Solving Too Big to Fail with SIDM

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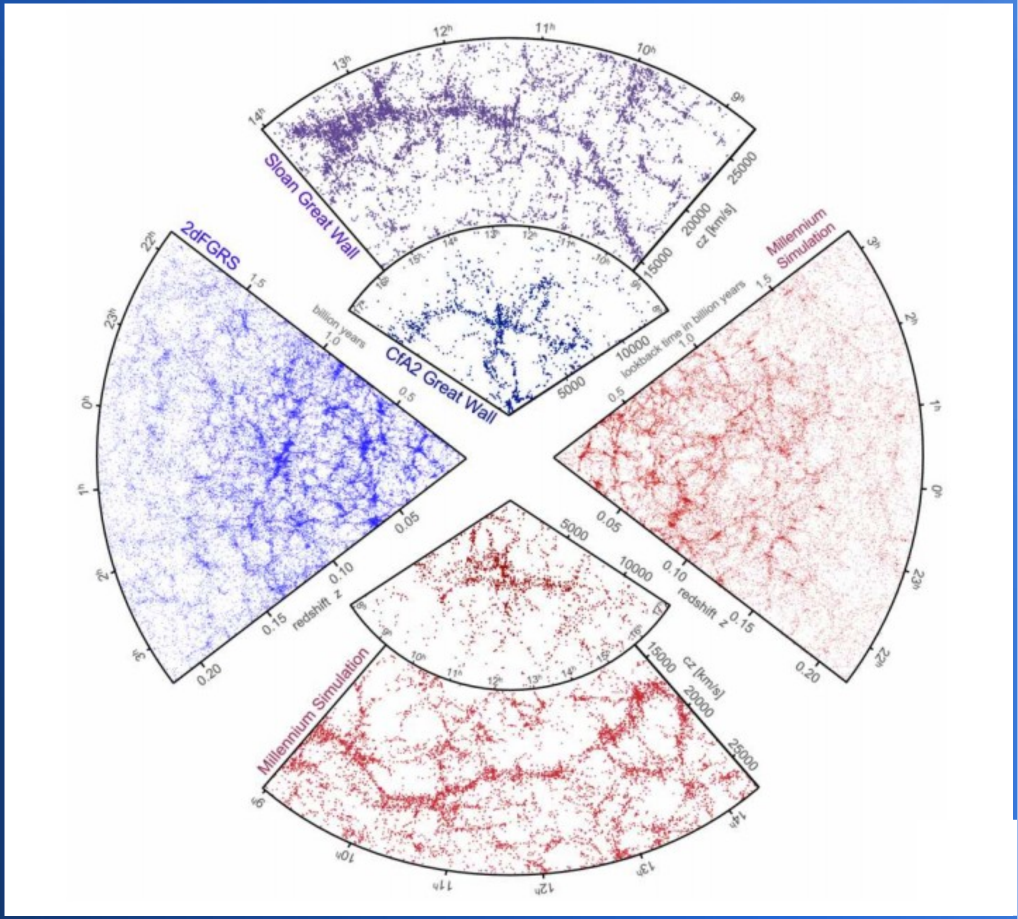
The universe as we understand it

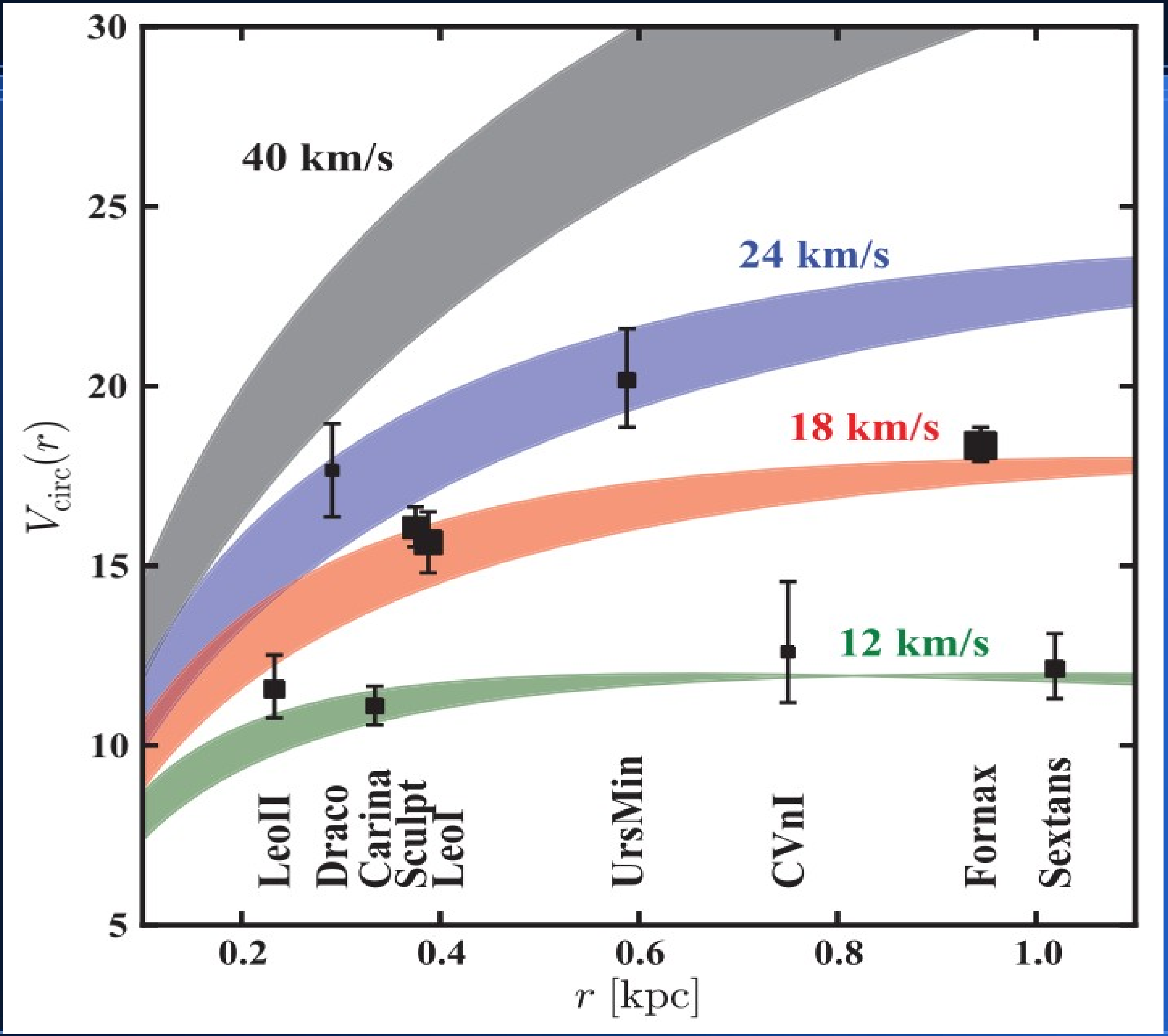
- ΛCDM Model describes universe well
- Simulations agree with observations on large scales



- Some small scale problems

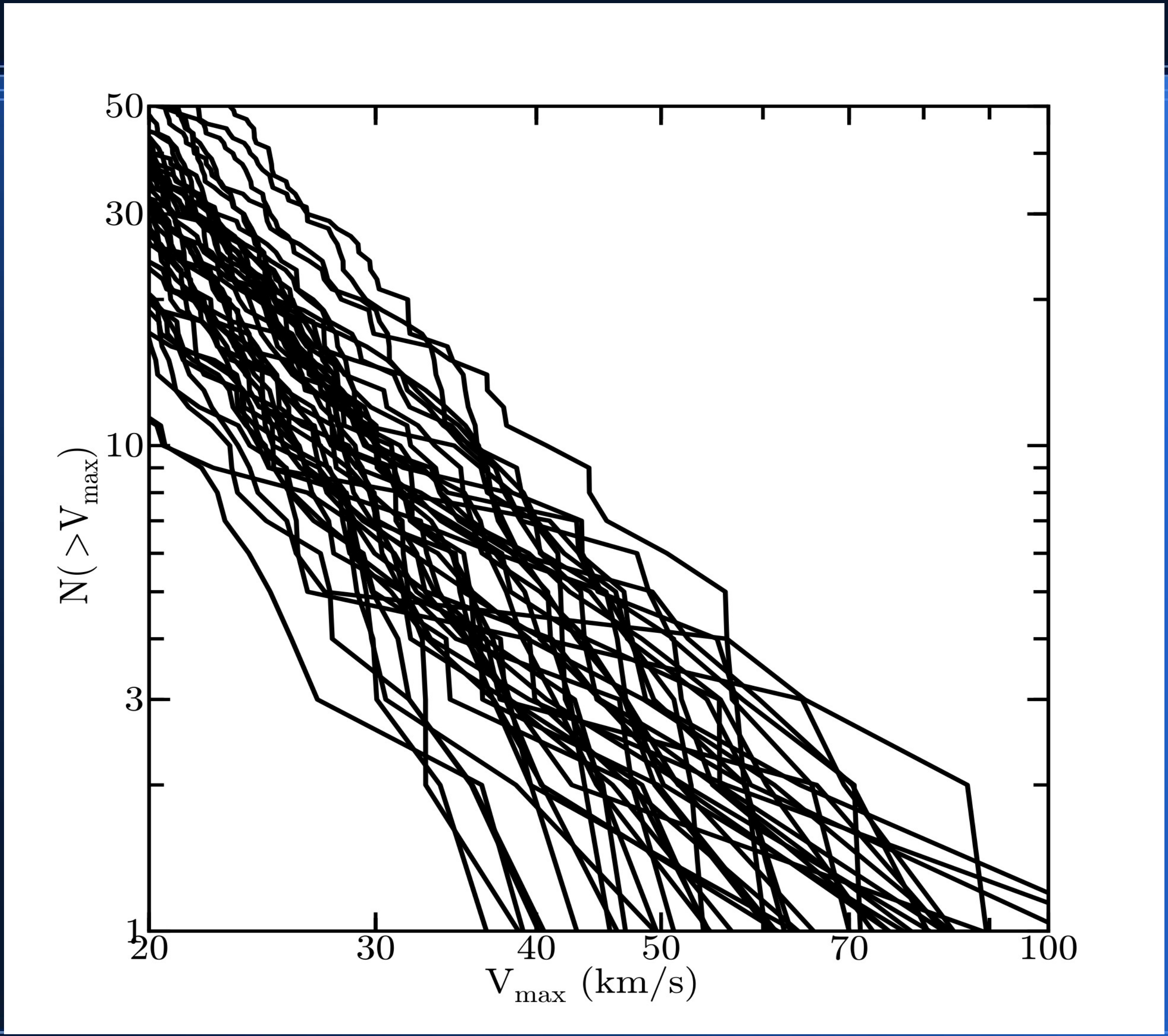
Springel et al. 2006

The Too Big to Fail Problem



Boylan-Kolchin et al. 2012

The Too Big to Fail Problem



Garrison-Kimmel et al, in prep

Solutions

- Baryons?
  - Unlikely from energy perspective (Garrison-Kimmel+2012; Penarrubia+2012)
- Small MW?
  - Difficult to explain Leo I (Boylan-Kolchin+2013), presence of LMC/SMC, and LG timing argument (vdMarel+2012)
- Stochastic formation?
  - Requires extremely variant sampling, suppression in dense halos
- New Dark Matter physics?

Solution: SIDM?

- DM with self-interactions $\sigma/m \sim 1cm^2/g$ can lower densities in halo centers (Spergel & Steinhardt 2000). Set by: $\Gamma = n\sigma v \sim H_0$
- $1cm^2/g$ is HUGE (~2 barn/GeV ~ nuclear scattering); This is >10 orders of magnitude higher than WIMP, but *amazingly* still viable observationally [Bullet cluster OK].
- Many well-motivated DM models have big self-interactions: "Asymmetric DM", "Hidden Charged DM", "Atomic DM", etc. (Zurek,Feng,Sigurdson,Weiner,Kaplinghat,Randall,Buckley)
- Though some models predict velocity-dependent cross sections, we will explore constant cross sections to gain intuition.

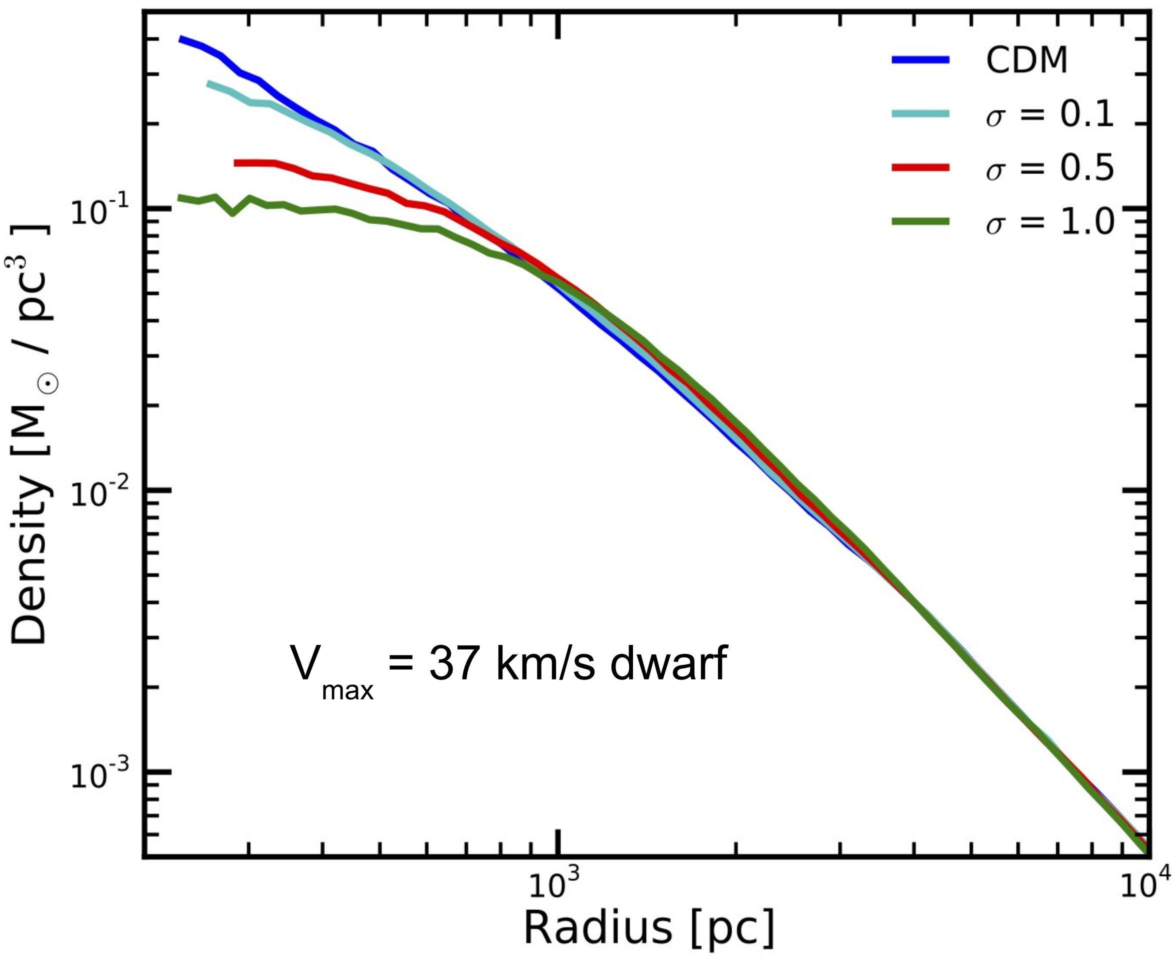
Cosmological Simulations

- Cosmological zoom-in simulations of dwarf halos:

  -V_{max} = 37 km/s, 42 km/s, 54 km/s

- F_{res} = 20 pc, m_p = 1000 M_{sun} [60 pc and 8,000 M_{sun} for 54 km/s run]
- Identical ICs for CDM and SIDM versions
- SIDM cross sections of 0.5 cm^2/g, 1.0 cm^2/g and 0.1 cm^2/g

Results: Example Density Profile



Higher cross-section SIDM models produce cores of the right size

r_{core} ~ 500pc

and right density

~0.1 Msun/pc3

to match dSphs (see Strigari et al. 08)

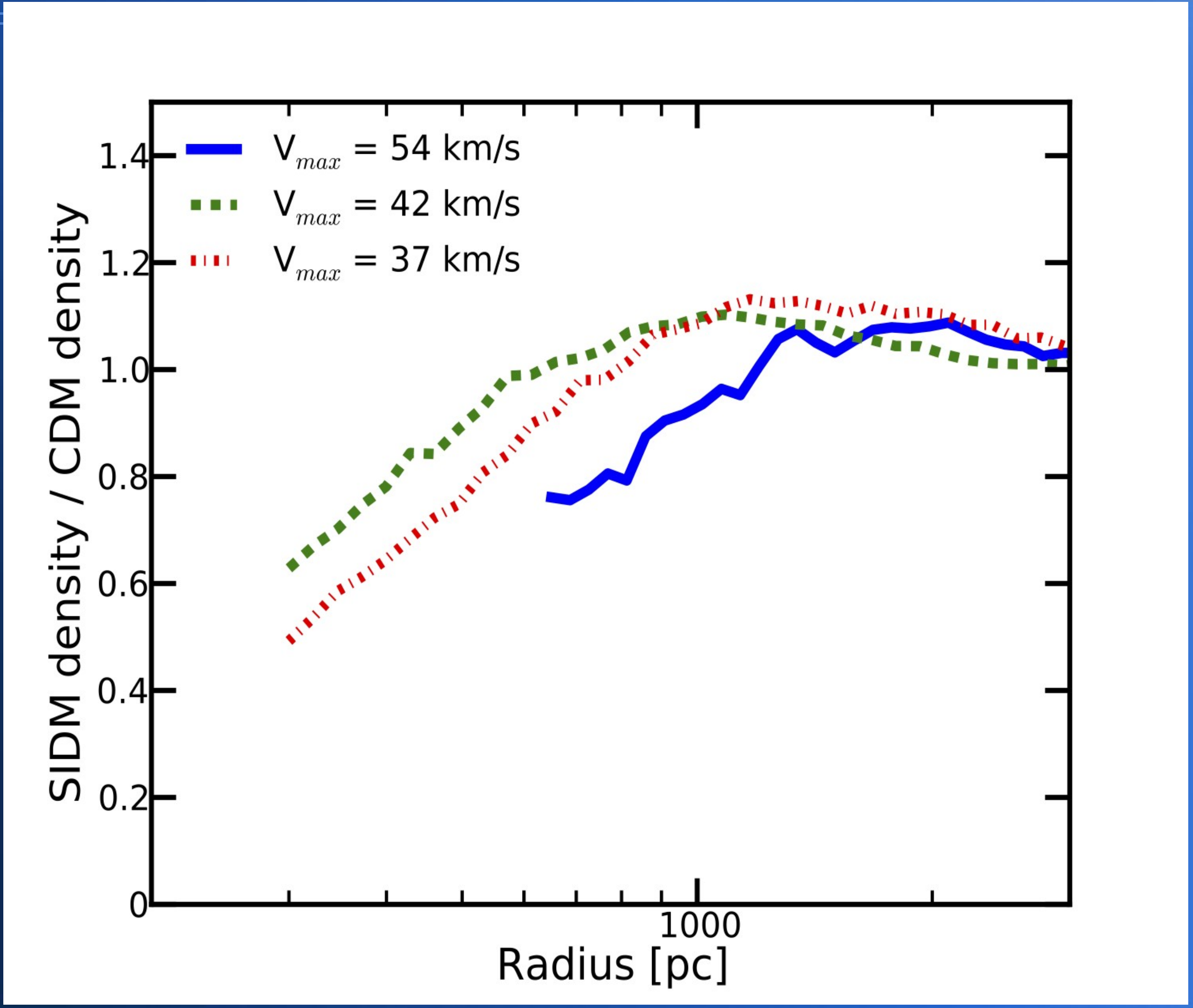
Elbert et al, in preparation

Results

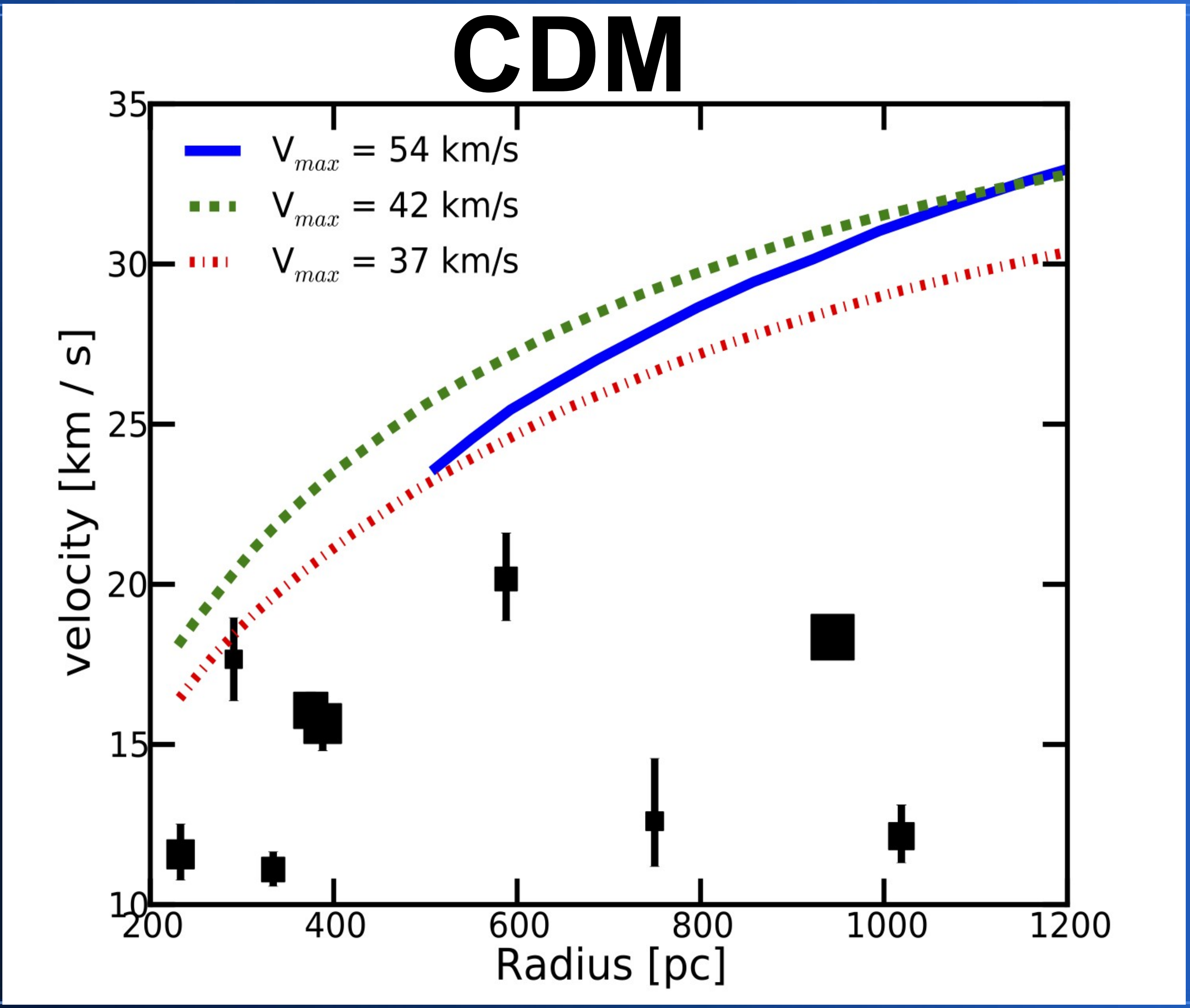
SIDM $\sigma/m = 0.5\ cm^2/g$

vs.

CDM

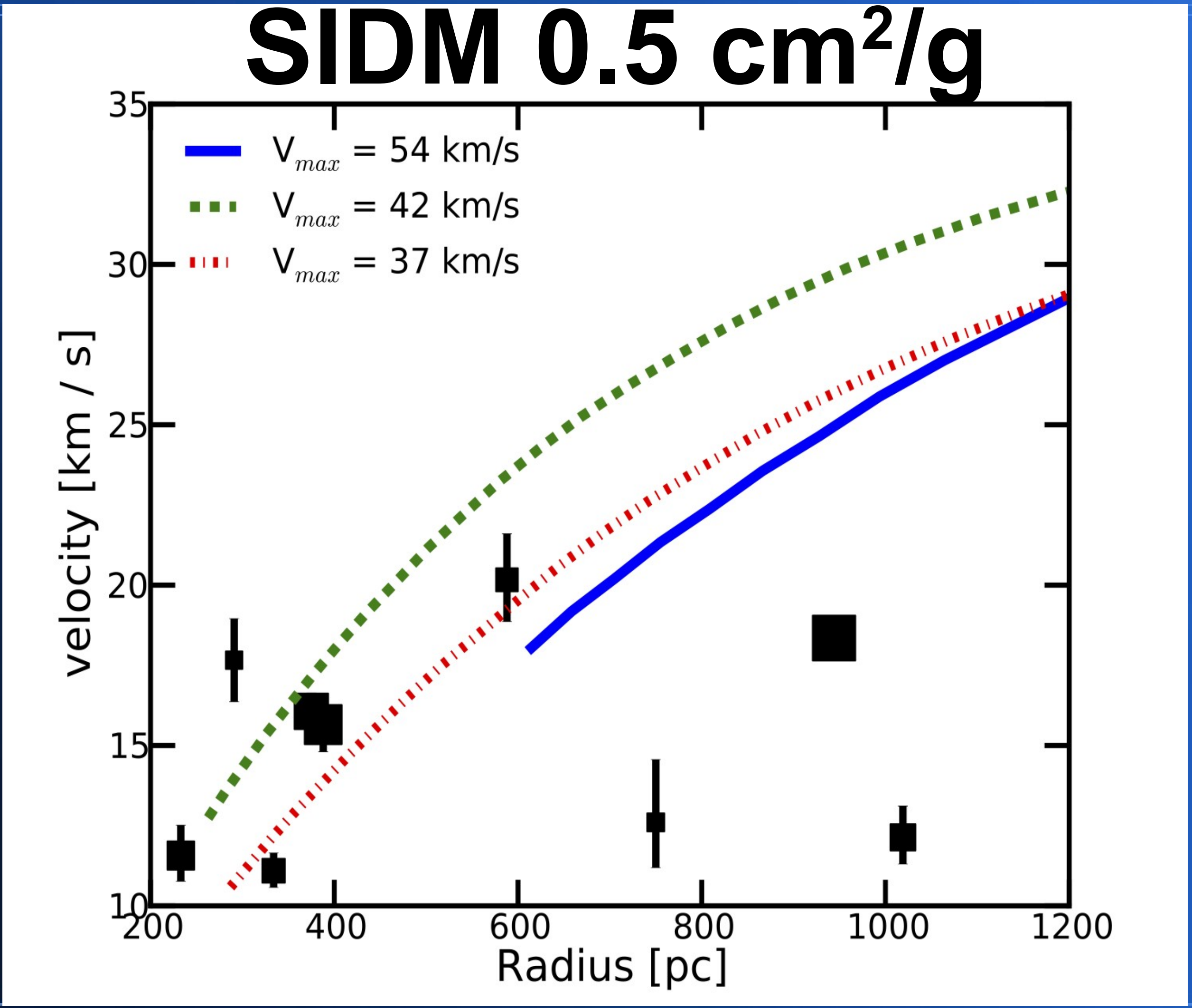


Results



Elbert et al, in prep

Results



Elbert et al, in prep

Conclusions

- Cluster observations rule out $\sigma/m > 1\ cm^2/g$, $\sim 0.5\ cm^2/g$ is viable.
- SIDM with cross sections $\sigma/m \sim 0.5\ cm^2/g$ allow MW dwarfs to populate halos with large V_{max}
- Even without a velocity-dependent cross section, SIDM with $\sigma/m \sim 0.5\ cm^2/g$ can solve Too Big to Fail, produce ~ kpc scale cores in LSBs, and remain consistent with cluster shapes.

- **SIDM can solve Too Big to Fail**

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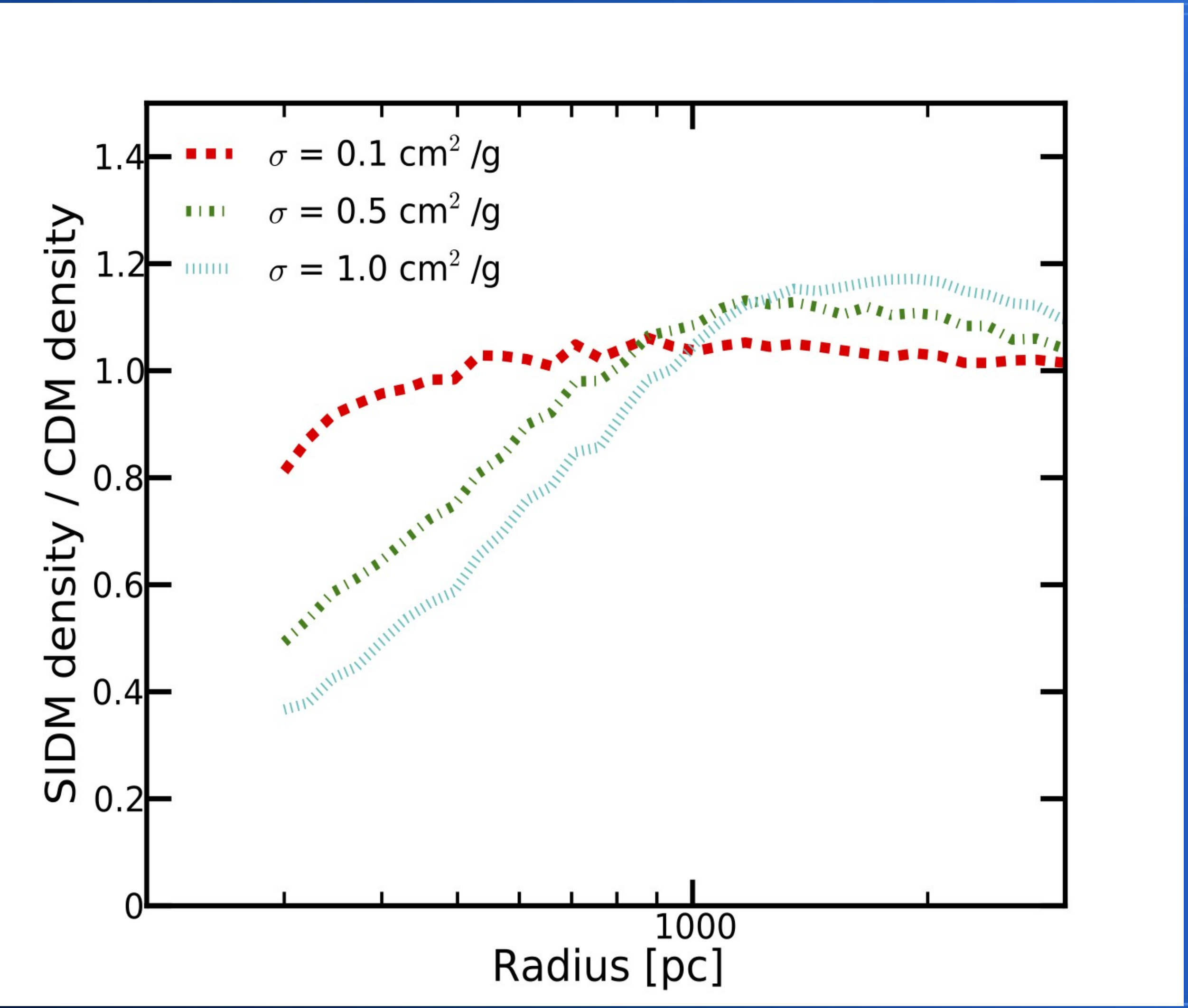
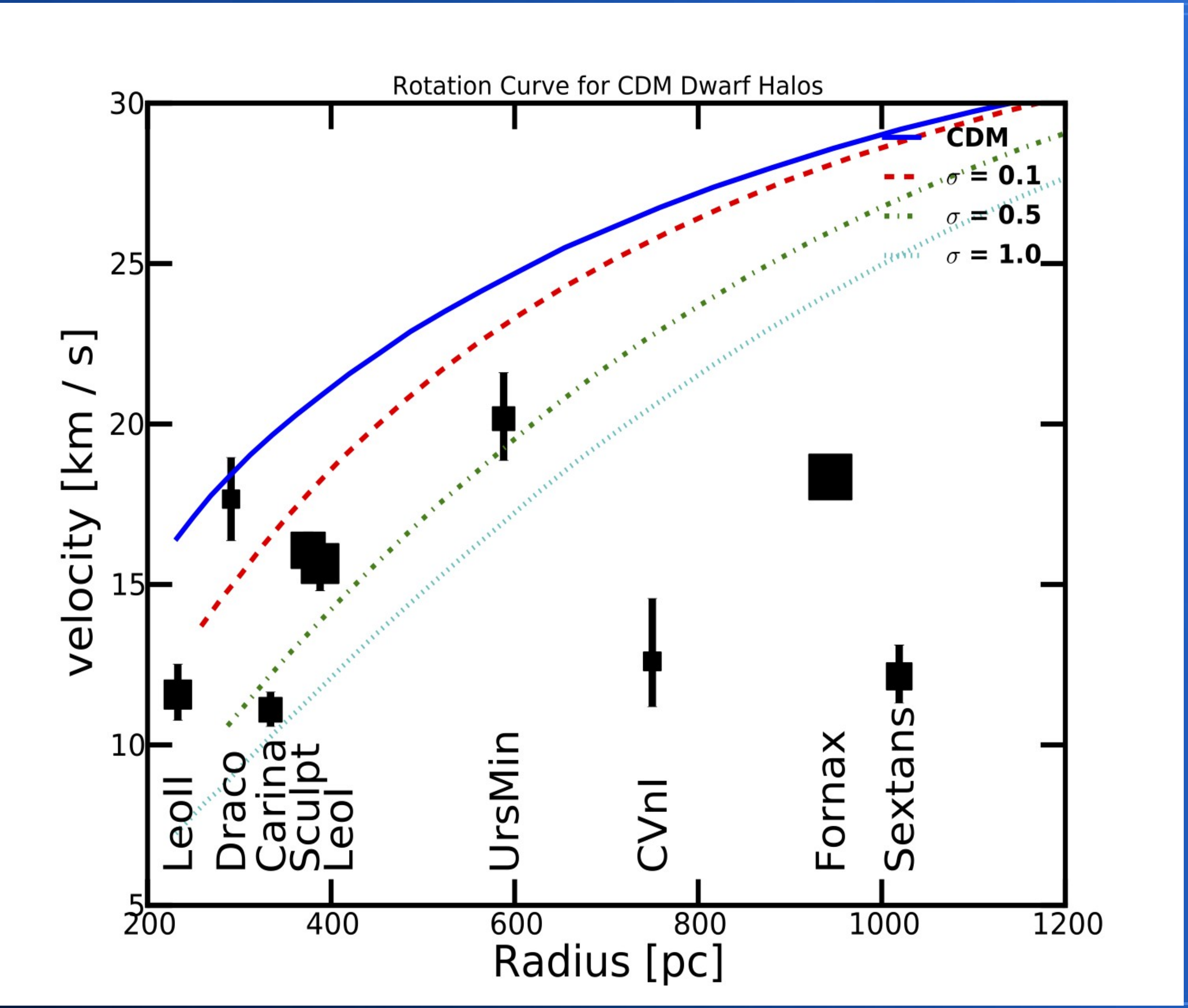
Appendix: Multiple Cross Sections



Appendix: Multiple Cross Sections



Appendix: Multiple Cross Sections