Determination of the DM density profile of the MW
(and how much to trust it)

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In collaboration with:
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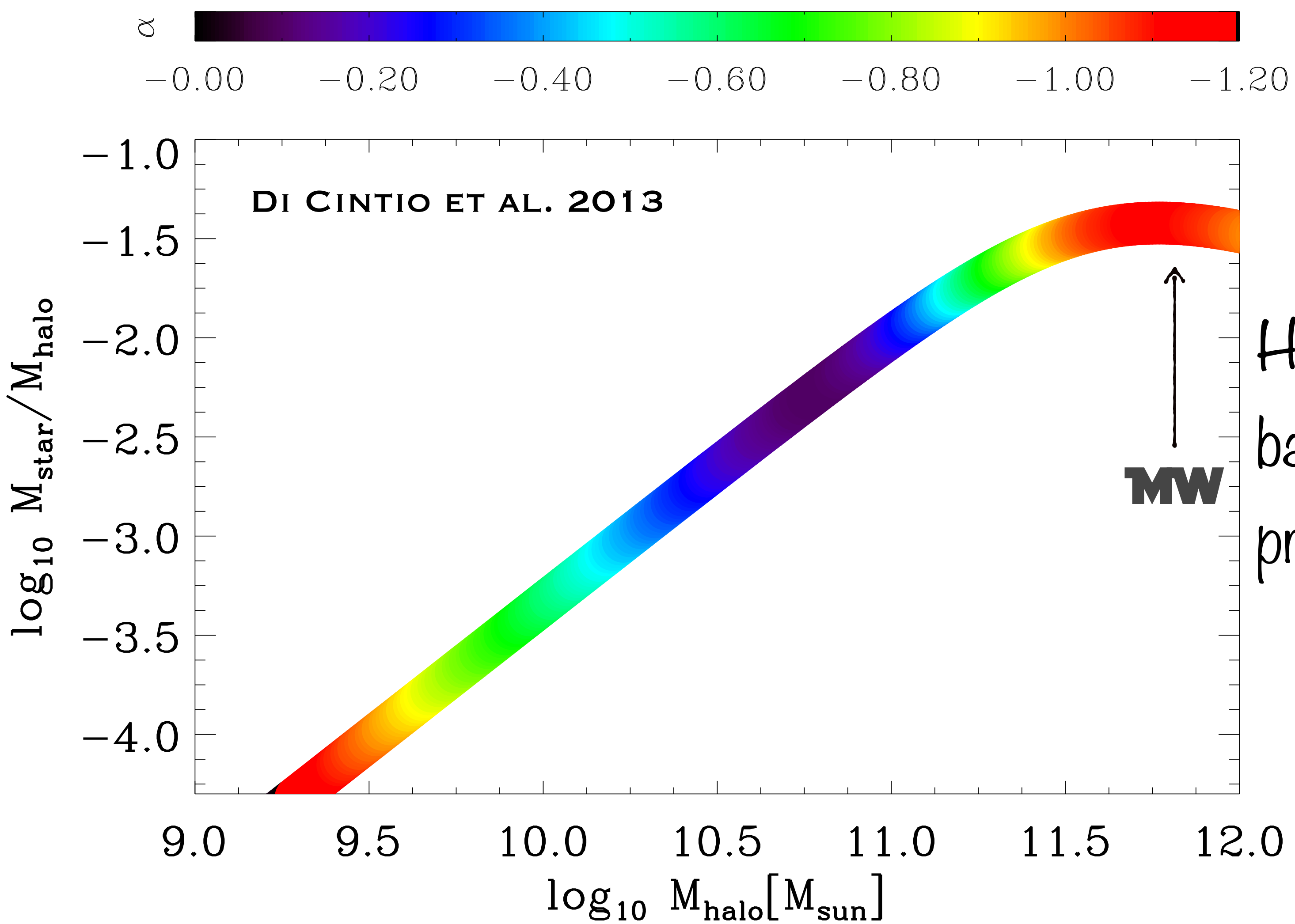
OUTLINE

- Why the knowledge of the DM distribution in the MW is important
- MW RC compilation
- MCMC - based reconstruction and results
- Mock RCs and MCMC - based reconstruction of their DM parameters
- Conclusions

Why it is important

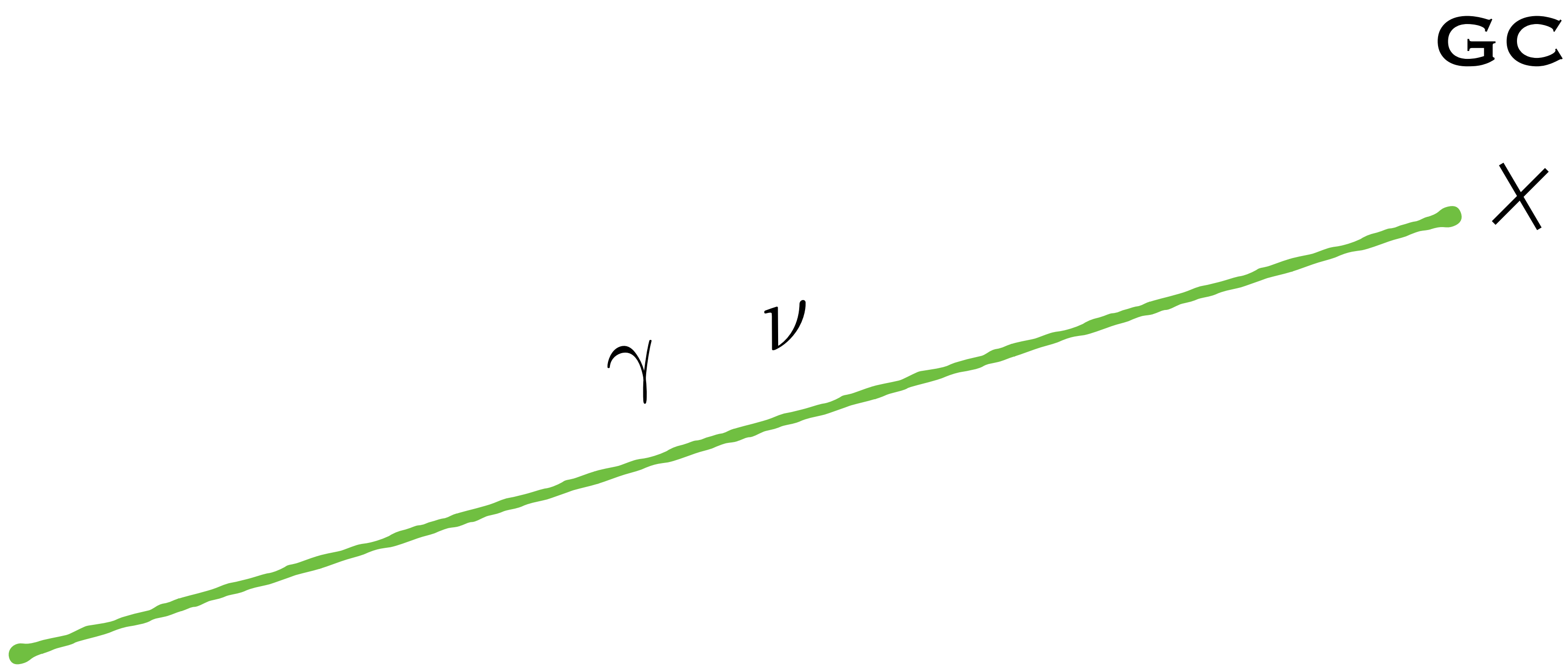
Galaxy formation theories



Hydrodynamical N-body simulations with baryonic feedback predict cuspy DM density profiles for galaxies with $M_{halo} \gtrsim \mathrm{few} \times 10^{11}\ M_{\odot}$

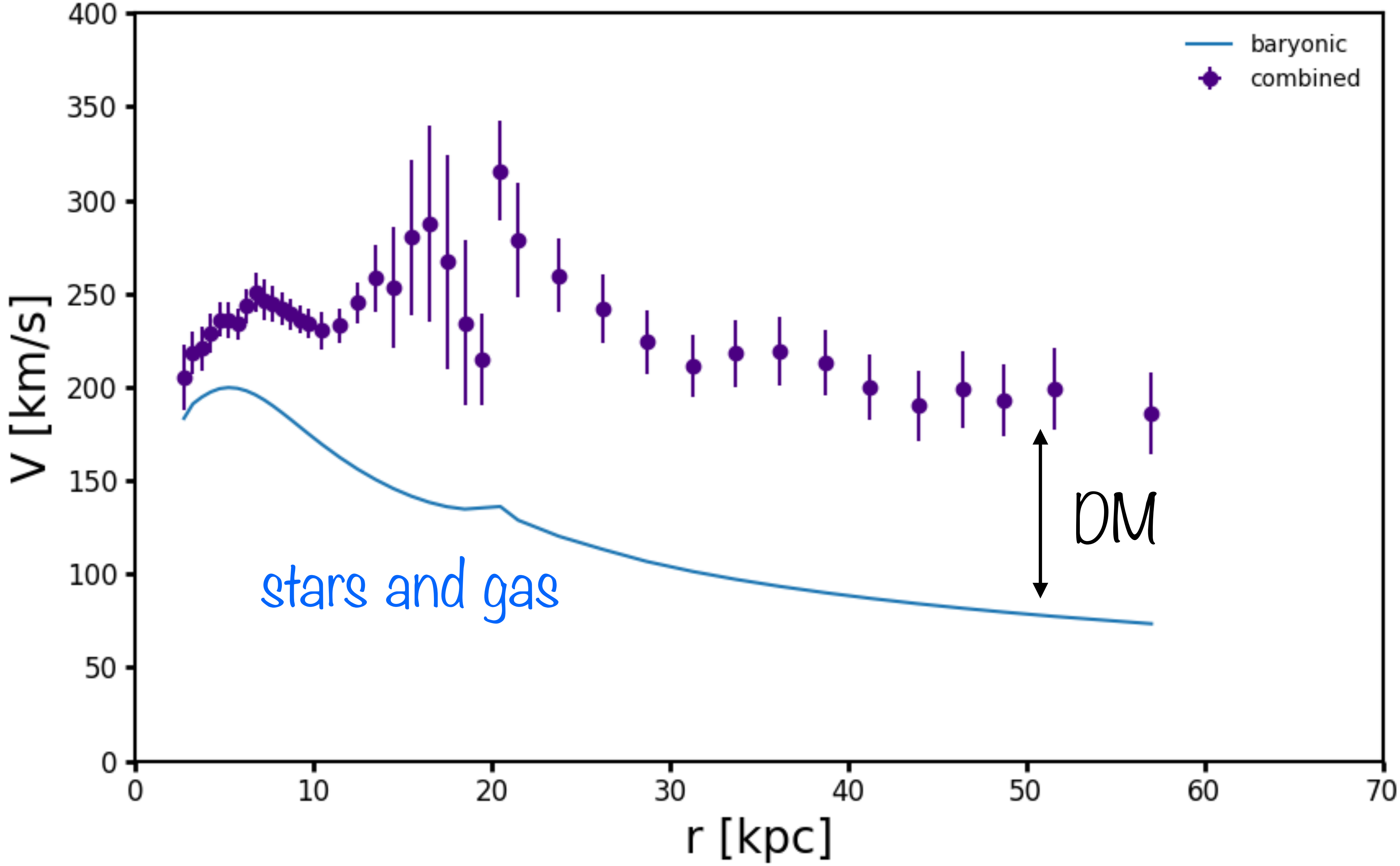
Why it is important

Indirect DM searches

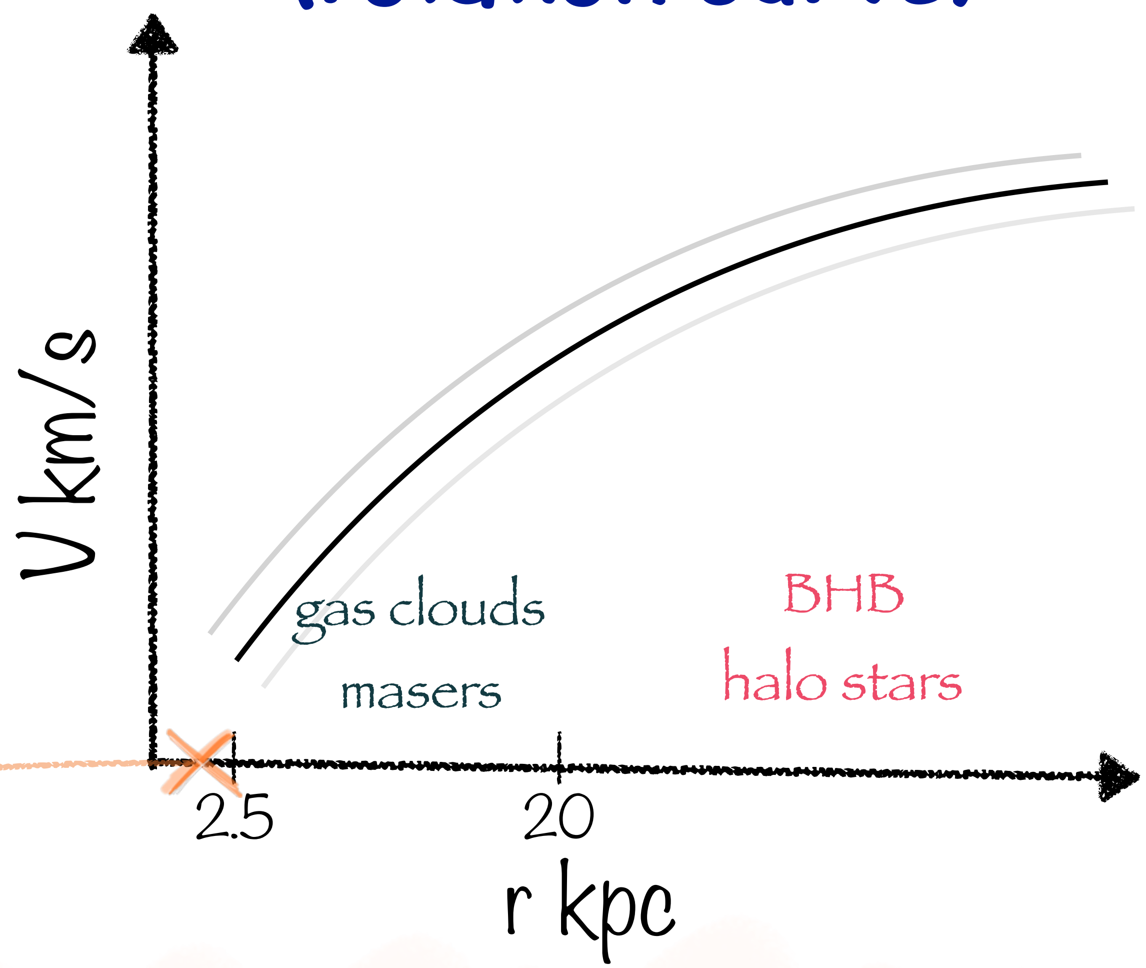


$$\frac{d\Phi}{dE} = \text{particle phys.} \int_{\Delta\Omega} d\Omega \int_{los} \rho^2_{DM}(l, \Omega) dl$$

Dynamics of the MW



Tracers of the total potential (rotation curve)

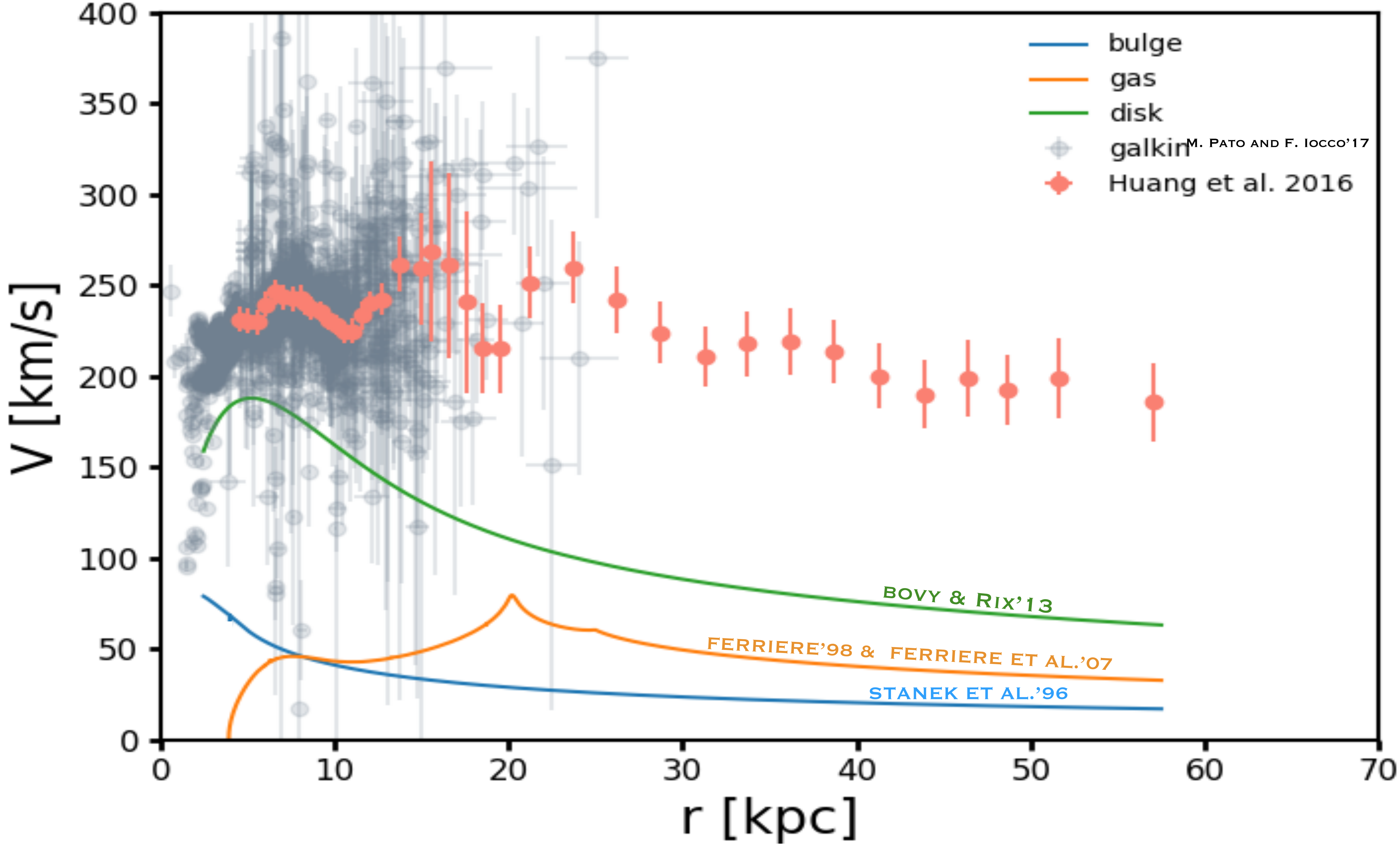


In the very inner part $\lesssim 2.5\ kpc$ we have triaxial bulge and nonaxisymmetric features of the Galactic bulge.

Compilation of MW RC

$(U_\odot, V_\odot, W_\odot) = (7.01, 10.13, 4.95)$ km/s

$\Theta_0 = 239.89$ km/s $\quad R_\odot = 8.34$ kpc



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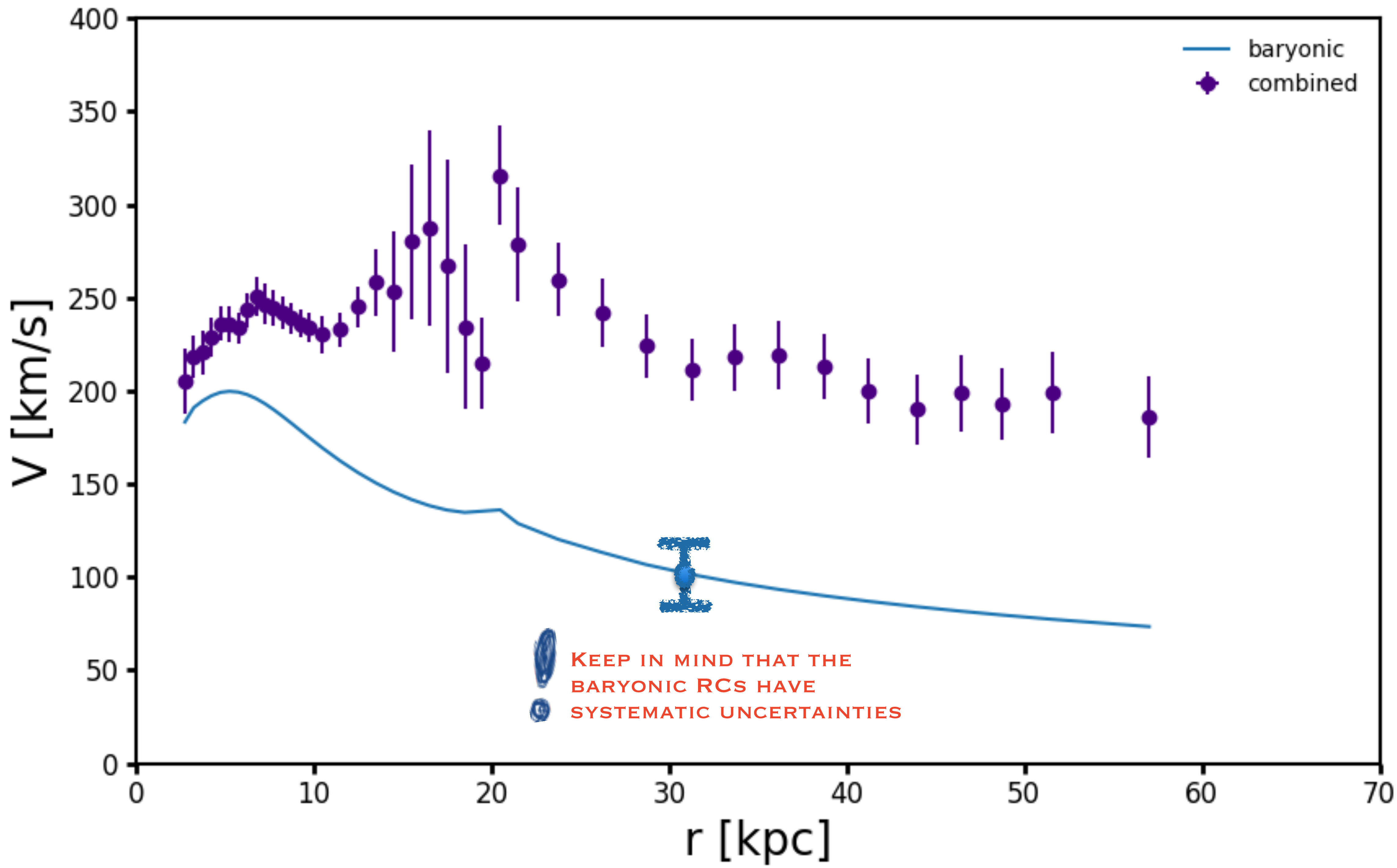


Methodology

standard approach

SEE E.G. SOFUE & RUBIN'01, CATENA & ULLIO'09...

total gravitational potential:

$$\phi_{total} = \phi_{bar} + \phi_{dm}$$

DM potential assuming spherical symmetry:

$$\phi_{dm} = -\frac{GM_{dm}(r)}{r} \longleftarrow M_{dm}(r) = 4\pi \int_0^R \rho_{dm}(r) r^2 dr$$

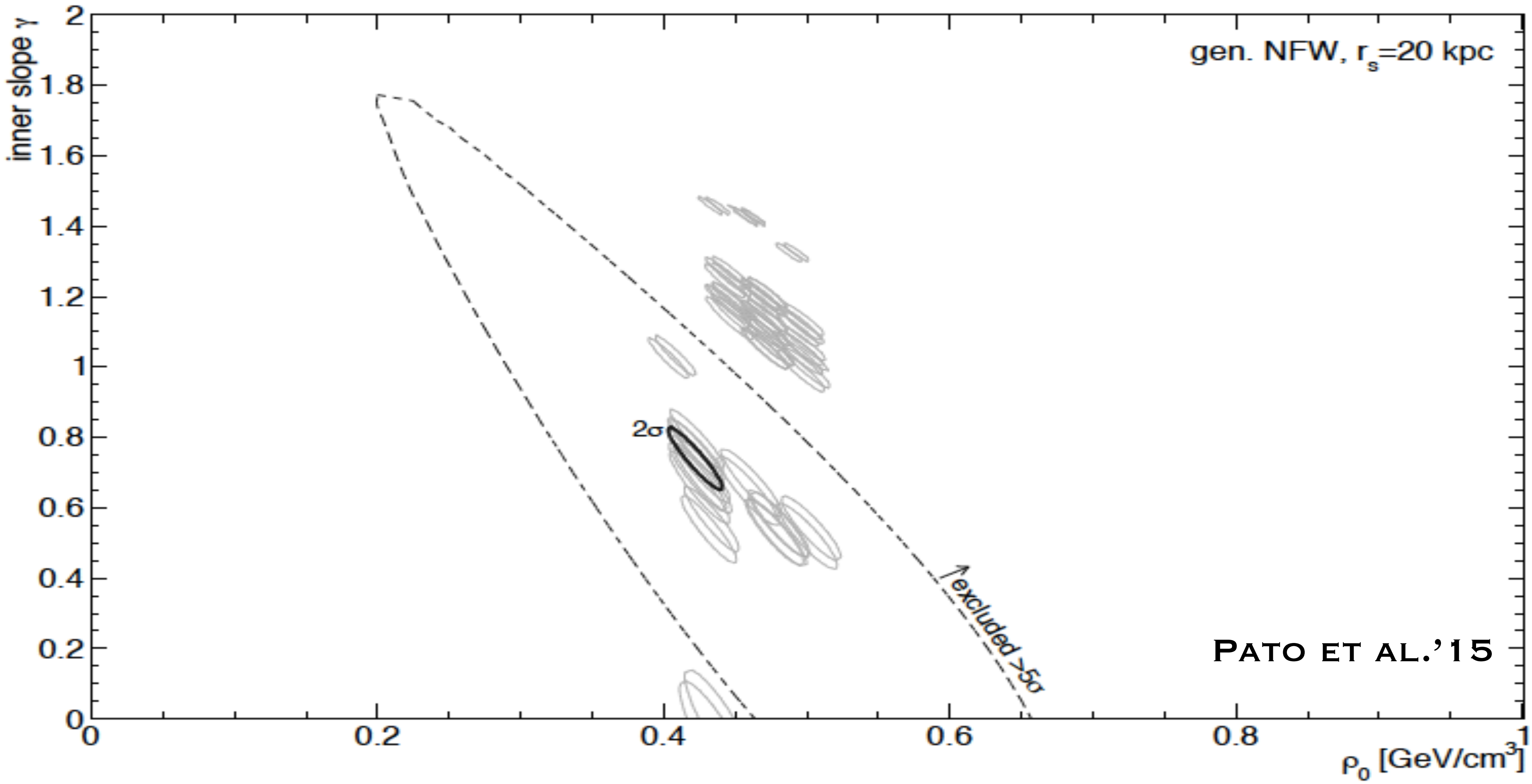
gNFW DM density profile:

$$\rho(R) = \frac{\rho_s}{(R/R_s)^\gamma (1 + R/R_s)^{3-\gamma}} \longleftarrow \rho_s = \rho_0 \left(\frac{R_0}{R_s}\right)^\gamma \left(1 + \frac{R_0}{R_s}\right)^{3-\gamma}$$

R_0 - Sun's position
ρ_0 - density at Sun's location

Methodology

standard approach



Pato et al.'15

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see also e.g. Sofue & Rubin'01, Catena & Ullio'09...

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Our free parameters: $\gamma \; \rho_0 \; r_s$

MCMC-based reconstruction

$$-2\mathrm{Ln}(\mathcal{L}) \propto \chi^2$$

where

Pato et al.'15

$38 \pm 4\, M_\odot/pc^2$ ⇓ (Stellar surface density term)

2.17 ± 0.47 ⇓ (Microlensing optical depth term)

$$\chi^2 = \sum_{i=1}^{n} \frac{(V^i_{totalRC} - V^i_{DM+bar}(r_s,\gamma,\rho_0))^2}{(\sigma^i_{totalRC})} + \frac{(\Sigma^{obs}_* - \Sigma_*)^2}{(\sigma^{obs}_{\Sigma_*})^2} + \frac{(<\tau>^{obs} - <\tau>)^2}{(\sigma^{obs}_\tau)^2}$$

Stellar surface density (disk)

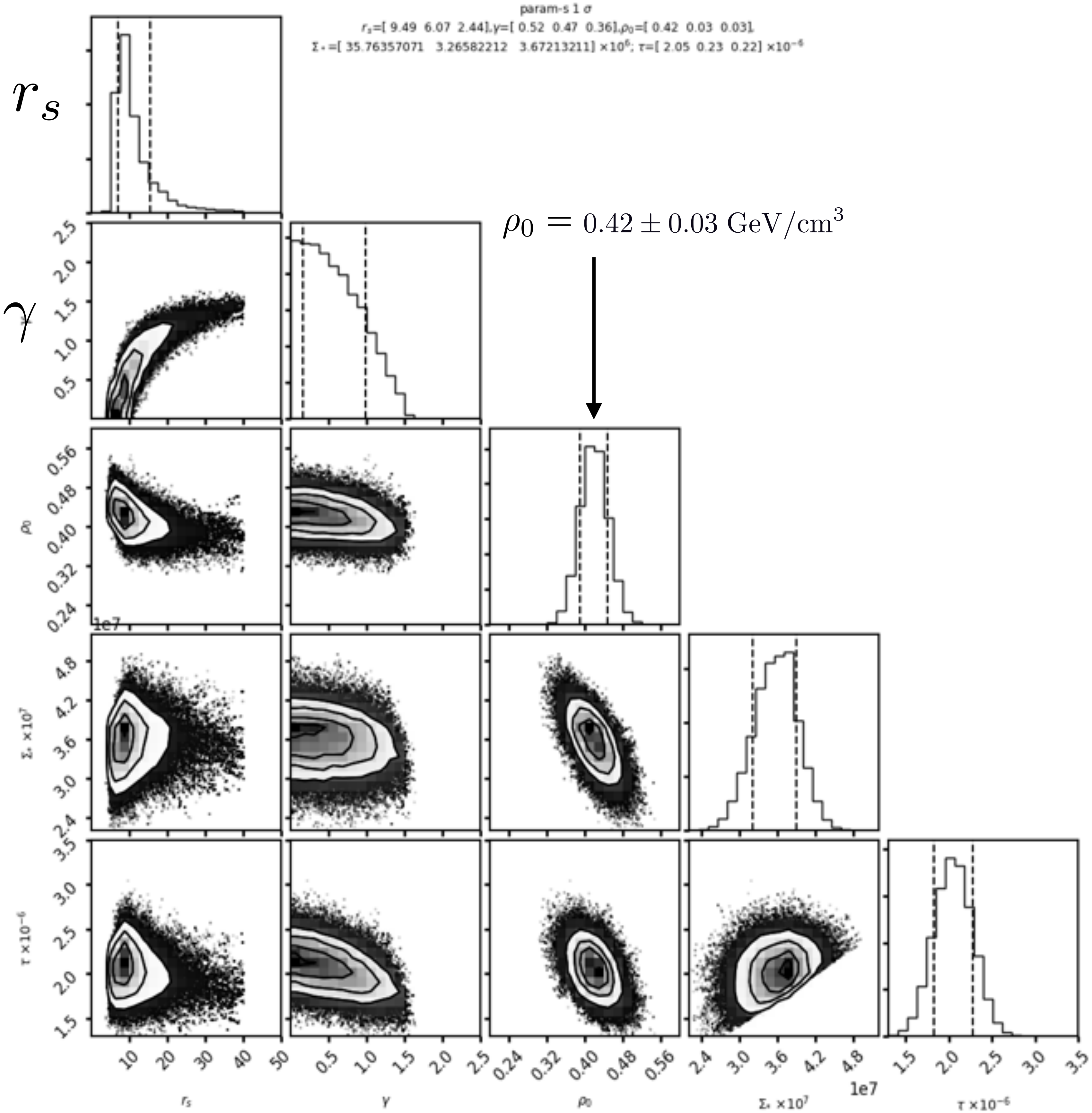
Microlensing optical depth (bulge)

MCMC-based reconstruction

r_s

γ

$\rho_0 = 0.42 \pm 0.03\ \mathrm{GeV/cm^3}$



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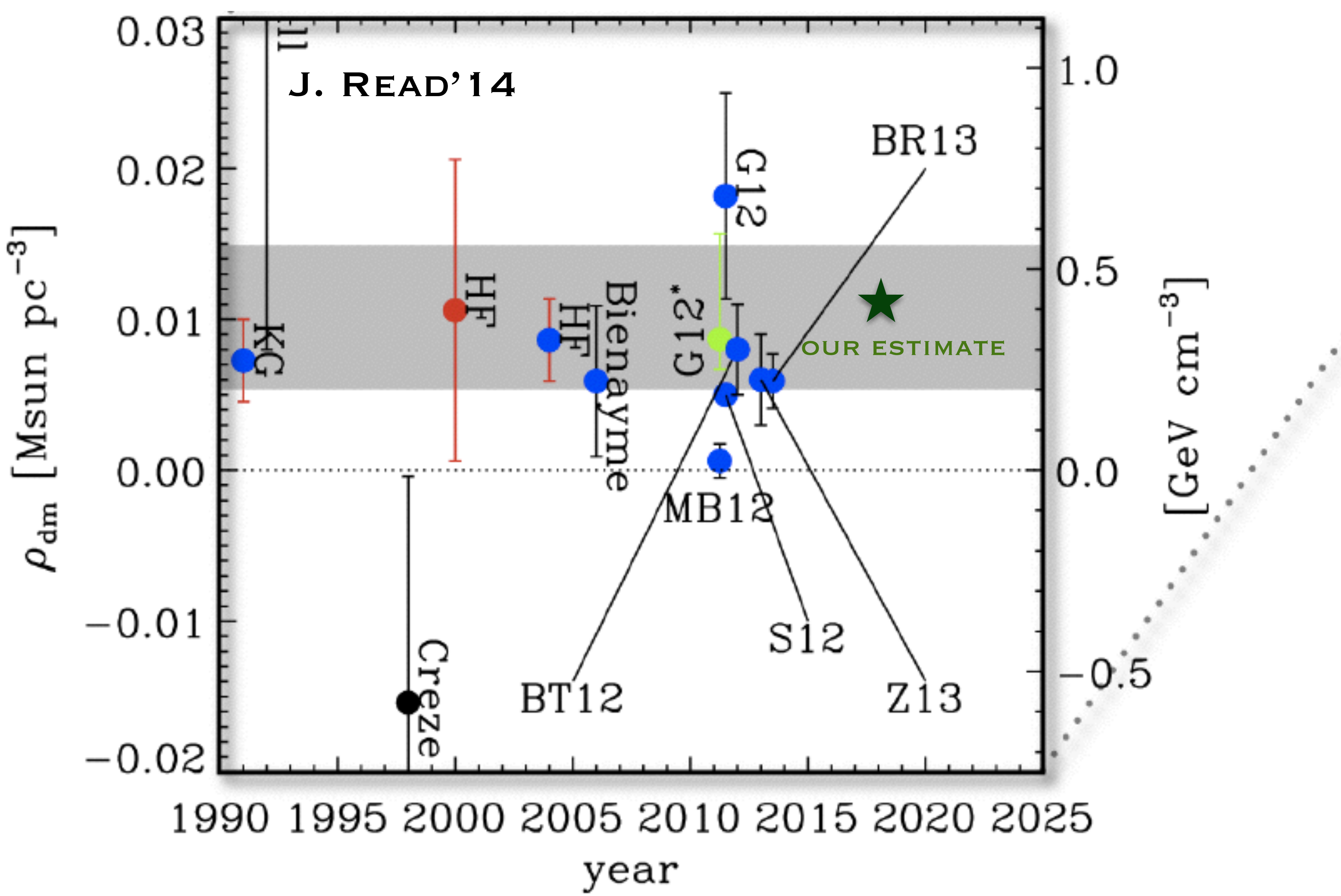

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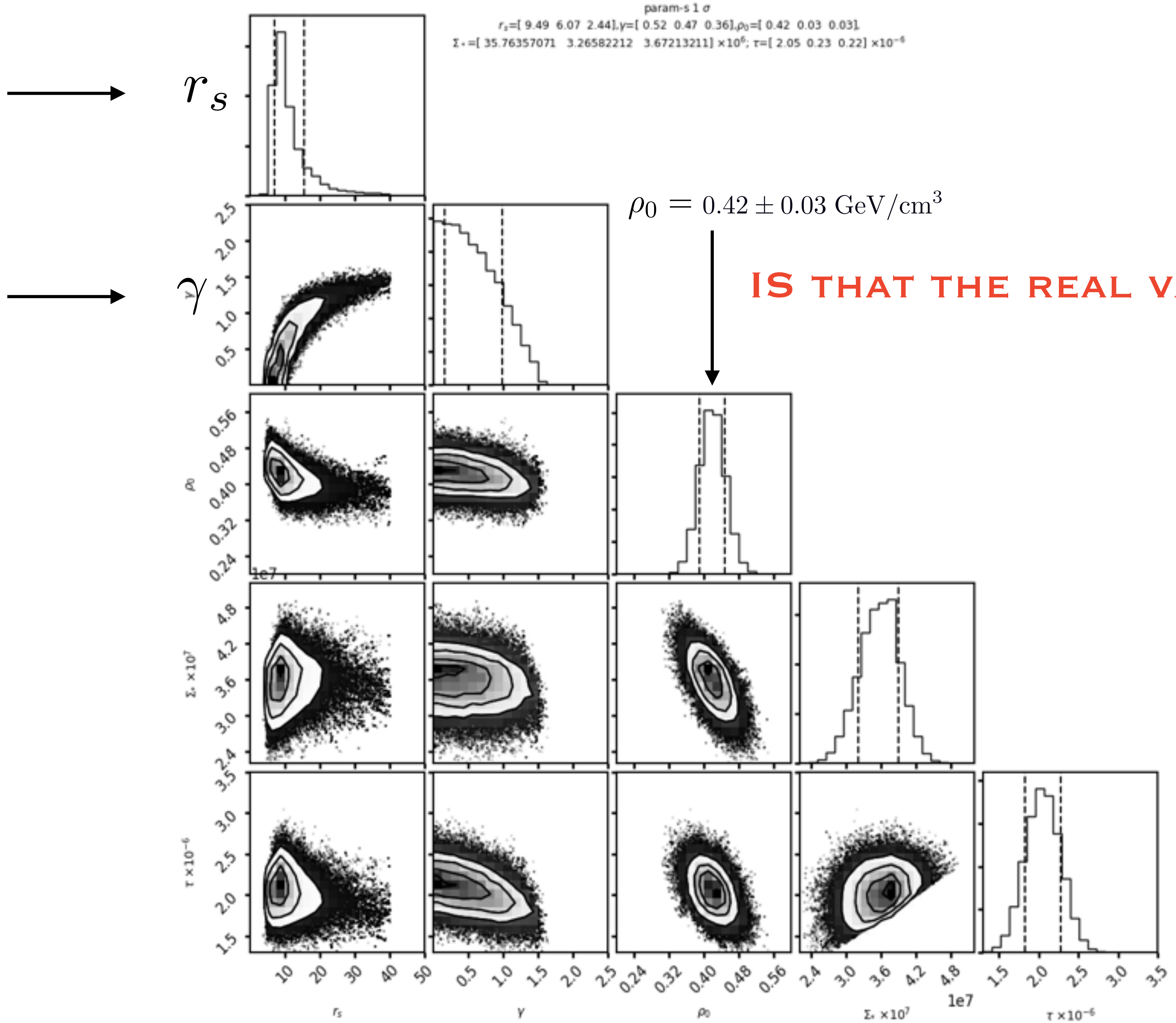


$\rho_0 = 0.42 \pm 0.03\ \mathrm{GeV/cm^3}$

IS THAT THE REAL VALUE?

MCMC-based reconstruction and mock RCs

The idea is to test the MCMC-based reconstruction by creating mock rotation curves based on "underlying known" DM profiles (+ visible) and with the same statistical properties of the observed RC

We use the following way to create the mock data:

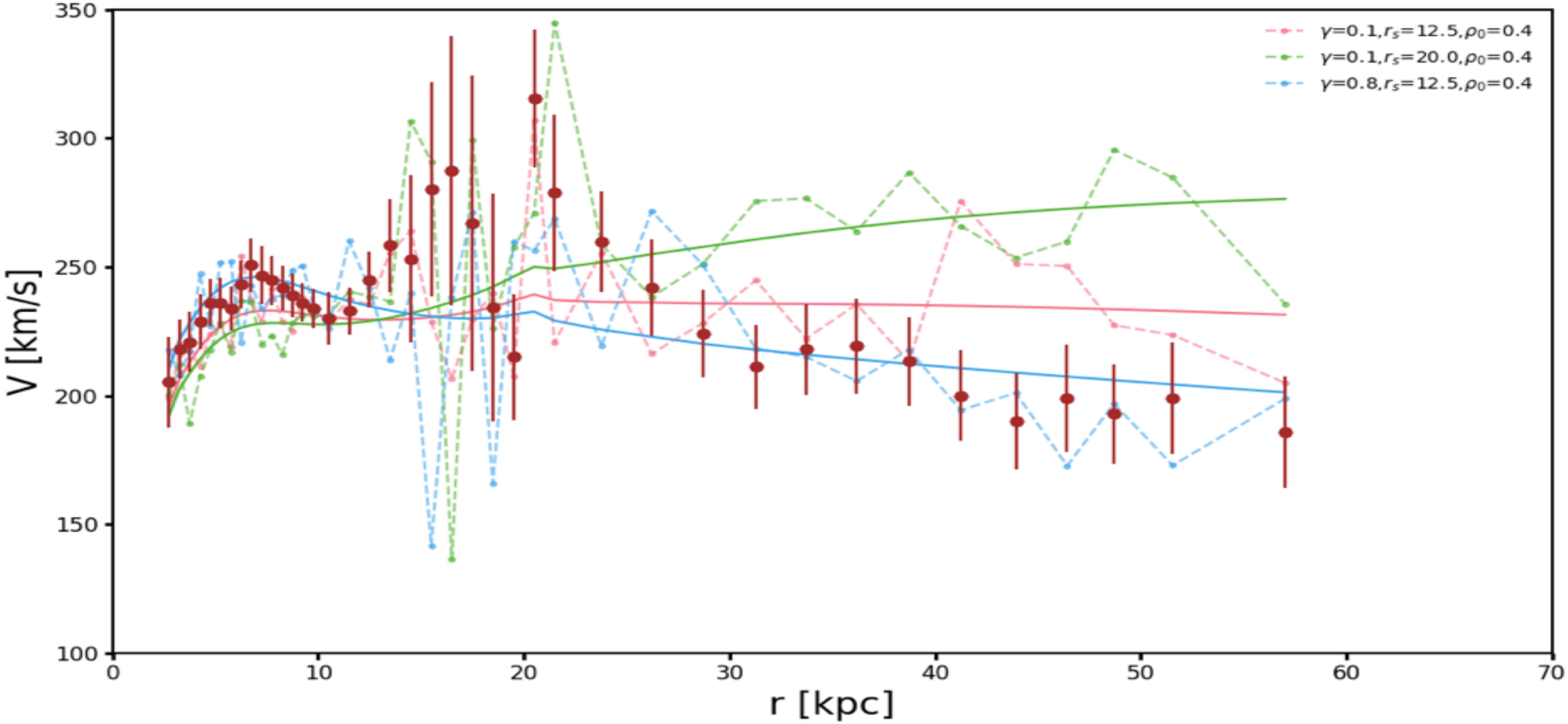
$$V_{mock} = V_{fiducial} + X\,\sigma$$

and

$$V_{fiducial} = V_{bar} + V_{gNFW}$$

X is the standard random gaussian variable with mean=0 and std dev=1 and σ is the error of the observed total RC

MCMC-based reconstruction and mock RCs



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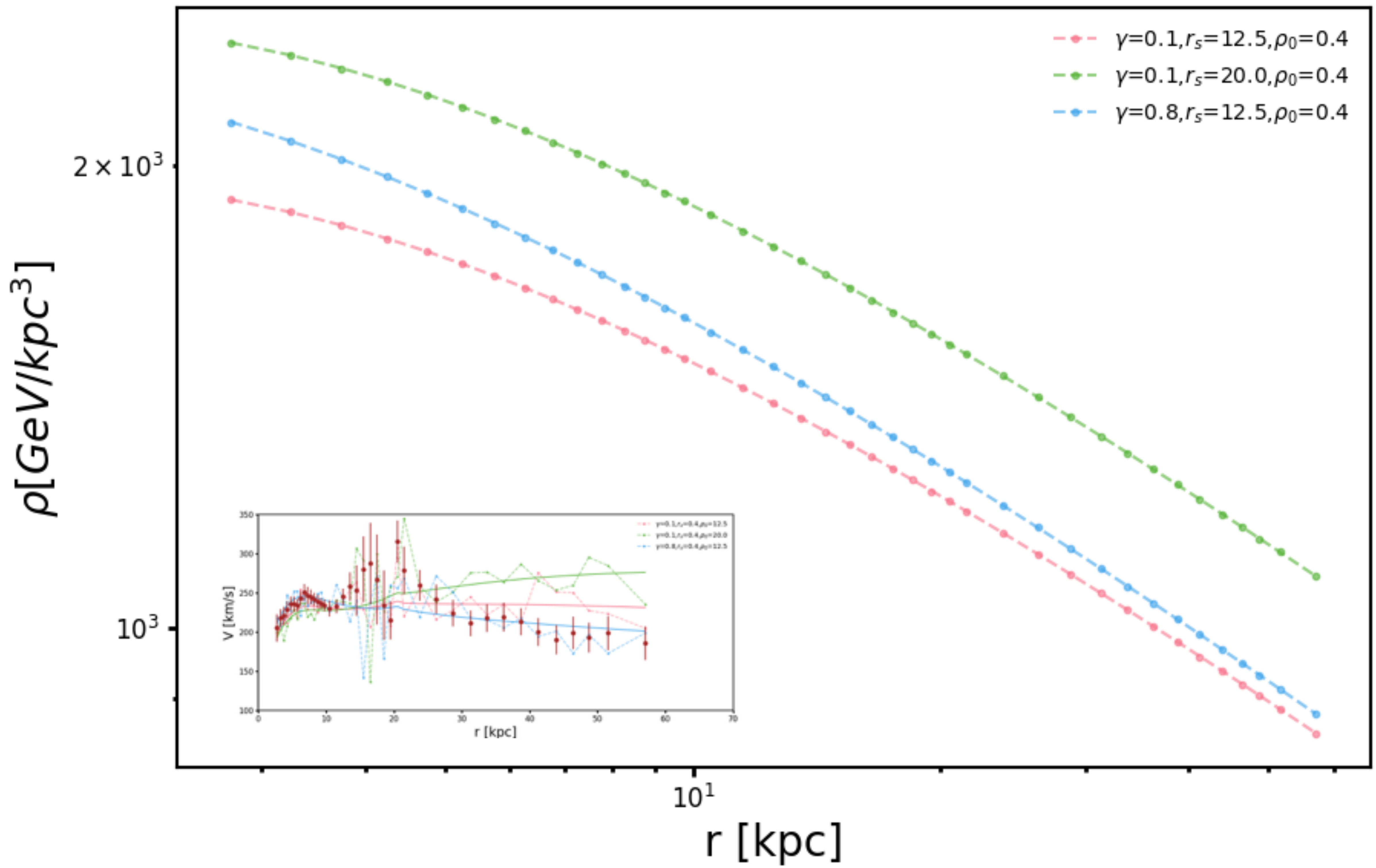

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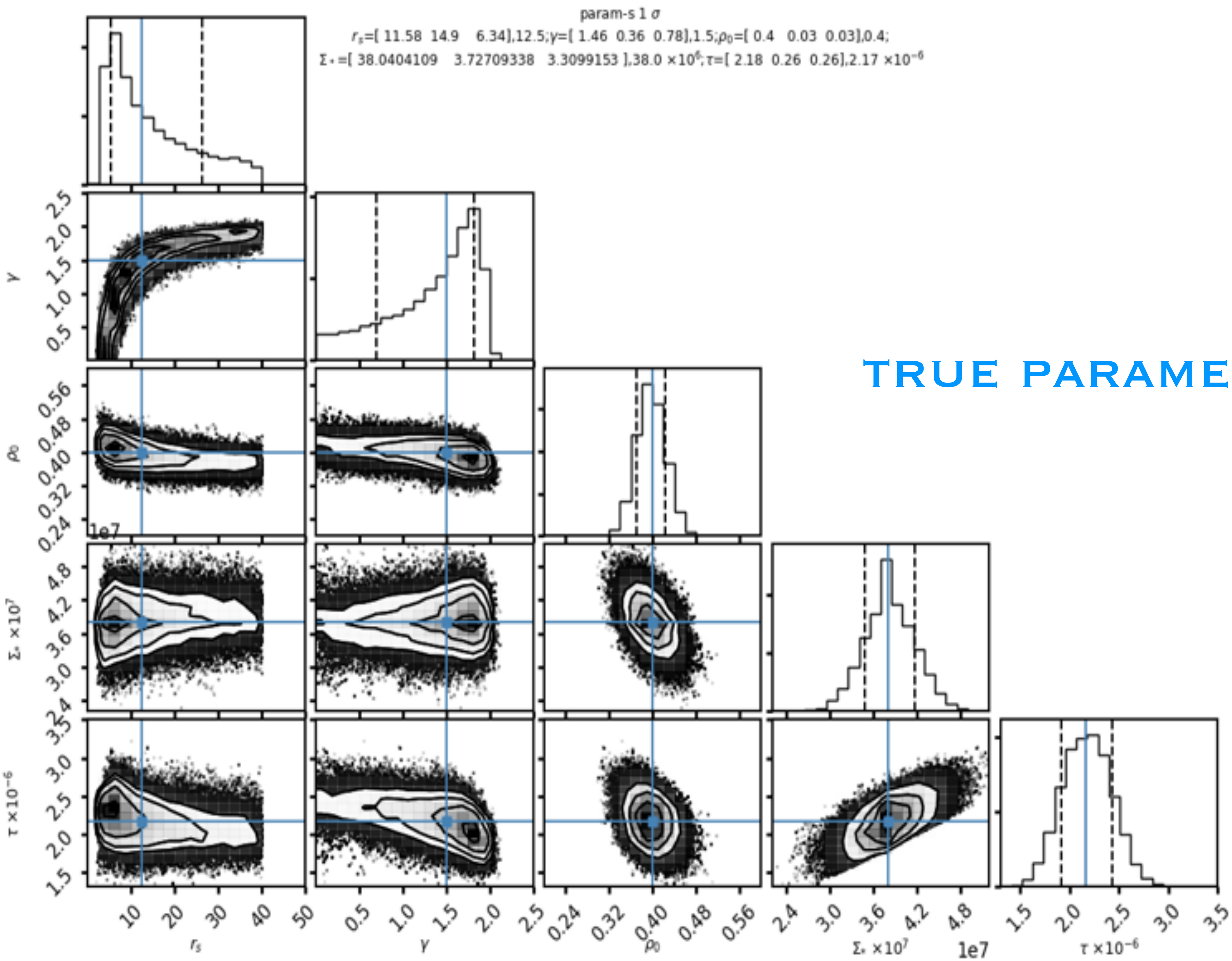


TRUE PARAMETERS

MCMC-based reconstruction and mock RCs

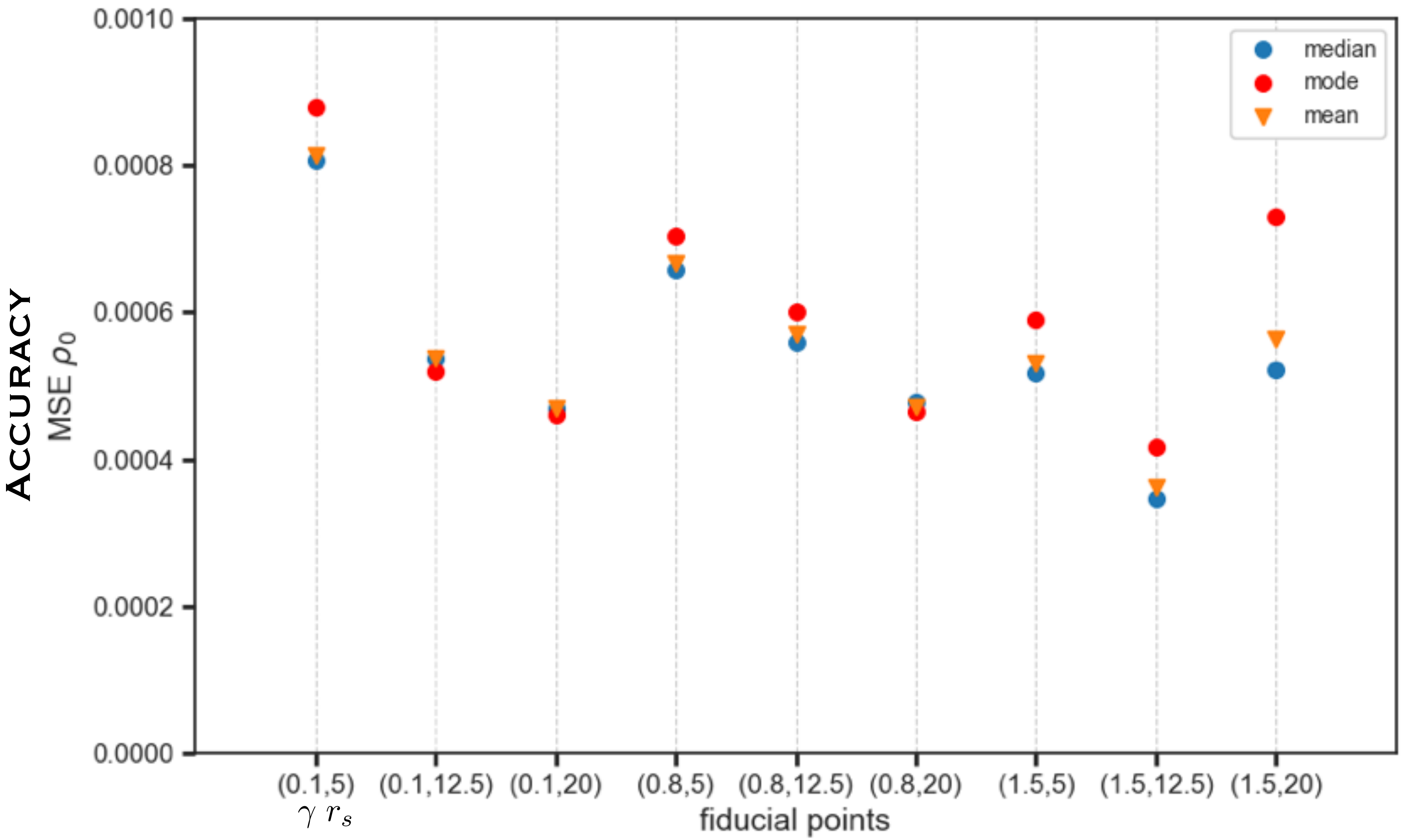
Do I perform well in all cases (also extreme DM profiles)?

Which parameter space is reconstructed better?

What is the best estimator (median, mode, mean)?

Does the estimator depend on the position in the parameter space?

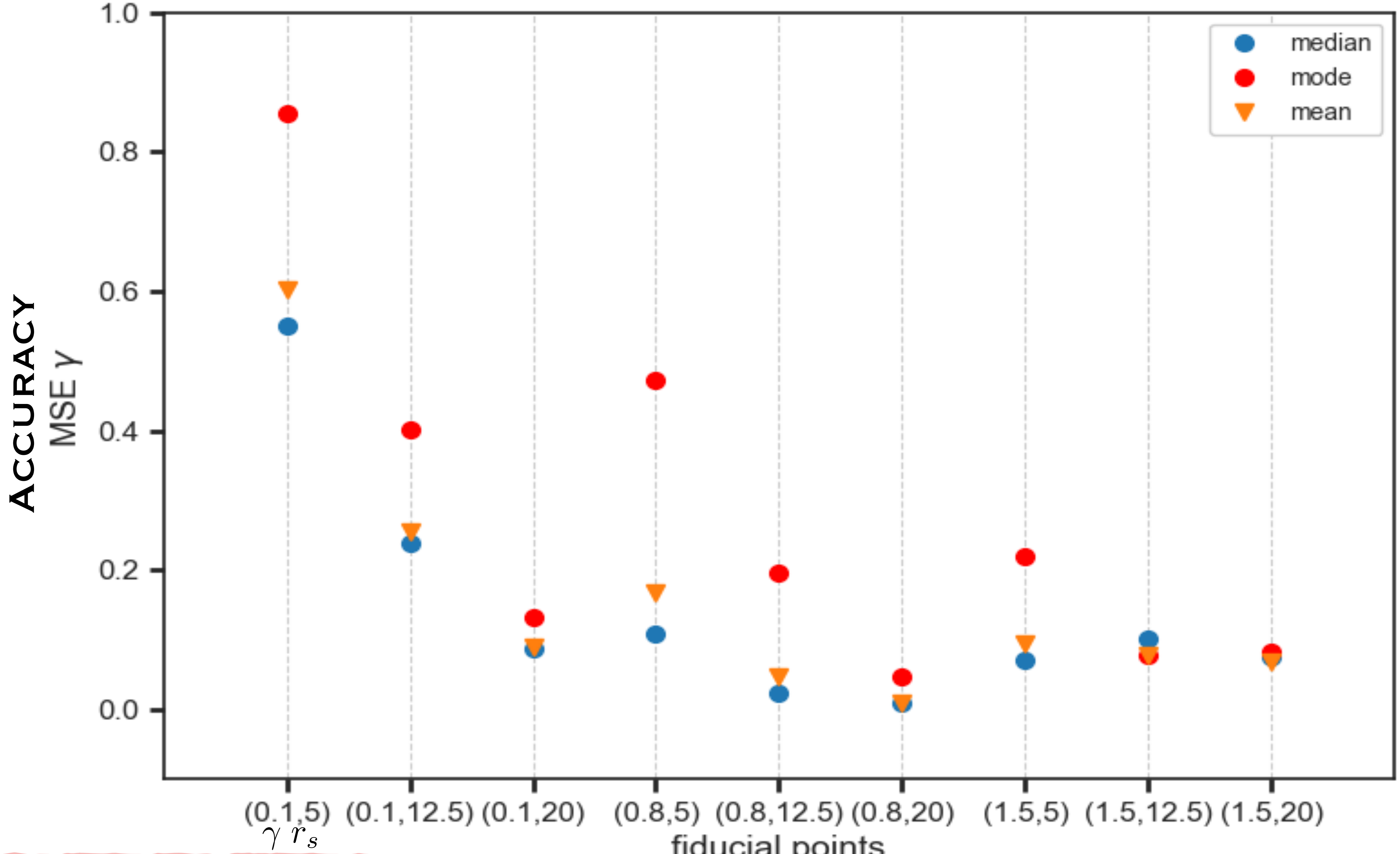
Results



PRELIMINARY

$$\rho_0 = 0.4\ GeV/cm^3$$

Results



PRELIMINARY

PRELIMINARY

Conclusions

- the reconstructed value of the local DM density is always compatible with the actual within ~8%
- somewhat larger values of the inner DM density slope are better reconstructed

Further steps

- to analyse the MCMC-based results of the actual RC on the basis of mock data
- to investigate how the DM parameters vary by varying the morphology of of the baryonic components
- to include the DM halo oblateness in the mock data