Rotation Curves from finite temperature scalar field DM

Scalars 2013

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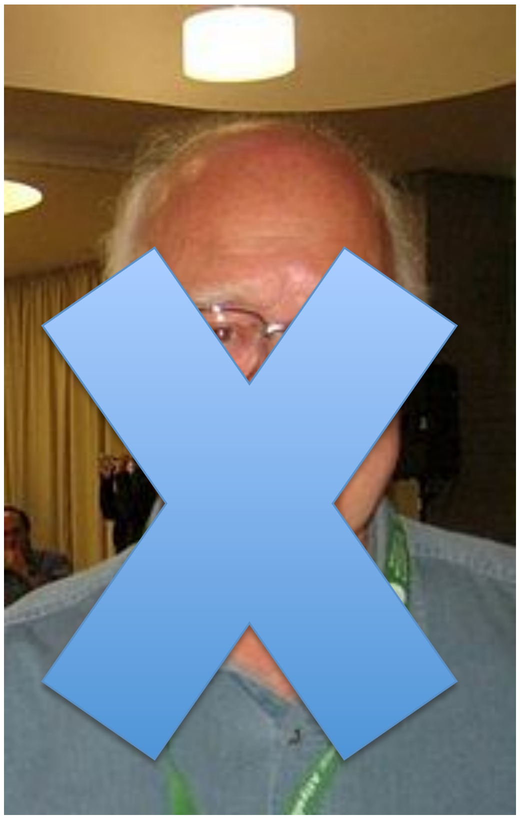
Cinvestav

Higgs



CHARGED Higgs

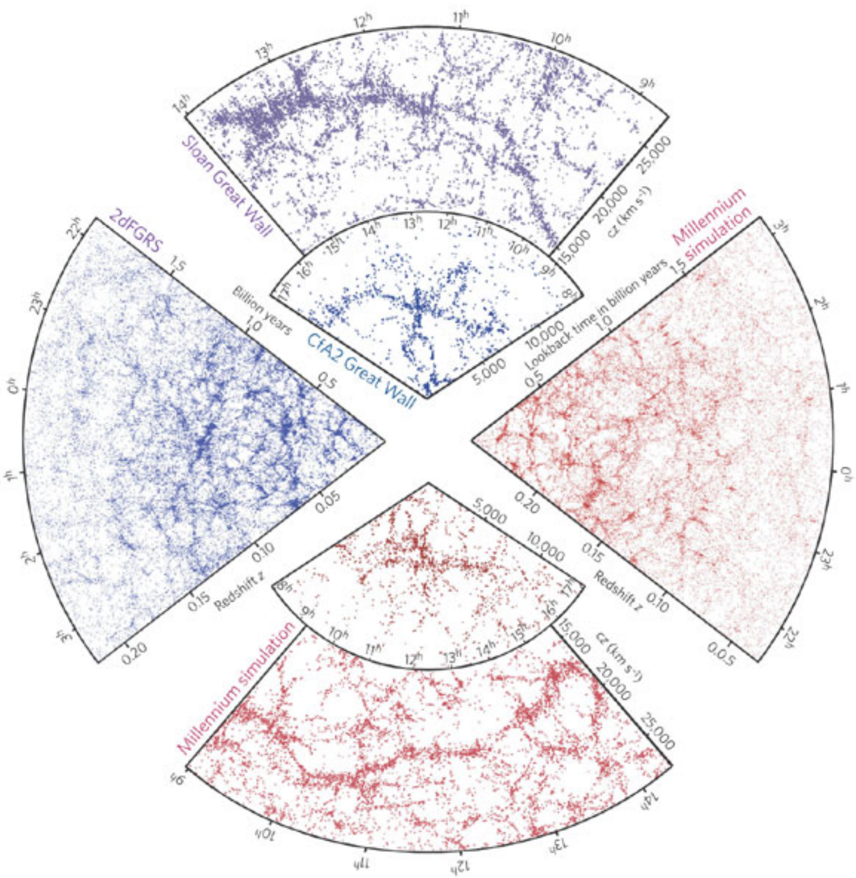
Maybe YOU SHOULD GO TO LECTURE HALL A NOW!

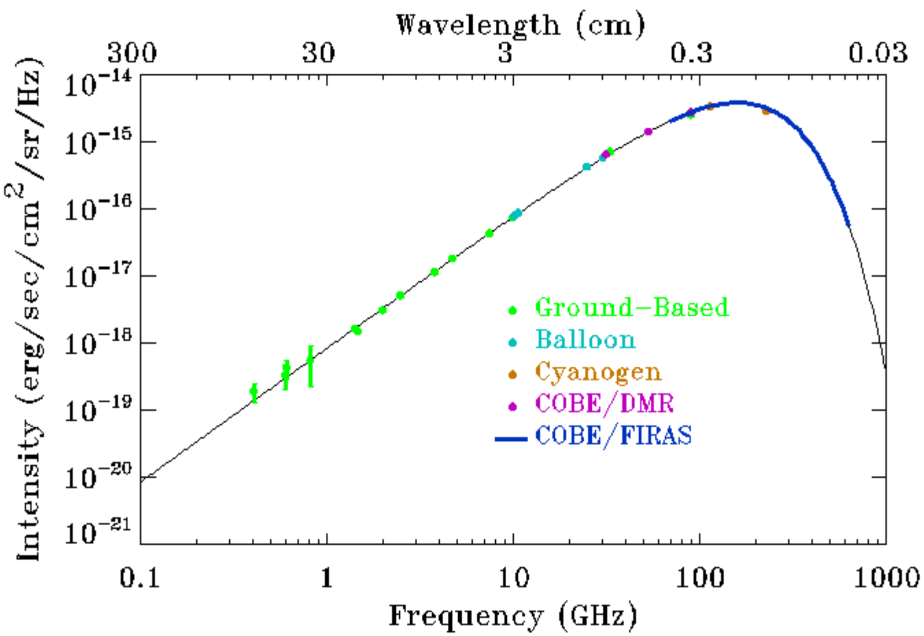
What this talk is about:

- CDM simulations and problems
- Scalar Field DM model
- SFDM Halos
- Conclusions

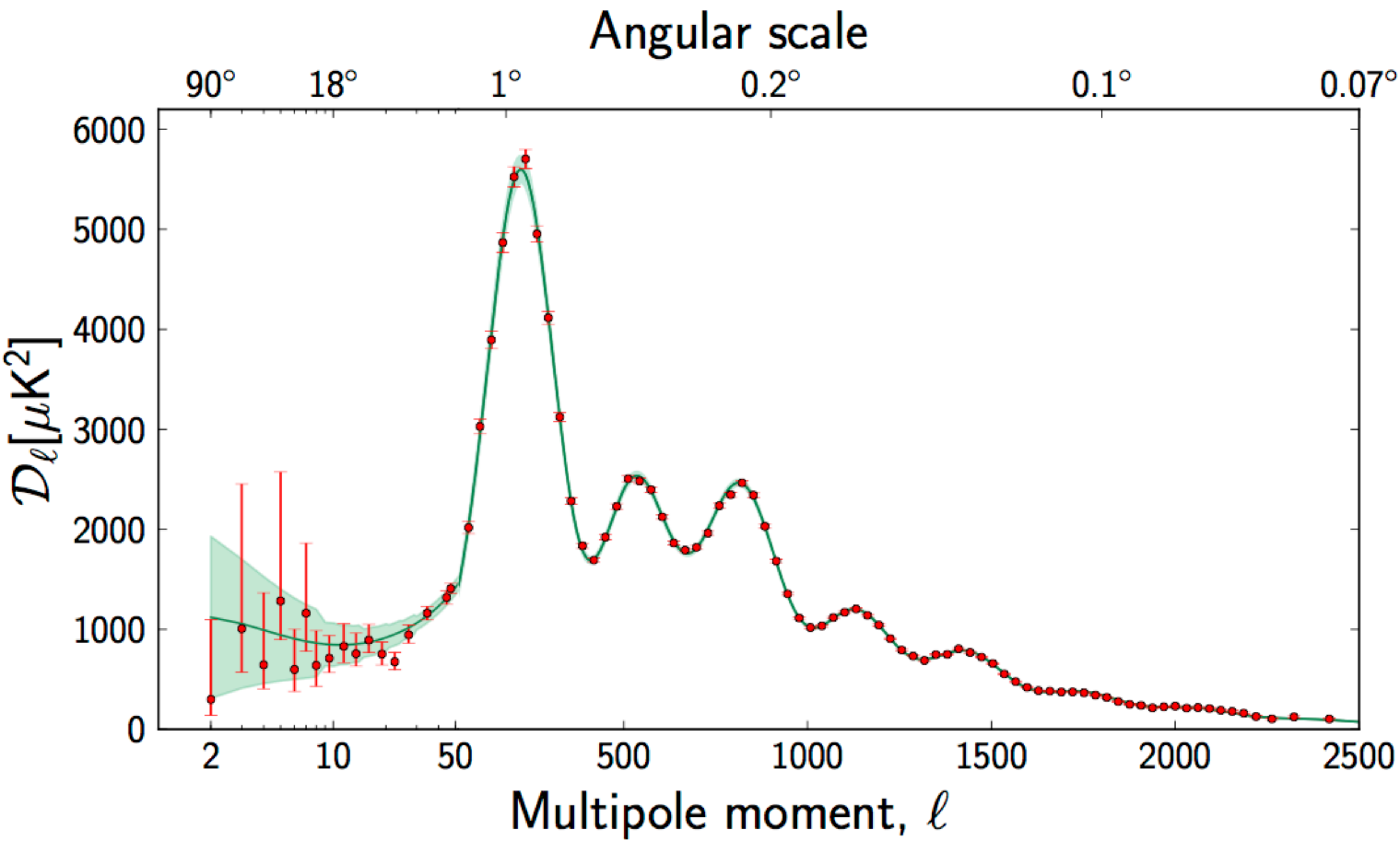
ΛCDM

Cosmological test are accurately described.



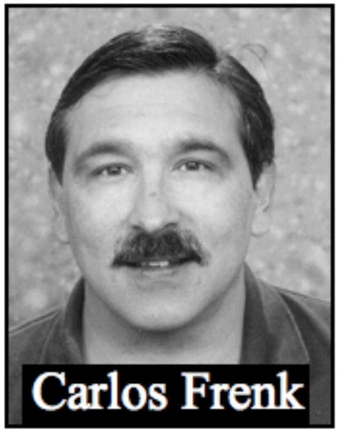


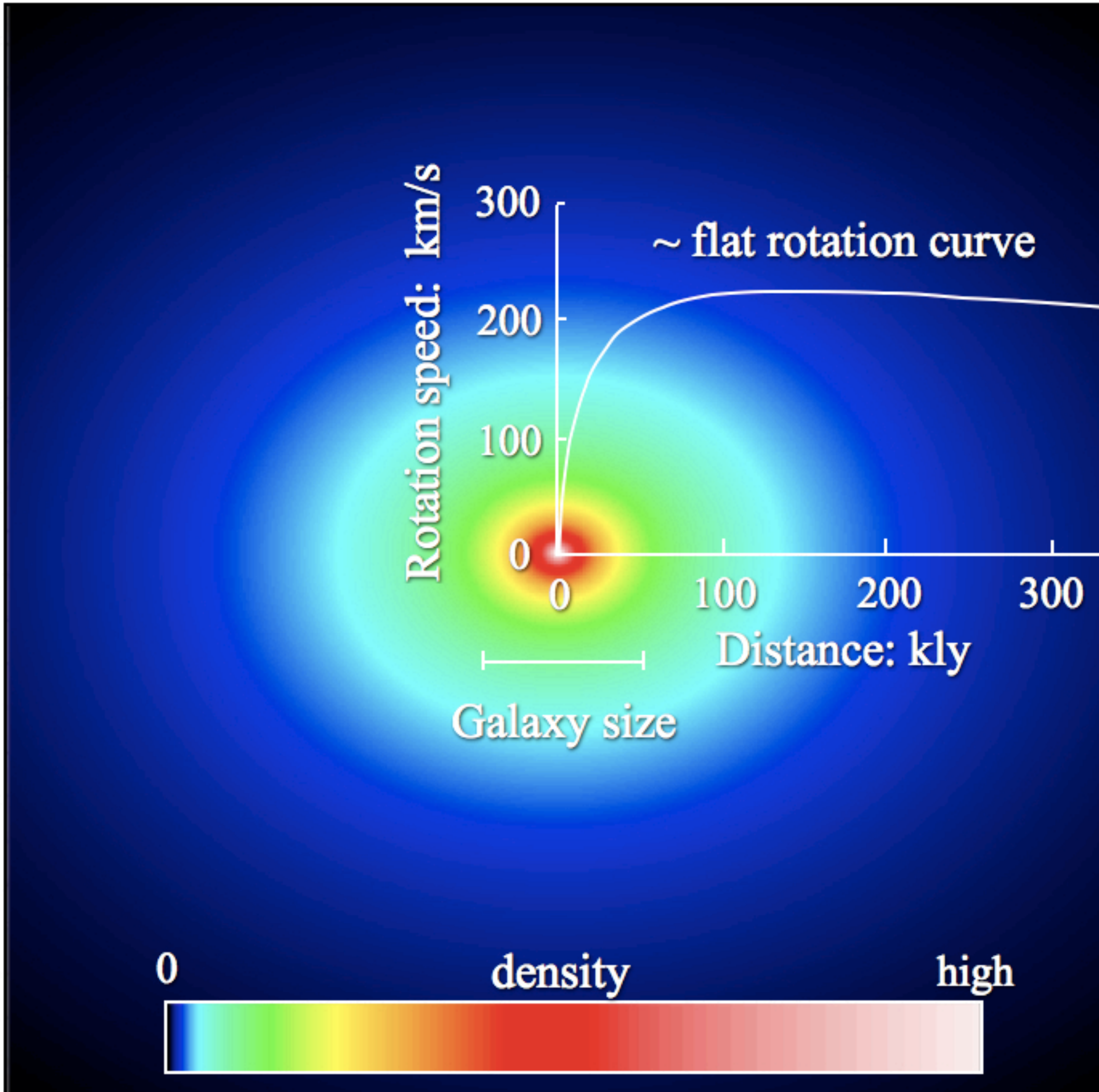
LSS,CMB, Angular Power Spectrum etc.



Angular scale
90°
18°
1°
0.2°
0.1°
0.07°
6000
5000
4000
3000
2000
1000
0
$\mathcal{D}_\ell [\mu K^2]$
2
10
50
500
1000
1500
2000
2500
Multipole moment, ℓ

The "NFW" form for dark matter halos





ΛCDM long standing issues

- Standard model of cosmology predicts 26% of the matter in the Universe is DM.
- Nature of DM remains unknown(neutralino,WDM, axion,…)
- Three main unsolved issues
- Cusp/core problem
- Missing galaxy problem
- Too big to fail problem

Garrison-Kimmel(2013),Boylan-Kolchin, Michael; Bullock, James S.; Kaplinghat, Manoj(2013)

- Cusp/core problem
- Difficulties to describe observed central densities of dark halos in LSB

(cusp profiles predicted $\rho \approx r^{-1}$).

Missing galaxy problem

- Excess of satellite halos

predicted by N-body simulations Moore et al. (1999), Penny et al (2009).

- Too big to fail problem
- Most massive halos do not contain galaxiesBullock, James S.; Kaplinghat, Manoj(2013)

- Alternative explanations to the current paradigm of structure formation

Galaxies are a good test to CDM

Cusp/Core problem

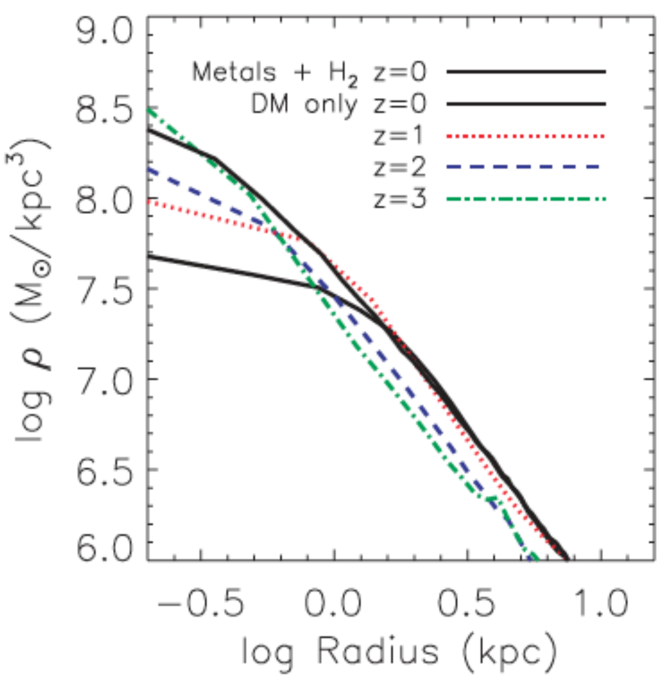


Figure 3. The DM density profile of a dwarf galaxy in our sample, at $z = 4, 3, 1, 0$. The prolonged process of cusp flattening due to many separate outflows results in a shallow inner profile at $z = 0$. For comparison, the density profile of the same galaxy, but simulated with DM only, is shown in the black dot–dashed line. In the DM only simulation, the DM maintains its cuspy density profile at all redshifts.

Low Surface Brightness (LSB) galaxies, dwarfs and UFD

Even if SN Feedback is able to remove cusps is some galaxies. Same FB recipe **unlikely to work in LSBs and dwarf galaxies, smaller halos have higher DM concentrations**

SATELLITES IN CDM

- Sawala et al.(2012) find in their simulation TWICE as many satellites of a given luminosity around a MW size CDM halo

Feedback
Tidal Interation

- Satellite galaxies are too luminous :"wrong" FB methods?

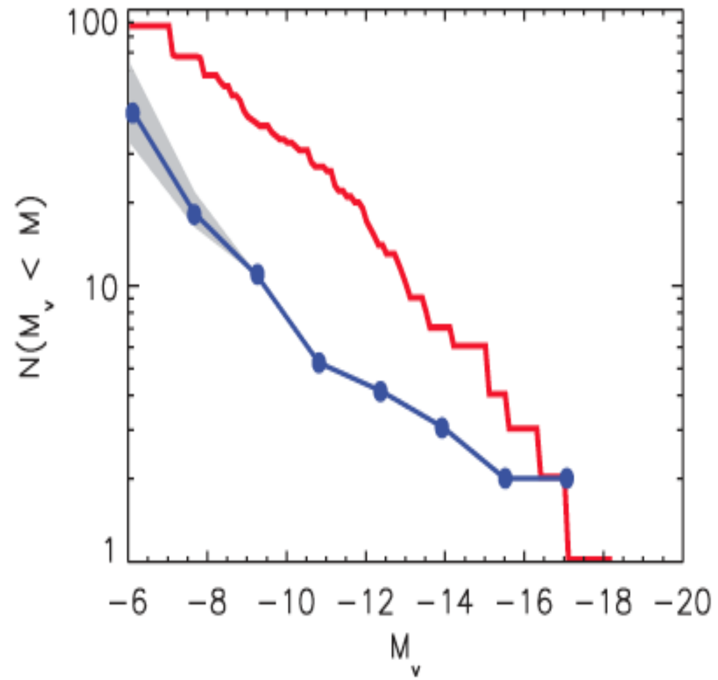
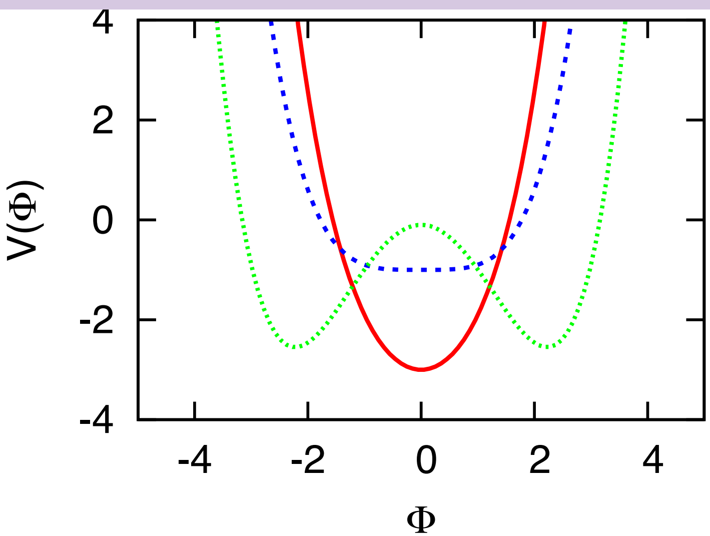


Figure 5. Cumulative satellite luminosity function, in our simulation (red), compared to observational estimates of the Milky Way by Tollerud et al. (2008) (blue), corrected for completeness, both within a radius of 417 kpc. The simulation produces approximately twice as many satellites of a given luminosity compared to the Milky Way.

Scalar Field Dark Matter

- This model supposes that DM is a real SF minimally coupled to gravity, described by a scalar potential and that only interacts gravitationally with the rest of the matter (Matos & Ureña-López, Phys. Rev. D 63 (2001) [astro-ph/0006024],Robles & Matos 2013, ApJ, 763, 19[arXiv:1207.5858], arXiv:1302.0903)

$$V(\Phi) = -\frac{1}{2}\mathbf{m}^2\Phi^2 + \frac{\lambda}{4}\Phi^4 + \frac{\lambda}{8}T^2\Phi^2 - \frac{\pi}{90}T^4 + \frac{\mathbf{m}^4}{4\lambda}$$

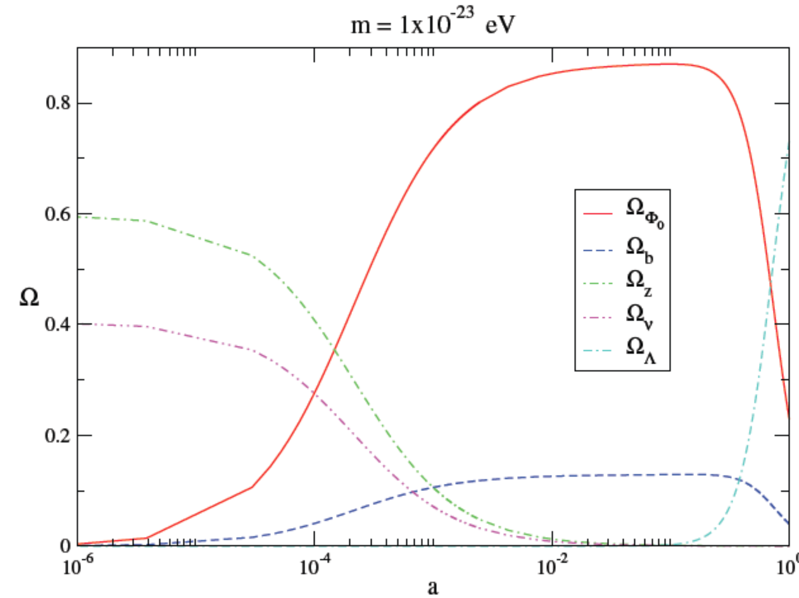


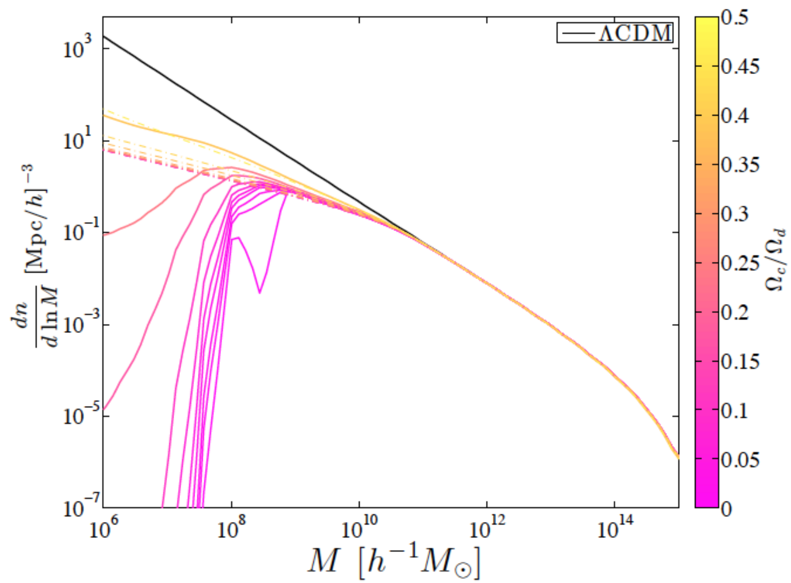
Large scale resembles CDM behavior

- Can reproduce the cosmological evolution of the Universe, Matos, Vázquez-González and Magaña, Mon. Not. Roy. Astron. Soc. 393 (2009) 1359 [astroph/0806.0683]

- Small mass (10^{-23}eV) natural cut off in mass power spectrum (no satellite problem) Tonatiuh Matos et al. Mon. Not. R. Astron. Soc. 393, 1359–1369 (2009),David J. E. Marsh,Joseph Silk, arXiv:1307.1705v1

- SFDM halos can fit very well rotation curves of LSB galaxies and central density profiles can be reproduced, Robles and Matos, Mon. Not. Roy. Astron. Soc. 422 (2012) 282 [arXiv: 1201.3032]
- Consistent with acoustic peaks of the CMB radiation, Rodríguez-Montoya et al., Astrophys. J.721 (2010) [arXiv: 0908.0054]





Using the Newtonian gauge

$$ds^2 = a^2 \left\{ -(1+2\psi)d\tau^2 + (1-2\phi)dx^i dx_i \right\}$$

$$d/d\eta = a(d/dt)$$

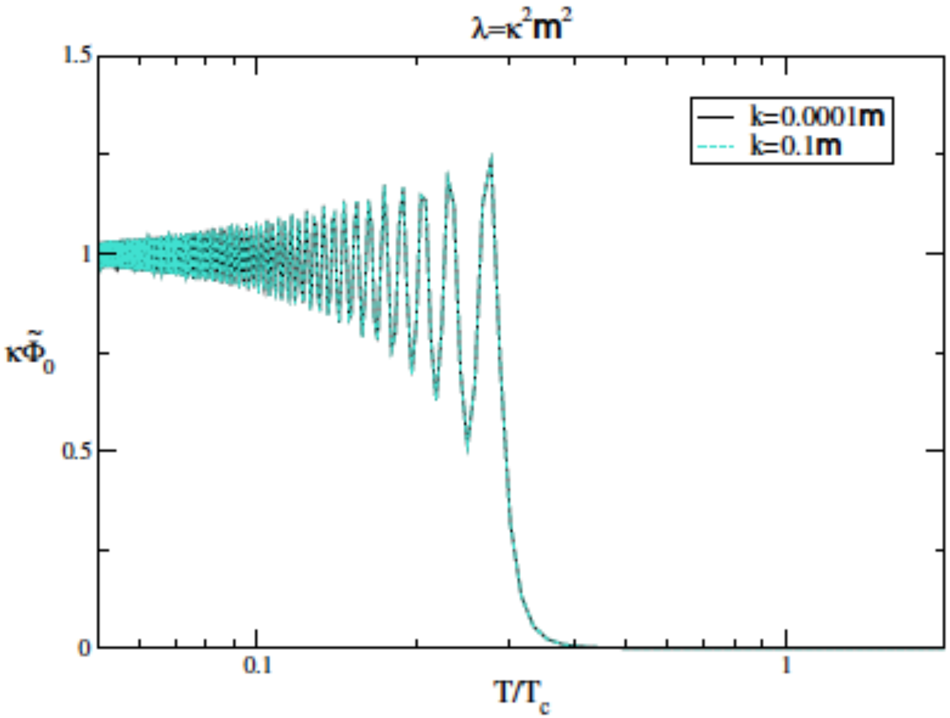
With respect to cosmological time t we have

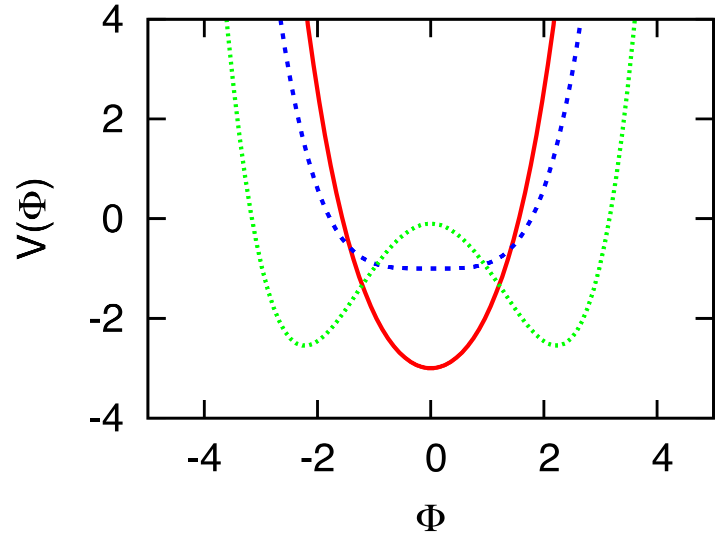
$$\begin{aligned}
\delta T^0_0 &= -\delta\rho_\Phi = -(\dot\Phi_0 \delta\dot\Phi - \dot\Phi_0^2\psi + V_{,\Phi}\,\delta\Phi), \\
\delta T^0_i &= -\frac{1}{a}(\dot\Phi_0 \delta\Phi_{,i}\,), \\
\delta T^i_j &= \delta P_\Phi = (\dot\Phi_0 \delta\dot\Phi - \dot\Phi_0^2\psi - V_{,\Phi}\,\delta\Phi)\delta^i_j.
\end{aligned}$$

$$\begin{aligned}
-8\pi G\delta\rho_\Phi &= 6H(\dot\phi + H\phi) - \frac{2}{a^2}\nabla^2\phi, \\
8\pi G\dot\Phi_0\delta\Phi_{,i} &= 2(\dot\phi + H\phi)_{,i}\,, \\
8\pi G\delta P_\Phi &= 2[\ddot\phi + 3H\dot\phi + (2\dot H + H^2)\phi]
\end{aligned}$$

$$\ddot{\phi} + 6H\dot{\phi} - \frac{1}{a^2}\nabla^2\phi + (2\dot{H} + 4H^2)\phi + 8\pi G\, V_{,\Phi}\,\delta\Phi = 0.$$

$$\delta\ddot{\Phi} + 3H\delta\dot{\Phi} - \frac{1}{a^2}\nabla^2\delta\Phi + V_{,\Phi\Phi}\,\delta\Phi + 2V_{,\Phi}\,\phi - 4\dot{\Phi}_0\dot{\phi} = 0.$$





SFDM halos

Near the minimum of *V and after T<<T$_{C,}$* assuming Newtonian limit and relating the density as usual ρ≈(const.)Φ^2

CORE PROFILE

$$\rho(r) = \rho_0 \frac{Sin^2(kr)}{(kr)^2}$$

$$k_j R = j\pi,$$

FINITE HALO IMPLIES

Rotation curve profile

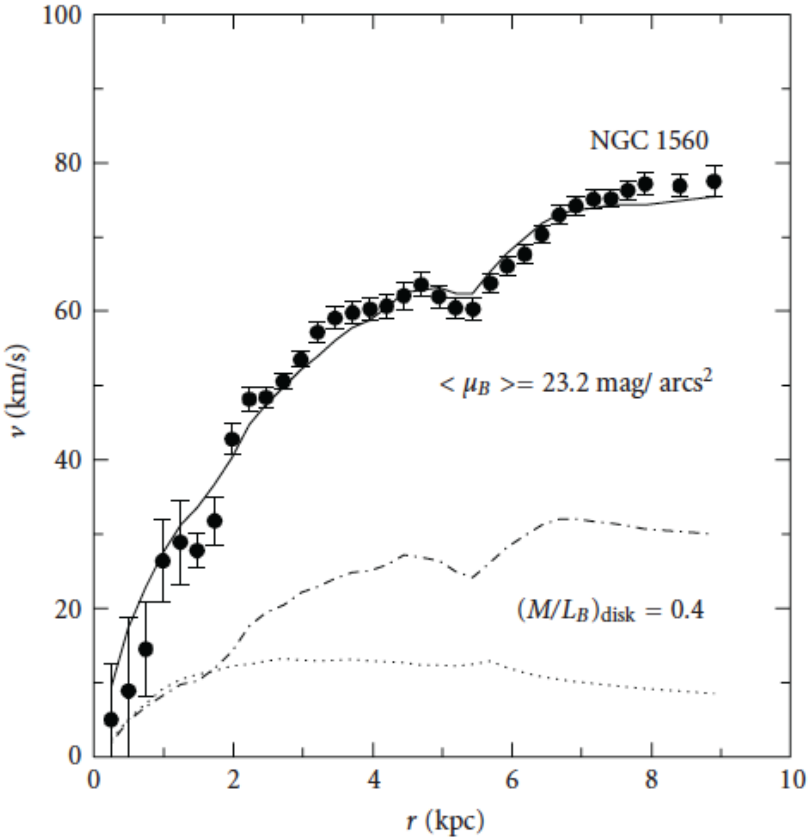
SF (CORE)

$$V_{SF}^2(r) = \frac{4\pi G\rho_0}{2k^2}\left(1 - \frac{Sin(2kr)}{2kr}\right)$$

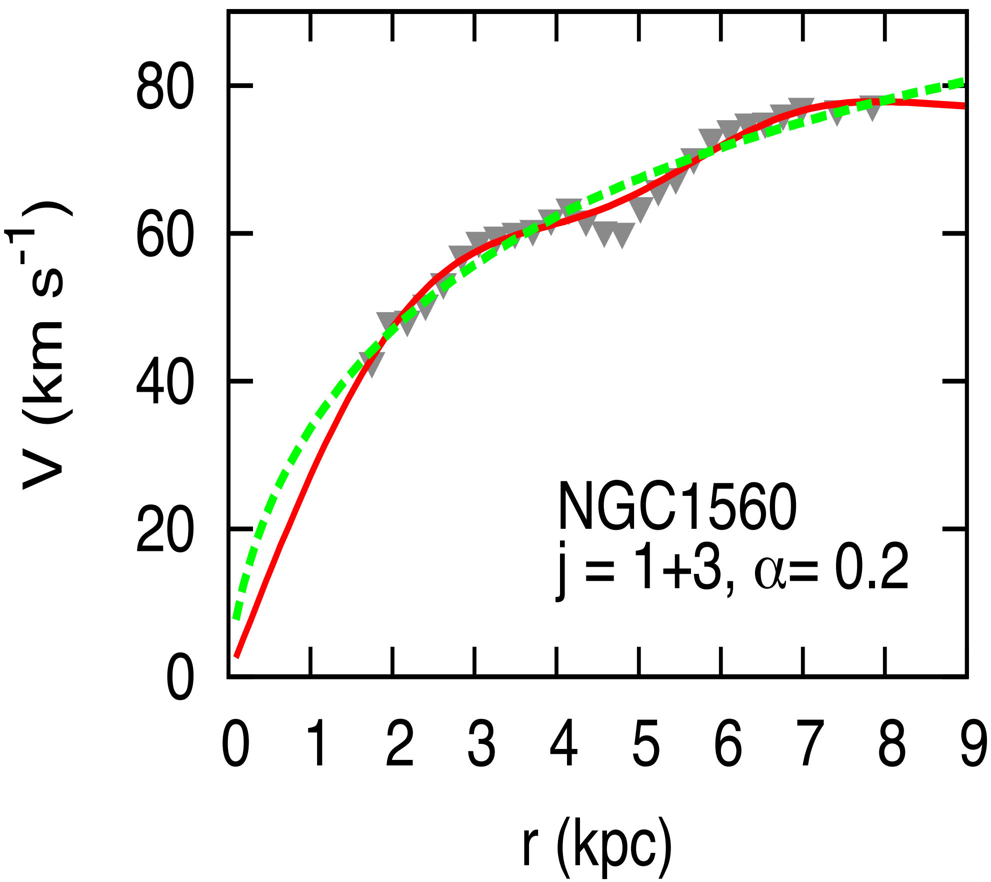
EINASTO (CUPS)

$$V_E^2(r) = 4\pi G\rho_{-2}\frac{r_{-2}^3}{r}\left(\frac{e^{2/\alpha}}{\alpha}\left(\frac{\alpha}{2}\right)^{(3/\alpha)}\int_0^{(r/r_{-2})^\alpha(2/\alpha)} e^{-t}t^{(3/\alpha)-1}\,dt\right)$$

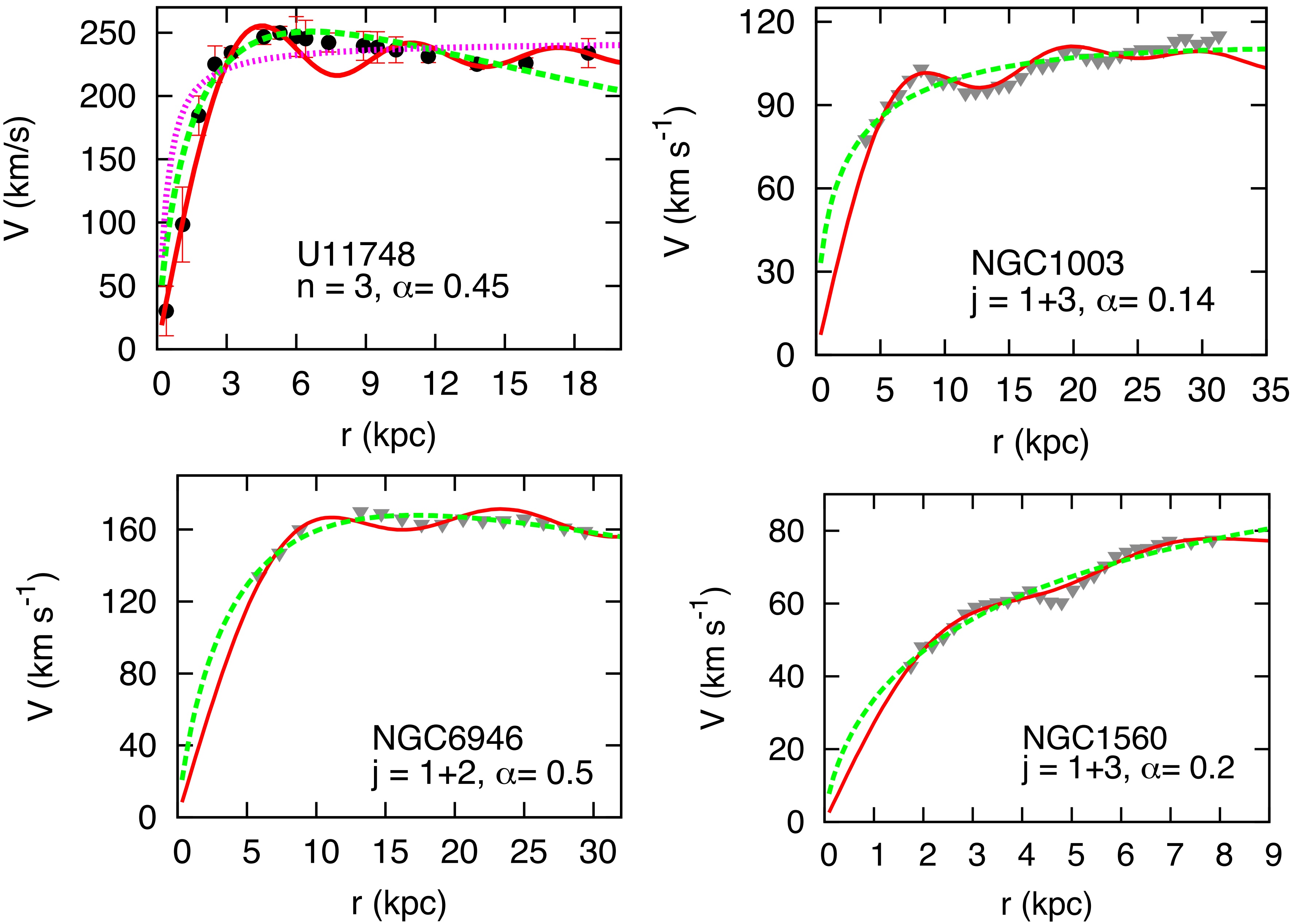
NGC 1560



MOND FIT



SFDM Fit (red), Einasto (green) Victor H. Robles, T. Matos, MNRAS 422: 282–289



V (km/s)
r (kpc)
U11748
n = 3, α= 0.45
V (km s-1)
r (kpc)
NGC1003
j = 1+3, α= 0.14
V (km s-1)
r (kpc)
NGC6946
j = 1+2, α= 0.5
V (km s-1)
r (kpc)
NGC1560
j = 1+3, α= 0.2

Conclusions

- ΛCDM is successful but probably is not the final answer, other models are possible.
- SFDM fits maintains the successes of CDM at large scales but provides possible solutions to small scales
- Density profile is constant and not empirical.
- RC fits of large and small spirals are in very good agreement with data.
- We propose baryons play a minor role in the RC of LSBs and dwarfs => ADD feedback but only what is needed.
- Reduces the number of small satellites due to the cut off in MPS.