

# Understanding Dwarf Galaxies in order to understand Dark Matter

## Hot gas explodes out of young dwarf galaxies

Simulation by **Andrew Pontzen, Fabio Governato** and  
**Alyson Brooks** on the **Darwin Supercomputer**, Cambridge UK.

Simulation code **Gasoline** by **James Wadsley** and **Tom Quinn**  
with metal cooling by **Sijing Sheng**.

Visualization by **Andrew Pontzen**.

**Alyson Brooks**

Rutgers, the State University of New Jersey

In collaboration with the University of Washington's N-body Shop™  
*makers of quality galaxies*

# STARTING ASSUMPTION: THERE IS NO SMALL SCALE “CRISIS”

	CDM+Baryons	
Bulge-less disk galaxies	✓	Governato et al. (2010), Nature, 463, 203 Brook et al. (2011), MNRAS, 415, 1051
The Cusp/Core Problem	✓	Pontzen & Governato (2012), MNRAS, 421, 3464 DiCintio et al. (2014); Chan et al. (2015), Tollet et al. (2016)
Too Big to Fail	✓	Zolotov et al. (2012), Brooks & Zolotov (2014), Frings (2017), Garrison-Kimmel et al. (2019)
Missing Satellites	✓	Brooks et al. (2013), Wetzel et al. (2016), Buck et al. (2019)
Missing Dwarfs	✓	Maccio et al. (2016), Brooks et al. (2017), Chauhan et al. (2019)
Diversity	?	Santos-Santos et al. (2018)
Planes of Satellites		Buck et al. (2016), Ahmed et al. (2017)

# STARTING ASSUMPTION: THERE IS NO SMALL SCALE “CRISIS”

	CDM+Baryons	WDM	SIDM
Bulge-less disk galaxies	✓		
The Cusp/Core Problem	✓		✓
Too Big to Fail	✓	✓	✓
Missing Satellites	✓	✓	
Missing Dwarfs	✓	✓	
Diversity	?		✓
Planes of Satellites			

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Diversity	?	?	✓
Planes of Satellites			

## **KEY PROBLEMS**

**CAN WE CONTINUE TO UNDERSTAND THE  
FORMATION AND EVOLUTION OF DWARF GALAXIES  
IN A VANILLA CDM MODEL?**

**WE NEED BARYONS IN ALTERNATIVE DM  
MODELS. IS THERE A SMOKING GUN THAT POINTS  
TO A GIVEN DM MODEL?**

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**Ferah's Talk**

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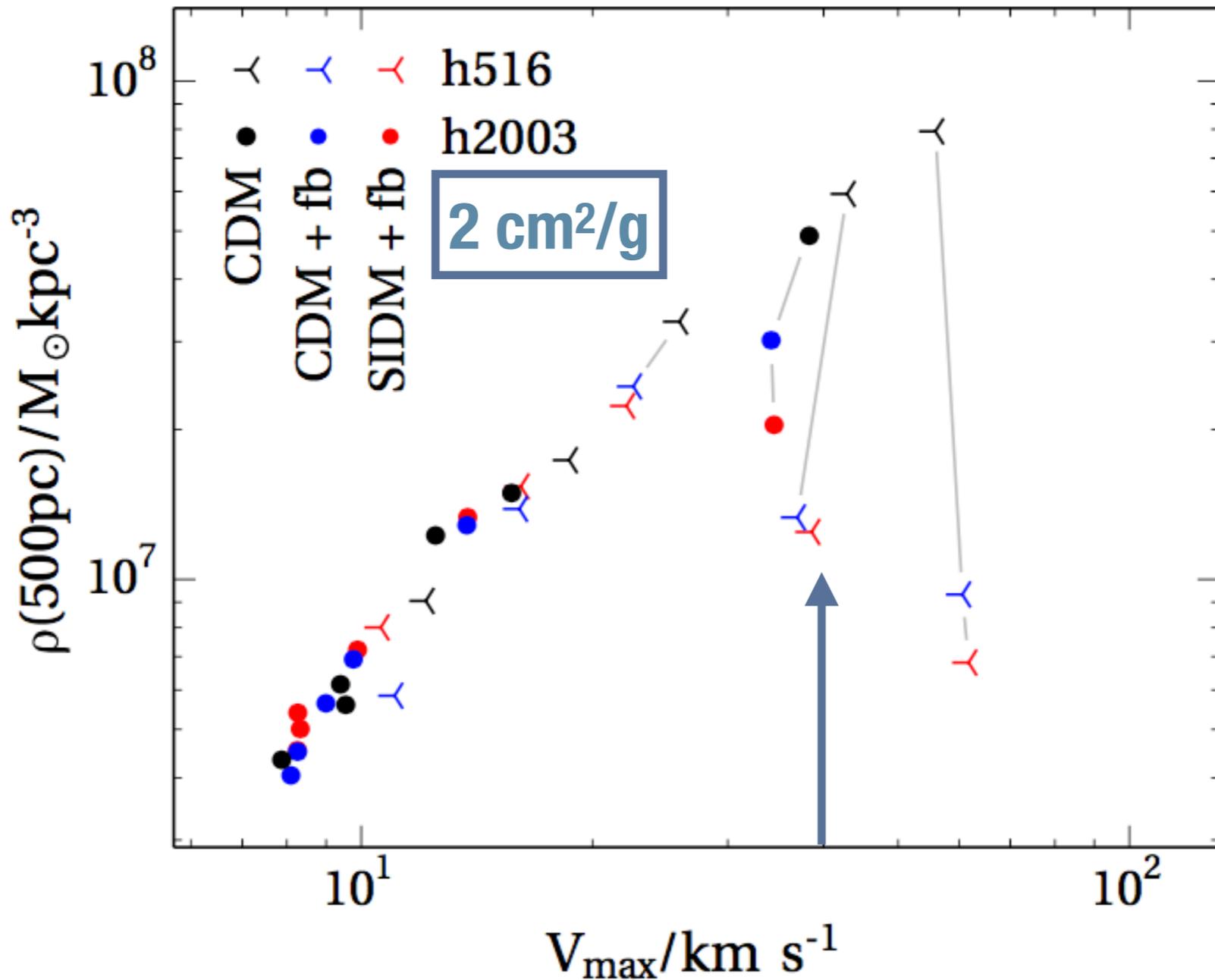
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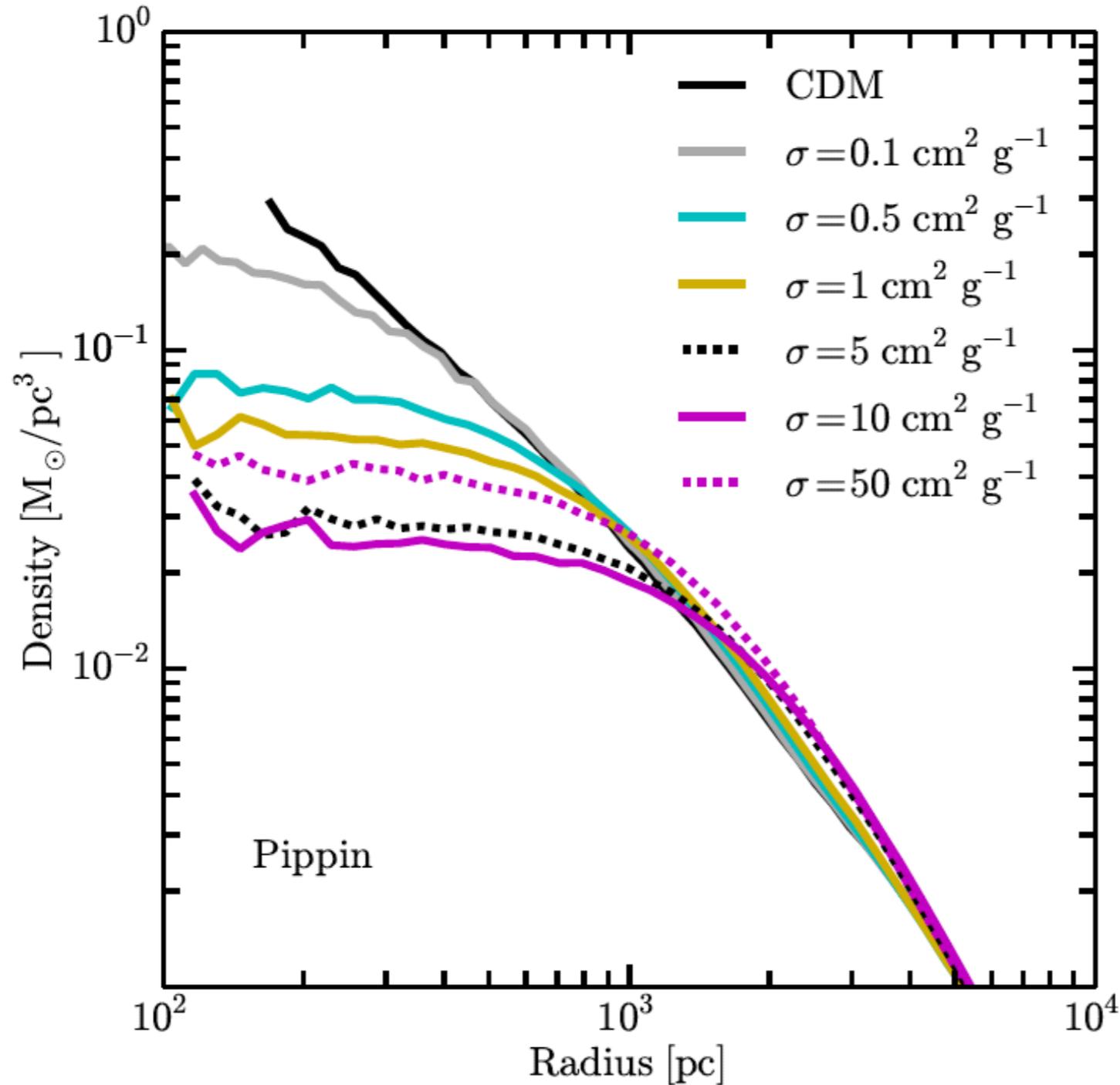
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**this talk**

# SIDM: THE CONSTRAINTS ARE WEAKENING

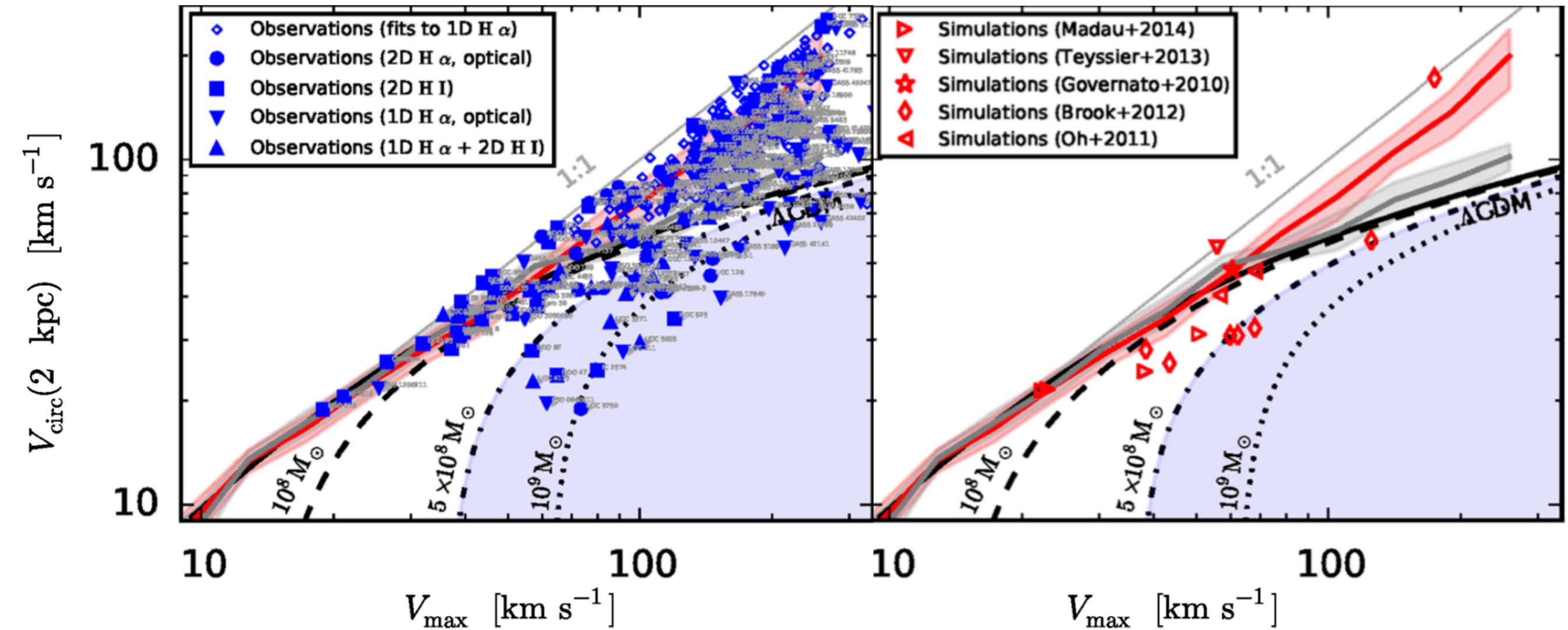


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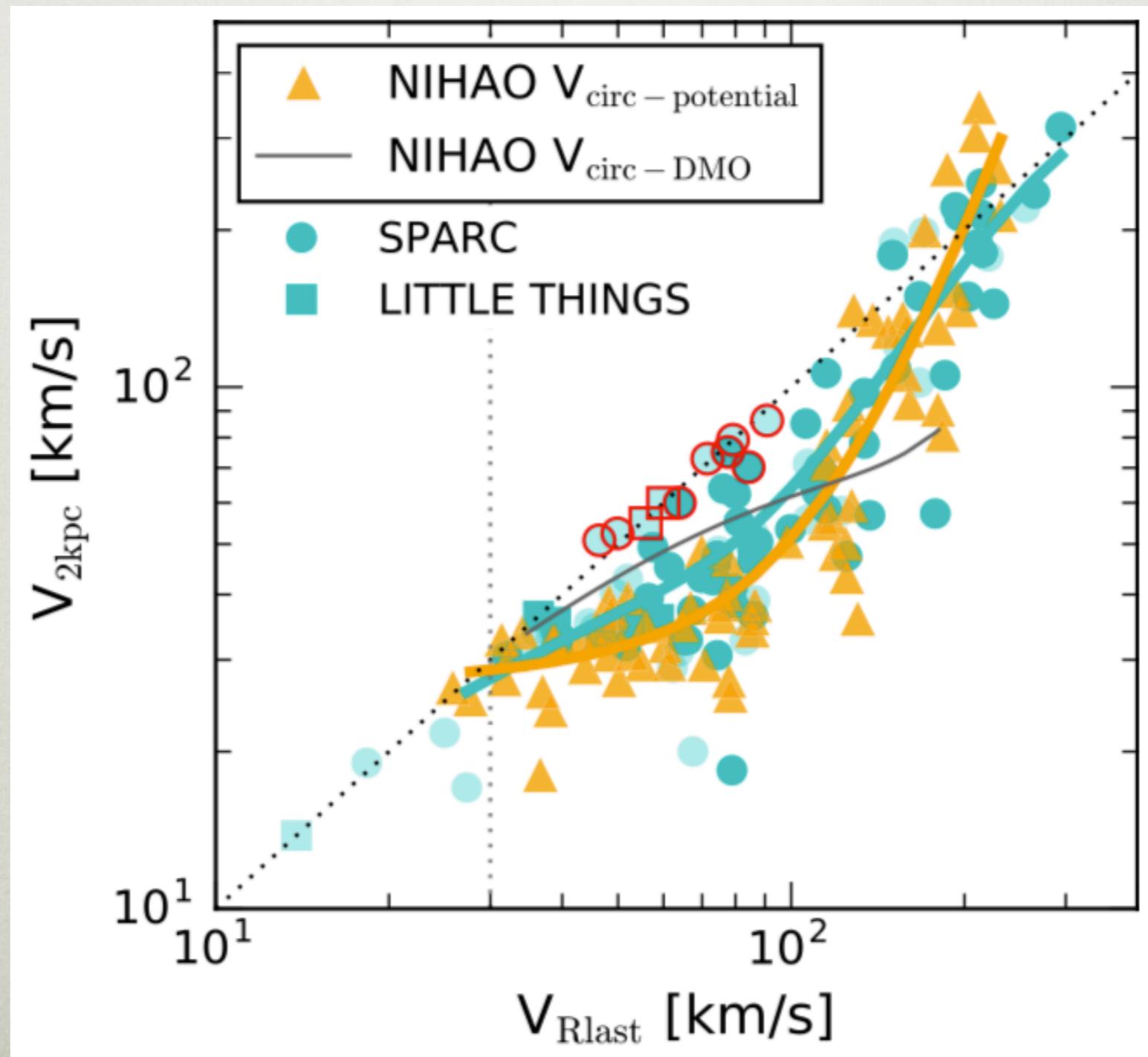


results for  
a  $9 \times 10^9 M_{\text{sun}}$  halo

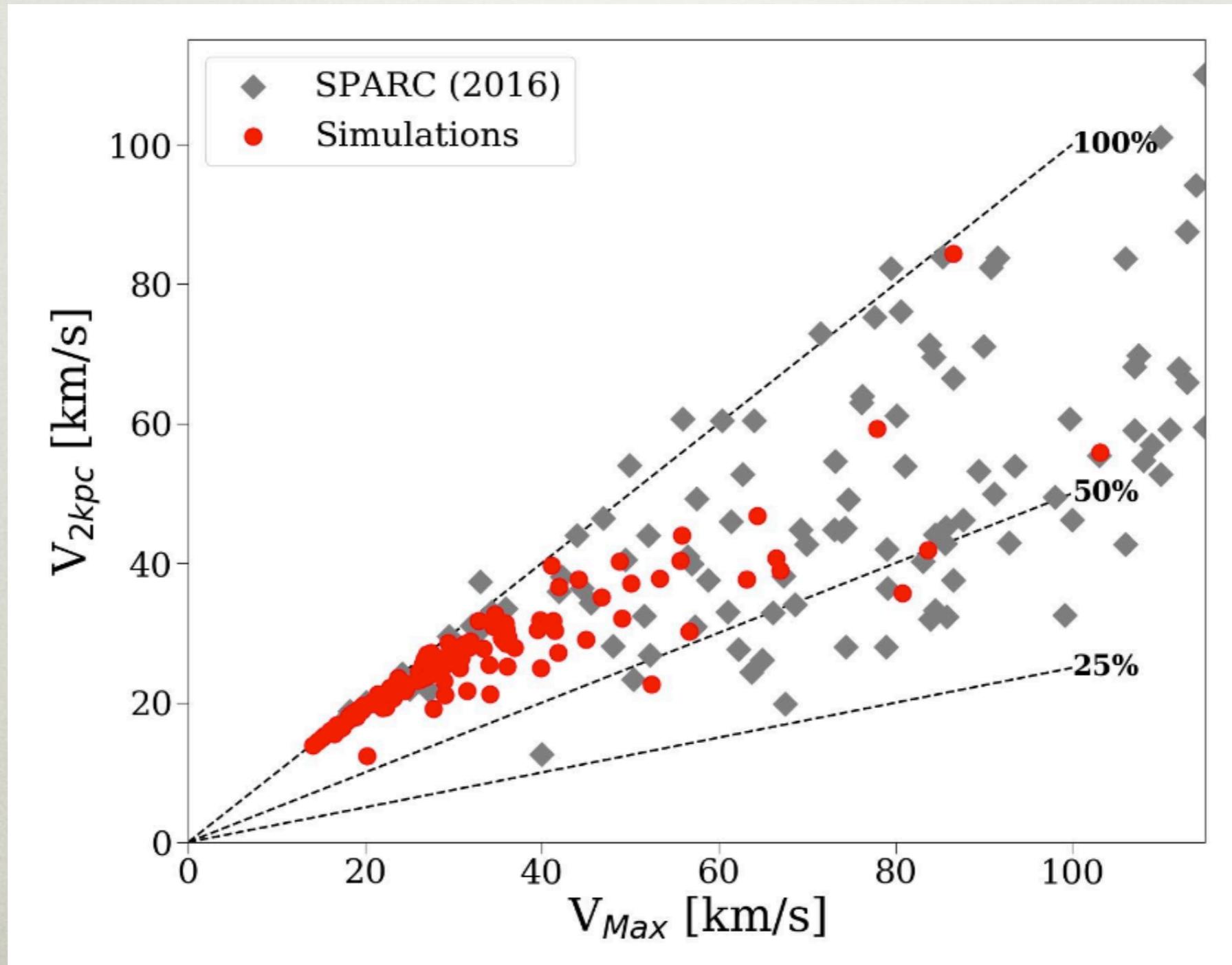
# DIVERSITY OF ROTATION CURVES



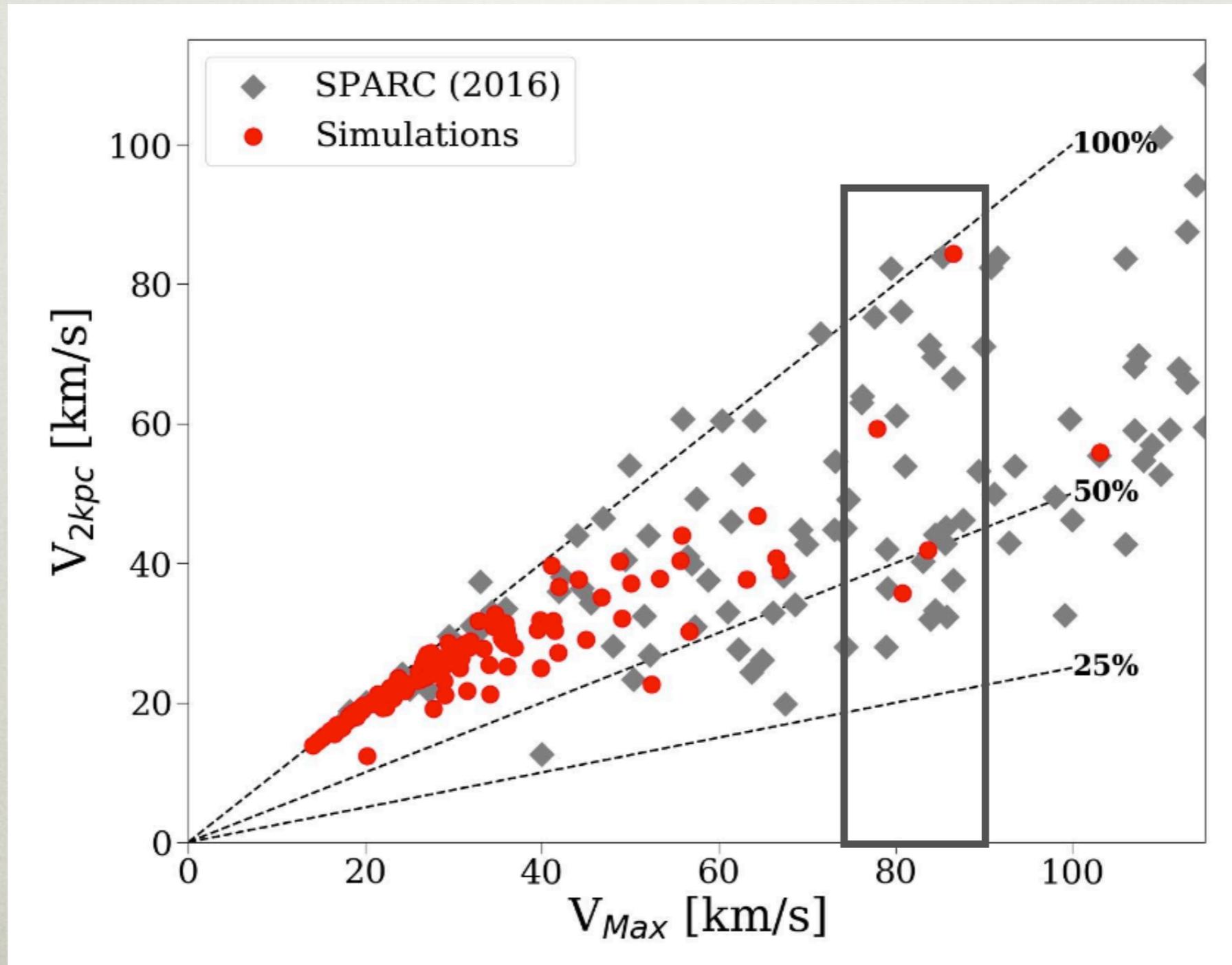
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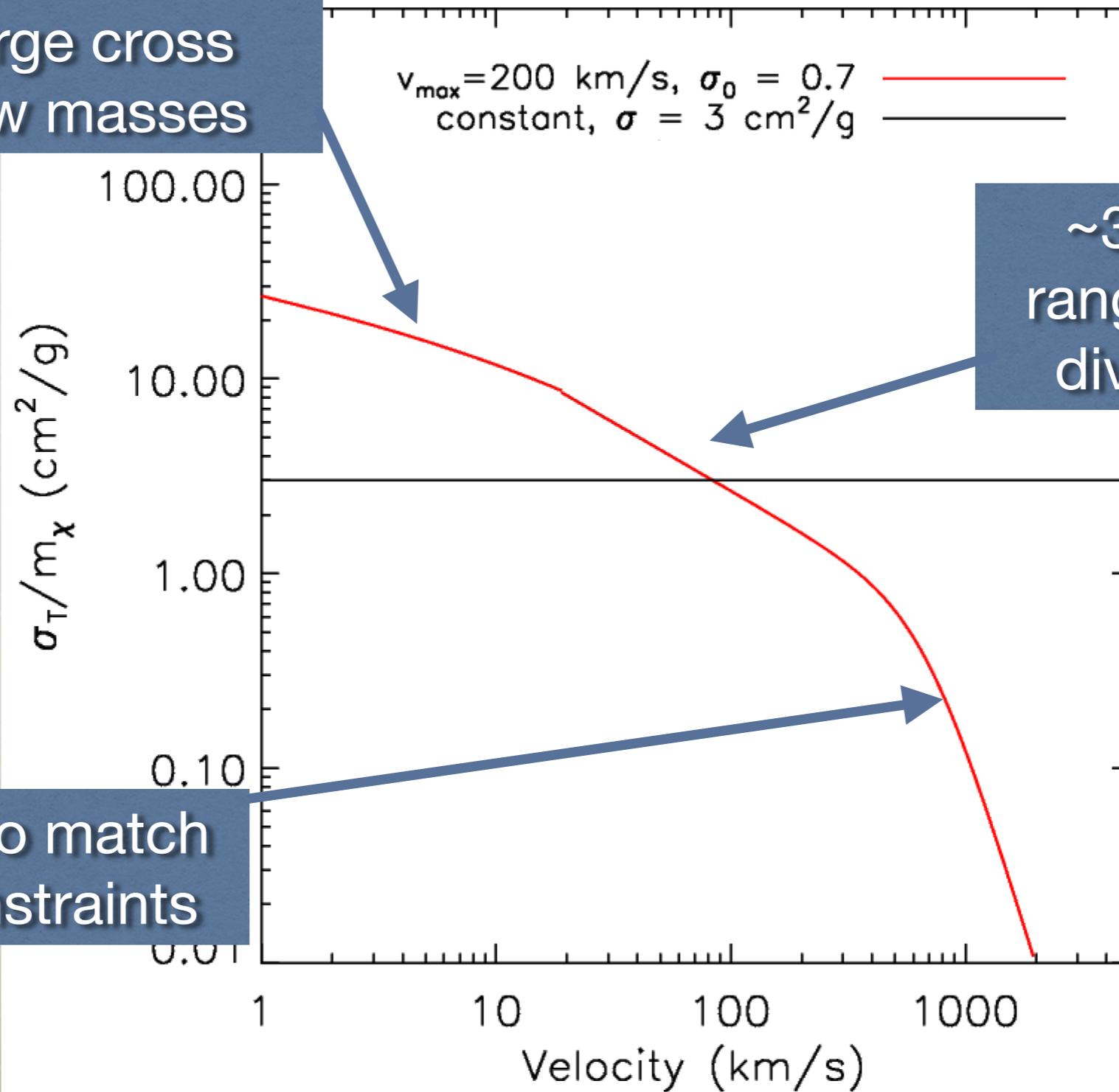


# DIVERSITY OF ROTATION CURVES



# FUTURE: RE-RUN IN SIDM

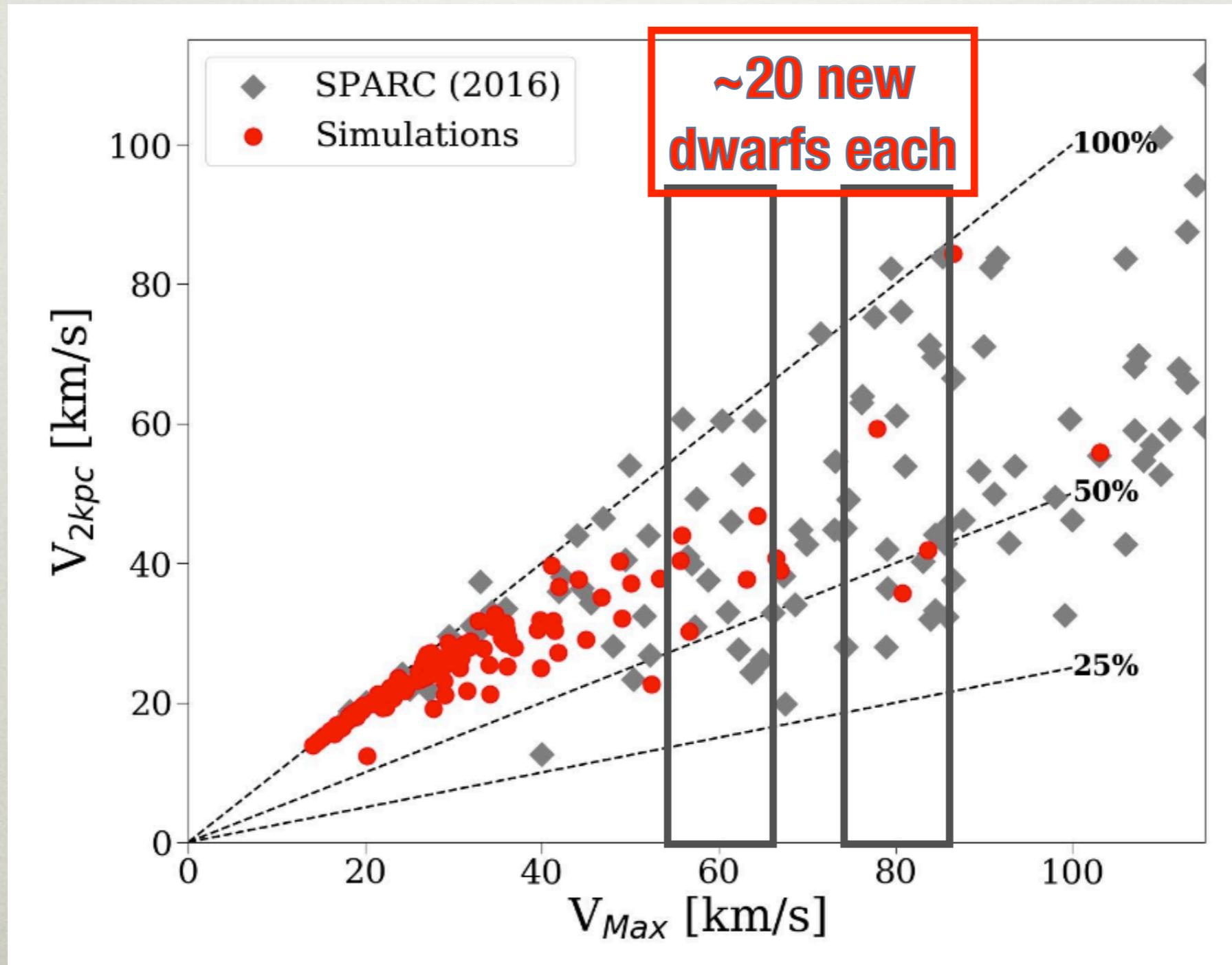
allows for large cross section at low masses



~3 cm<sup>2</sup>/g across range of galaxies in diversity problem

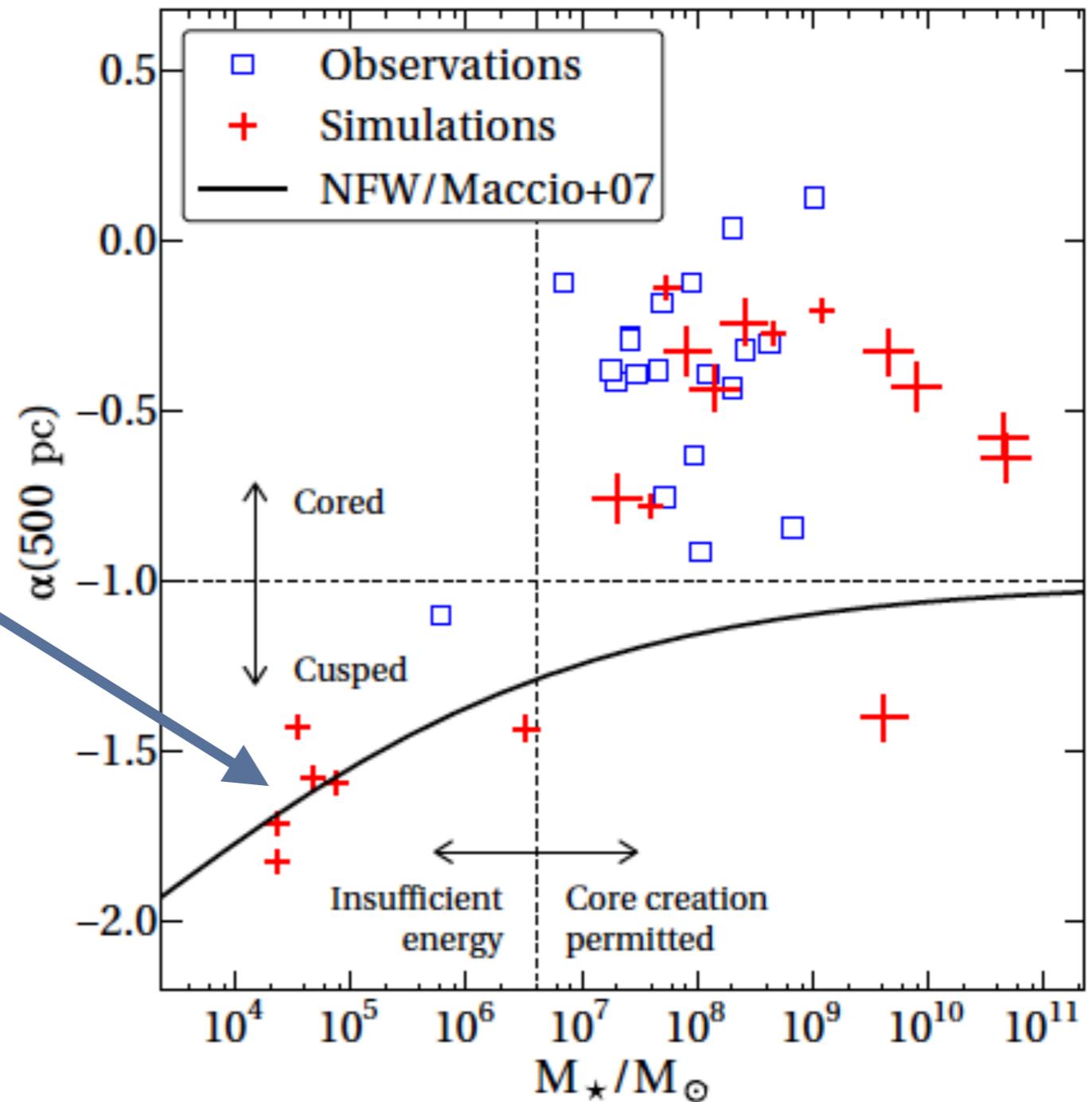
< 1 cm<sup>2</sup>/g to match cluster constraints

# DIVERSITY OF ROTATION CURVES



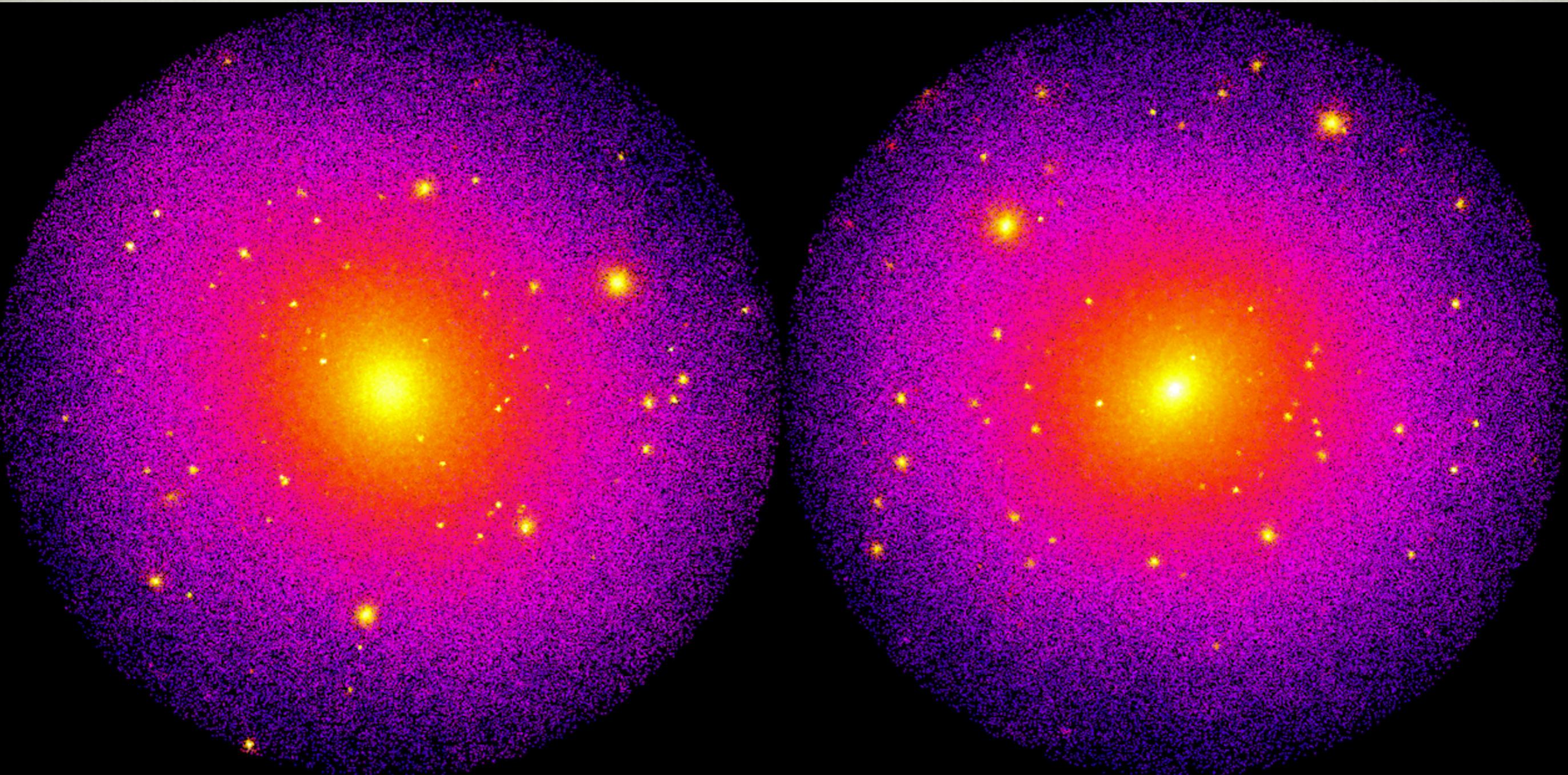
# ASTROPHYSICAL CONSTRAINTS ON DARK MATTER: THE IMPORTANCE OF ULTRA-FAINT DWARFS

If galaxies in this mass range are observed to have large cores, then something beyond CDM is necessary



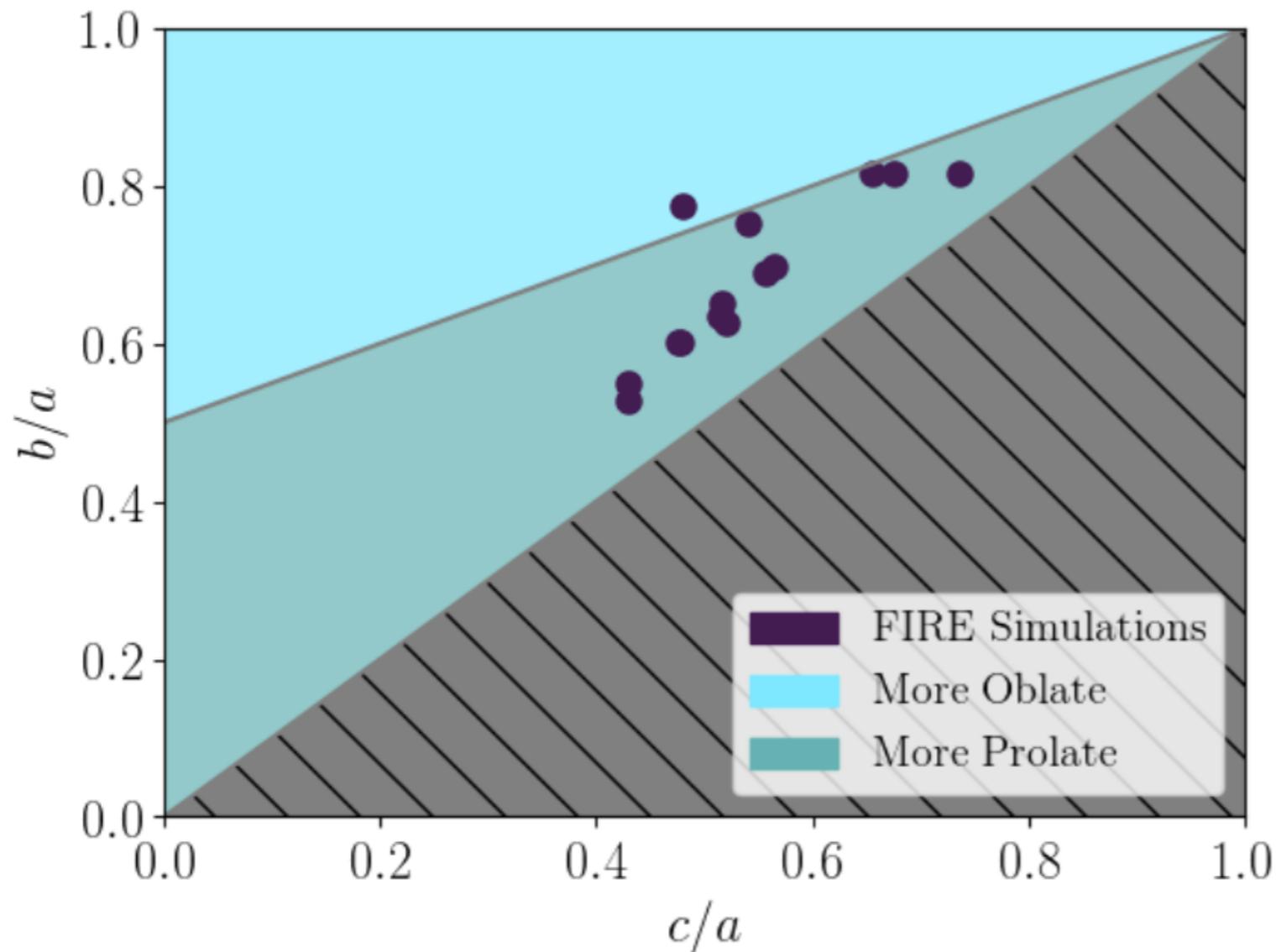
see Brooks (2014)  
arXiv:1407.7544 for a review

# GALAXY SHAPES AS A TRACER?



from review in arXiv:1407.7544

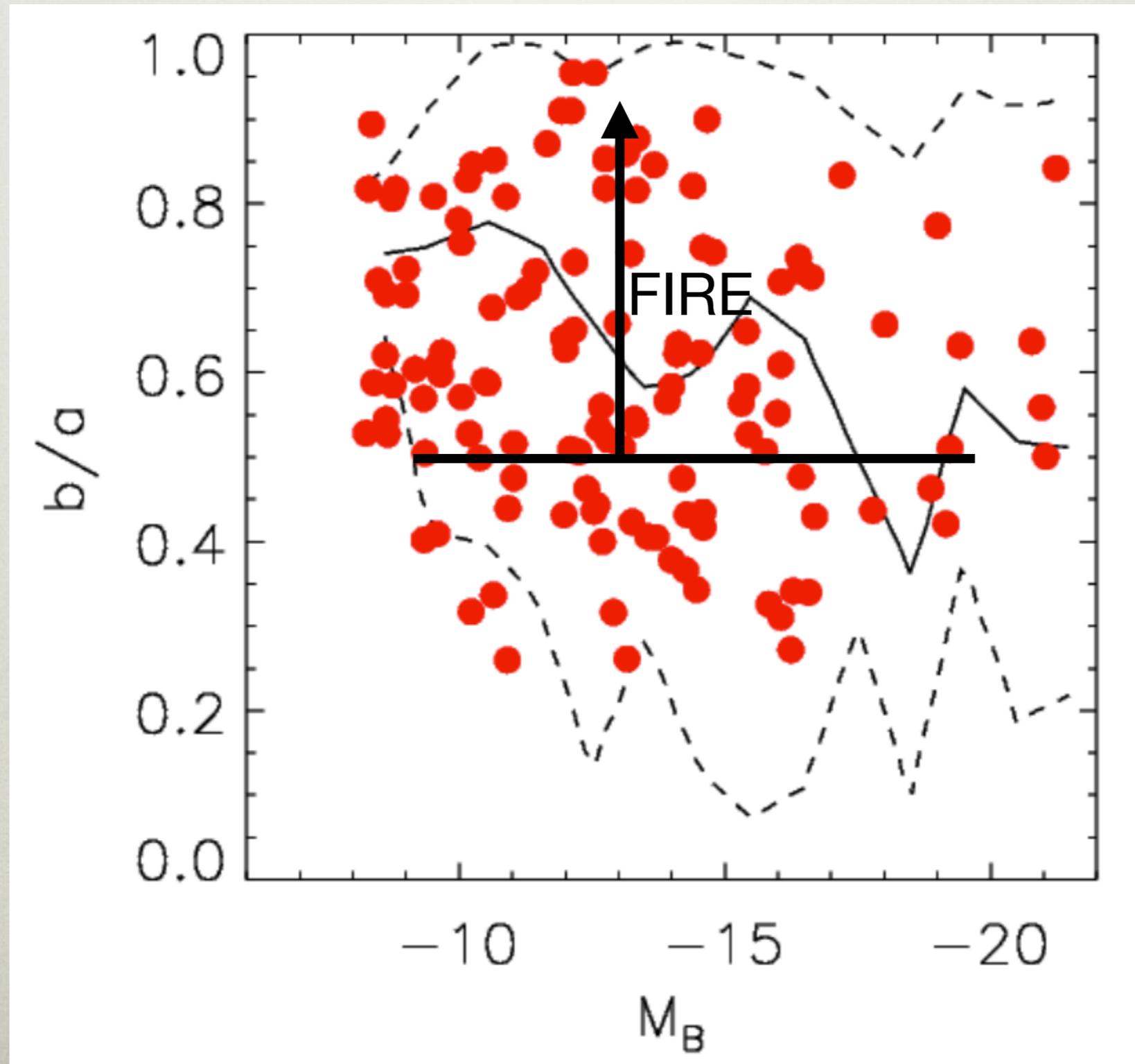
# GALAXY SHAPES AS A TRACER?



Large cores should affect the shapes of dwarf galaxies?

(a) Distribution of stellar axis ratios  $b/a, c/a$  evaluated at half-light. As shown, the FIRE galaxies are largely prolate in stellar distribution

# GALAXY SHAPES AS A TRACER?



# Conclusions

To constrain the Dark Matter model, we must understand the impact of baryonic physics on galaxy formation!

Future observations of dwarf galaxies ( $M_{\text{star}} < 10^7 M_{\text{sun}}$ ) are the excellent probes to constrain dark matter properties/model (and also star formation/feedback)

Baryonic physics alleviates the current problems with CDM, but that doesn't mean CDM is the correct model. Very little work has been done to discover whether galaxy formation can be reproduced in models outside of CDM

