

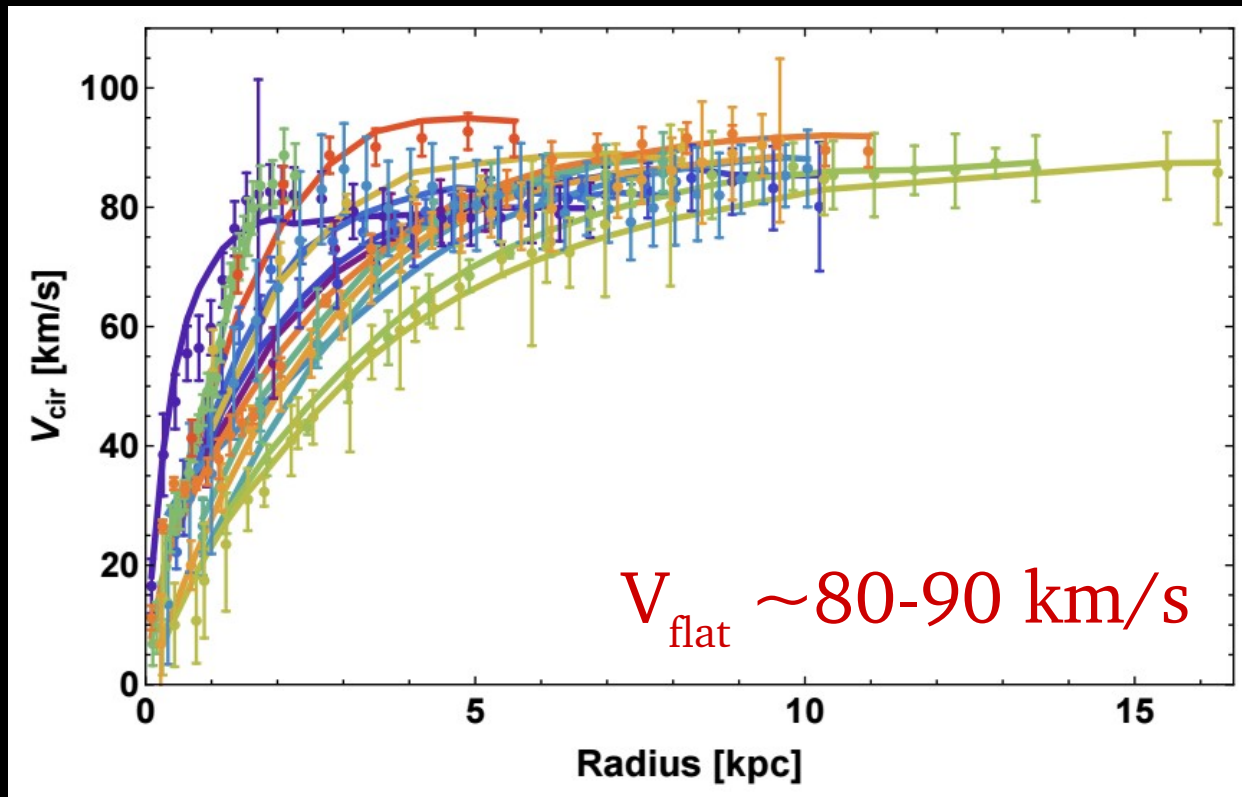
Self-interacting Dark Matter:

An Explanation for Diversity & Uniformity in Galactic Rotation Curves?

Anna Kwa (UC Irvine) Aug. 7th 2017
@ TeVPA 2017, Columbus OH

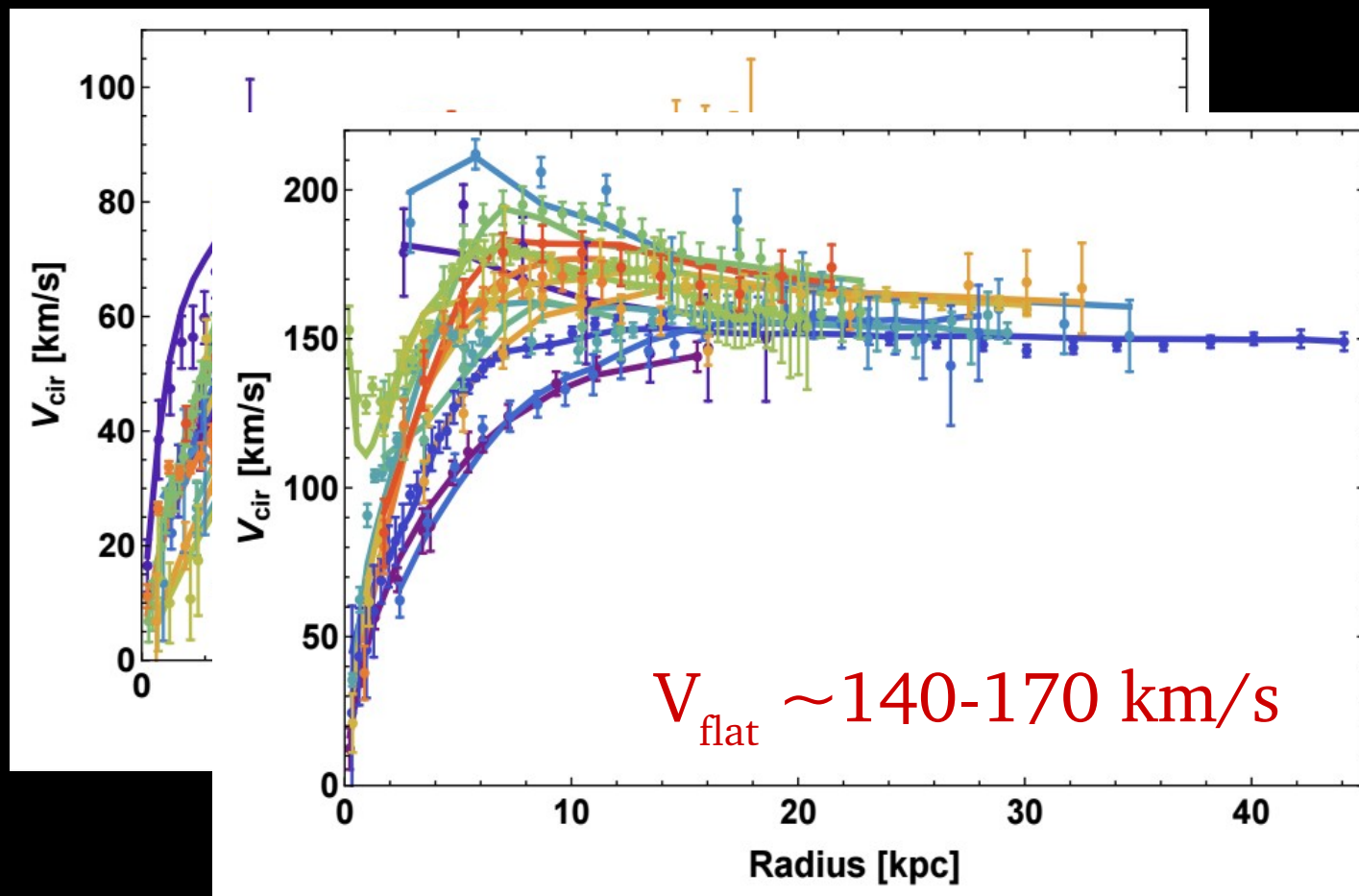
with Manoj Kaplinghat (UC Irvine), Tao Ren (UC
Riverside), & Haibo Yu (UC Riverside)

Galactic rotation curves are “surprisingly diverse”...



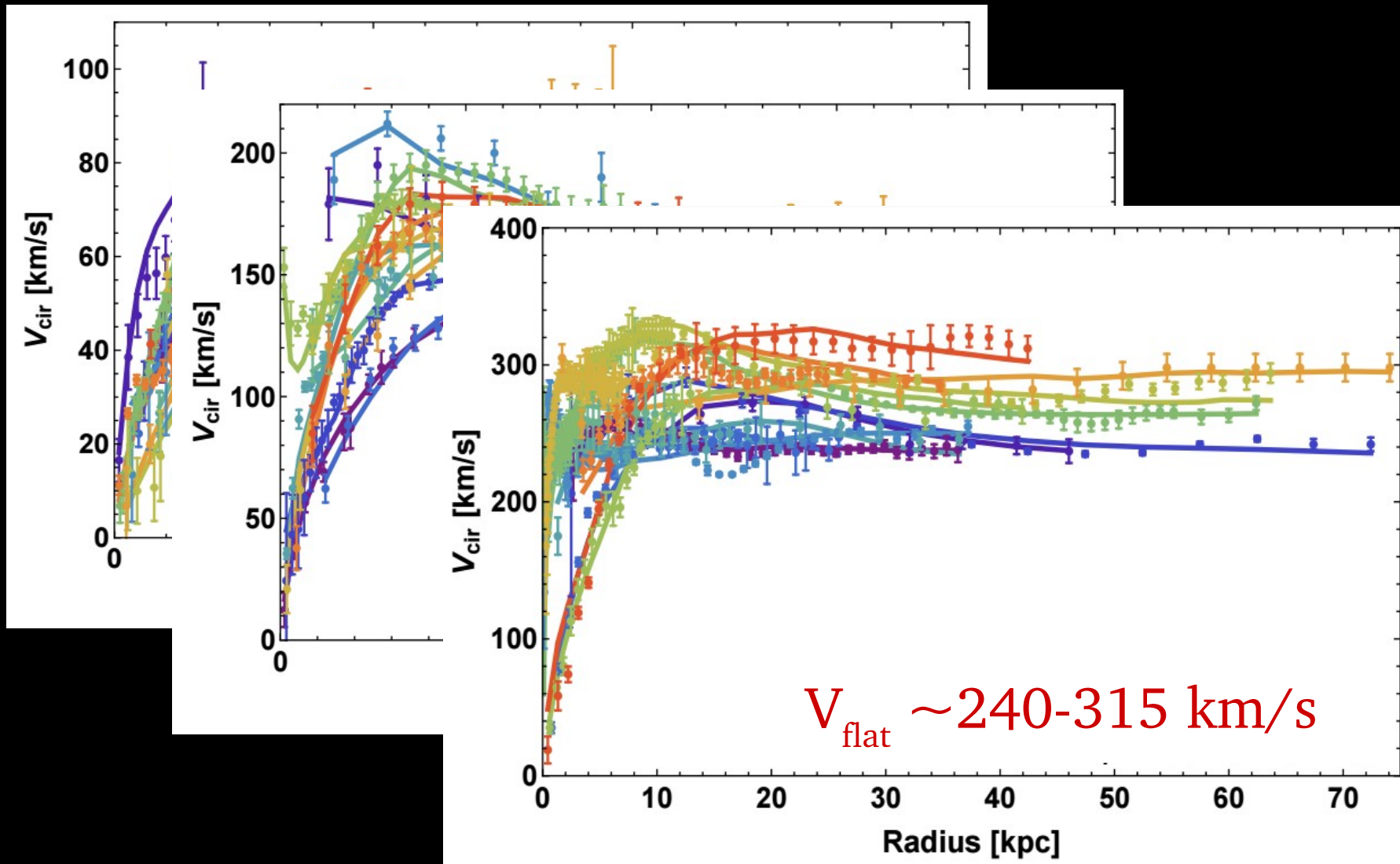
Galaxies with similar V_{flat} (proxy for mass) can have very different inner rotation curves

Galactic rotation curves are “surprisingly diverse”...



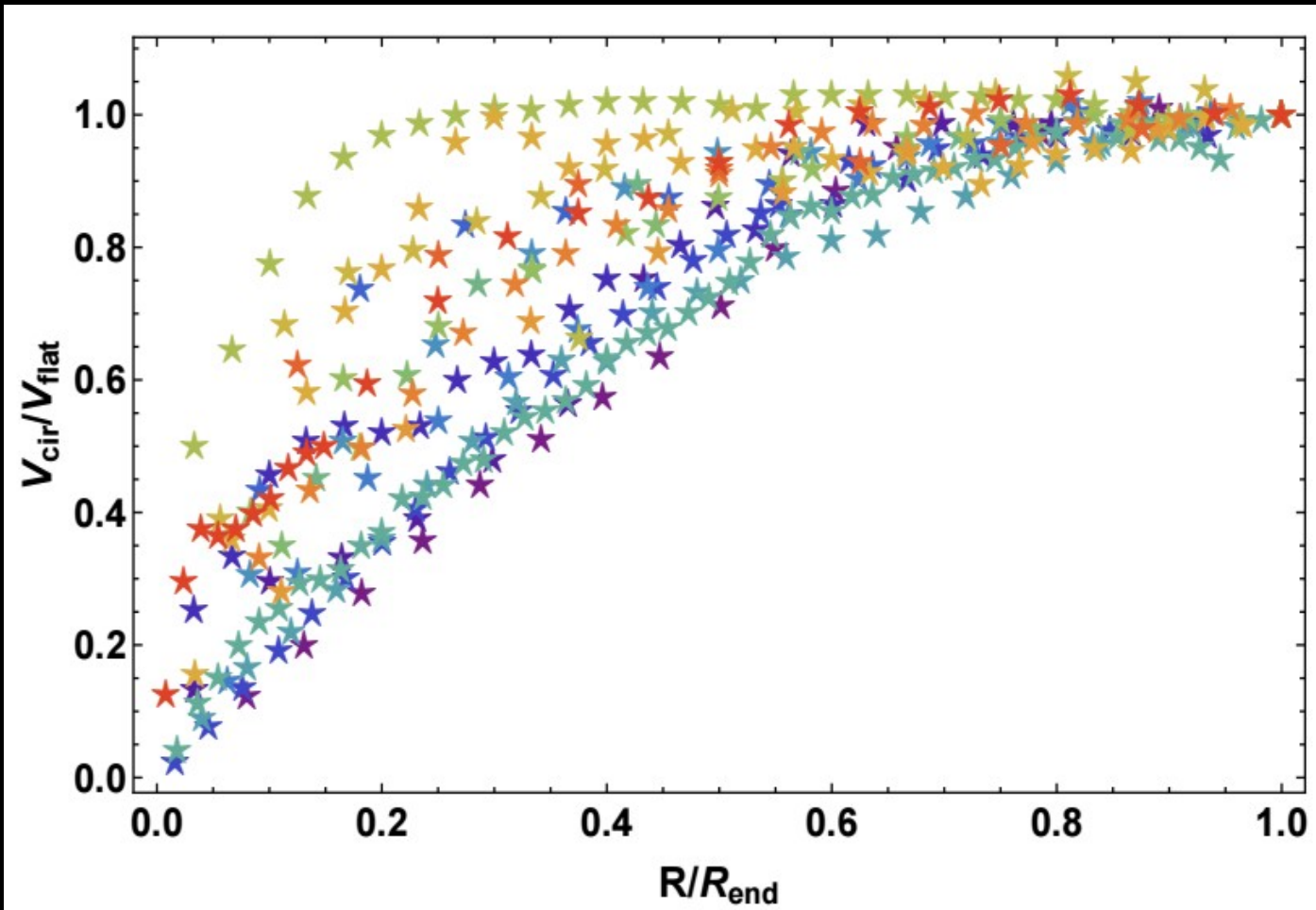
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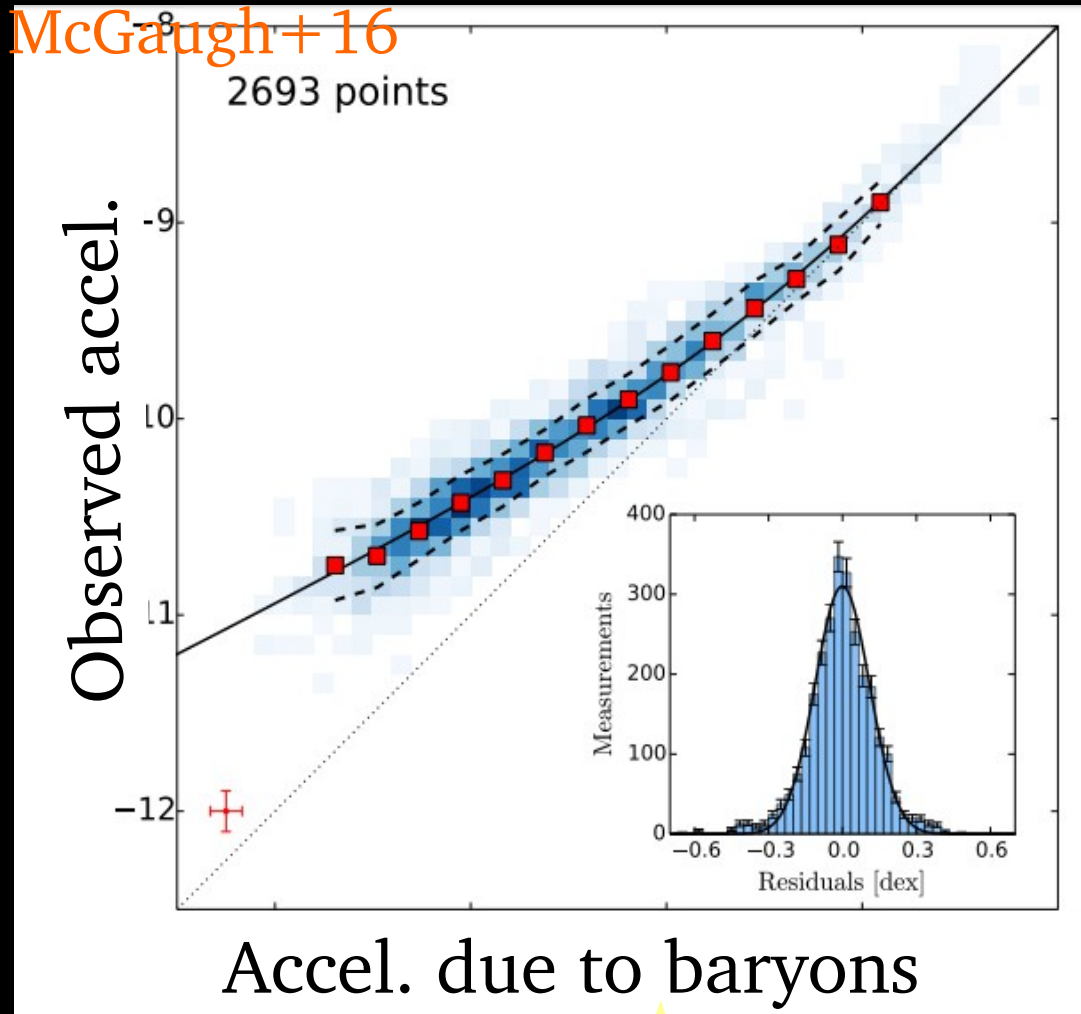
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Galactic rotation curves are “surprisingly diverse”...



Galaxies with similar V_{flat} (proxy for mass) can have very different inner rotation curves

...but also very uniform in other aspects.



“Radial acceleration relation” (McGaugh+16)

Tight relation between g_{baryons} and g_{obs} , despite the wide range mass distributions in galaxies

Signature of MOND?

Or, dark matter that can respond to the influence of baryons?

Need to assume stellar M/L ratio

SIDM interactions

+ scatter in concentration-mass relation

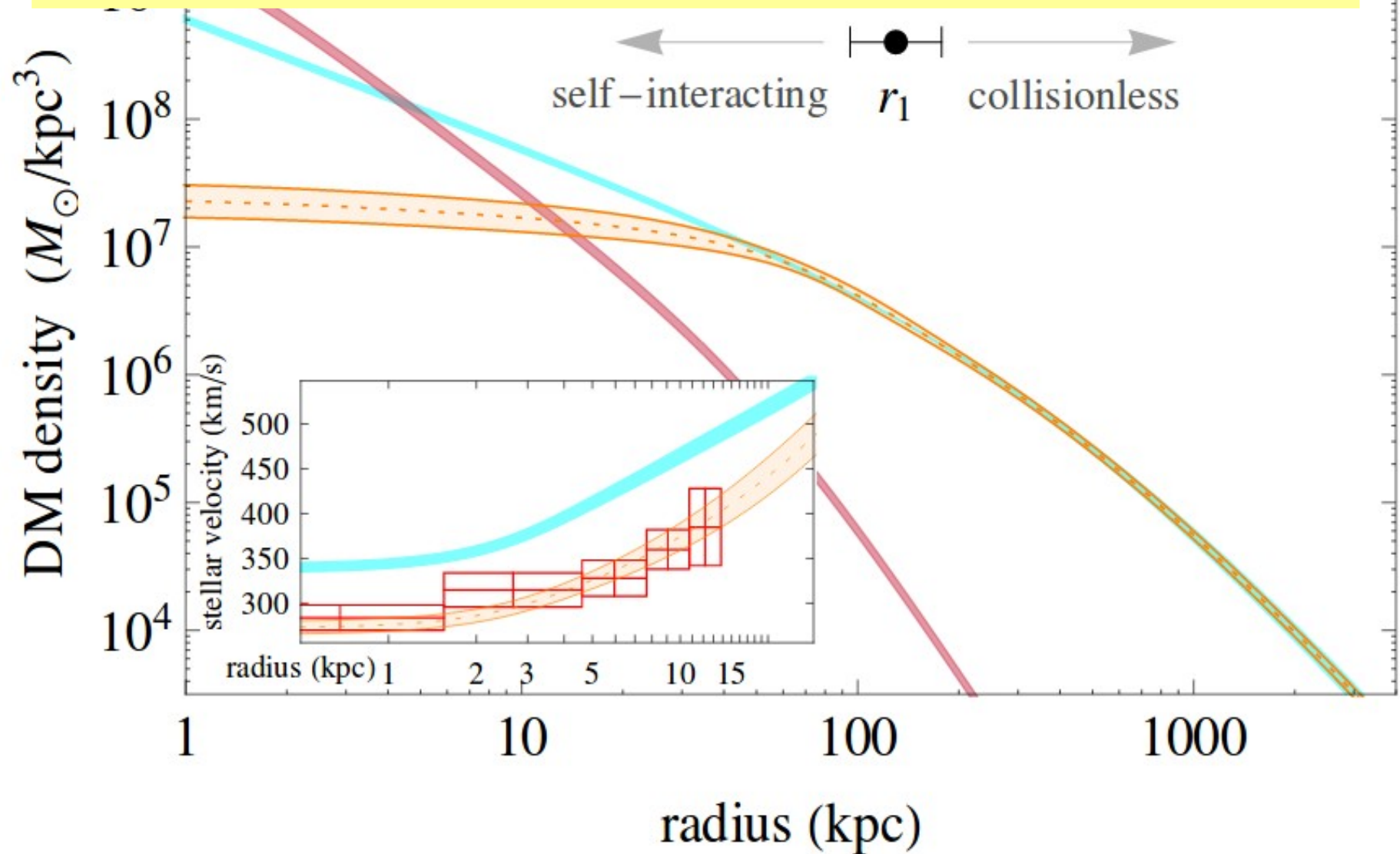
+ variety in baryon distributions

= observed diversity in rotation curves?

If so, do other quantities/relations (stellar mass-to-light ratios, cosmological concentration-mass relation) also agree with accepted ranges?

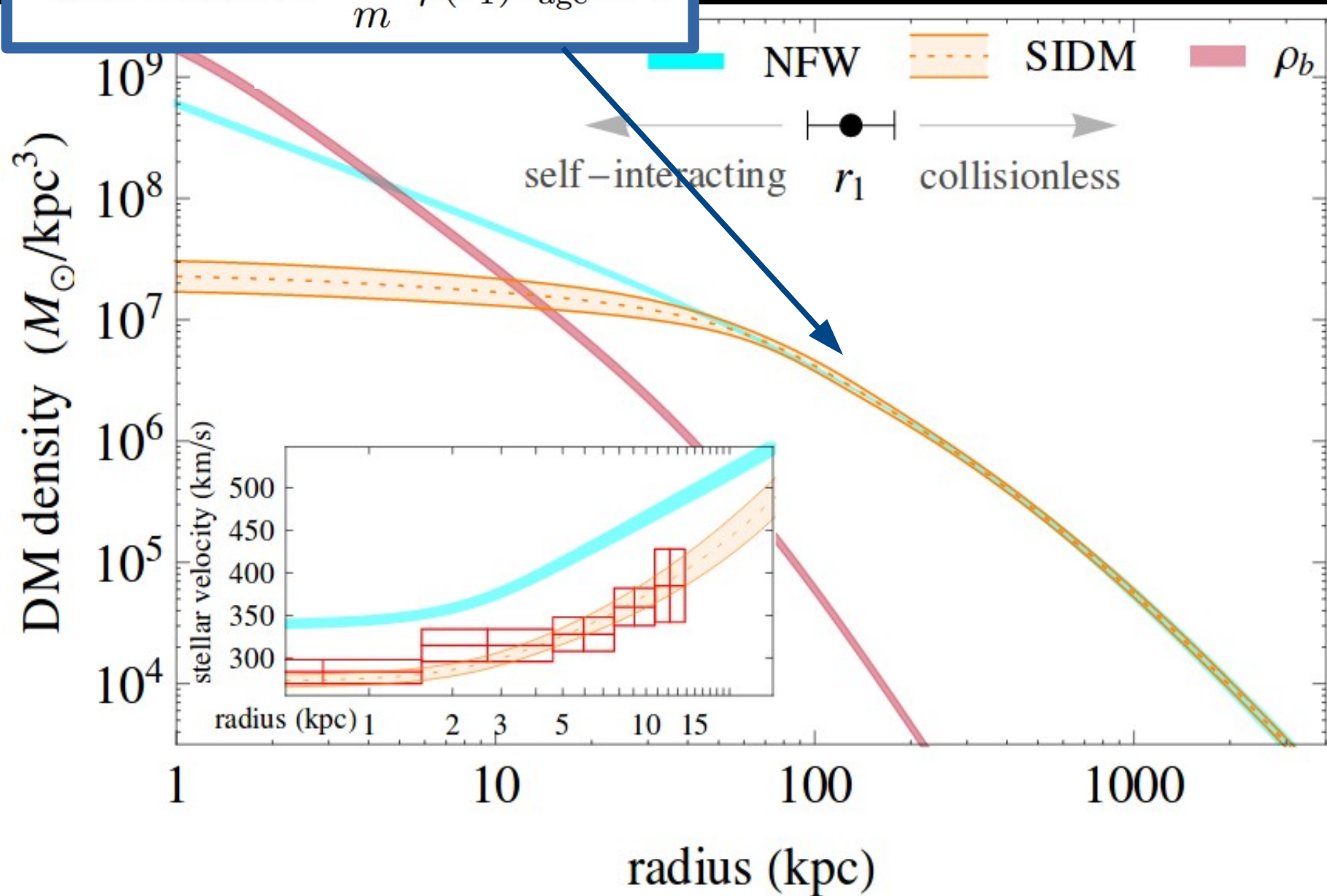
Do we recover the radial acceleration relation?

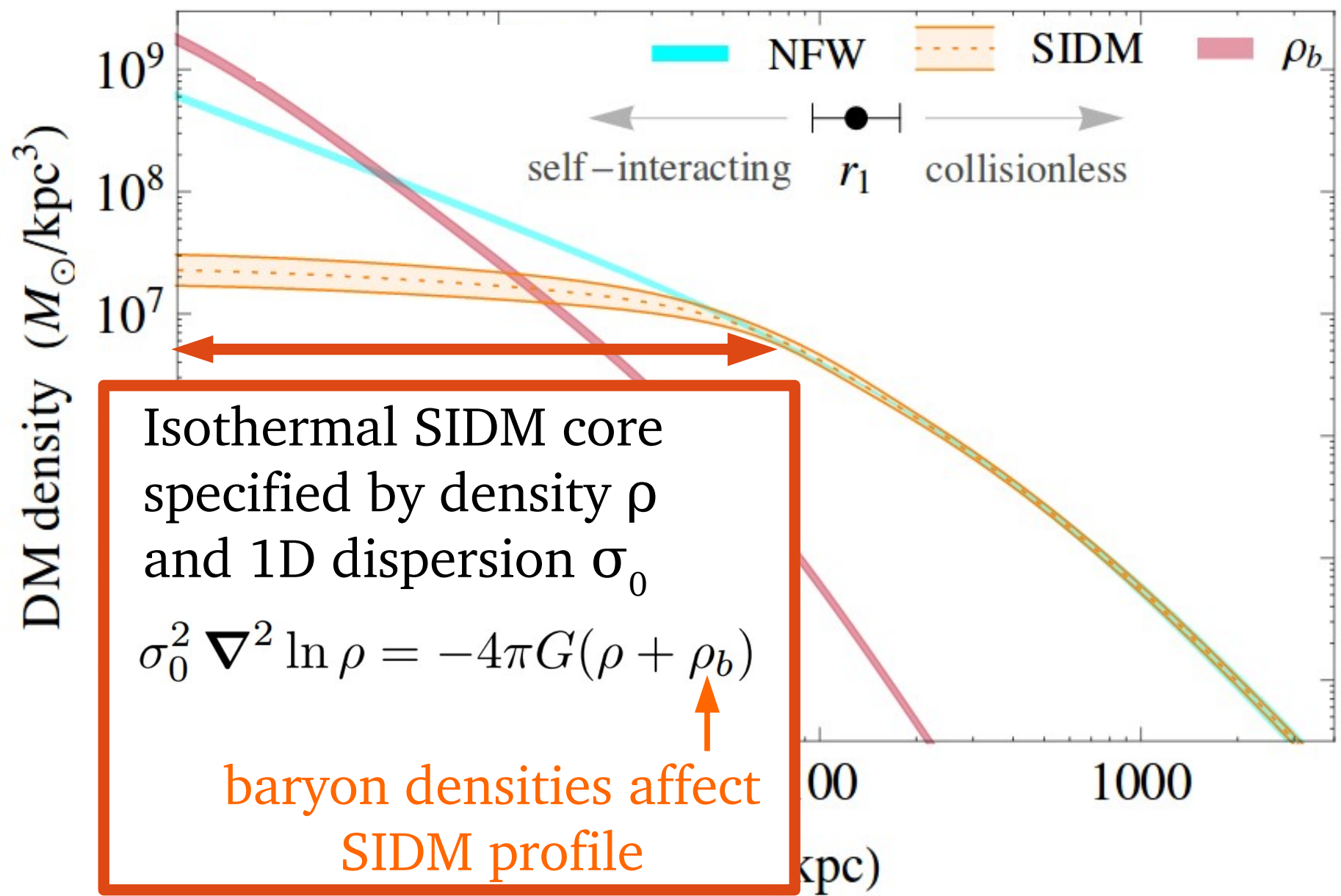
How is the density profile in an SIDM halo determined?

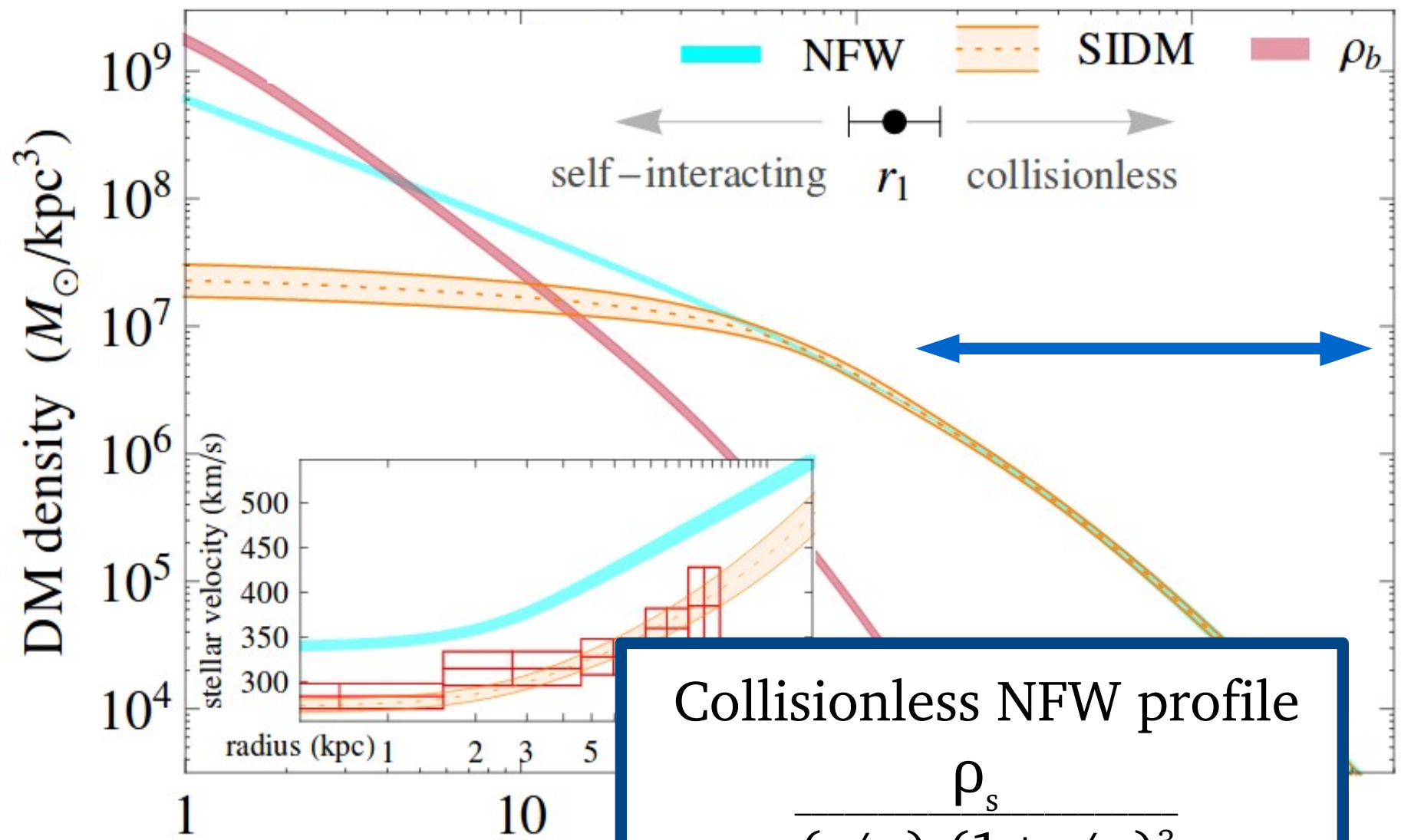


characteristic scale r_1

$$\text{rate} \times \text{time} \approx \frac{\langle \sigma v \rangle}{m} \rho(r_1) t_{\text{age}} \approx 1$$



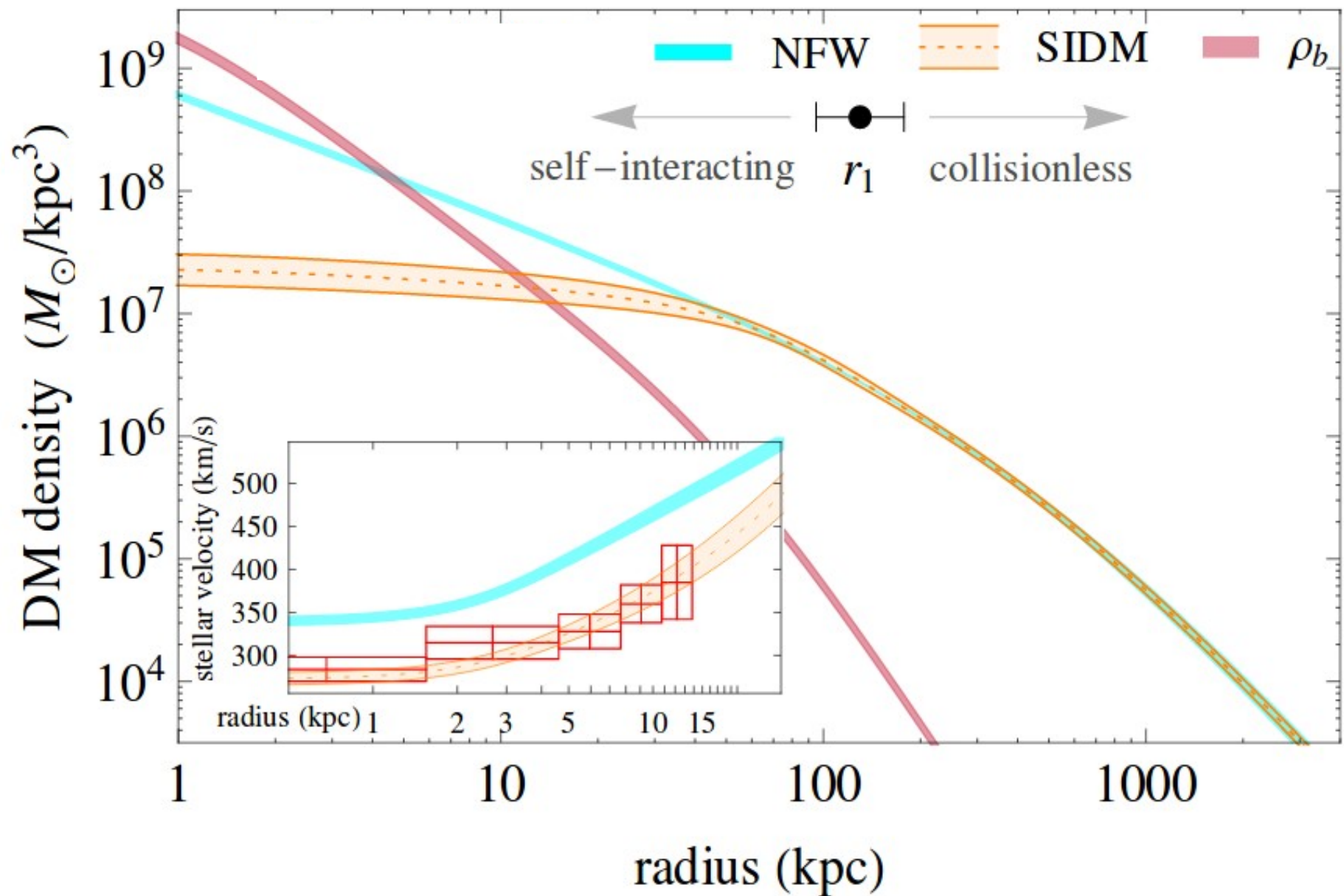




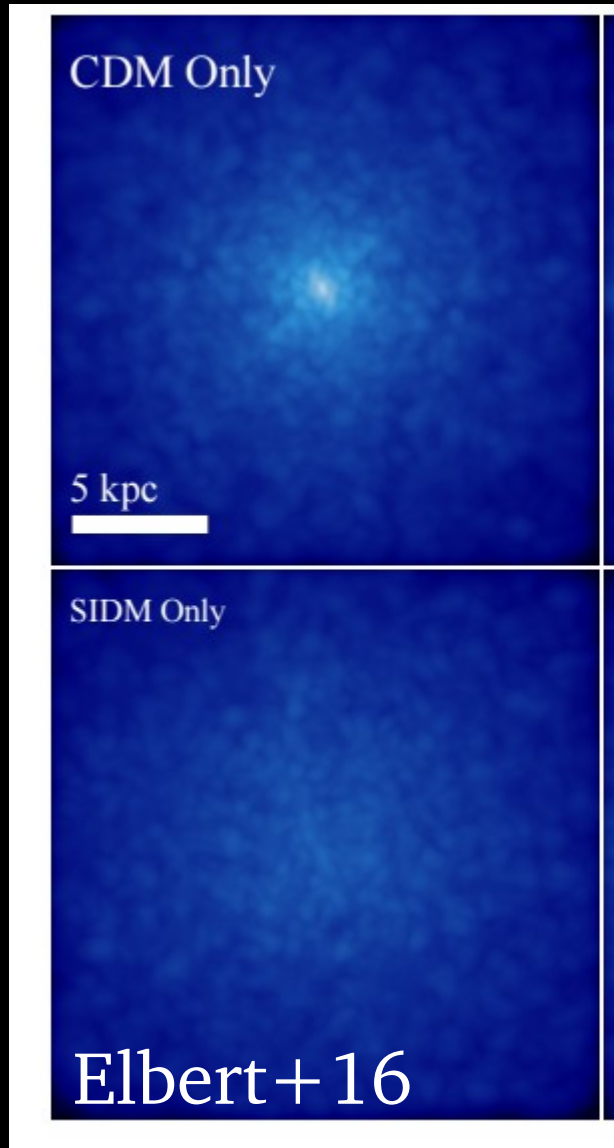
Collisionless NFW profile

$$\frac{\rho_s}{(r/r_s) (1+r/r_s)^3}$$

scatter in concentration-mass relation leads to
scatter in core radius r_1

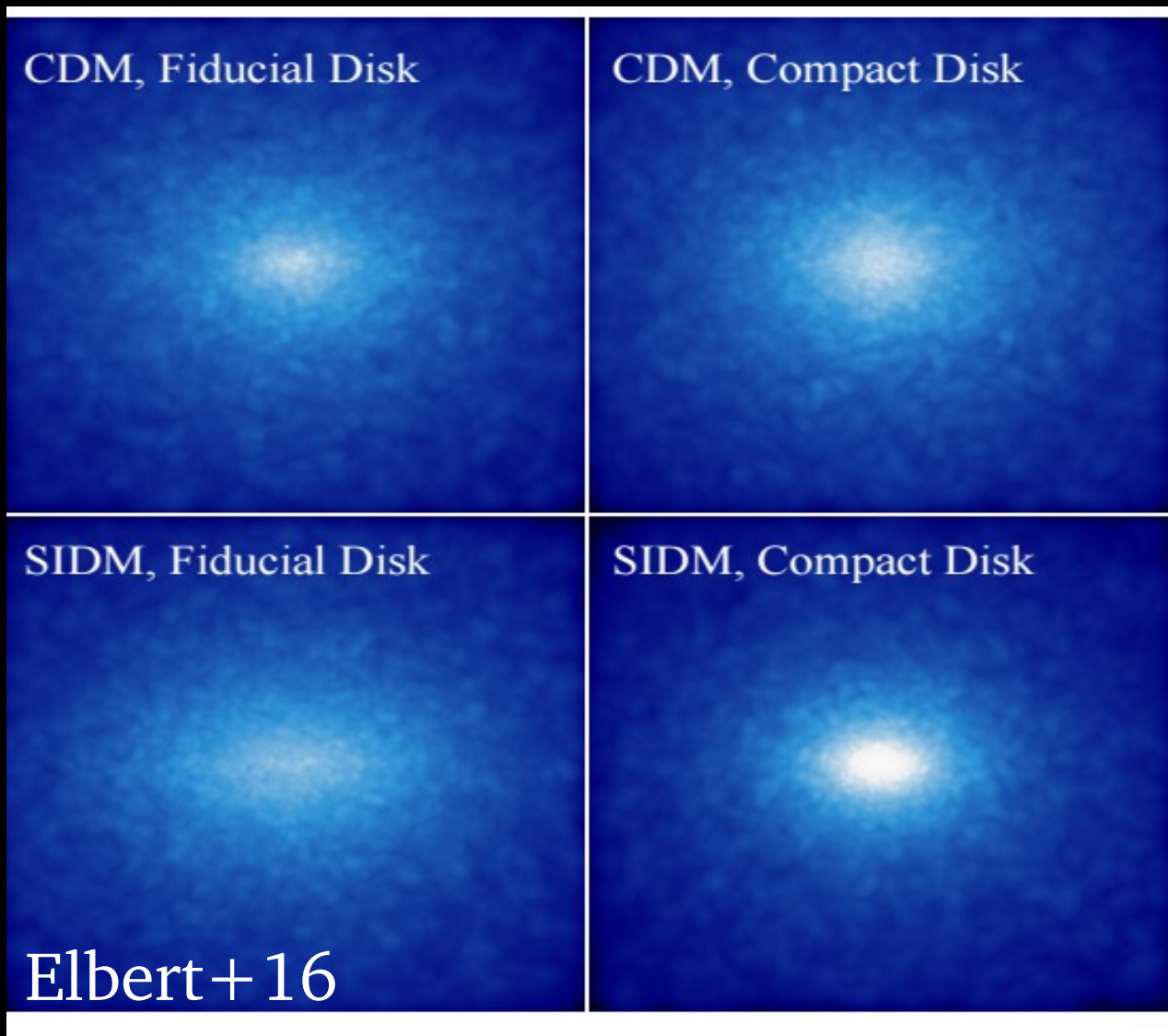


Self-interacting dark matter can assume very different (cuspy/cored) inner density profiles in similar mass galaxies



Dark matter only simulations:
CDM halos have higher central
densities than SIDM halos

Self-interacting dark matter can assume very different (cuspy/cored) inner density profiles in similar mass galaxies



DM+baryons
simulations

Thermalization in
innermost regions of
SIDM halos: DM
profile influenced by
baryons' gravitational
potential

Two methods of finding best-fit SIDM profiles from rotation curves and surface brightness profiles (**SPARC sample**, Lelli+16):

1. Fit using template grid of baryonic disk potentials and NFW halos
2. MCMC fit (core density, core 1D dispersion, M/L)

Specify:

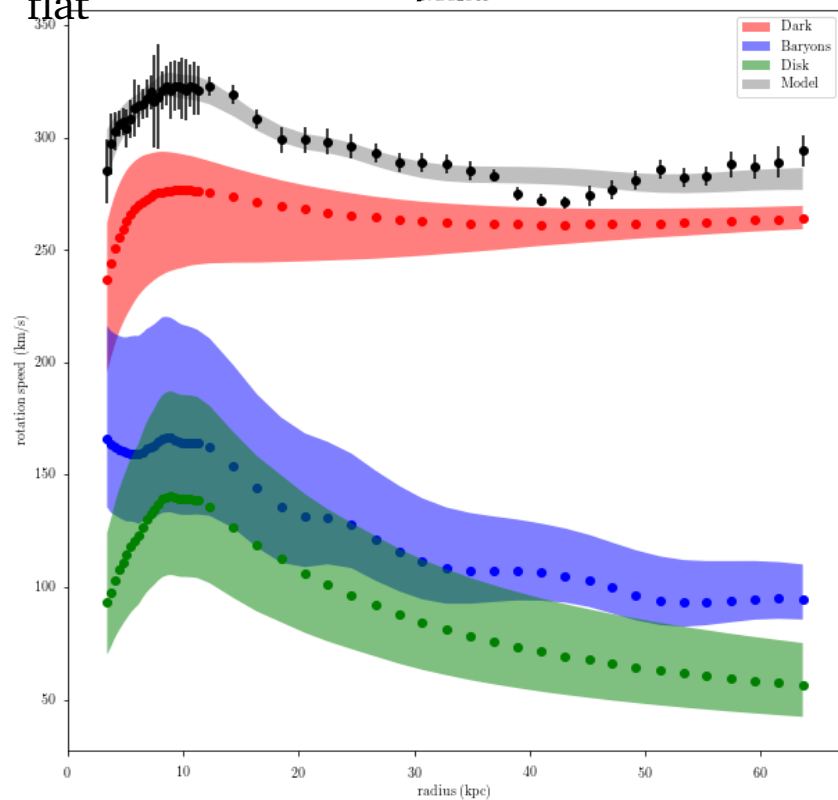
Fixed* self-interaction cross section σ/m

* assumes that any variation in scattering cross section within a velocity-dependent SIDM model is small within mass ranges considered

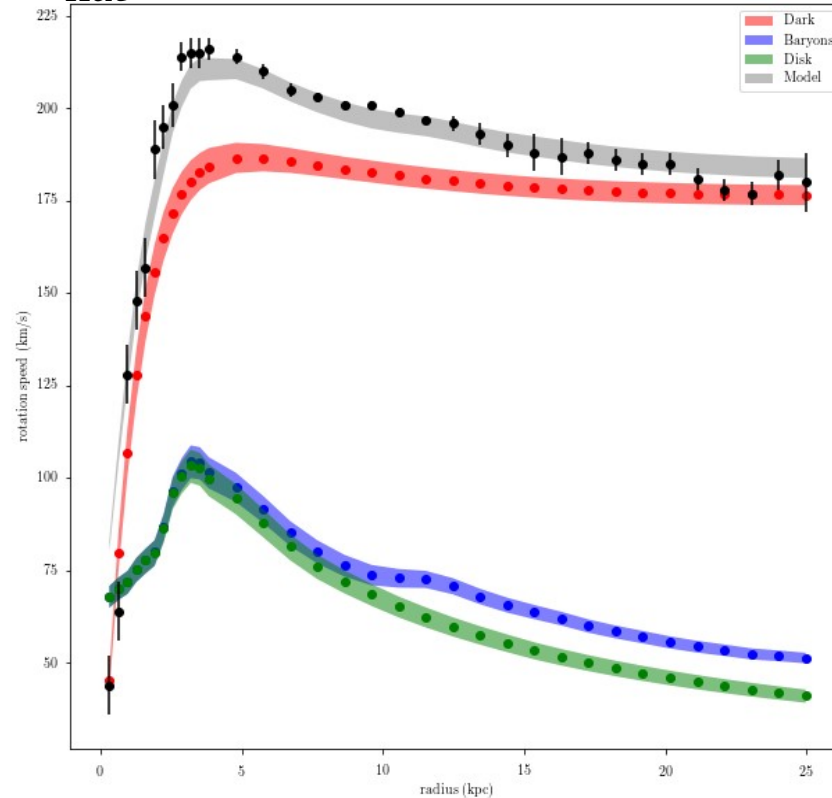
Cosmological $v_{\text{max}} - r_{\text{max}}$ (a.k.a. concentration-mass) relation from N-body simulations

Red=dark matter
Blue=total baryons
Green=disk
Grey=total model

$V_{\text{flat}} \sim 300 \text{ km/s}$



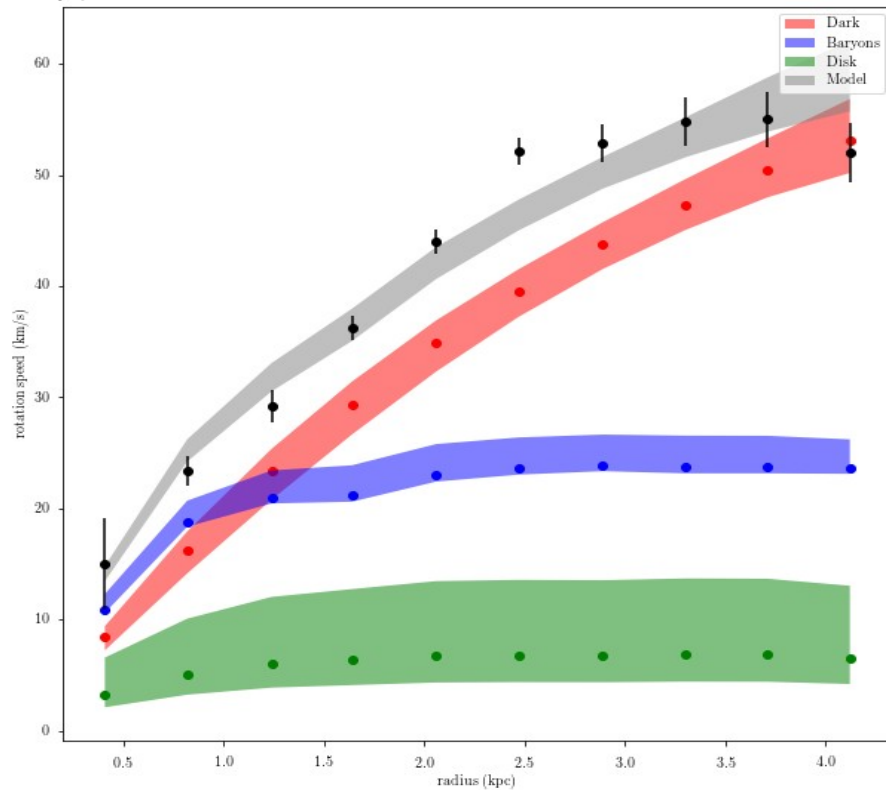
$V_{\text{flat}} \sim 180 \text{ km/s}$



Red=dark matter
Blue=total baryons
Green=disk
Grey=total model

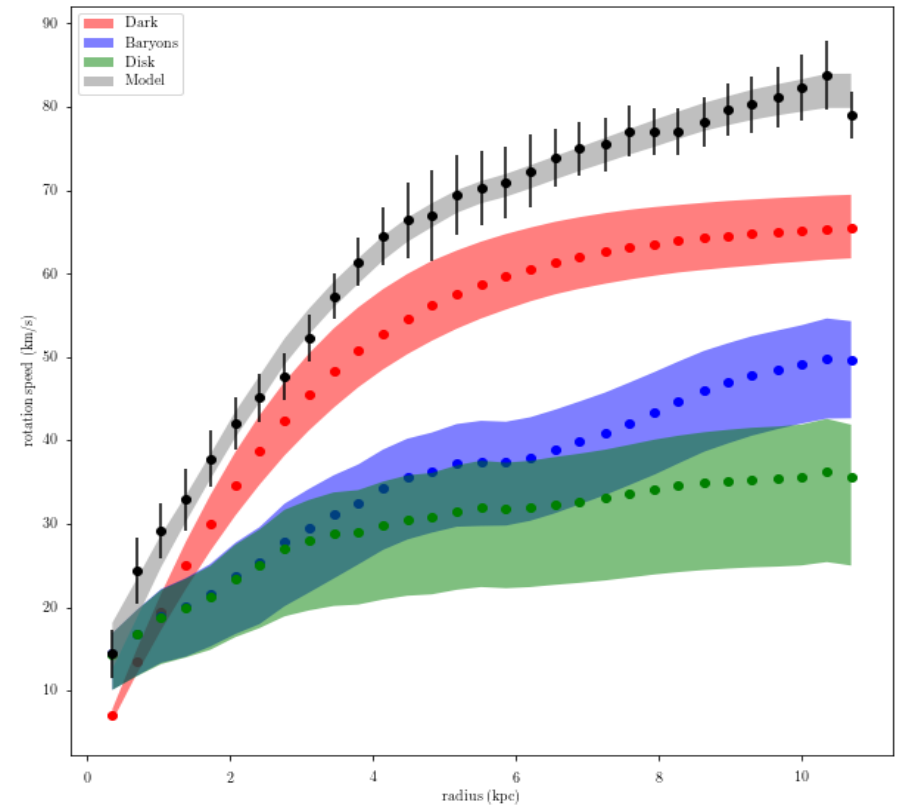
$V_{\text{flat}} \sim 55 \text{ km/s}$

DDO168

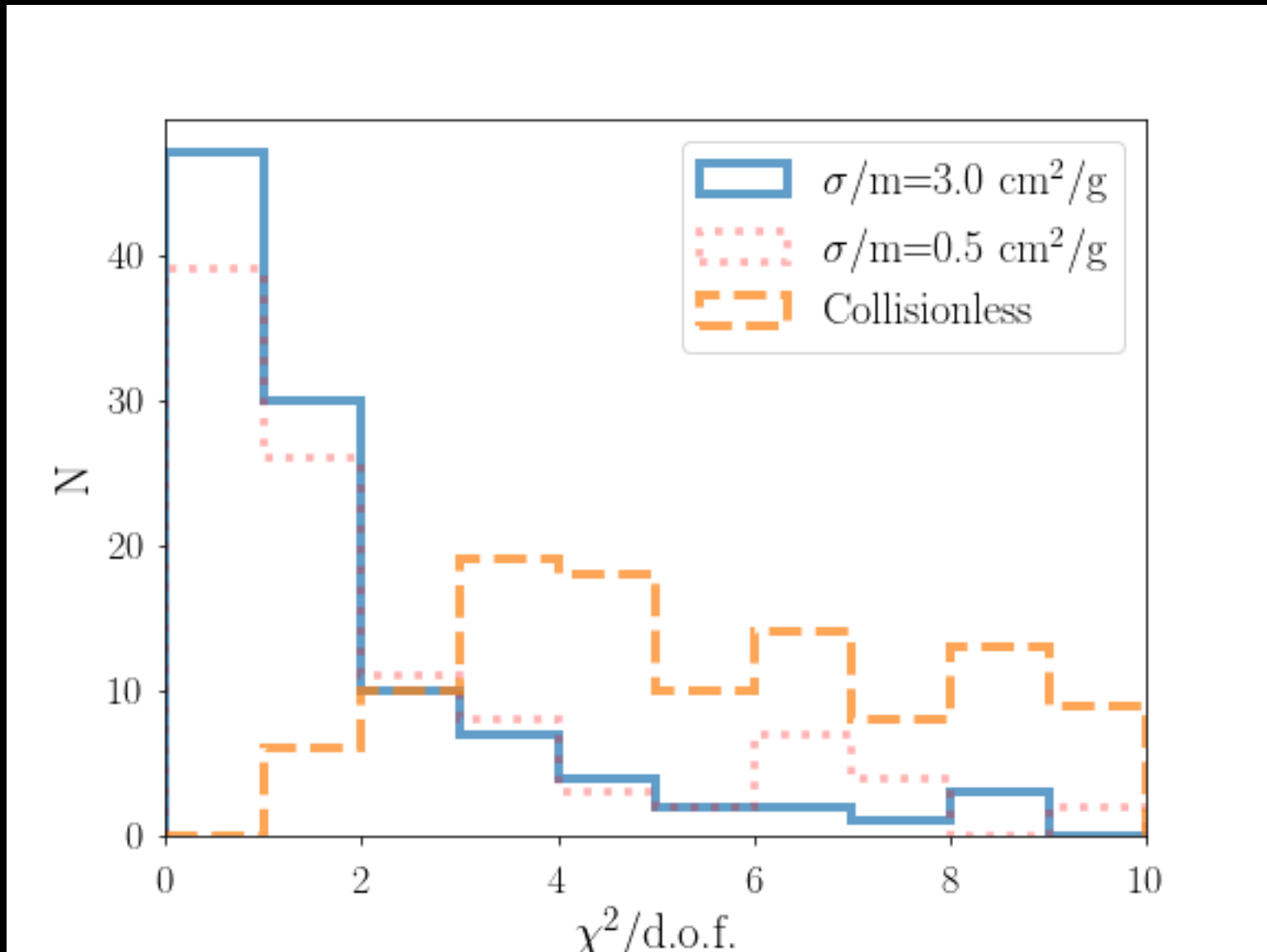


$V_{\text{flat}} \sim 80 \text{ km/s}$

UGC07524

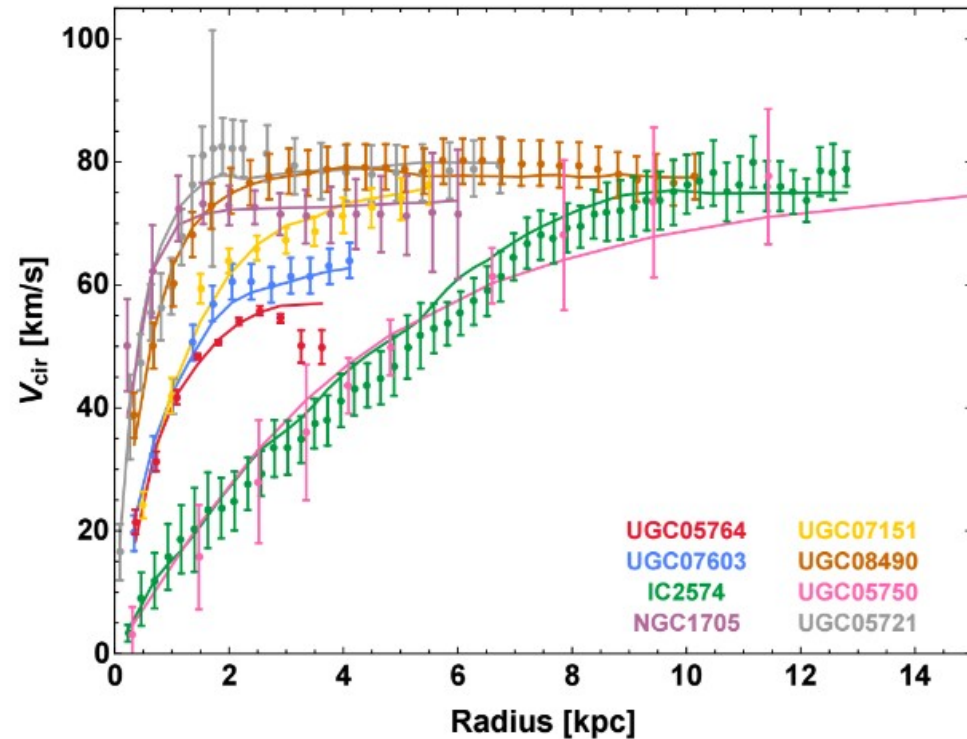
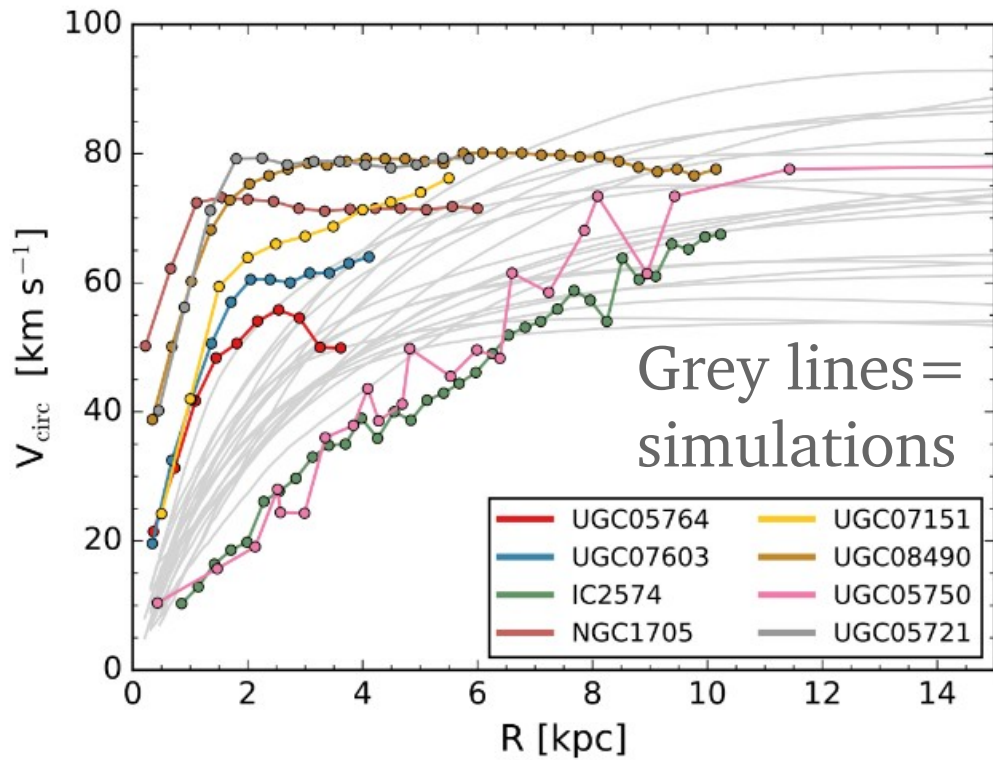


Fits prefer SIDM cross sections $\sim 3 \text{ cm}^2/\text{g}$ over lower cross sections or collisionless DM



Strong baryonic feedback

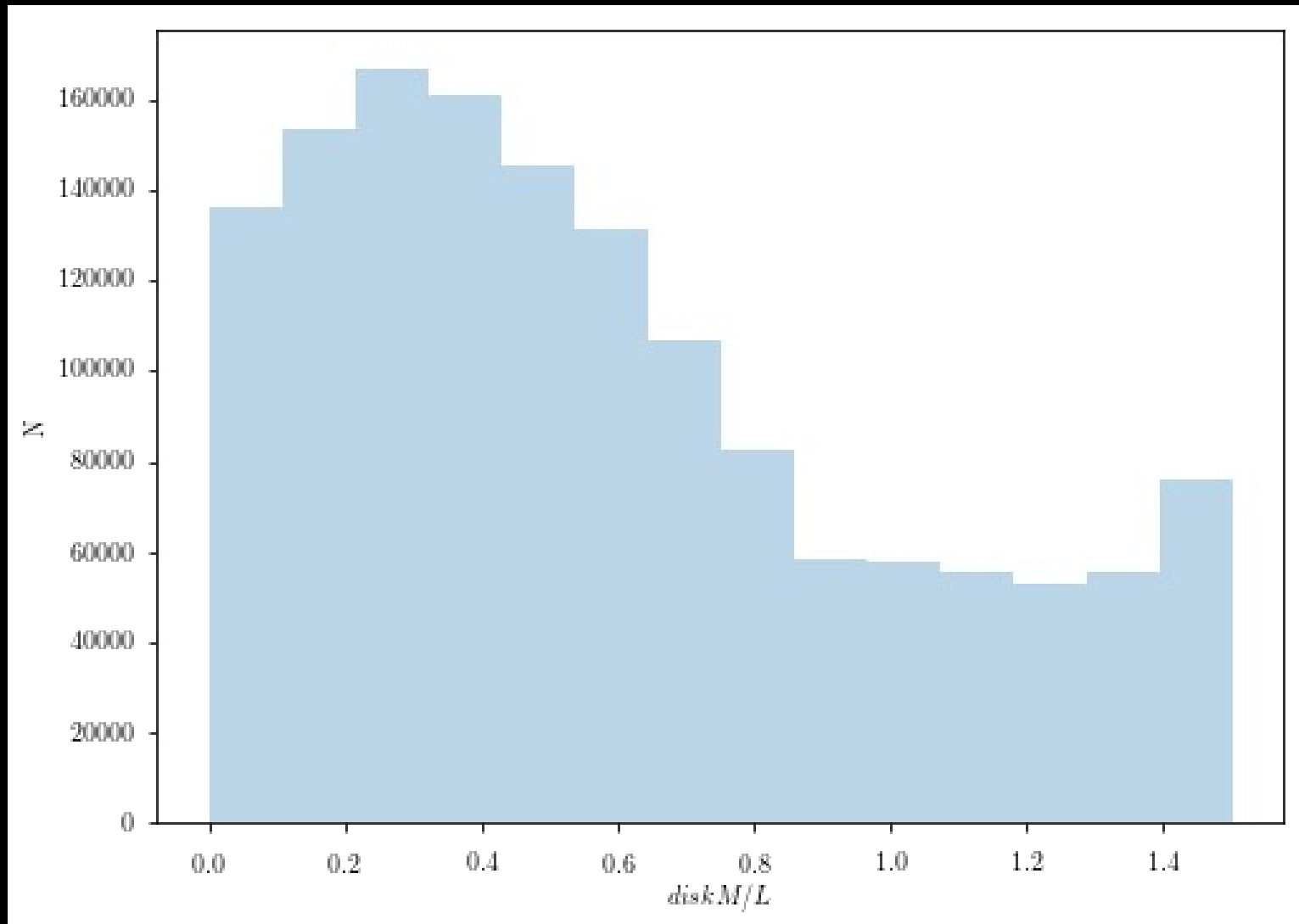
SIDM under the influence
of baryons



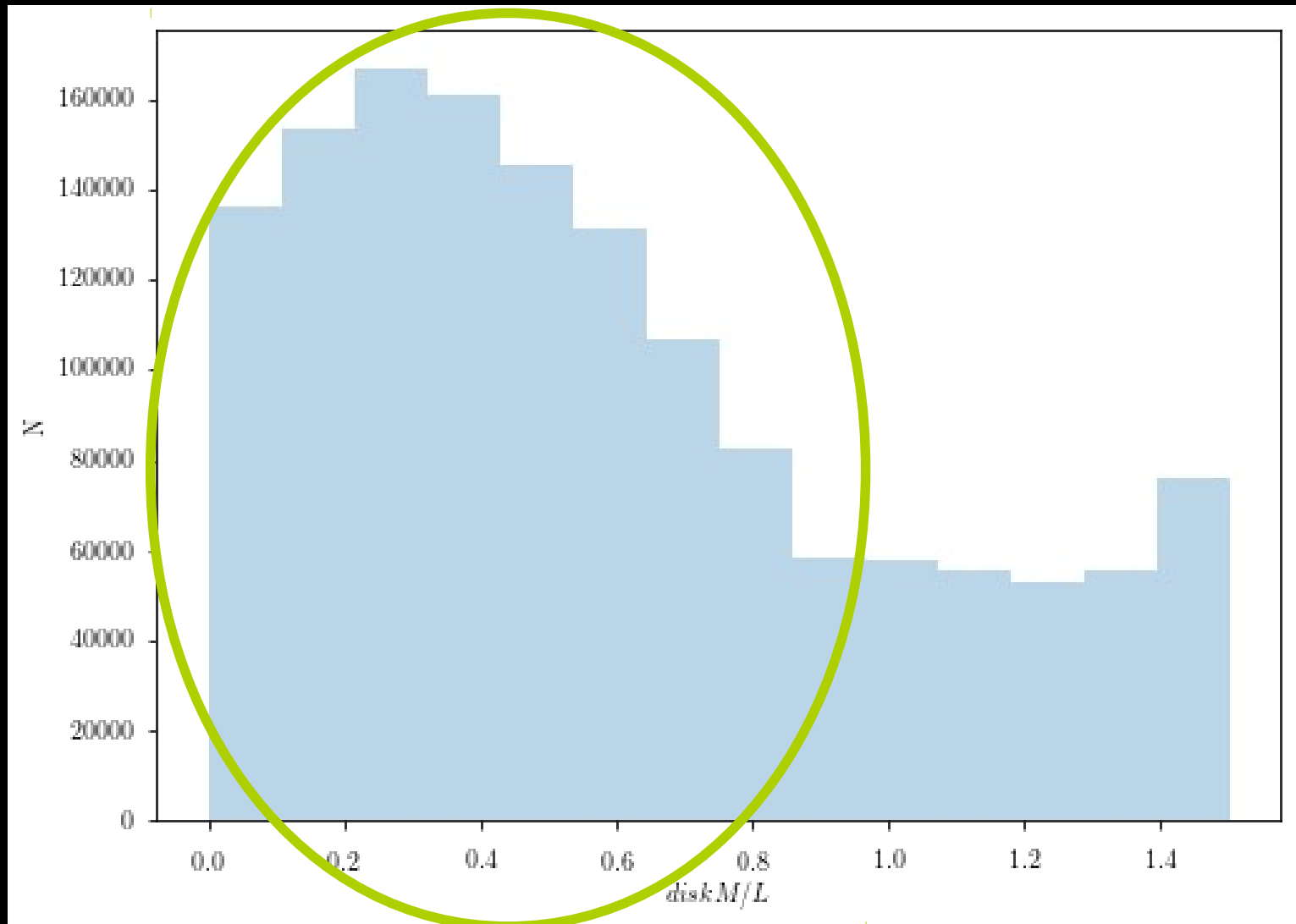
Santos-Santos+17,
NIHAO collaboration

This work

Stellar mass to light (M/L) ratios from MCMC fits

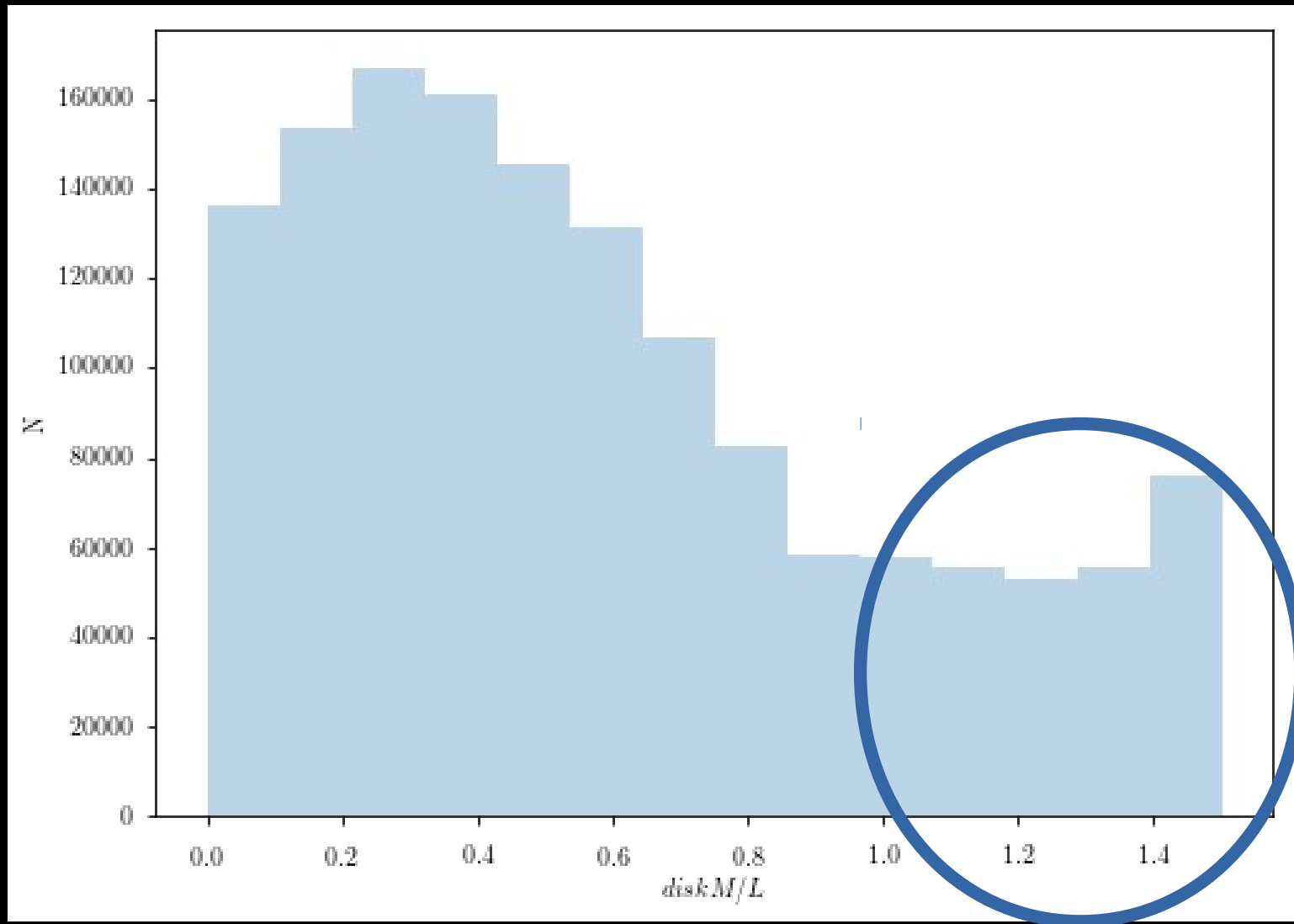


Stellar mass to light (M/L) ratios from MCMC fits



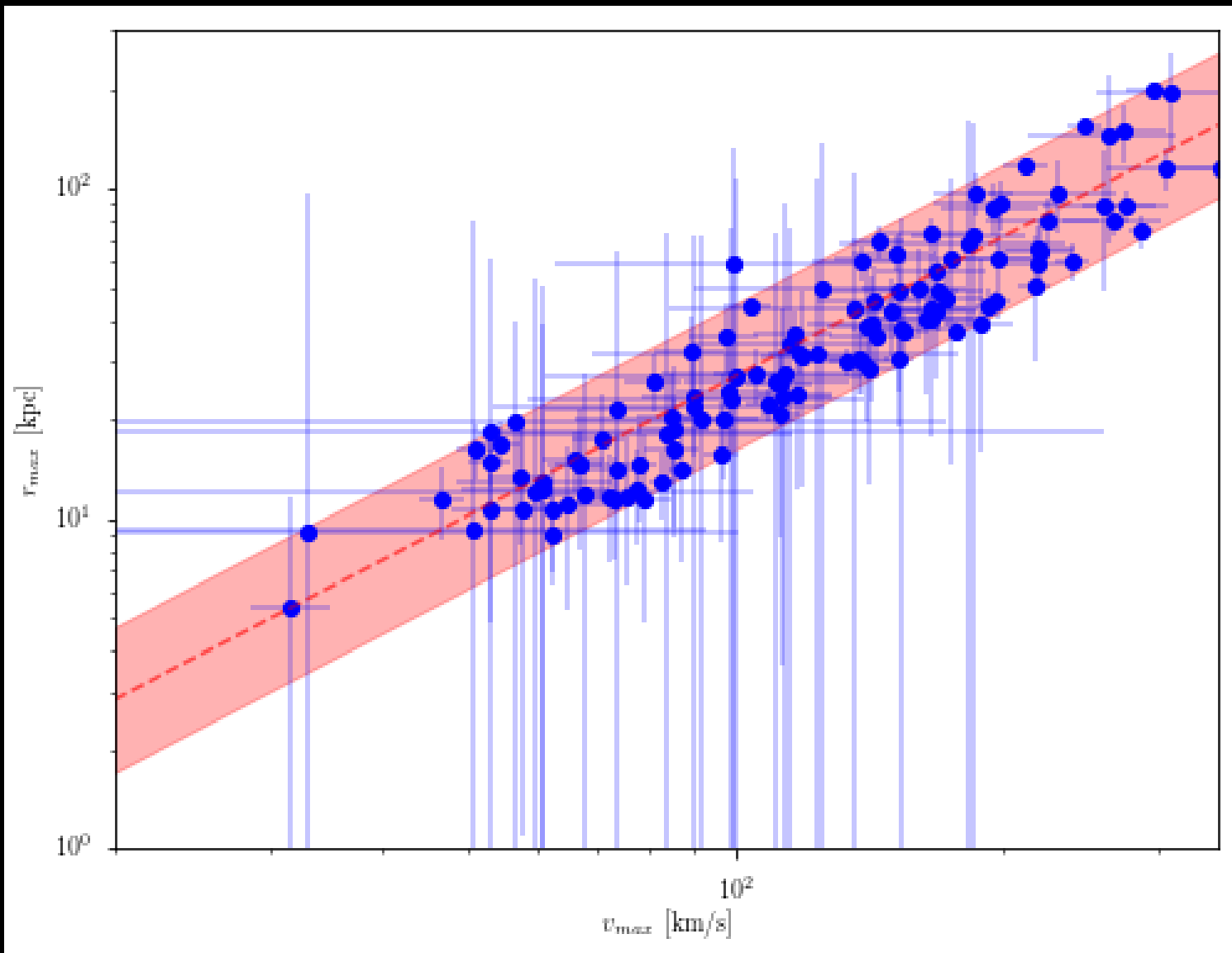
General agreement with
population synthesis models
($M/L \sim 0.4-0.6$)

Stellar mass to light (M/L) ratios from MCMC fits

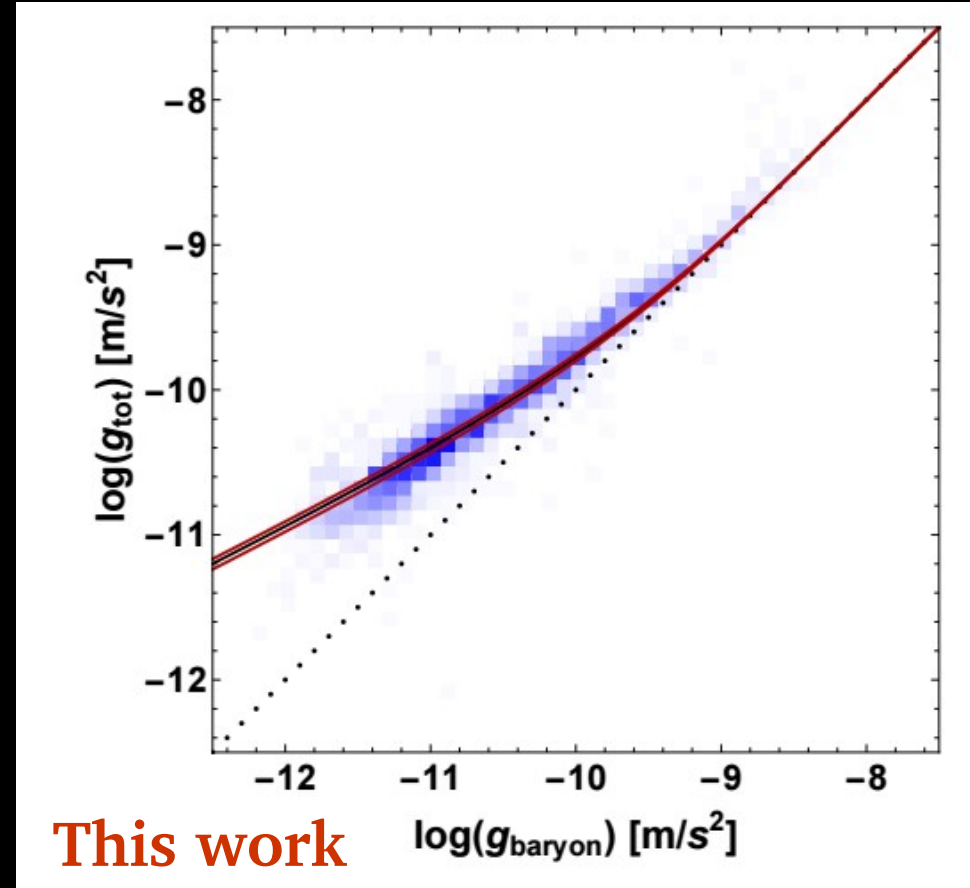
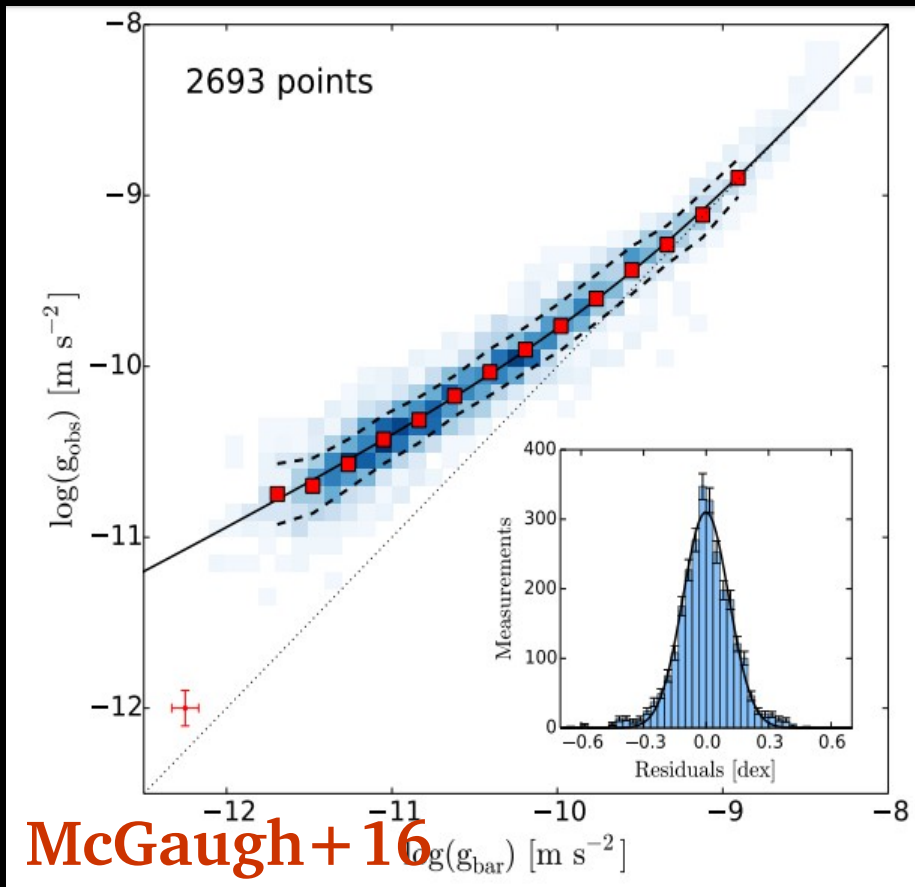


Radial variation in stellar populations driving M/L higher? Beware of bias from inner data points

$V_{\text{max}} - R_{\text{max}}$ relation (concentration-mass)



Use M/L values to predict g_{baryon} and recover radial acceleration relation

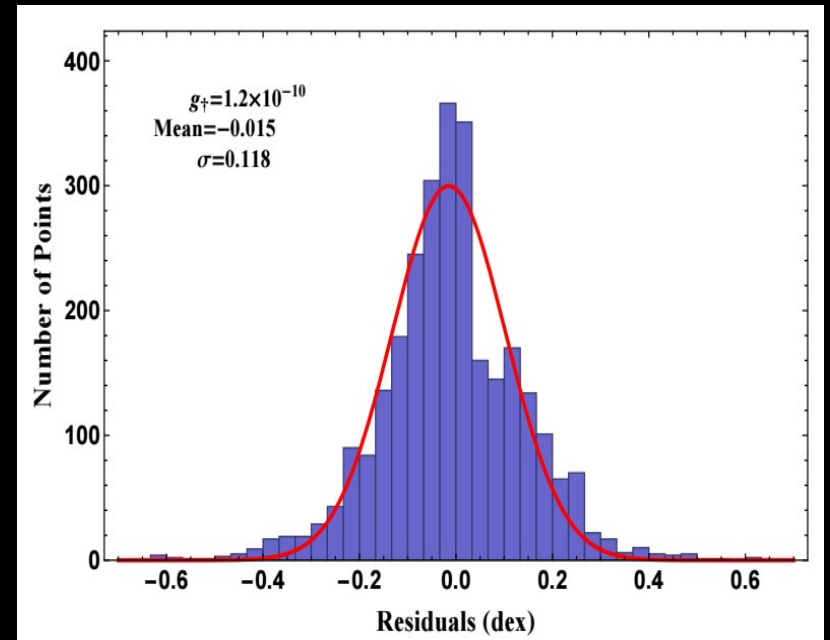
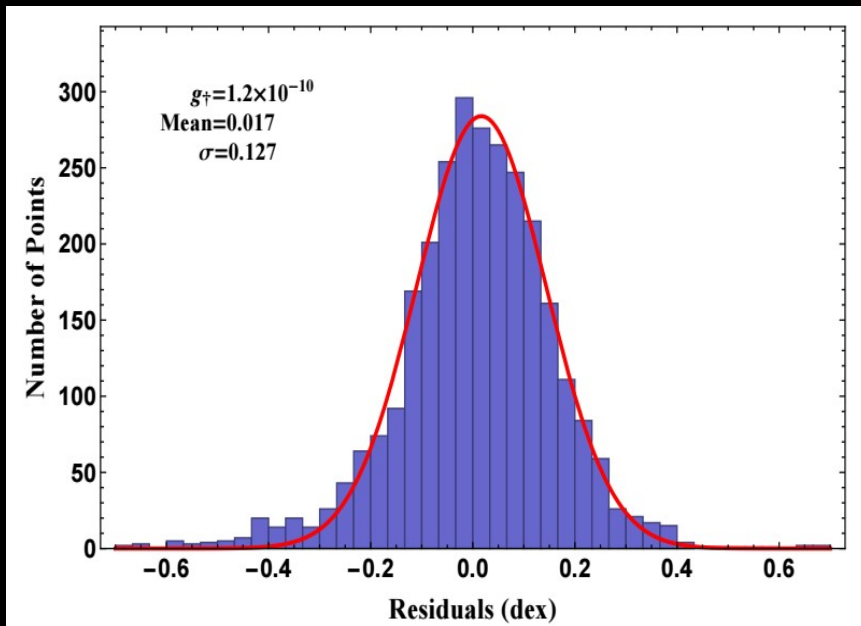


Scatter in data points from empirical radial acceleration relation is equal to / less than McGaugh+16

$$g_{\text{obs}} = \mathcal{F}(g_{\text{bar}}) = \frac{g_{\text{bar}}}{1 - e^{-\sqrt{g_{\text{bar}}/g_{\dagger}}}}$$

McGaugh+16
(M/L fixed to 0.5)

This work
(M/L ratios freely fit to data
with SIDM)



Takeaway message

Self-interacting dark matter with interaction cross sections $\sim \text{few cm}^2/\text{g}$ can fit a *diversity* of rotation curve shapes across a variety of galaxy masses...

... while also recovering the *uniformity* in the radial acceleration relation between g_{baryon} and g_{obs} .