Self-interacting Dark Matter:
An Explanation for Diversity & Uniformity in Galactic Rotation Curves?

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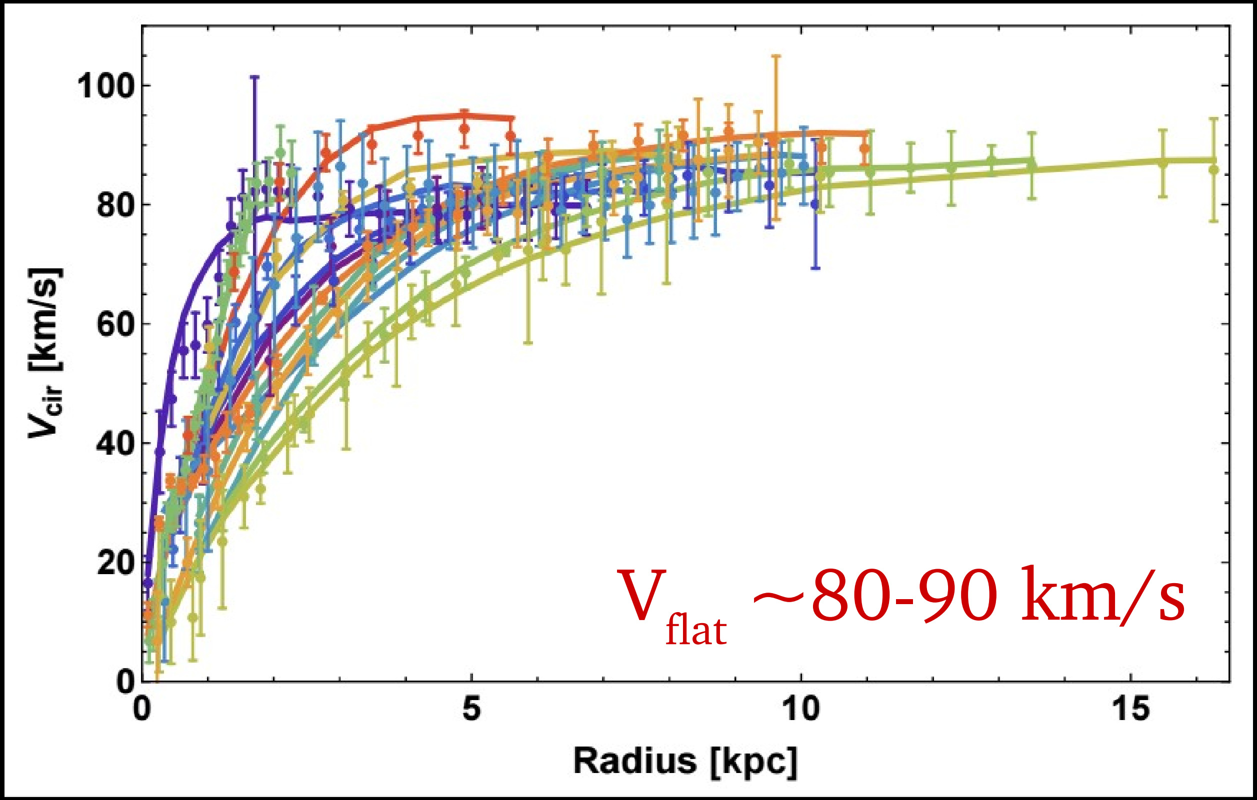
Galactic rotation curves are “surprisingly diverse”…



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

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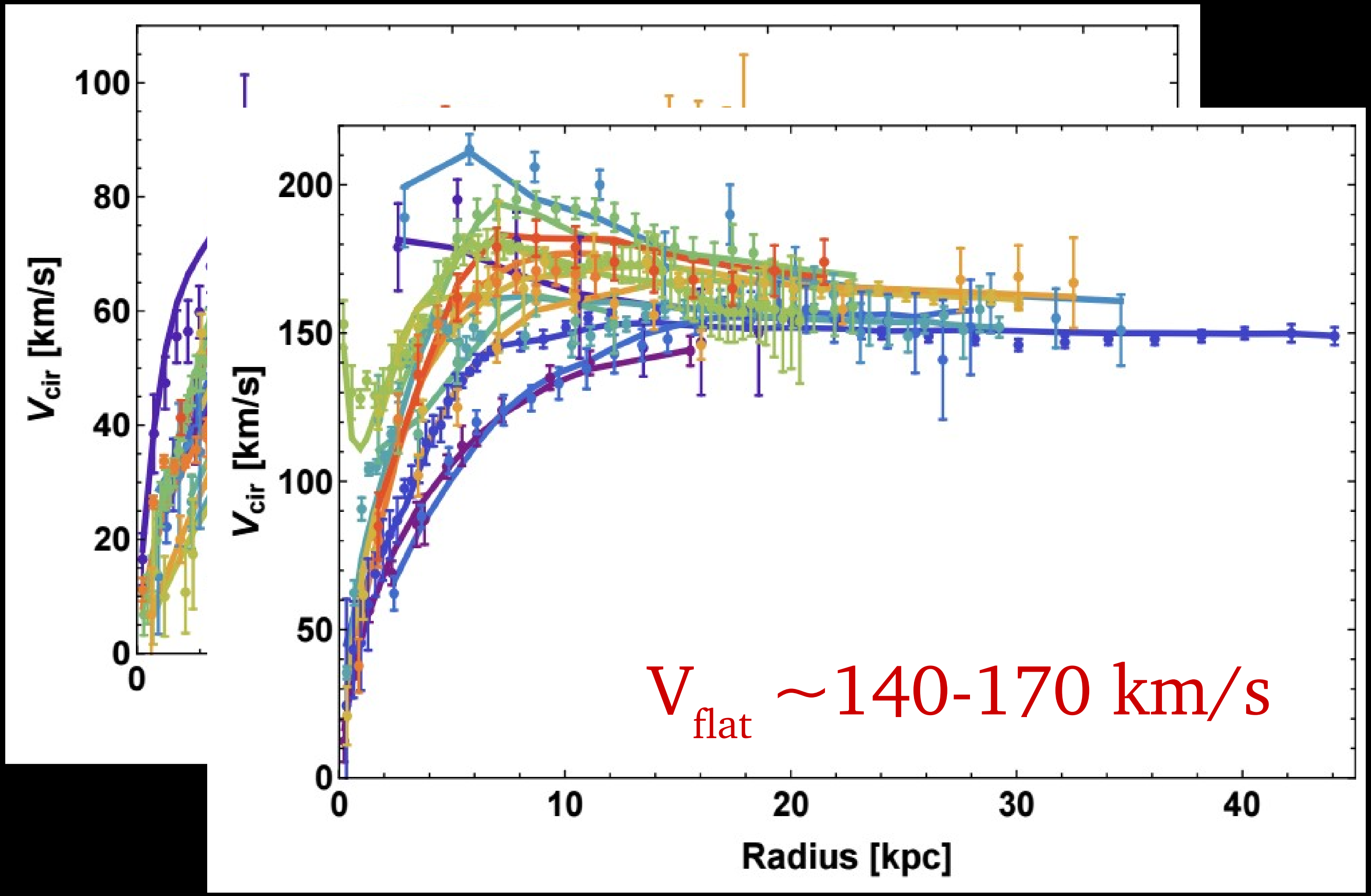

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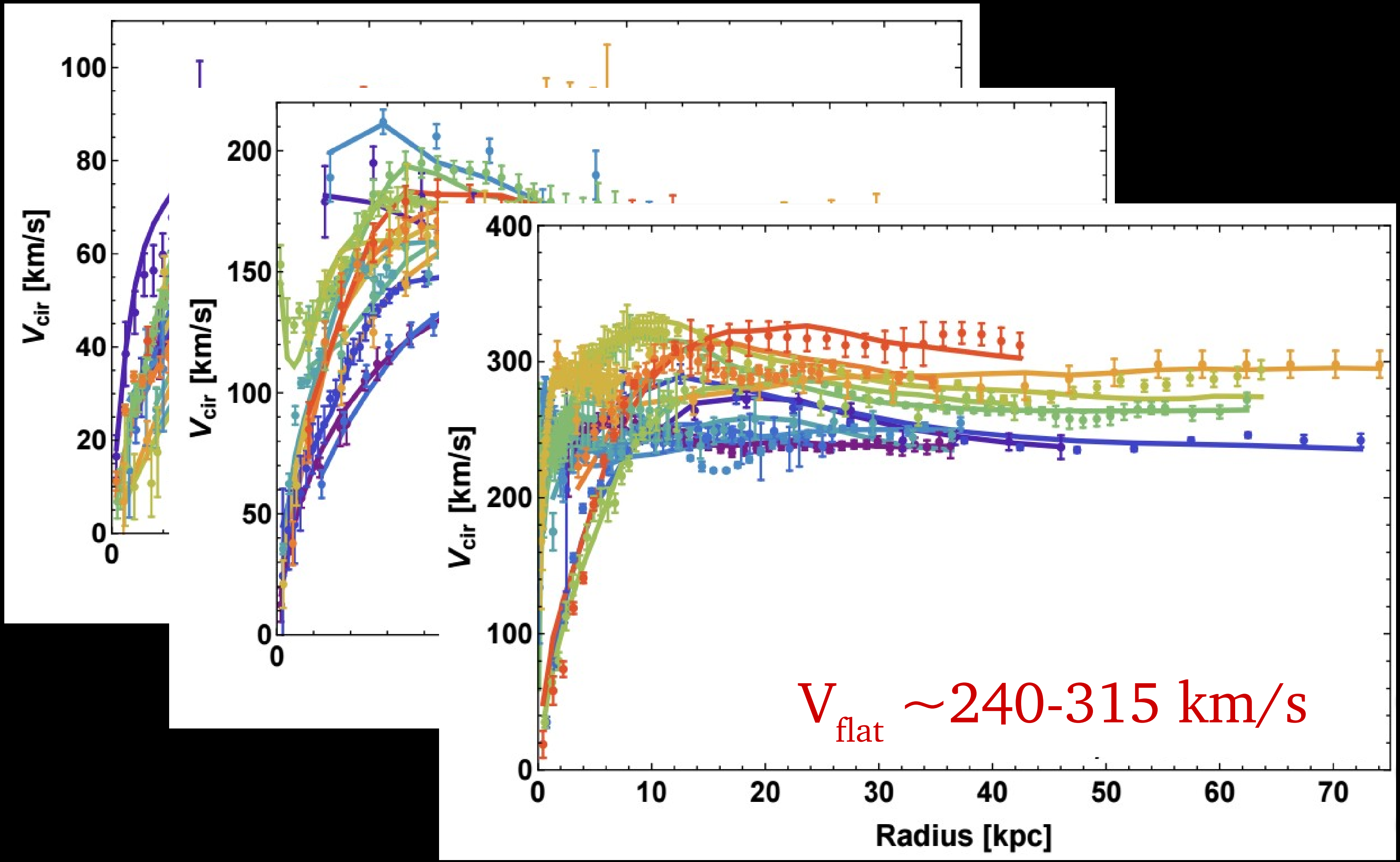

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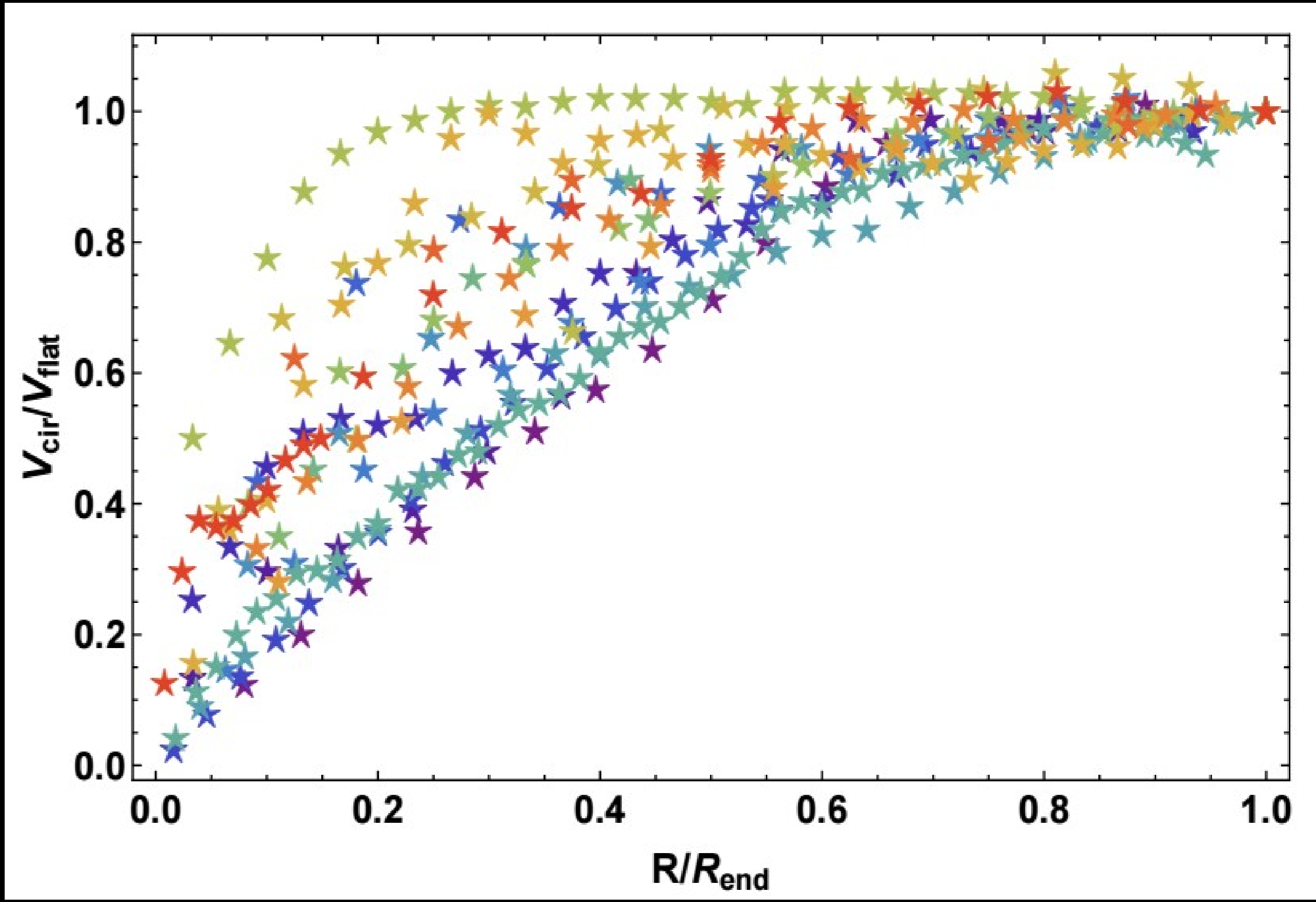
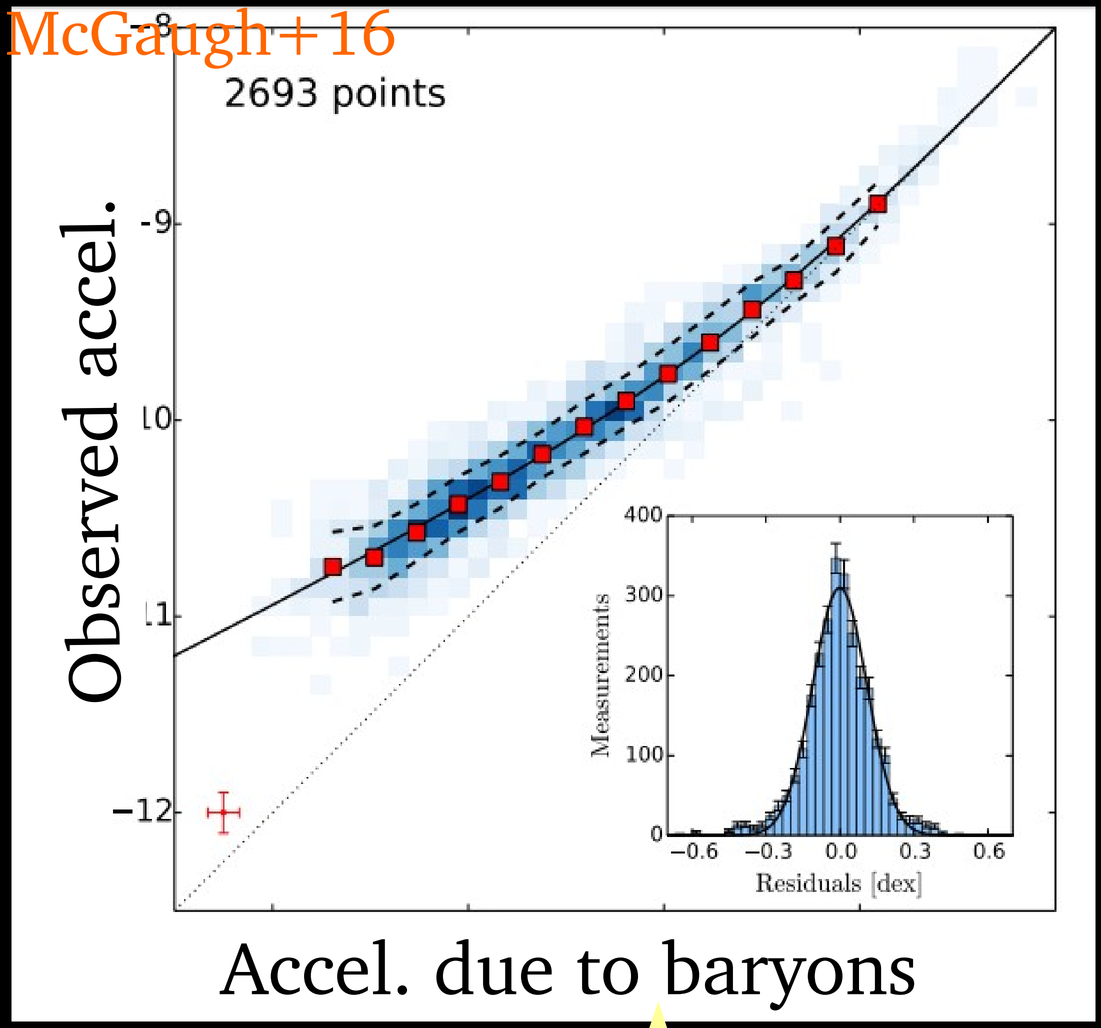


Galaxies with similar V_{flat} (proxy for mass) can have very different inner rotation curves

...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?

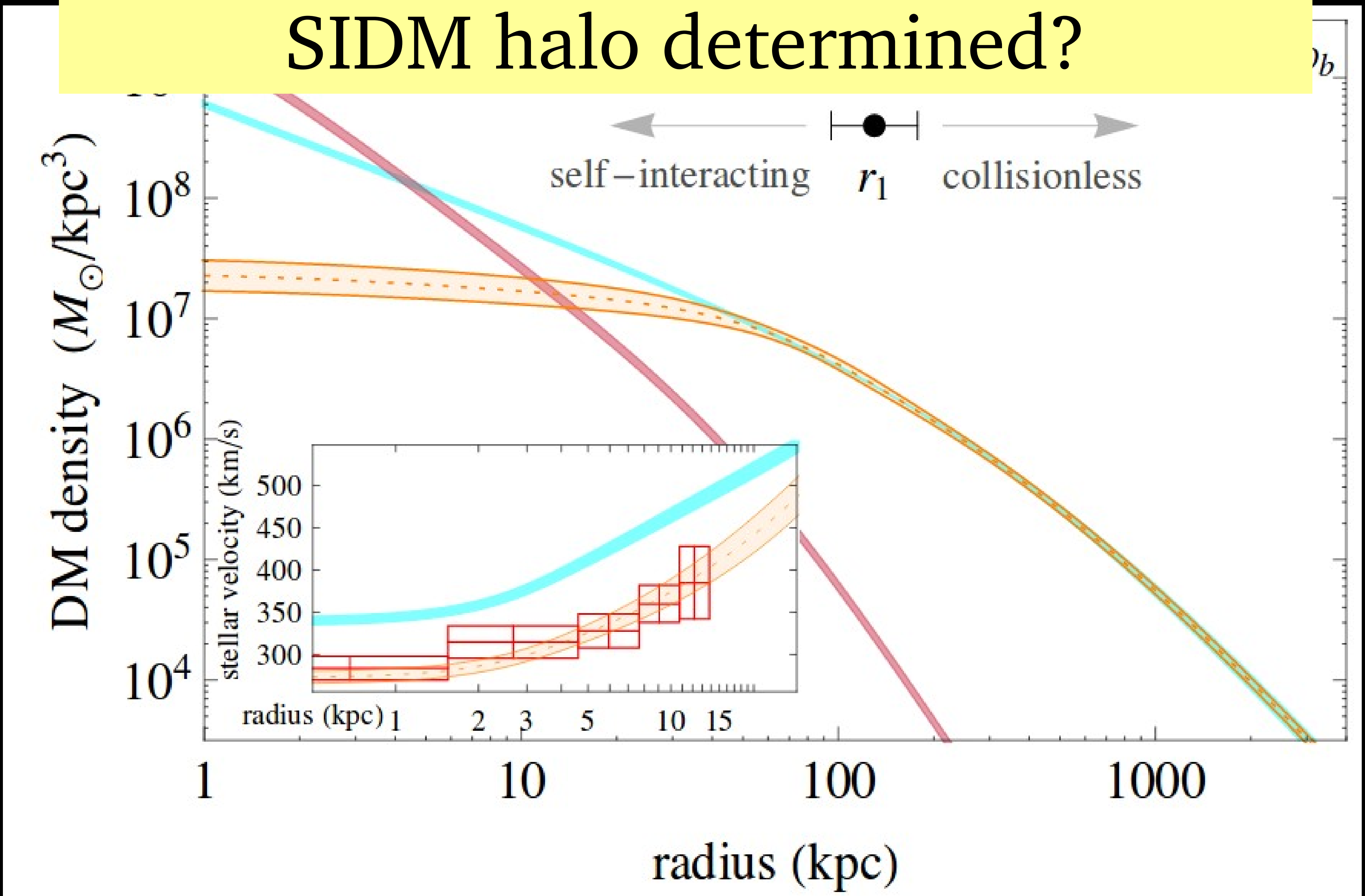
Need to assume stellar M/L ratio

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?

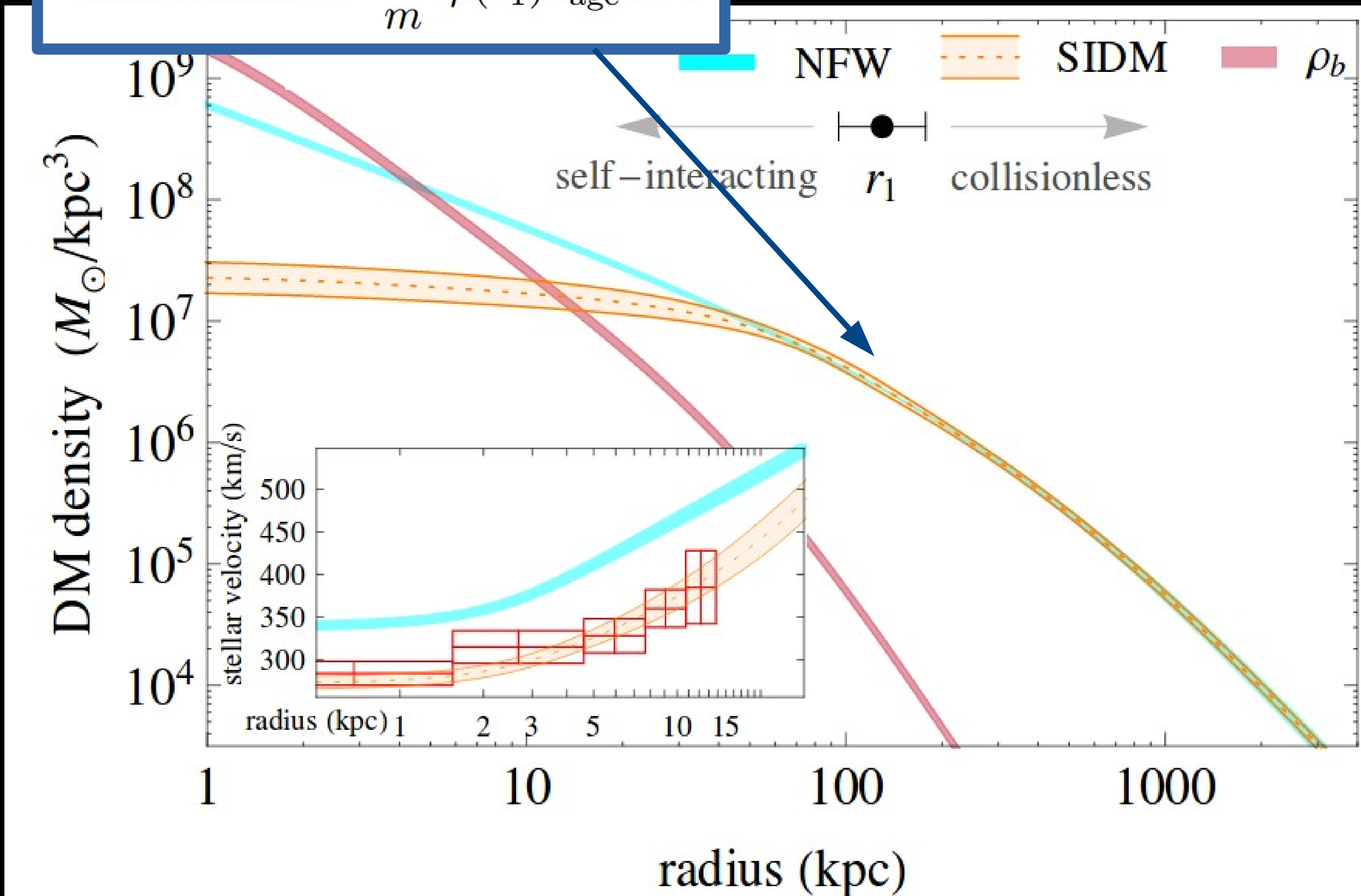
Do we recover the radial acceleration relation?

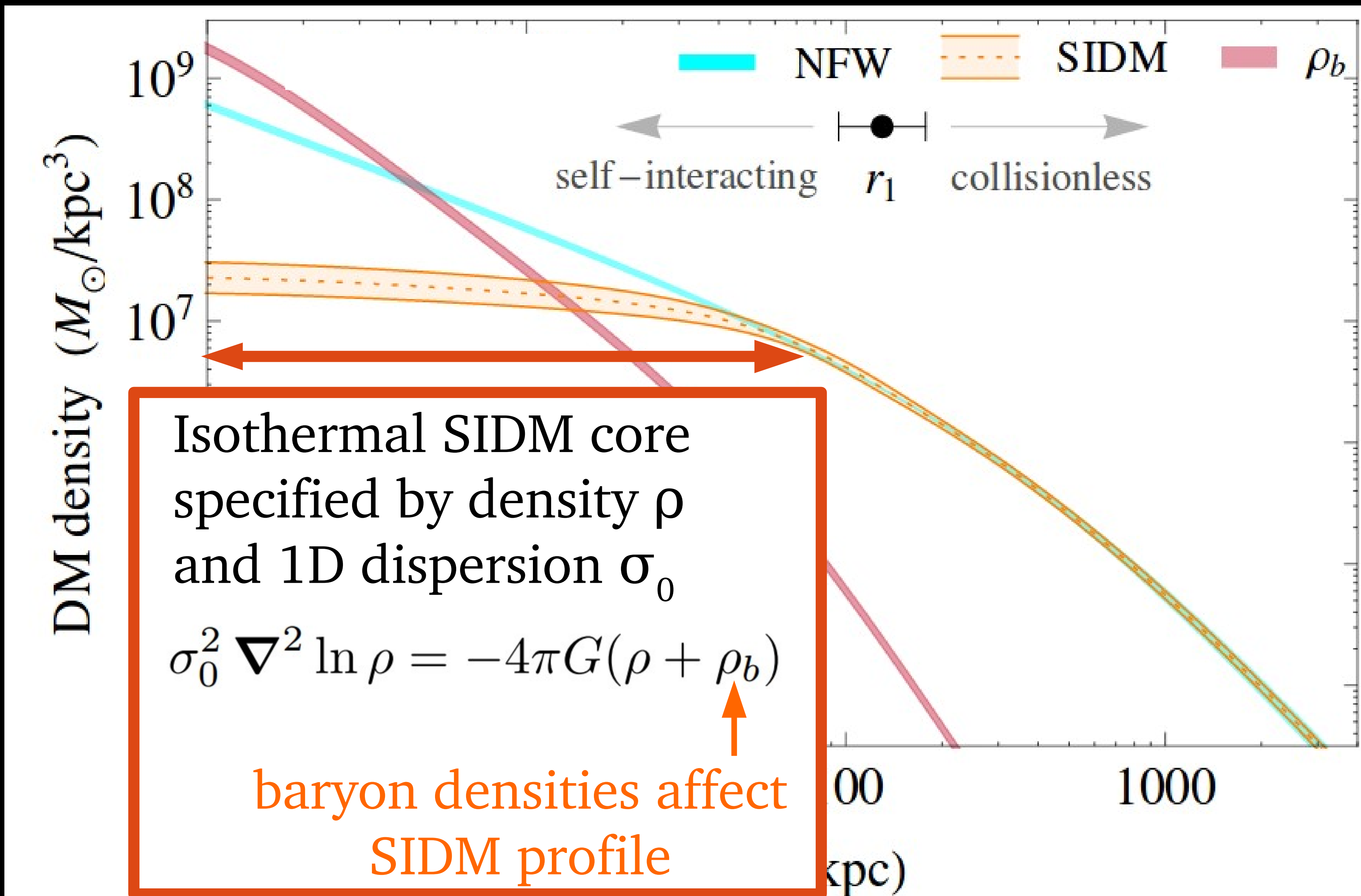
How is the density profile in an SIDM halo determined?



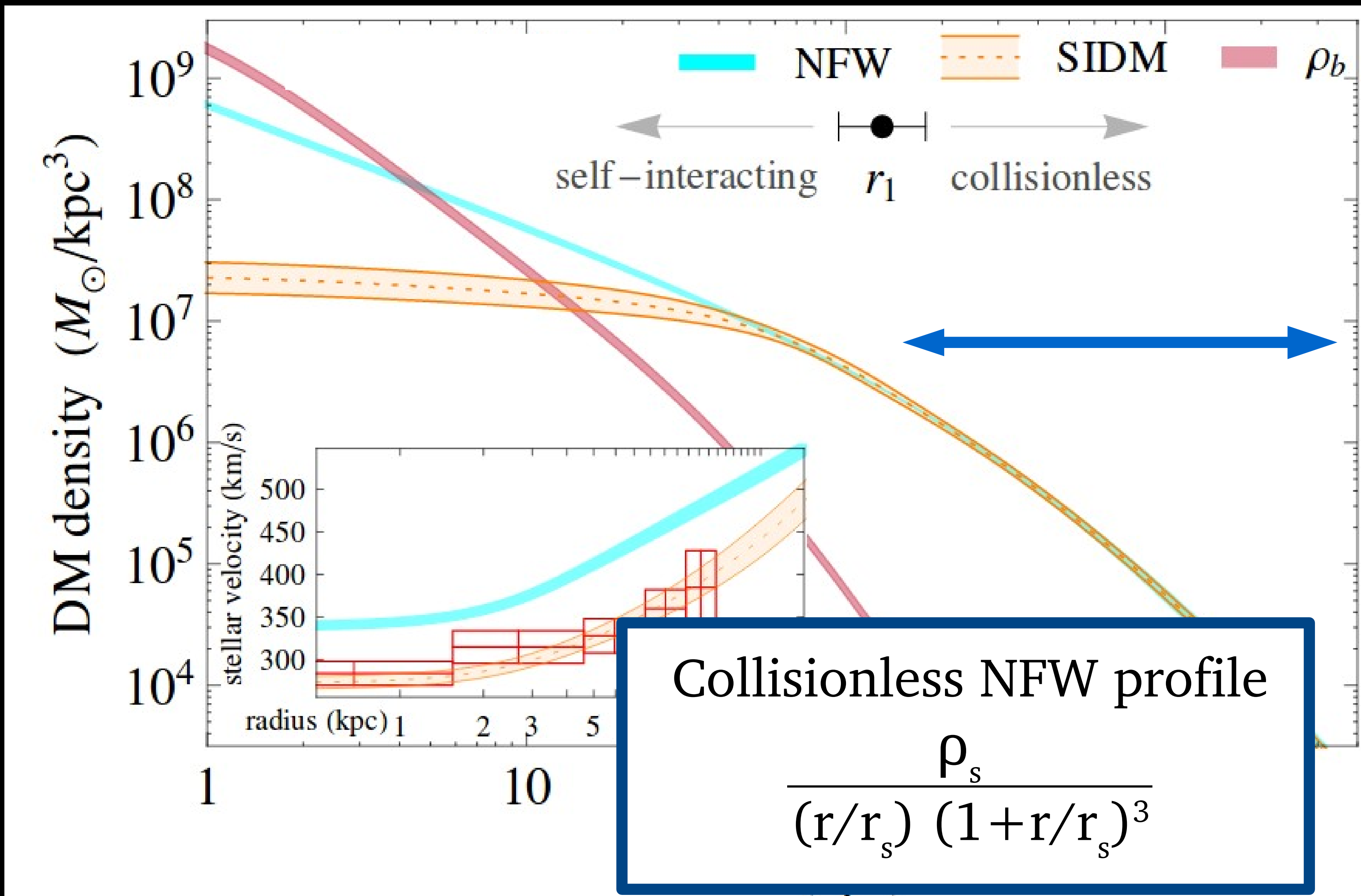
characteristic scale r_1

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





NFW
SIDM
ρ_b
self−interacting
r_1
collisionless
10^9
10^8
10^7
DM density $(M_\odot/\mathrm{kpc}^3)$
1000
Isothermal SIDM core
specified by density ρ
and 1D dispersion σ_0
$\sigma_0^2 \nabla^2 \ln \rho = -4\pi G(\rho + \rho_b)$
baryon densities affect
SIDM profile



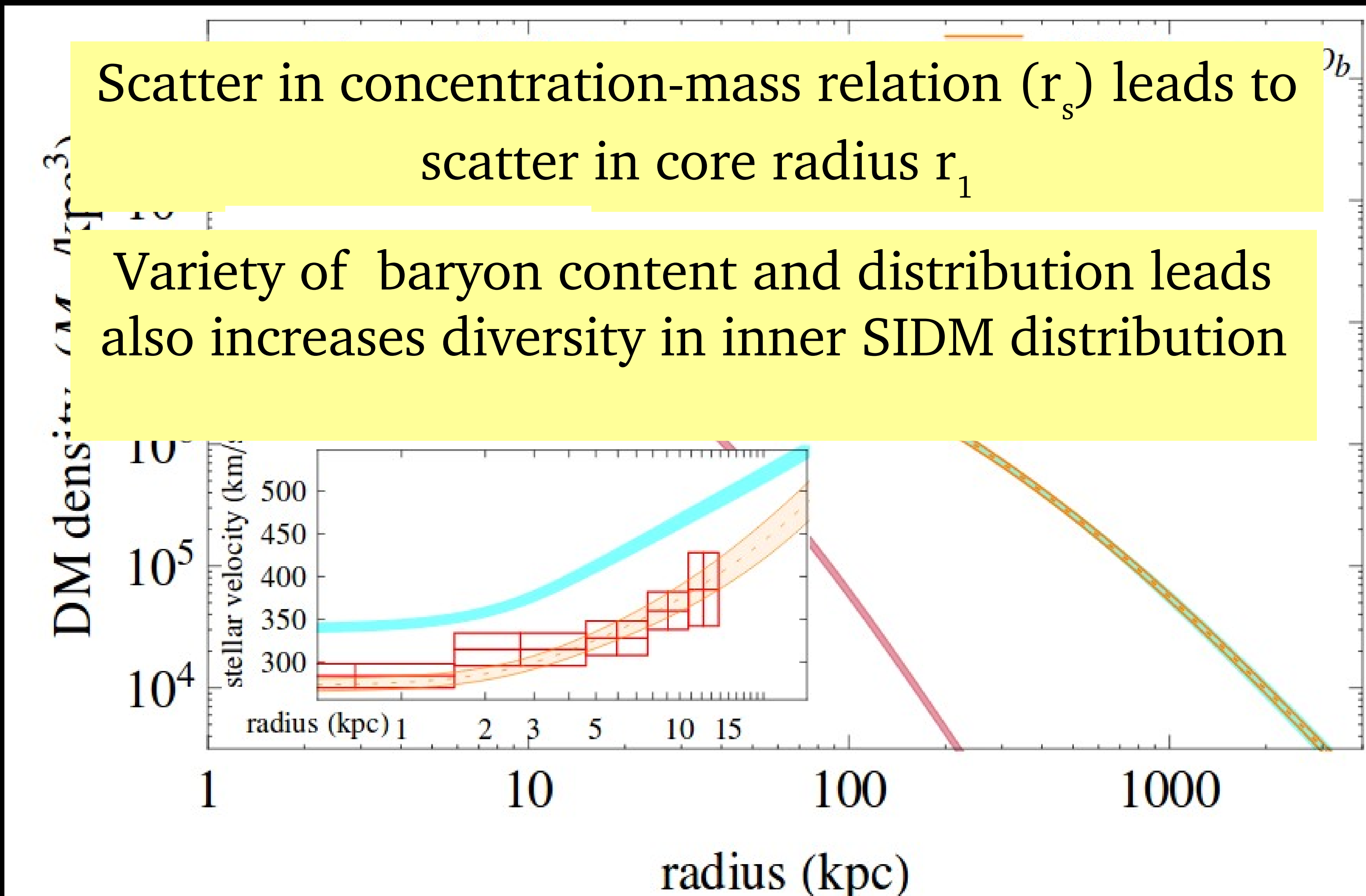
Collisionless NFW profile

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

Same mass range of galaxies can have very different SIDM density profiles (and rotation curves) due to:

Scatter in concentration-mass relation (r_s) leads to scatter in core radius r_1

Variety of baryon content and distribution leads also increases diversity in inner SIDM distribution



SPARC
Spitzer Photometry & Accurate Rotation Curves

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

MCMC fit

Want to find:

- SIDM density profile and contribution to rotation curve
- Stellar mass-to-light ratio

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_{max} - r_{max} (a.k.a. concentration-mass) relation from N-body simulations

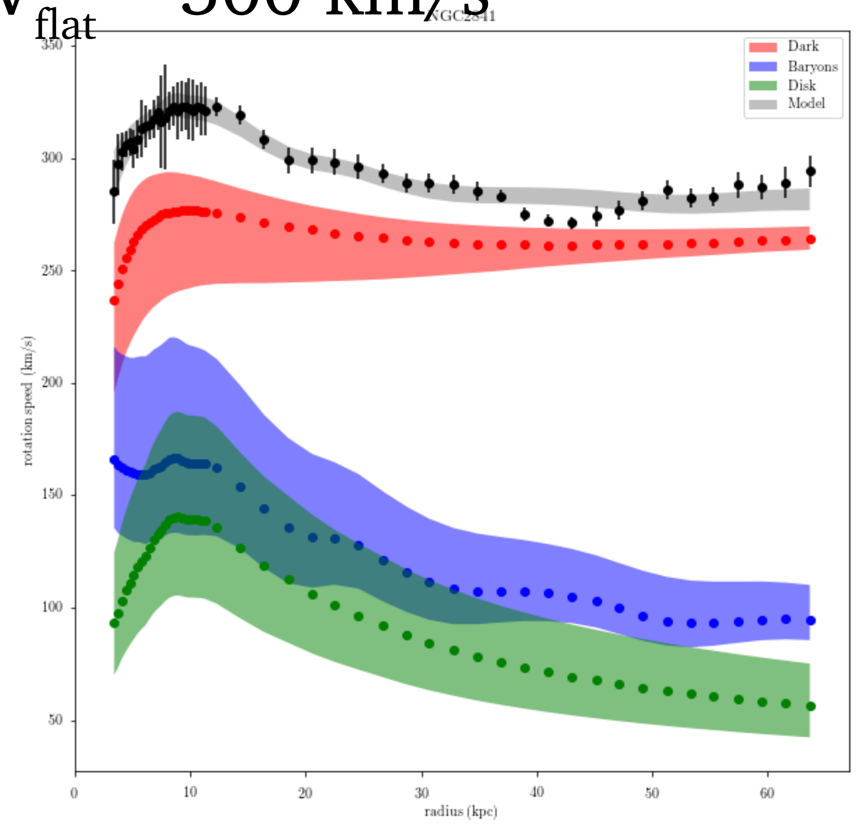
Red=dark matter

Blue=total baryons

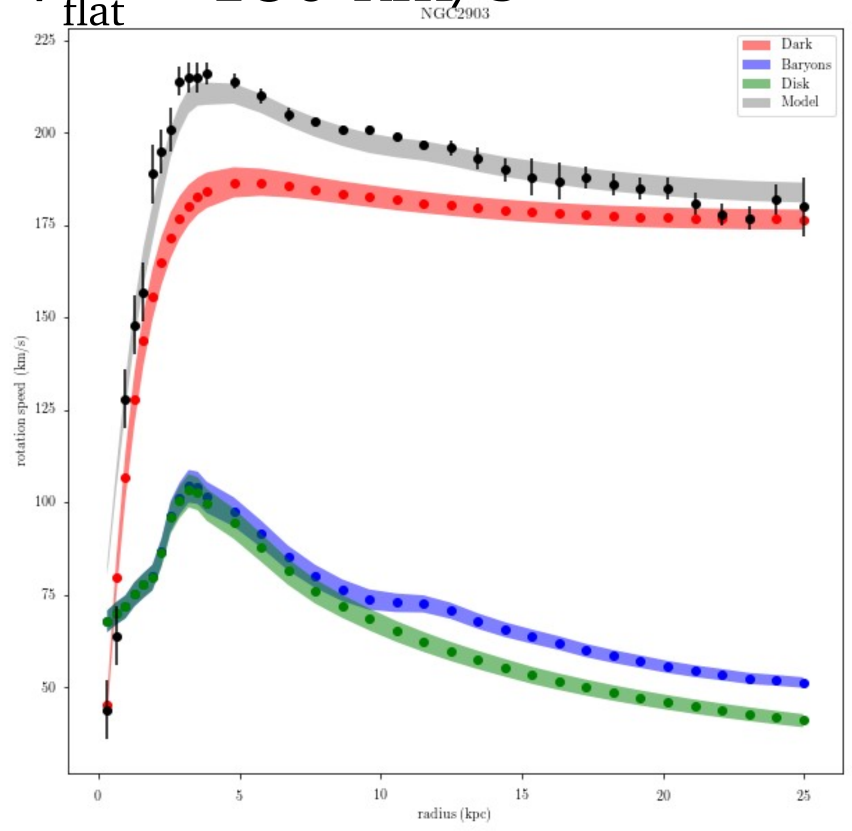
Green=disk

Grey=total model

V_{flat} ~300 km/s

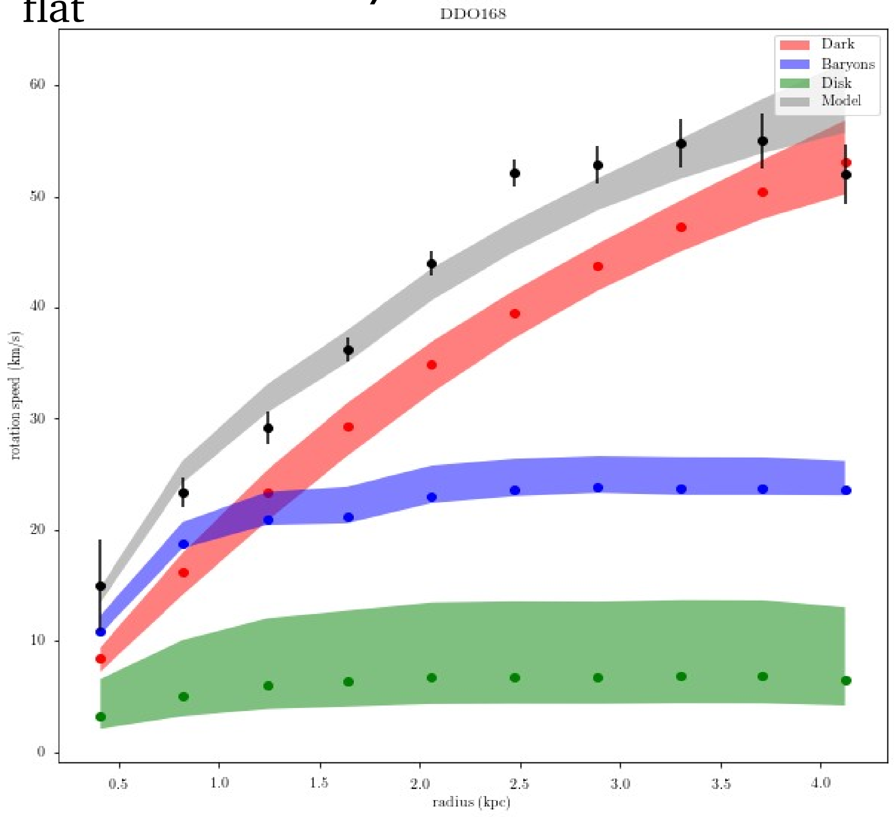


V_{flat} ~180 km/s

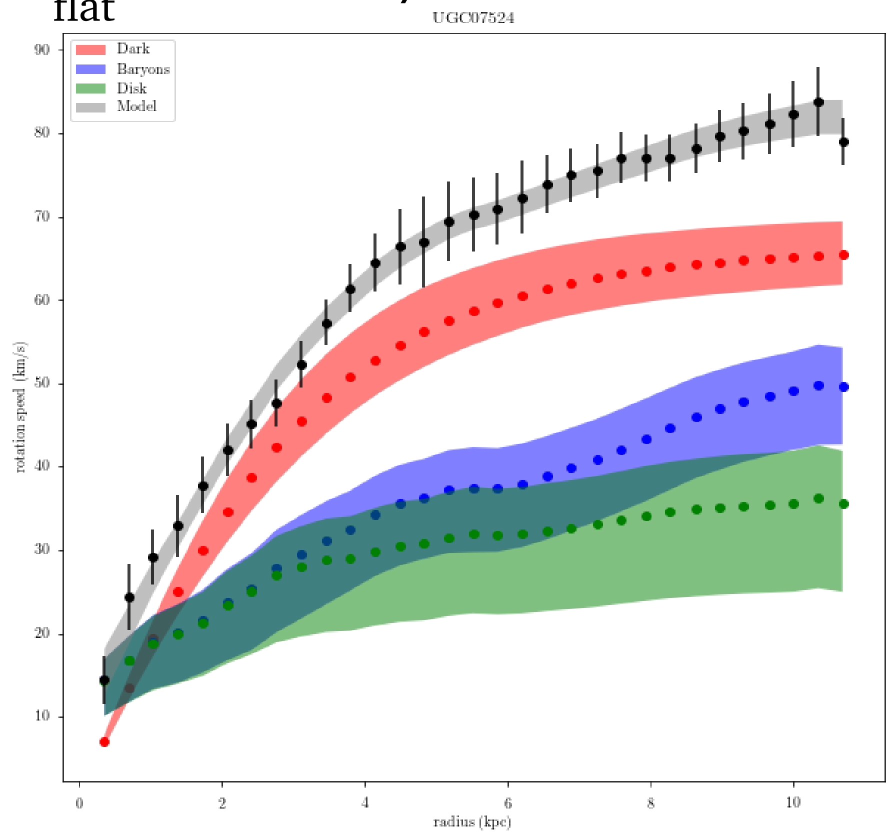


Red=dark matter
Blue=total baryons
Green=disk
Grey=total model

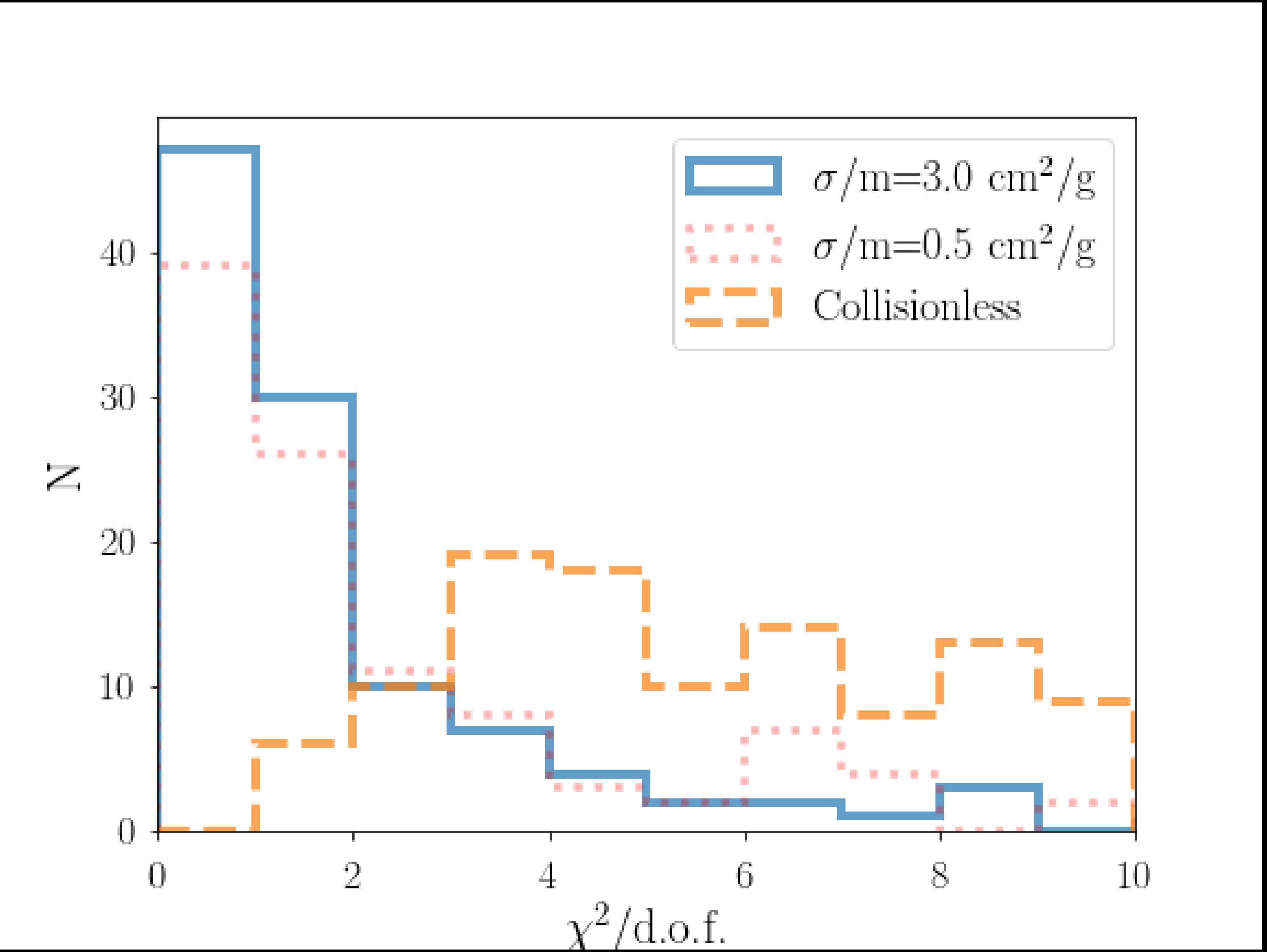
V_{flat} ~55 km/s



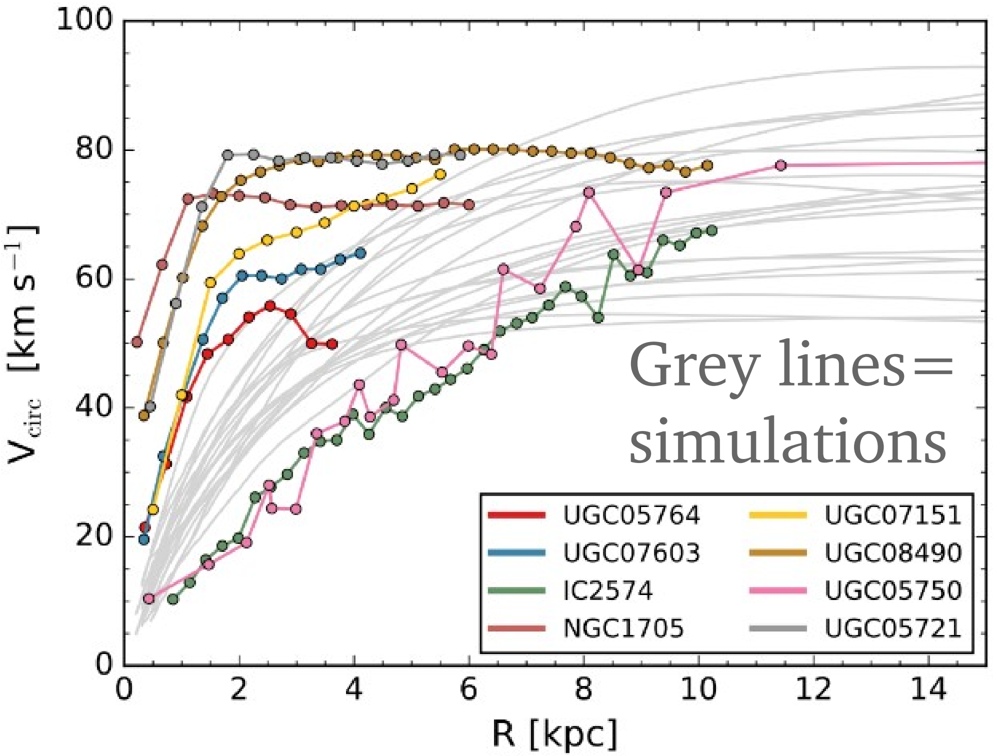
V_{flat} ~80 km/s

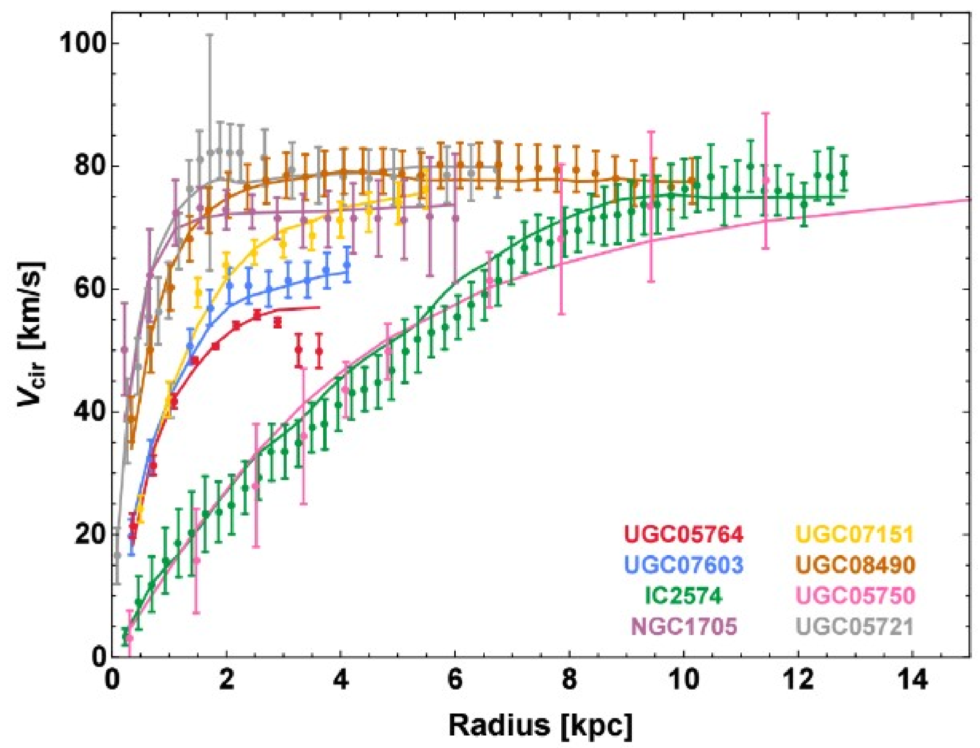


Fits prefer SIDM cross sections ~3 cm²/g over lower cross sections or collisionless DM



Strong baryonic feedback vs. SIDM under the influence of baryons

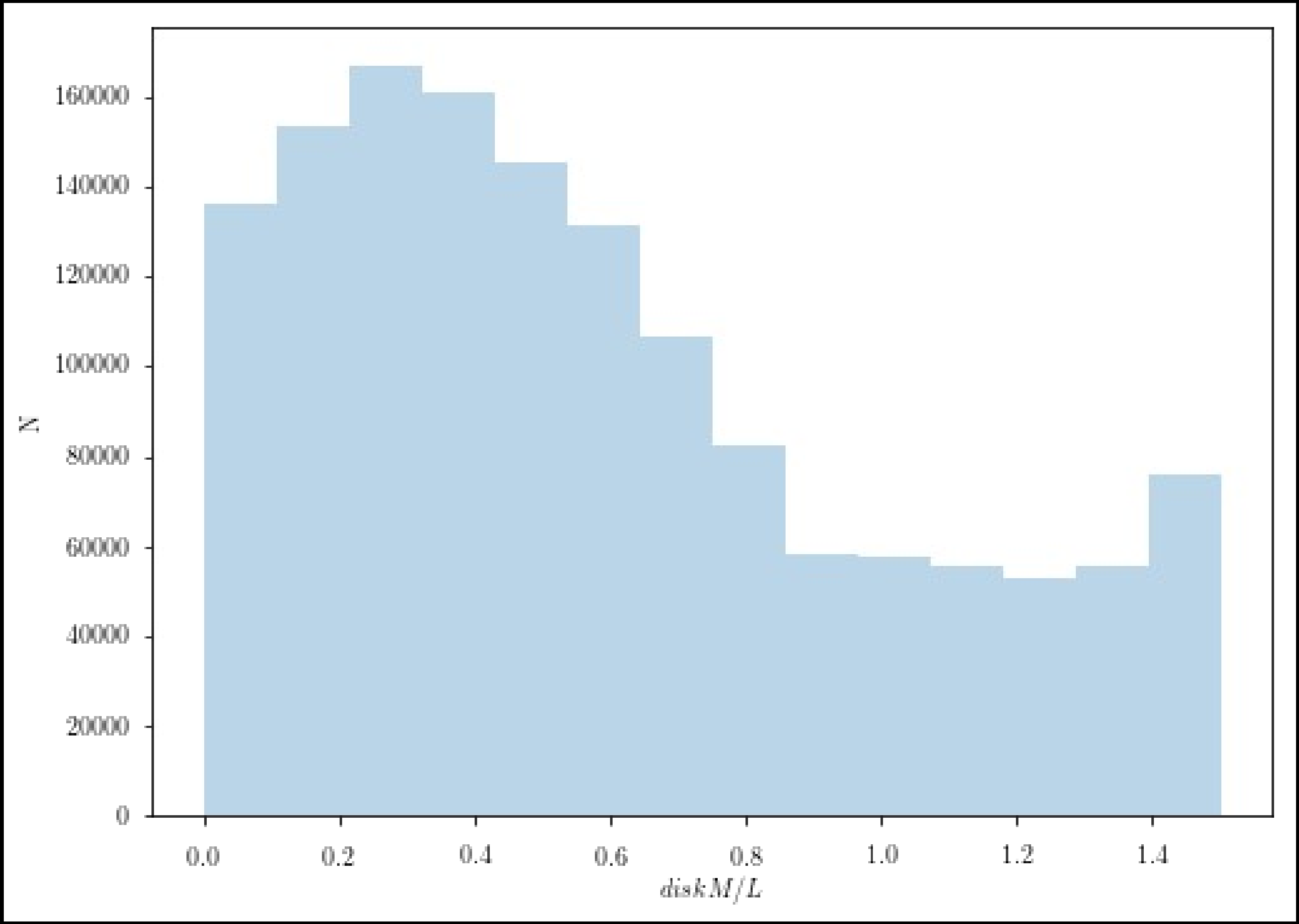




Santos-Santos+17, NIHAO collaboration

This work

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



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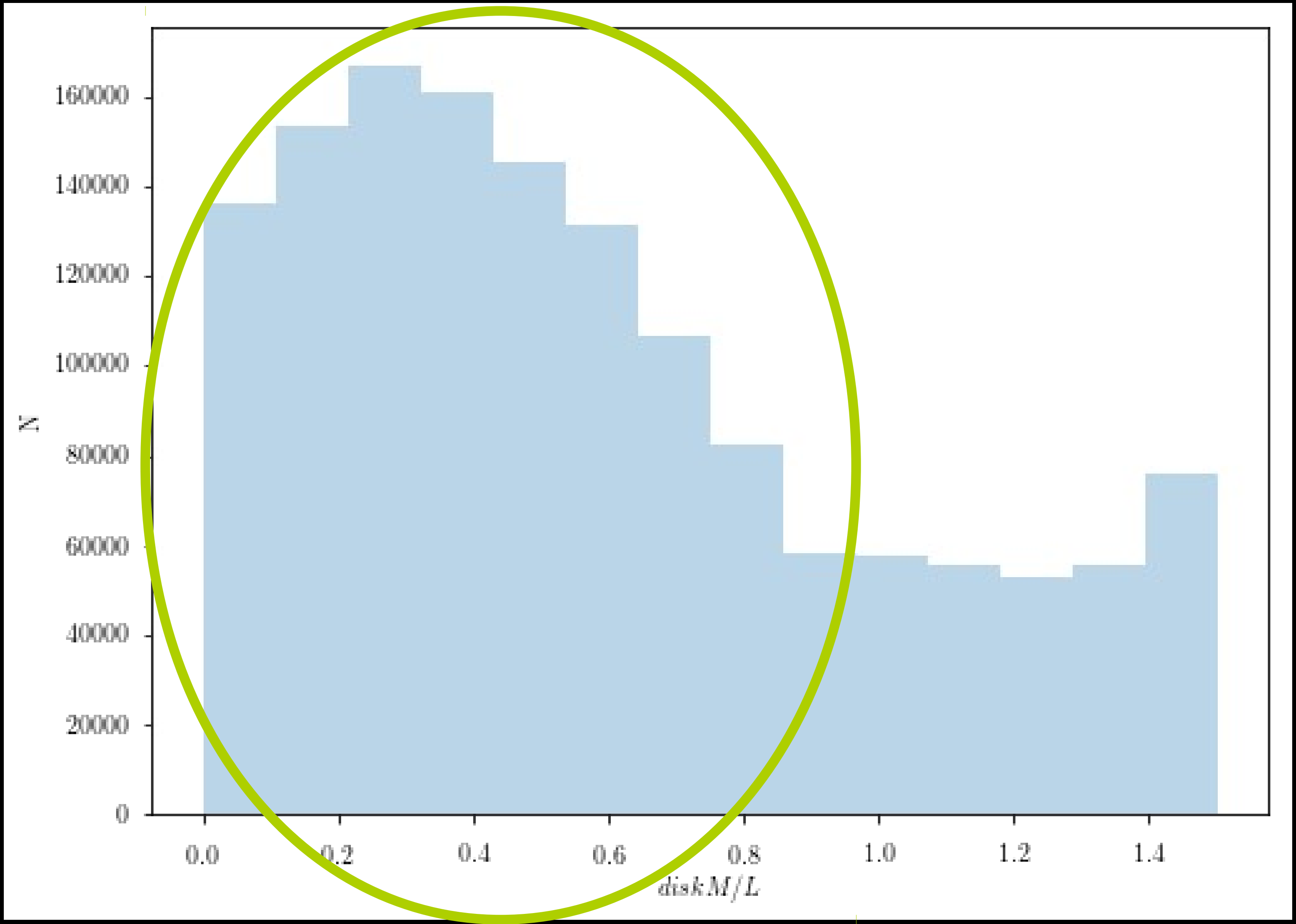

General agreement with population synthesis models (M/L ~0.4-0.6)

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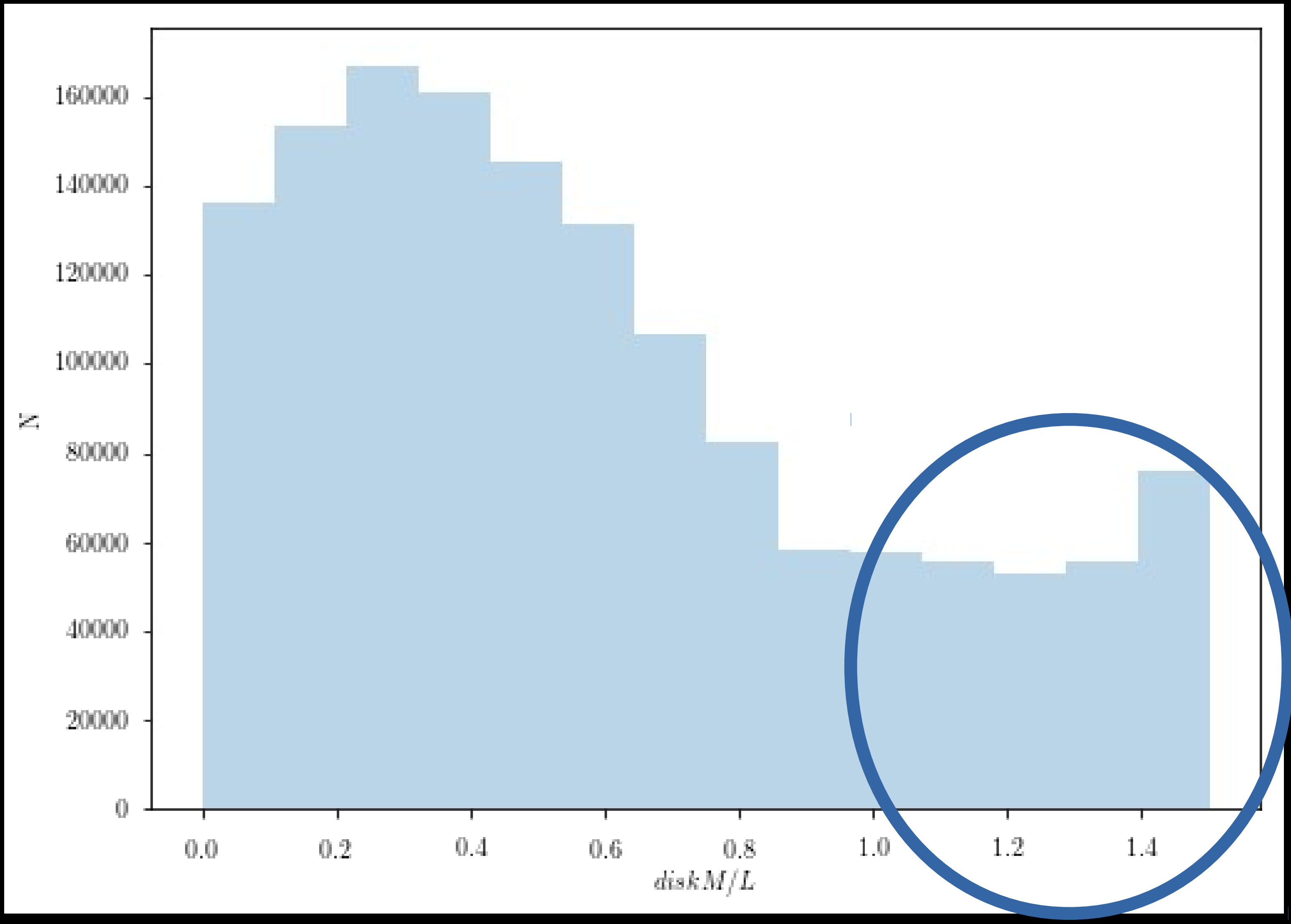
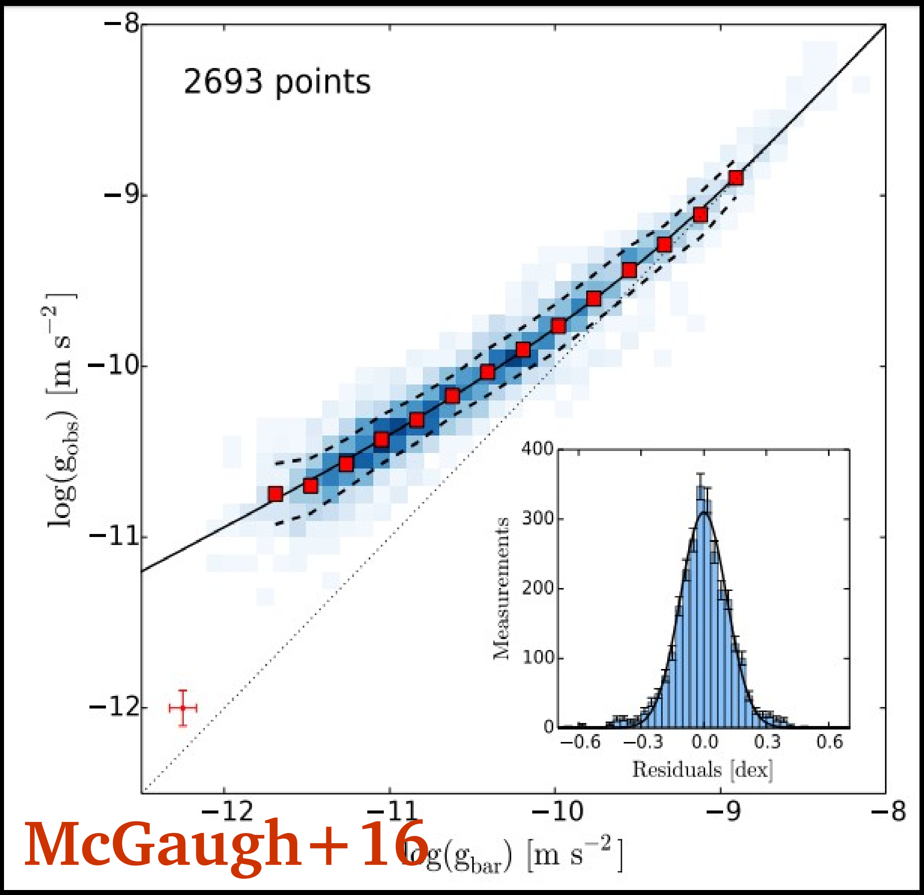
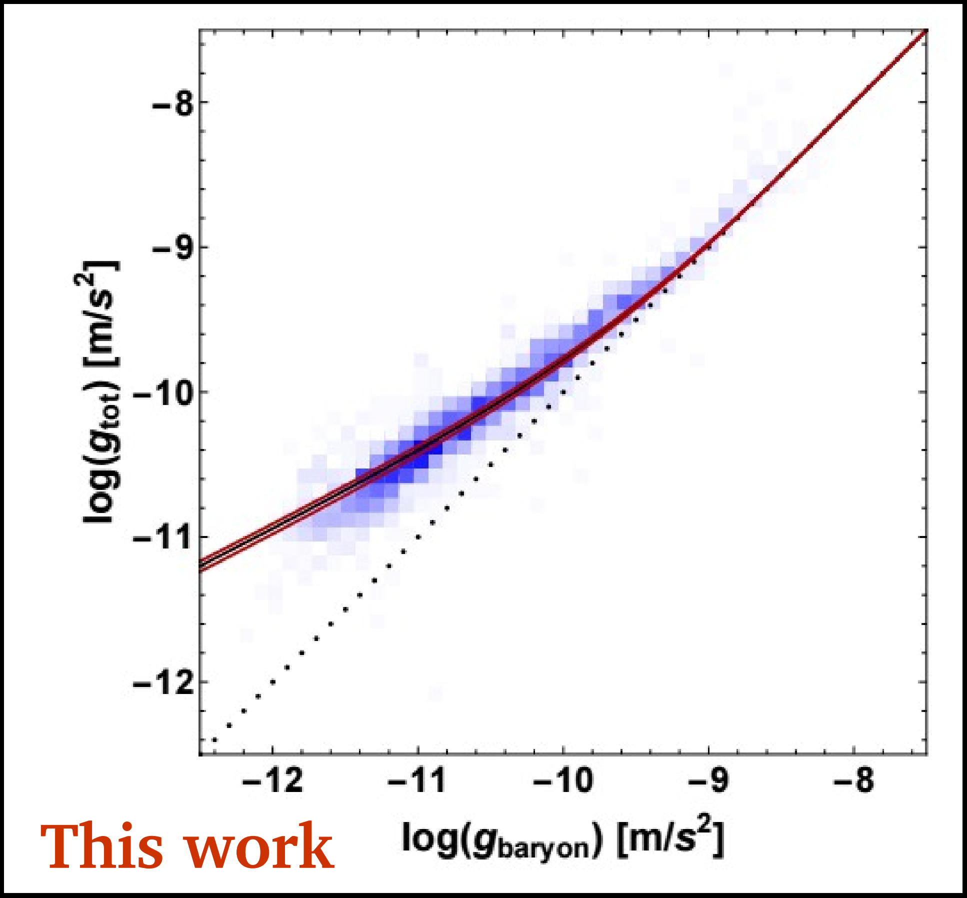


Radial variation in stellar populations driving M/L higher? Beware of bias from inner data points

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



McGaugh+16

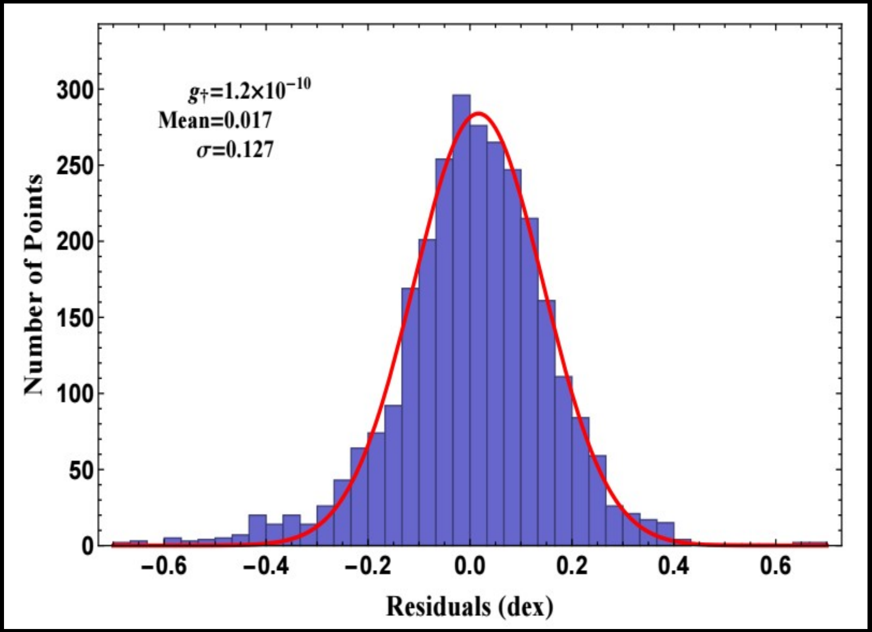


This work

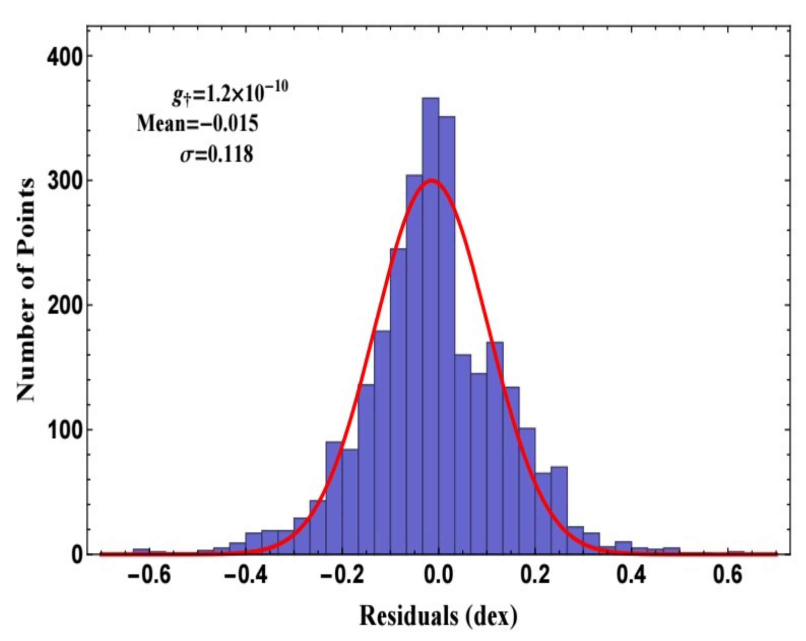
Scatter in data points from empirical radial acceleration relation is equal to / less than McGaugh+16

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

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 ~few cm^2/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} .