Implications from Structure Formation for Dark Matter

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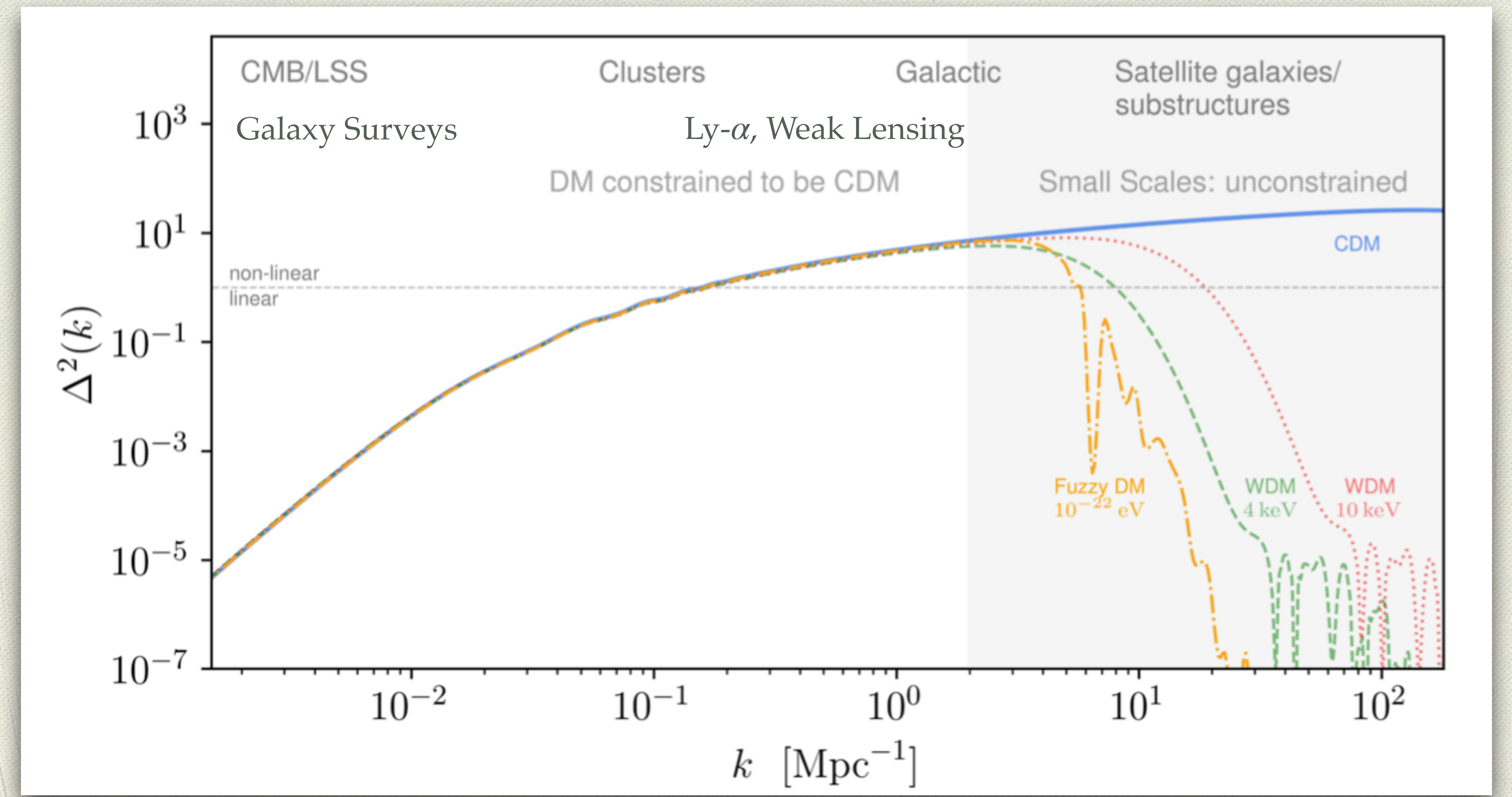
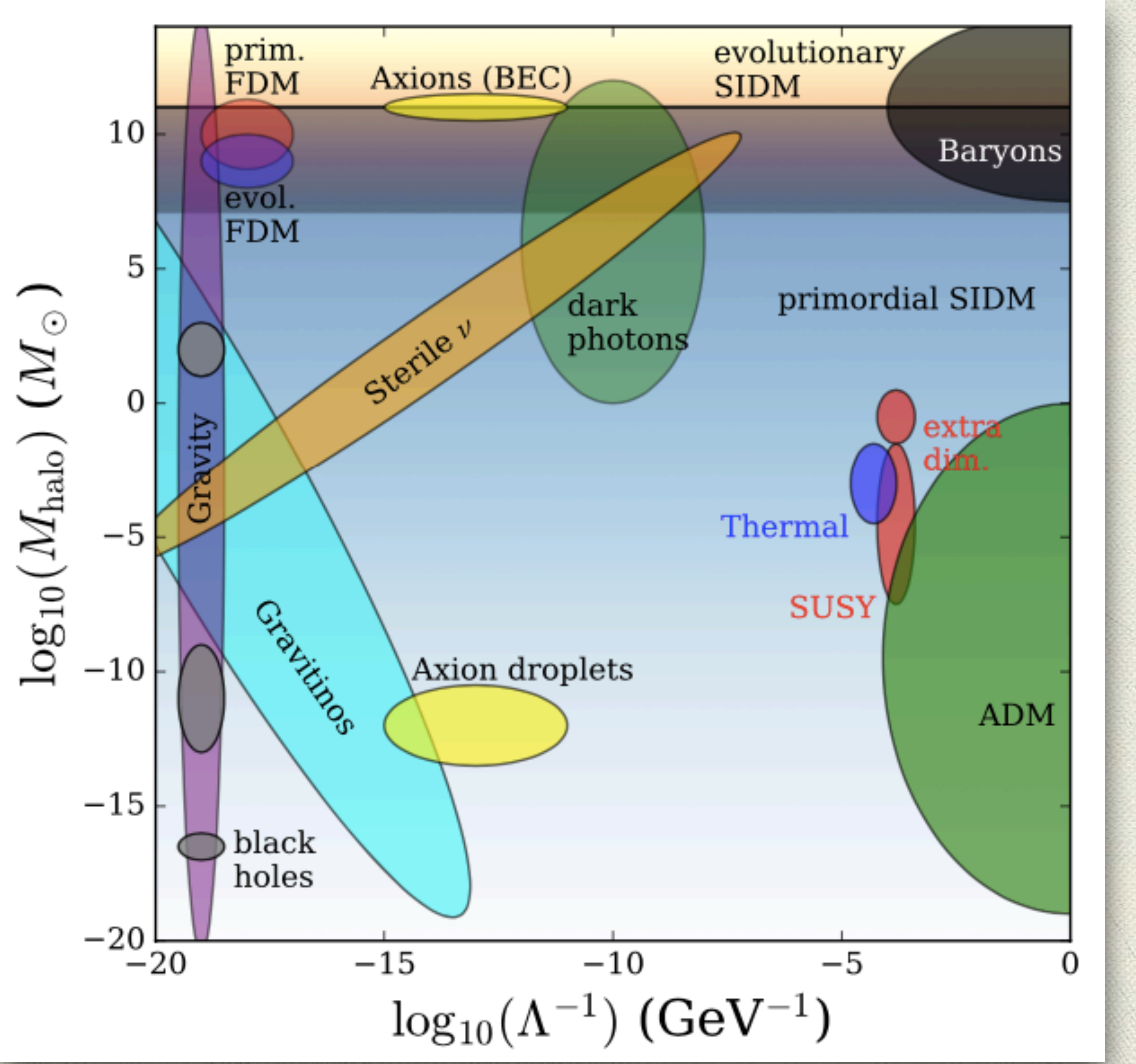
Power Spectrum

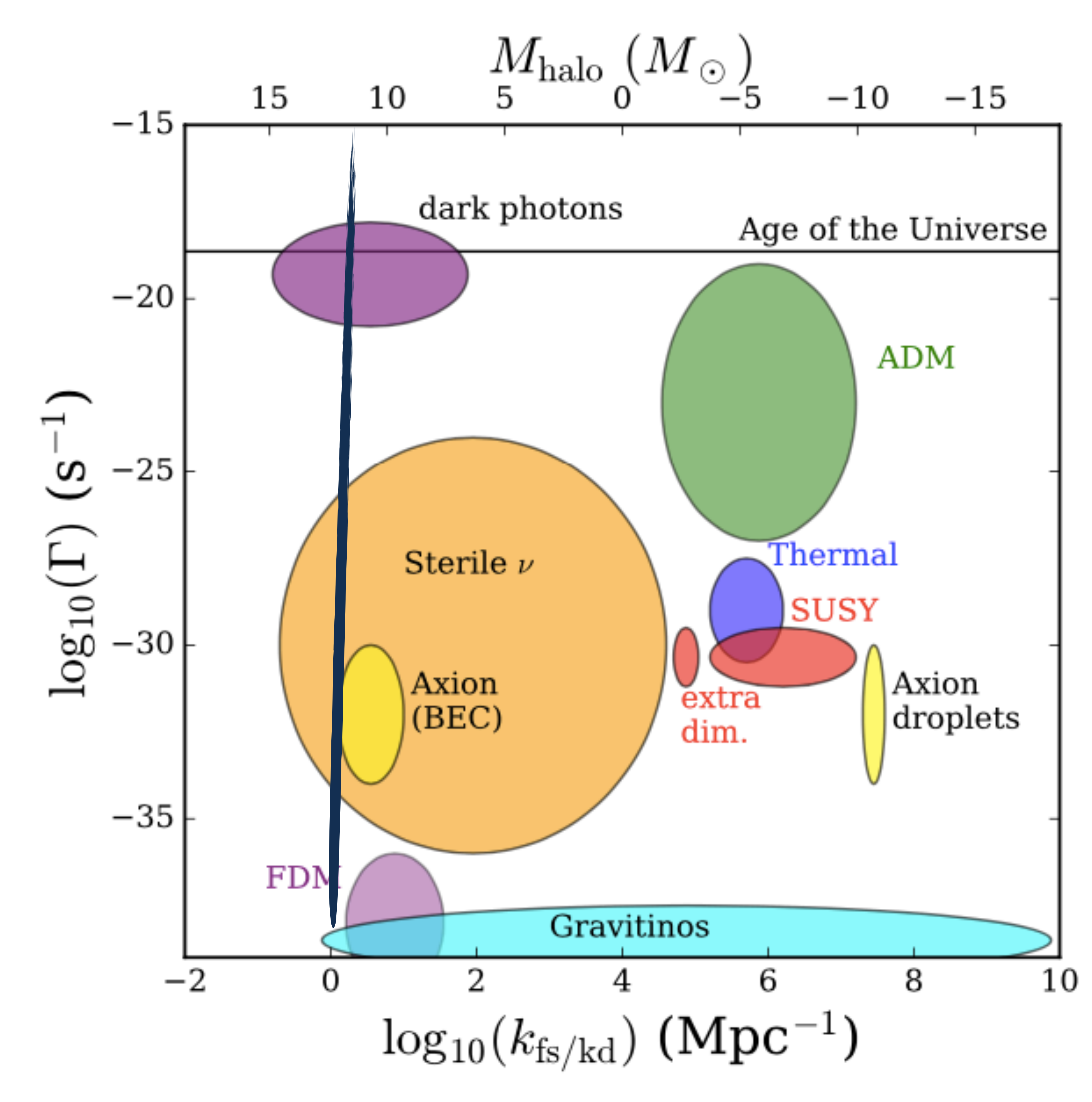


E. G. M. Ferreira *Astron . Astrophys . Rev* . 29 (2021) *no*.1,7

Dark Matter Models:

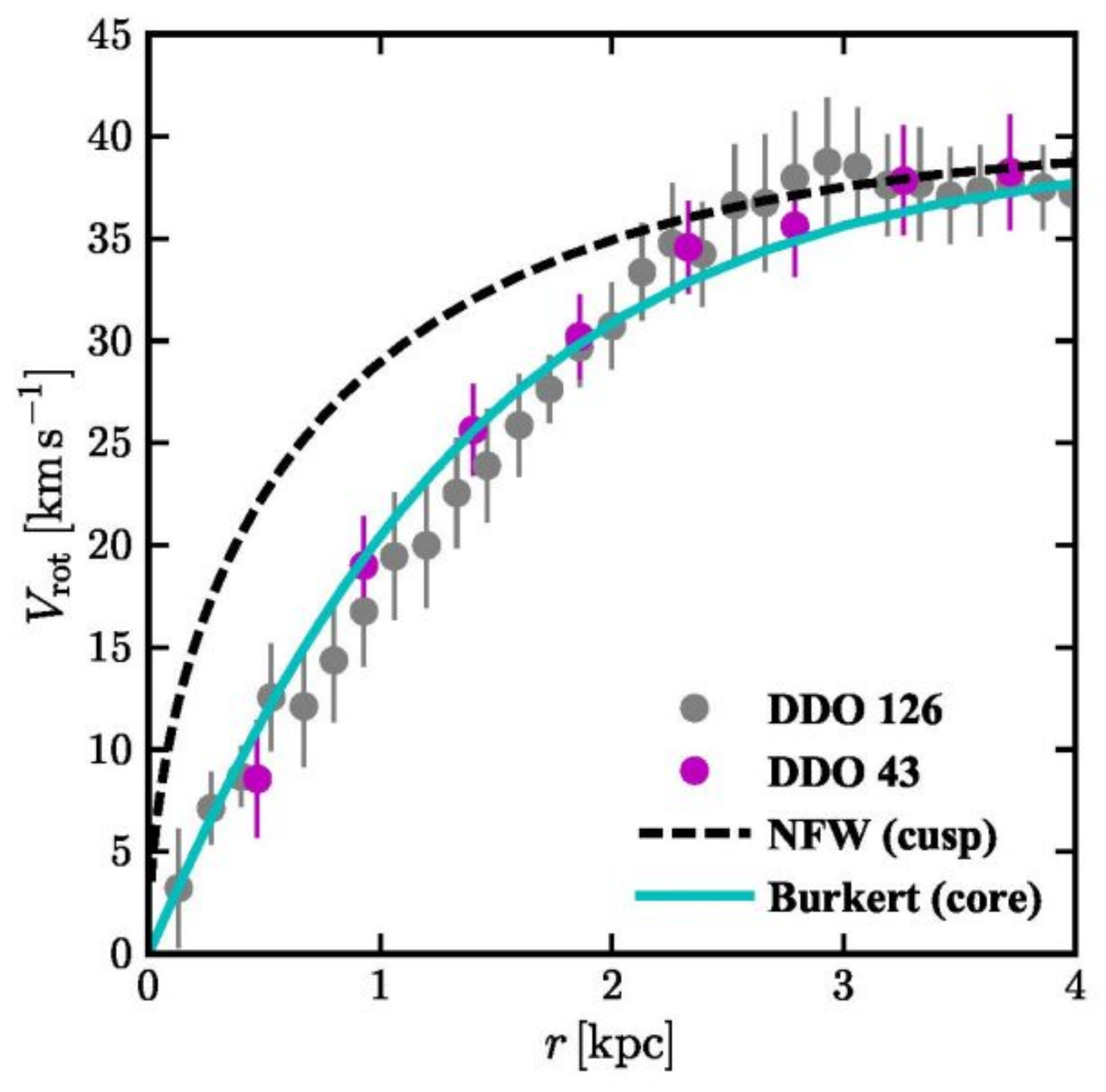


Slide "stolen" from talk by Arka Banerjee, WDMAP, IOP 2024

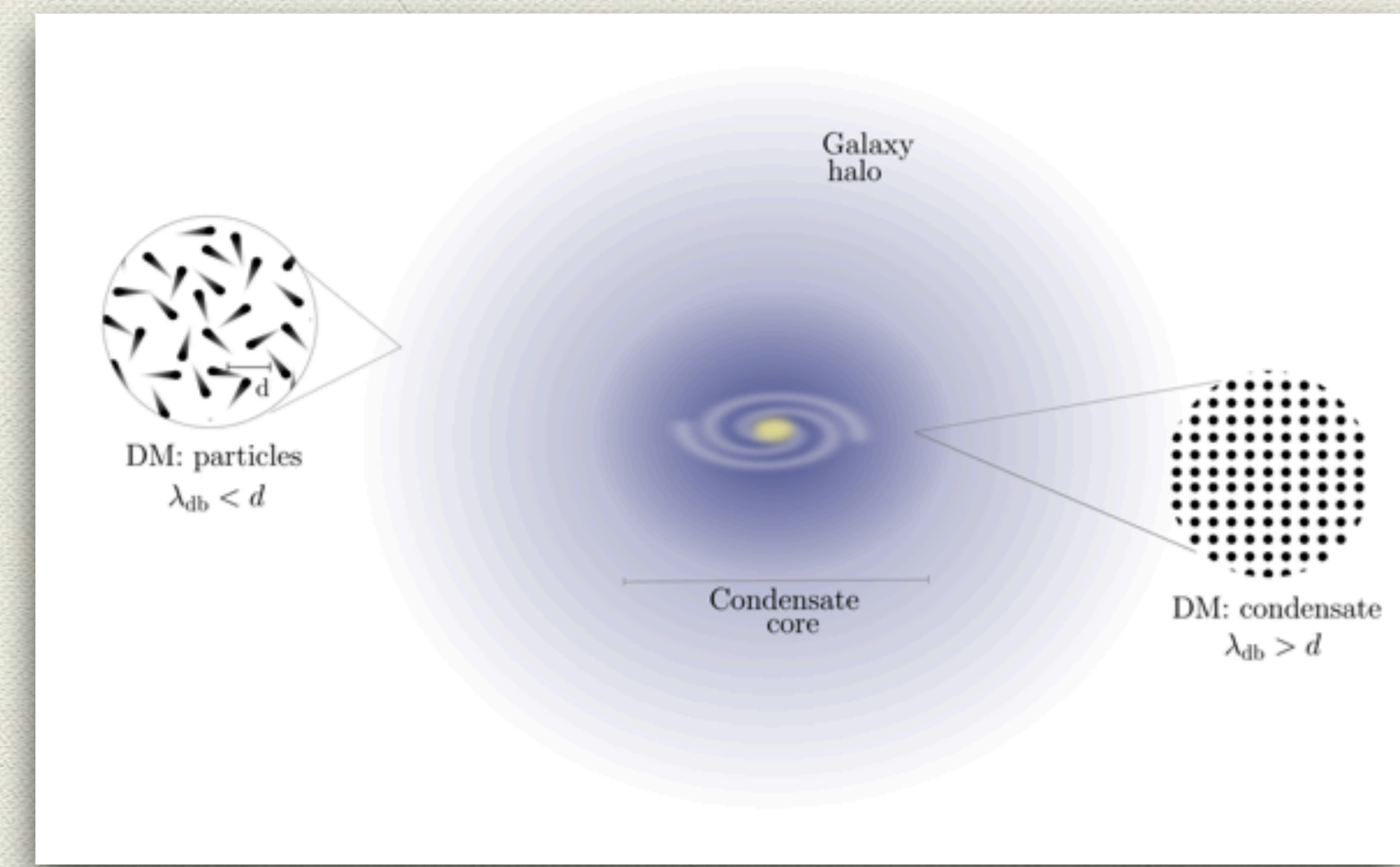


Buckley ,Peter; Phys.Rept. 761 (2018) 1-60

Core-Cusp:



Oh et al. 2015. AJ 149:180



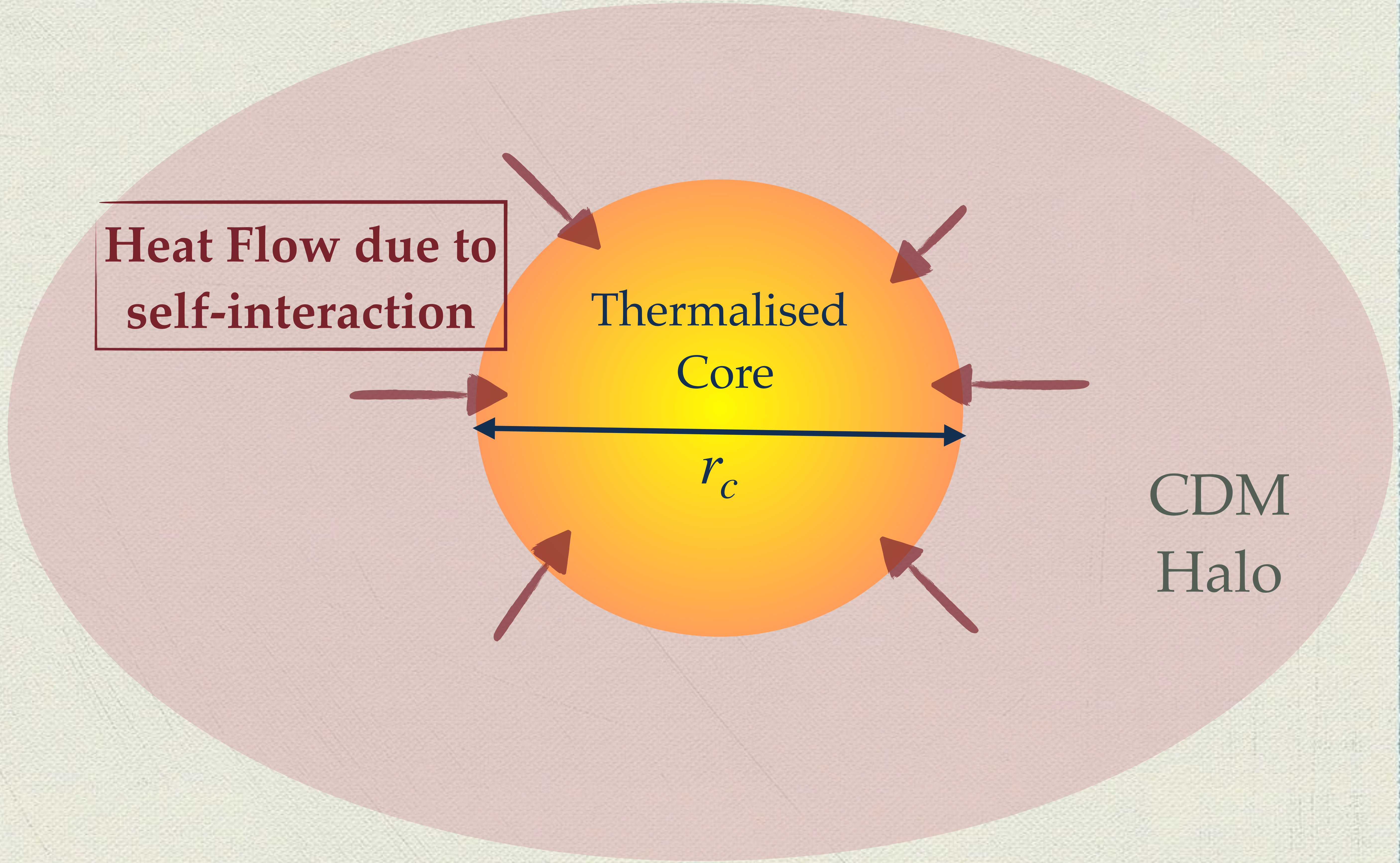
Fuzzy DM Solution:

- solitonic core
- classical halo

Witten et al, Phys. Rev. D 95, 043541 (2017)

SIDM: alternative solution to core cusp

- Self interaction can facilitate the transport of heat from the Halo tail where DM is not gravitationally frozen and thermalise the central region.
- This thermalisation opposes the cusp formation and leads to a core like galactic centre with a non-zero core radius estimated by r_c



Core Radius: quick estimate

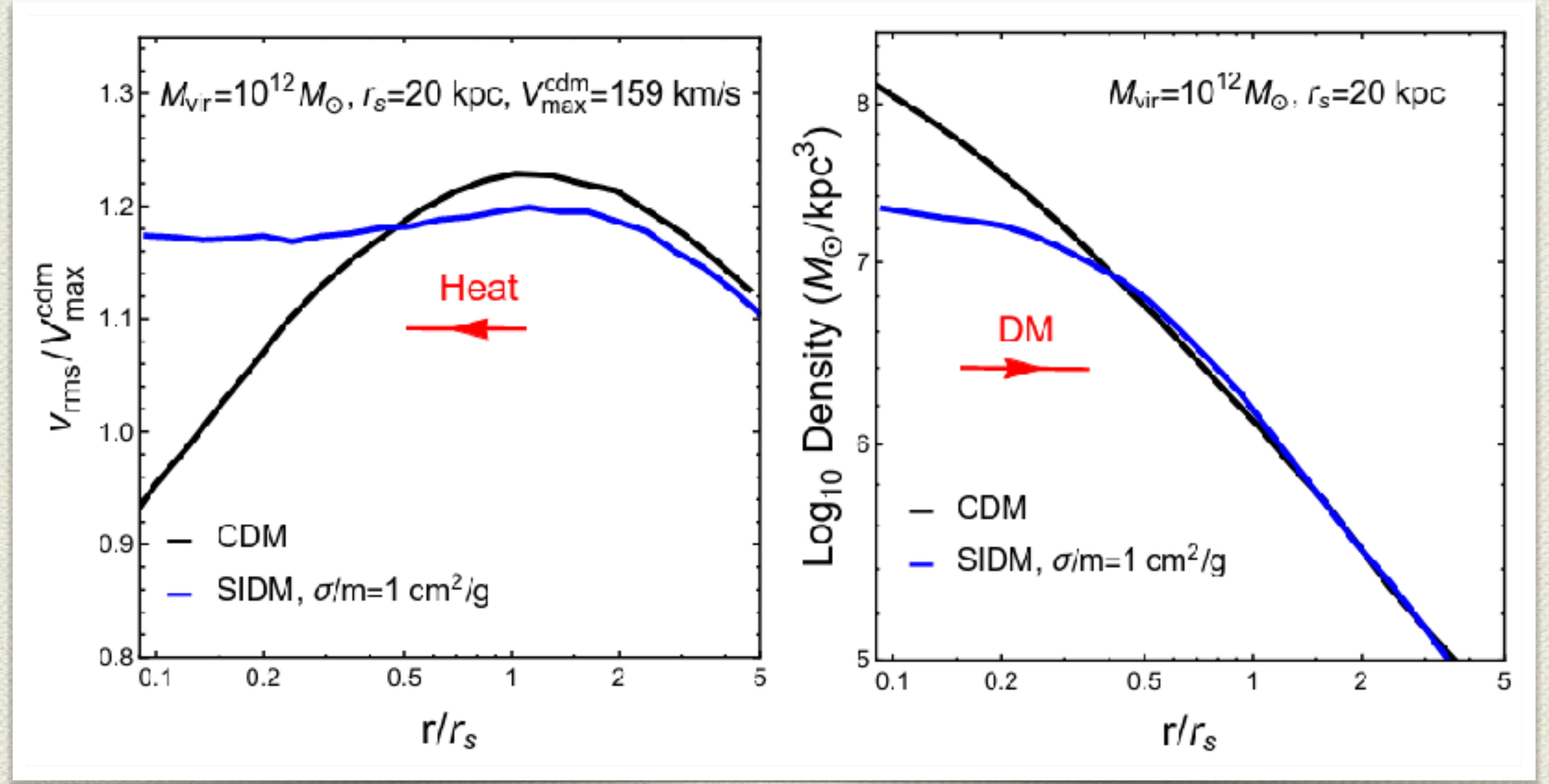
Assume the density profile of a galaxy: $\rho(r)$

The number density follows: $n(r) = \rho(r)/m$

The thermally averaged cross section of dark matter self interaction can be considered to be constant in the core region and given by: $\langle \sigma v \rangle_{self}$

Then we can estimate the core radius to be the location of critical density that would drive at least one self interaction in the galactic lifetime:

$$\langle \sigma v \rangle_{self} \frac{\rho(r_c)}{m} t_{age} \sim 1$$



Kaplinghat et al, PRL 116 (2016) 041302

N-Body simulations from our kitchen garden

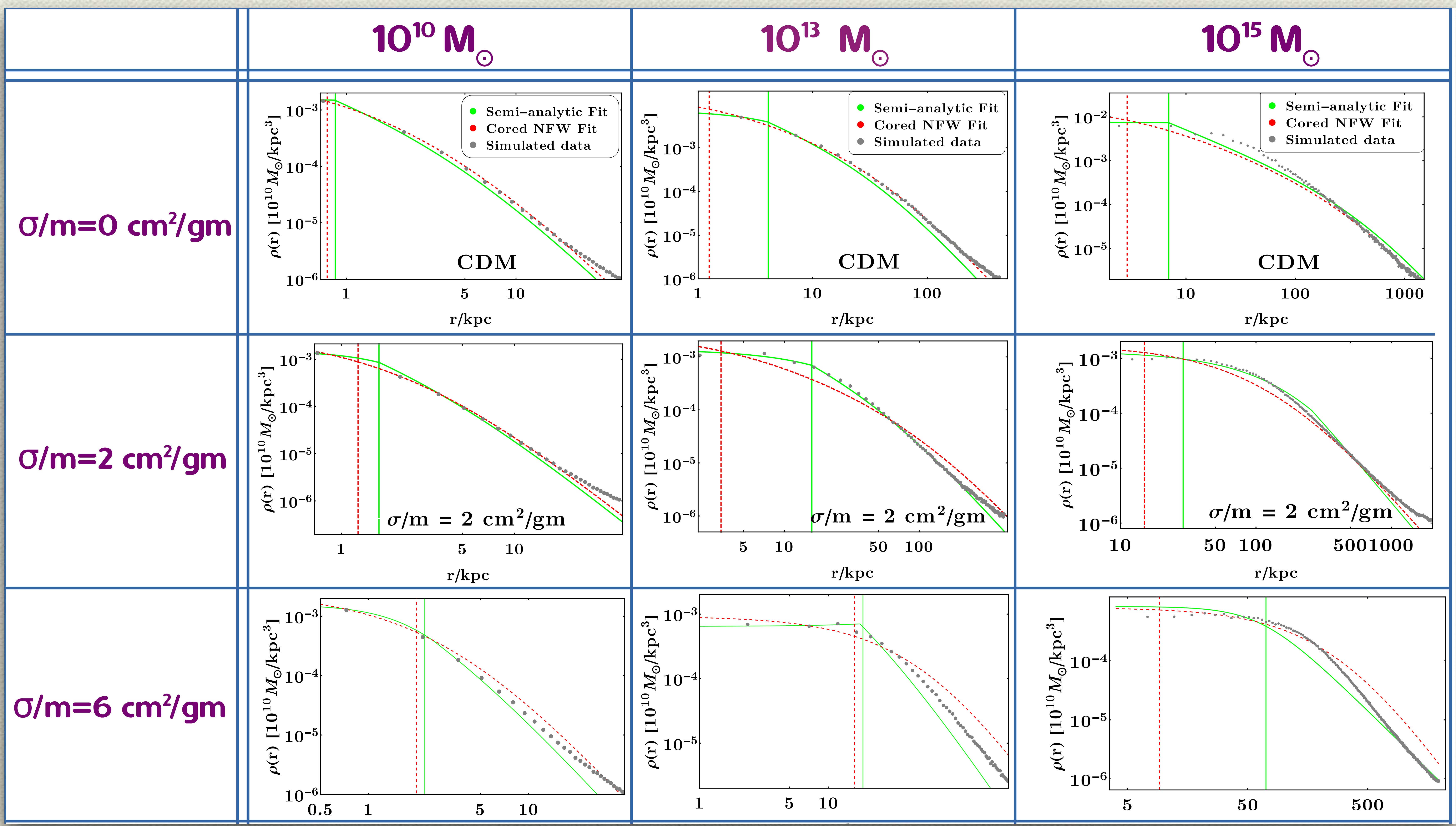
Grey dots: Simulated data

Green solid line: fitted to the semi analytic Jeans model

$$\rho(r) = \begin{cases} \rho_{\mathrm{iso}}(r) = \rho_o e^{-h(r/r_o)} & r \le r_1 \\ \rho_{\mathrm{NFW}}(r) = \frac{\rho_s}{\frac{r}{r_s}\left[1+\frac{r}{r_s}\right]^2} & r > r_1 \,. \end{cases}$$

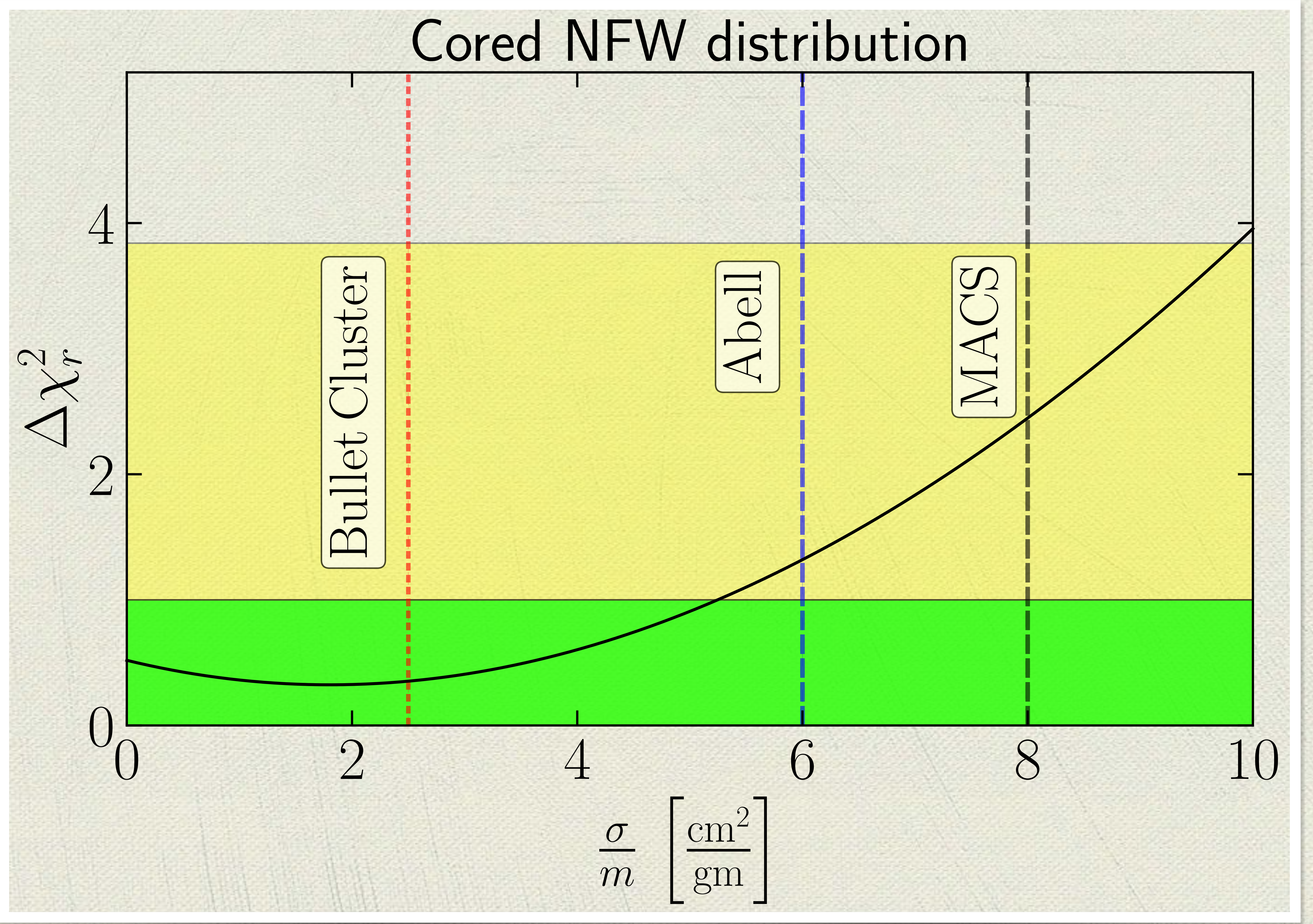
Red dotted line: fitted cored NFW model

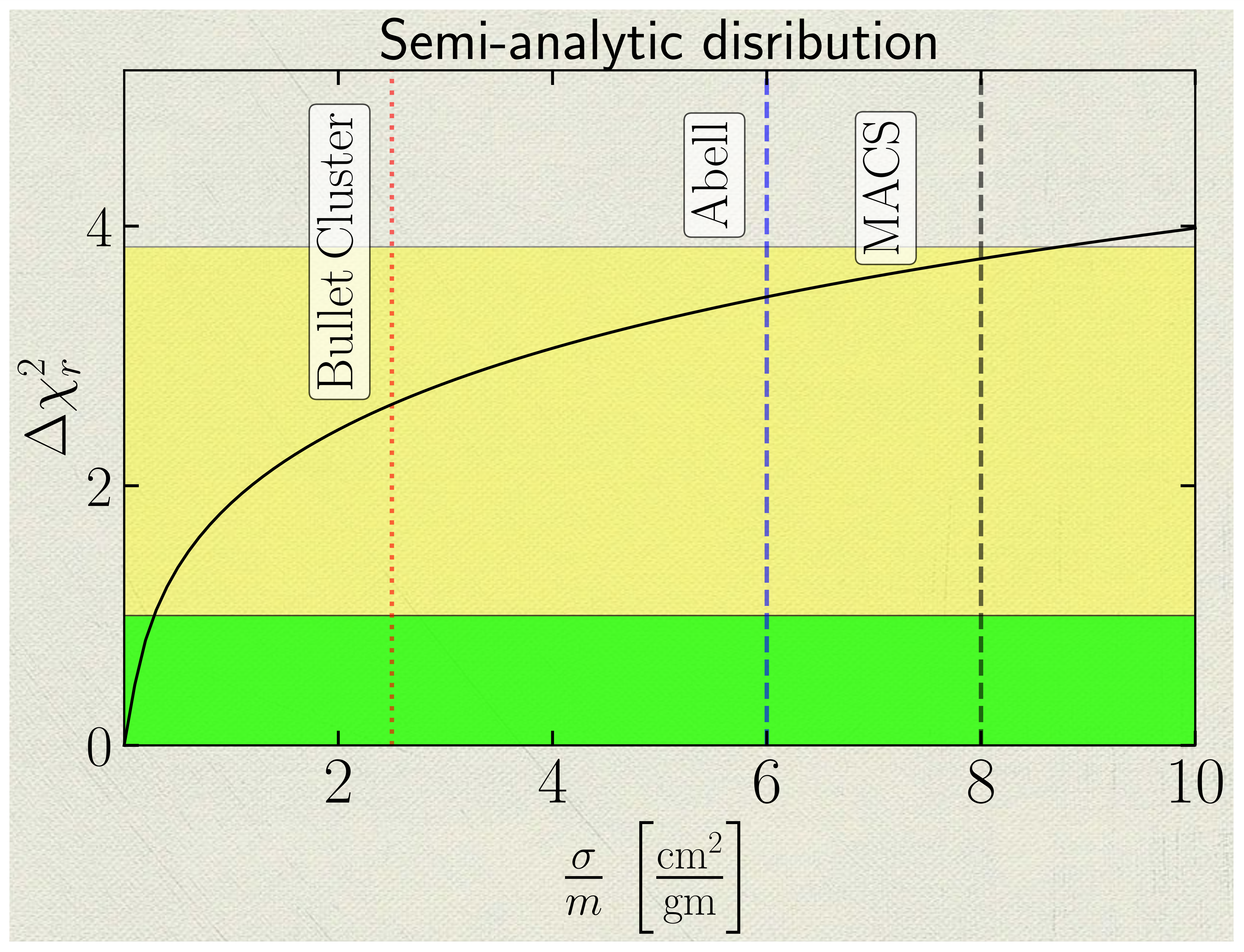
$$\rho_{\mathrm{cNFW}}(r) = \frac{r_s \rho_s}{r_c[1+\frac{r}{r_s}]^2[1+\frac{r}{r_c}]}$$



Sarkar, TSR, Shaw JCAP 09 (2022) 011

Constraints on DM self-interaction

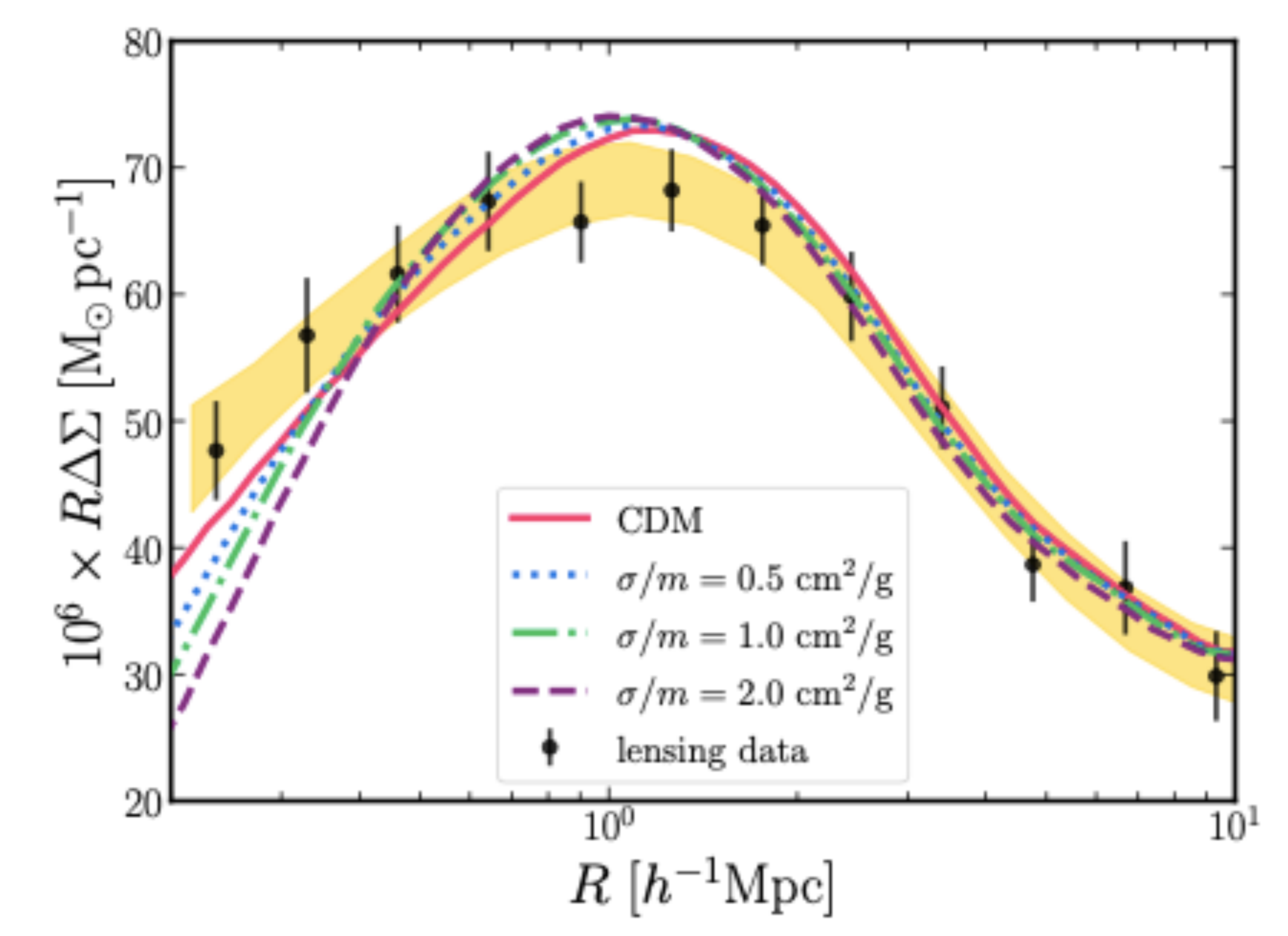


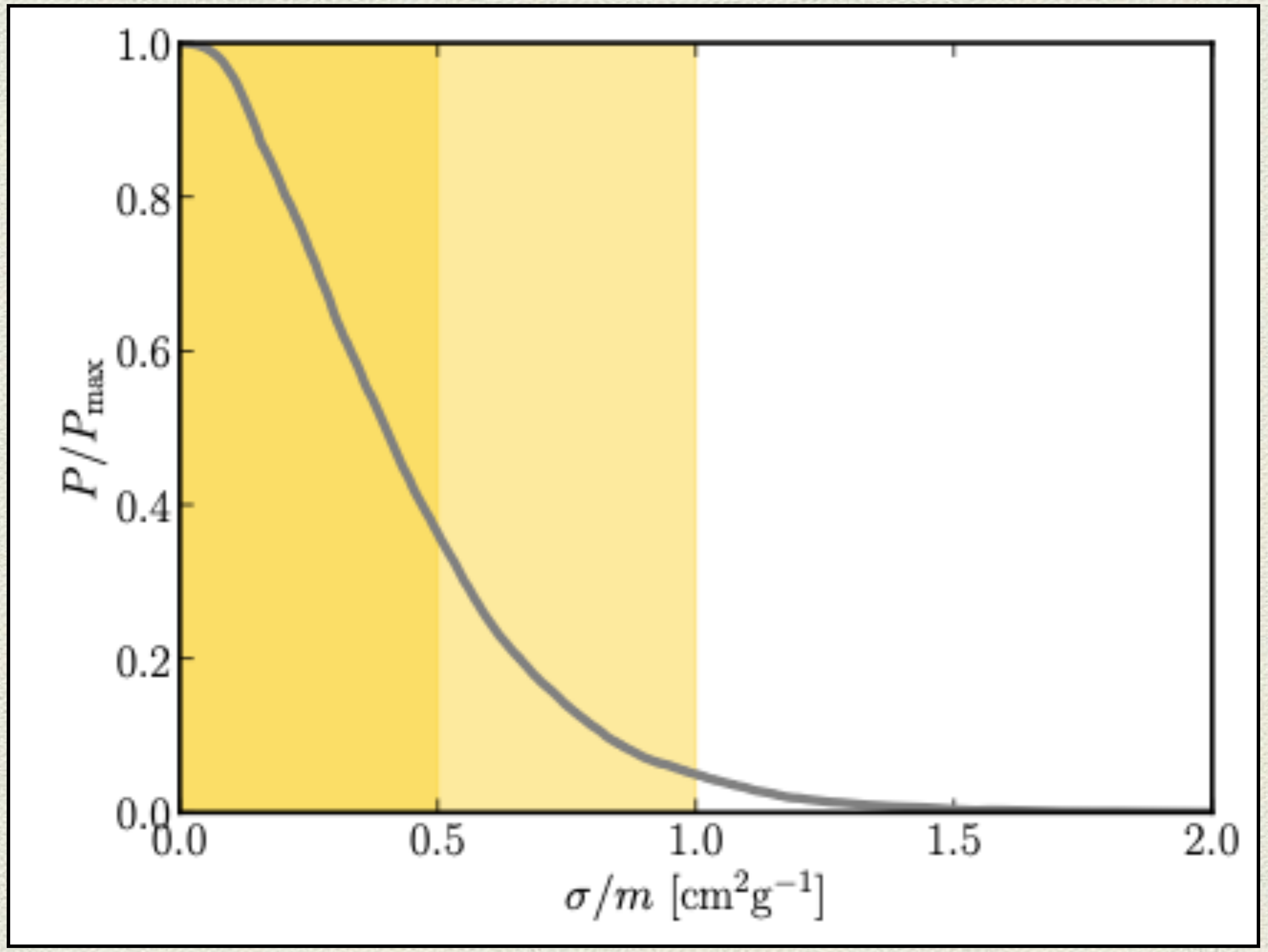


$\sigma_{self}/m_{dm} < 9.8cm^2/gm$

Sarkar, TSR, Shaw JCAP 09 (2022) 011

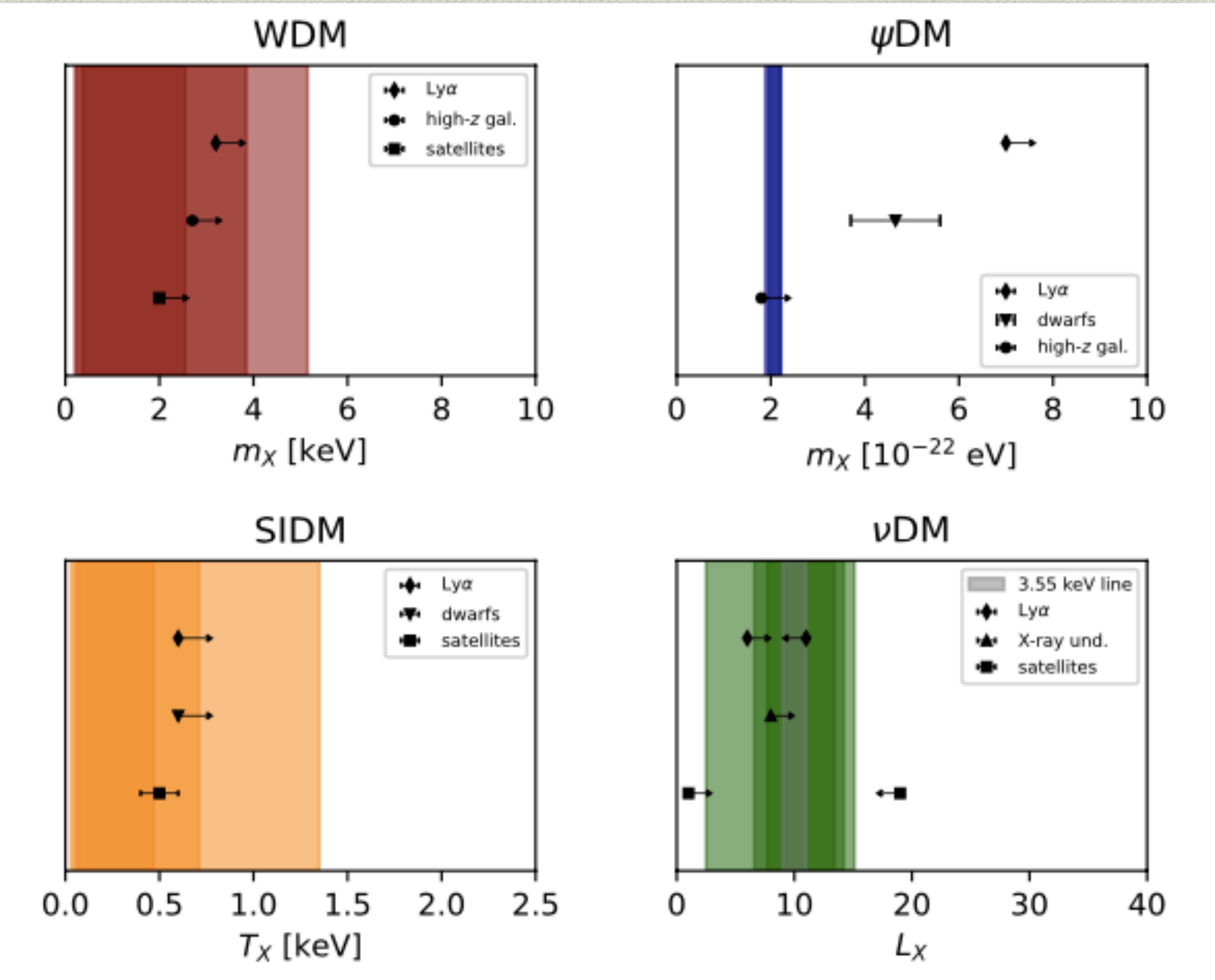
Updated Results from Micro-lensing in Galaxy Clusters





Adhikari et al, 2401.05788

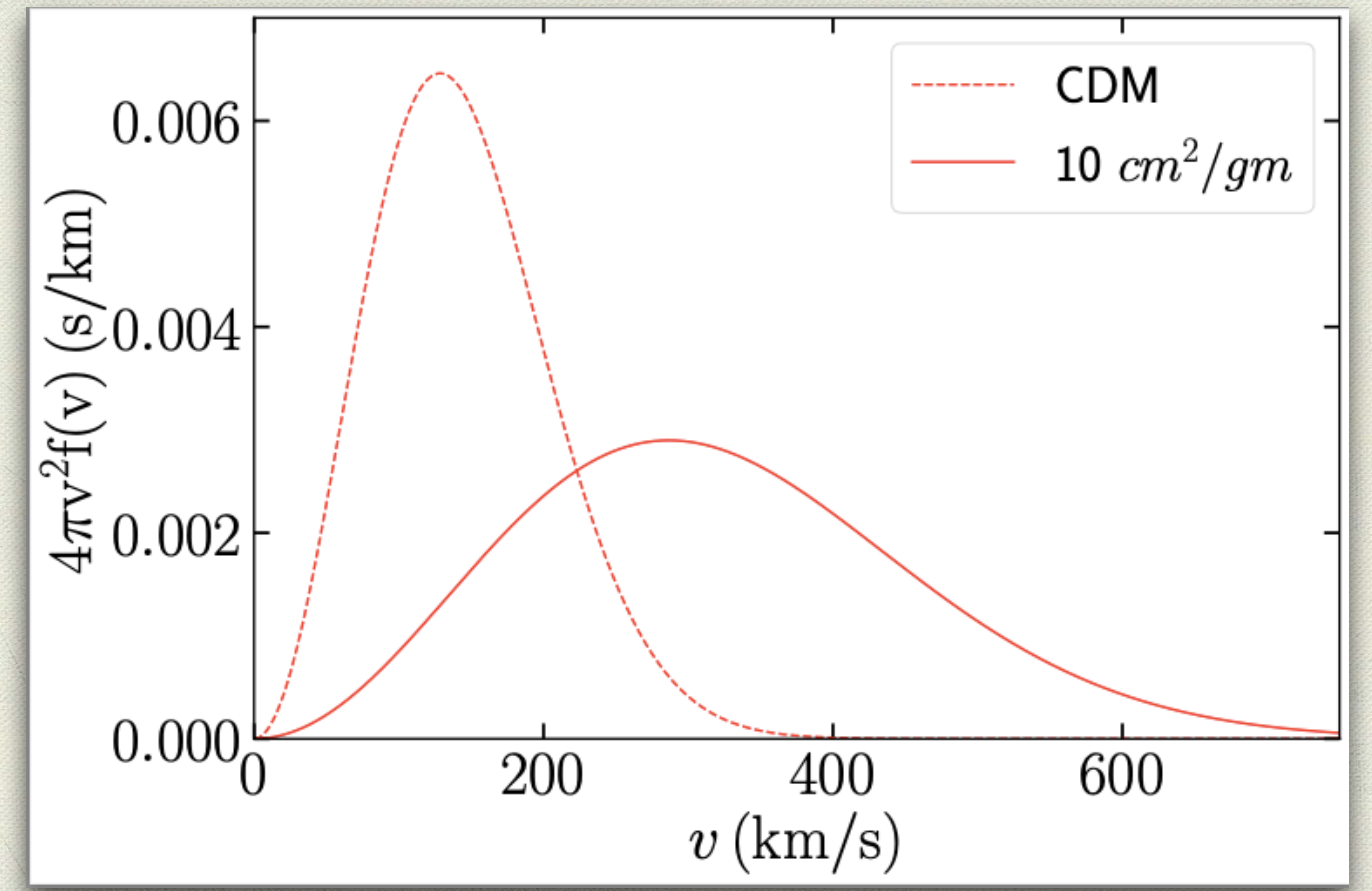
DM mass constraints from cosmic re-ionization history studies and primordial galaxy formation



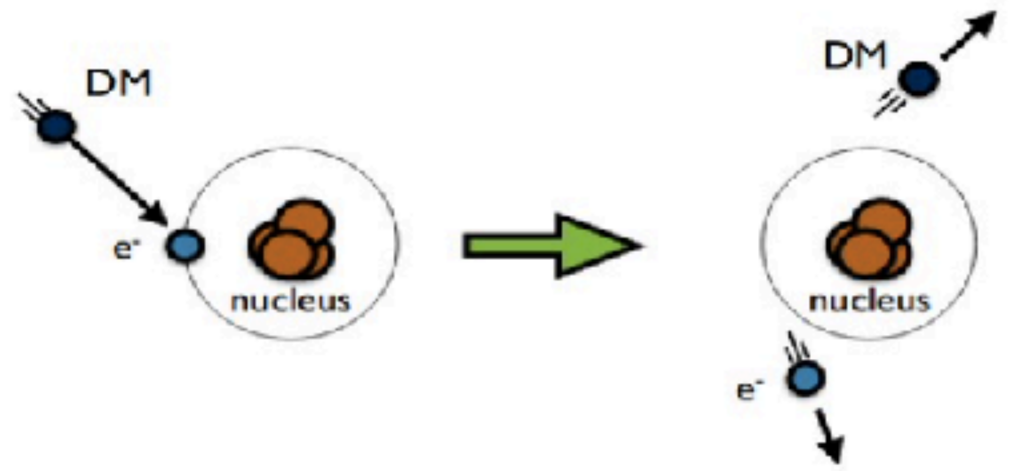
Lapi et al, Universe 8 (2022) 9, 476

Distortion of velocity distribution due to self-interaction

- The velocity distribution of dark matter in a galaxy may be modified by self-interaction of Dark Matter
- This may provide an handle to gain information about the self-interaction of Dark Matter



Impact on Direct Detection

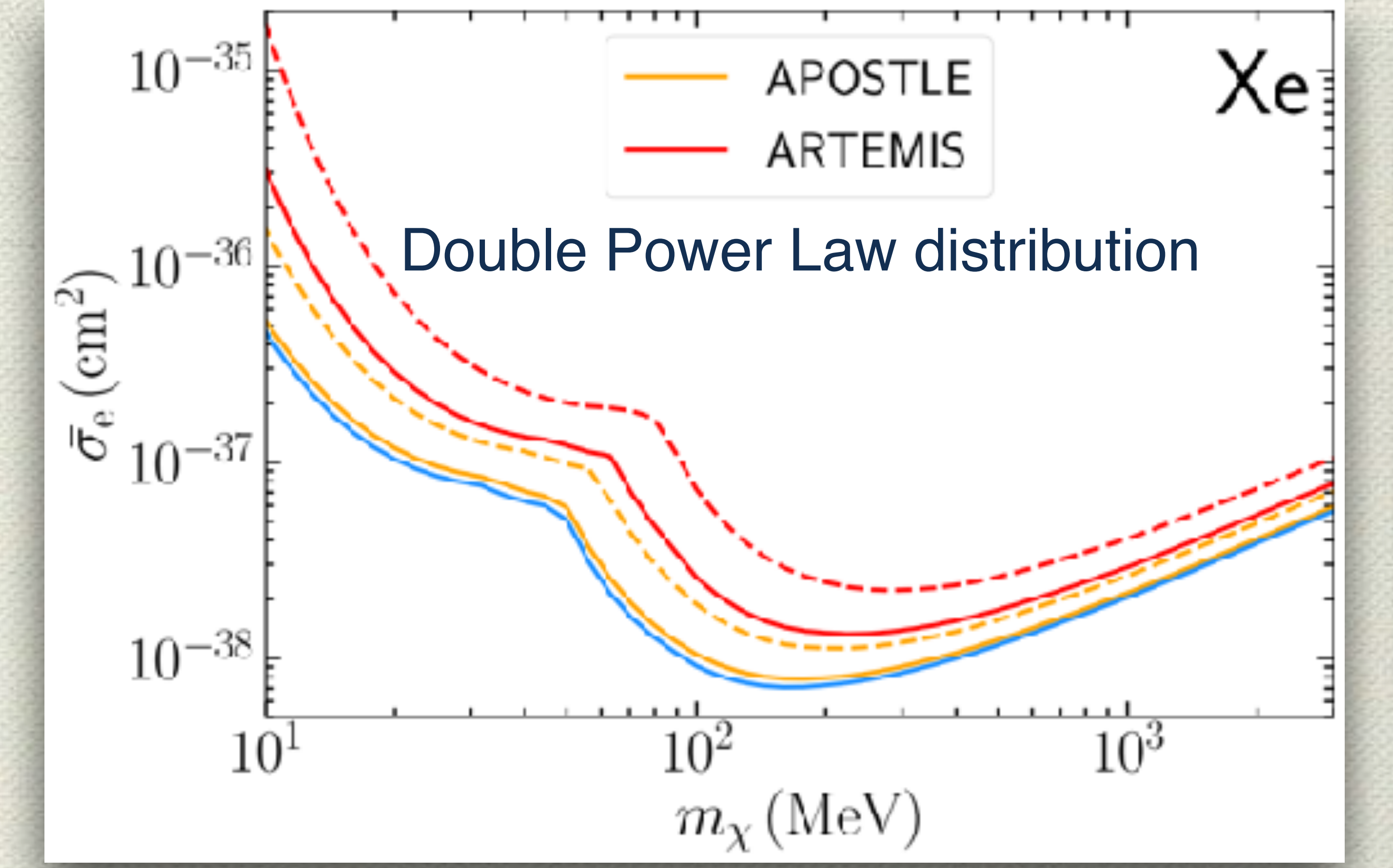


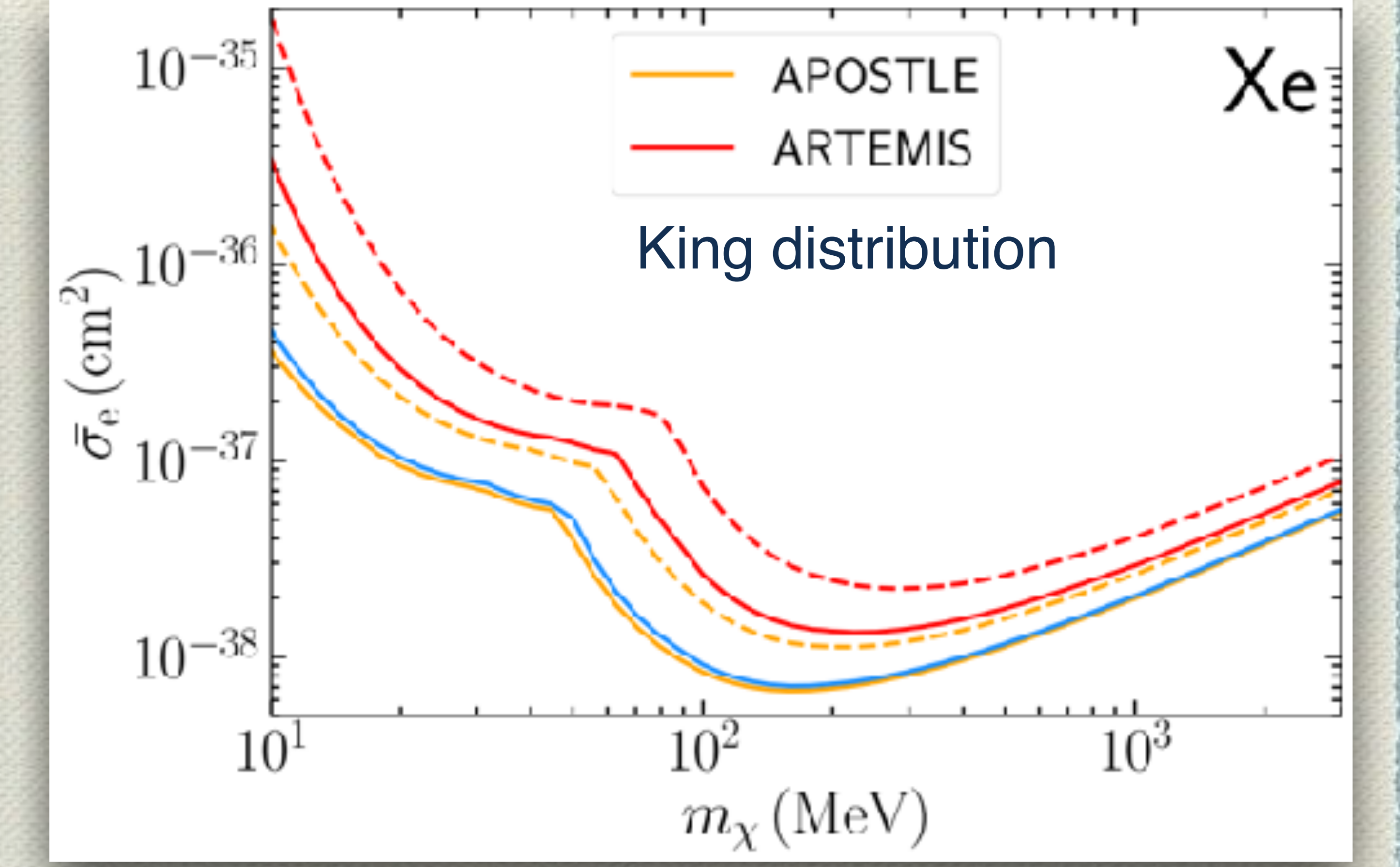
Courtesy: R. Essig

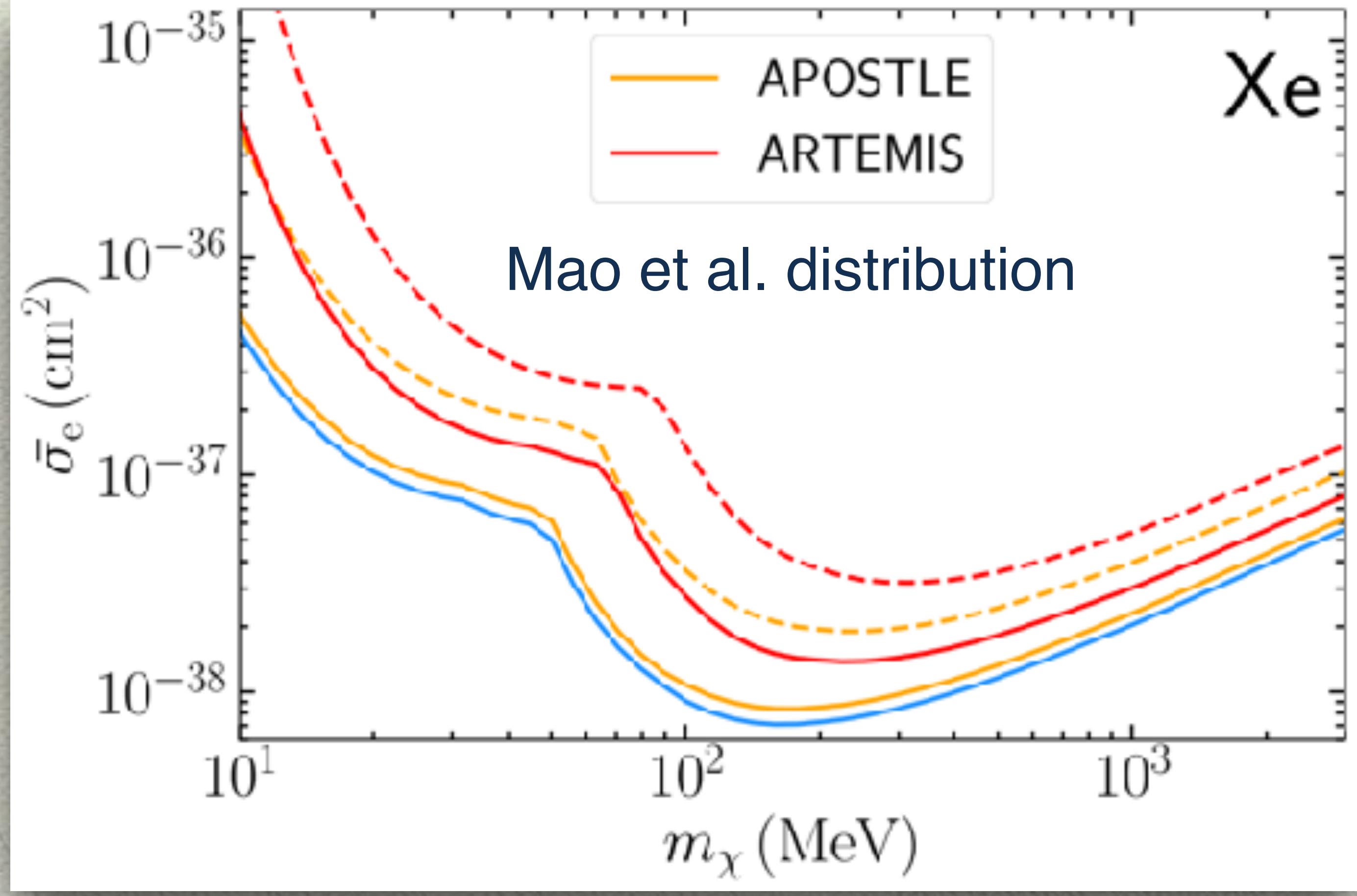
$$\frac{dR_{\rm ion}}{d\ln E_e} \propto N_T \frac{\bar{\sigma}_e}{8\mu_{\chi e}^2 m_\chi} \int q\,dq\, |f_{\rm ion}(E_e,q)|^2 \, \rho_\chi\, \eta\,(v_{\rm min}(E_e,q))$$

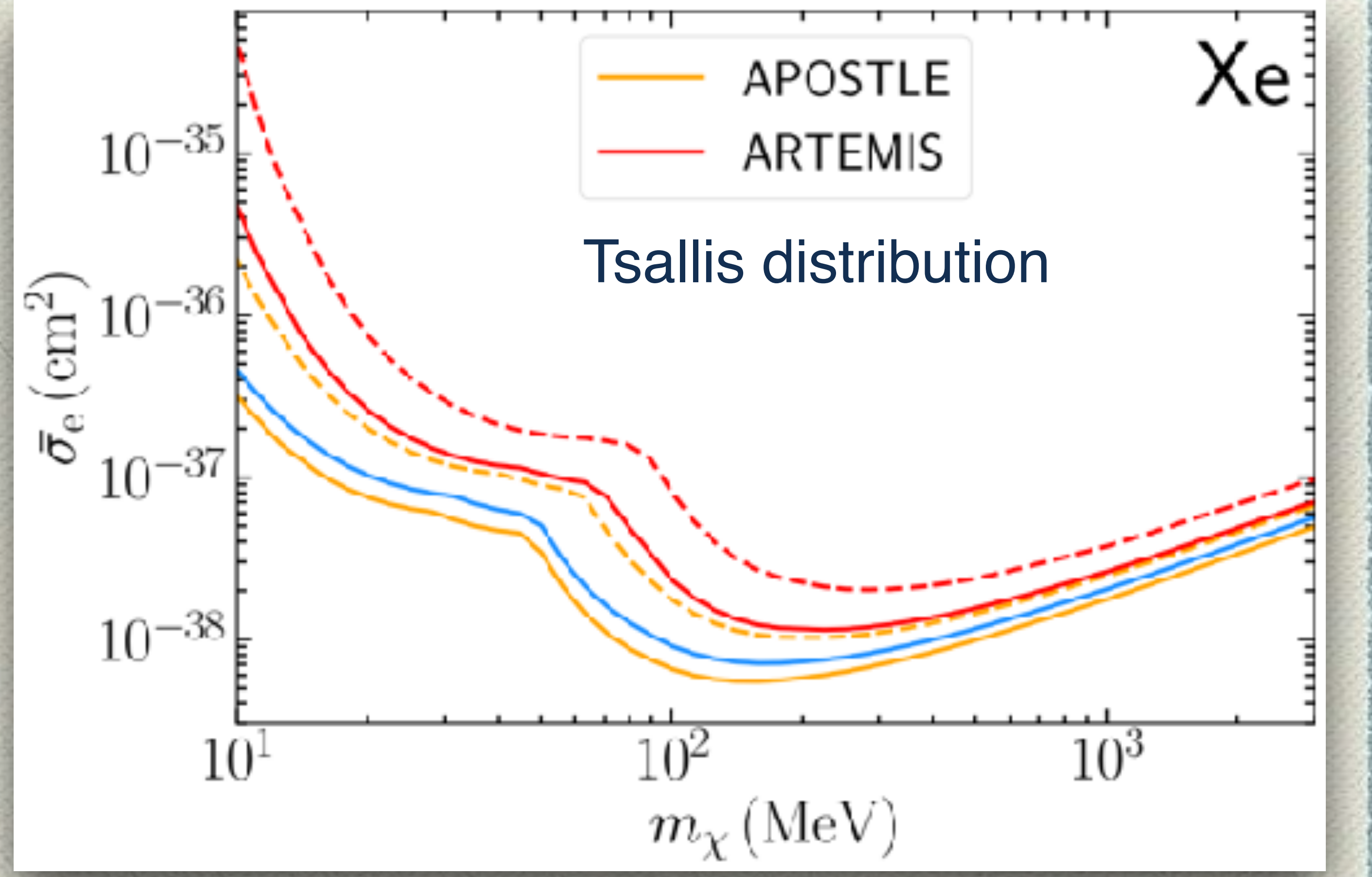
Velocity Distribution Function near Earth

The analysis shows the impact of velocity distribution extracted from CDM N-Body simulation on direct detection of electrophilic Dark Matter



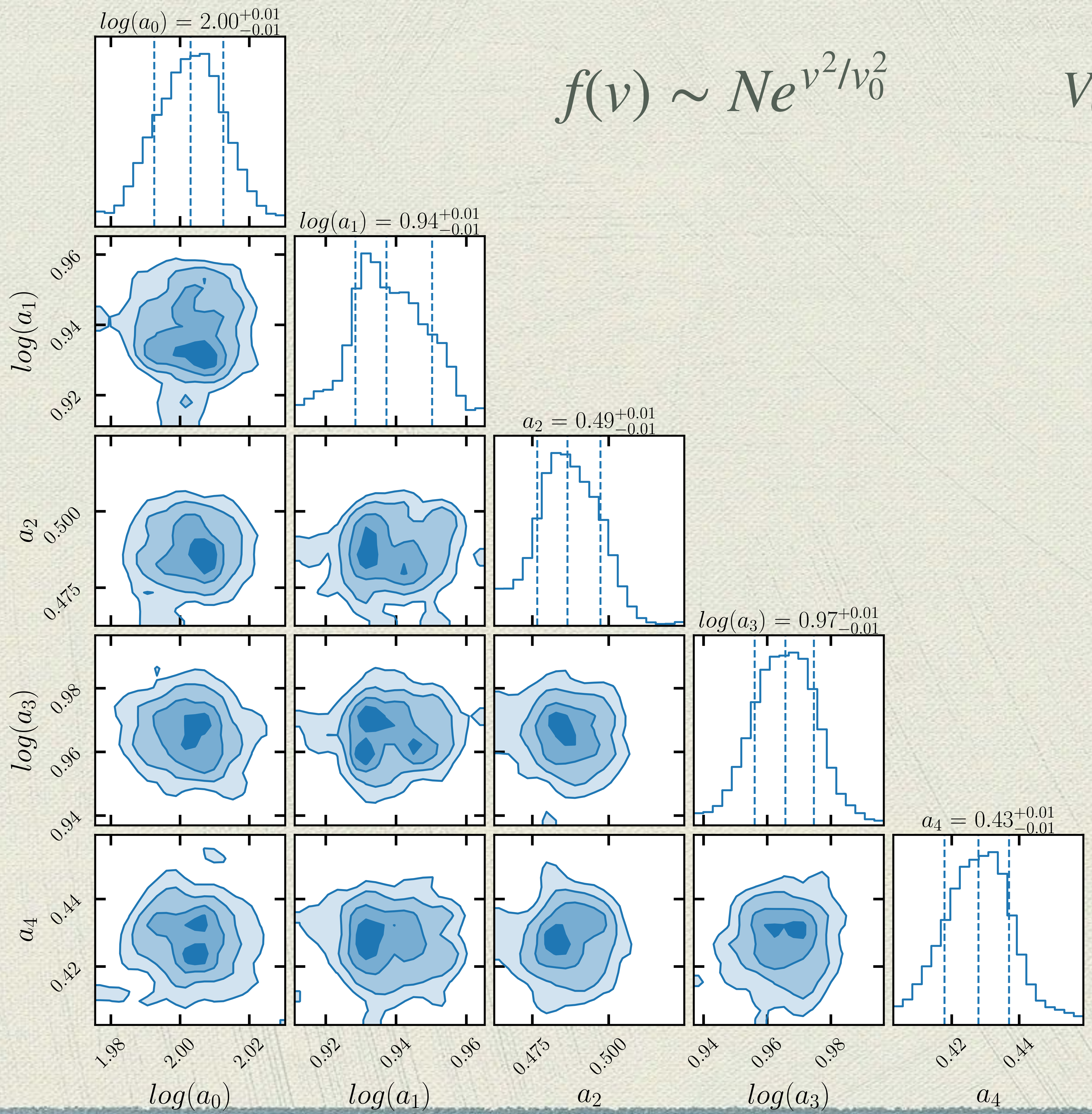






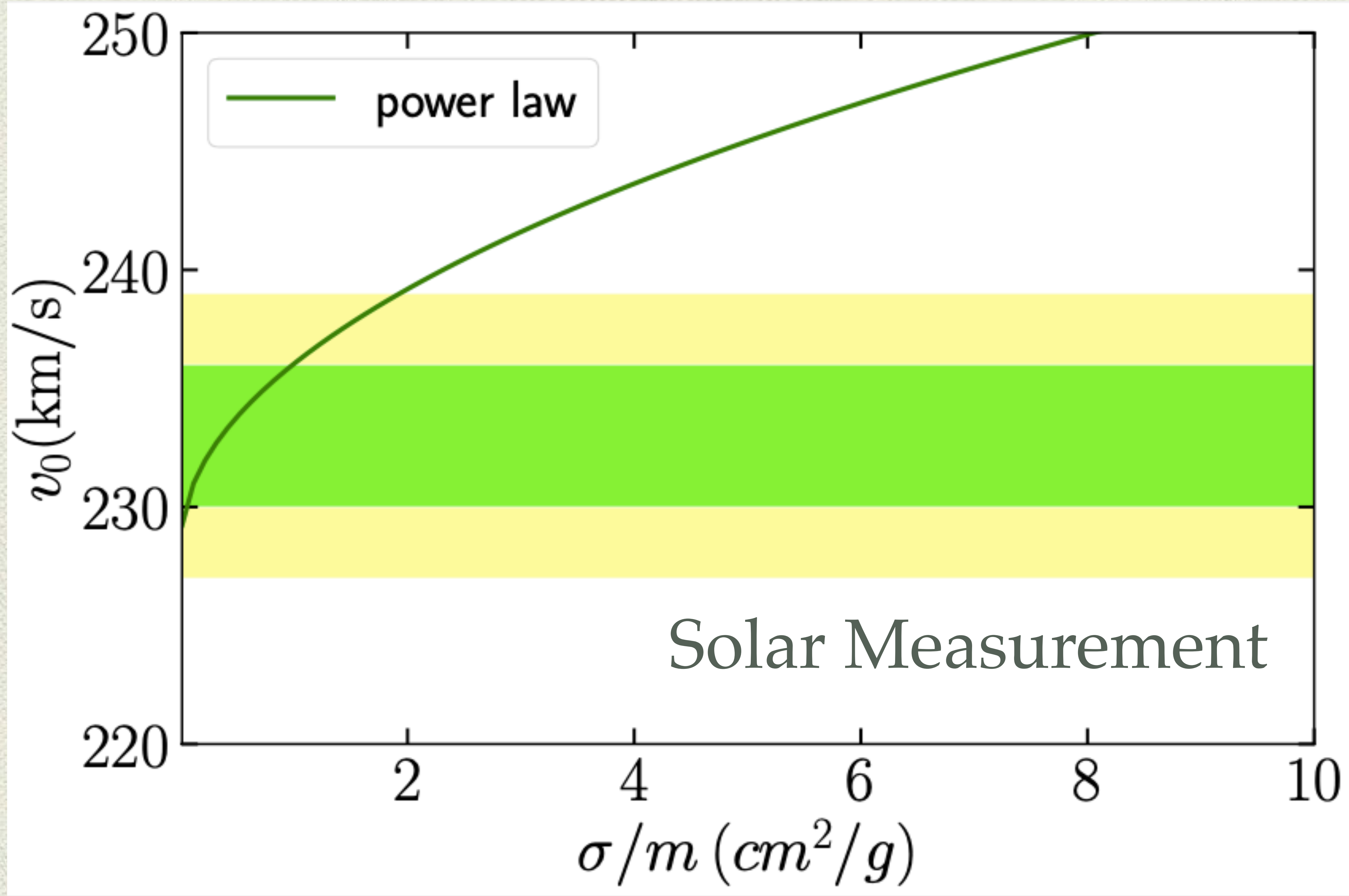
Maity, TSR, Sarkar Eur.Phys.J.C 81 (2021) 11, 1005

MWL Analysis:



$$f(v) \sim N e^{v^2/v_0^2}$$

$$V_0 = \sqrt{\frac{GM(r)}{r} + a_1 \frac{\sigma}{m} + a_2 \frac{M_*}{10^{10} M_\odot} + a_3 \left(\frac{\sigma}{m}\right)^2 + a_4 \left(\frac{M_*}{10^{10} M_\odot}\right)^2}$$

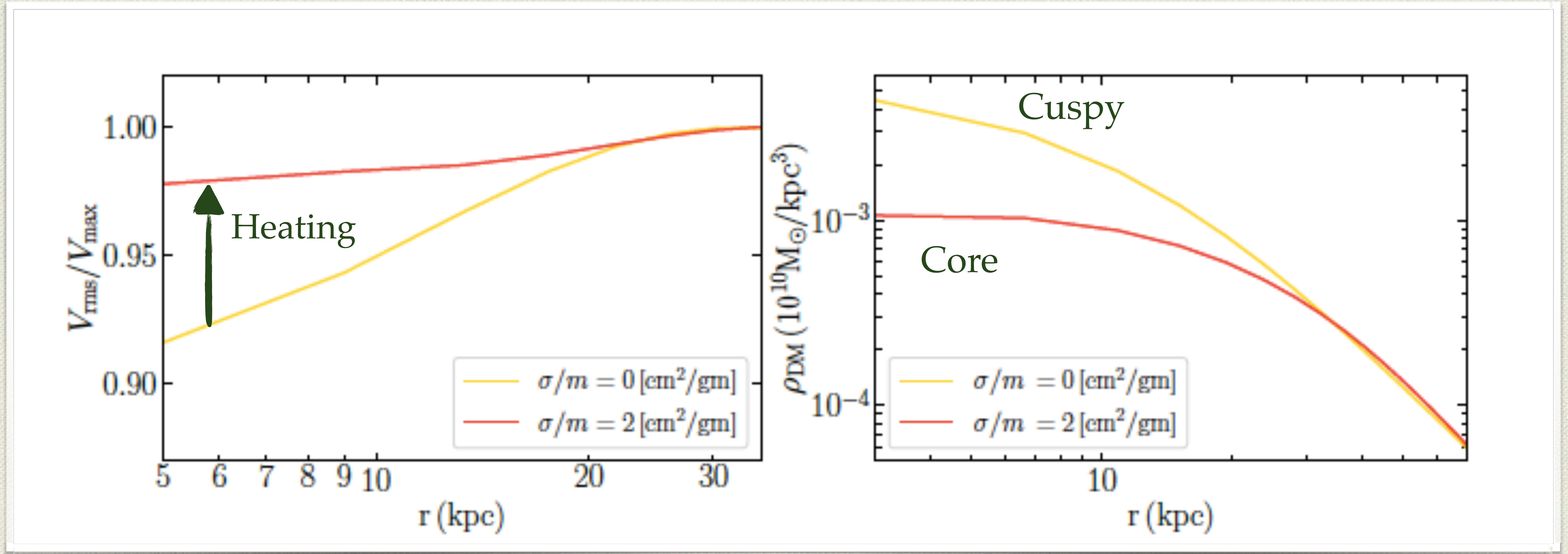


Sarkar, TSR, in preparation

Discussions:

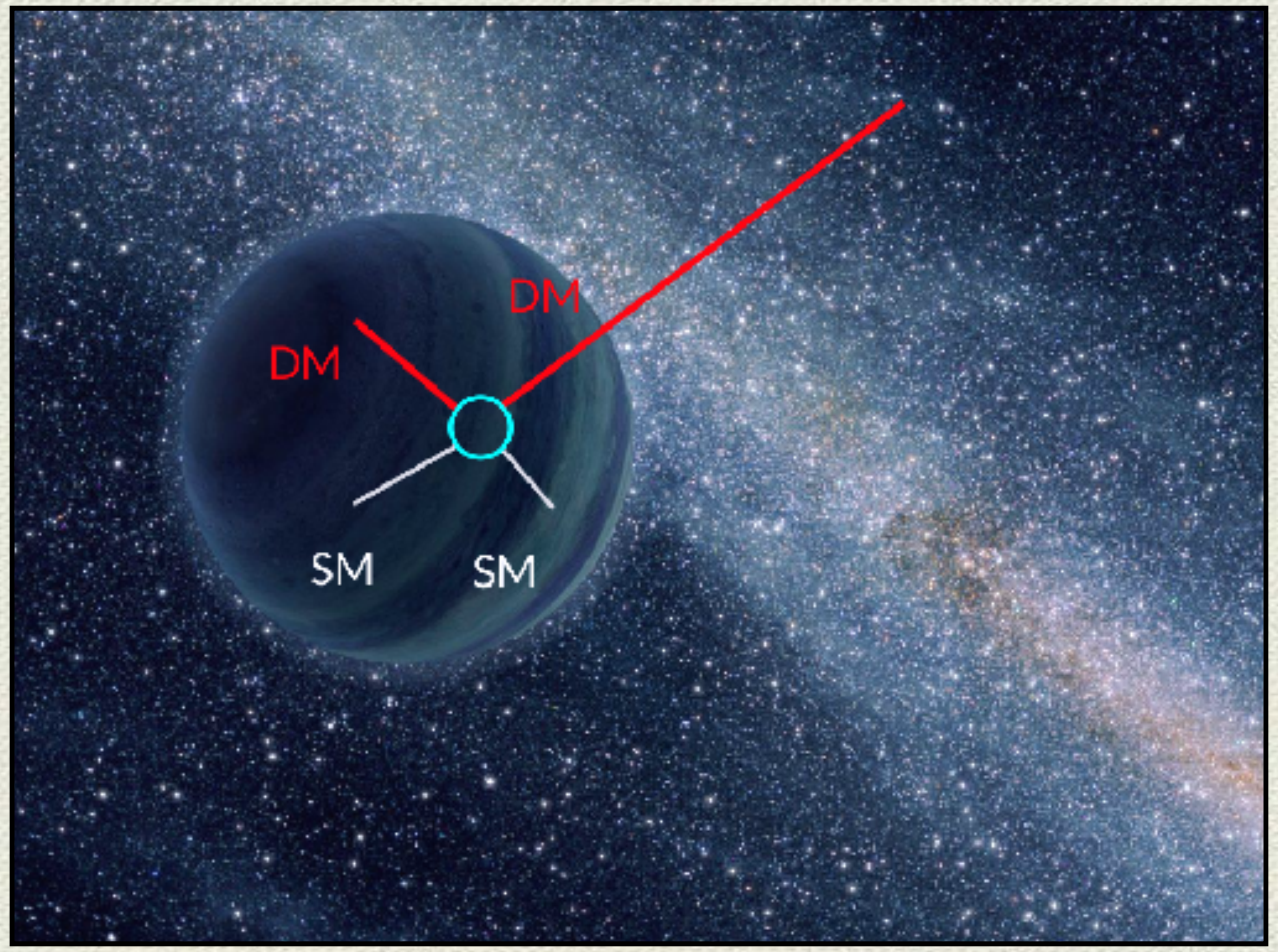
- Limits on warm dark matter: $m_{DM} > 7KeV??$
- Fuzzy DM: Limits from core size, complimentary constraints etc.
- SIDM: complimentary information beyond structure formation
- N-Body: need to implement interaction case by case basis, generalisation, computational limits etc

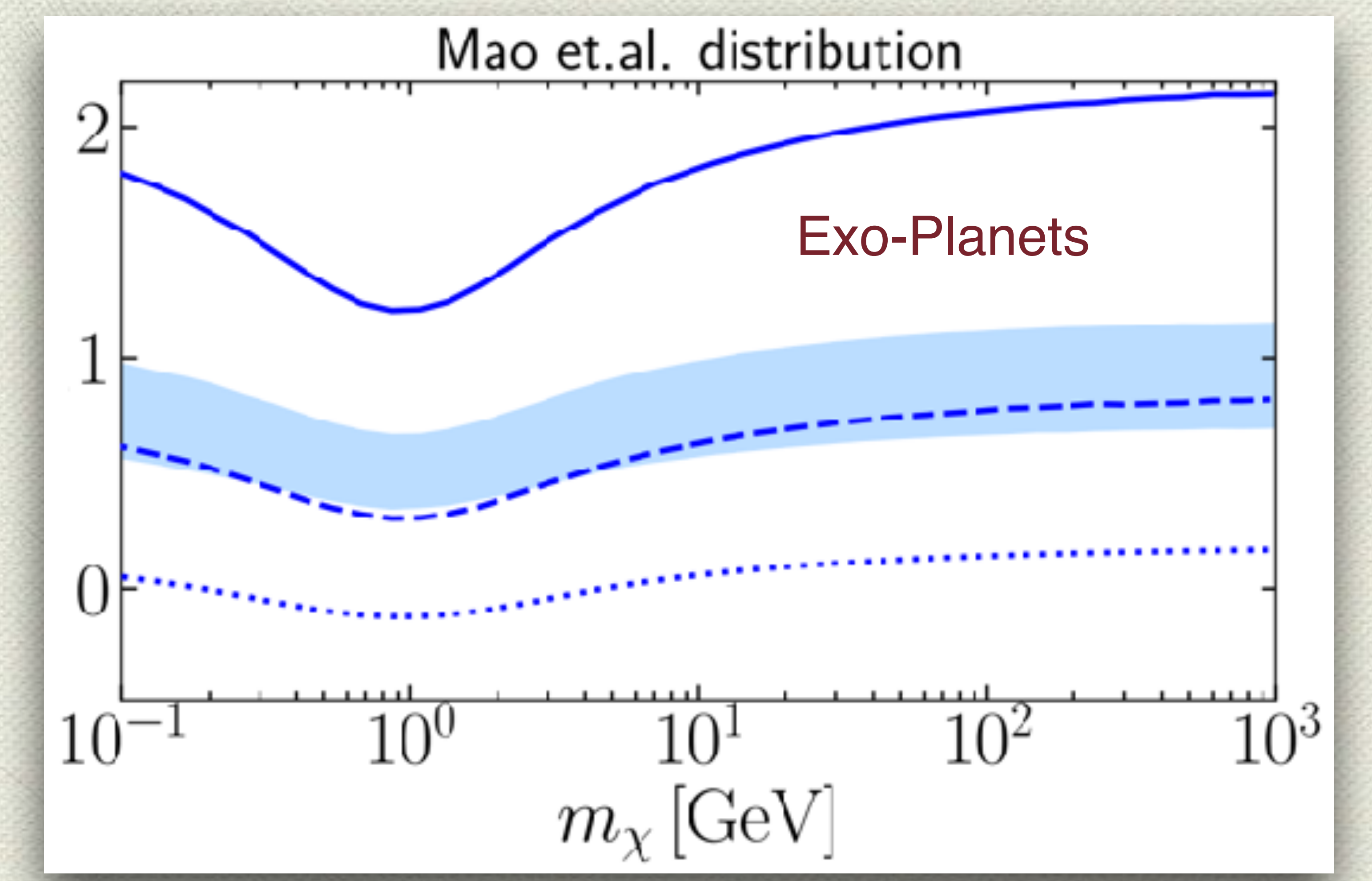
Backup slide: Thermalisation of cores in N-Body simulations

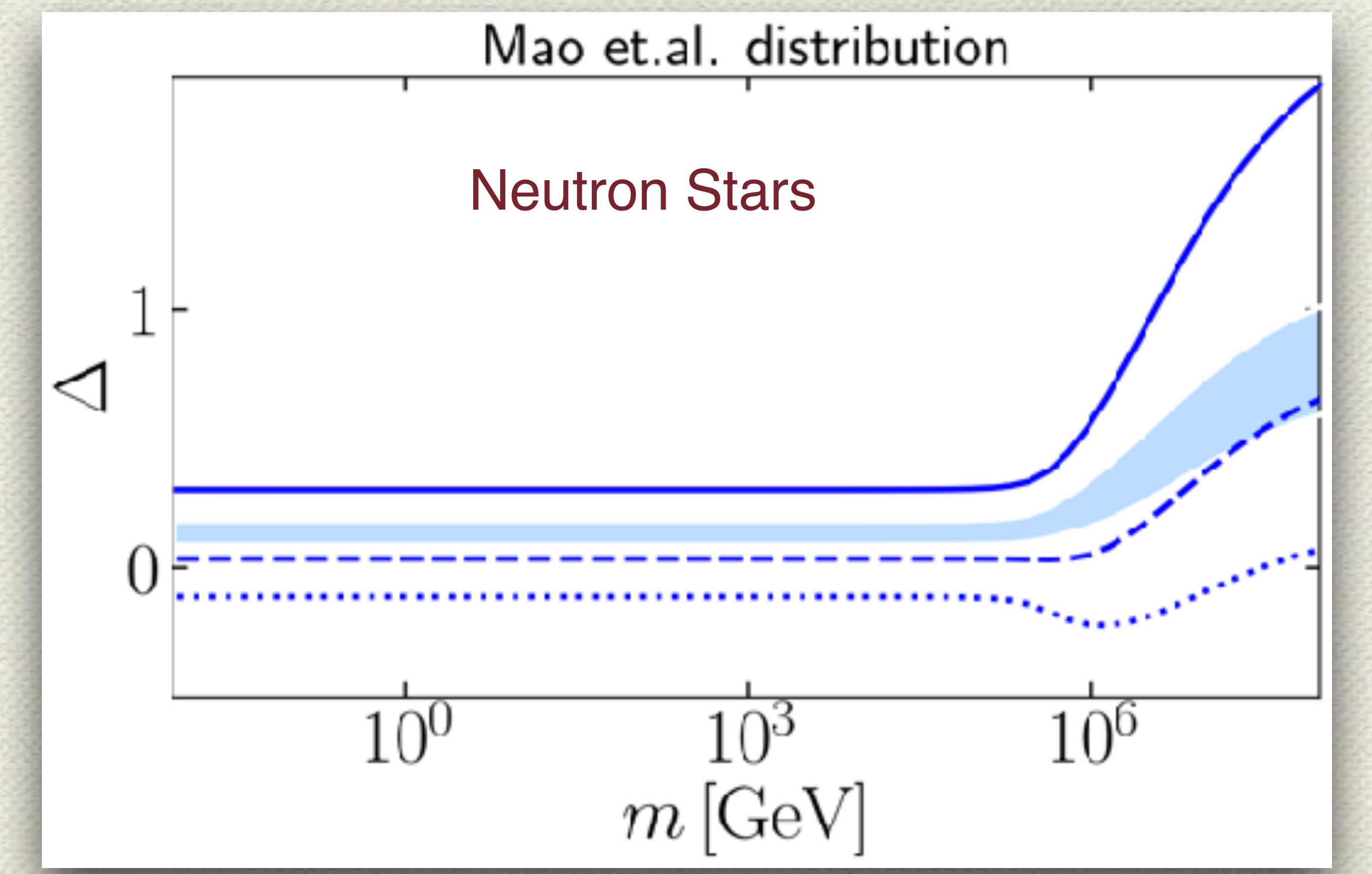


Sarkar, TSR, Shaw JCAP 09 (2022) 011

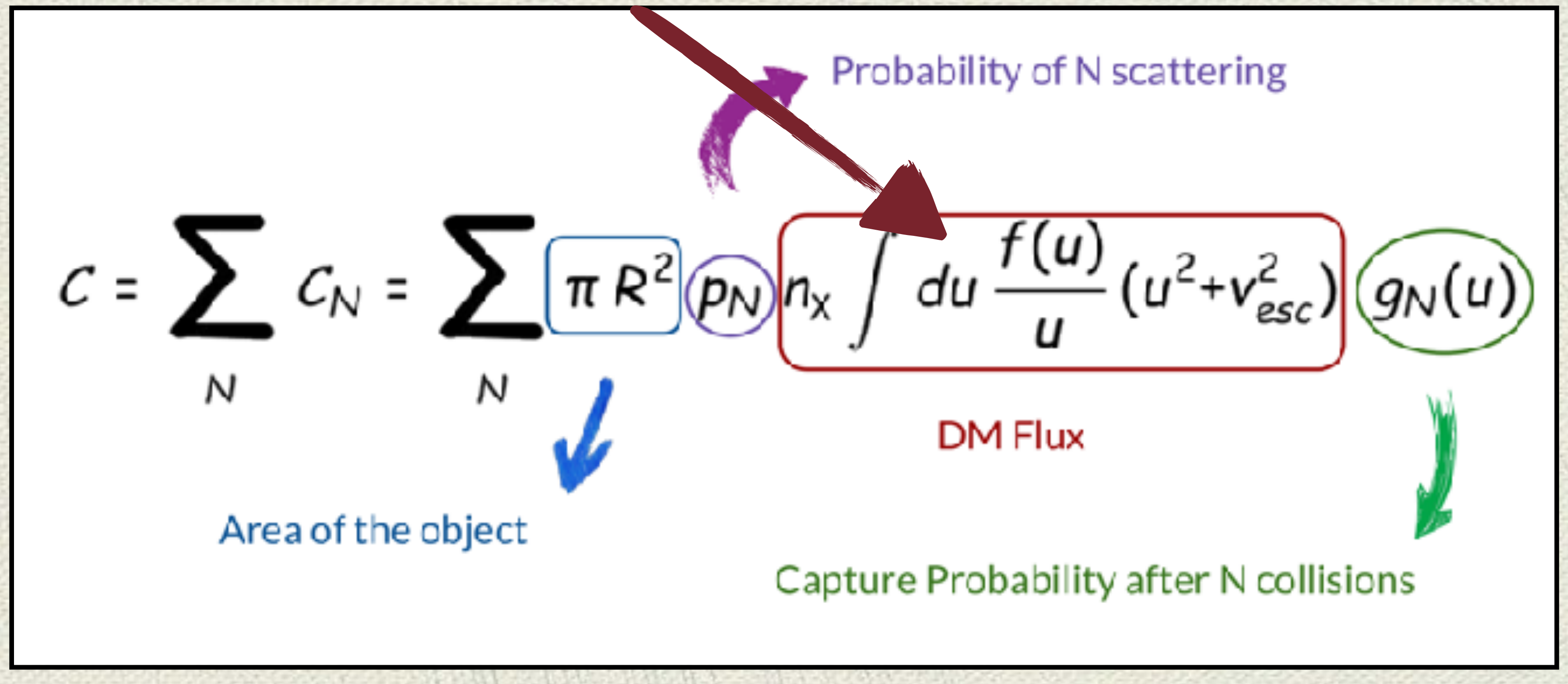
Backup slide:Impact on capture in celestial bodies:

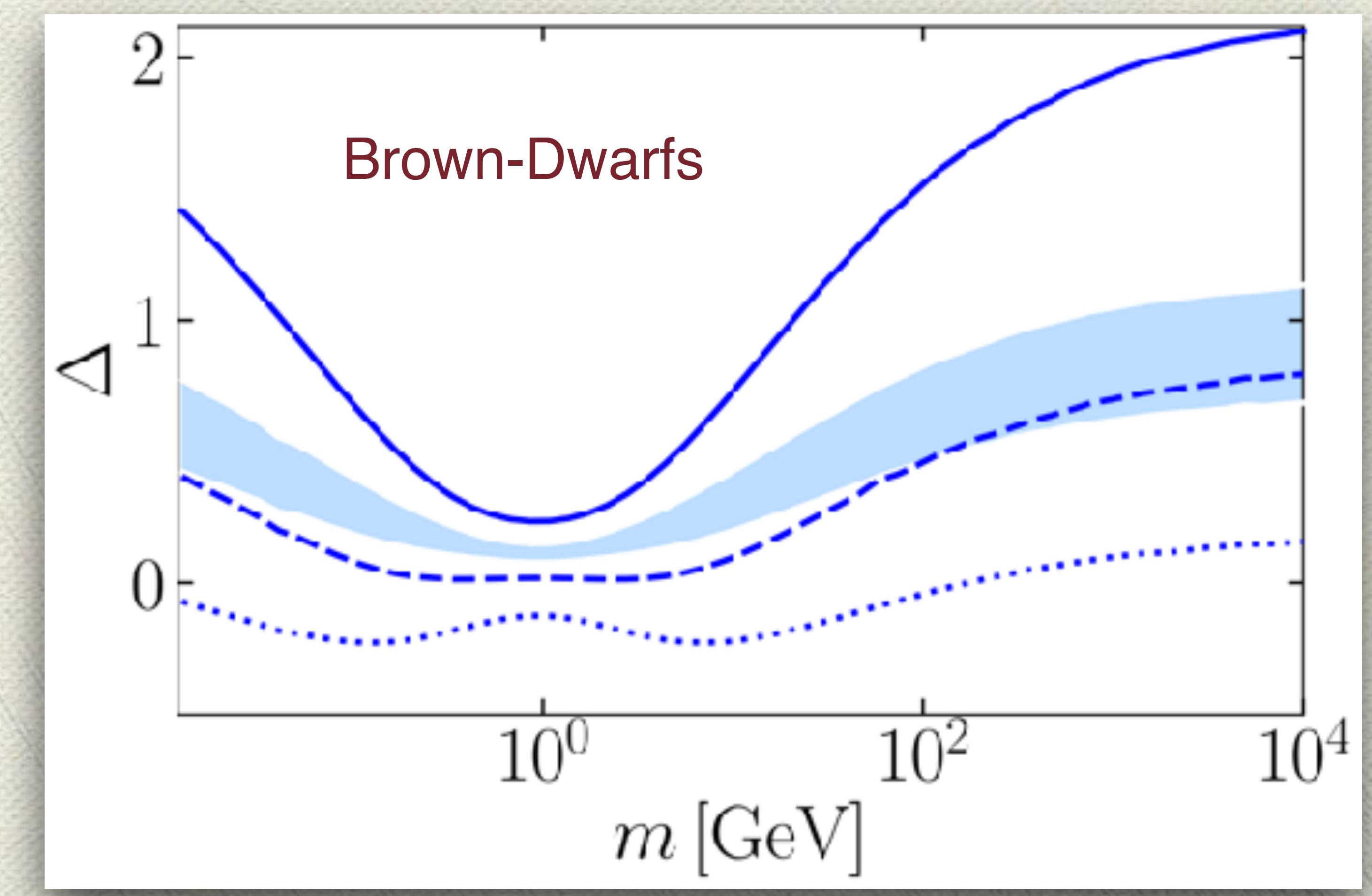


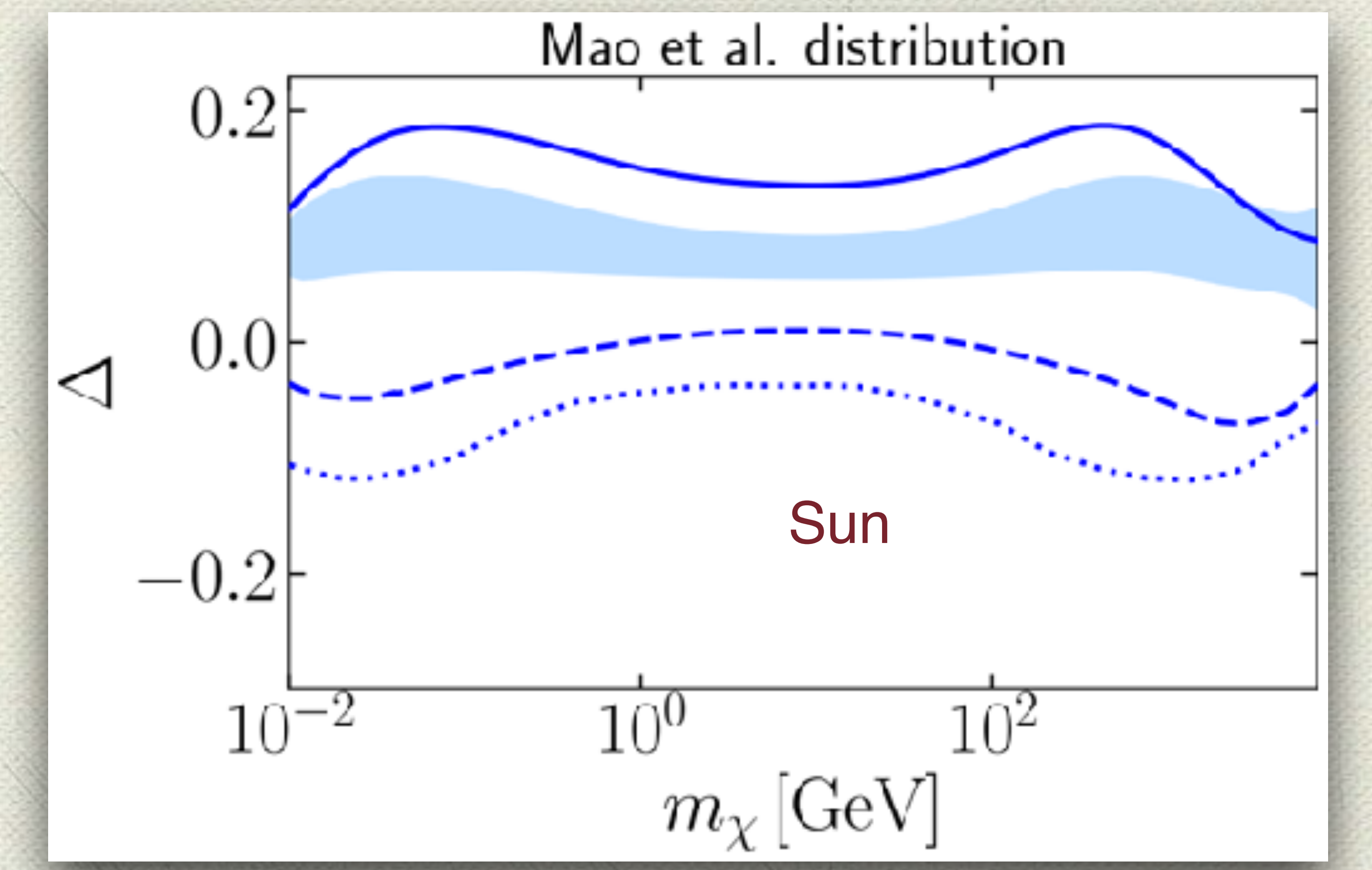




Velocity Distribution Function near Celestial Bodies





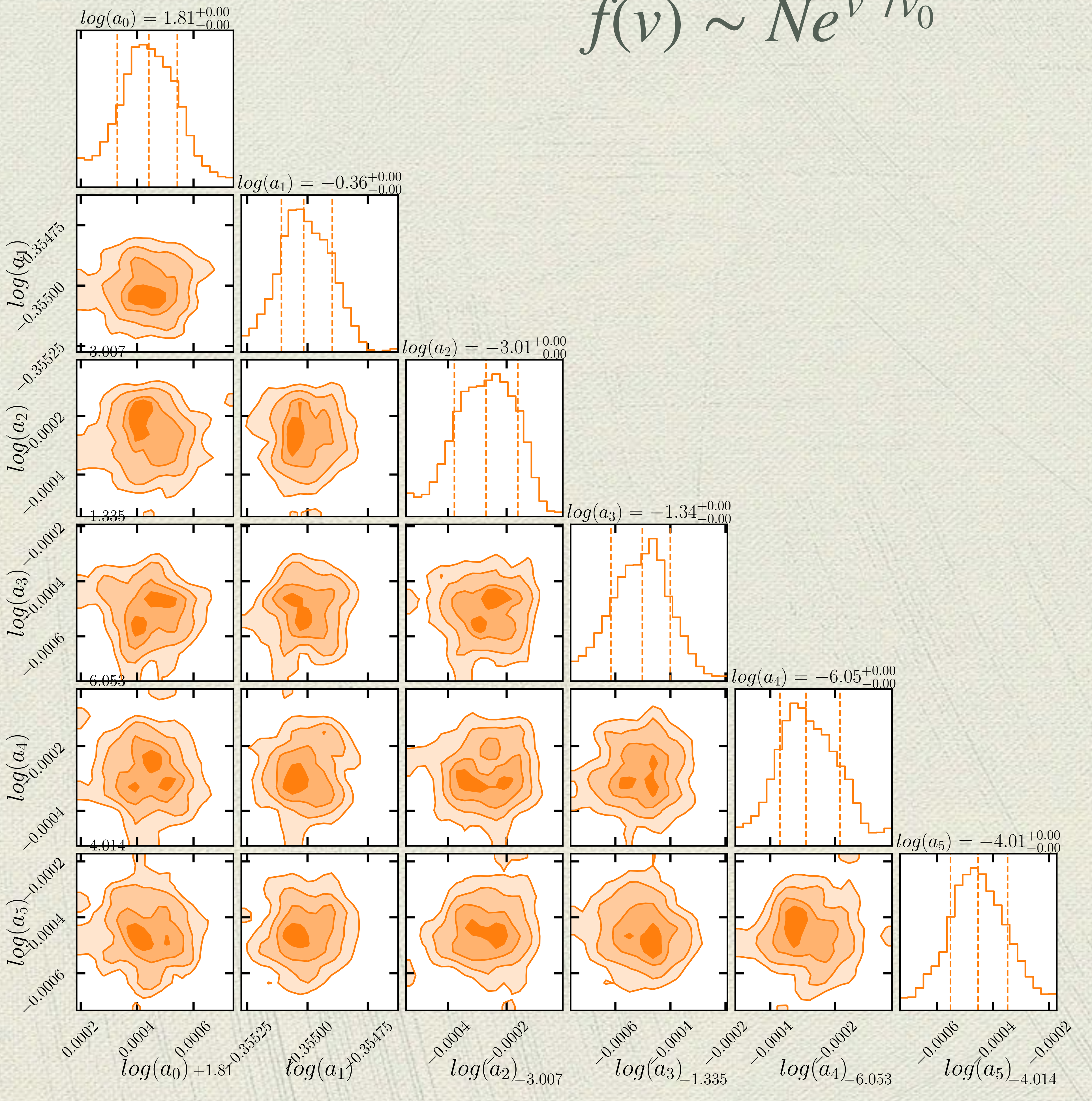


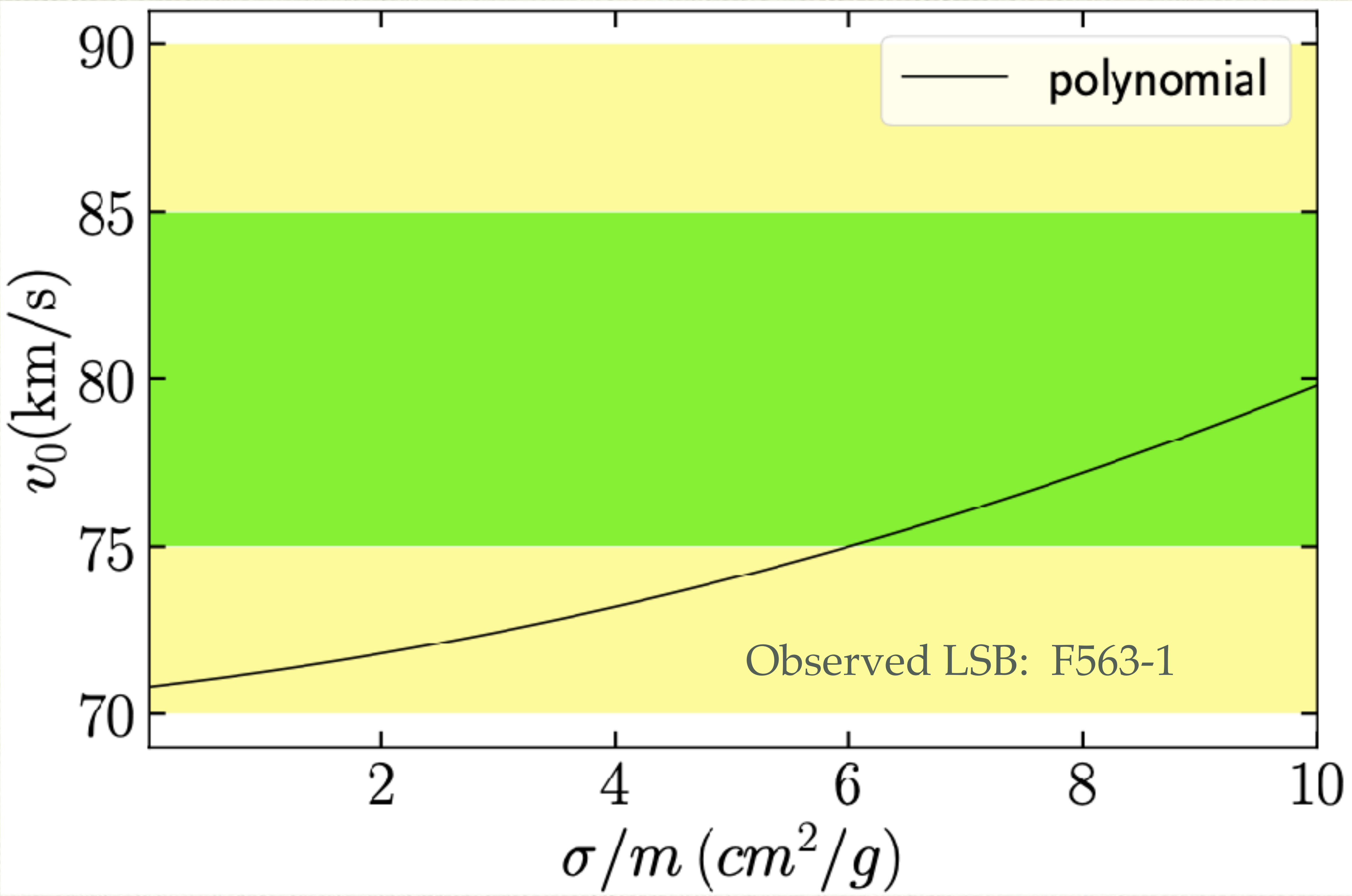
Debajit Bose, Sambo Sarkar, Phys.Rev.D 107 (2023) 6, 063010

Backup Slide: LSB Analysis

$$f(v) \sim N e^{v^2/v_0^2}$$

$$V_0 = \sqrt{\frac{GM(r)}{r} + a_1\frac{\sigma}{m} + a_2\frac{M_*}{10^{10}M_\odot} + a_3\left(\frac{\sigma}{m}\right)^2 + a_4\left(\frac{M_*}{10^{10}M_\odot}\right)^2}$$





Sarkar, TSR, in preparation