Understanding Dwarf Galaxies to Understand Dark Matter

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No Small Scale "Crisis" if Consider the Influence of Baryons

	CDM+Baryons	
Missing Satellites	✓	Brooks et al. (2013), Wetzel et al. (2016), Fattahi et al. (2018), Buck et al. (2019)
Too Big to Fail	✓	Zolotov et al. (2012), Brooks & Zolotov (2014), Frings (2017), Garrison-Kimmel et al. (2019)
Missing Dwarfs	✓	Maccio et al. (2016), Brooks et al. (2017), Chauhan et al. (2019)
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)
Diversity		Santos-Santos et al. (2018, 2020), Zentner et al. (2022), Roper et al. (2023)
Galaxy-Galaxy Strong Lensing		
Planes of Satellites		Garavito-Camargo et al. (2021)

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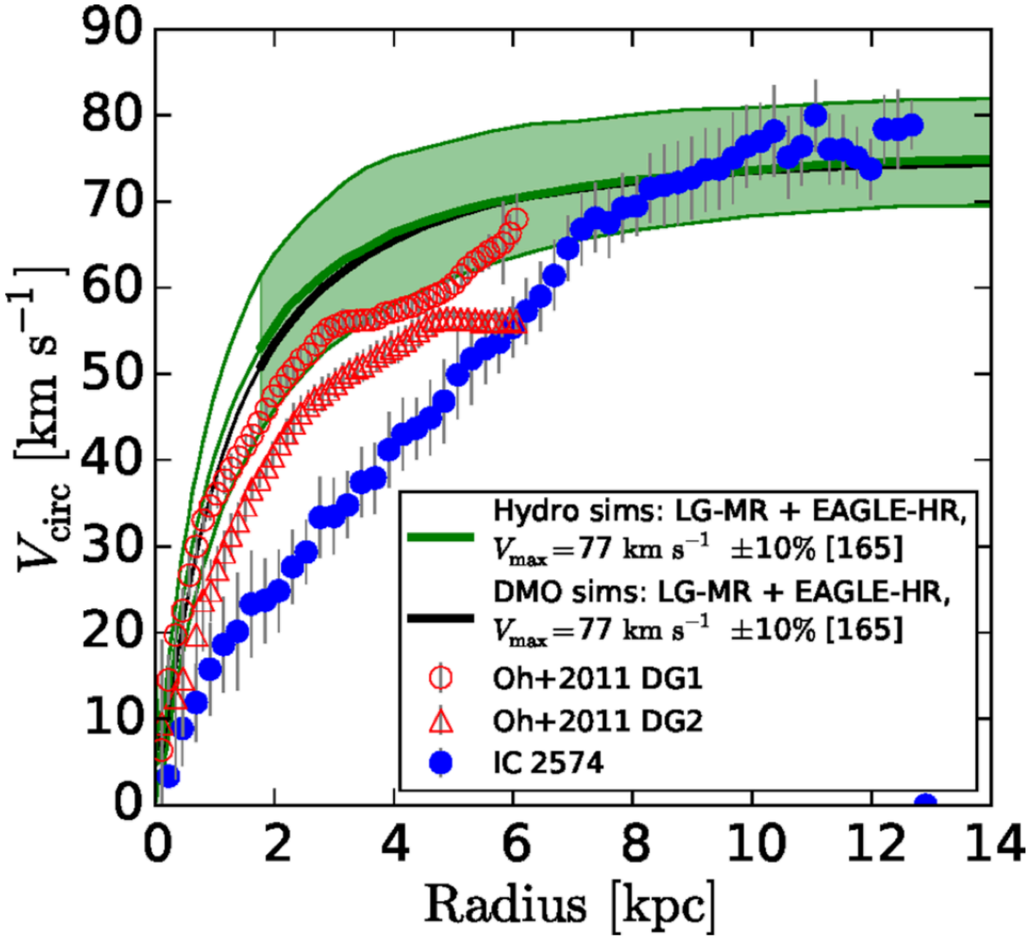
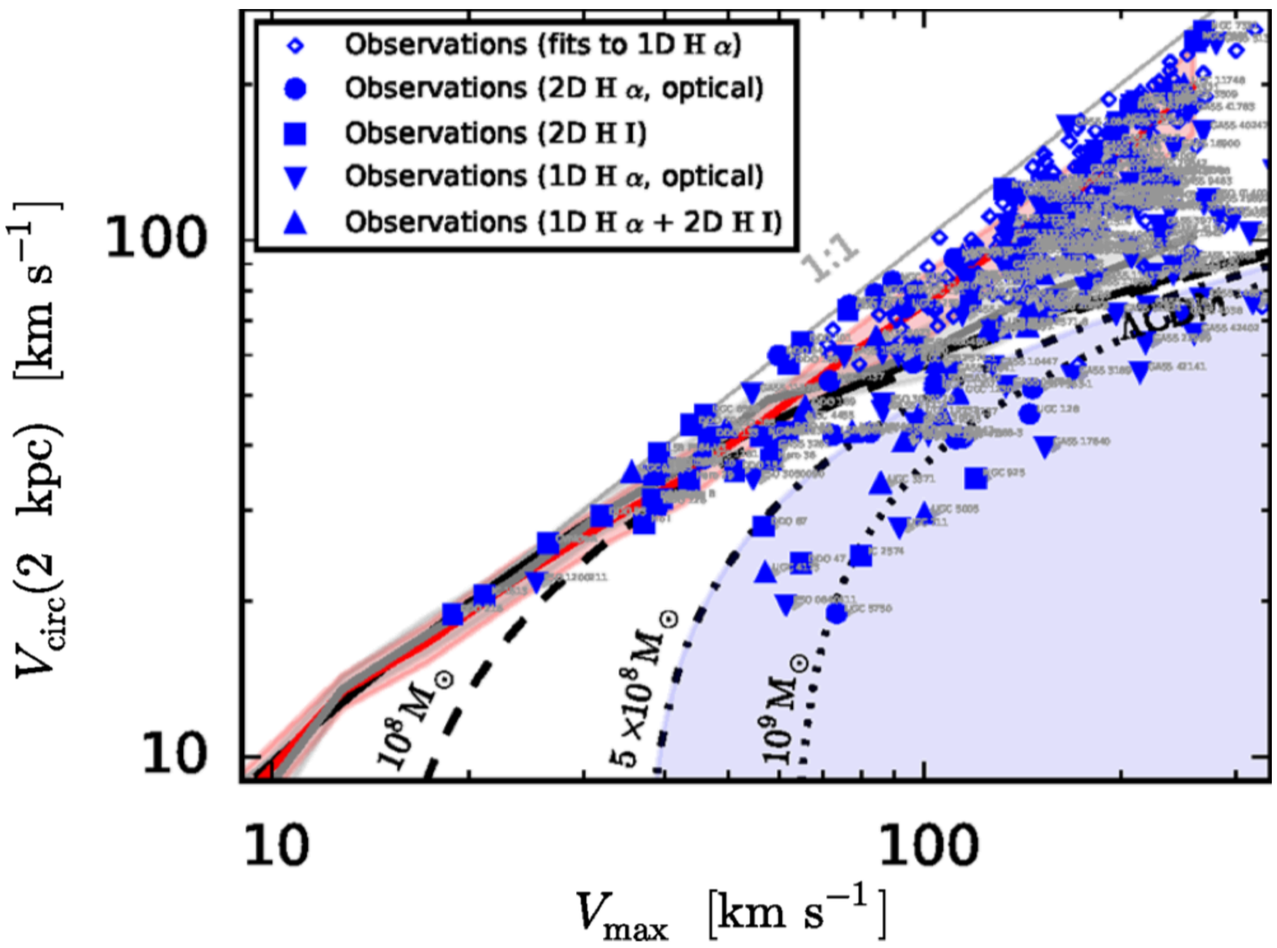
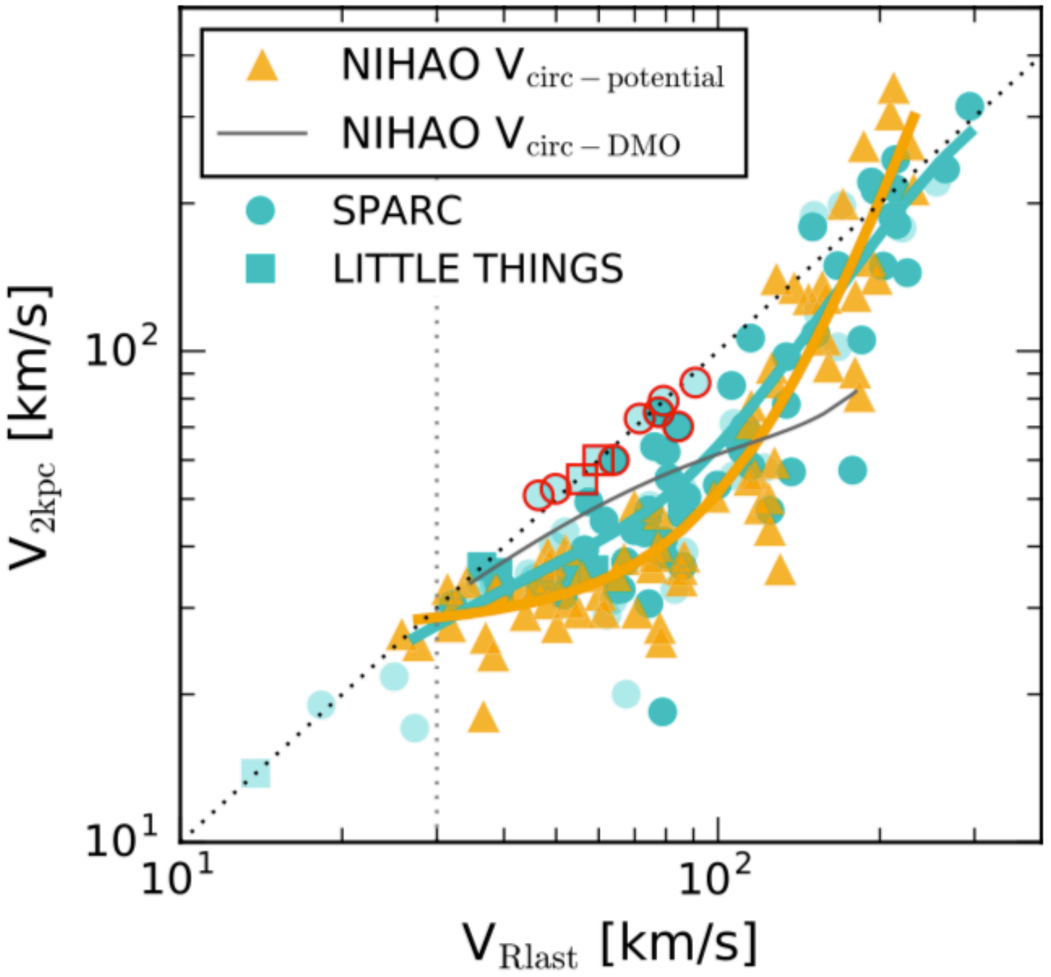
Disentangling Baryonic Physics from Dark Matter: Let's talk about Diversity



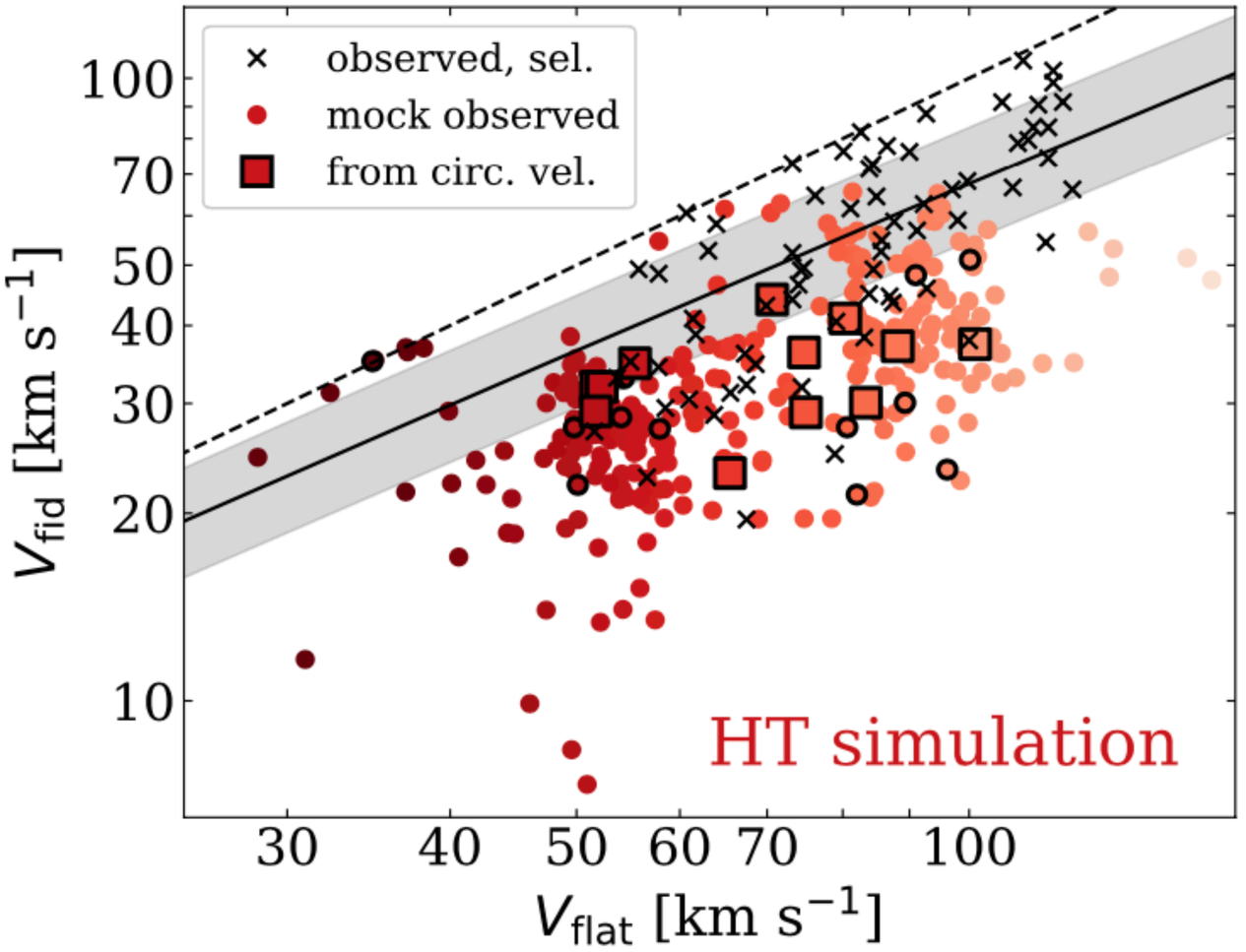


Oman et al. (2015)

Diversity Problem



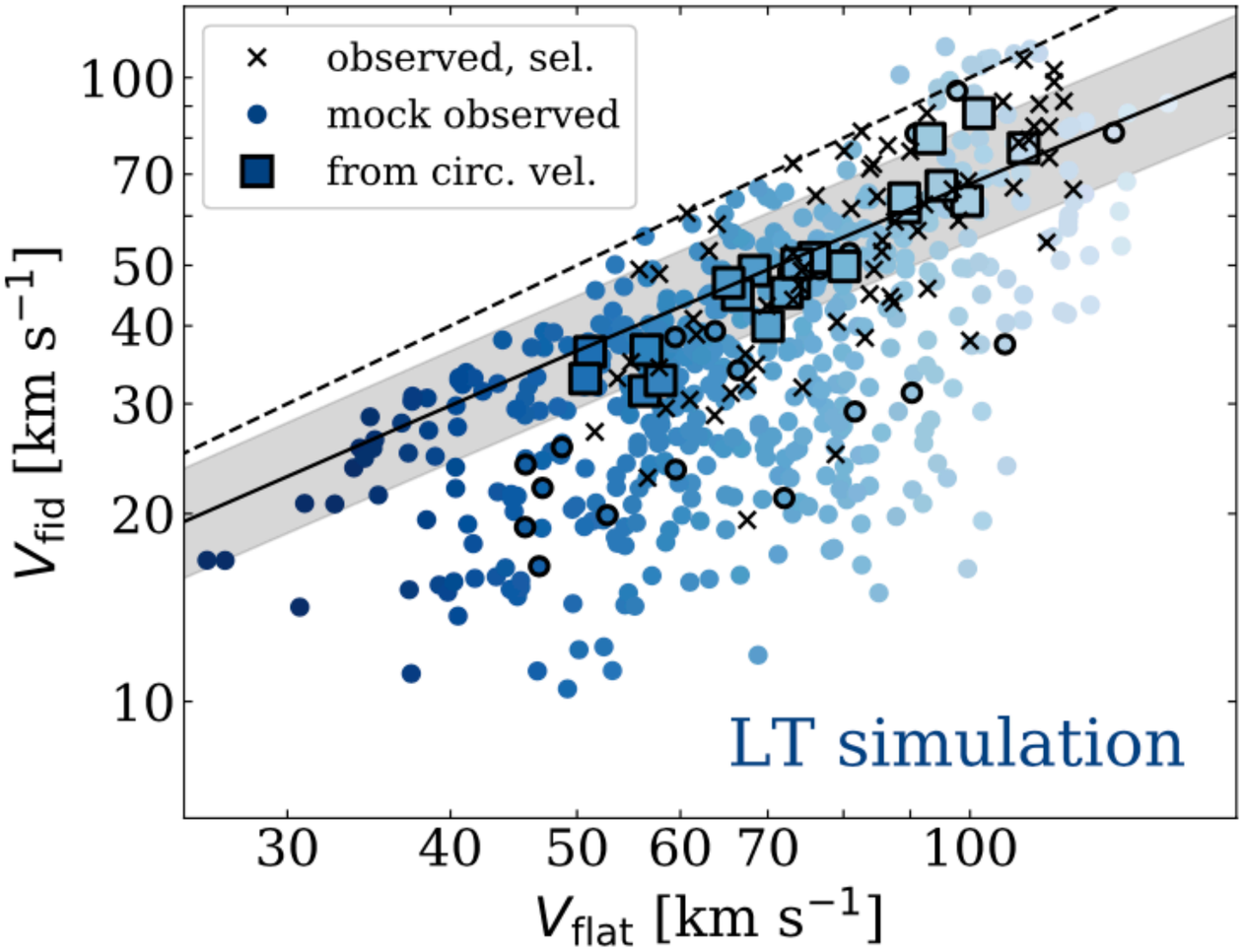
Santos-Santos et al. (2018)

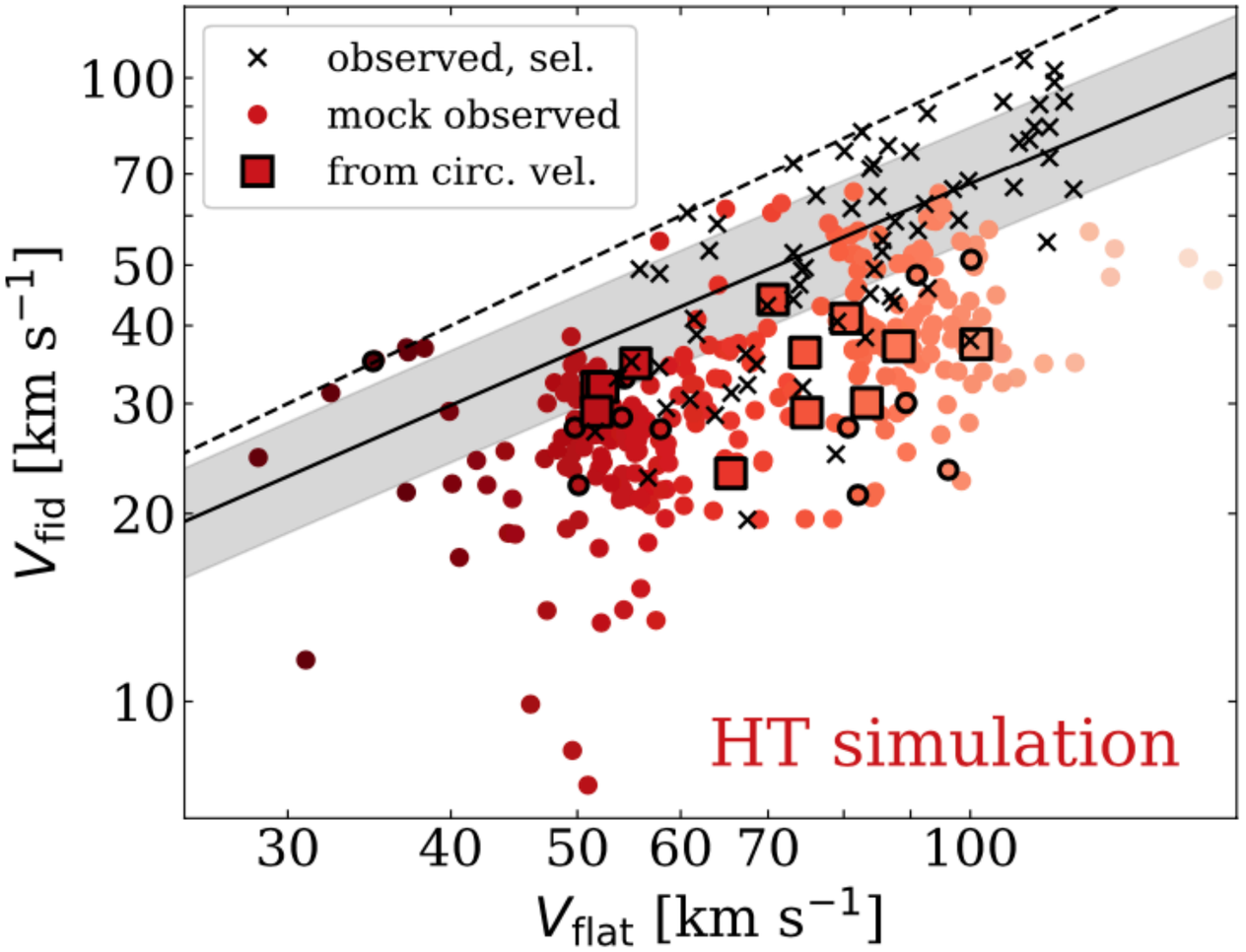


$$V_{\rm fid} = V_{\rm rot}(R = R_{\rm fid}); \qquad \frac{R_{\rm fid}}{\rm kpc} = \frac{V_{\rm flat}}{35\,{\rm km\ s^{-1}}}.$$

Roper et al. (2022)

Diversity Problem





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Diversity of Rotation Curves in SIDM

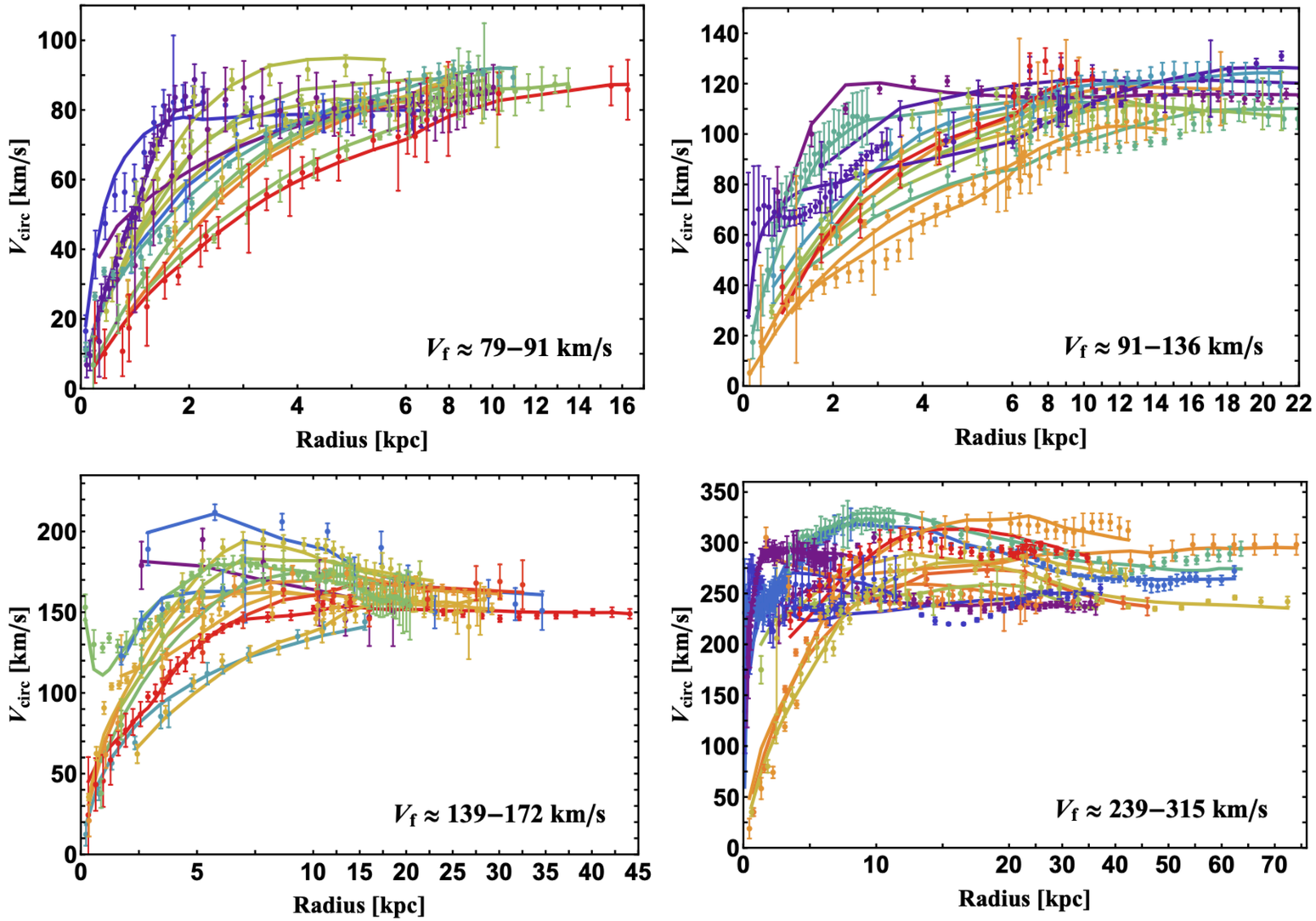
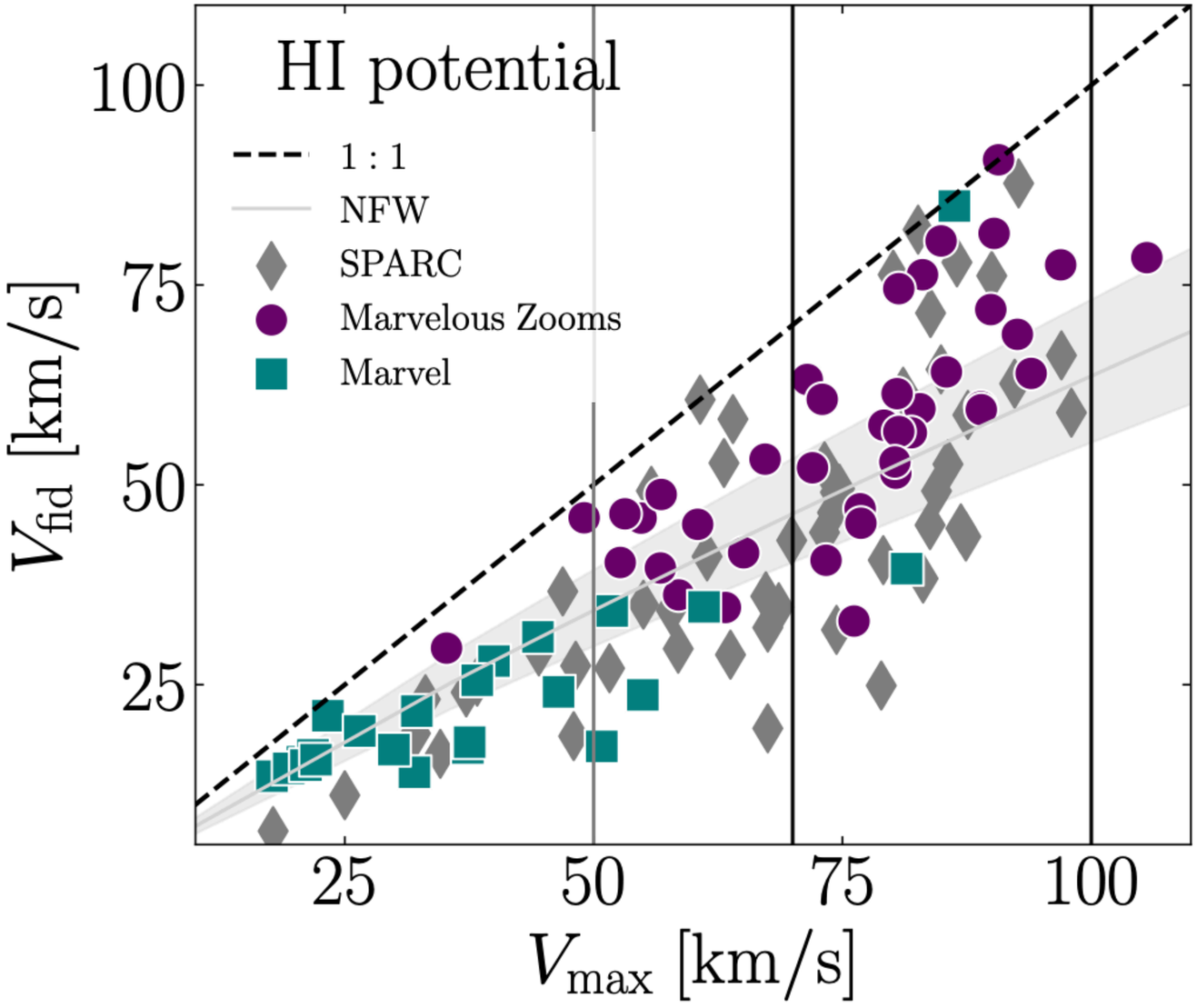


FIG. 1: SIDM fits (solid) to the diverse rotation curves across a range of spiral galaxy masses, where we take $\sigma/\mathrm{m} = 3\ \mathrm{cm}^2/\mathrm{g}$.

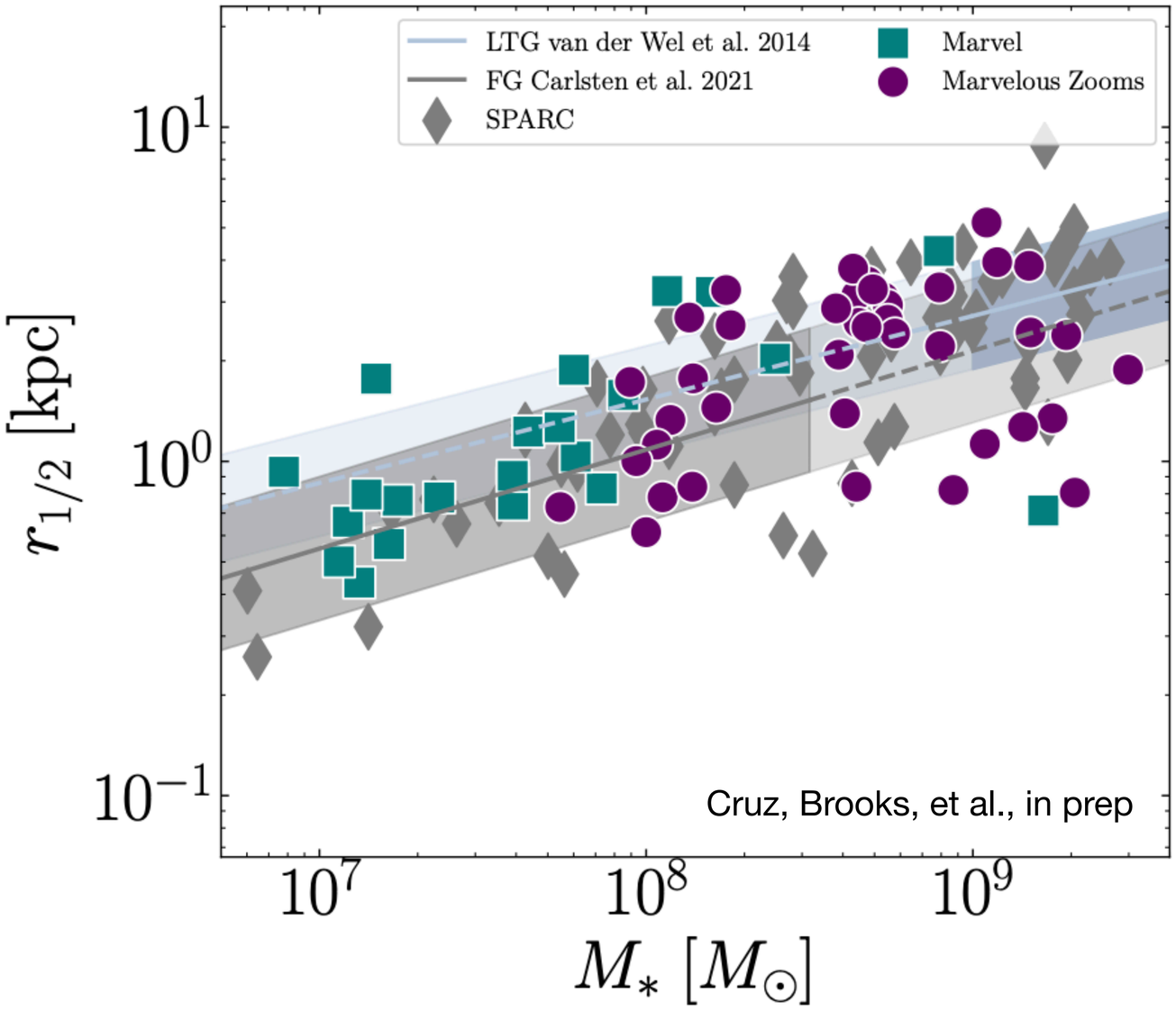
Ren, Kwa, Kaplinghat, Yu (2019)

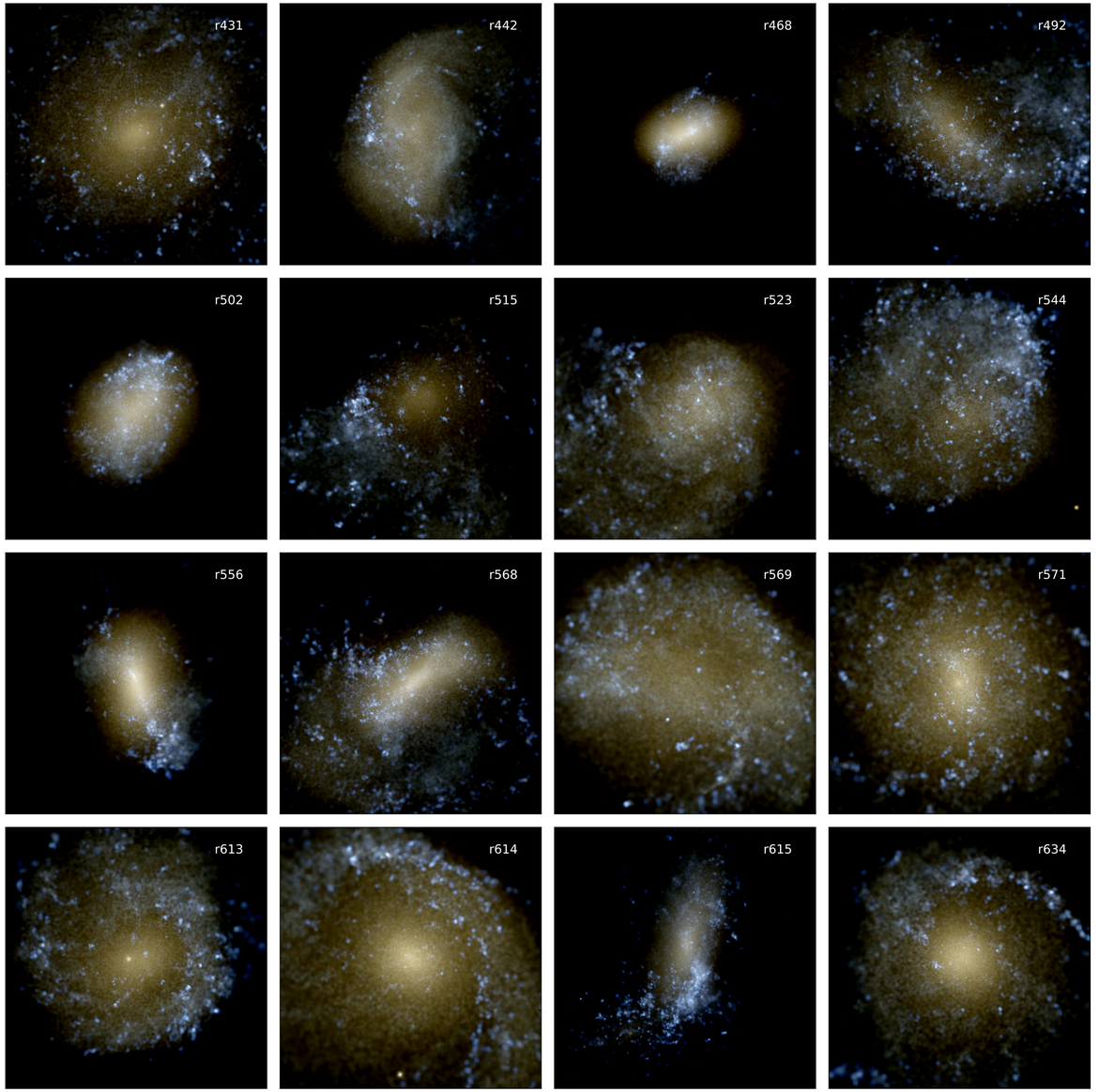
The Diversity of Rotation Curve Shapes



Cruz, Brooks, et al., in prep

Diversity in the size of our sample shows up where diversity is maximized for similar M_*





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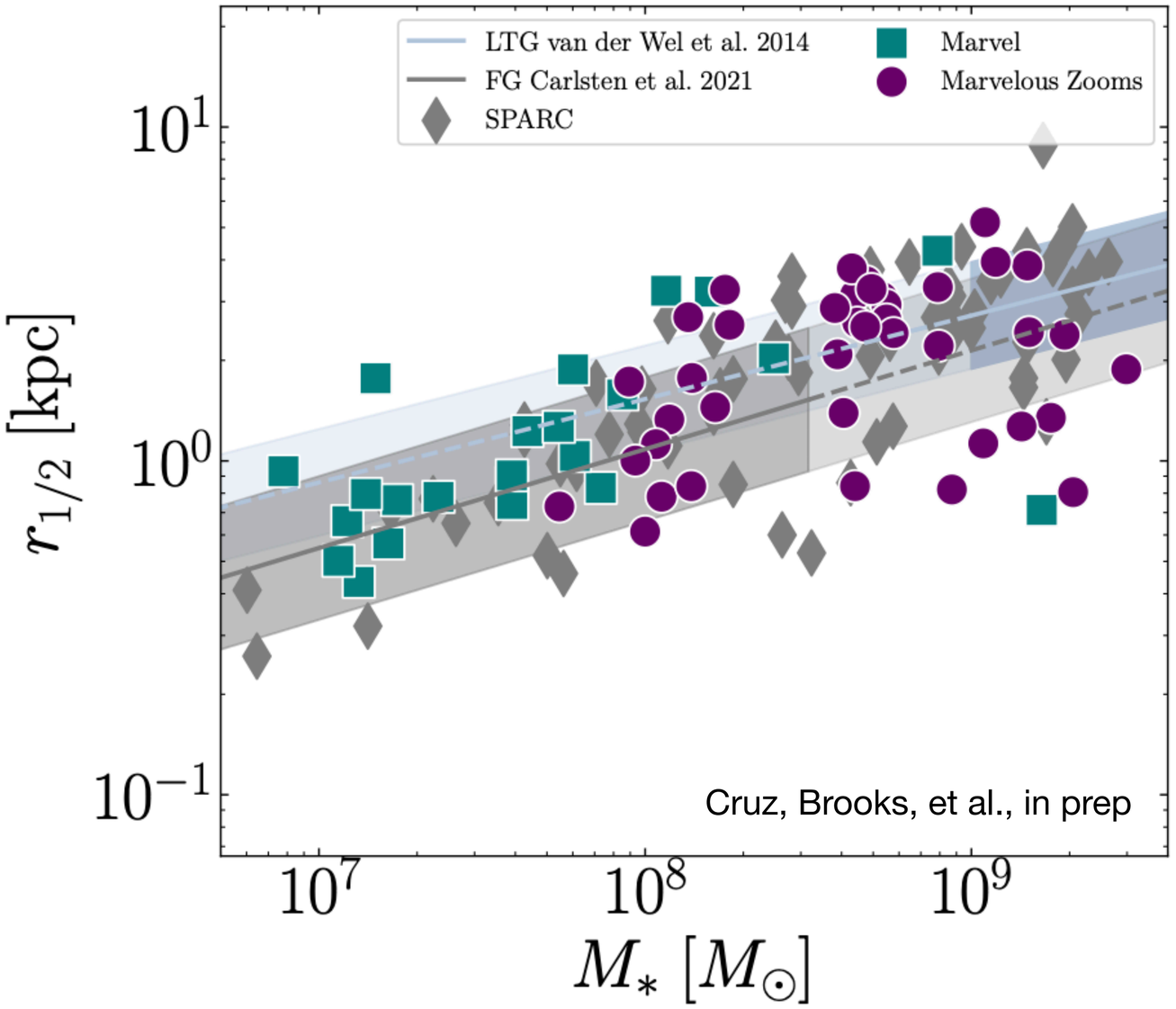
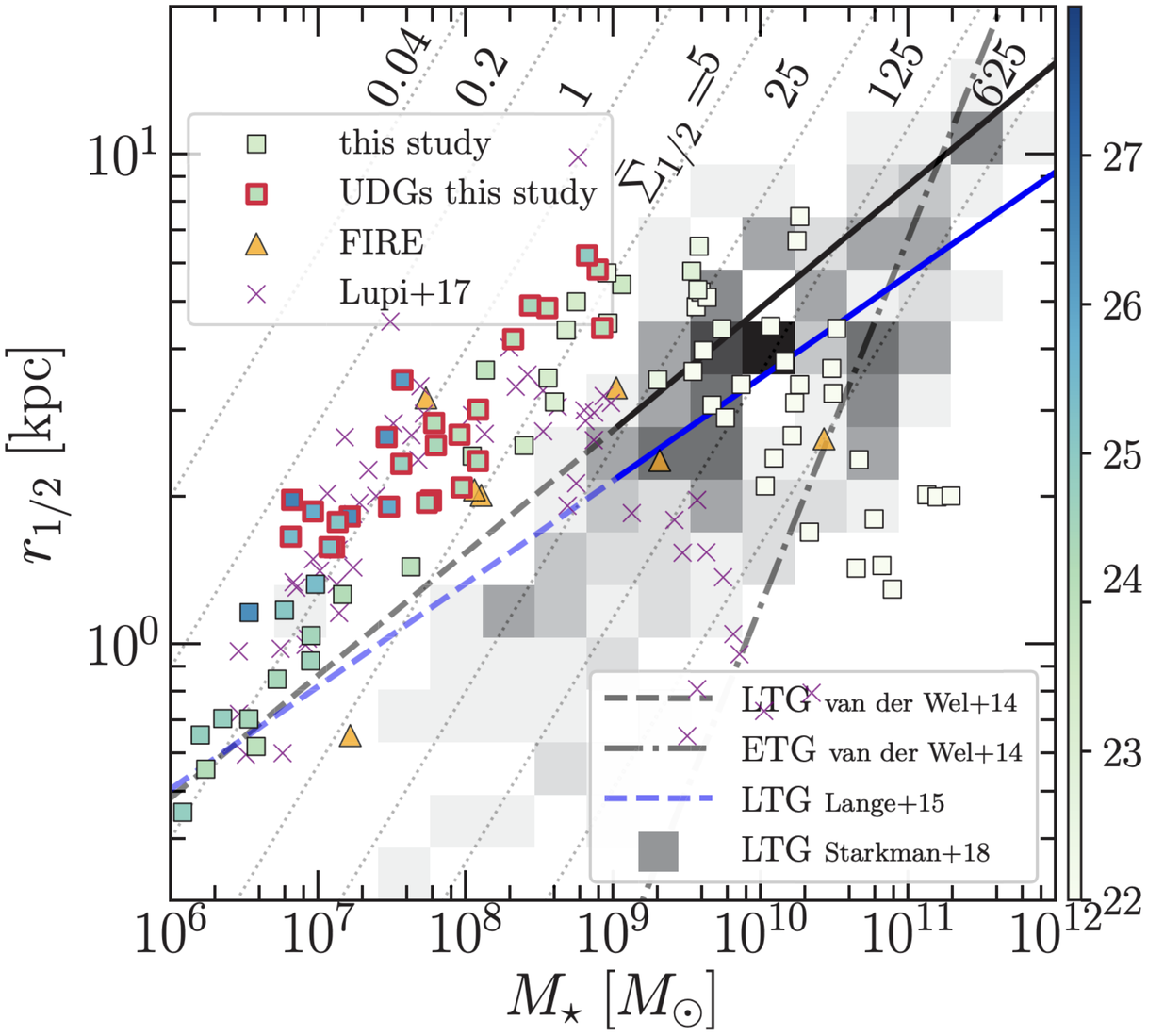
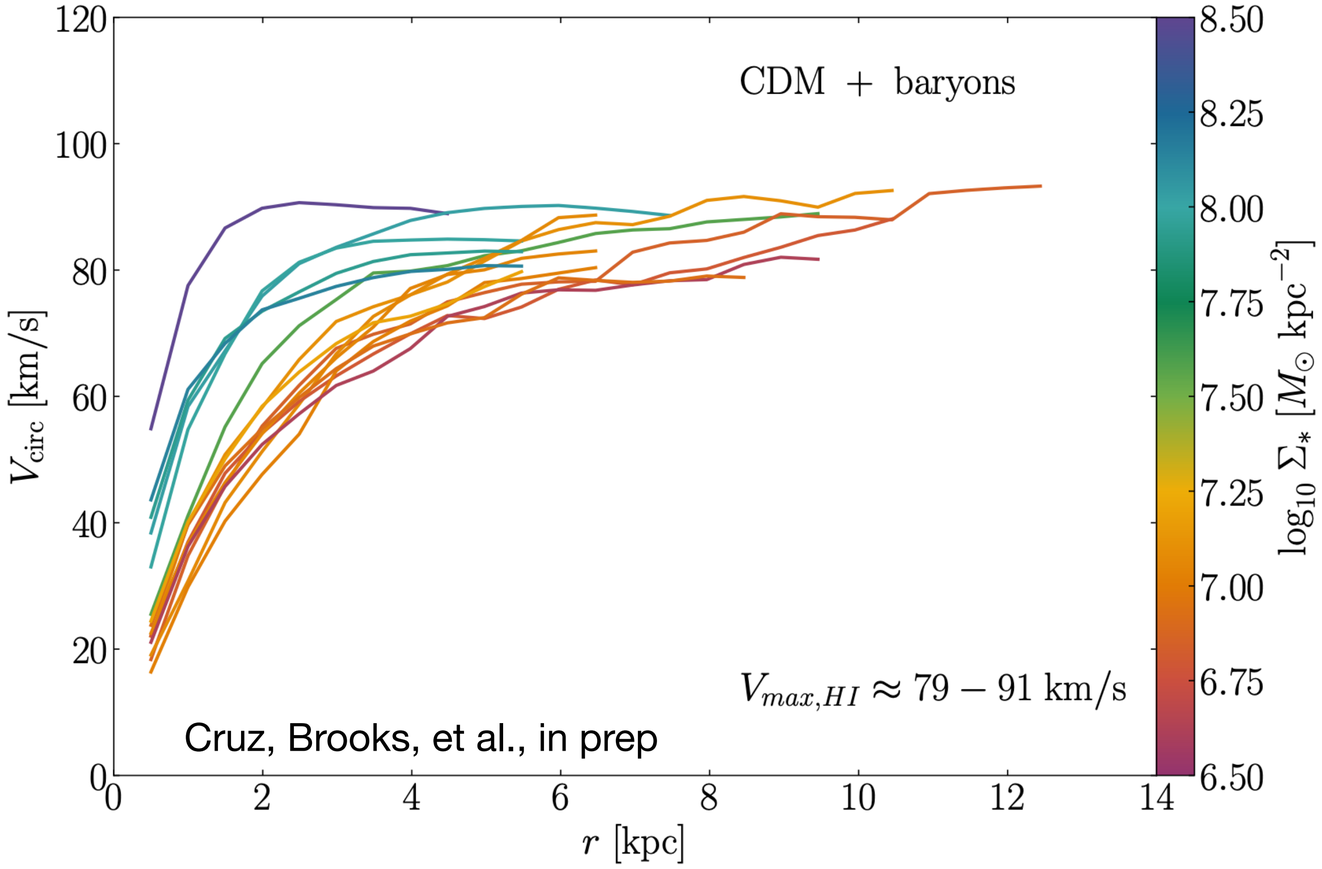




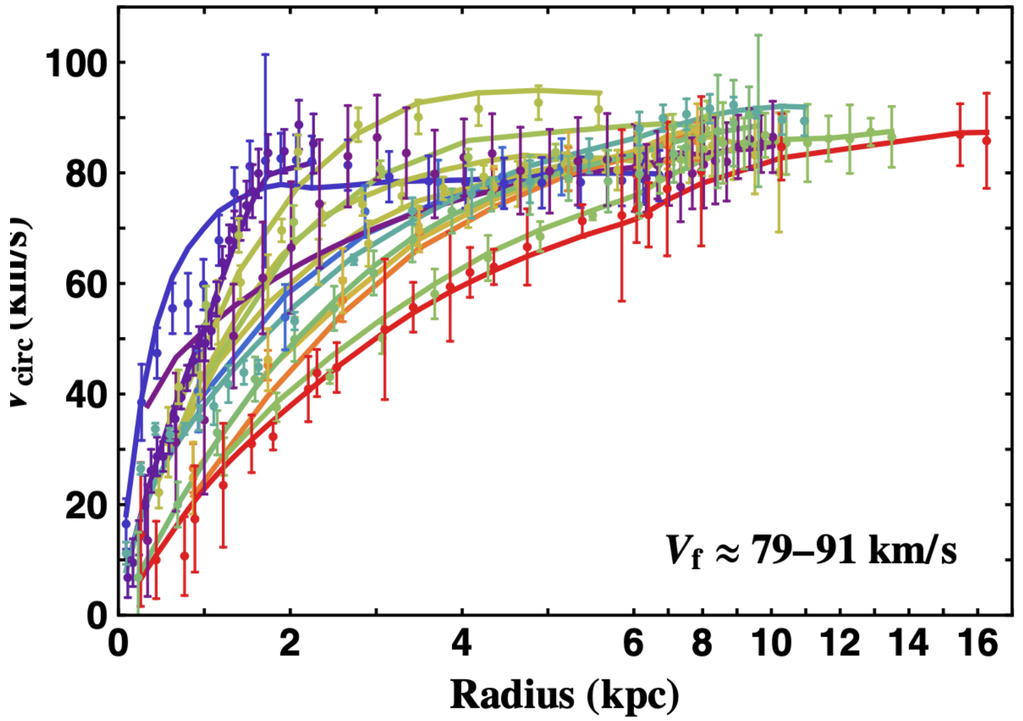
Jiang et al. (1811.10607)

The Marvelous Merian Dwarf Zooms exhibit diverse rotation curves (… that are influenced by surface brightness)

CDM and baryons

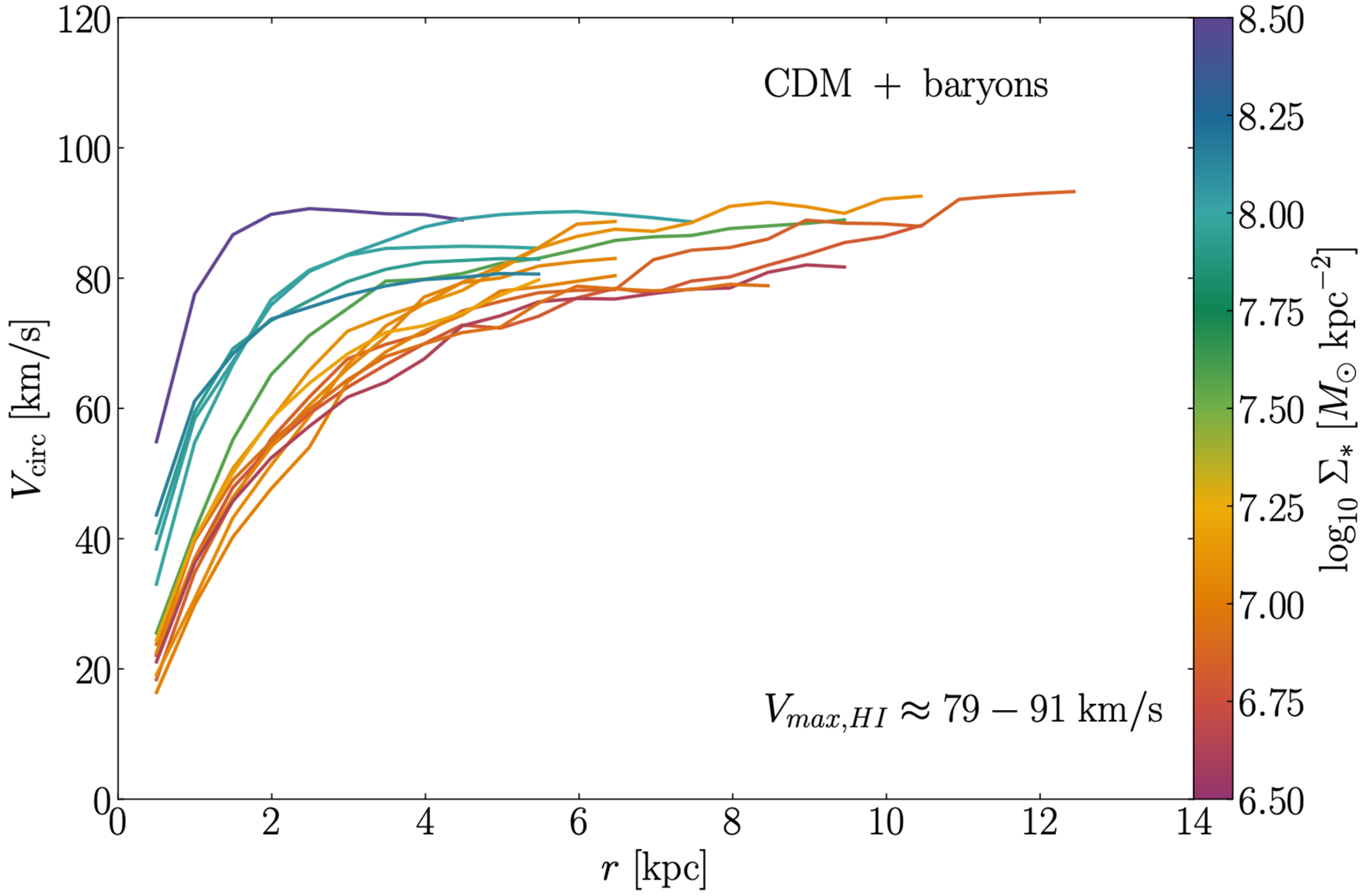


Self-Interacting Dark Matter (SIDM)



Ren et al. [1808.05695]

Diversity Exists in SIDM as well



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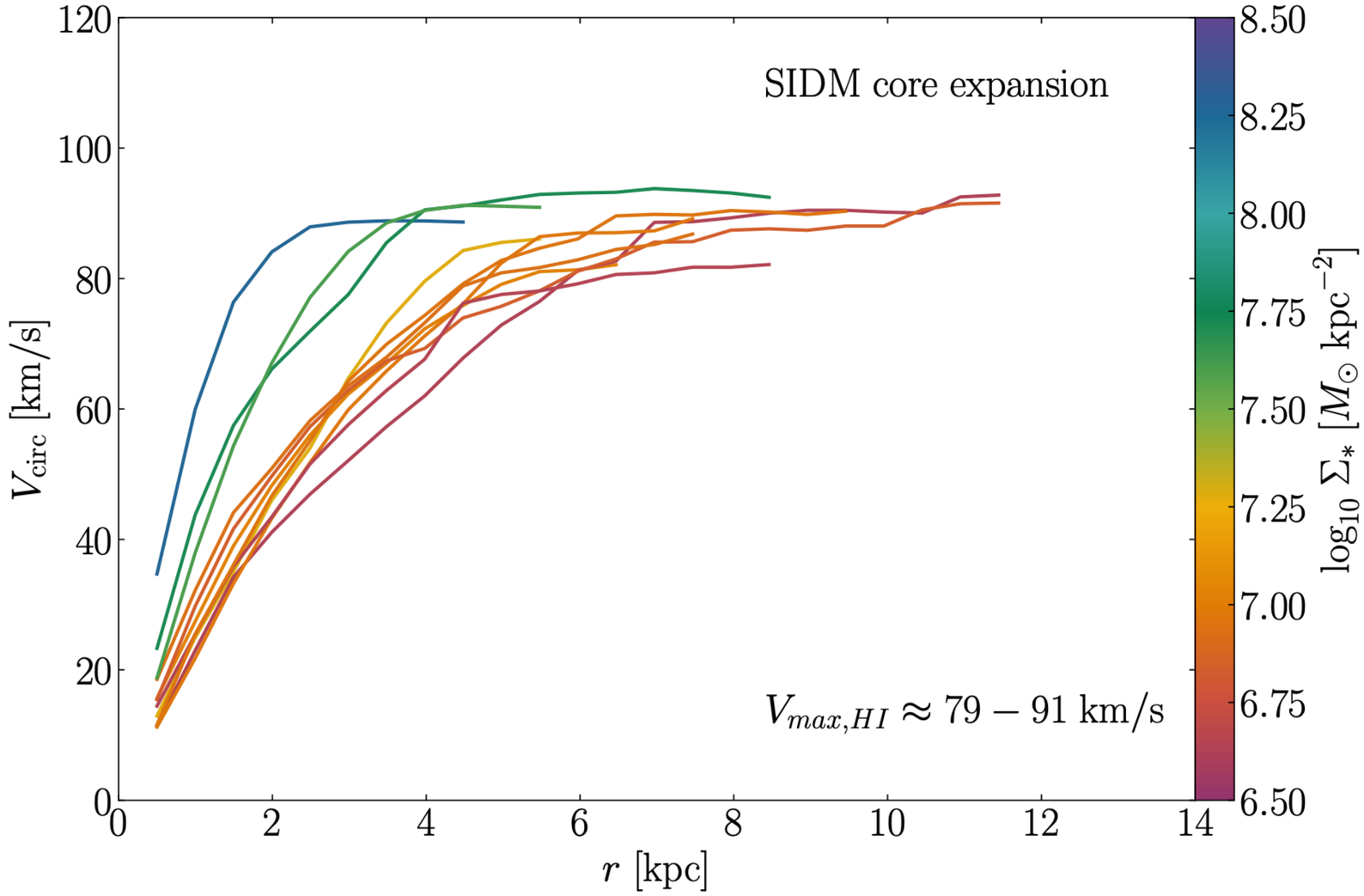

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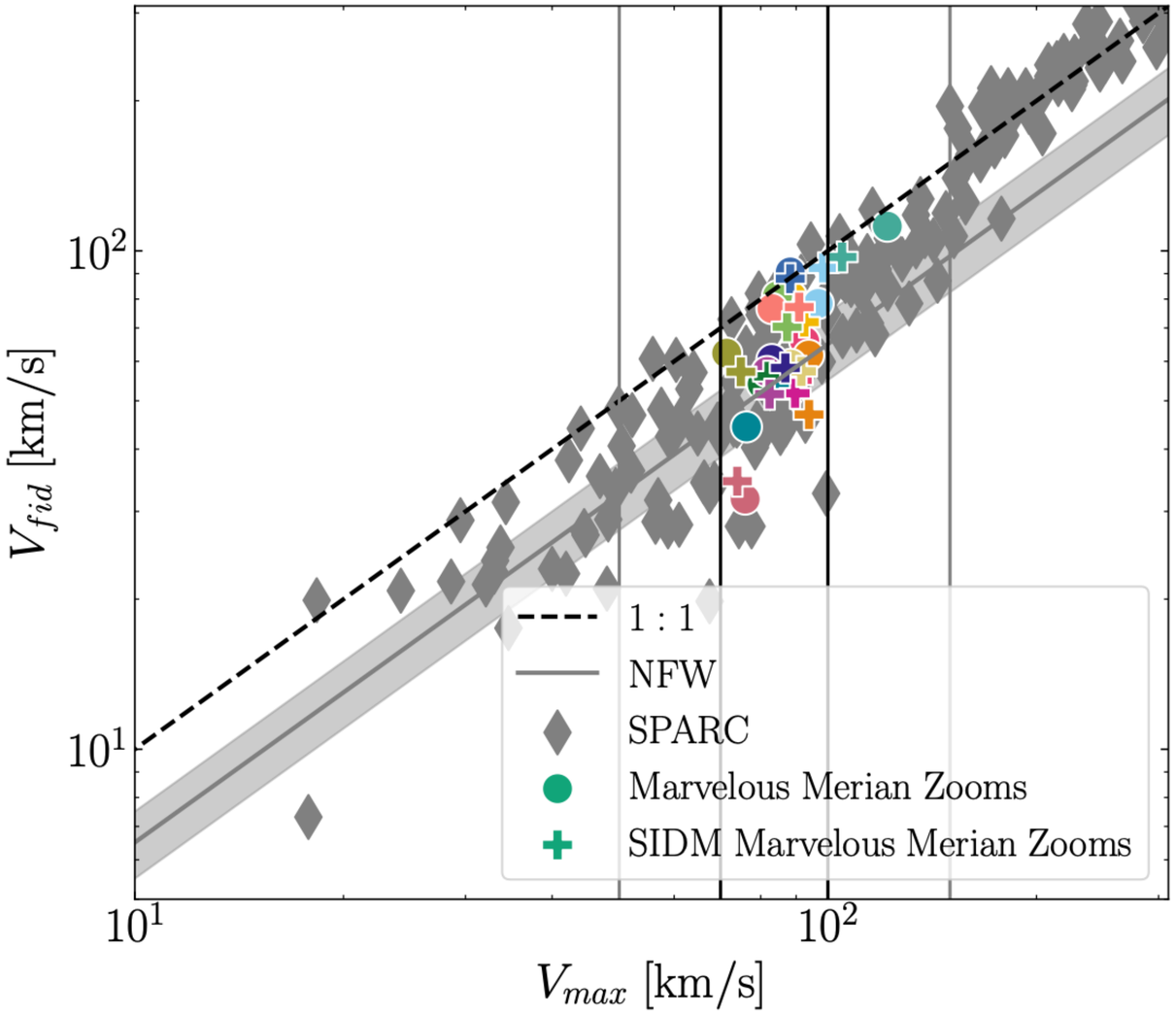
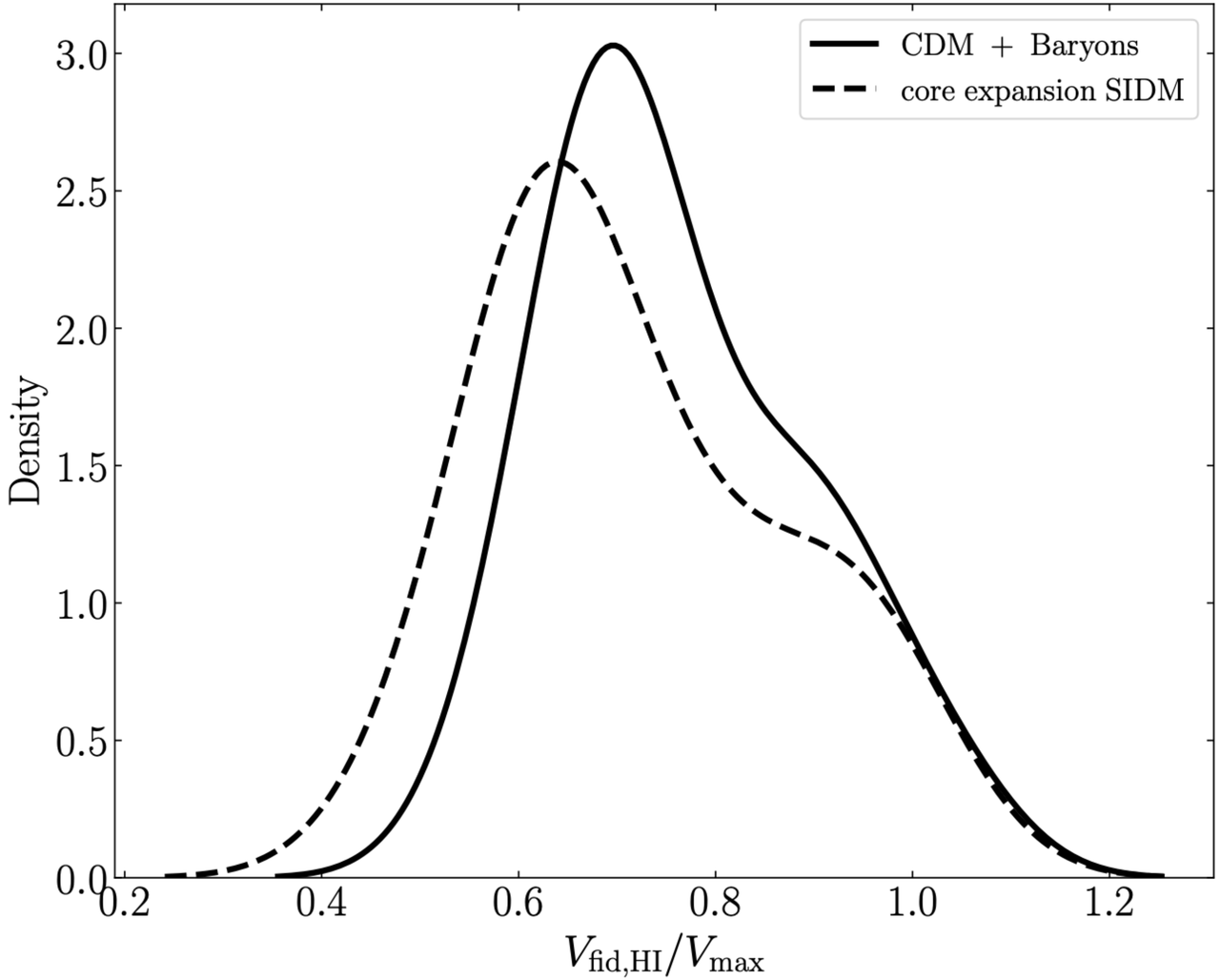
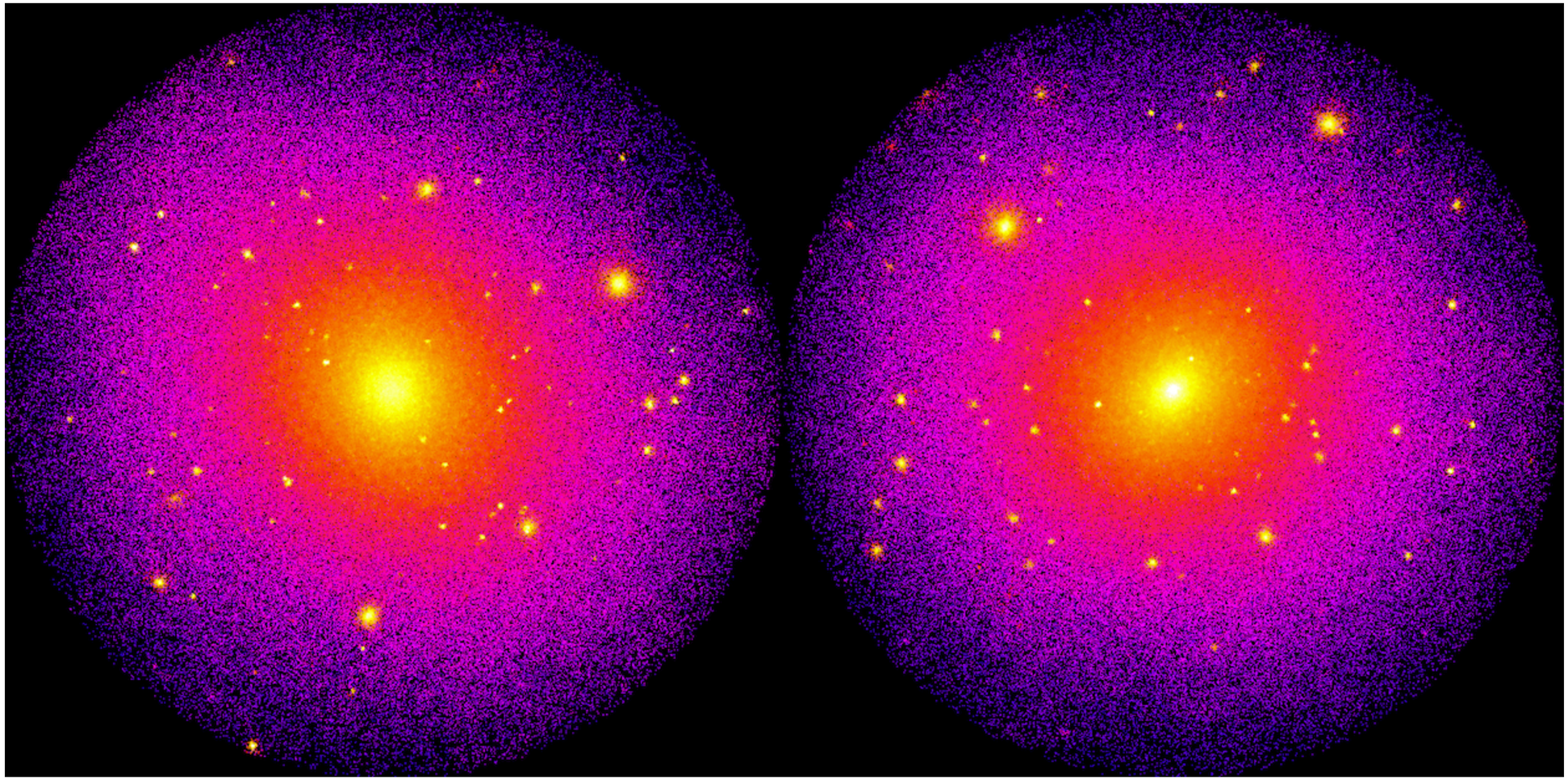




Galaxy Shapes as a Tracer?



from review in arXiv:1407.7544

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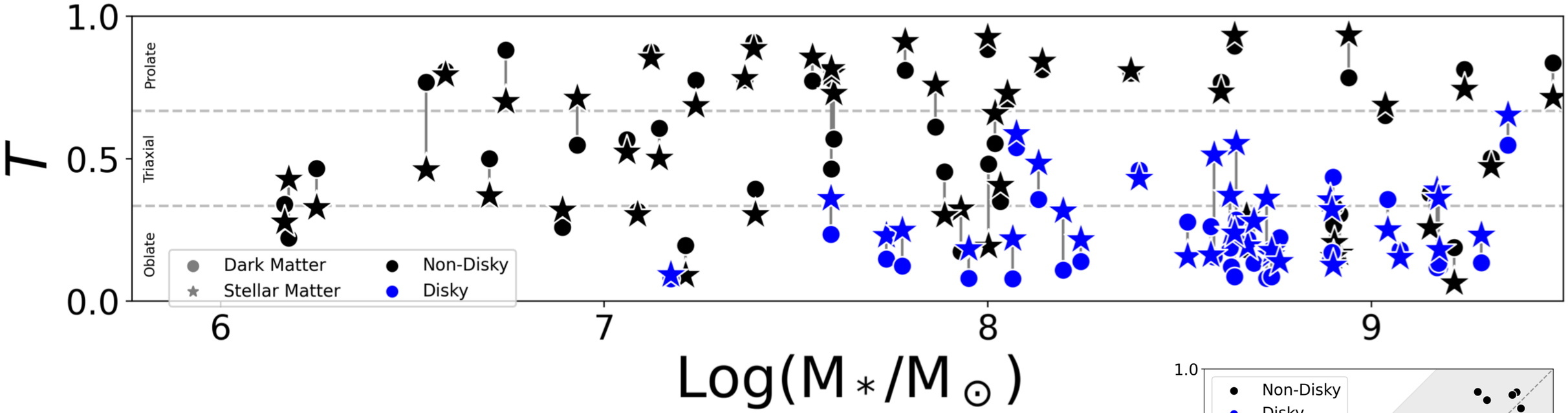
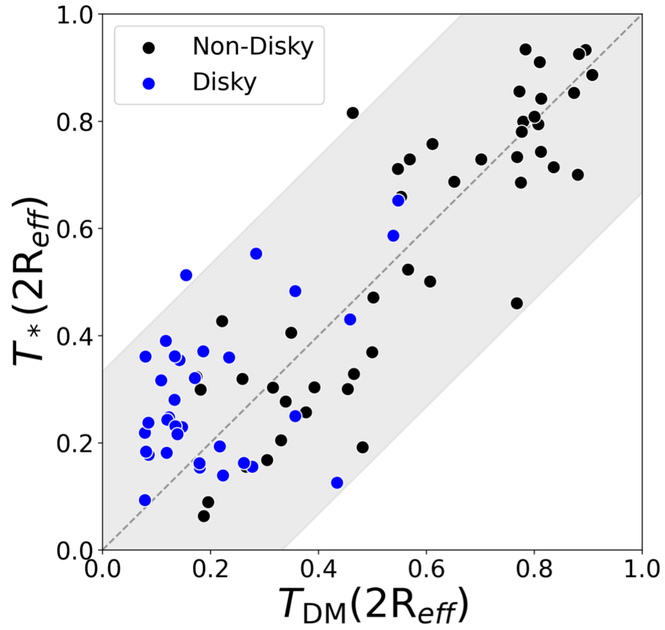


$$T = \frac{1-(b/a)^2}{1-(c/a)^2}$$



Keith et al. (2025)

See also Xu & Randall (2019) for FIRE

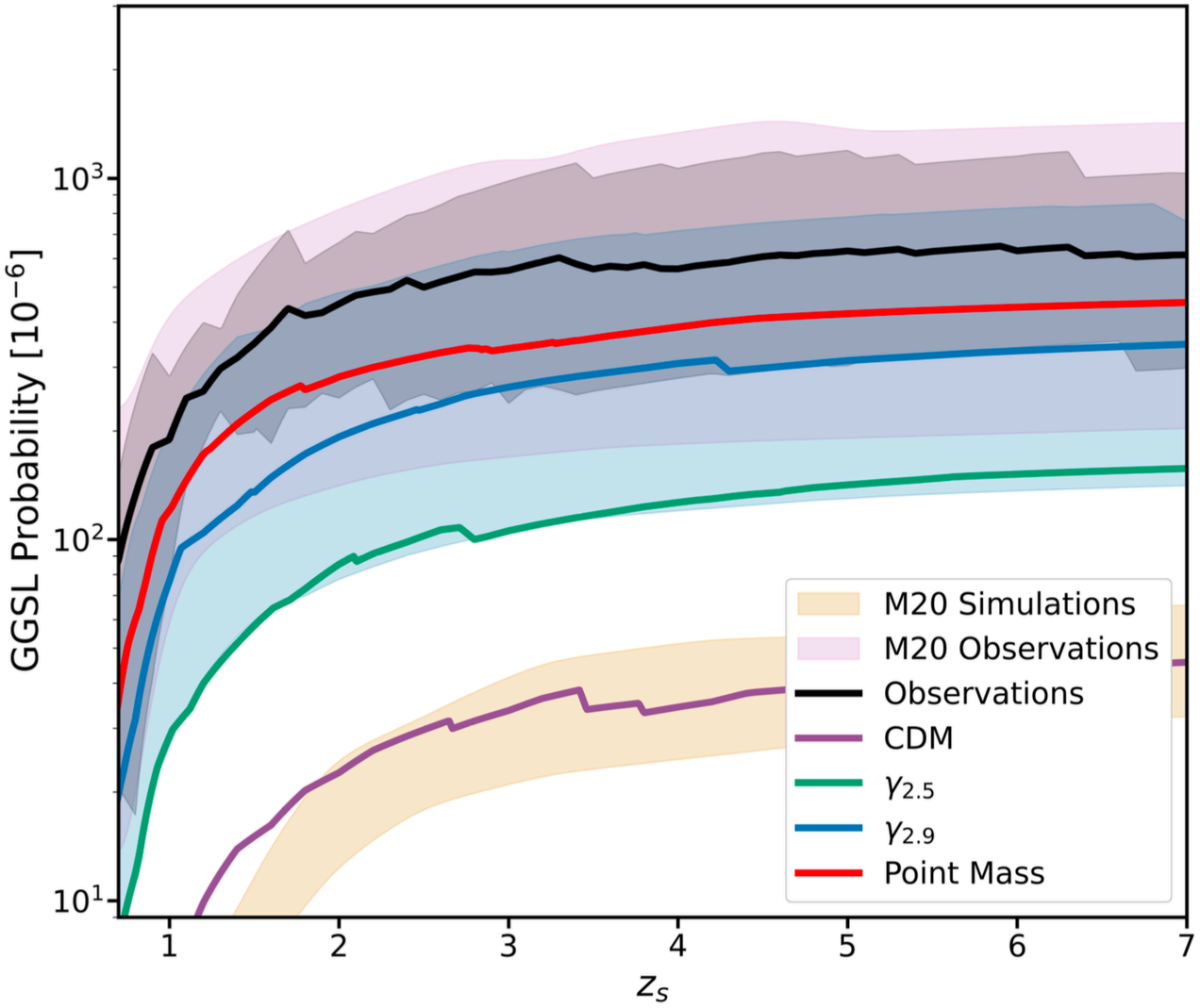
Challenges for Galaxy Simulators

(1) The Small

(e.g., ultra-faint dwarfs)

(2) The Dense

(e.g., galaxy-galaxy strong lensing)



Dutra, Natarajan, Gilman (2024)

Conclusions

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

(1) We need baryons in alternative DM models. Is there a smoking gun that points to a given DM model?

(2) Can we understand the formation and evolution of dwarf galaxies in a Vanilla CDM Model?

Or, we need to study dark matter in a regime where baryonic impacts are negligible