The Self-Interacting Dark Matter (SIDM) model

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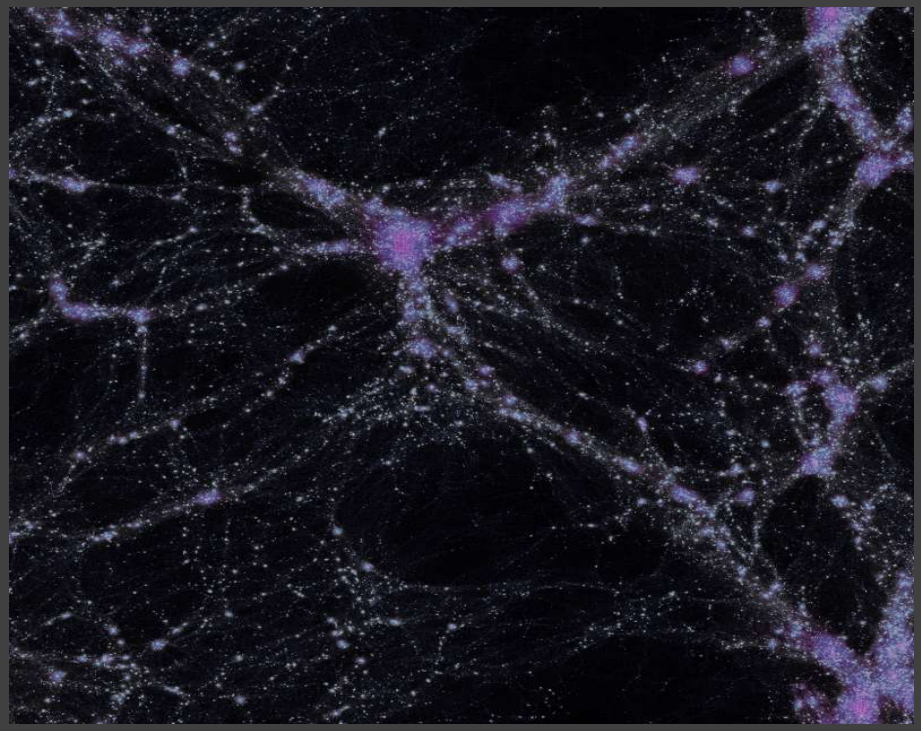
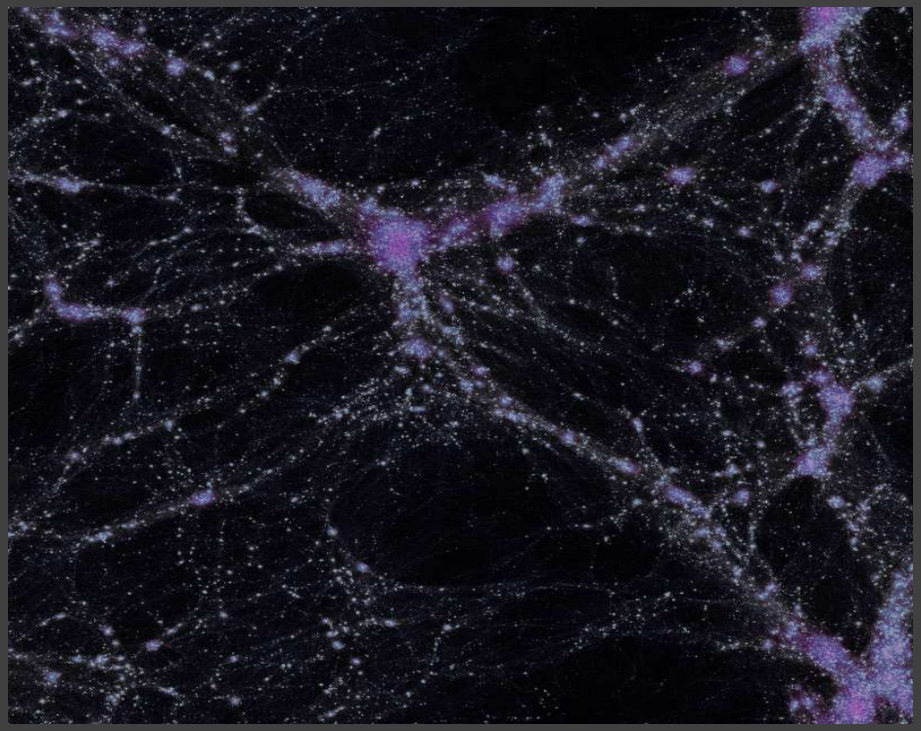
SIDM and CDM predictions deviate in the inner part of galaxies. Spergel and Steinhardt (2000)

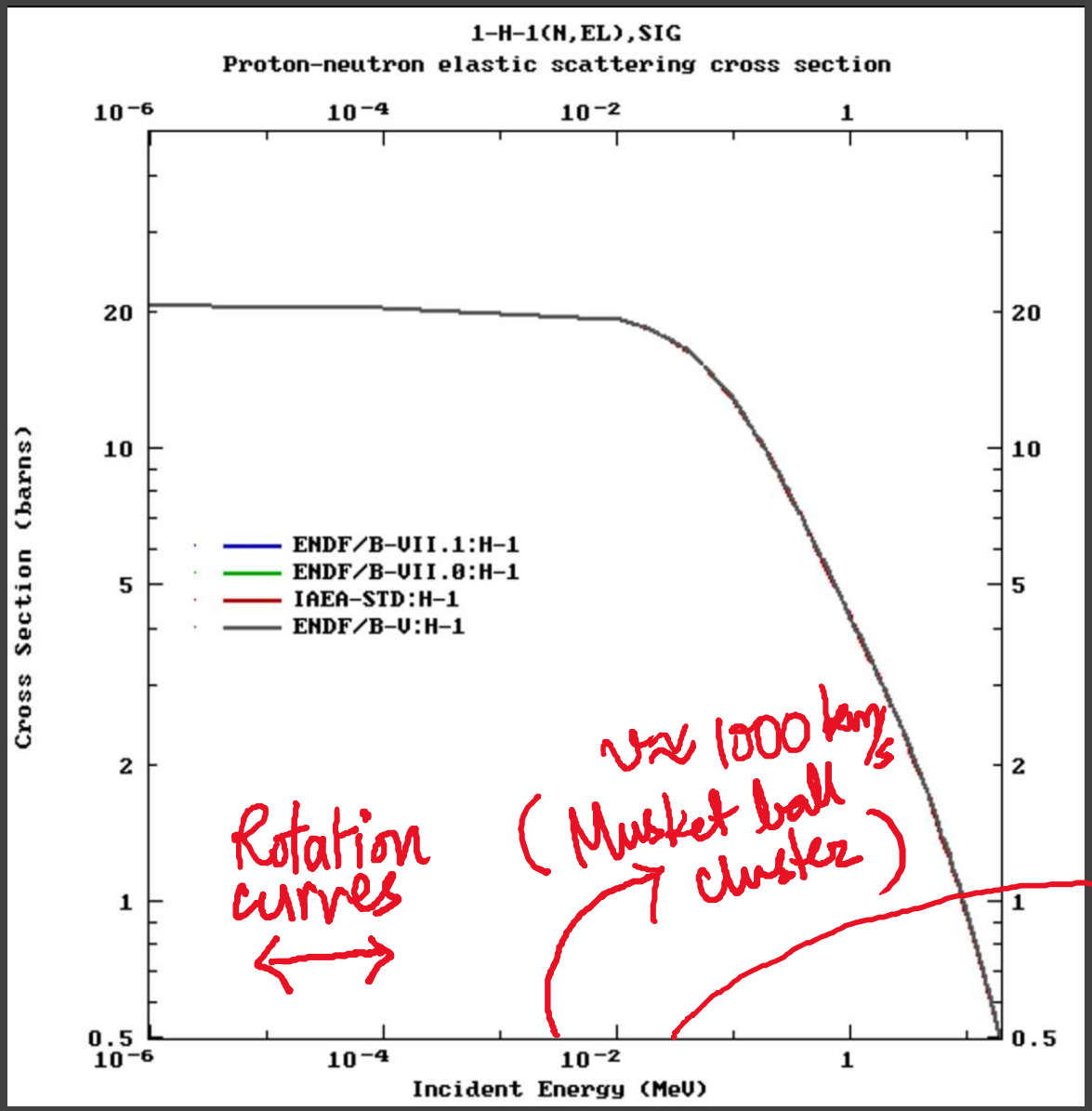
Large-scale structure same.





With James Bullock, Miguel Rocha, Annika Peter (2013)

A motivating Standard Model example



Minimal LSIDM model has one more parameter than LCDM

Hidden sector dark matter model with

$$\frac{\sigma}{m} \simeq \text{few } \frac{cm^2}{g}$$

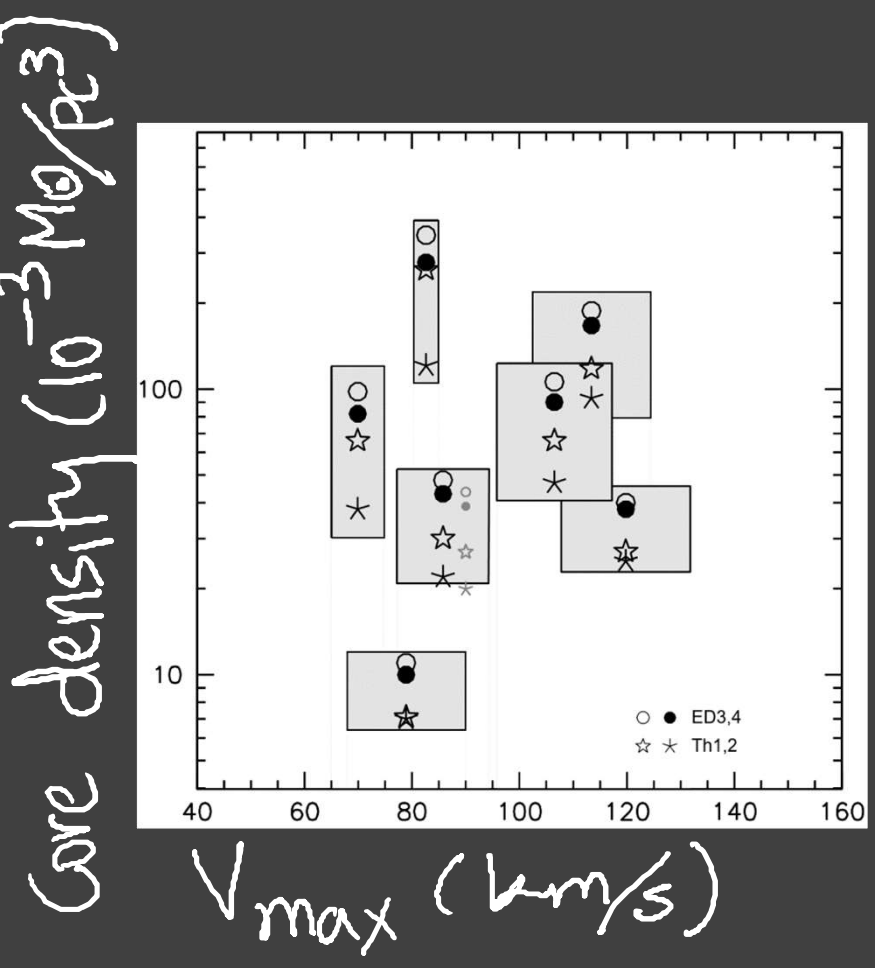
(in galaxies)

Qualitative predictions similar for a range of cross sections.

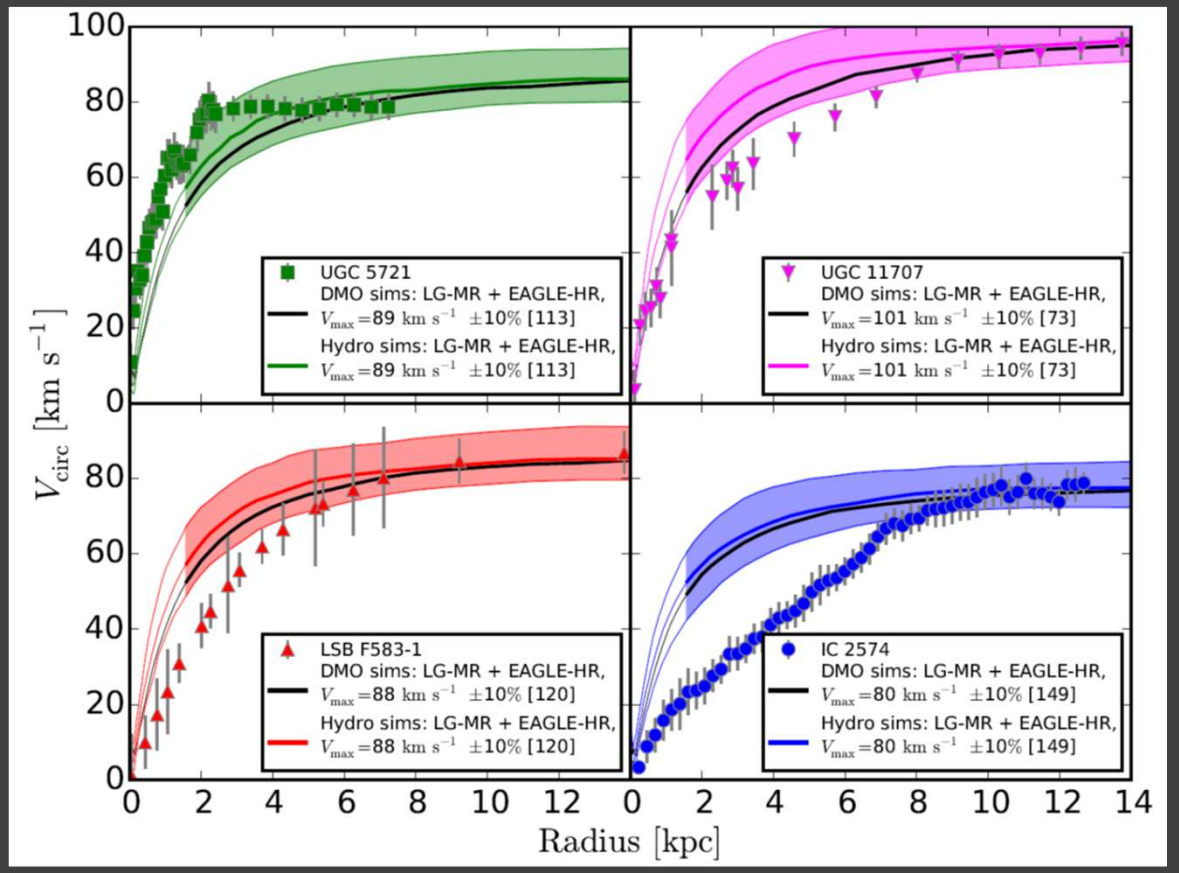
DM halo insensitive to star formation history because self-interactions push system towards equilibrium.

No need for velocity dependence for v < 200 km/s.

The puzzling diversity in rotation curves

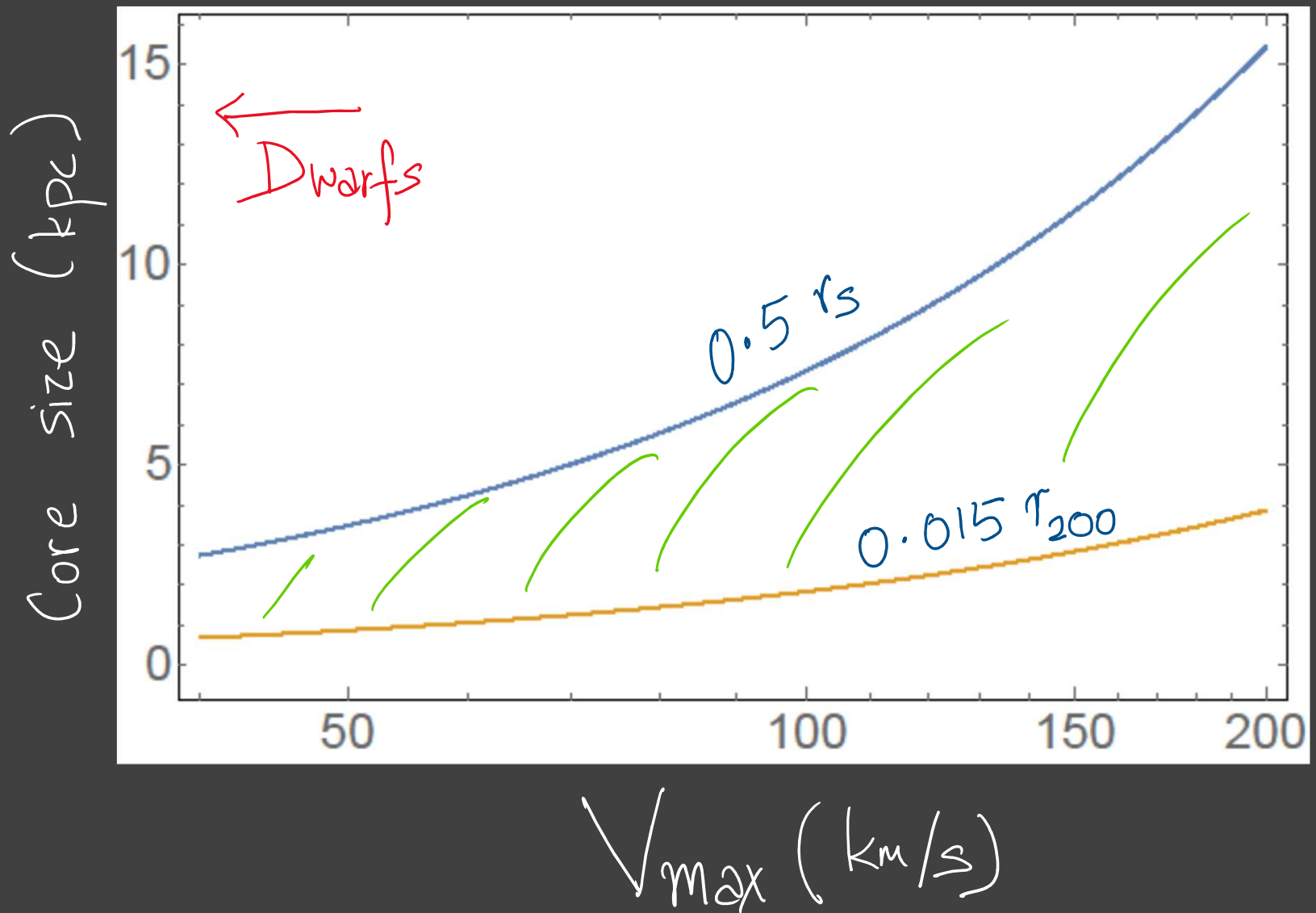


with Rachel Kuzio de Naray, Greg Martinez and James Bullock (2010)

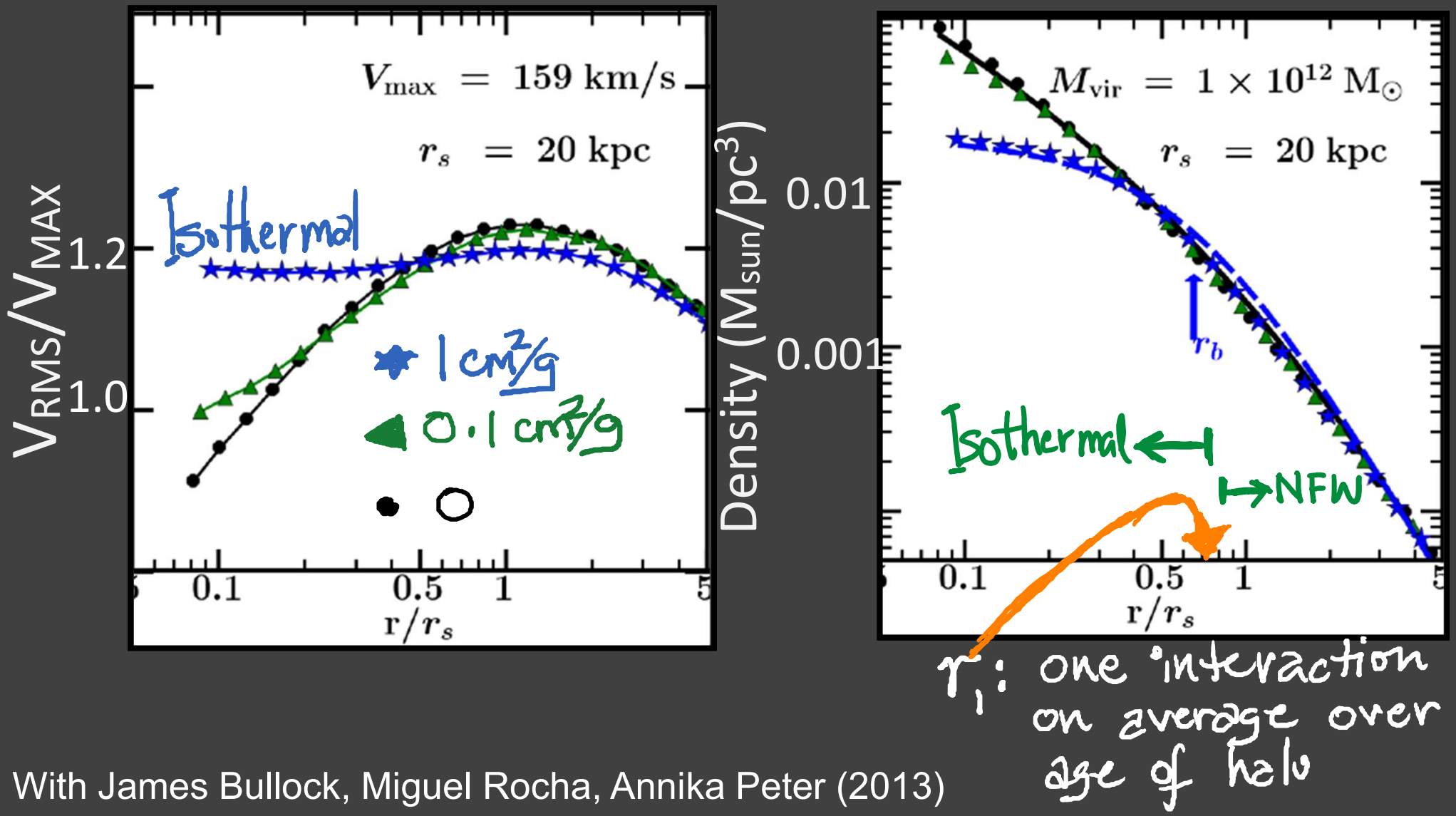


Oman et al, 2015

Diversity built into SIDM, but is it the right kind?



SIDM: thermalization of the inner halo



With James Bullock, Miguel Rocha, Annika Peter (2013)
Builds on Dave, Spergel, Steinhardt, Wandelt (2000)

Field galaxies: SIDM halo profile is almost uniquely determined

$$\rho_{\rm SIDM}(r) \propto e^{-\Phi_{\rm total}(r)/kT} \quad \text{for } r < r_1$$

- $r > r_1$: $\rho_{\rm SIDM} \approx \rho_{\rm CDM}$
- Interaction rate $\approx \frac{1}{\rm age}$ at r_1
- $kT \approx \frac{V_{\rm rms}}{\sqrt{3}} \approx \frac{1.1\, V_{\rm max}}{\sqrt{3}}$

With Ryan Keeley, Tim Linden and Hai-Bo Yu (2014)
With Oliver Elbert and James Bullock (2017)

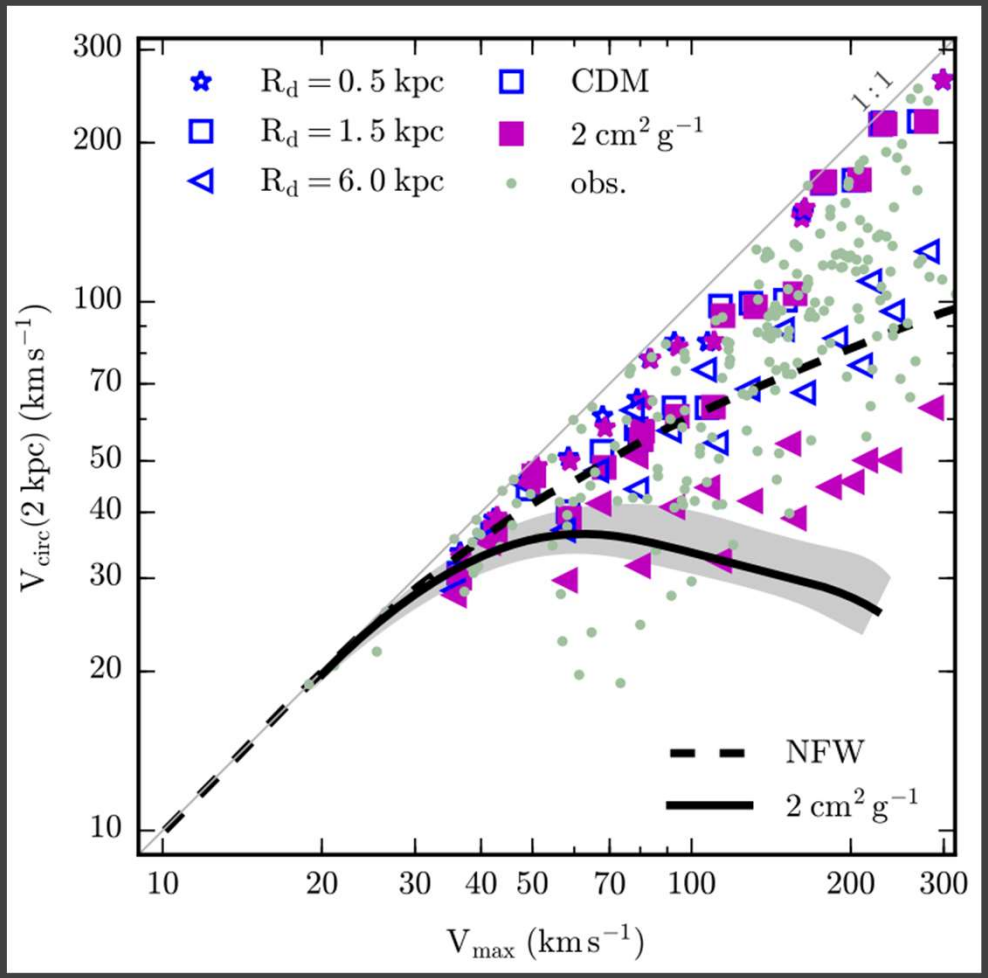
Field galaxies: both Cored and Cuspy

- SIDM does not predict large cores in all galaxies

↑ cores small / cuspy

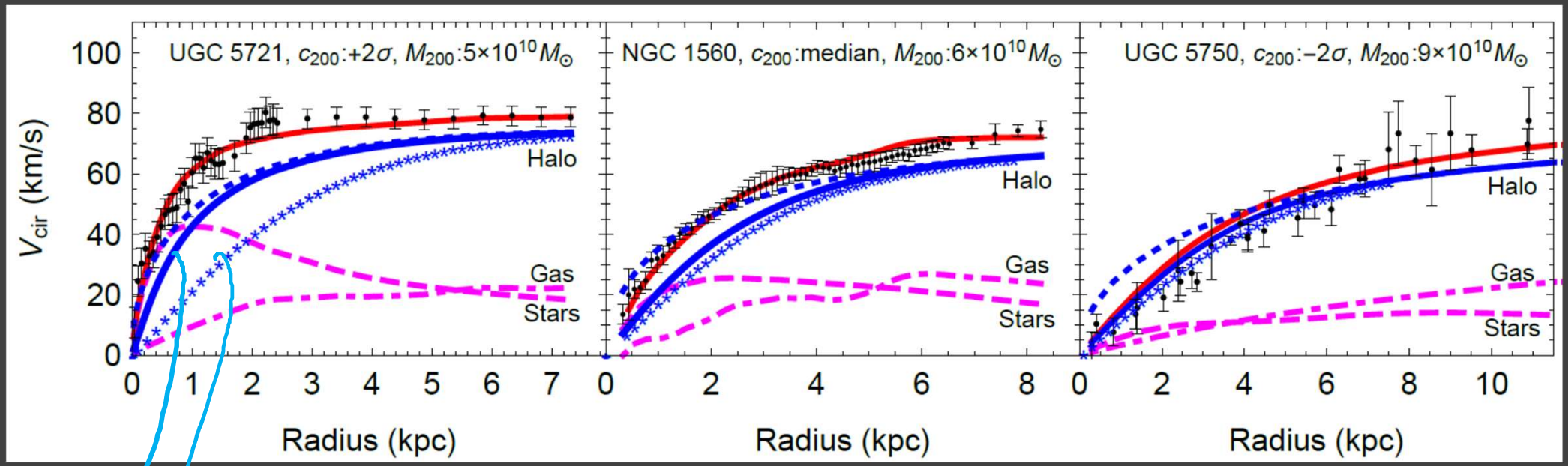
$\rho_* + \rho_{gas}$

↓ core size $\sim r_s$ (large!)



Creasey et al (2017)

How SIDM explains the diverse rotation curves: importance of LCDM concentration-mass relation

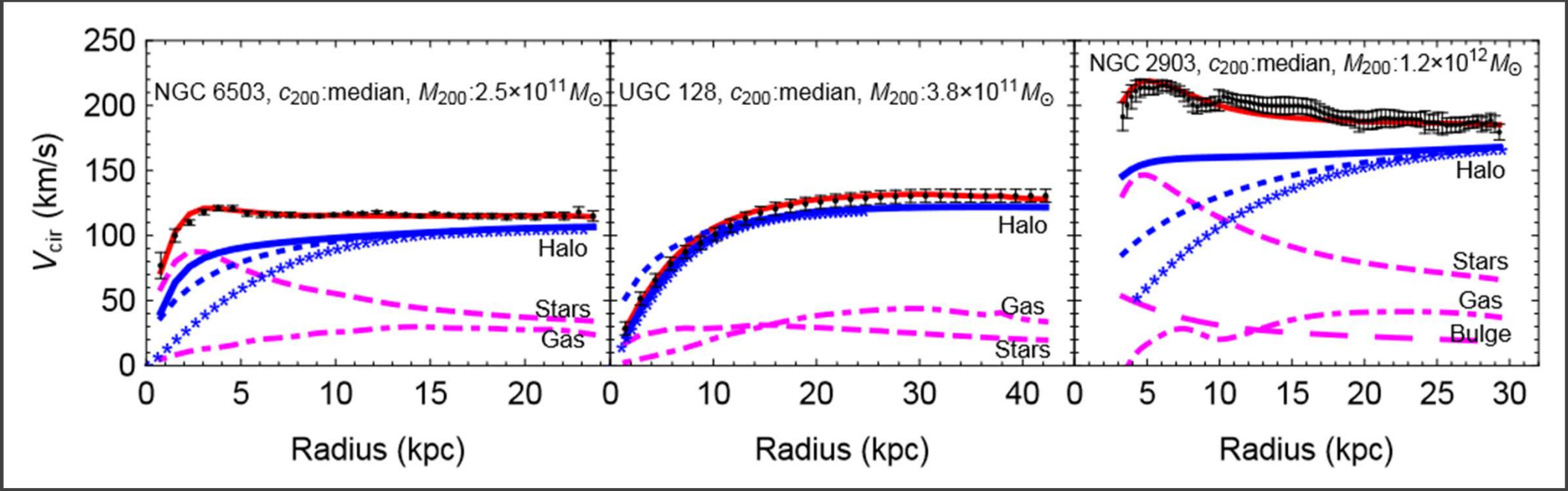


With Ayuki Kamada, Andrew Pace and Hai-Bo Yu (2017)

without including the potential of stars
correct SIDM density profile

Lower the stellar SB, lower density of dark matter required.

How SIDM explains the diverse rotation curves: impact of the baryonic potential

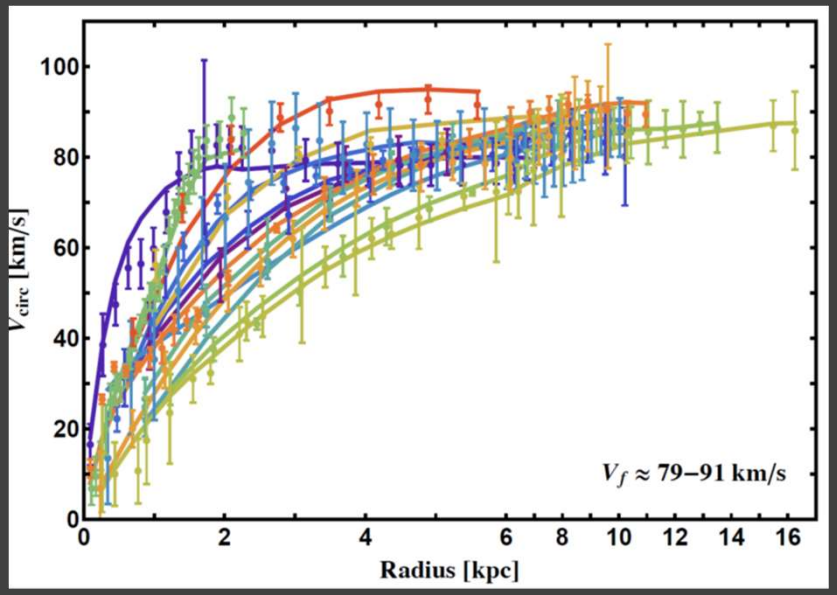


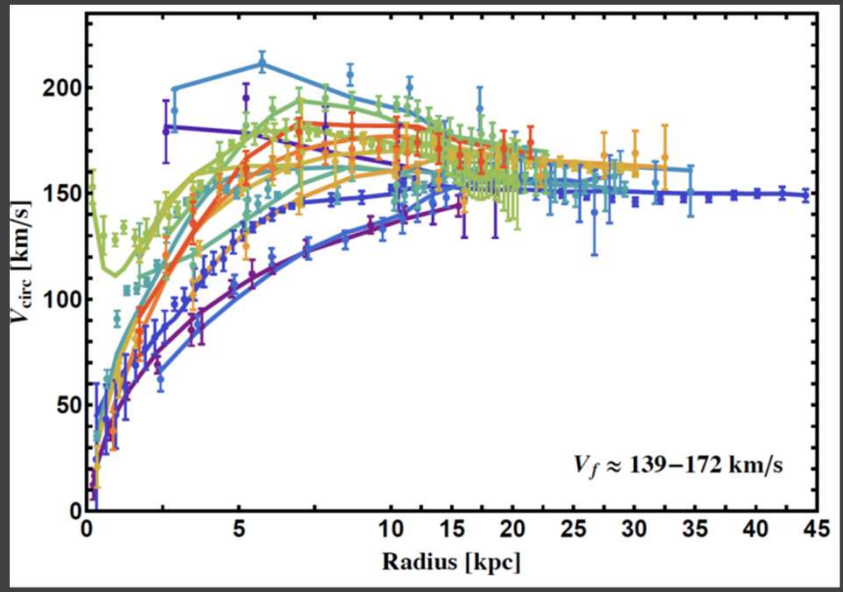
-- No need for cores in massive galaxies.

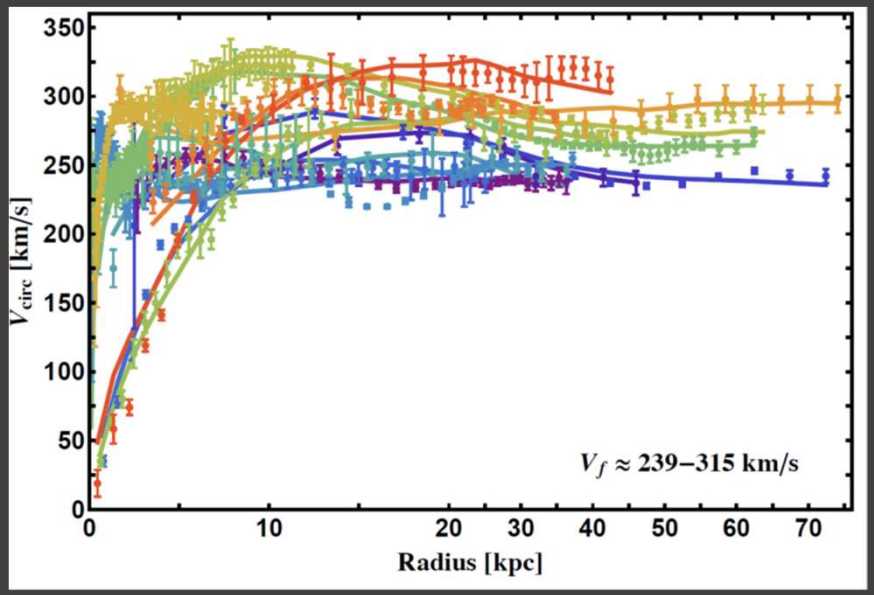
-- Roughly $1/r^2$ density profile for total mass profile.

With Ayuki Kamada, Andrew Pace and Hai-Bo Yu (2017)

SIDM fits to the rotation curves in the SPARC sample

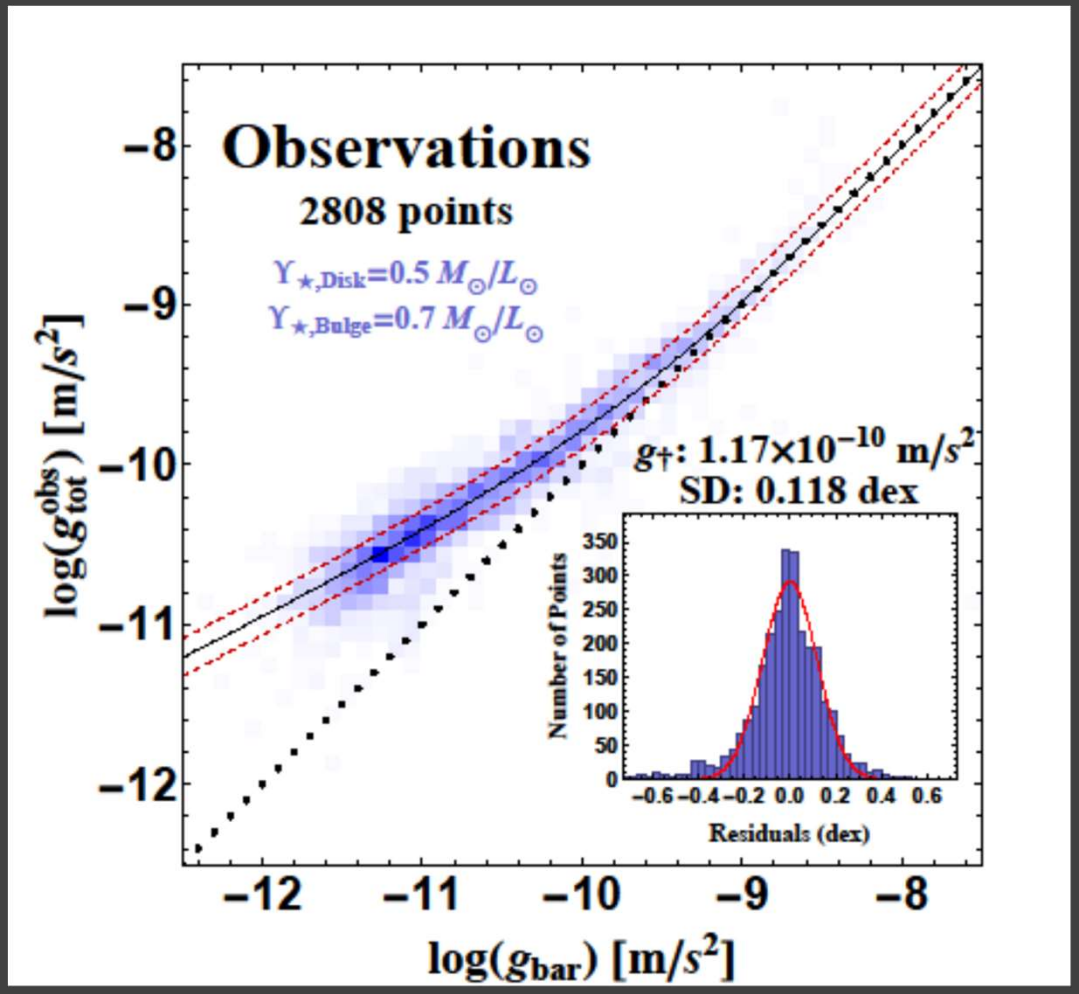






With Anna Kwa, Tao Ren and Hai-Bo Yu (to be posted soon)

The radial acceleration relation in the SPARC sample



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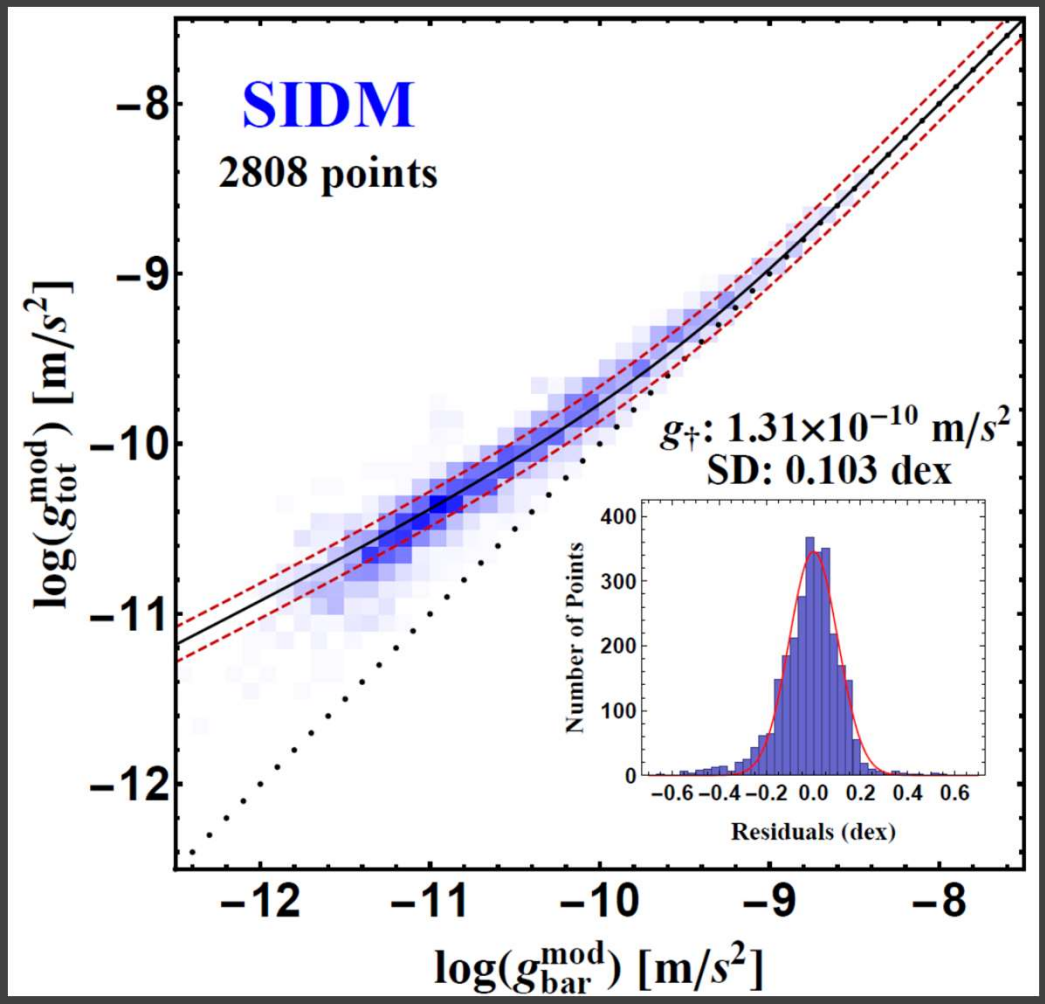
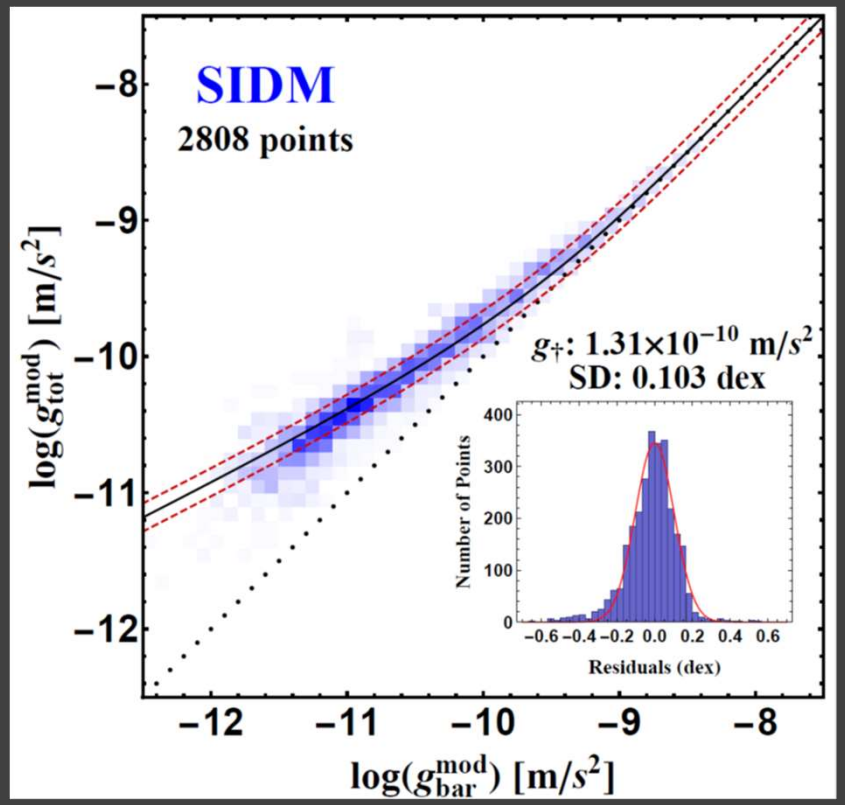


With Anna Kwa, Tao Ren and Hai-Bo Yu (to be posted soon)

Where does the acceleration scale come from?



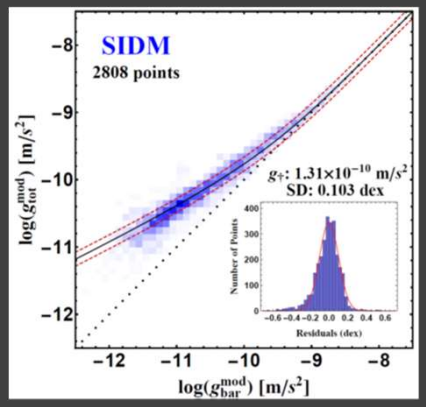
With Anna Kwa, Tao Ren and Hai-Bo Yu (to be posted soon)

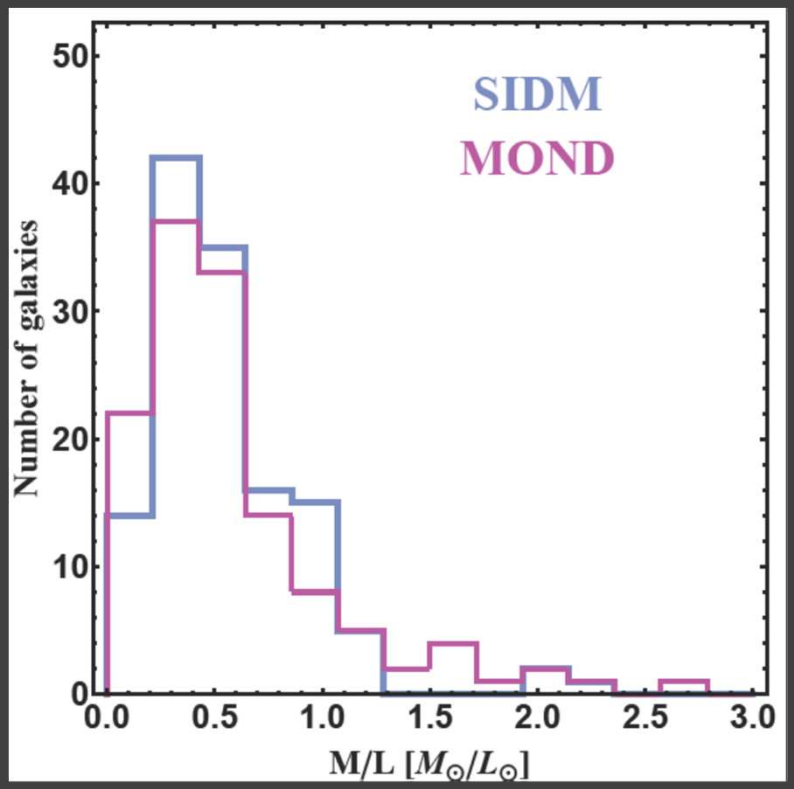
The acceleration scale in ΛCDM.

$$a_c = 2\pi G \Sigma_s r_s \simeq 0.15\, c H_0 \left(\frac{M_{200}}{10^{11} M_\odot/h}\right)^{0.2}$$

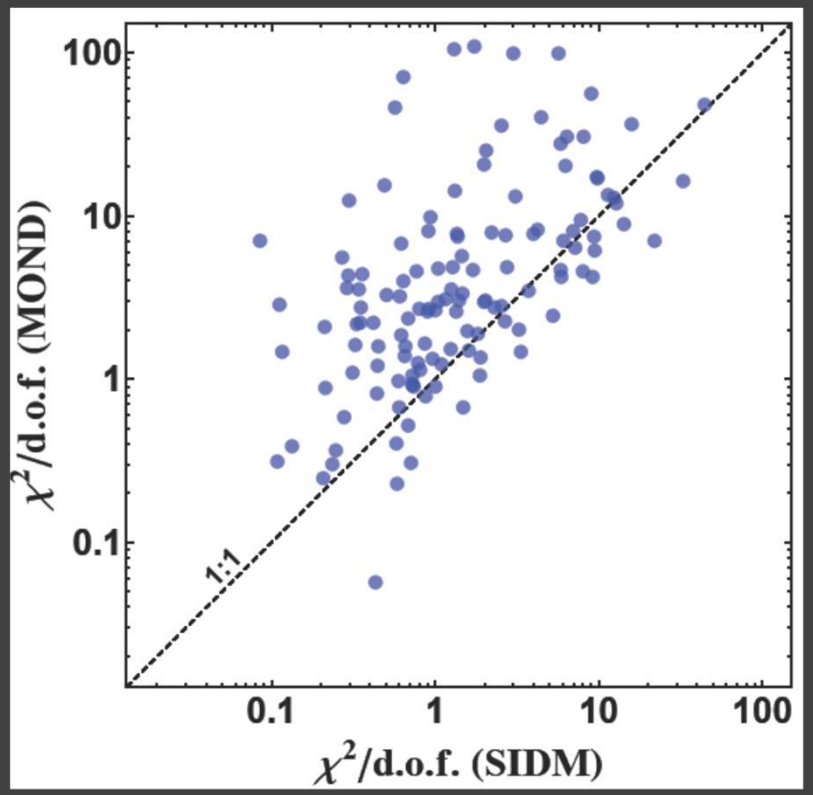
Arguments from Kaplinghat and Turner (2002)

Comparing to MOND fits

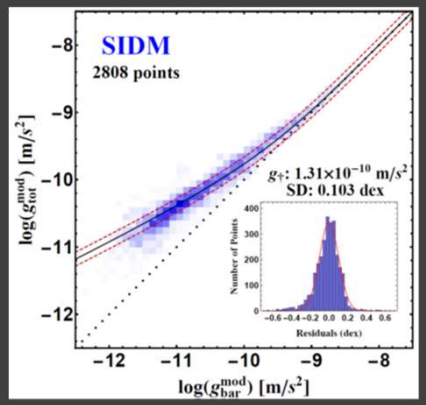


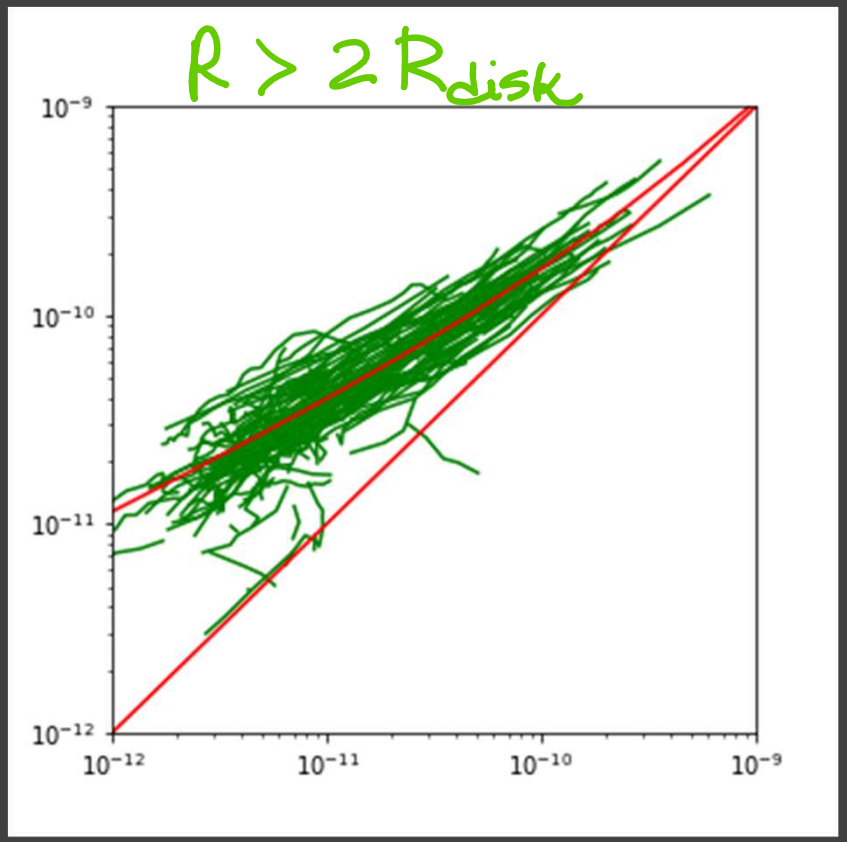


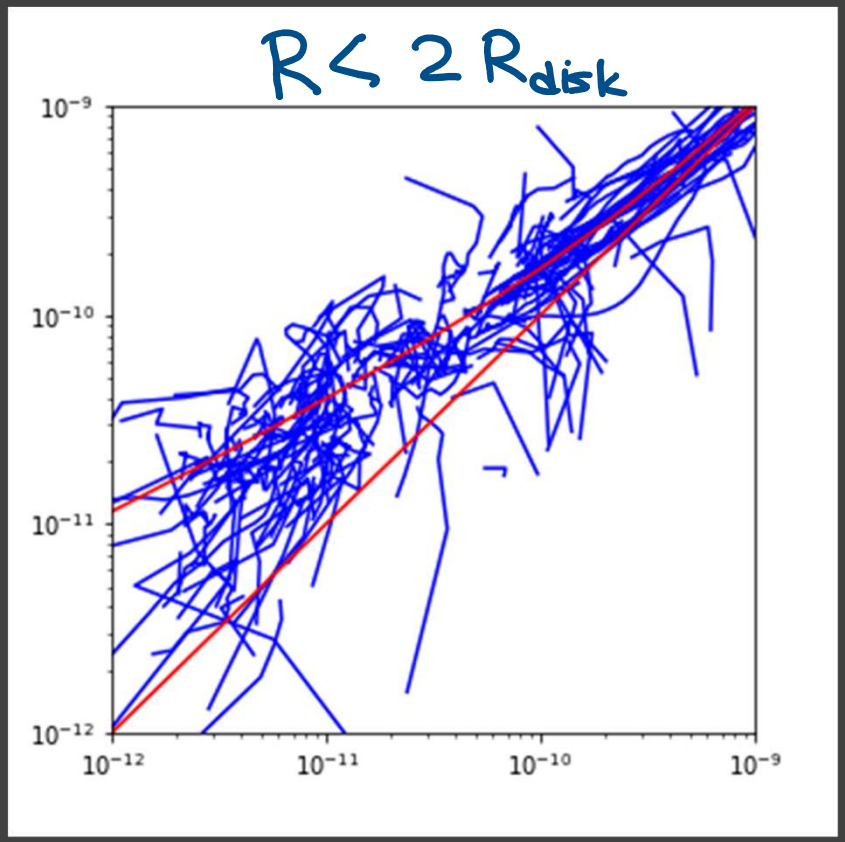
Stellar mass-to-light



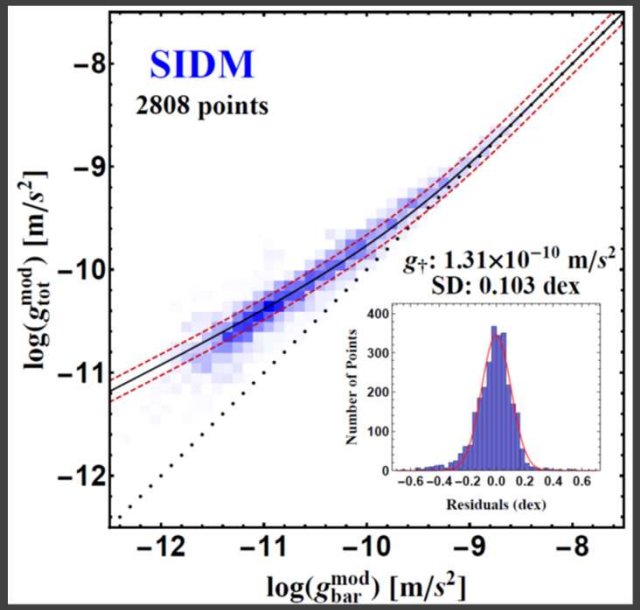
Is SIDM really MOND in spirit? No.

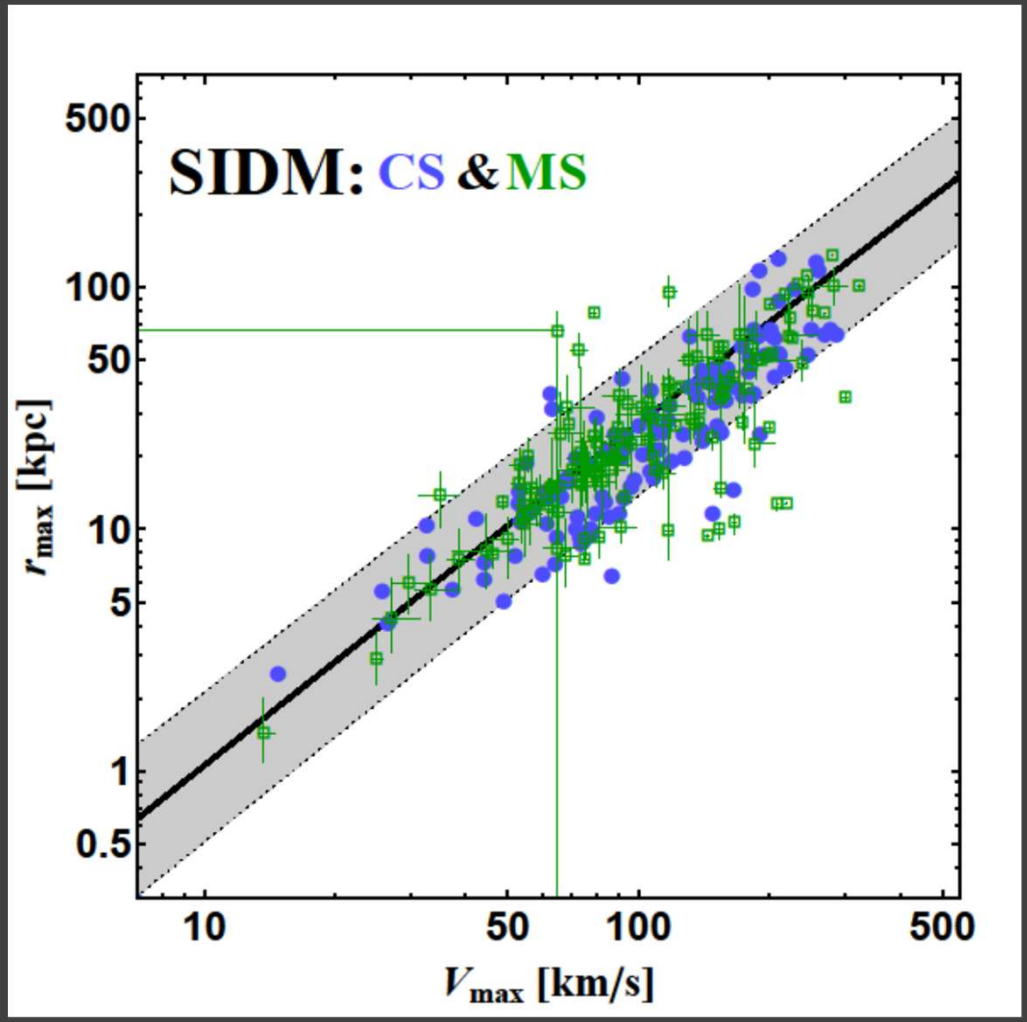






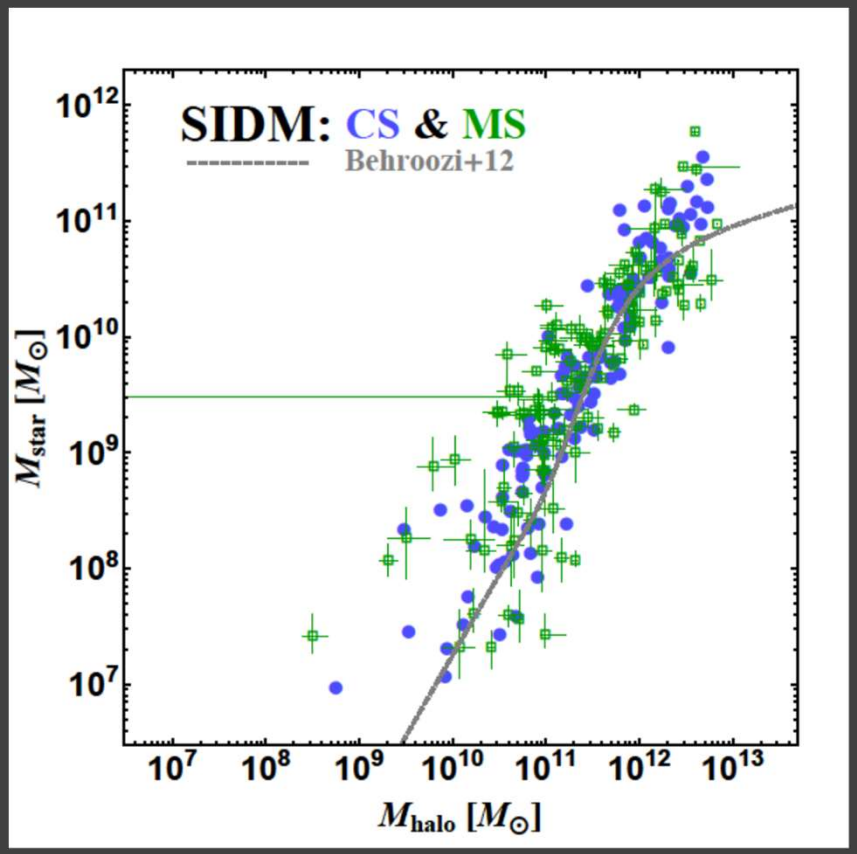
Importance of the concentration-mass relation



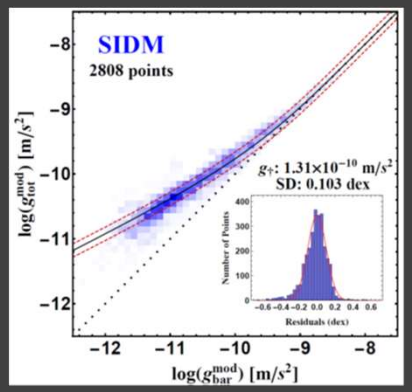


Concentration - mass relation

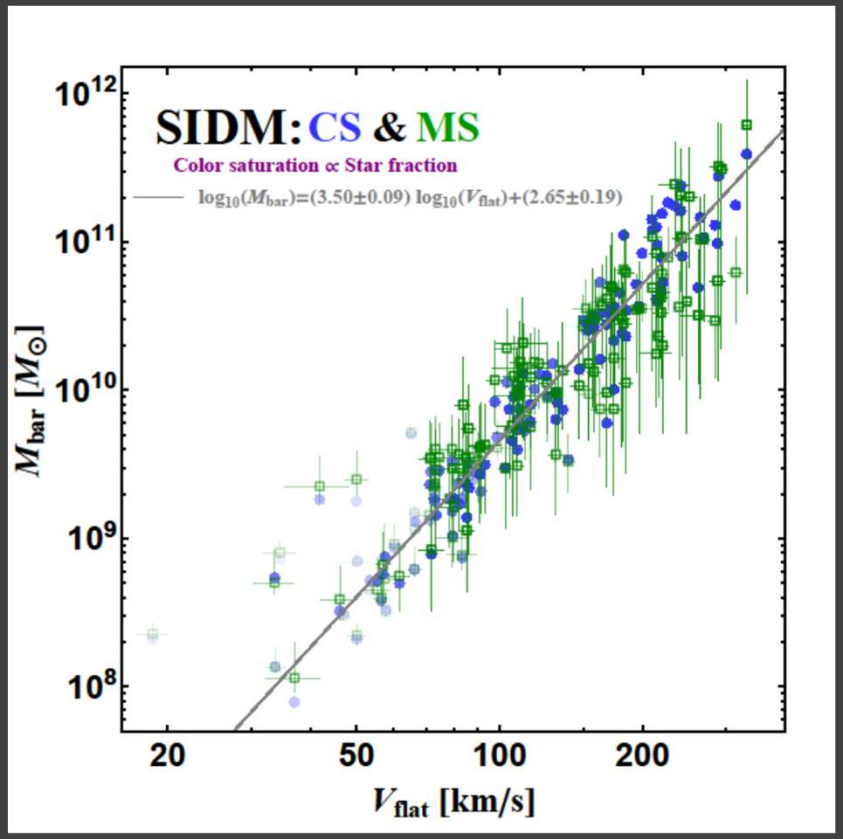
The radial acceleration relation in the SPARC sample



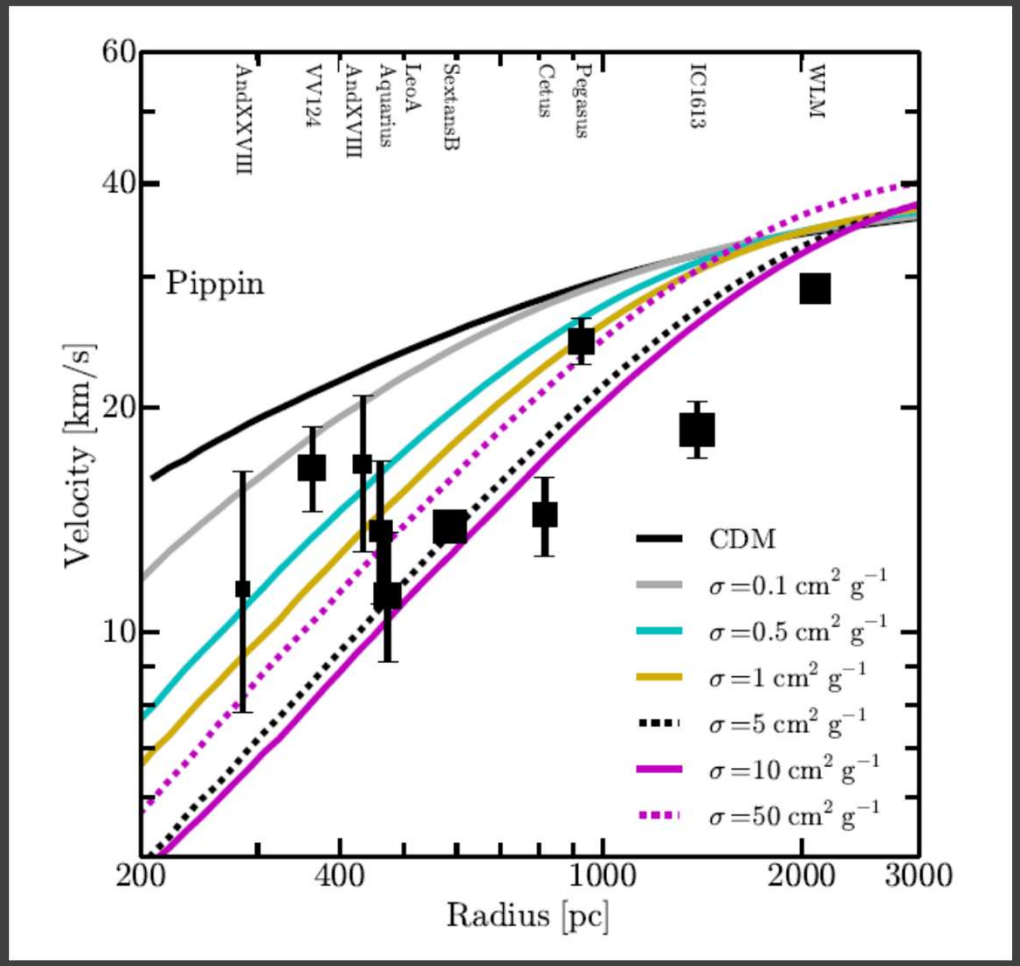
Stellar mass - halo mass relation (output)

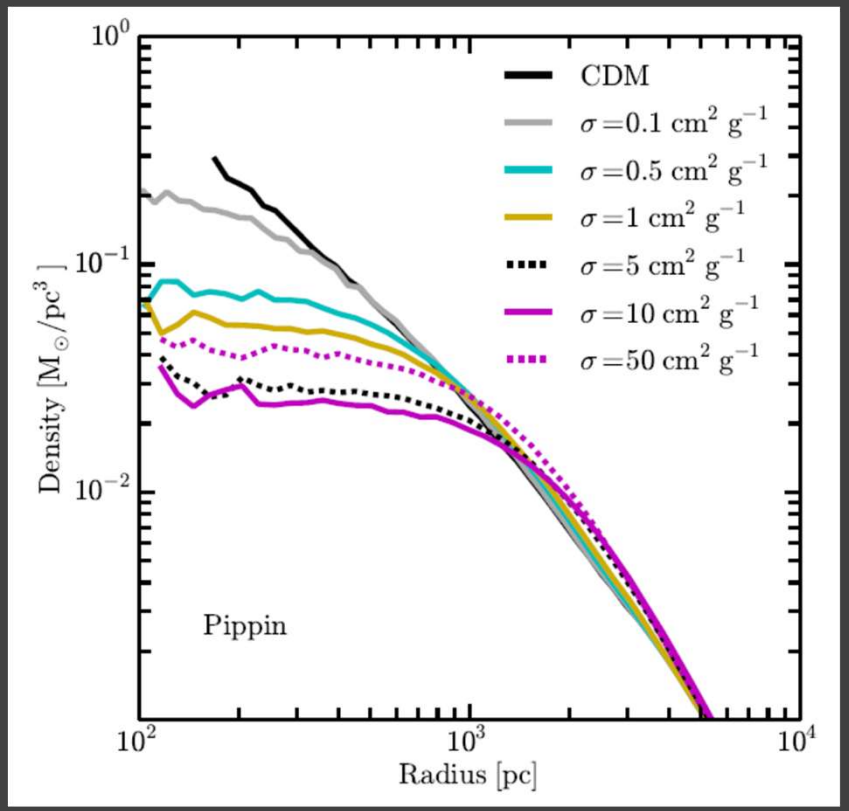


(output) Baryonic TF



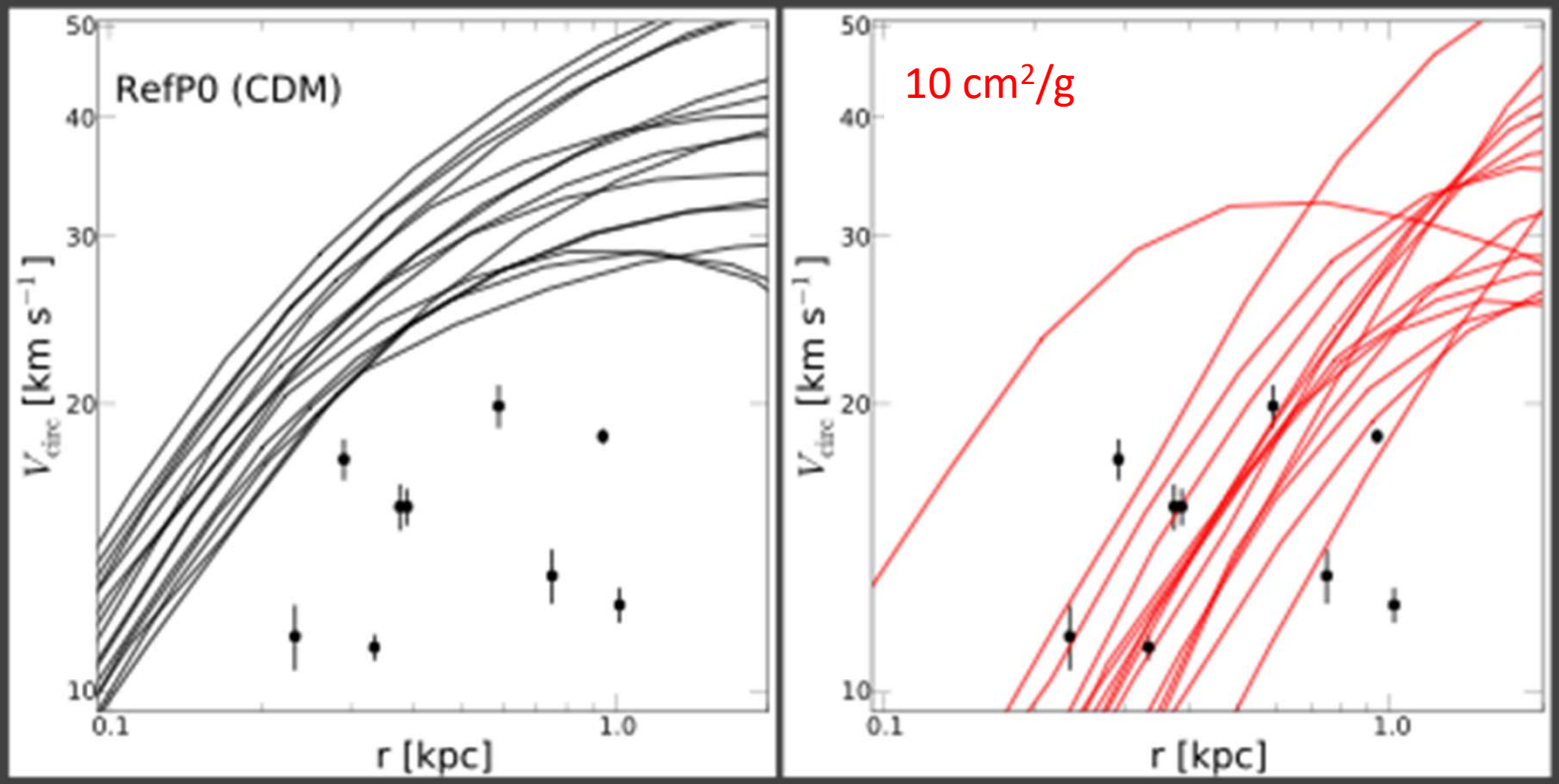
Local group dwarf field galaxies (too-big-to-fail problem)





Elbert et al 2014 (“No fine tuning”)

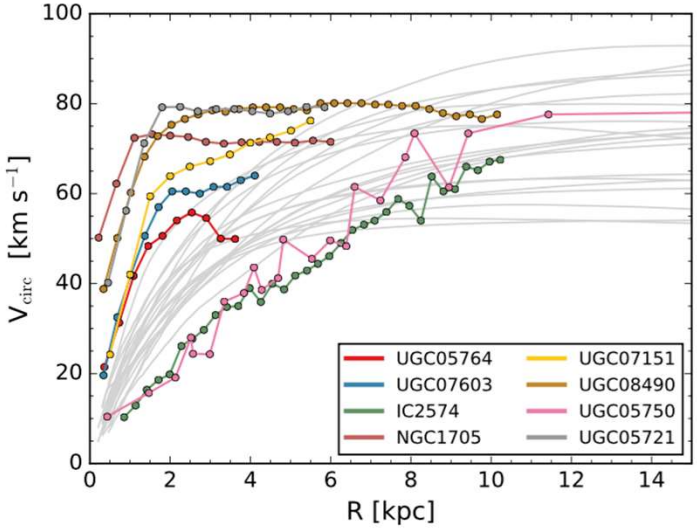
Dwarf satellite galaxies of the MW (too-big-to-fail problem)



Vogelsberger, Zavala and Loeb (2012)
Vogelsberger, Zavala and Walker (2012)

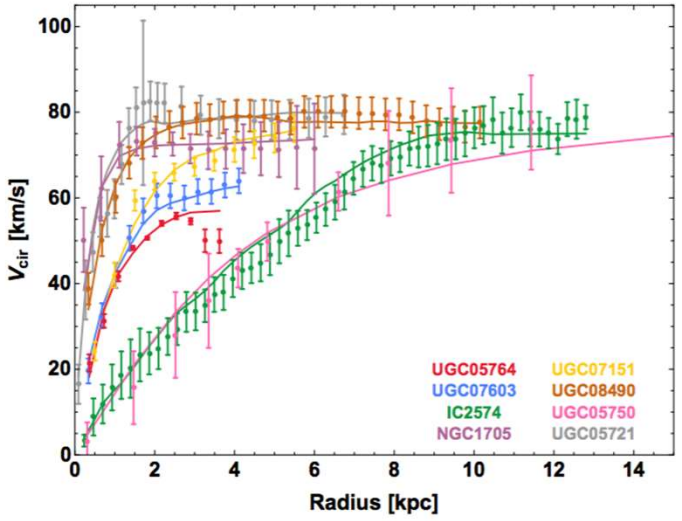
Could rotation curves distinguish LCDM and LSIDM?

Strong Feedback vs. SIDM



NIHAO simulations
strong feedback

Santos-Santos et al. (2017)

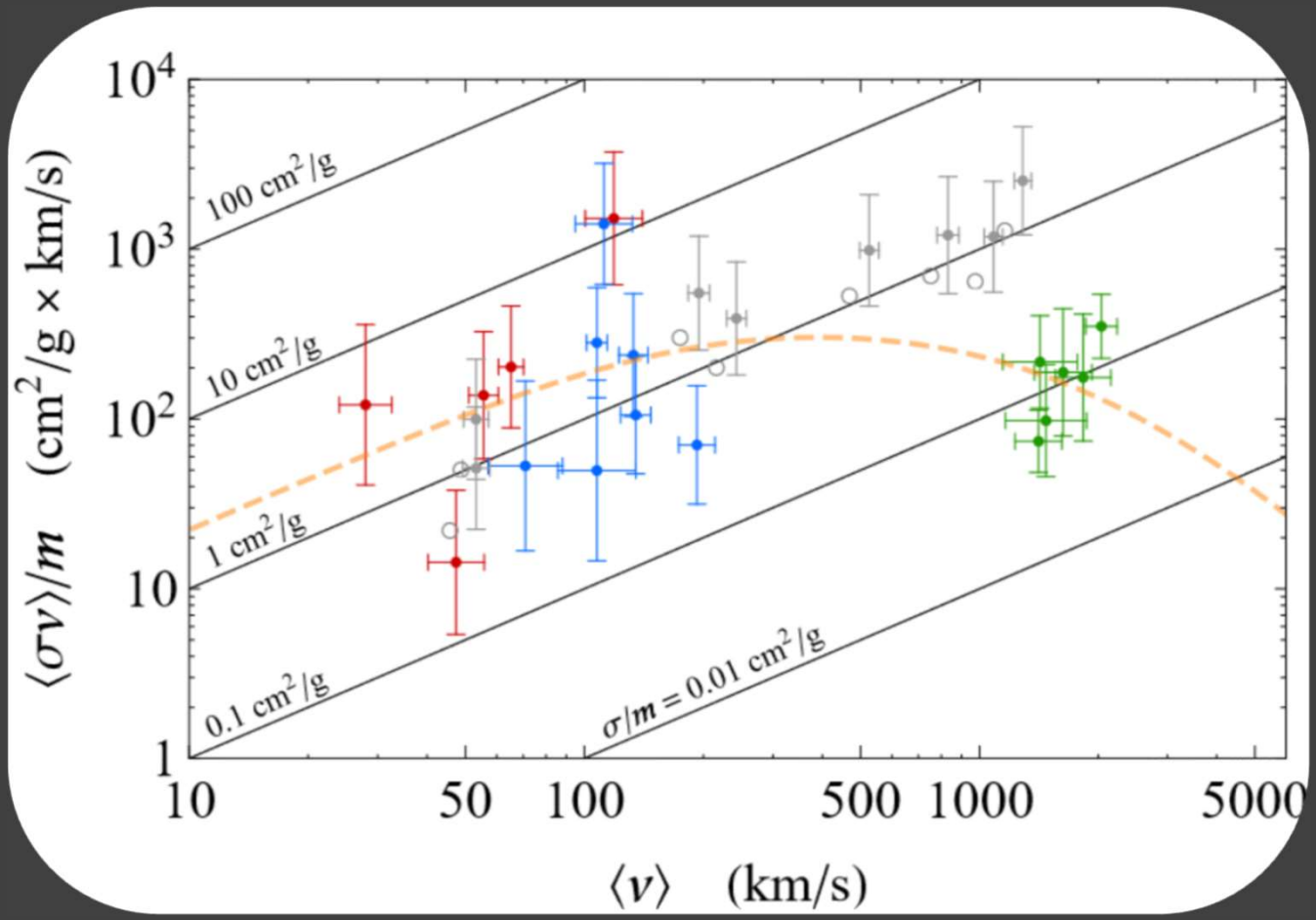


SIDM

with Kaplinghat, Kwa, Ren (in prep)

Slide from Hai-Bo Yu

The self-interaction cross section must decrease at high collision speeds



With Sean Tulin and Hai-Bo Yu (2015)

There is a simple way to preserve all the successes of the ΛCDM and explain the distribution of dark matter in the inner parts of galaxies: *allow for thermalization of dark matter.*