Theoretical Astroparticle Workshop

Contribution to PRIN 2012 - Midterm Review Workshop

" Looking for Dark Matter in Dwarf Spheroidal Galaxies "

INFN

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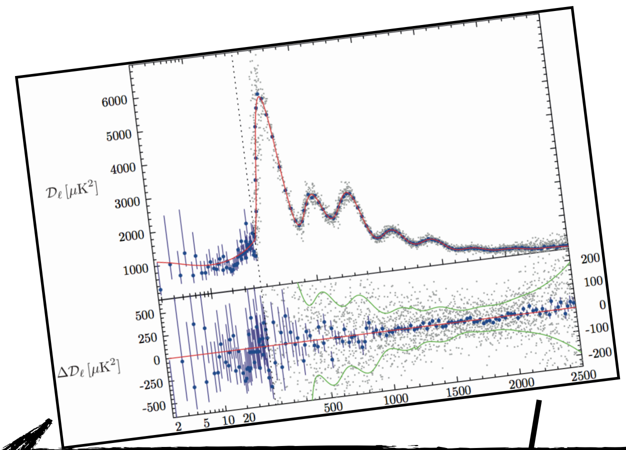
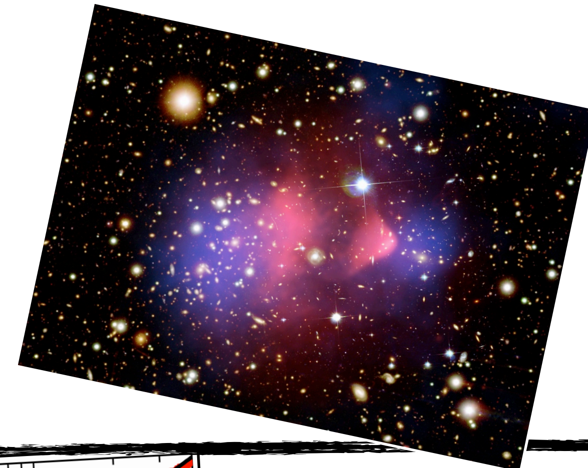
SISSA

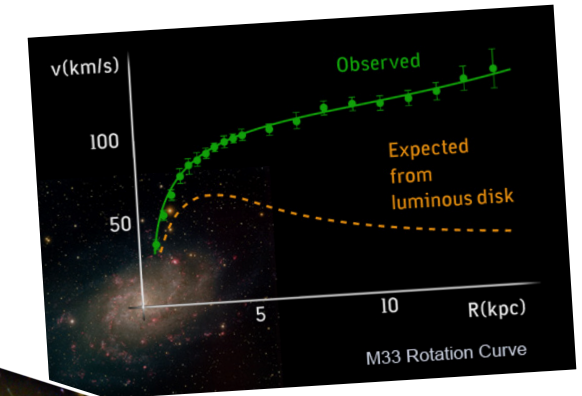
In collaboration with Piero Ullio

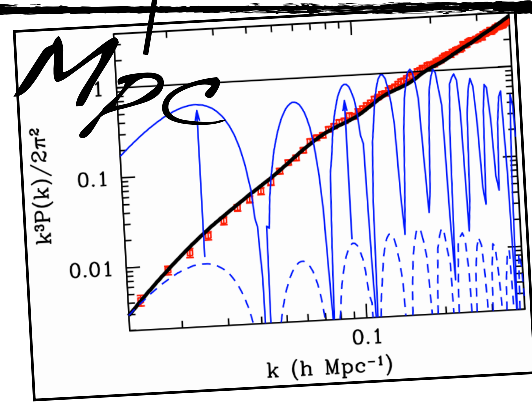
10 July 2015, University of Turin

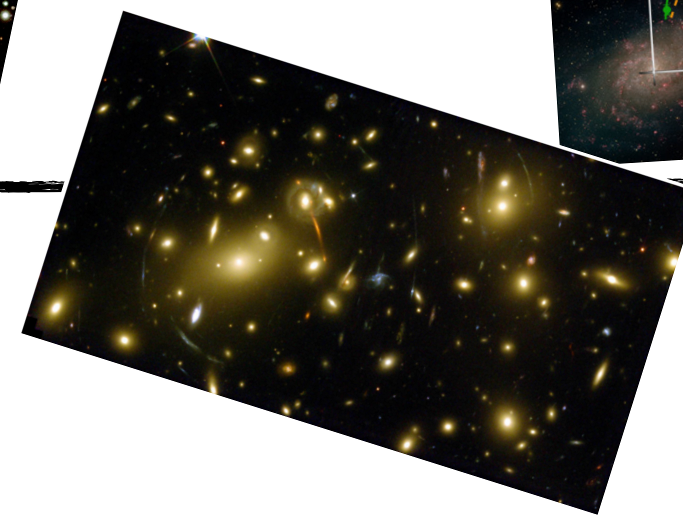
Evidence in favour of Dark Matter existence @ different scales ...







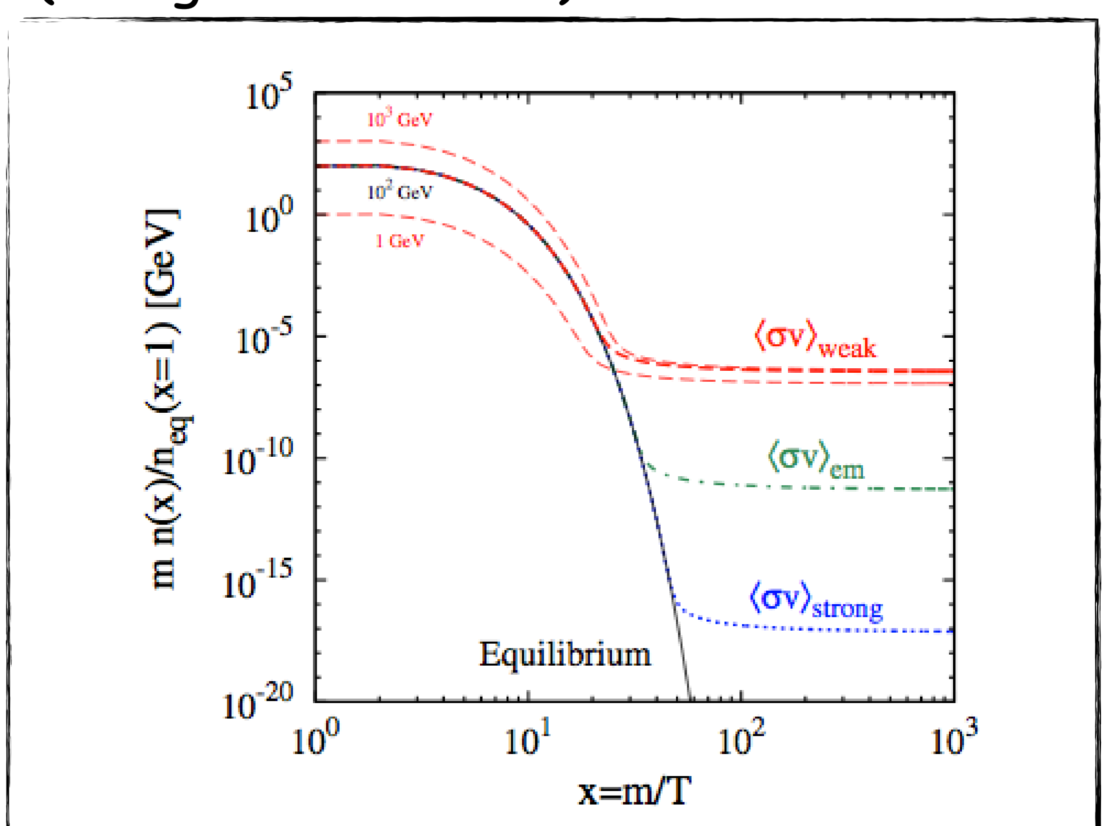




Mpc

kpc

(Steigman et al. '12)

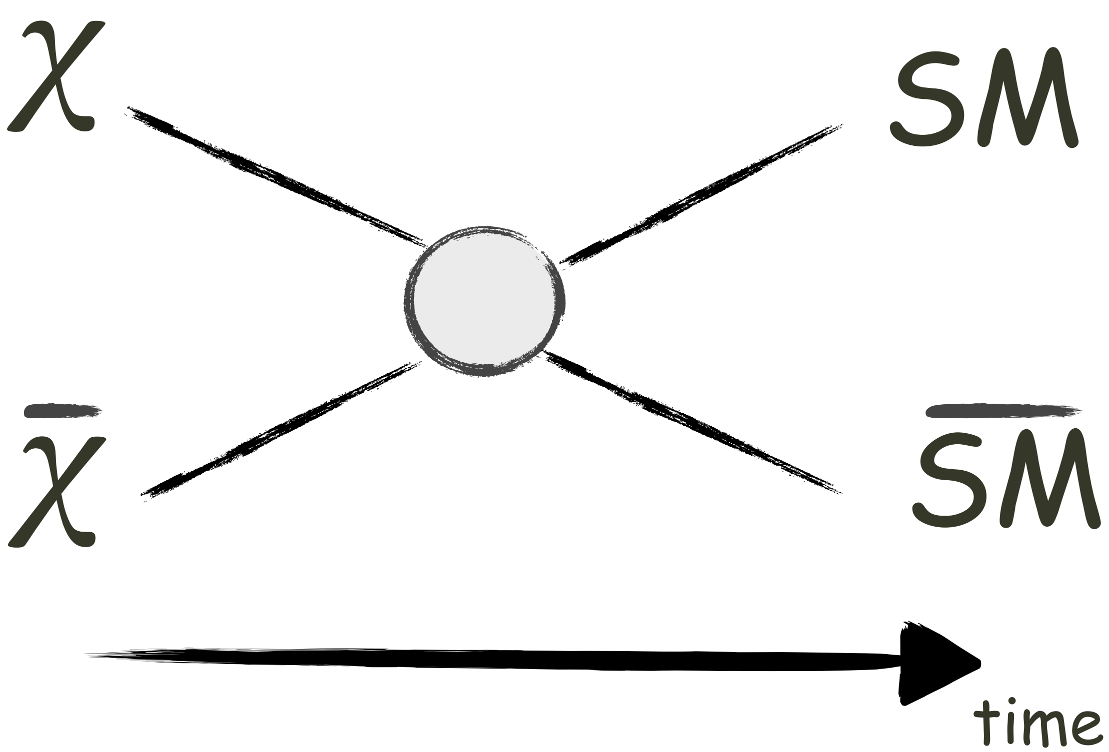


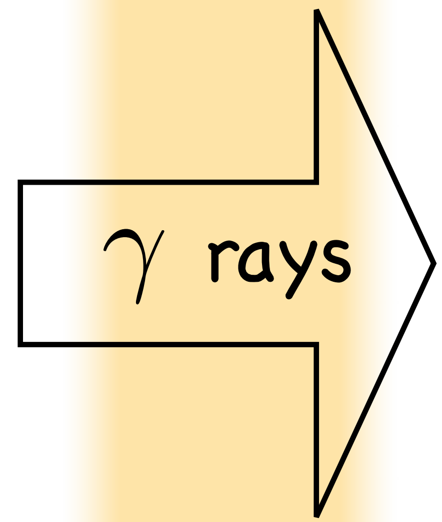
Beyond the Standard Model of Particle Physics opportunity !

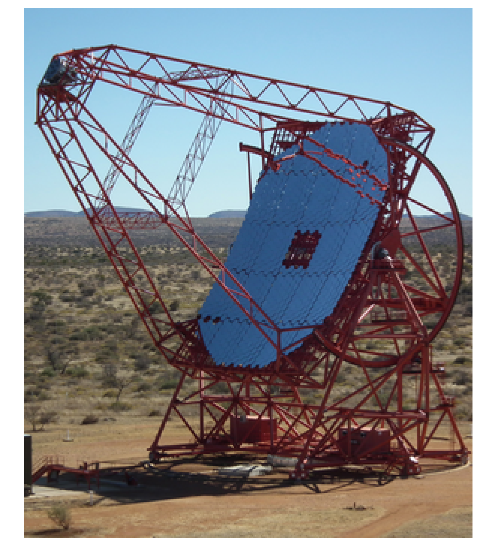
$$\Omega_\chi h^2 \sim \frac{3\times 10^{-27}\, cm^3\, s^{-1}}{<\sigma v>_{f.o.}}$$

Weakly **I**nteracting **M**assive **P**articles **miracle**

WIMP annihilation in the Sky







Expected flux of prompt gamma to be detected ?

$$\phi_\gamma \propto <\sigma v> \times J \rightarrow \sim \int d\ell\ \rho_\chi^2(r(\ell))/m_\chi^2$$

Milky Way (MW) Galactic Center: J ~ 10^{23} GeV^2/cm^5

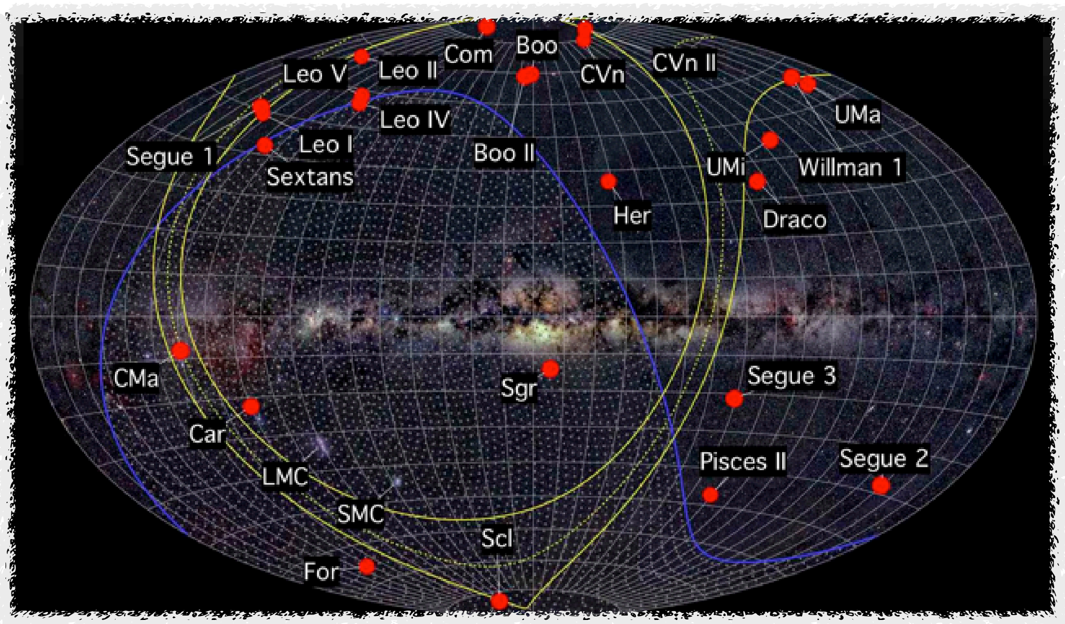
high J-factor value, but also complicated background!

Dwarf spheroidal galaxies (dSphs) are the ideal targets!

$$M/L \sim 10^{2-3} \times M_\odot/L_\odot$$

very faint objects with large mass-to-light ratio!

In particular, for Milky Way satellites:



high latitude position

suppressed gamma-ray flux from standard processes

heliocentric distances about 70 - 250 kpc

high J-value

✓ photometry for stellar density profile , $I(R)$

✓ spectroscopy for line-of-sight kinematics , $\sigma_{los}(R)$

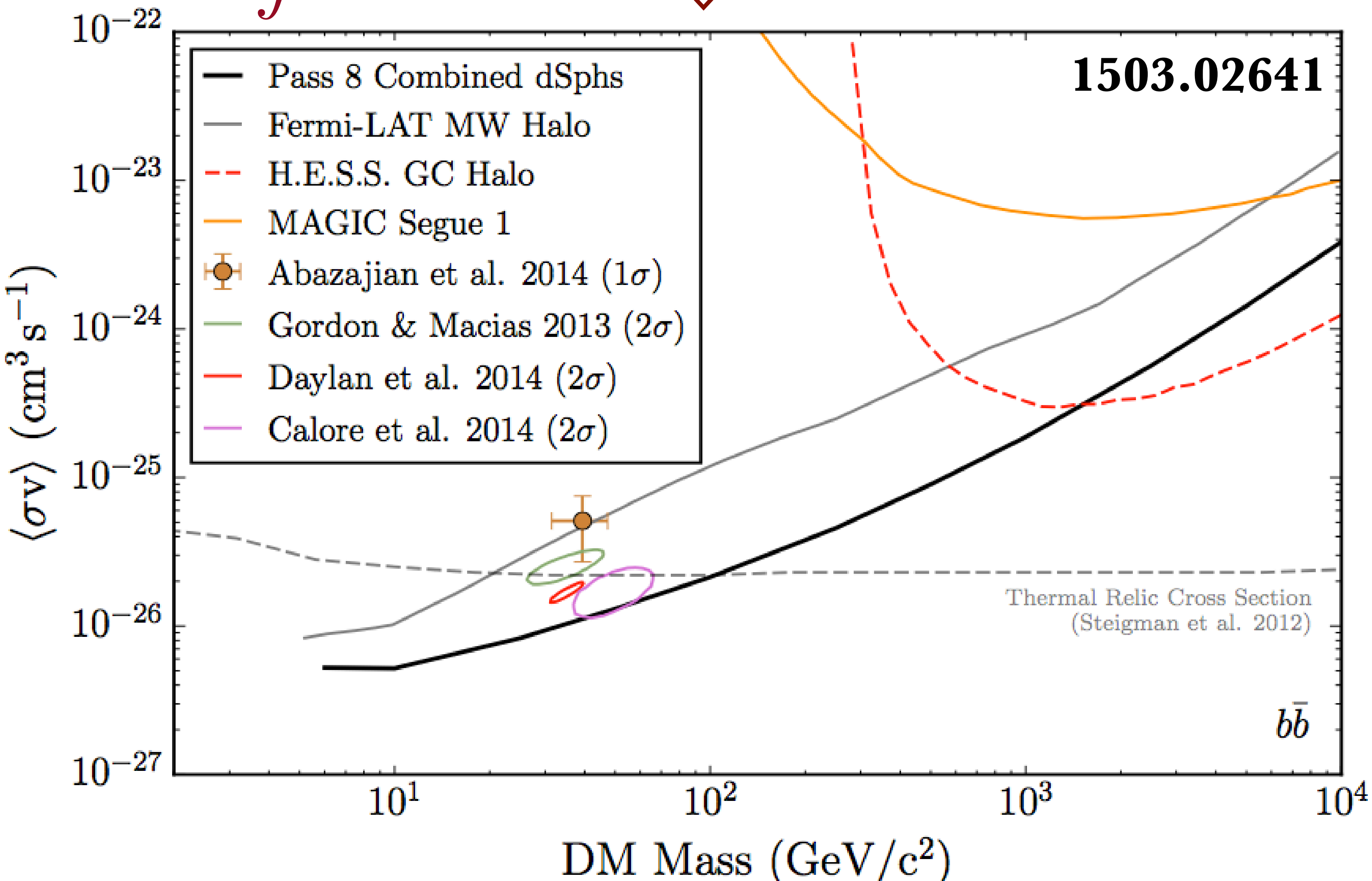
✗ full 3D kinematical knowledge , $\beta(r) \equiv 1 - \sigma_t^2(r)/\sigma_r^2(r)$

dSph ≡ collisionless spherical system in dynamical equilibrium

JEANS EQUATION

$$\sigma_{los}(R) = f(I, \rho_\chi, \beta)$$

$$\int d\beta \; p(\beta)$$



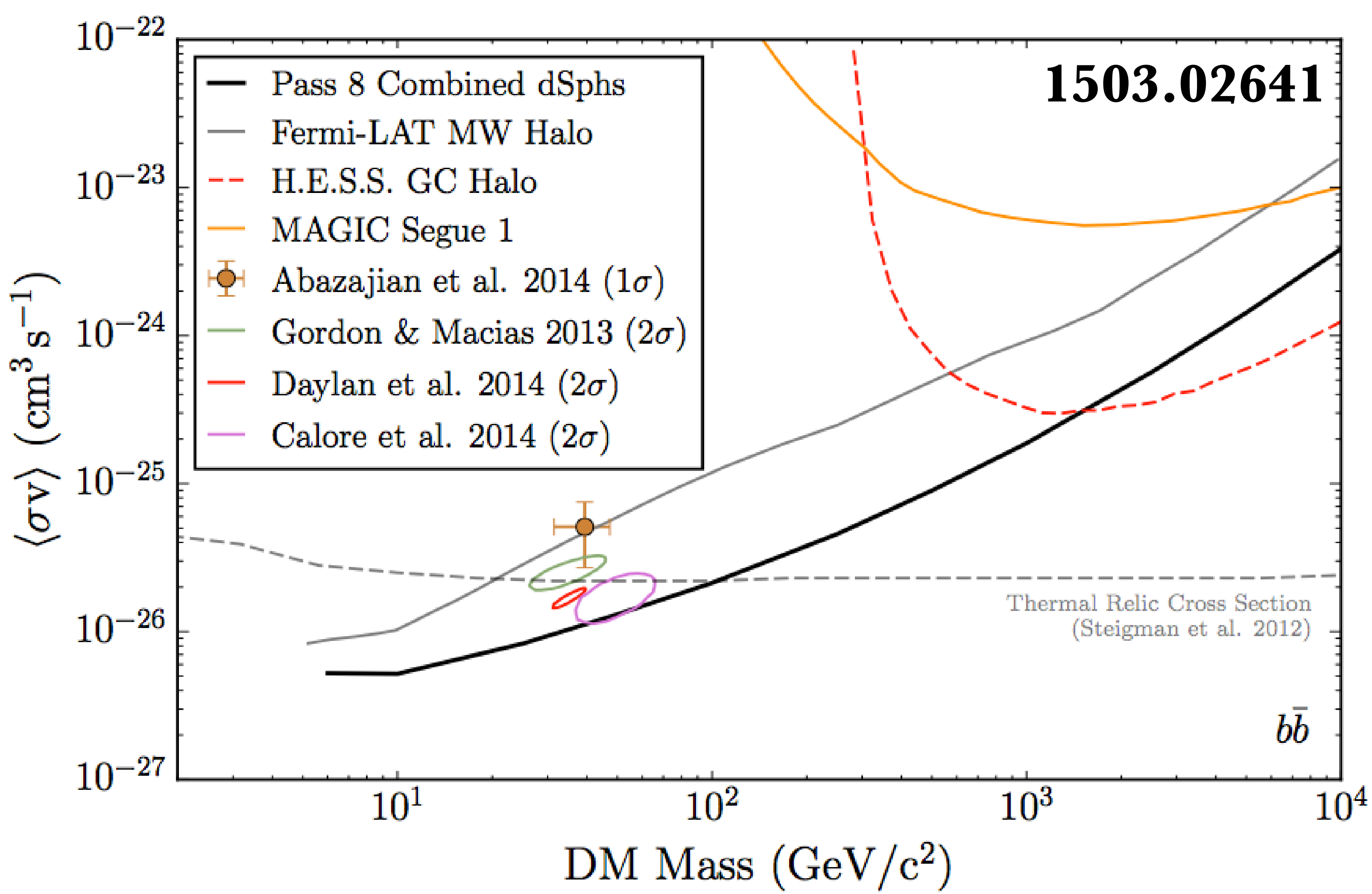
dSph ≡ collisionless spherical system in dynamical equilibrium

JEANS EQUATION

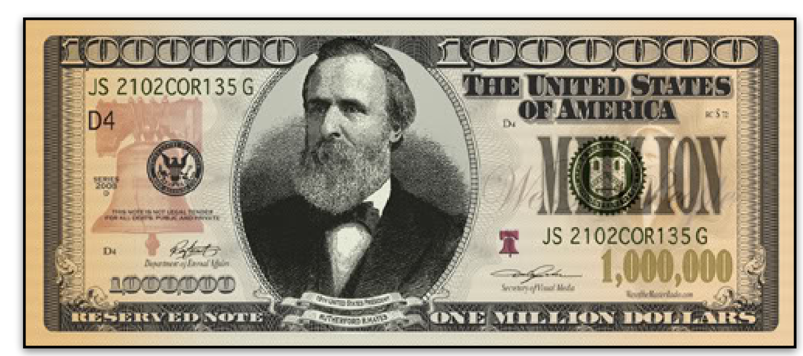
$$\sigma_{los}(R) = f(I, \rho_\chi, \beta)$$

$$-\infty < \beta(r) \leq 1$$

$$\int d\beta \; p(\beta)$$



1 Million Dollar Question



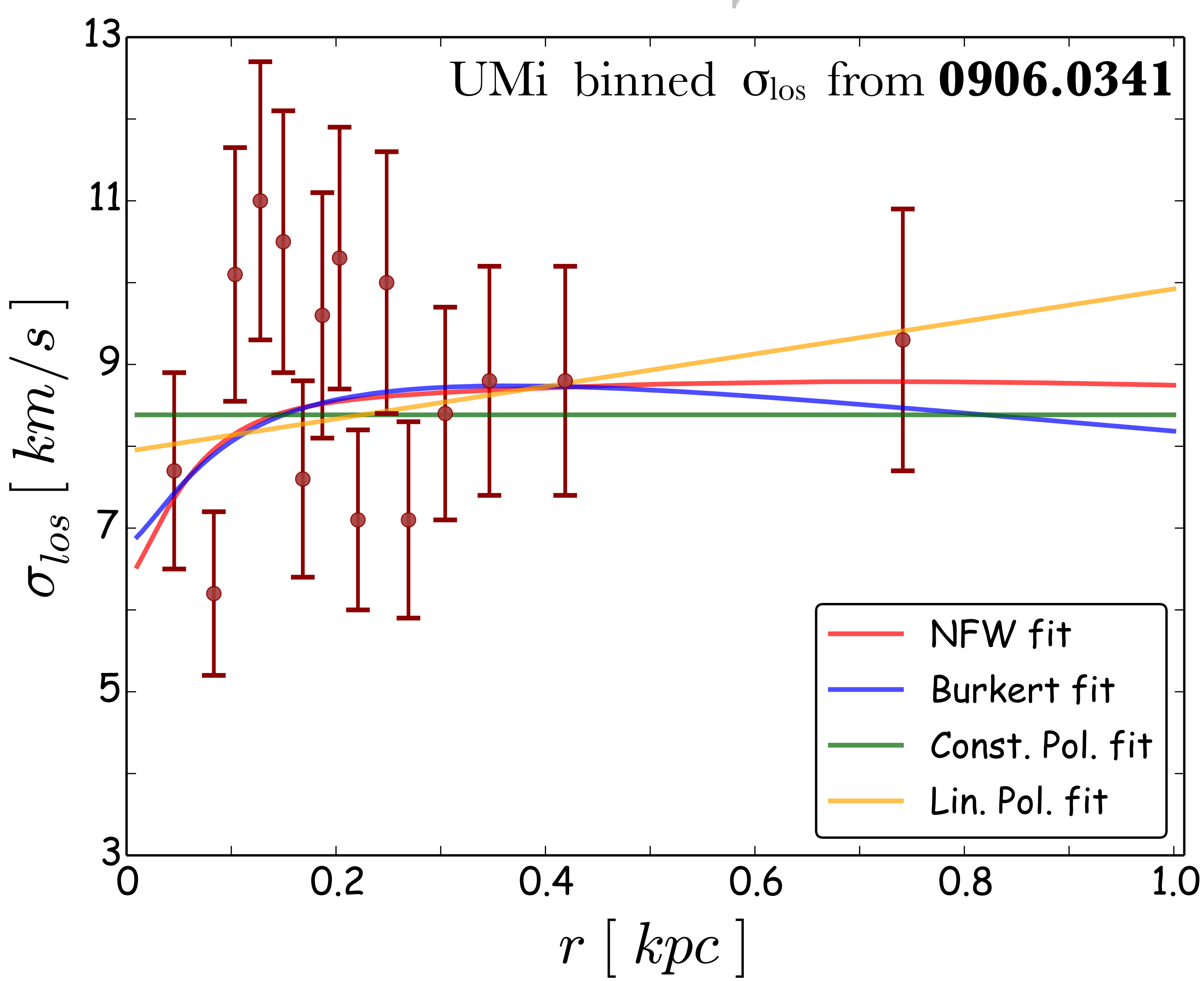
How do you marginalize on something you do not know?

OUR NOVEL APPROACH to attack the problem in a different way it may be worth inverting standard logic!

Jeans inversion

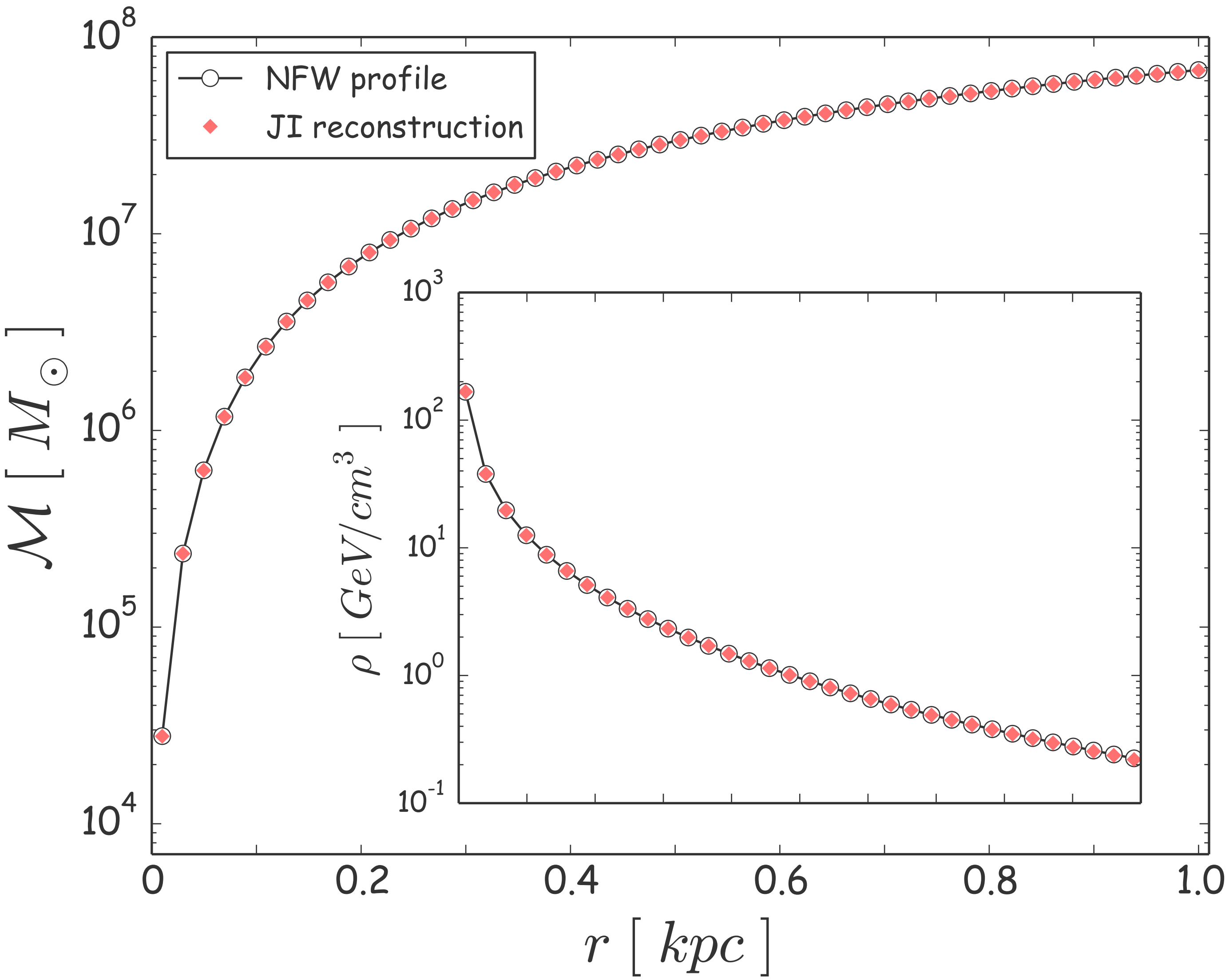
$$\sigma_{los}(R) = f(I, \rho_\chi, \beta)$$

$$\mathcal{M}_\beta(r) = \mathcal{F}\left(\sigma_{los}, I, \beta\right)$$



FOR A GIVEN FIT OF LINE-OF-SIGHT DISPERSION DATA ONE GETS ACCESS TO A MASS PROFILE IN TERMS OF β(r)

WE BREAK MASS-ANISOTROPY DEGENERACY!



The general expression for Jeans inversion is of the form

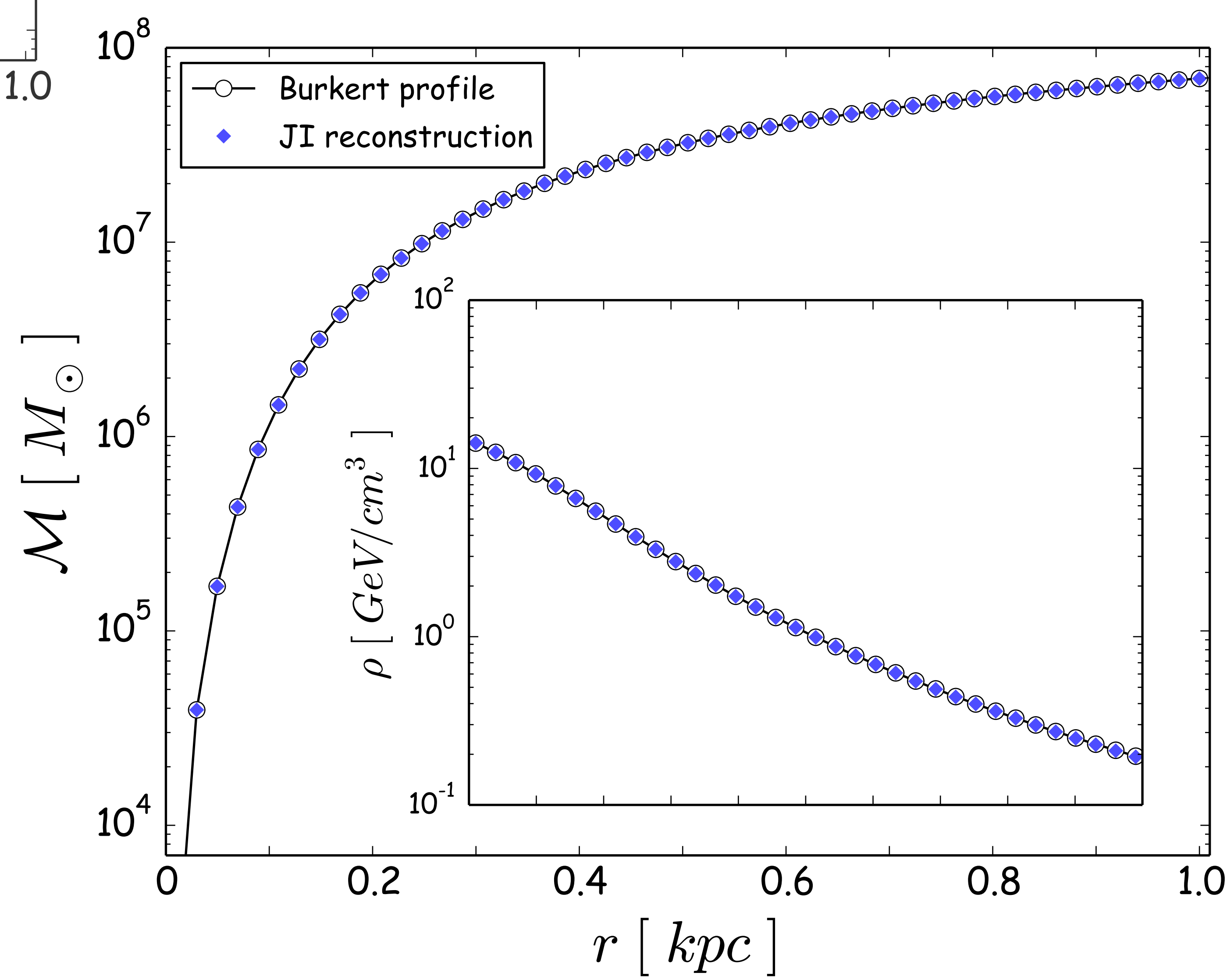
$$\mathcal{M}_\beta = \mathcal{A}_\beta(I) \int_r^\infty dR \frac{d^2 P}{(dR^2)^2} W_\beta(R, r)$$

where the pressure P is defined as

$$P = I\,\sigma_{los}^2$$

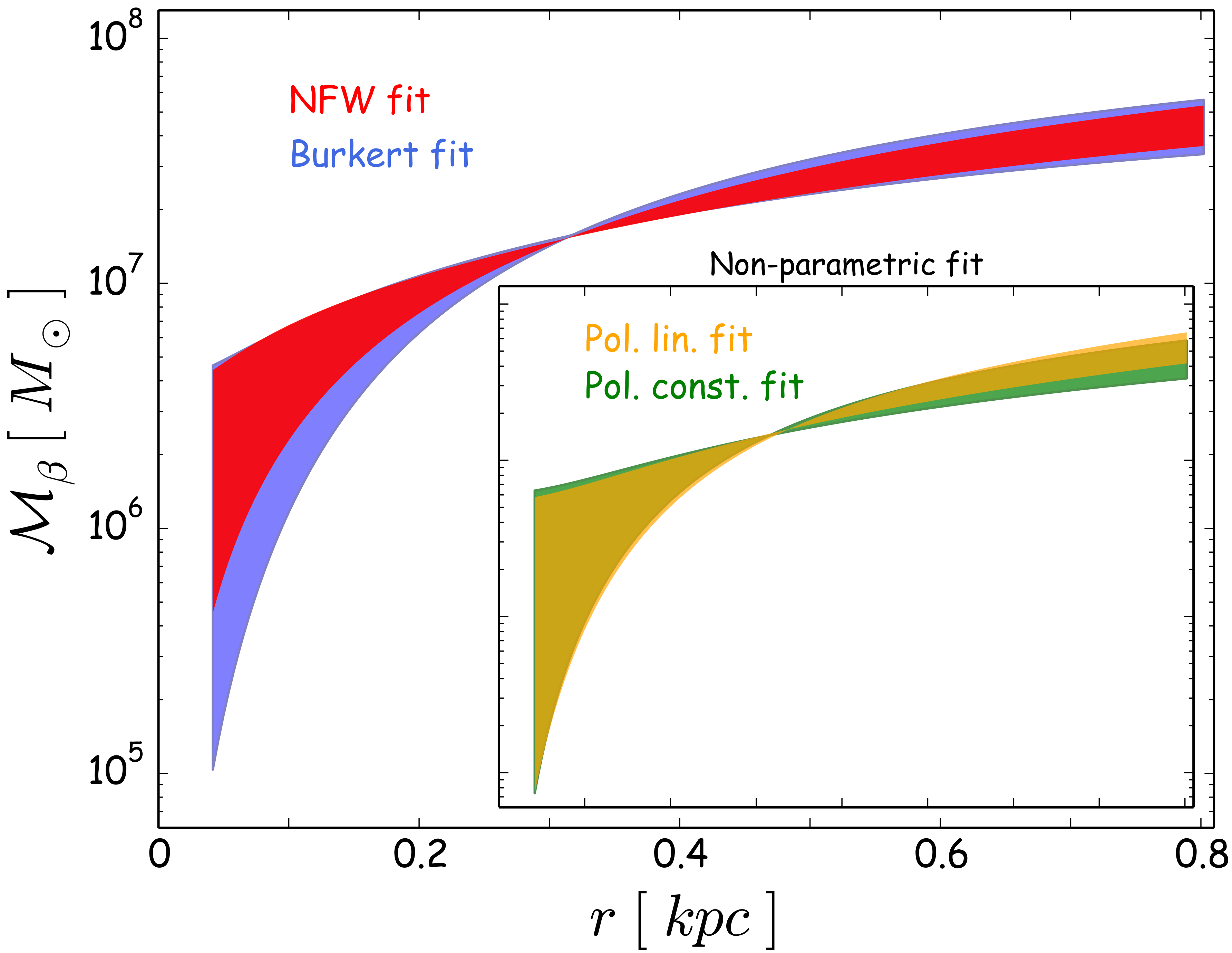
The inversion works pretty well also for the halo density.

$$\rho_{\chi\,\beta} = \frac{1}{4\pi r^2}\frac{d\mathcal{M}_\beta}{dr}$$



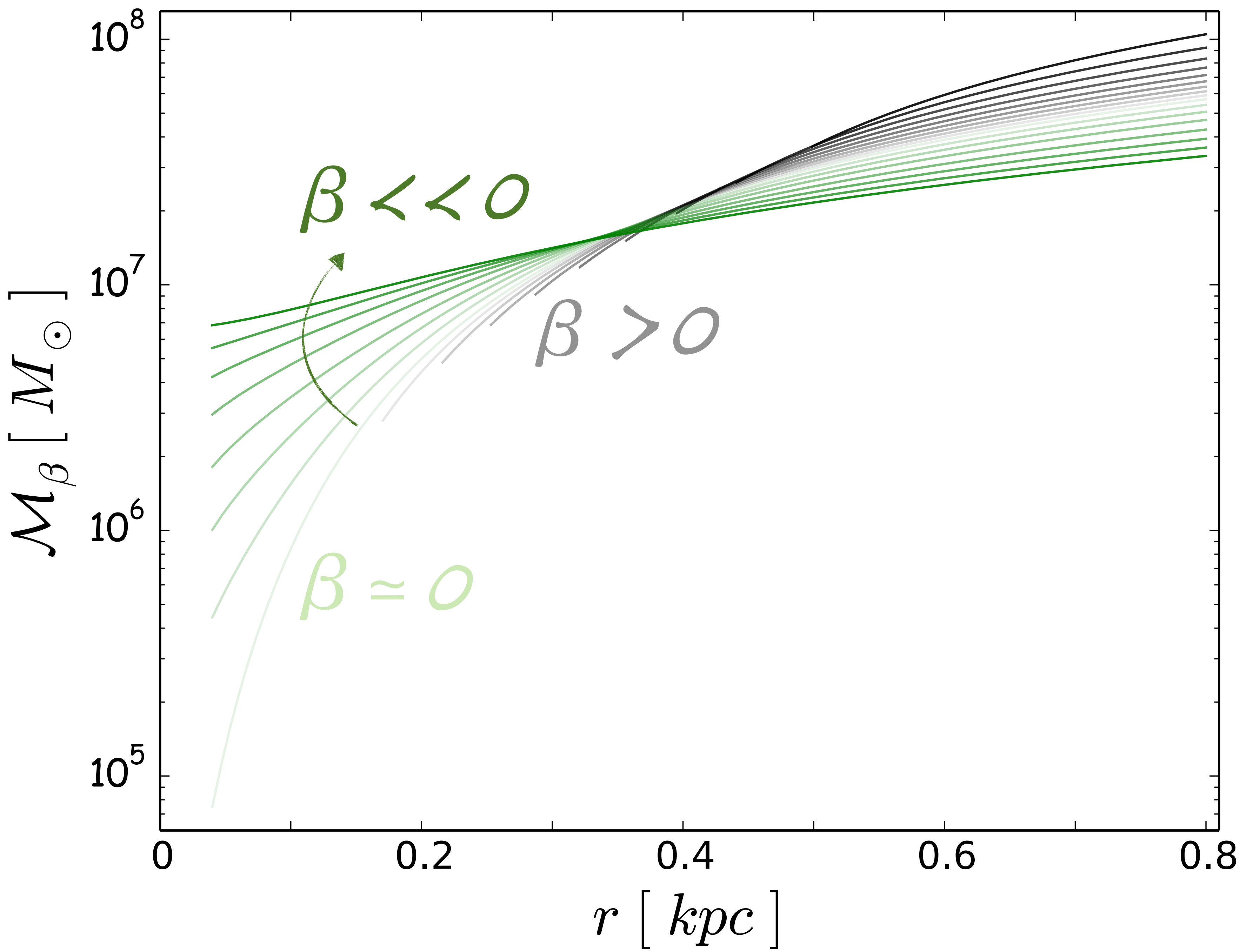
Let's get started with the simplest case: β(r) = const

$$\forall\,\beta \in (-\infty, 1]: \quad \begin{array}{l} 1)\;\; \mathcal{M}_\beta > 0 \\ 2)\;\; \mathcal{M}_\beta(r') - \mathcal{M}_\beta(r) \geq 0 \;\; \text{if} \;\; r' \geq r \end{array}$$



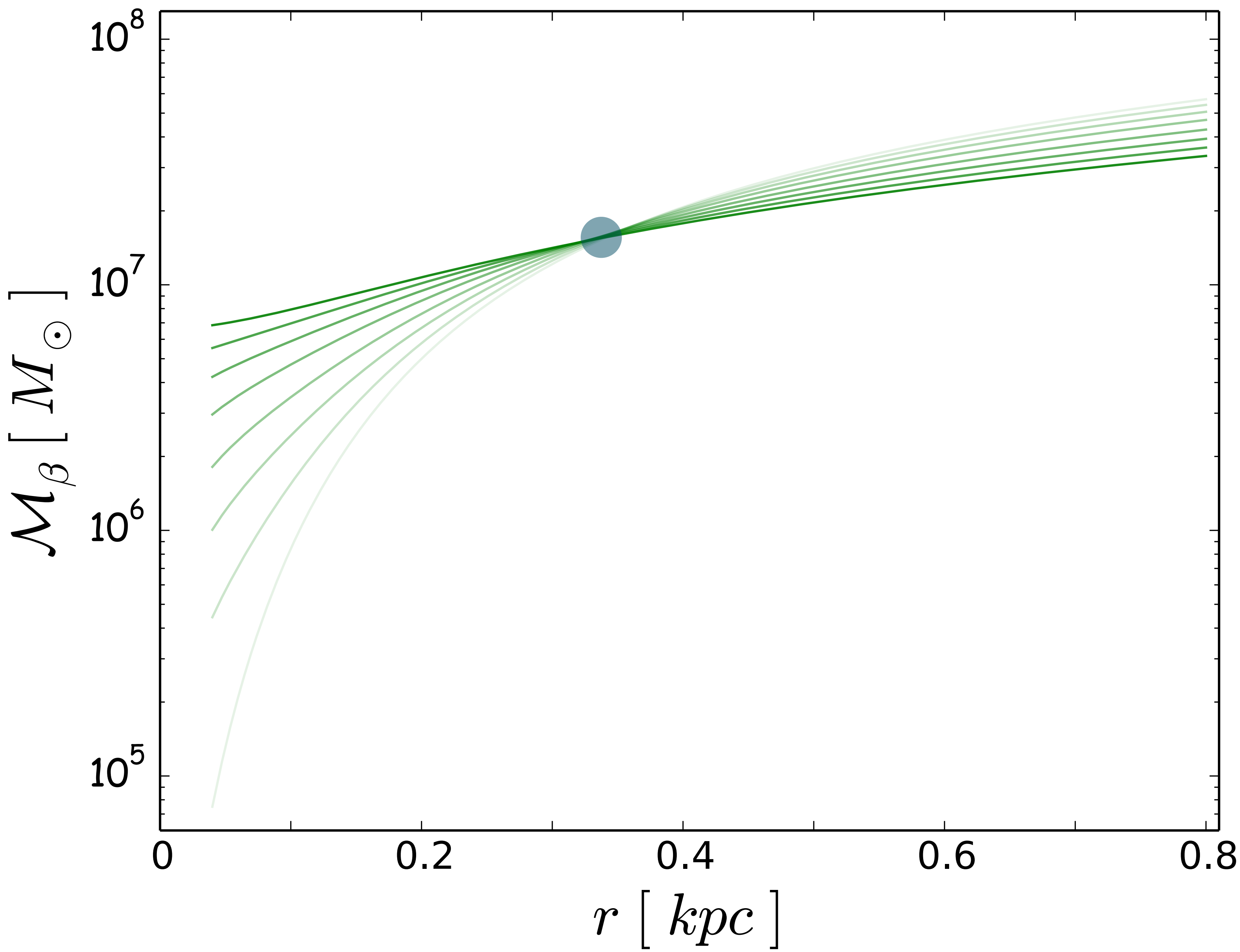
Fitting σ_{los} data with a constant fit yields an analytic expression in the case of constant orbital anisotropy within our Jeans inversion approach.

Taking a closer look @ this case :



Fitting σ_{los} data with a constant fit yields an analytic expression in the case of constant orbital anisotropy within our Jeans inversion approach.

We hit a special point where the dependence on the orbital anisotropy is minimized ....

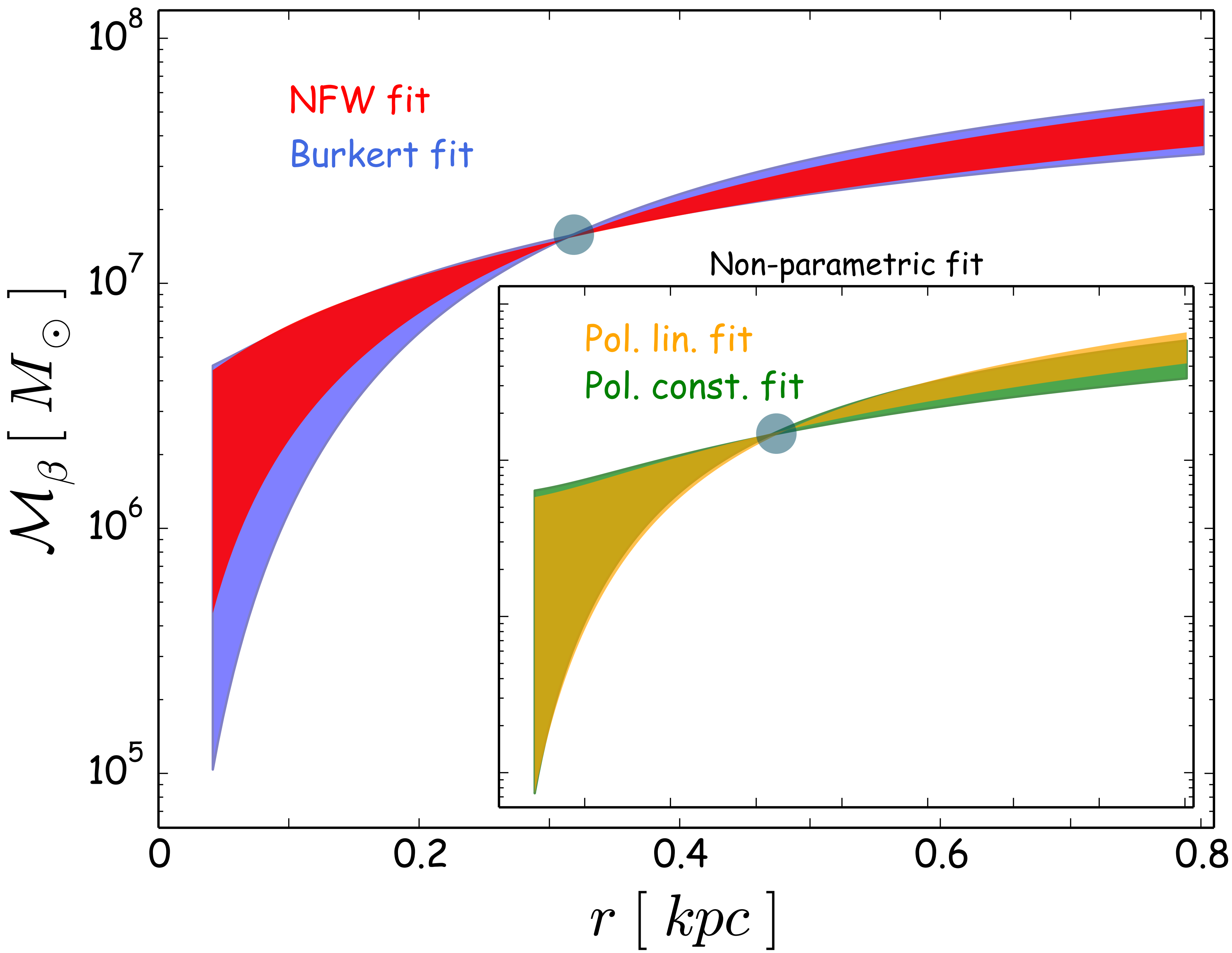


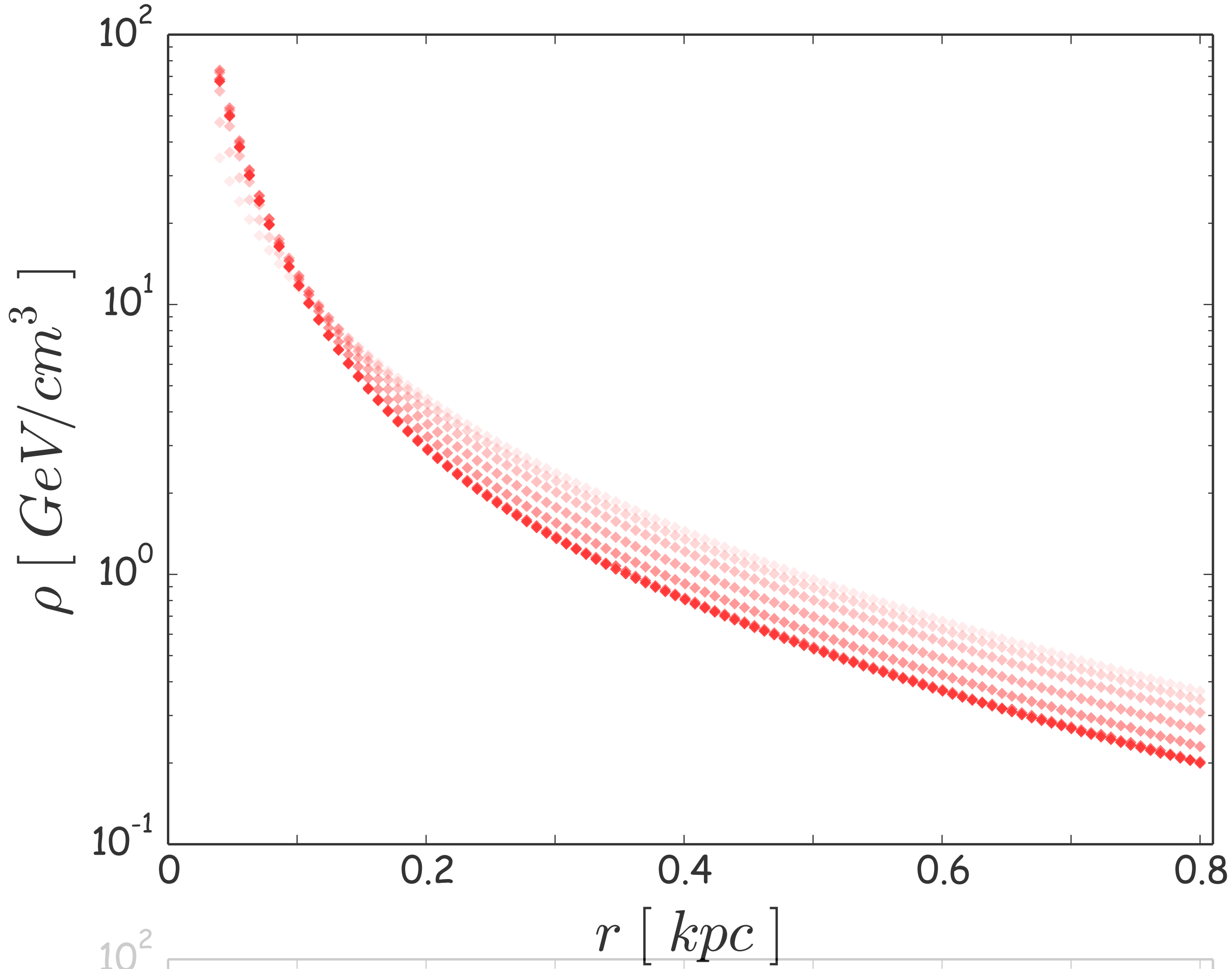
We give a proof of existence for a good (but not exact) mass estimator

(see e.g. **0908.2995**)

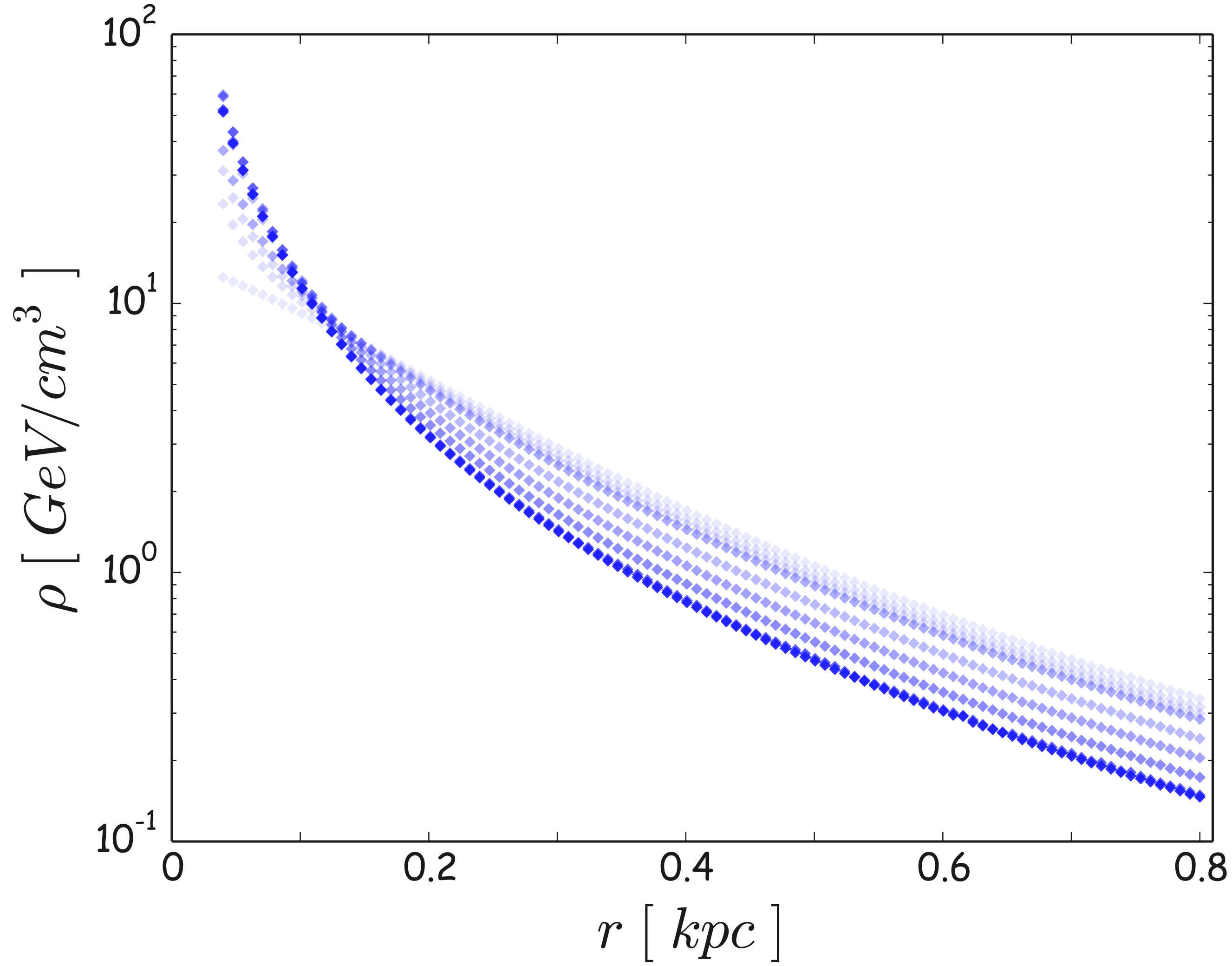
$$\mathcal{R}_{\bar{\beta}} \equiv 1 - \mathcal{M}_{\bar{\beta}}/\mathcal{M}_0 \rightarrow \mathcal{R}_{\bar{\beta}}(r_\star) = 0 \ , \ r_\star = r_{\star\,\bar{\beta}}$$

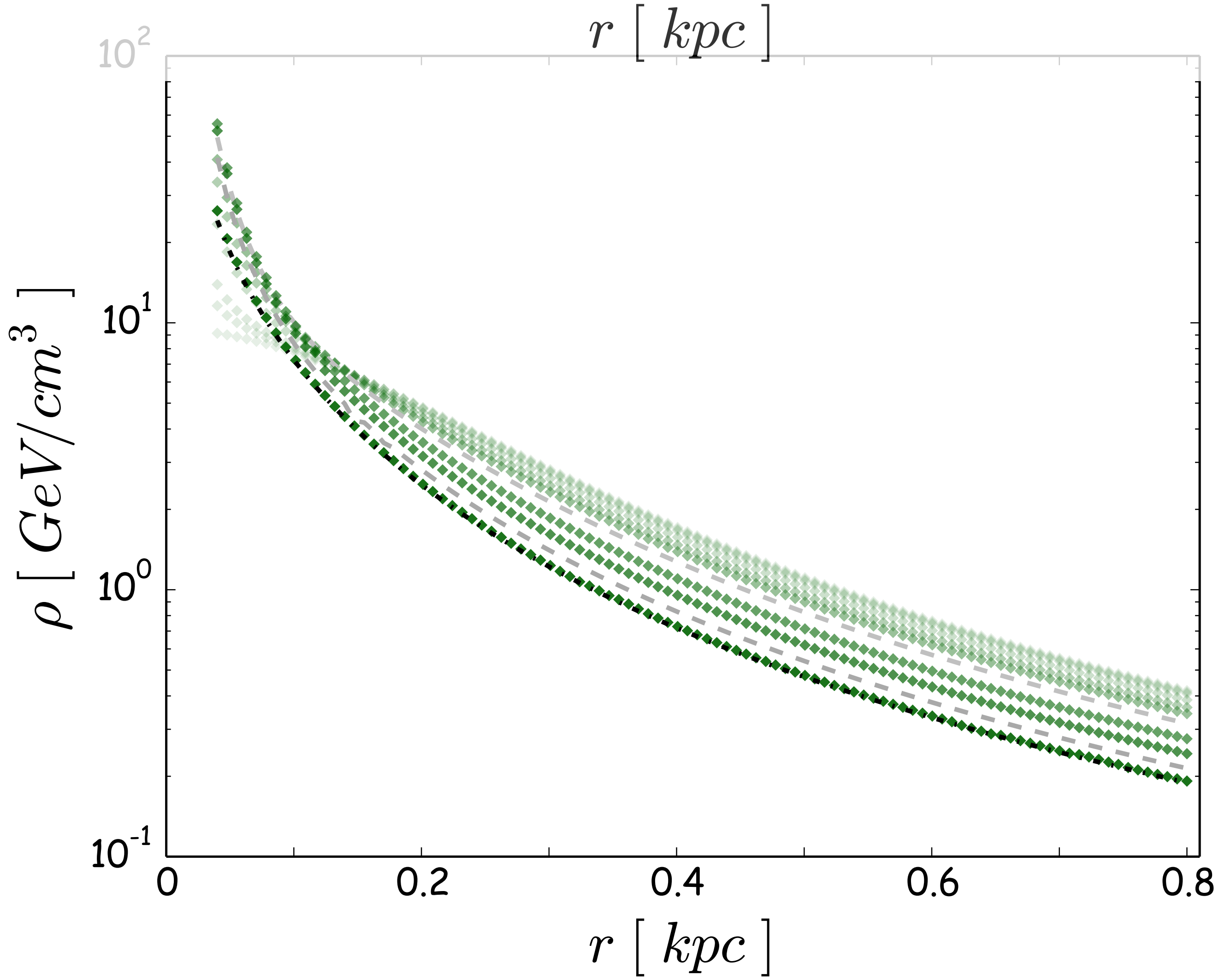
$r_\star \cong r_{1/2}$
mild dependence on β (% effect)





Negative anisotropy seems to require cuspier profiles.

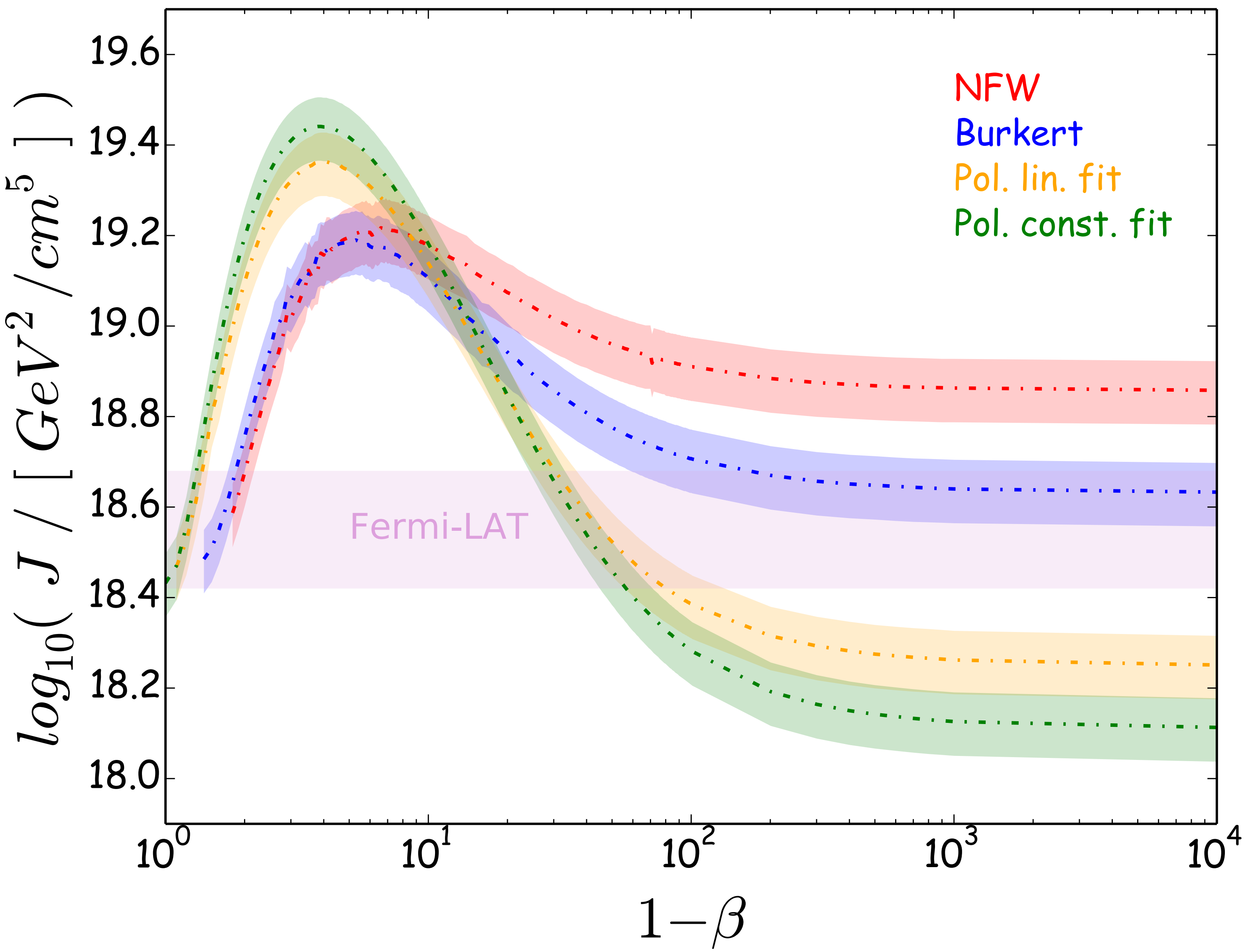




$M_{1/2}$ constraint turns out to be slightly milder.

The halo density here can “shift down” a bit!

The integration of $\rho^2{}_\chi$ along the line-of-sight yields the J-factor.



1. In all the 4 cases, “J-sampling” is largely dominated by very negative orbital anisotropies.

2. At face value, the minimum of J in parametric fits seems to agree with previous findings.
The non-parametric ones point to a few % of difference only.

Final Remarks

dSph galaxies represent a unique Dark Matter laboratory
(both for Indirect Searches as well as for N-body simulations)

They can confirm/falsify the Dark Matter interpretation of the GeV excess @ the GC

In this work we actually probed the robustness of the current tight upper-bound on $\langle \sigma v \rangle$ against what can be considered the greatest theoretical bias in the modelling.

One last effort to get deeper physical insights on the orbital anisotropy

dSph constraints turned out to be quite solid ...
... maybe the milestone of Indirect Searches!

Thank You!

☺