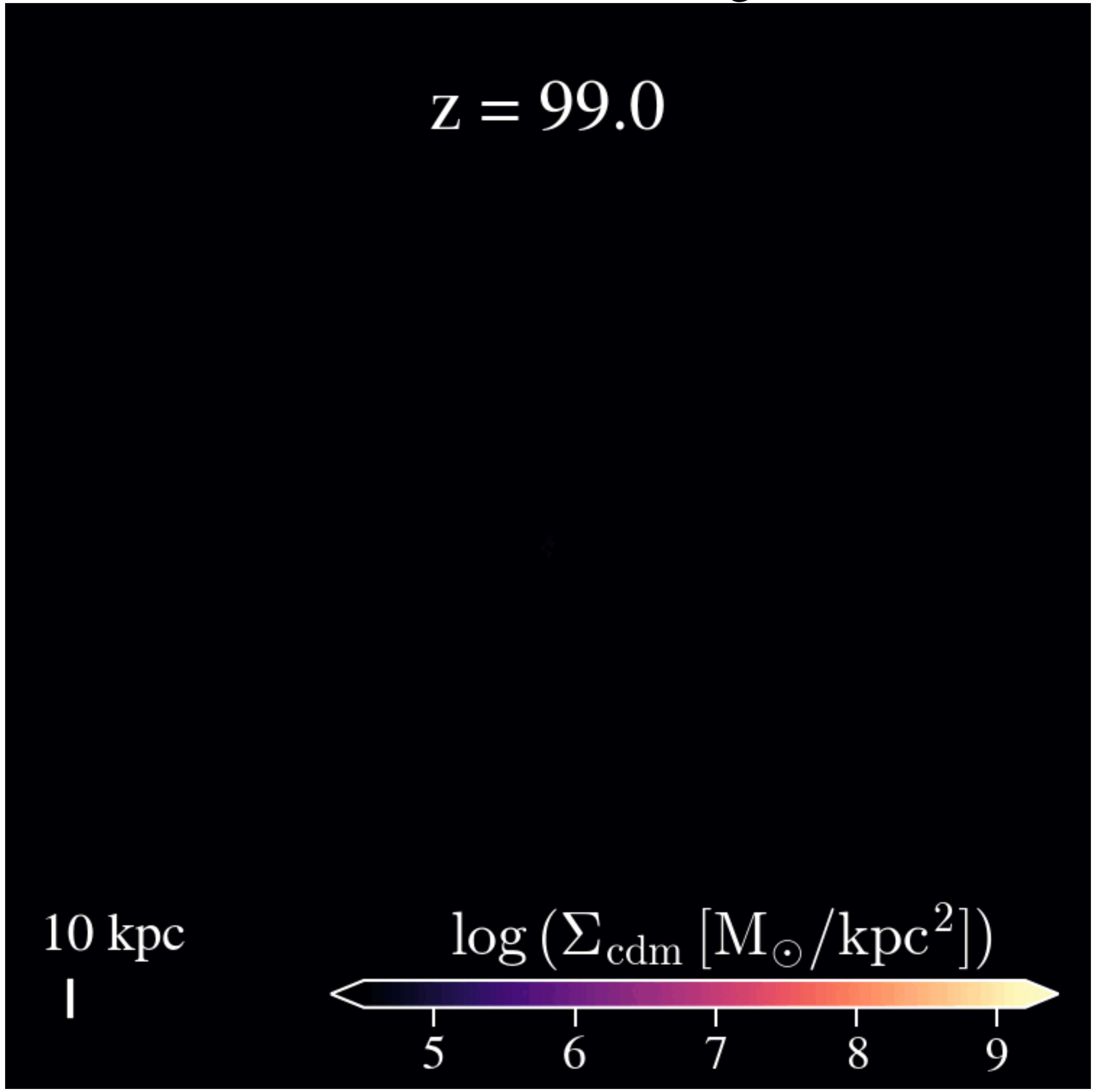


CDM vs SIDM with 70 cm^2/g

CDM

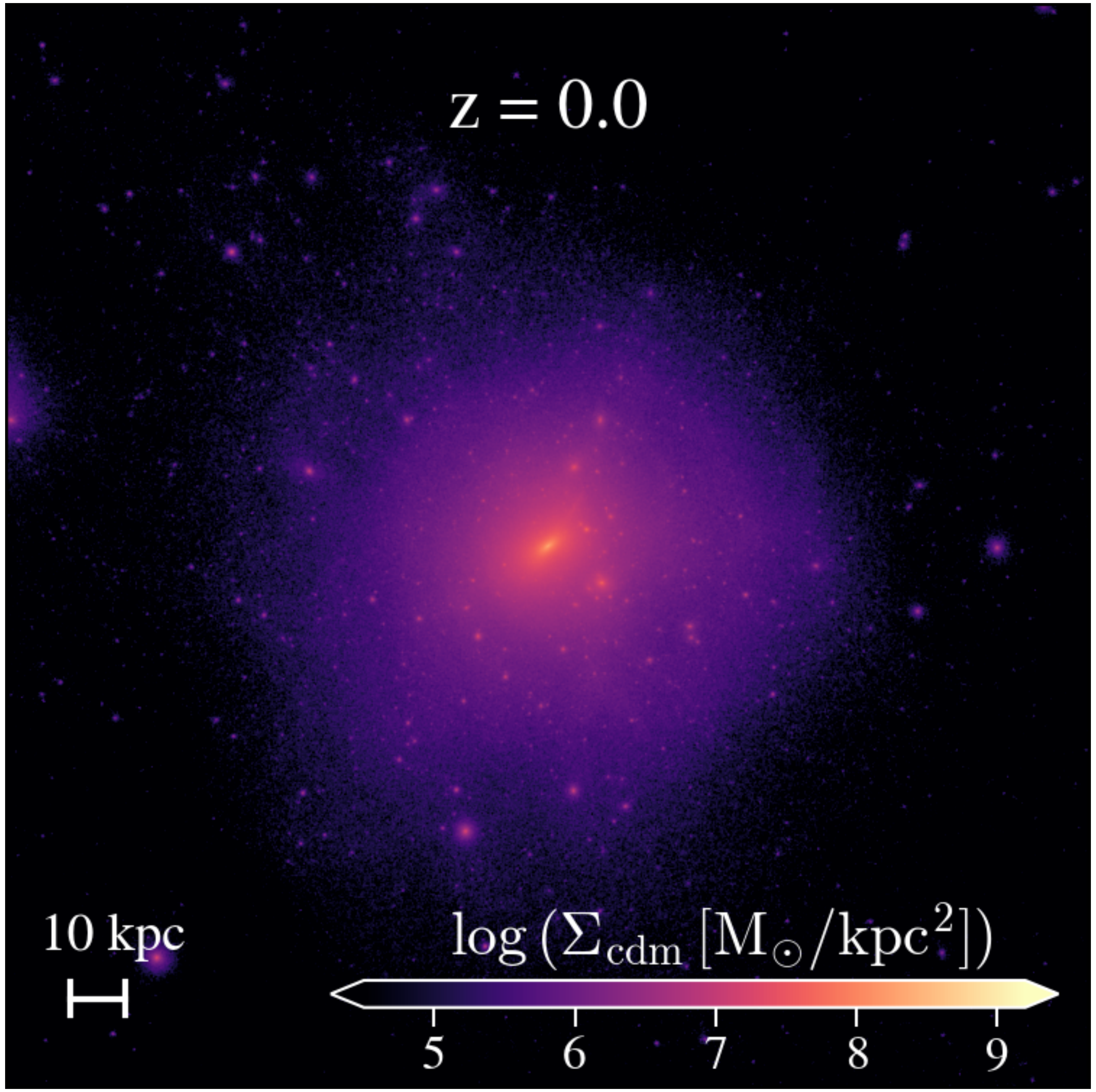


$\sigma/m = 70\ \mathrm{cm}^2/\mathrm{g}$

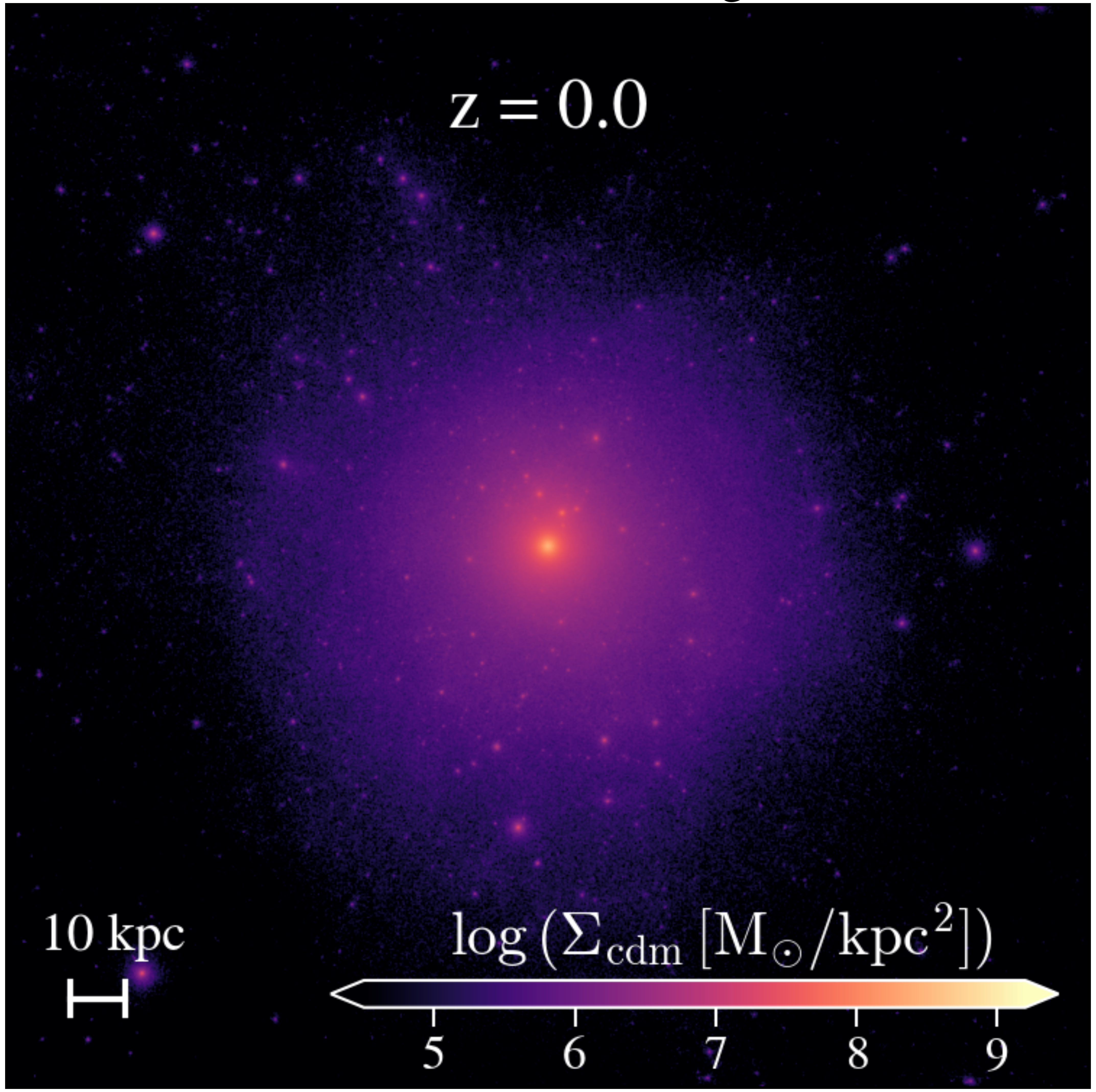


CDM vs SIDM with 70 cm^2/g

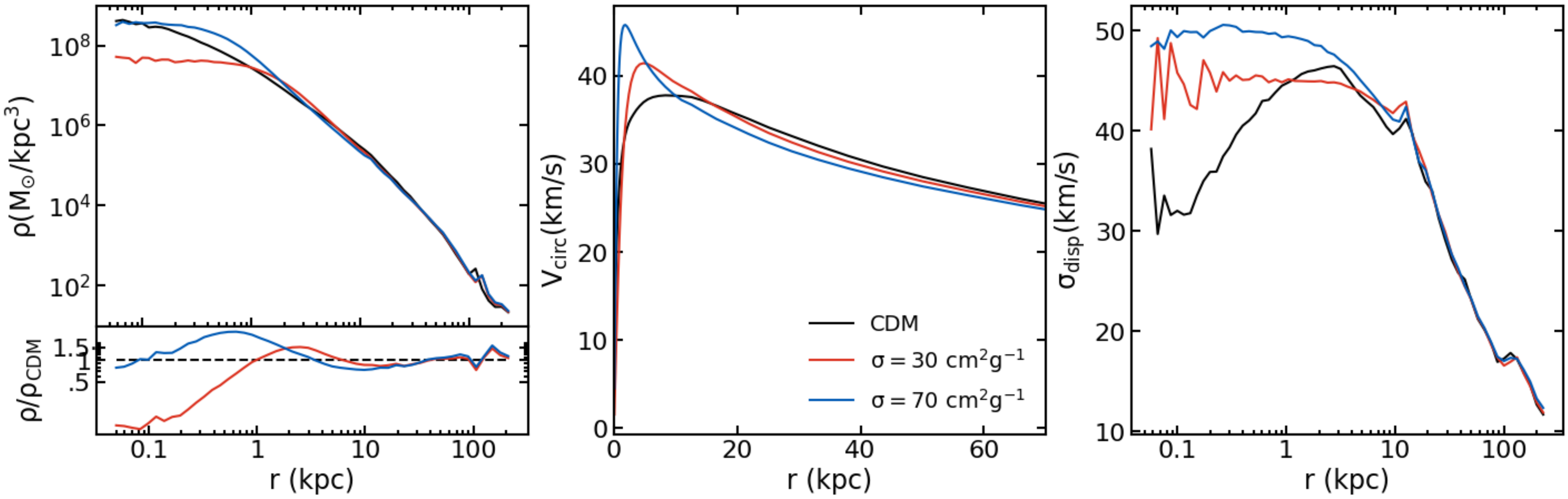
CDM



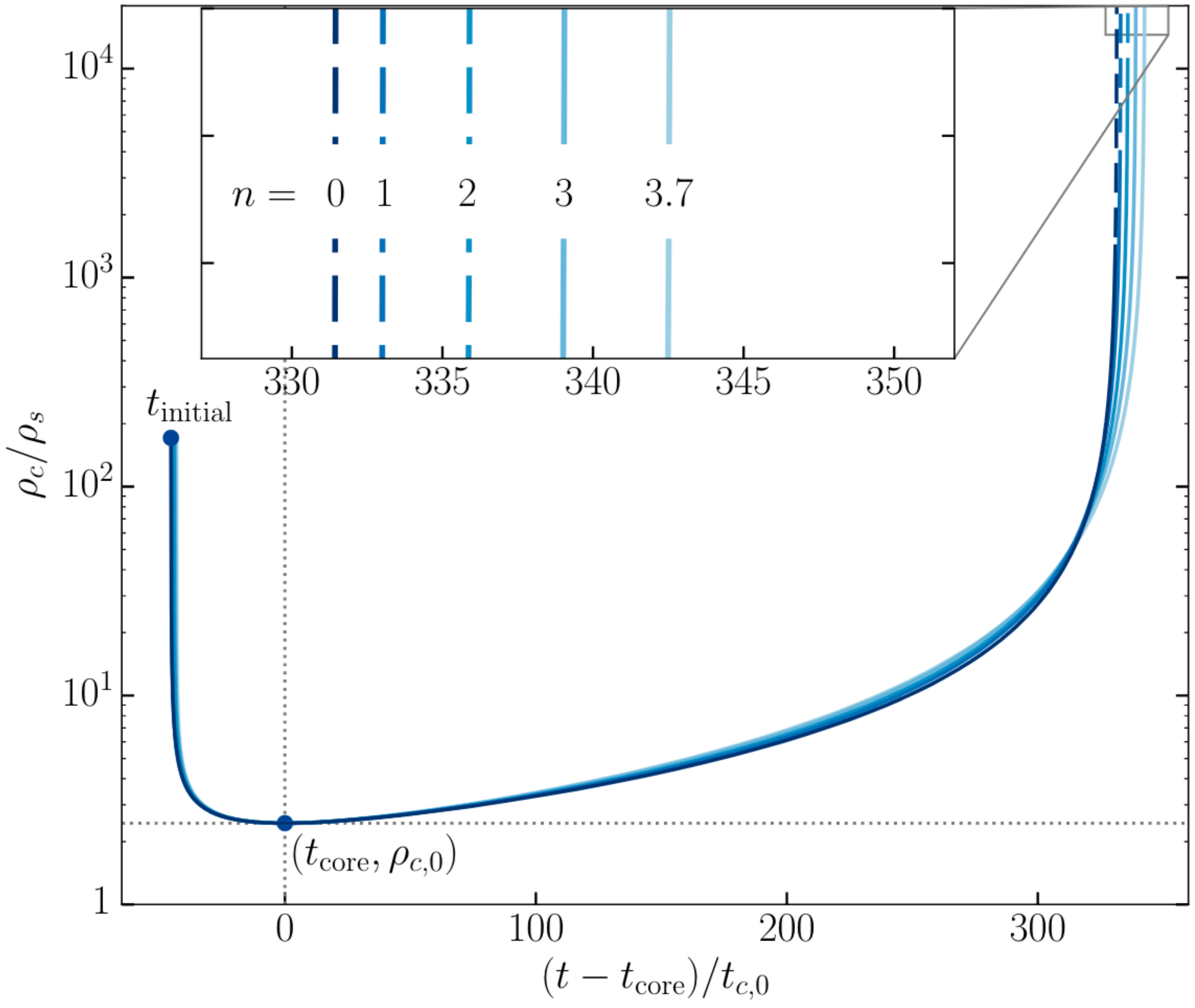
$\sigma/m = 70\ \mathrm{cm}^2/\mathrm{g}$



Isolated Dwarf: m10q



Collapse timescale in m10q



$$t_{coll} = \frac{1}{c_1}\left(\frac{6-\alpha}{3\alpha-2}\right) - n(\alpha-2) \times t_{c0}$$

$$t_{c,0}^{-1} = \frac{2}{3aC}\left(\frac{\sigma}{m_{DM}} v_0 \rho_0\right)$$

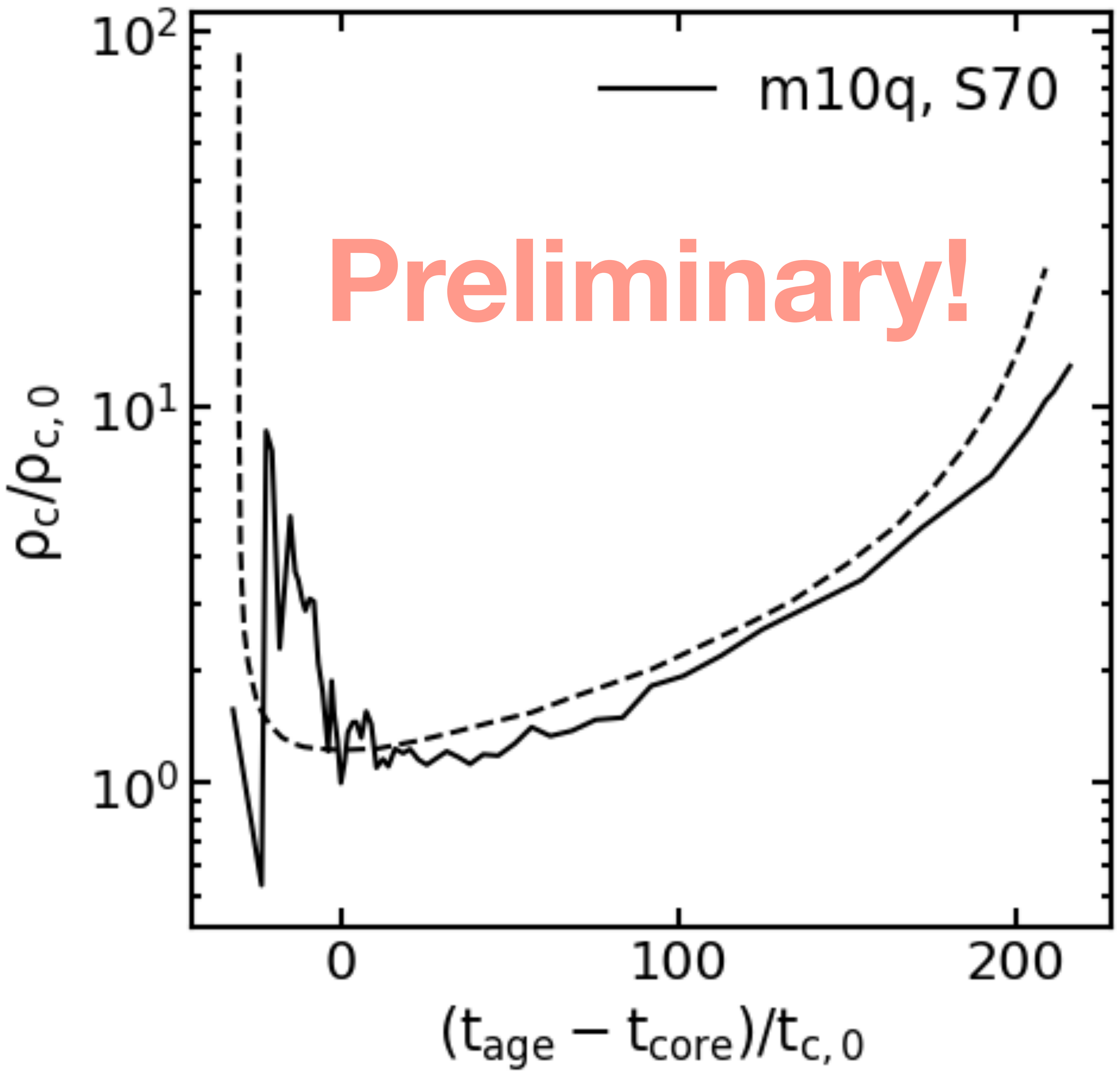
$$t_{coll} = 400 \times t_{c0}$$

$$t_{coll} \approx 23 \text{ Gyr}$$

Following Outmezguine et al. (2022) and Yang, Yu (2022)

Collapse timescale in m10q

$\sigma/m = 70\ \mathrm{cm^2/g}$



$$t_{coll} = \frac{1}{c_1}(\frac{6-\alpha}{3\alpha-2}) - n(\alpha-2) \times t_{c0}$$

$$t_{c,0}^{-1} = \frac{2}{3aC}(\frac{\sigma}{m_{DM}} v_0 \rho_0)$$

$$t_{coll} = 400 \times t_{c0}$$

$$t_{coll} \approx 23\ \mathrm{Gyr}$$

Following Outmezguine et al. (2022) and Yang, Yu (2022)

N-Body Simulations with SIDM: m10v

Dark Matter Only

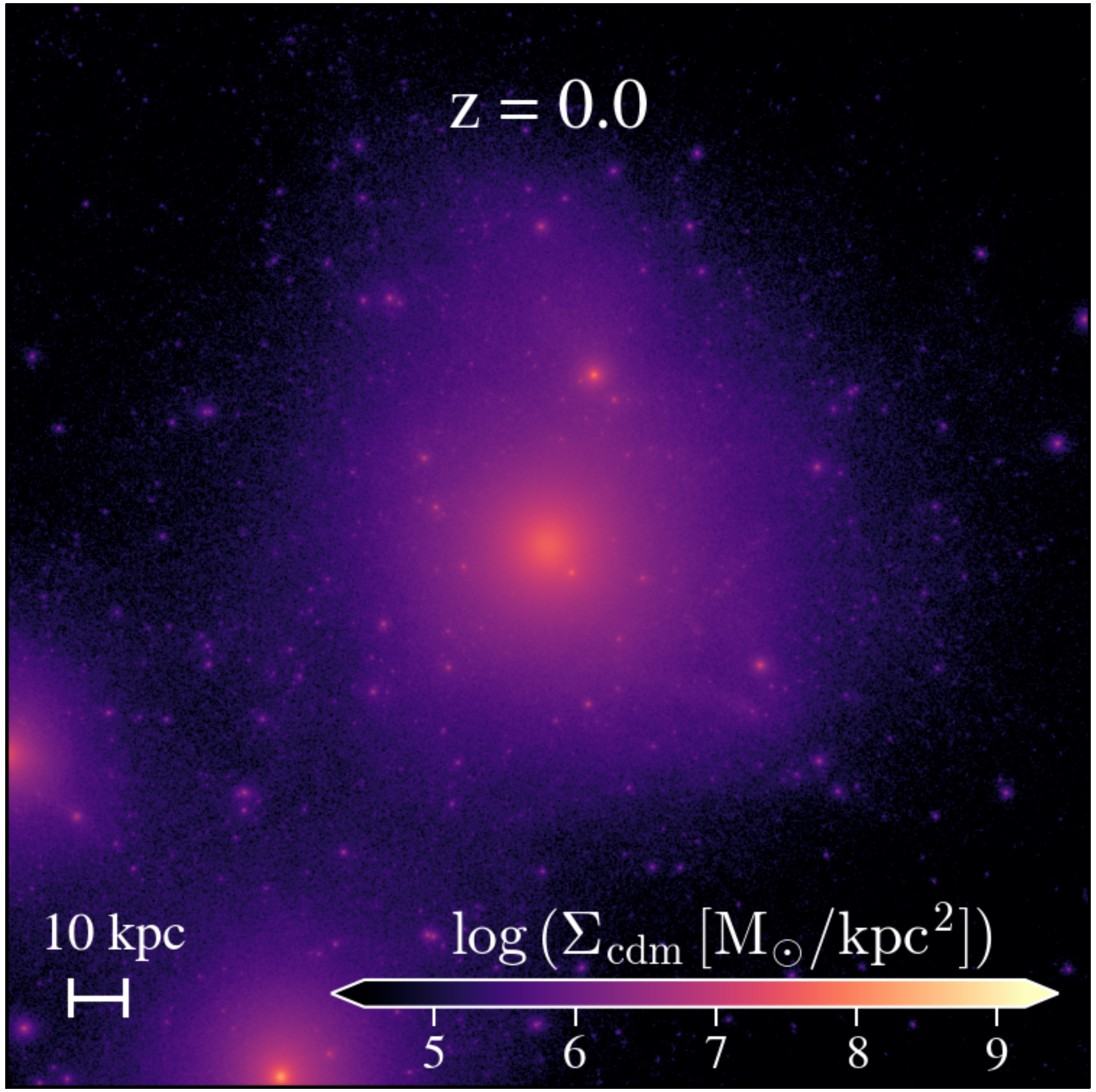
$$M_{\text{vir}} = 10^{10} M_{\odot}$$

$$m_{\text{DM}} = 1.5 \times 10^{3} M_{\odot}$$

$$\sigma/m = 200\ \text{cm}^2/\text{g}$$

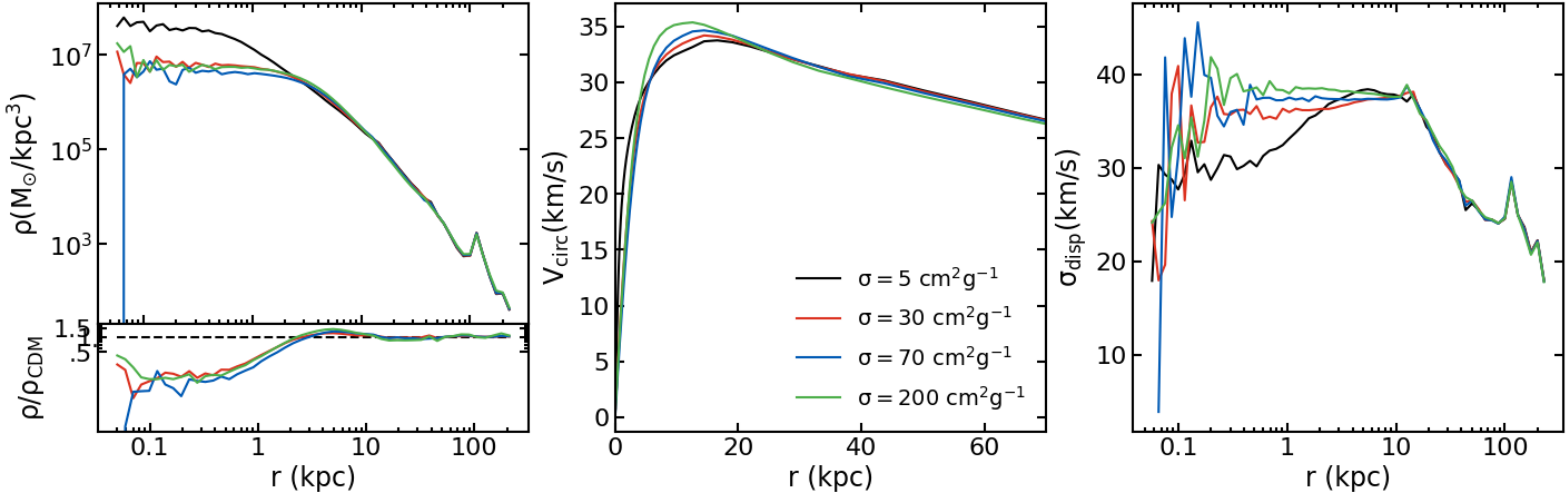
$$c = 10.4$$

Using FIRE Initial Conditions



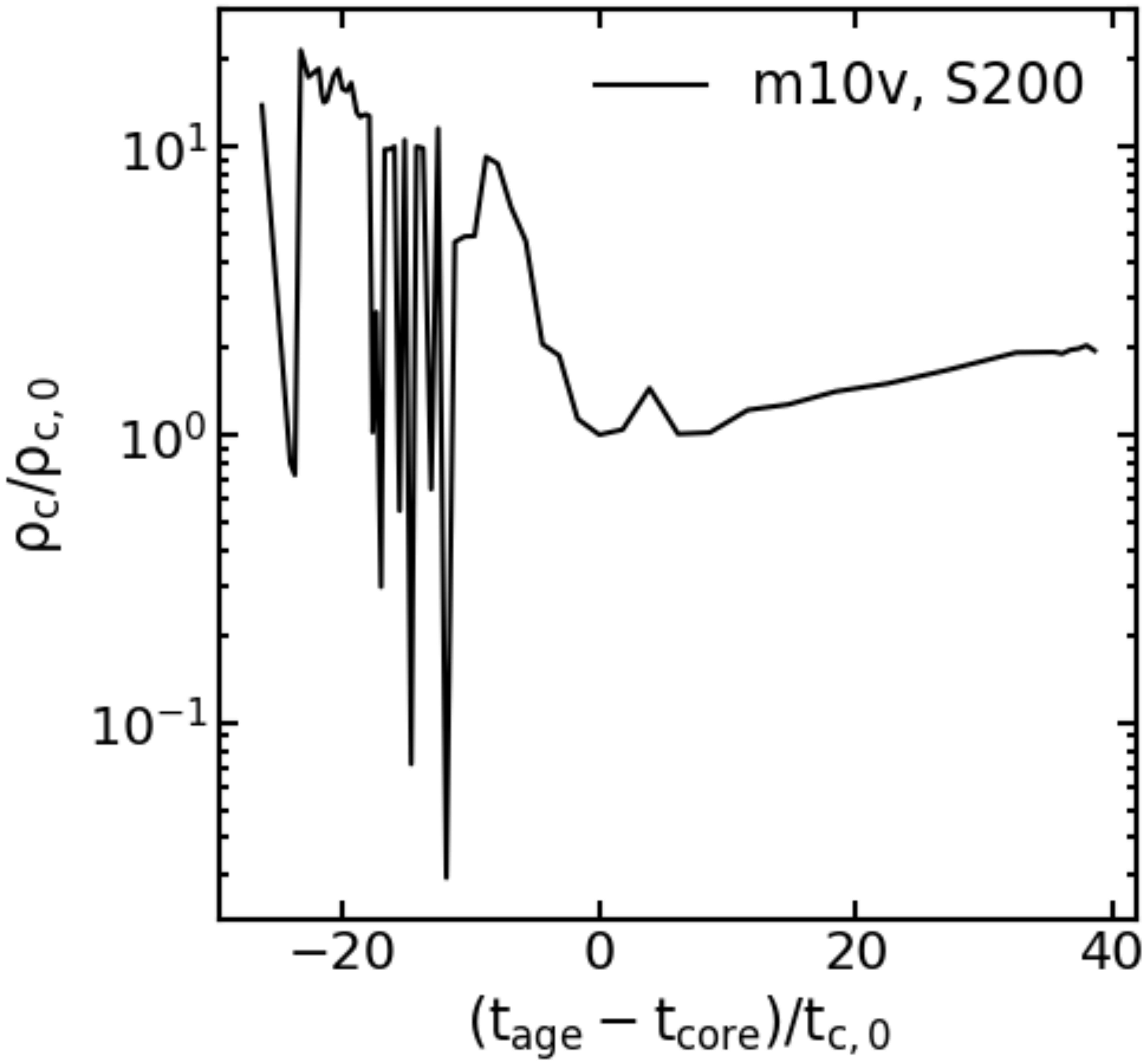
Isolated Dwarf: m10v

Low concentration: 10.4



Collapse timescale in m10q

$\sigma/m = 200\ \mathrm{cm}^2/\mathrm{g}$



$$t_{coll} = \frac{1}{c_1}\left(\frac{6-\alpha}{3\alpha-2}\right) - n(\alpha-2) \times t_{c0}$$

$$t_{c,0} = \frac{2}{3aC}\left(\frac{\sigma}{m_{DM}} v_0 \rho_0\right)$$

$$t_{coll} = 400 \times t_{c0}$$

$$t_{coll} \approx 85\ \mathrm{Gyr}$$

Following Outmezguine et al. (2022) and Yang, Yu (2022)

Conclusion and outlook

- Able to predict collapse timescale for field dwarf halos with large cross sections

- For median field dwarfs, need $\sim 70\ \mathrm{cm}^2/\mathrm{g}$ for core collapse

Future:

- Develop suite of SIDM sims with range of cross sections, concentrations, formation histories
  - Do the analytic collapse timescale predictions hold?

$\sigma/m = 70\ \mathrm{cm}^2/\mathrm{g}$