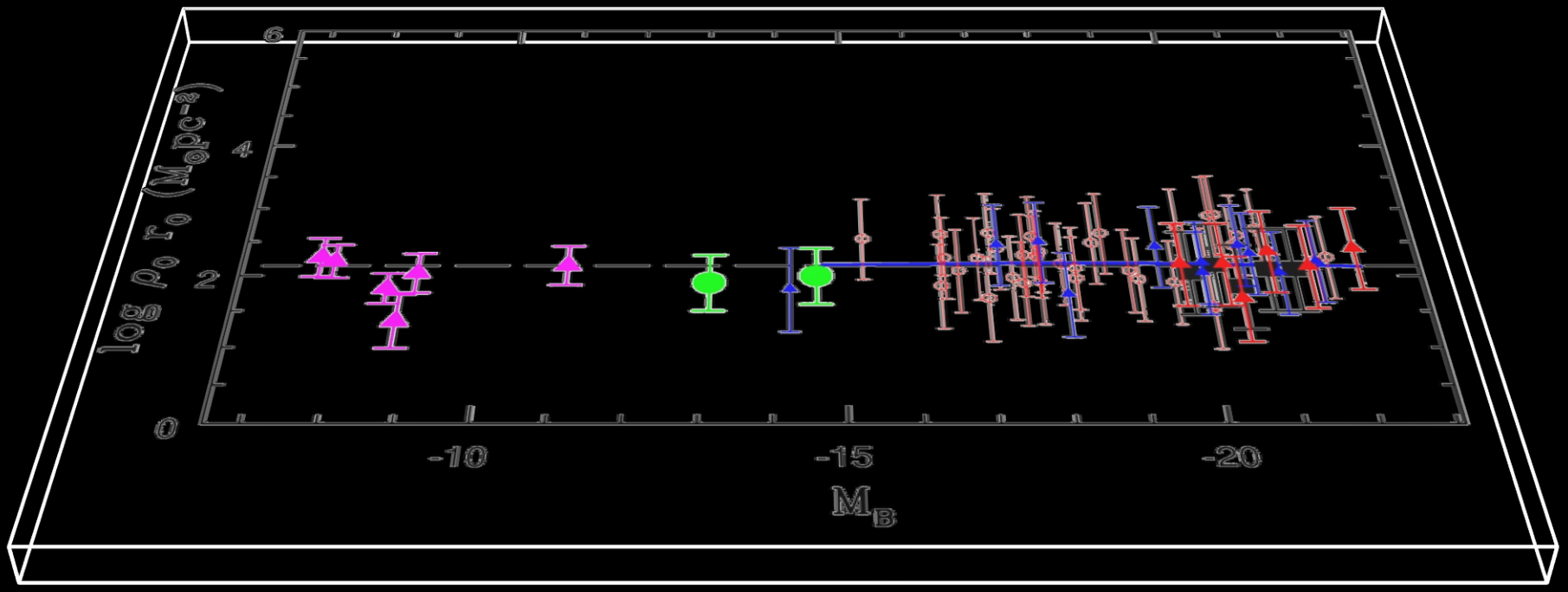
# THE CONSTANT DM SURFACE DENSITY IN GALAXIES (THE DM DISTRIBUTION IN GALAXIES)

Paolo Salucci (SISSA)



Persic, M.; **S. P.,** Stel, F. ***1996 MNRAS, 281, 27***

***The universal rotation curve of spiral galaxies - I. The dark matter connection***

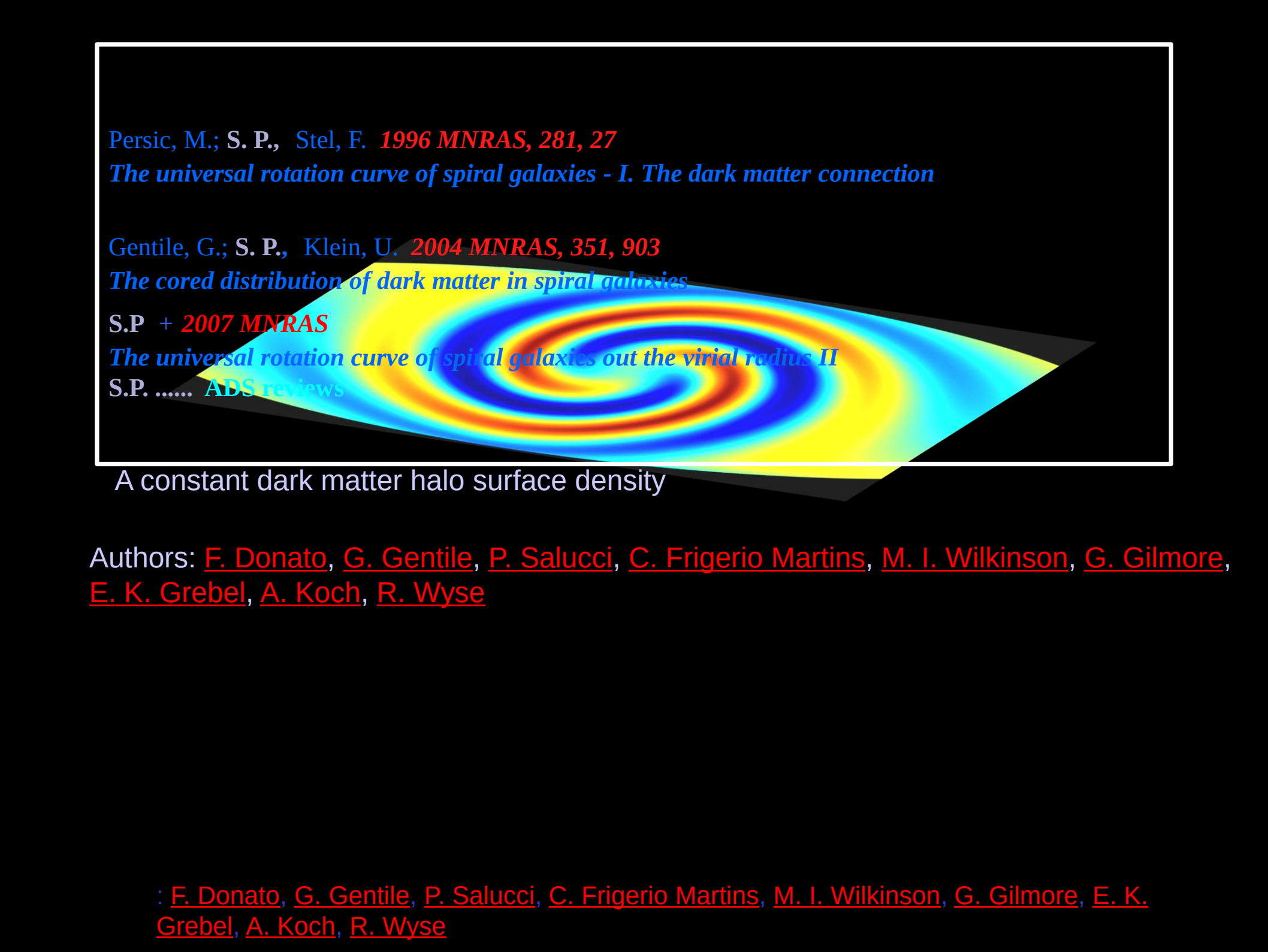
Gentile, G.; **S. P.,** Klein, U. ***2004 MNRAS, 351, 903***

***The cored distribution of dark matter in spiral galaxies***

**S.P** + ***2007 MNRAS***

***The universal rotation curve of spiral galaxies out the virial radius II***

**S.P. ..... ADS reviews**



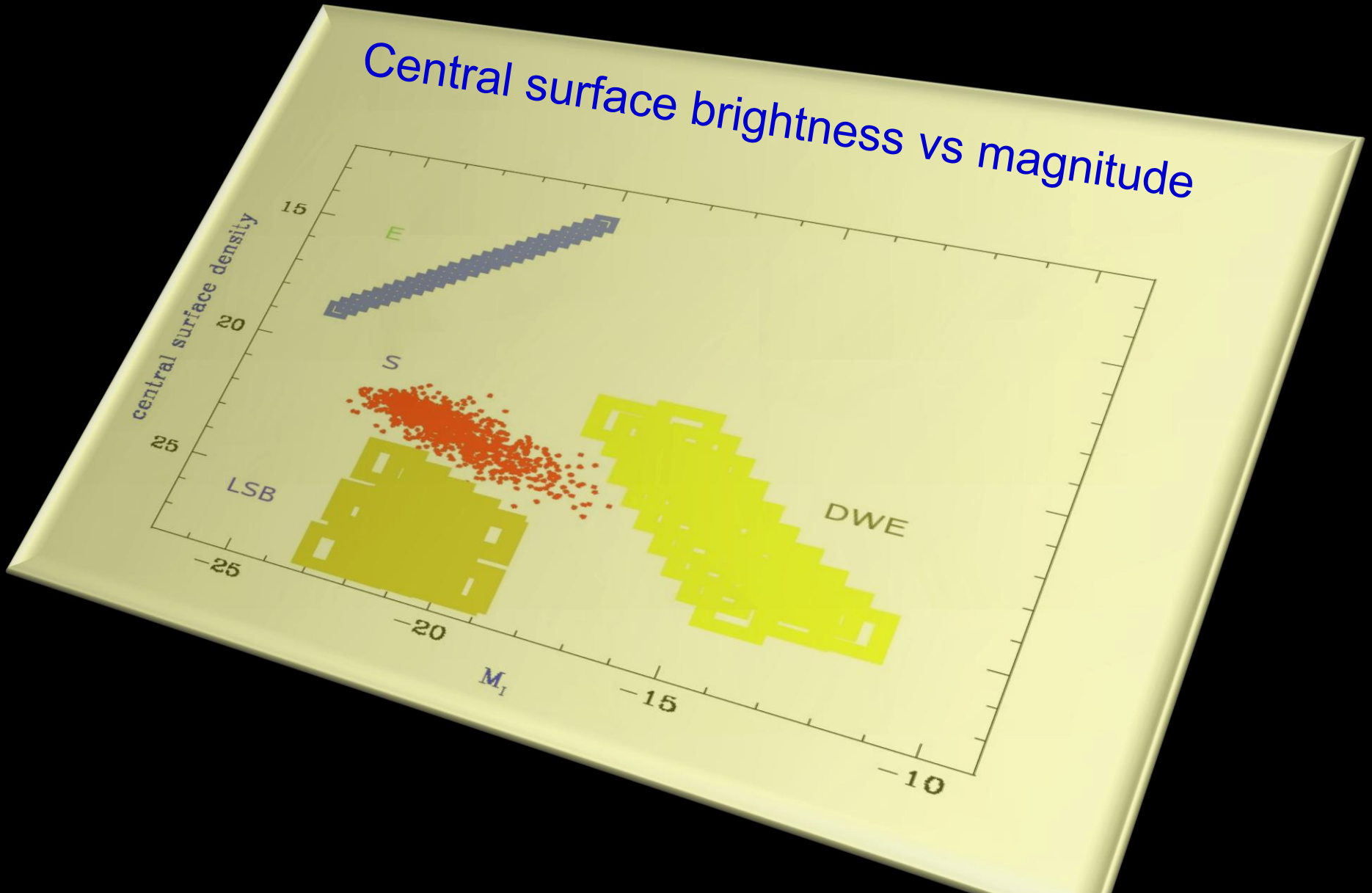
A constant dark matter halo surface density

Authors: F. Donato, G. Gentile, P. Salucci, C. Frigerio Martins, M. I. Wilkinson, G. Gilmore, E. K. Grebel, A. Koch, R. Wyse

: F. Donato, G. Gentile, P. Salucci, C. Frigerio Martins, M. I. Wilkinson, G. Gilmore, E. K. Grebel, A. Koch, R. Wyse

# The Realm of Galaxies

**15 mag range, 4 types, 16 mag arsec$^{-2}$.range**

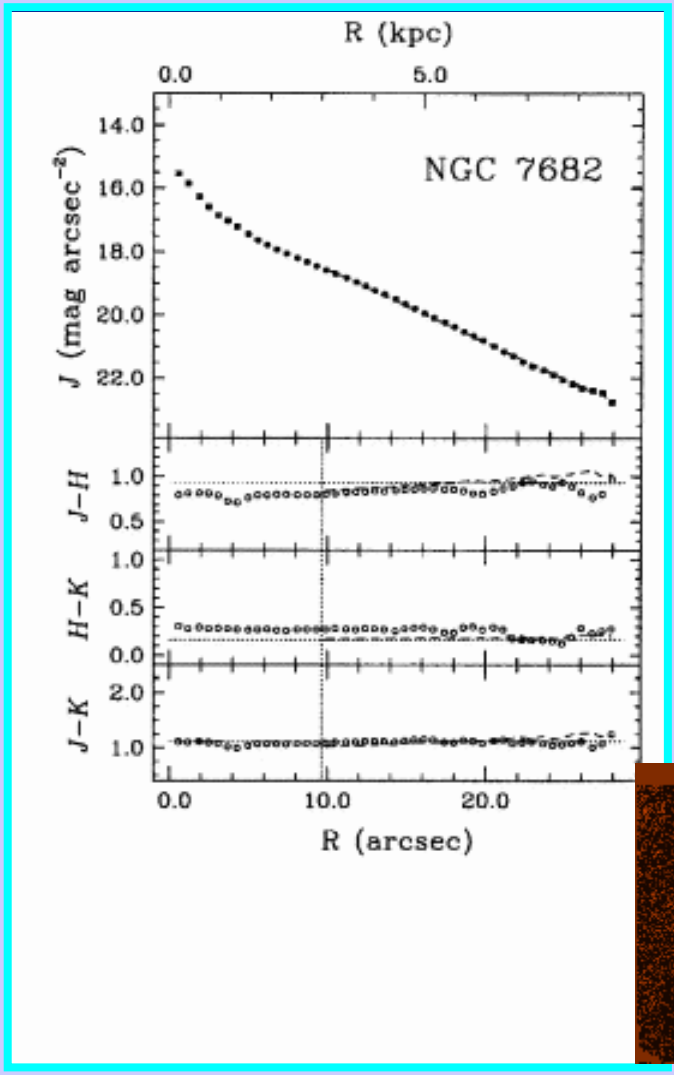


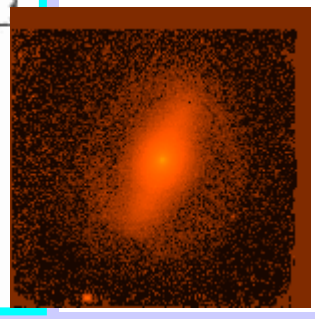
**Stellar** distribution $L(R/R_D)/L_T$ is independent of luminosity

The light surface profile $I(r) = I_0 \exp(-R/R_D)$.

A mass lenght-scale

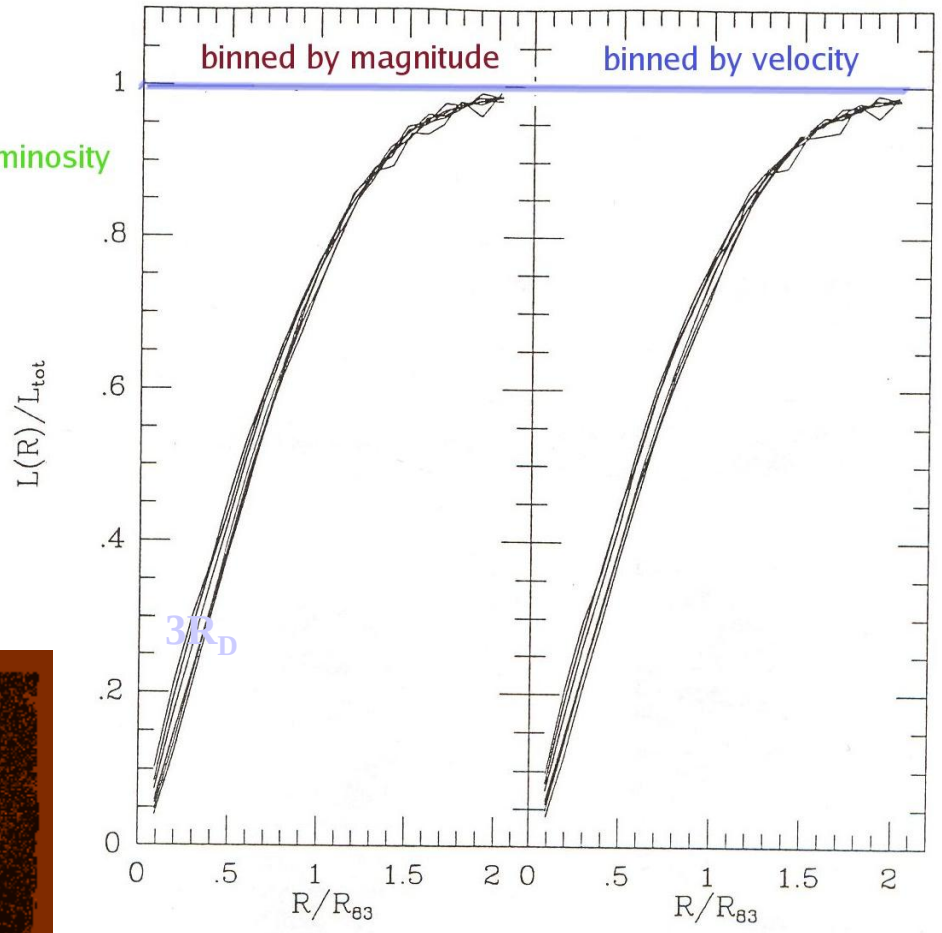
Colors are radially constant



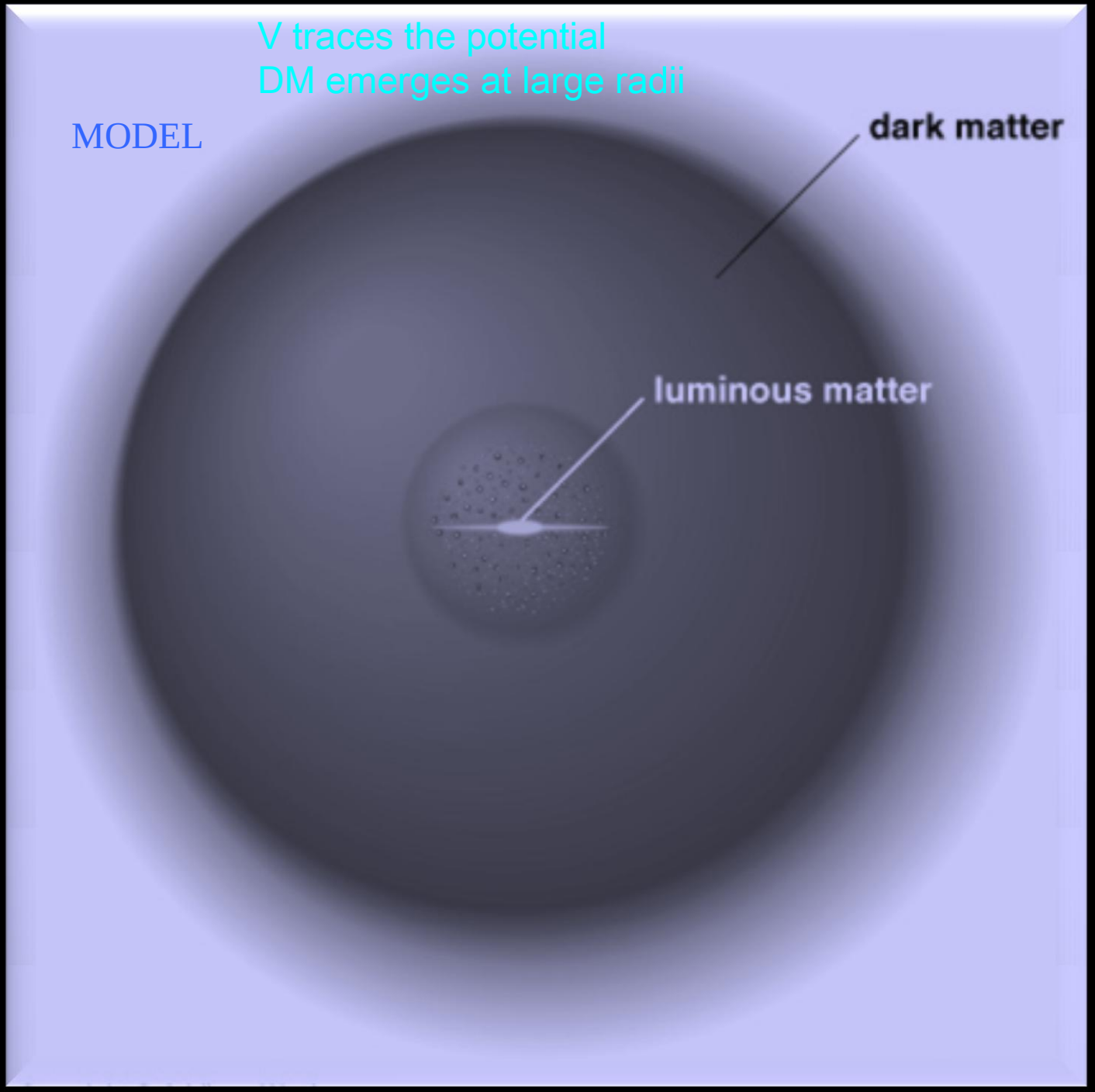
fraction of luminosity

1000 objects

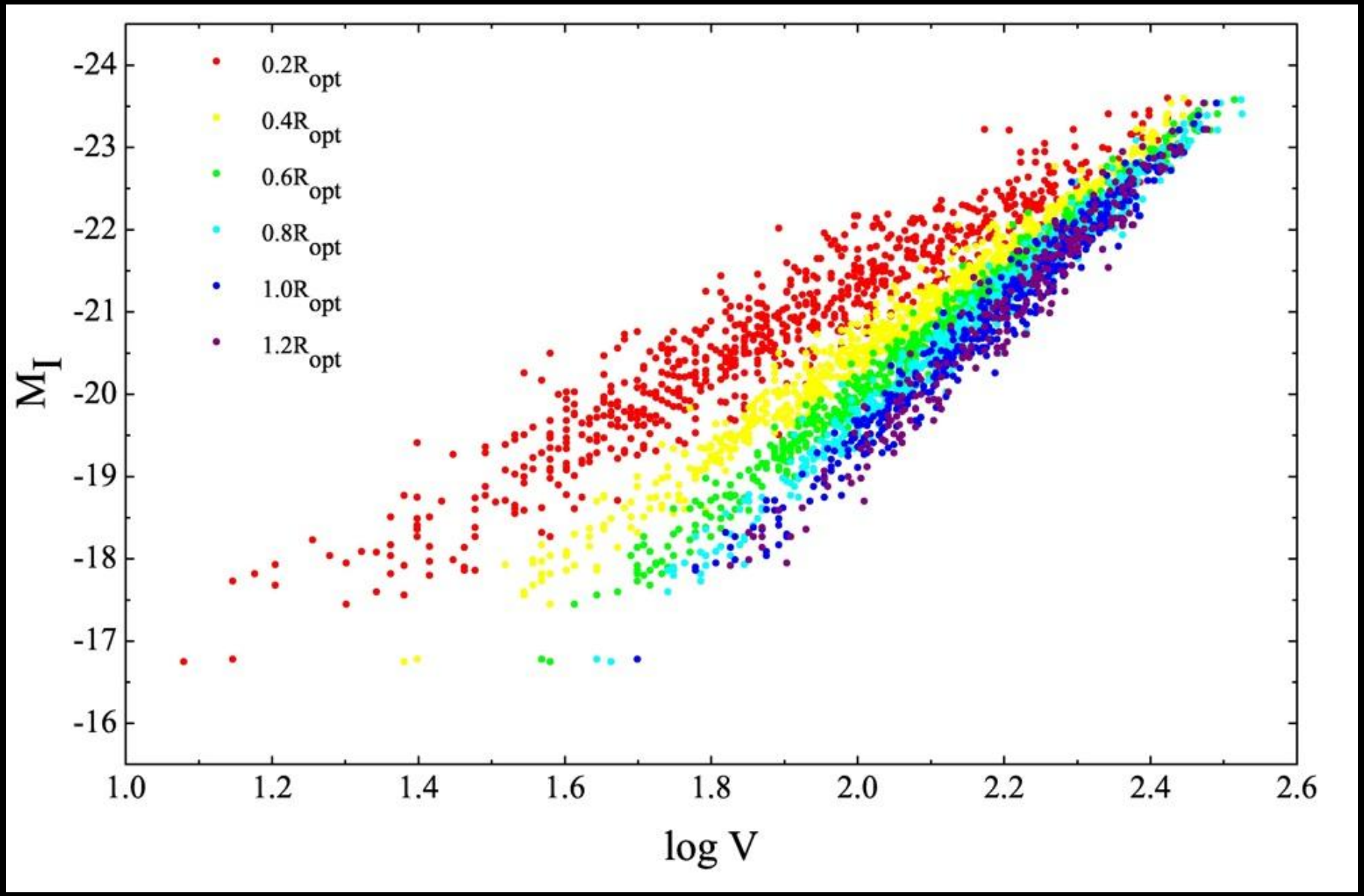


V traces the potential
DM emerges at large radii

MODEL



# Radial TF


0.2R opt
0.4R opt
0.6R opt
0.8R opt
1.0R opt
1.2R opt
M I
-24
-23
-22
-21
-20
-19
-18
-17
-16
1.0
1.2
1.4
1.6
1.8
2.0
2.2
2.4
2.6
log V

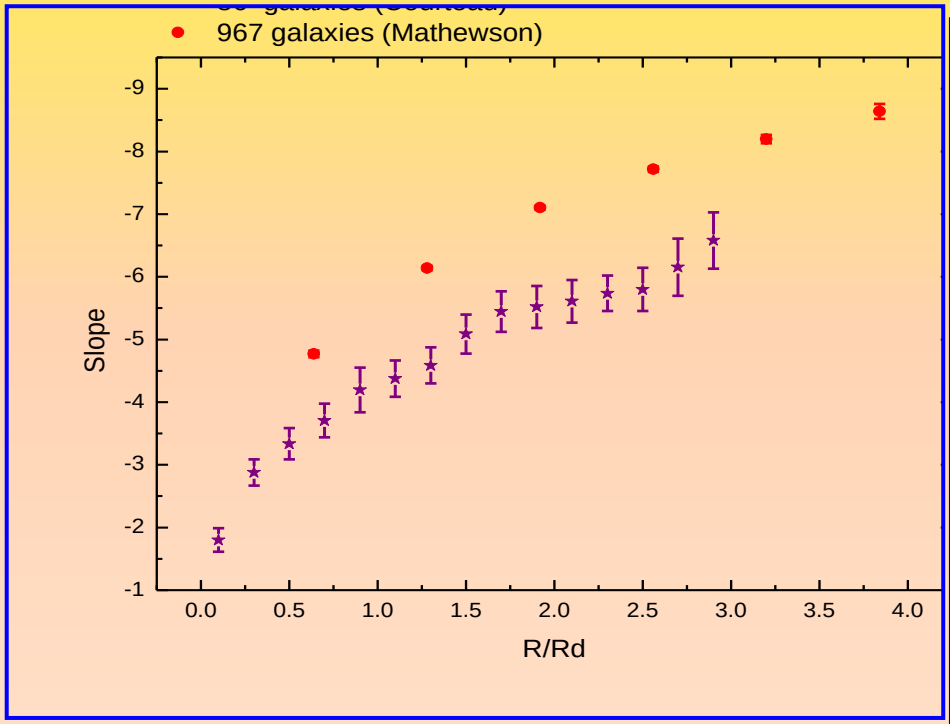
# Slope and scatter of the TF-relations:

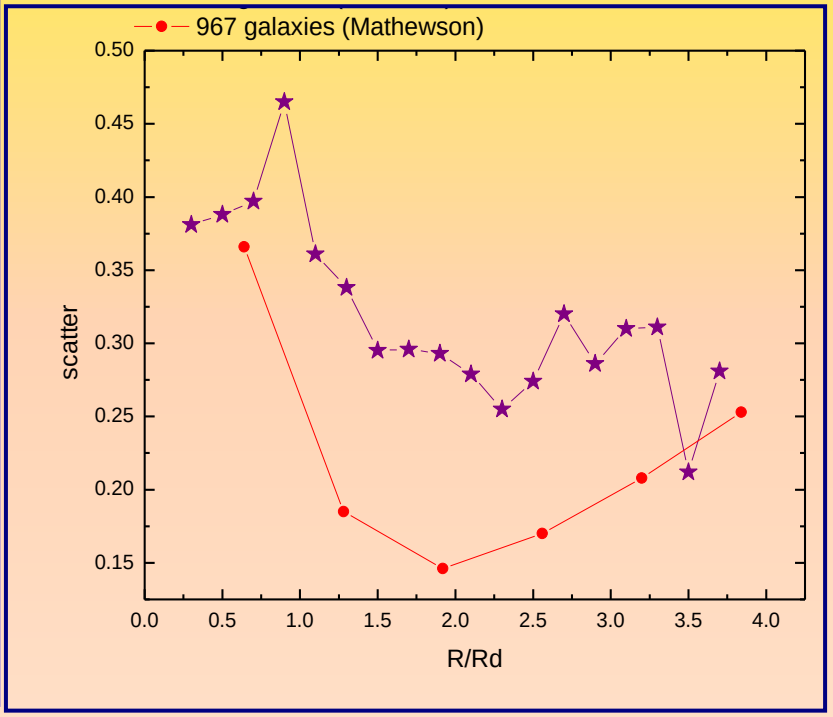
$$M_B = a_i + b_i \log V(x_i)$$

The slope increases from -4 to -8.

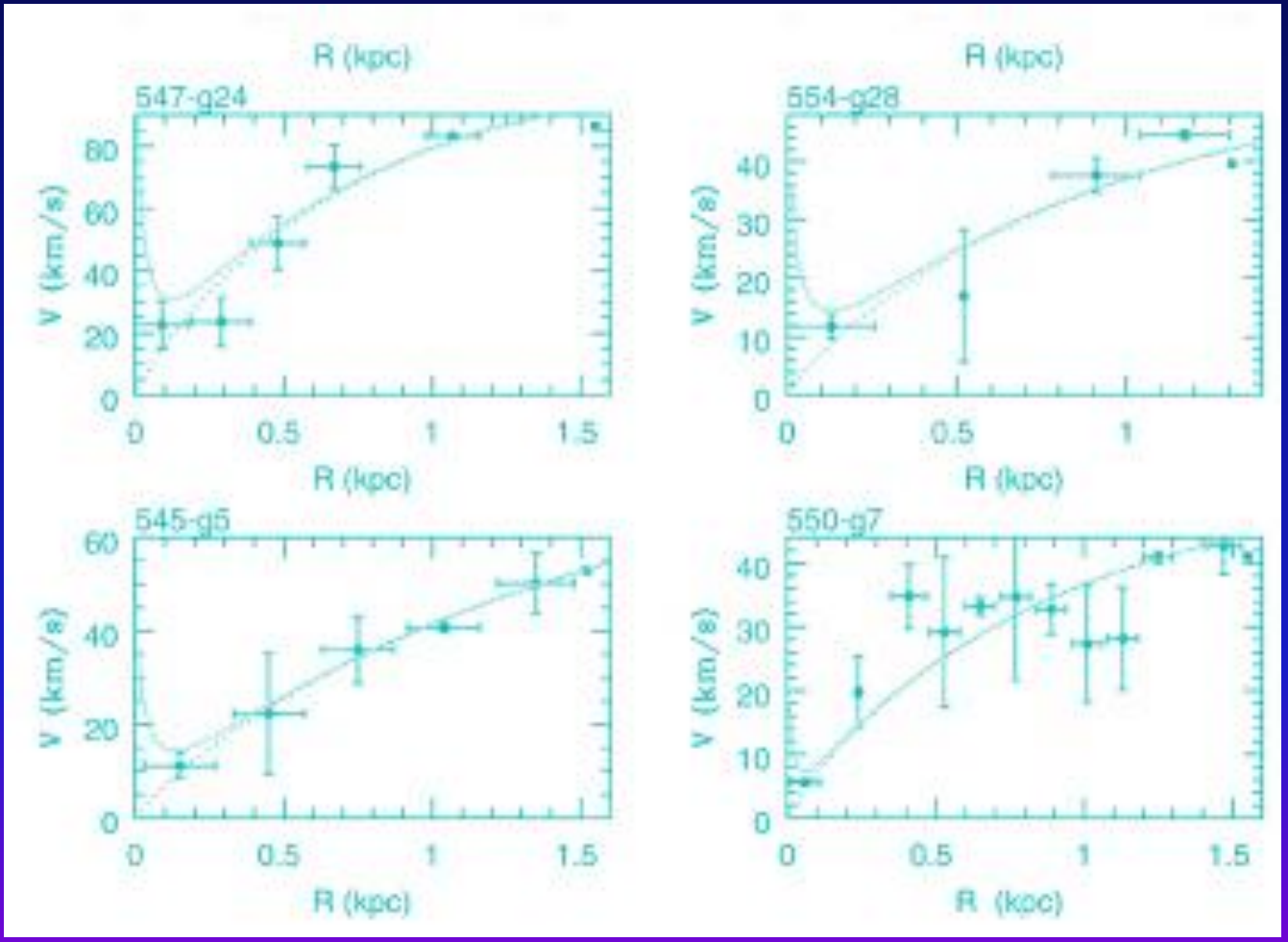
No change in slope ↔ no DM or a constant fraction of DM

The minimum scatter 0.2 mag at 2.2 $R_D$

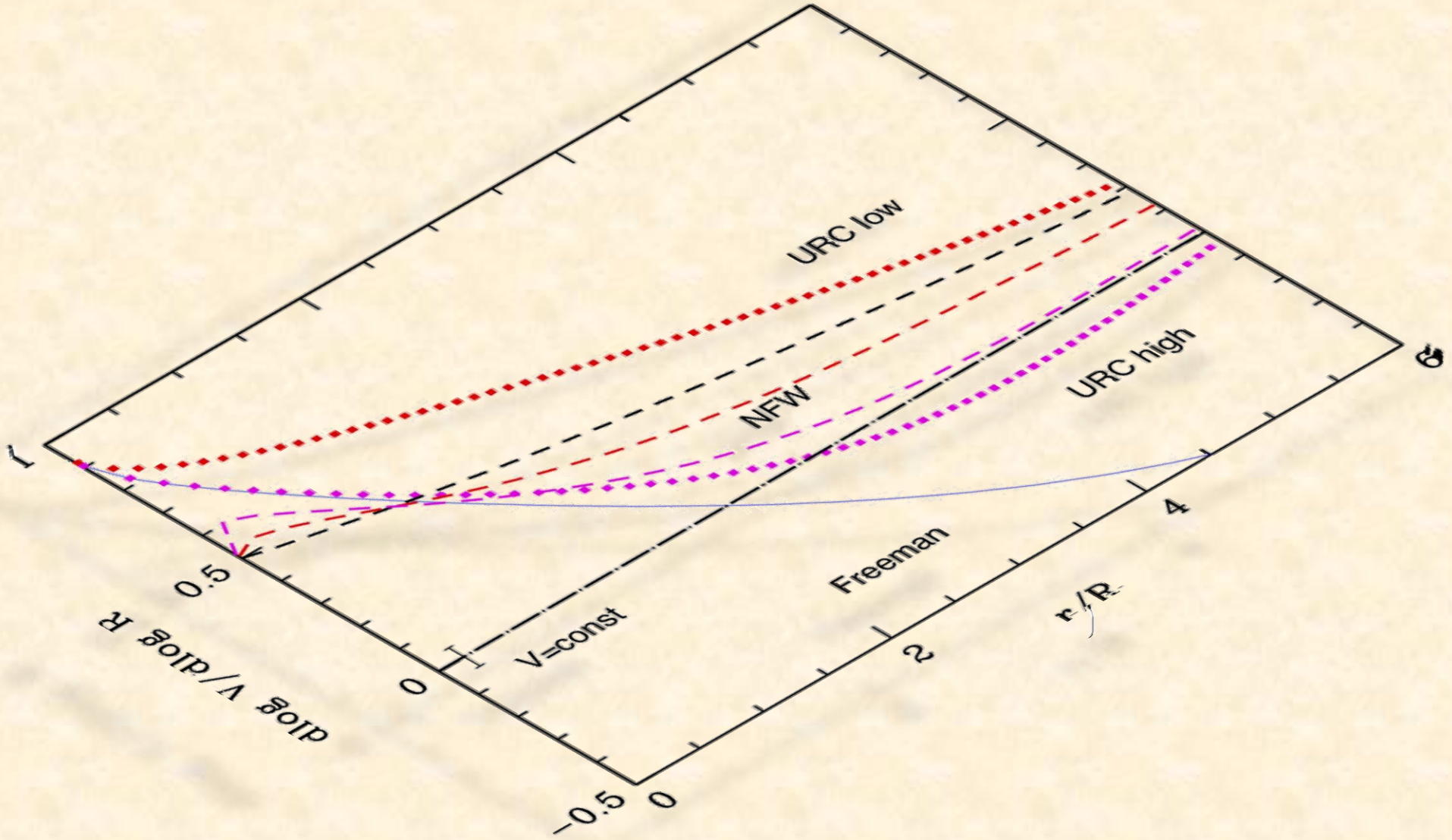


Modelling the very inner circular velocities:
light traces the mass
RC trace the grav  potential



# The role of the slope of the RC



# The URC concept

- @ fixed **L** and **X**=R/$R_D$, the Cosmic Variance of V(**X**,**L**) is one order of magnitude smaller than the variations that:

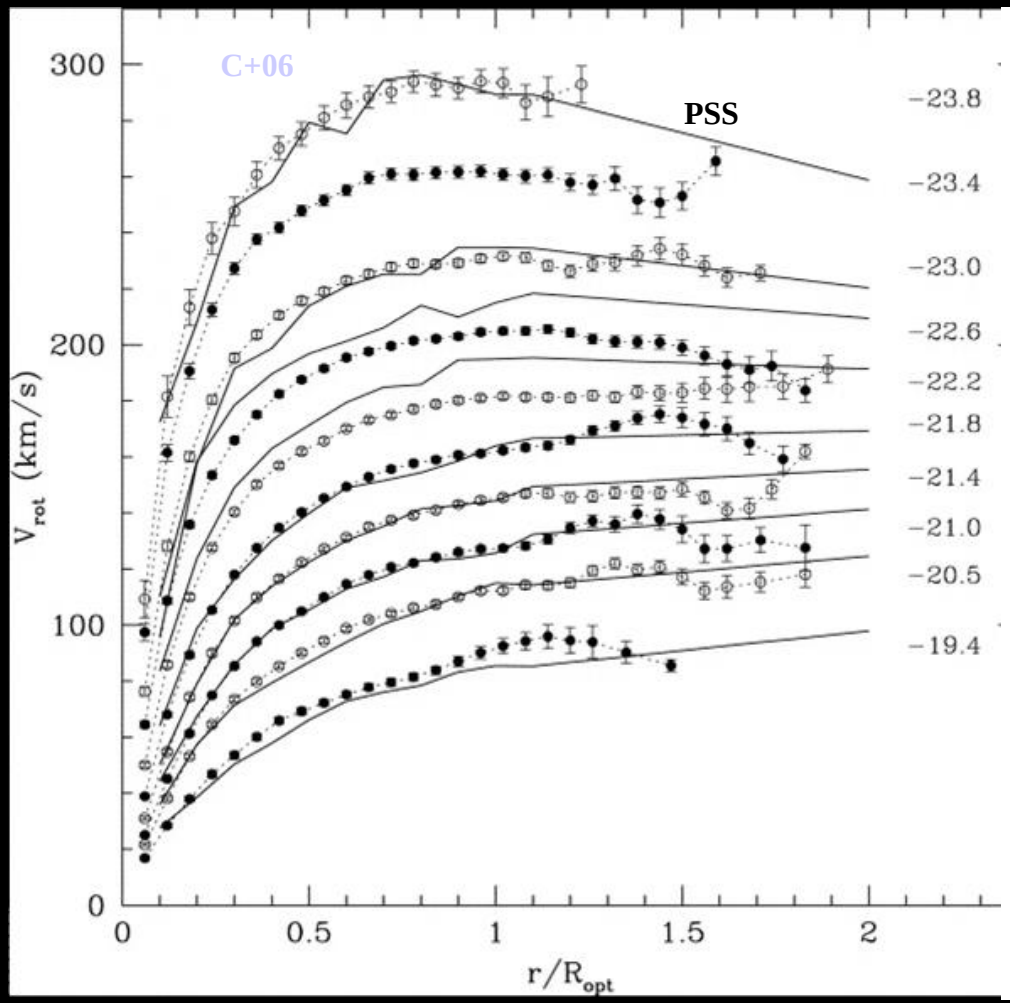
- in each galaxy, V(**X**) shows as **X** varies.
- V(**X**) shows, @ each **X**, in galaxies of different **L**

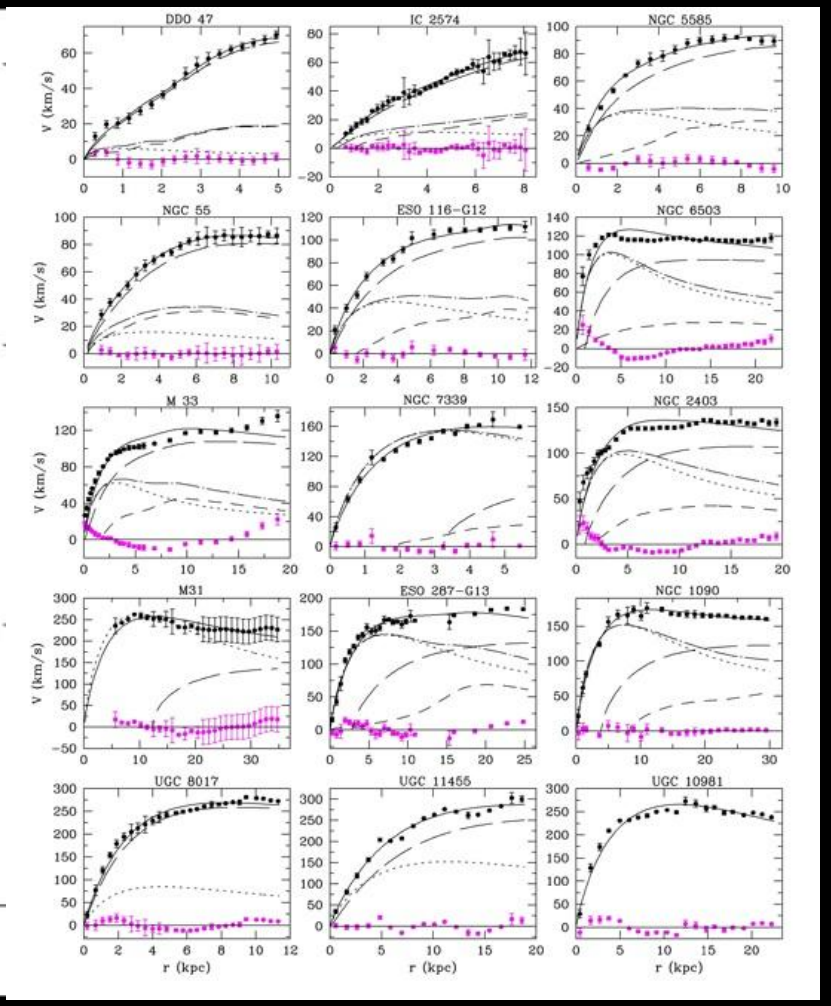
# Phenomenology of spiral kinematics

## The rotation curves

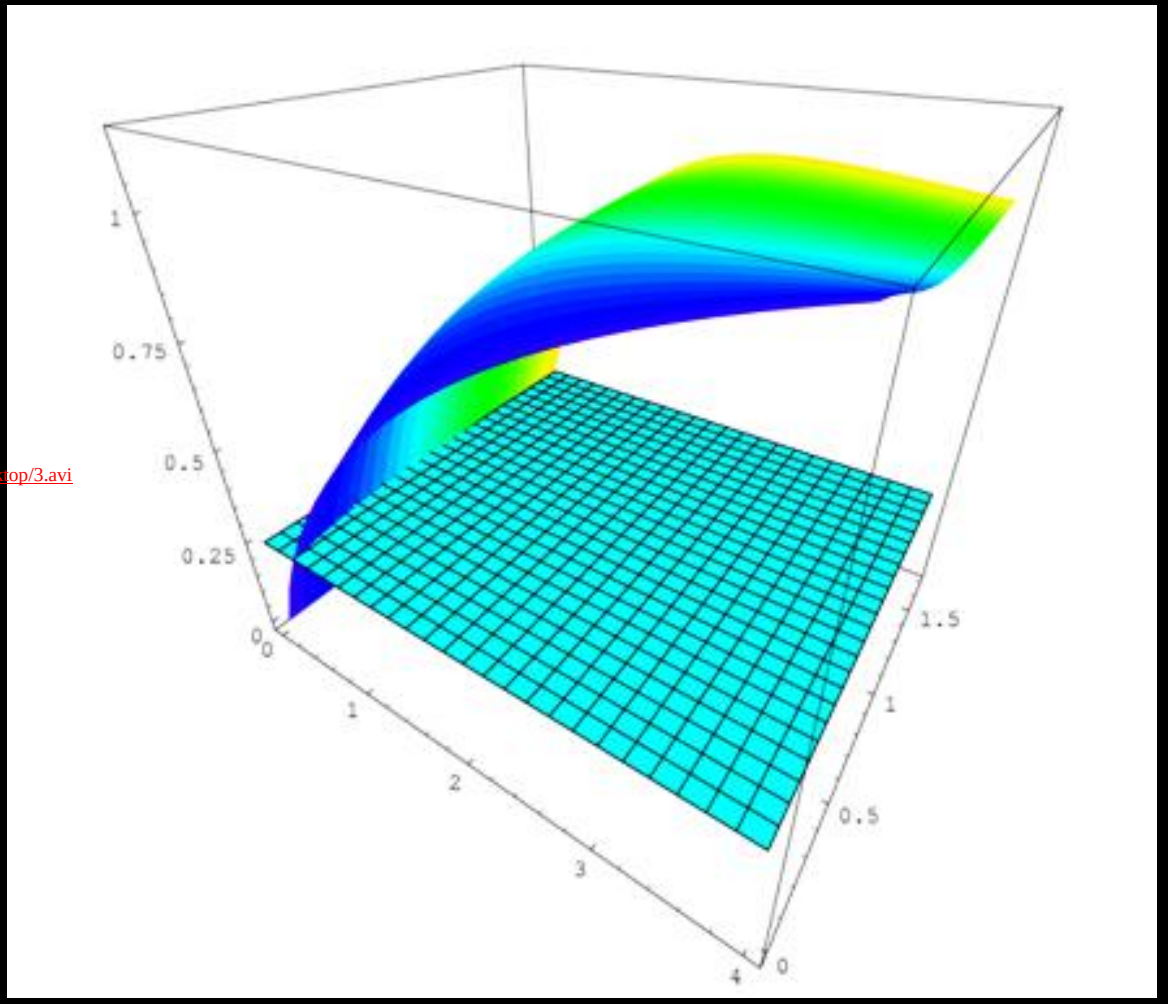
*3200 coadded*

*individual*



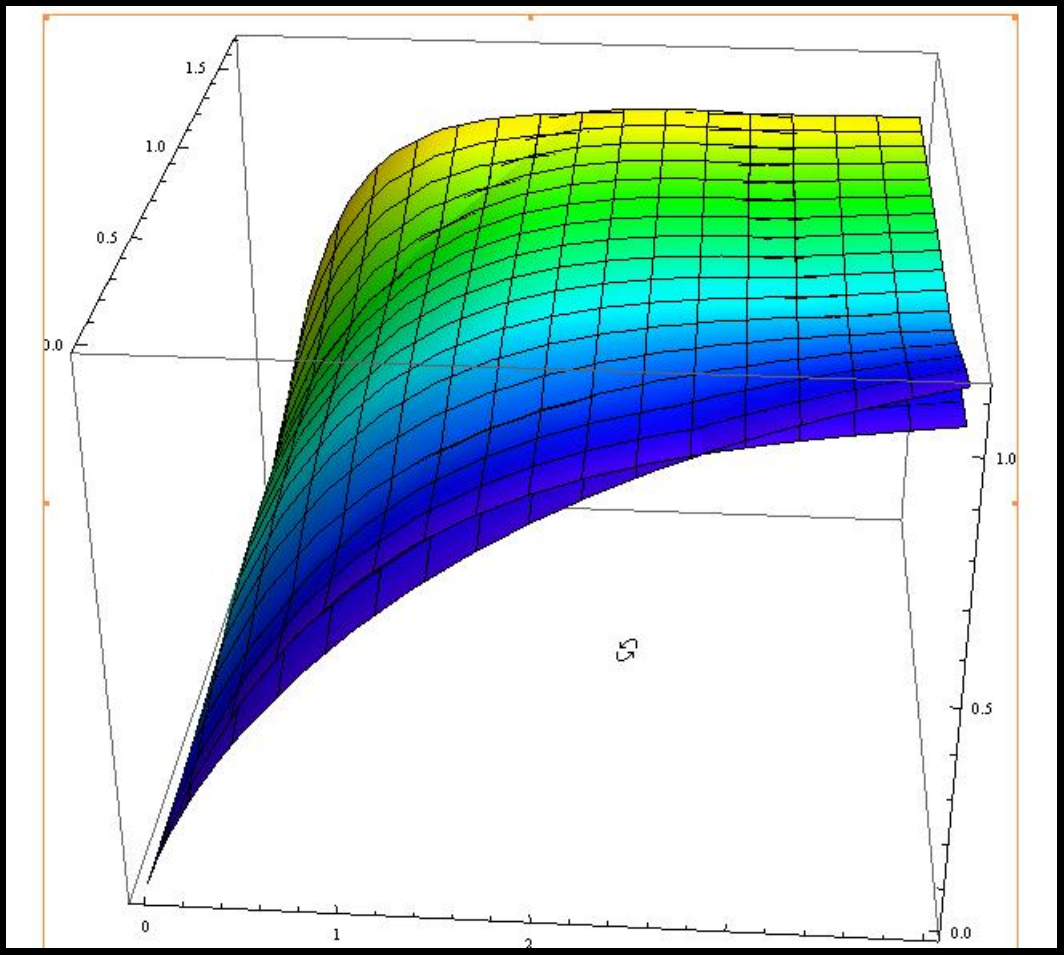



# The URC




../Desktop/3.avi

# 2 samples: PSS 1000 Catinella et al 2200



# Rotation curve modelling.

$$V_{tot}^2 = V_{DM}^2 + V_{disk}^2 + V_{gas}^2$$

- : **from I-band photometry**
- **from HI observations**
-

dark halos with constant density cores

dark halos with “cusps” (NFW, Moore)

**HI-scaling**

MOdified Newtonian Dynamics

# NFW Halos

$$\rho_{NFW}(r) = \frac{\rho_s}{(r/r_s)(1+r/r_s)^2}$$

$$c_{vir} \equiv r_{vir}/r_s$$

$$M_{NFW}(r) = M_{vir}\,\frac{A(r, r_s)}{A(c_{vir}, r_s/r_s)}$$

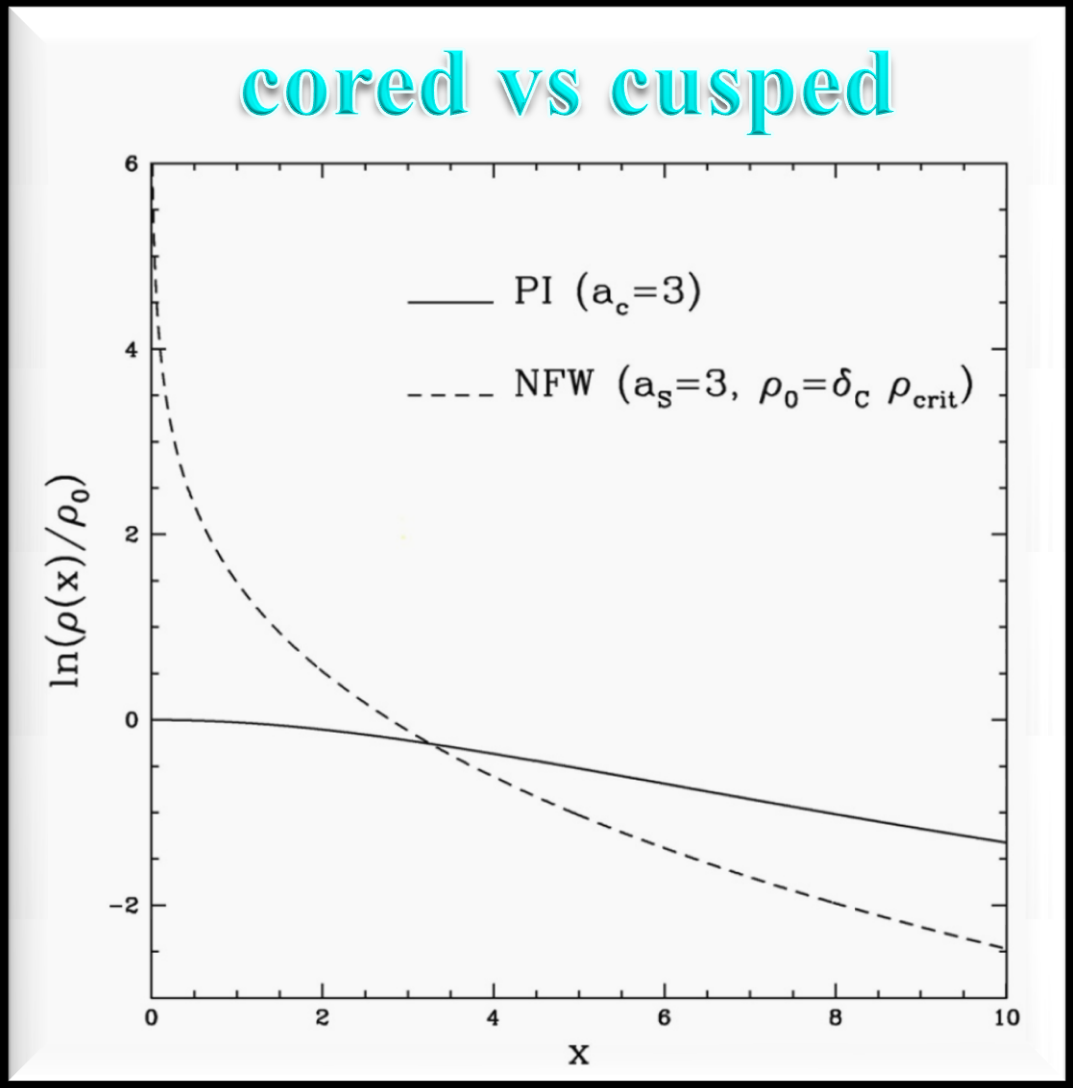
$$A(x_1, x_2) \equiv \ln(1+x_1/x_2) - (1+x_2/x_1)^{-1}$$

# Burkert Halos

$$\rho_B(r) = \frac{\rho_0}{(1+r/r_0)[1+(r/r_0)^2]}$$

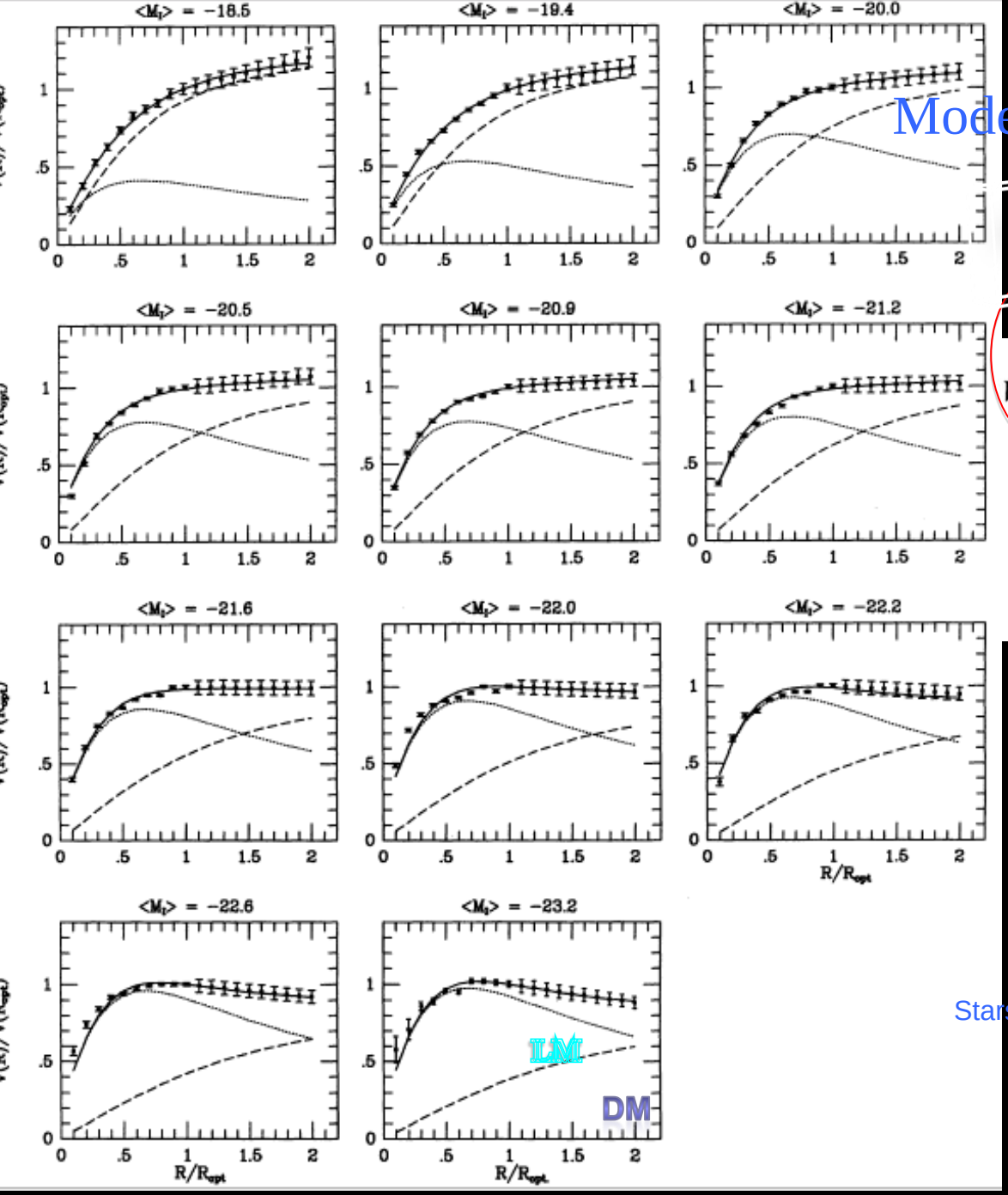
The profile is characterized by a density–core of extension $r_0$ and value $\rho_0$, resembles the NFW profile at large radii.

# cored vs cusped




**$V_{NFW}$ fits uniquely a rotation curve**

# Modelling the Universal Rotation Curve




rotation velocity

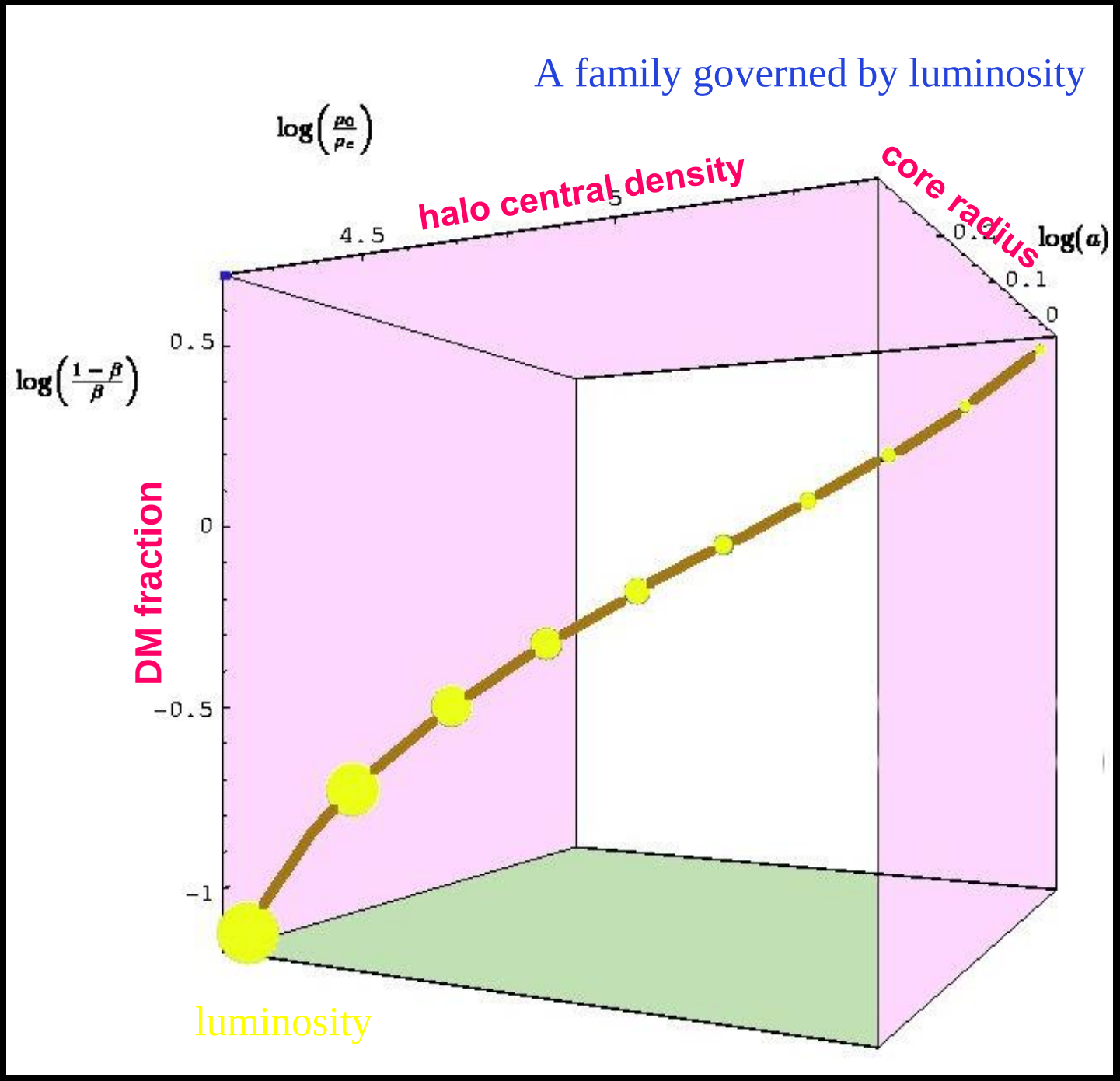
stellar contribution

$$V_{\rm URC}\left(\frac{R}{R_{\rm opt}}\right) = V(R_{\rm opt})\left\{\left(0.72 + 0.44\log\frac{L}{L_*}\right)\frac{1.97x^{1.22}}{(x^2+0.78^2)^{1.43}} + 1.6\exp\left[-0.4(L/L_*)\right]\frac{x^2}{x^2+1.5^2\left(\frac{L}{L_*}\right)^{0.4}}\right\}^{1/2} \quad \text{km s}^{-1}$$

dark matter contribution

Stars

A family governed by luminosity



# Virial halo masses

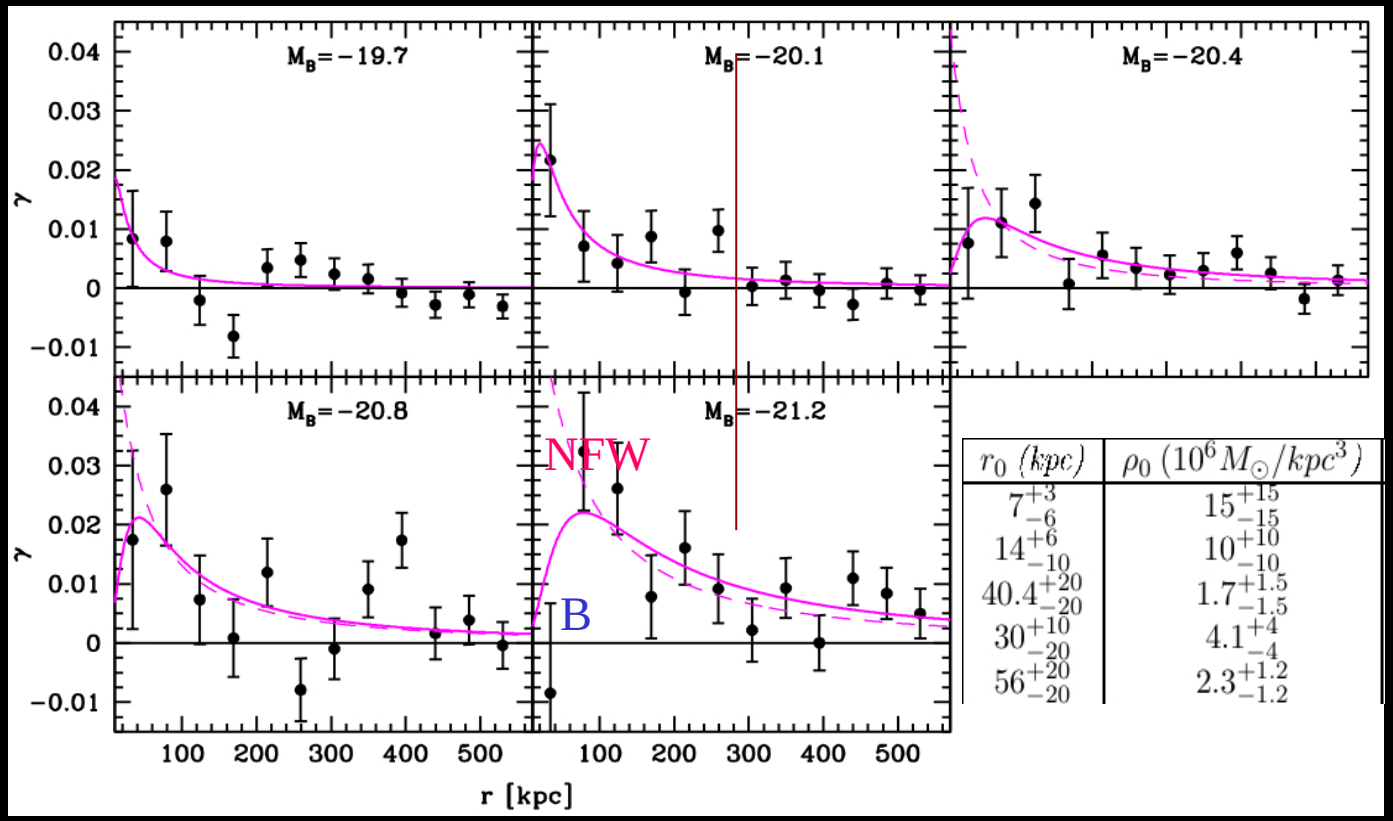
$$\mathrm{BMF}(M_b)\,dM_b = (1.94\times10^{-3}\,\tilde{M}_b^{-1.2}\,e^{-\tilde{M}_b/1.9} + 4\times10^{-7}\,\tilde{M}_b^{-2.6})\,\frac{dM_b}{10^{11}M_\odot}$$

$$HMF\{M_h\}\,dM_h = A\,M_h^{-1.84}\,dM_h$$

$$HMF\{M_h\}\,dM_h/dM_b\,dM_b = BMF\{M_b\}\,dM_b$$

# Halo masses from weak lensing

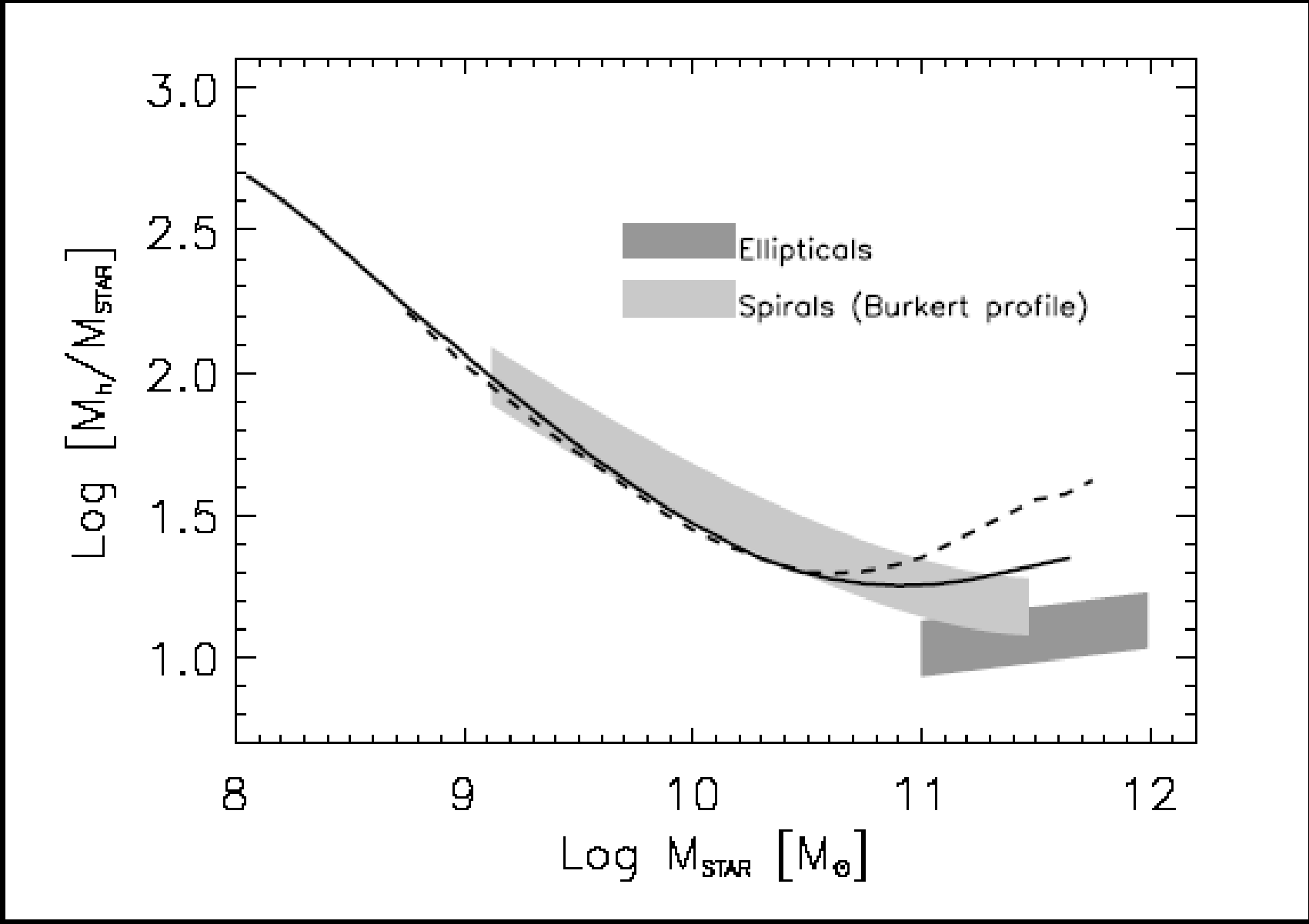
With a density profile we model the tangential shear
Obtain the structural free parameters.



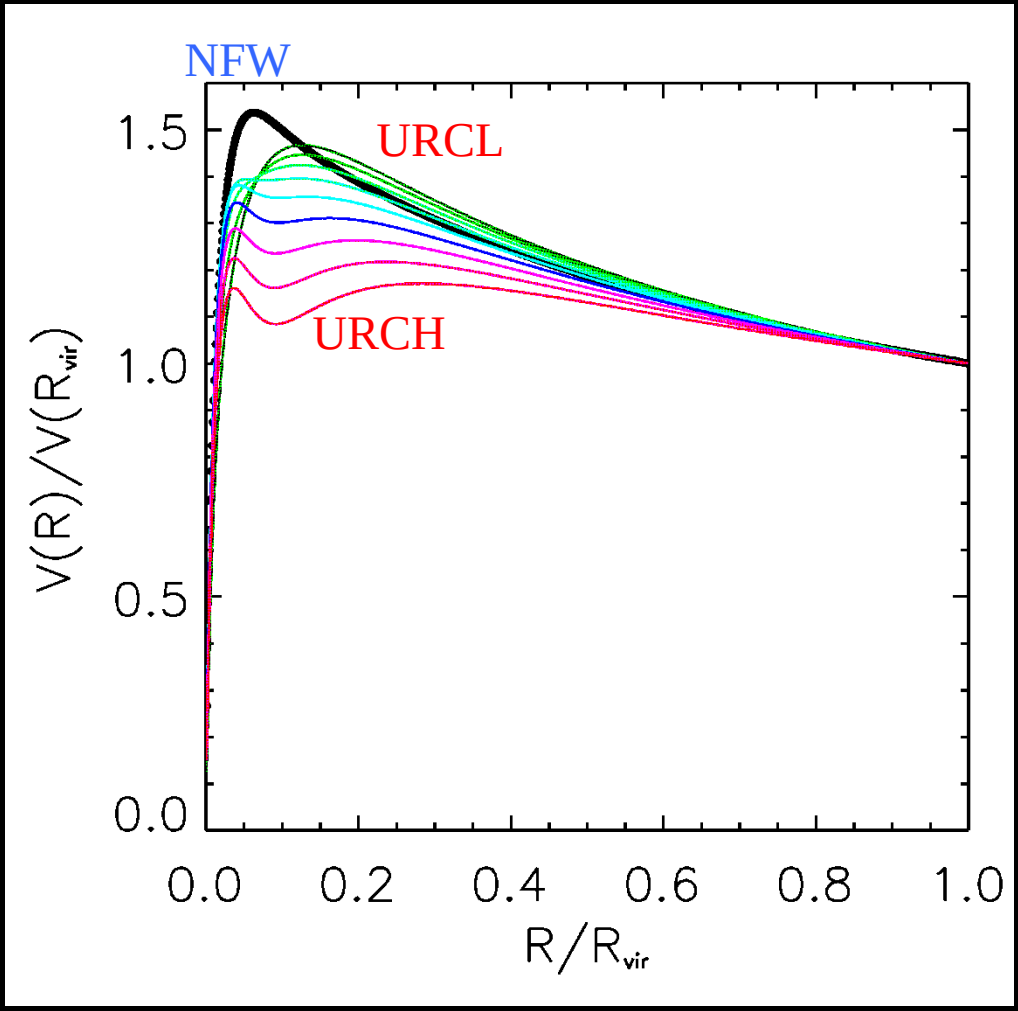

| $r_0$ (kpc) | $\rho_0$ ($10^6 M_\odot/kpc^3$) |
|---|---|
| $7^{+3}_{-6}$ | $15^{+15}_{-15}$ |
| $14^{+6}_{-10}$ | $10^{+10}_{-10}$ |
| $40.4^{+20}_{-20}$ | $1.7^{+1.5}_{-1.5}$ |
| $30^{+10}_{-20}$ | $4.1^{+4}_{-4}$ |
| $56^{+20}_{-20}$ | $2.3^{+1.2}_{-1.2}$ |

Same results as those obtained from RCs.

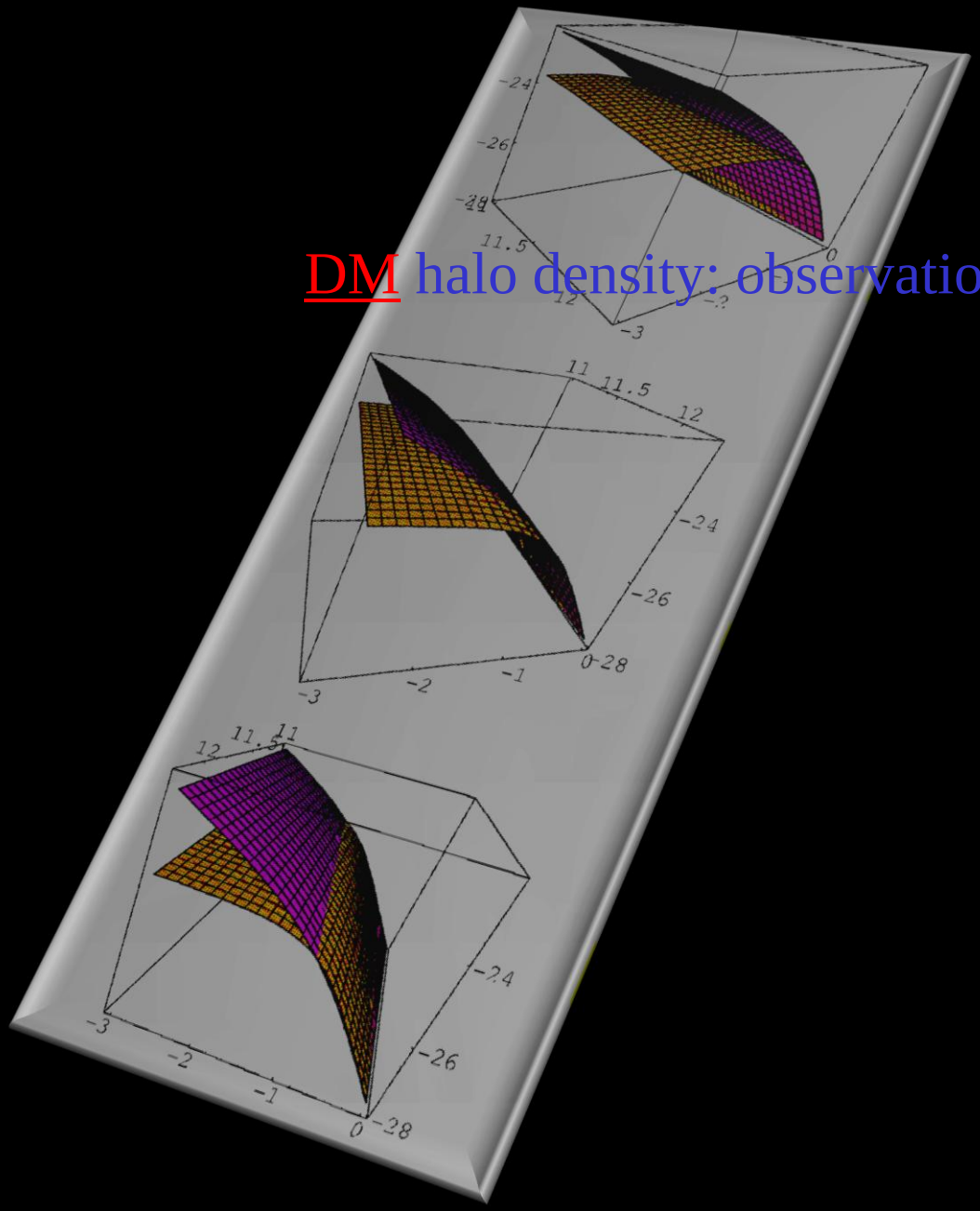
Burkert profile provides excellent fit, better than NFW.


3.0
2.5
2.0
1.5
1.0
Log [M_h/M_STAR]
Ellipticals
Spirals (Burkert profile)
8
9
10
11
12
Log M_STAR [M_⊙]

# THE UNIVERSAL VELOCITY CURVE



# DM halo density: observations vs simulations

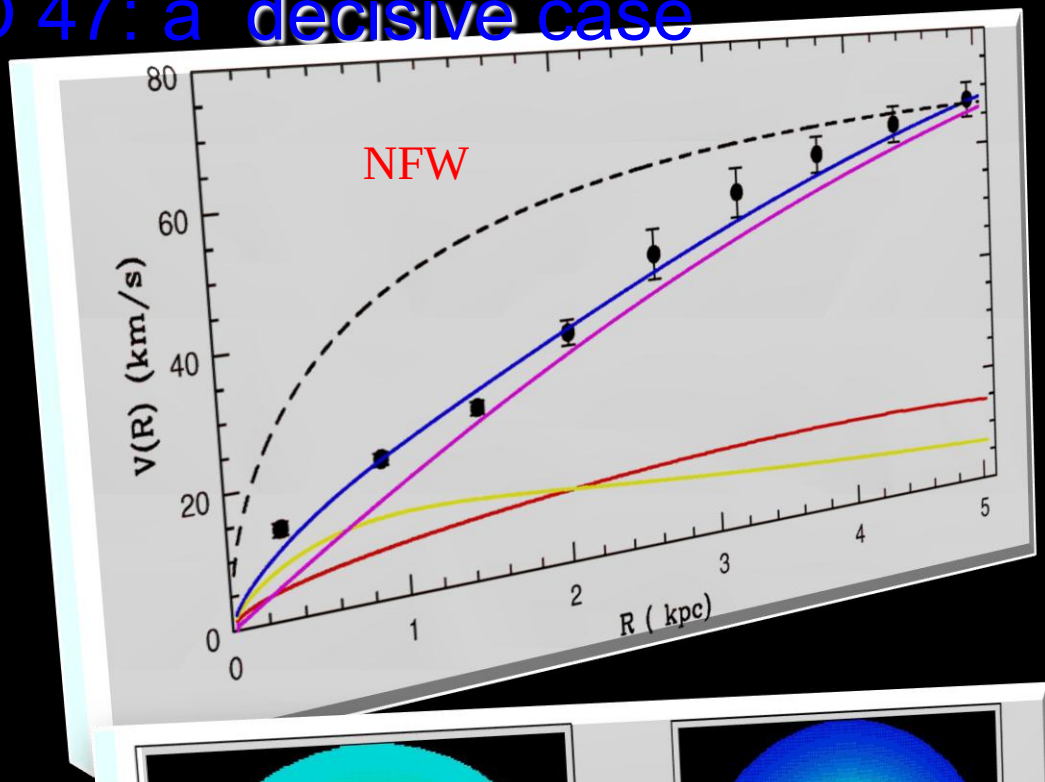


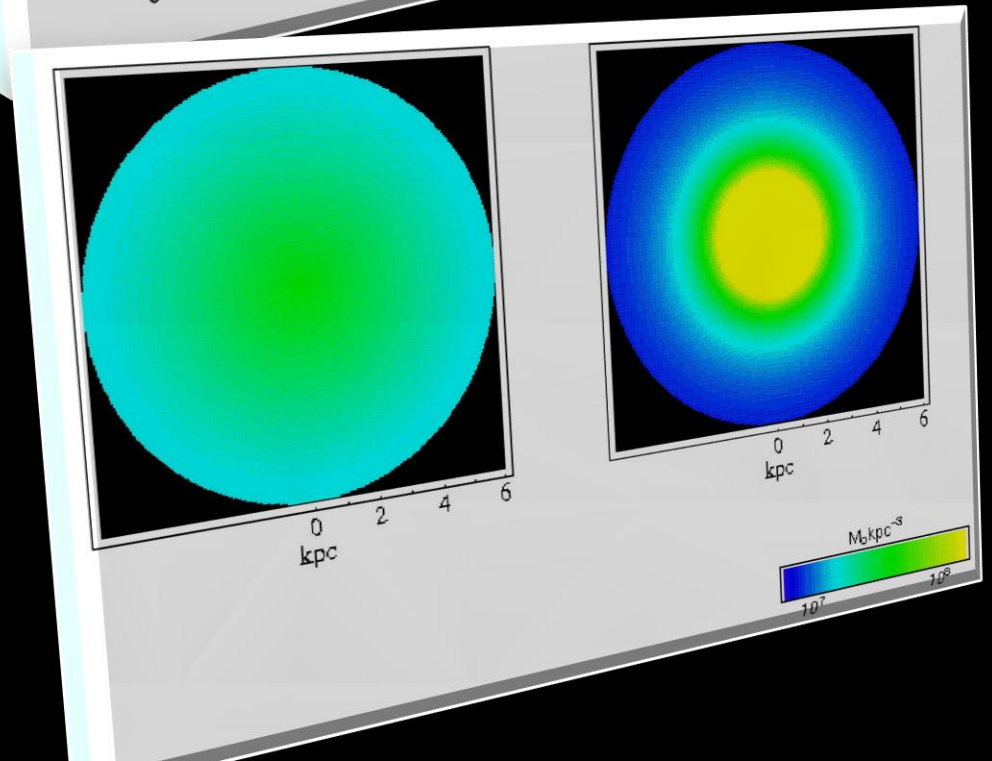
## NFW HALOS

- Fit badly the RCs
- Unphysically too low stellar mass-to-light ratios
- Unphysically too high halo masses

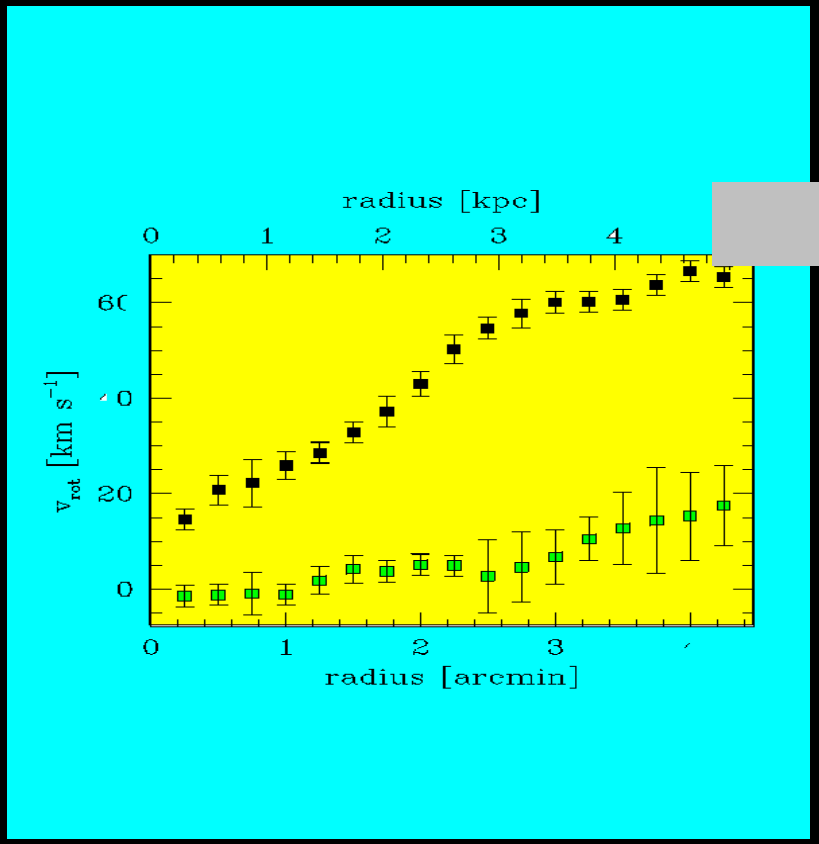

Moore, Nature 370, 629 (1994)
Kravtsov et al., ApJ 502, 48 (1998)
Salucci & Burkert, ApJ 537, L9 (2000)
de Blok, McGaugh & Rubin, AJ 122, 2396 (2000)
Salucci MNRAS, 320, 1 (2001)
Marchesini, D'Onghia, Chincarini et al. ,ApJ 575, 801 (2002)
de Blok & Bosma, A&A 385, 816 (2002)
Salucci, Walter & Borriello, A&A 409, 53 (2003)
Donato, Gentile, Salucci, MNRAS, 353, L17 (2004)
Gentile, Salucci, Klein et al., MNRAS 351, 903 (2004)
Gentile, Burkert, Salucci et al. ApJ 634, L145 (2005)
Spekkens & Giovanelli AJ 132, 1426 (2006)
Gentile, Salucci, Klein, et al. MNRAS, 375, 199 (2007)
Salucci, Lapi, Tonini et al MNRAS 378, 41 (2007)
Kuzio de Naray, McGaugh & de Blok, ApJ 676, 920 (2008)
de Blok, Walter, Brinks et al. AJ 136, 2648 (2008)
Spano, Marcelin, Amram et al. MNRAS 383, 297 (2008)
Walter, Brinks, de Blok et al. AJ, 136, 2563 (2008)
Trachternach, de Blok, Walter, et al. AJ, 136, 2720 (2008)
van Eymeren Trachternach Kurihaleki et al arXiv:0906.4654

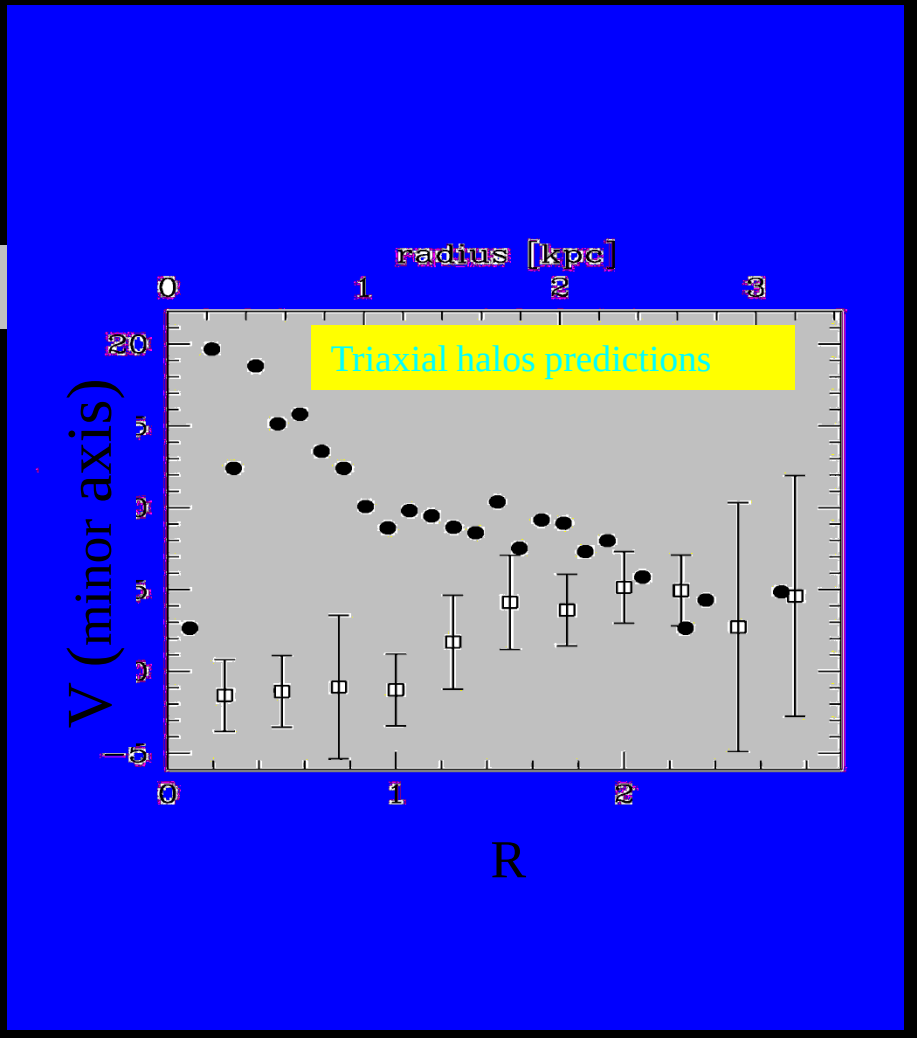
# DDO 47: a decisive case



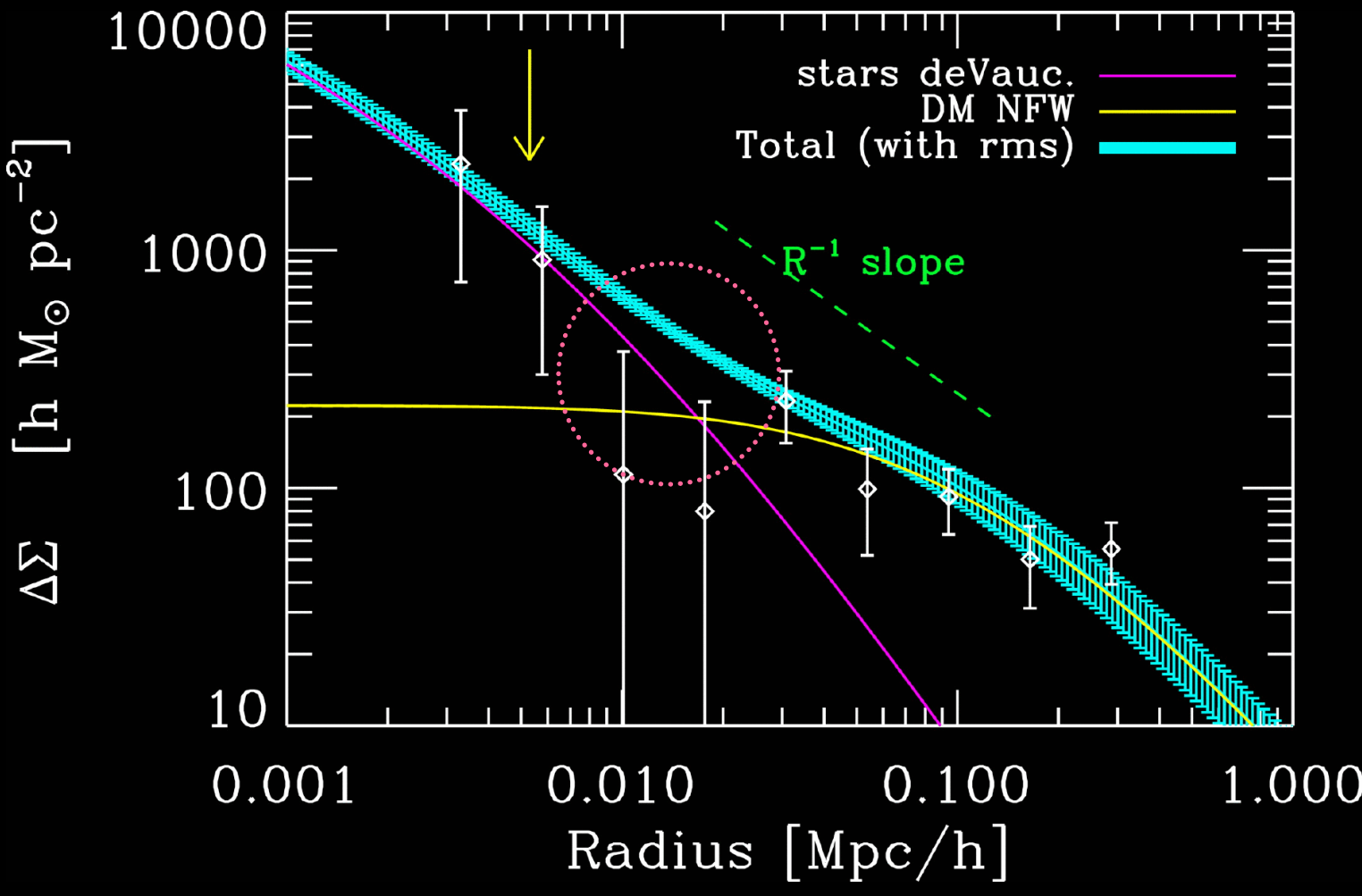
# Non-circular motions?



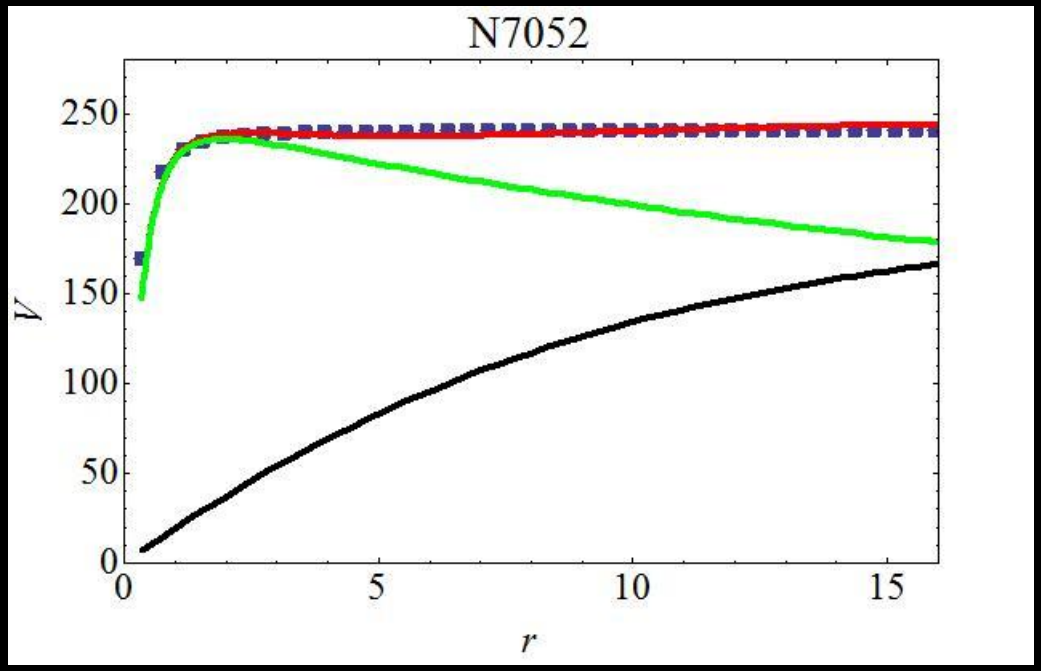



# DM in early-types: weak+strong lensing

*22* bright E/S0s at *z* ~ 0.2 (SLACS: Gavazzi et al. 2007)

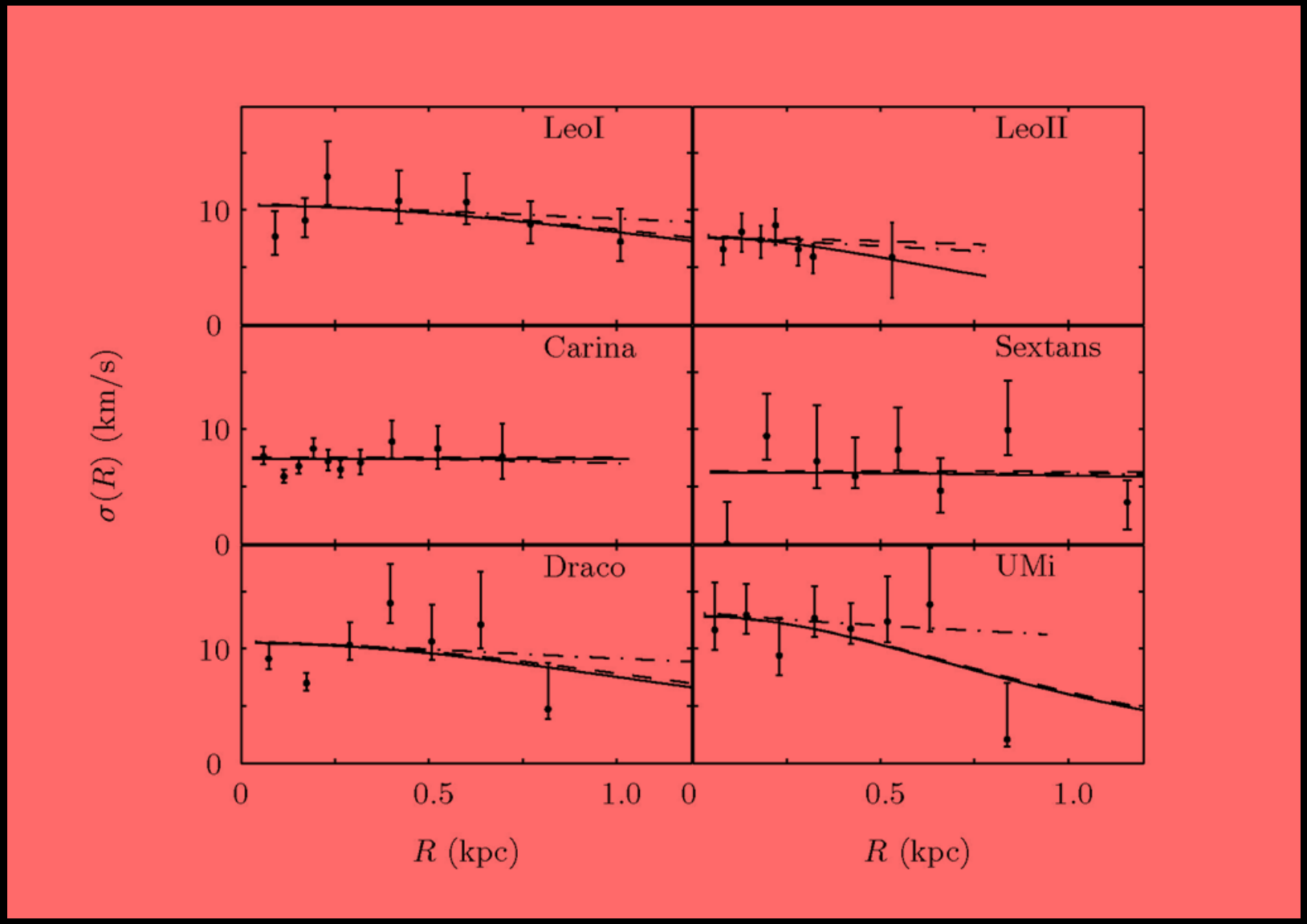



# Ellipticals as Spirals: M(r)=r T dlog n/dlog R

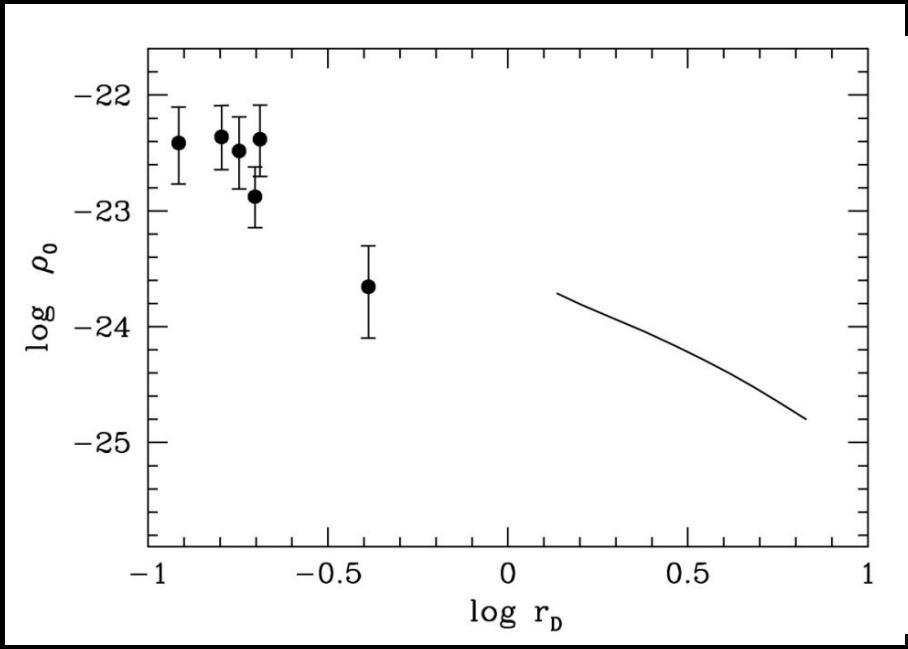


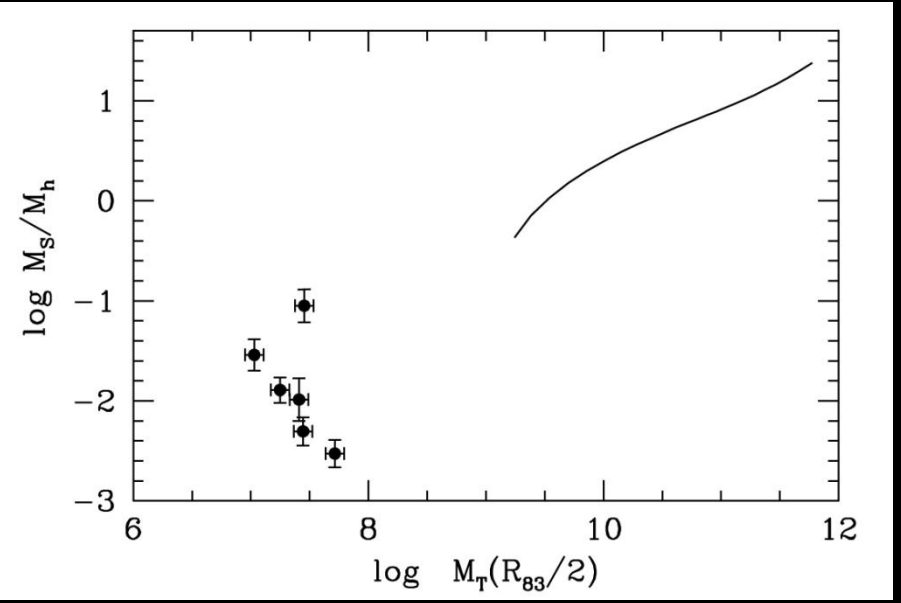
# dSphs dispersion velocities analysis

$$V_{cir}^2(r) = -\frac{r}{\rho(r)}\frac{d}{dr}(\sigma^2(r)\rho(r)) - 2\beta\sigma^2(r)$$



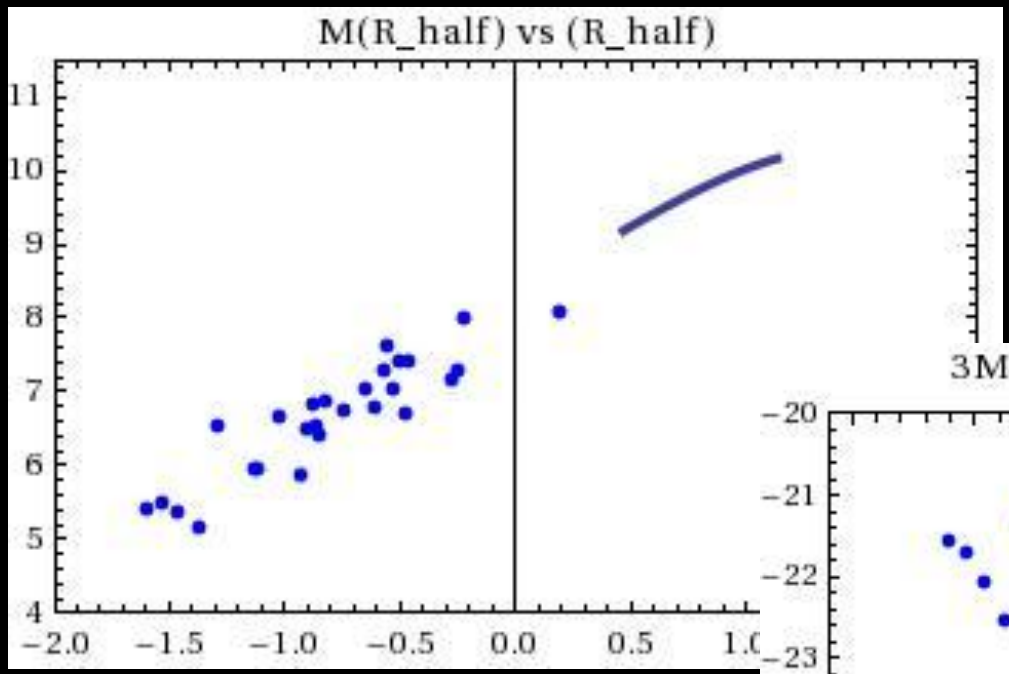
# Structral properties of dSph's

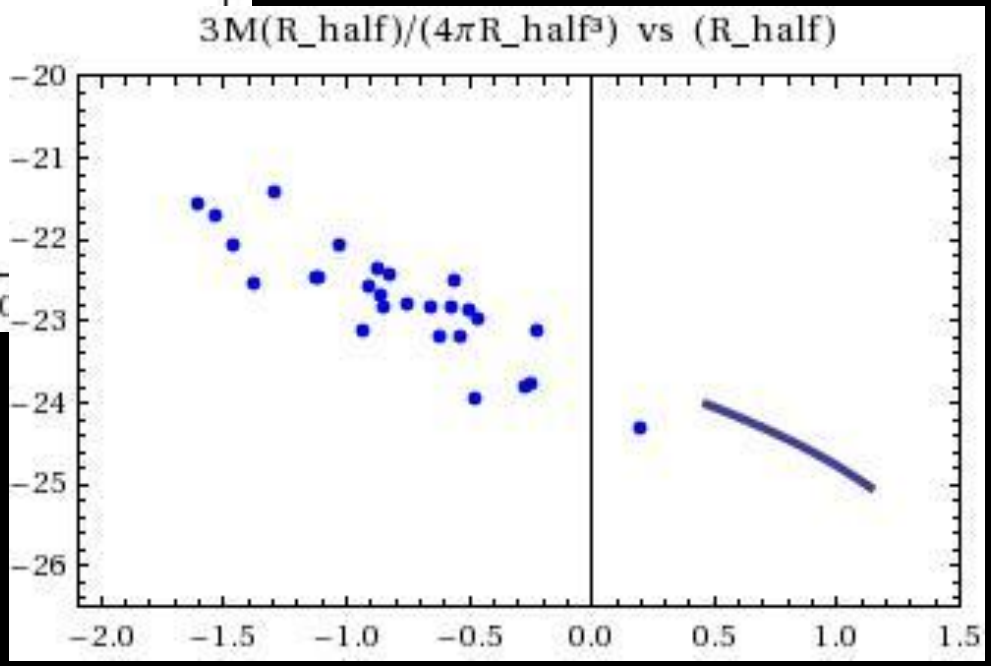


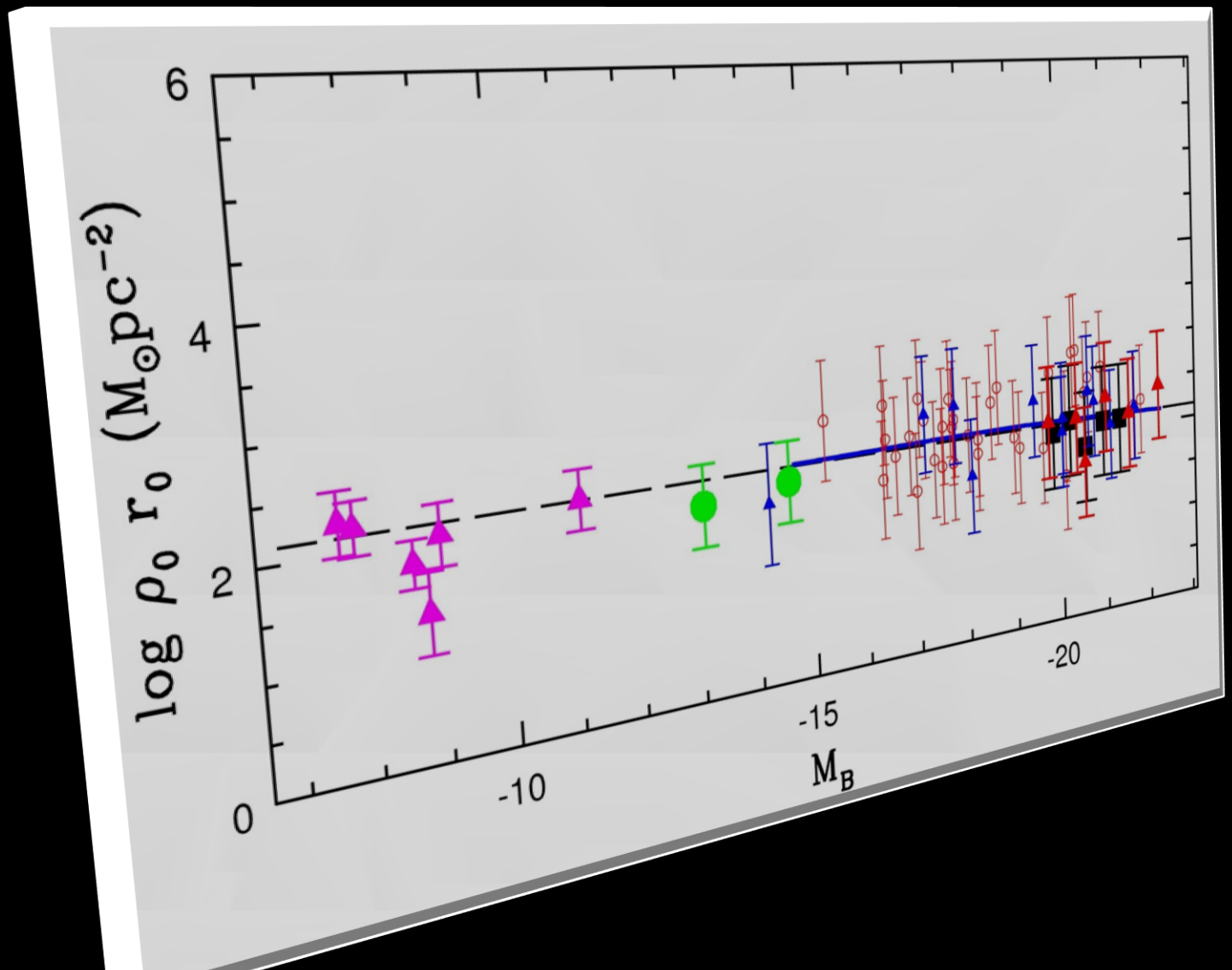
# Dwarf Spheroidal Galaxies

A Universal Mass Profile Walker et al 09



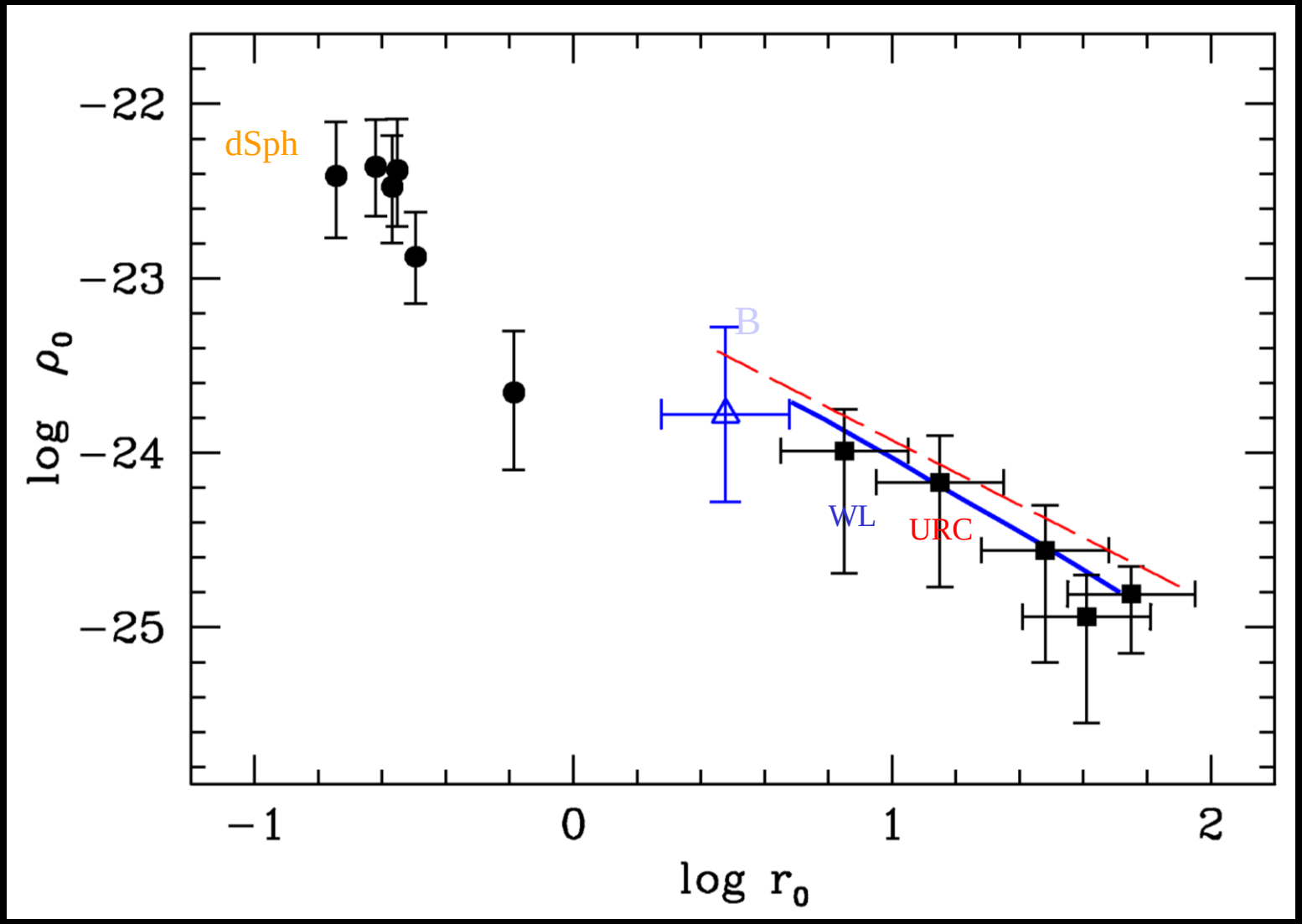



# The constant surface density $\rho_0 r_0$

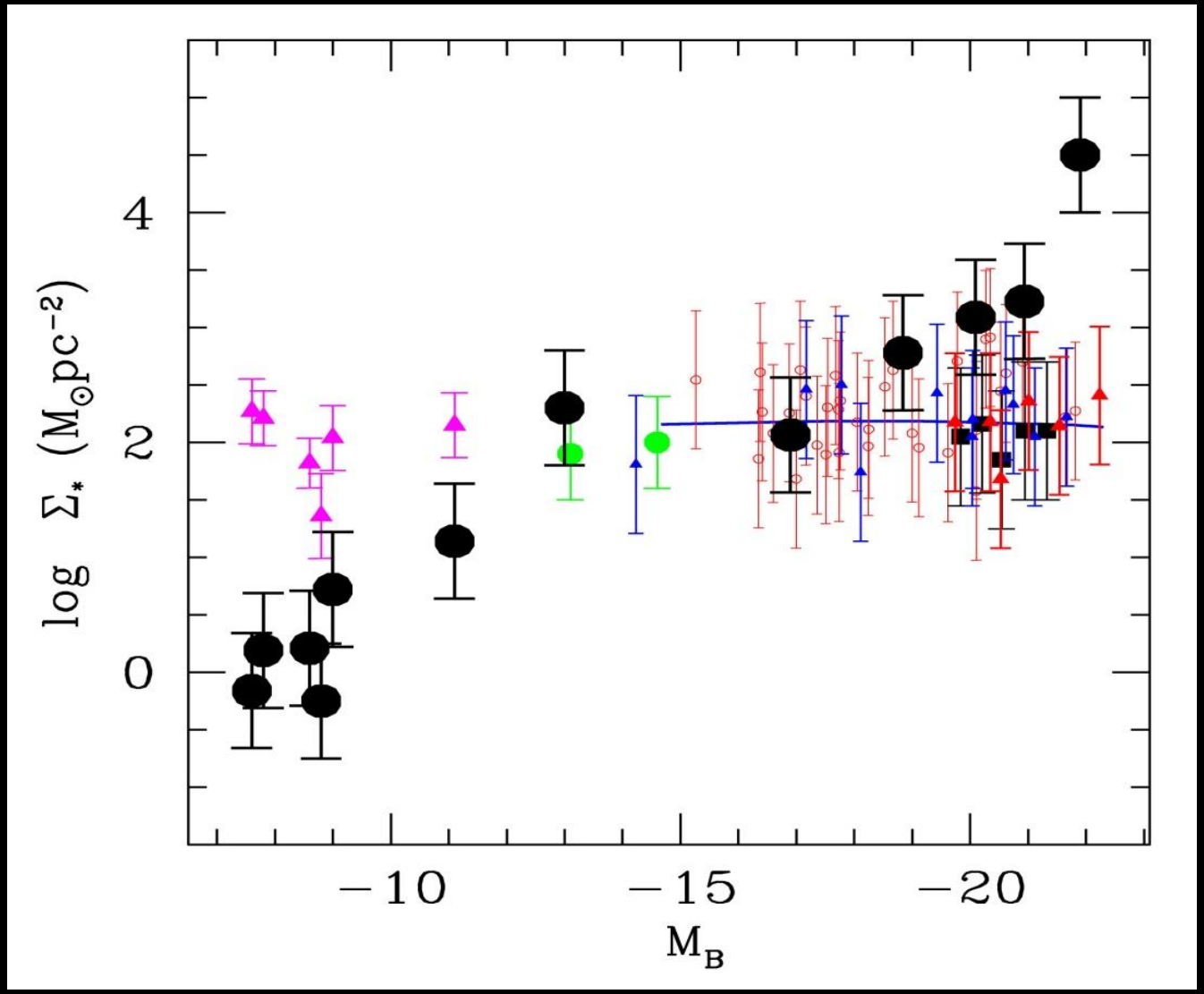


# Halo central density vs core radius

$$\rho_0 = 10^{-23} \, (r_0/\mathrm{kpc})^{-1} \, \mathrm{g/cm^3}$$



# The central stellar surface density



CONSEQUENCES

The mass of the particle ( de Vega , Sanchez, 2009) keV scale

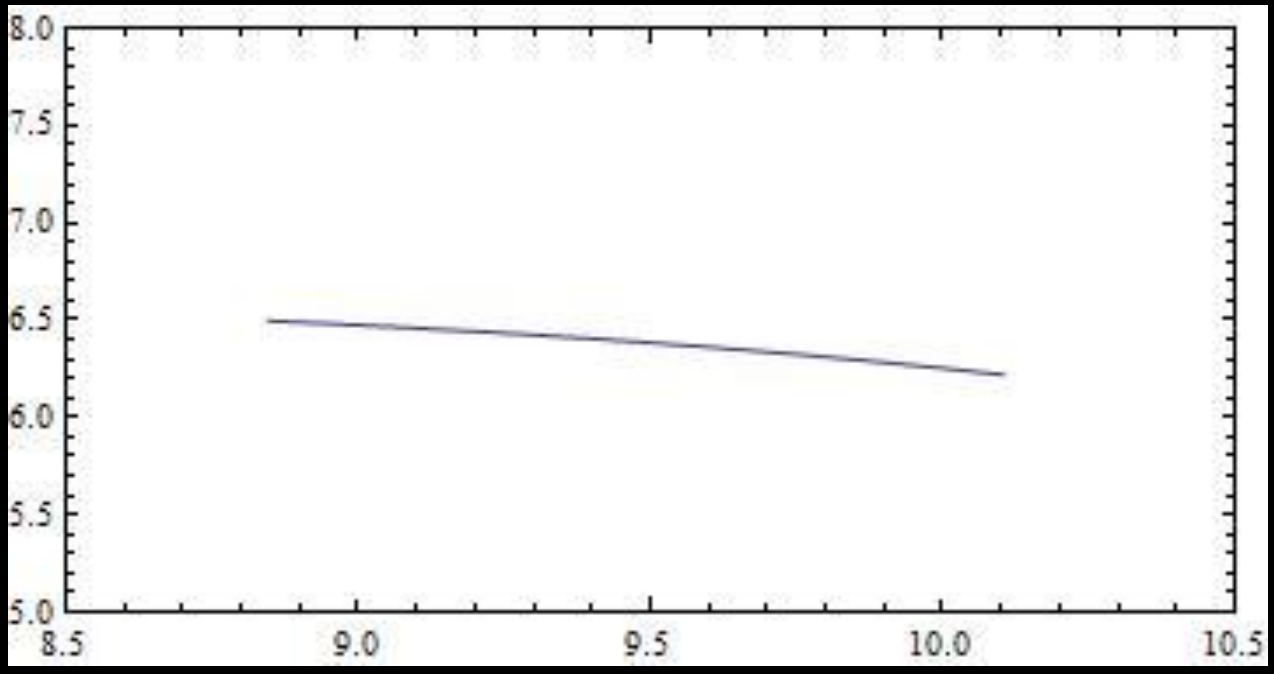
The Nature of the particle

Galaxy Scaling laws are important

Alternative Gravity

Additional proof for cored models

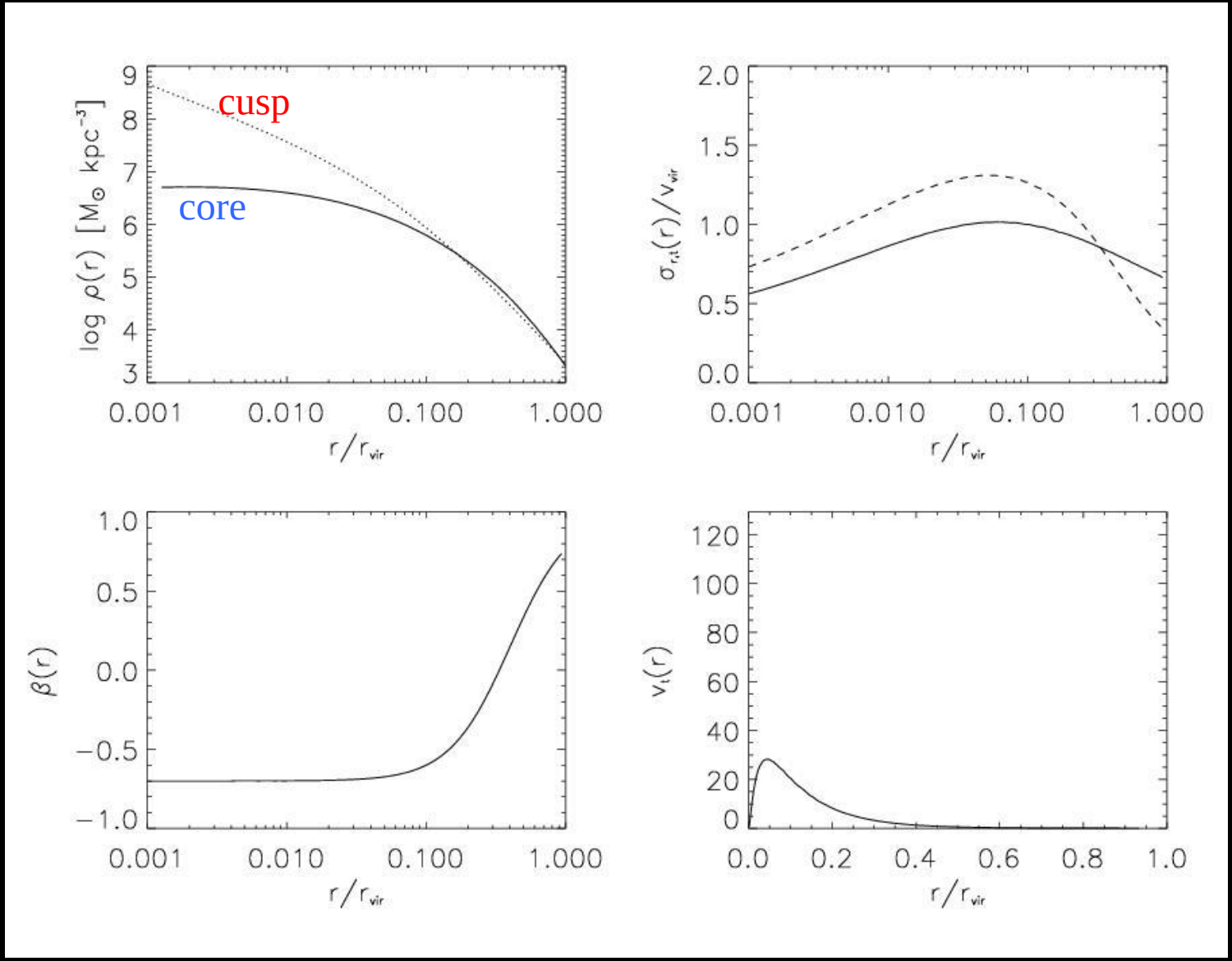
# CONSTANT MASS ?



A way out?

angular momentum exchange between baryons and DM

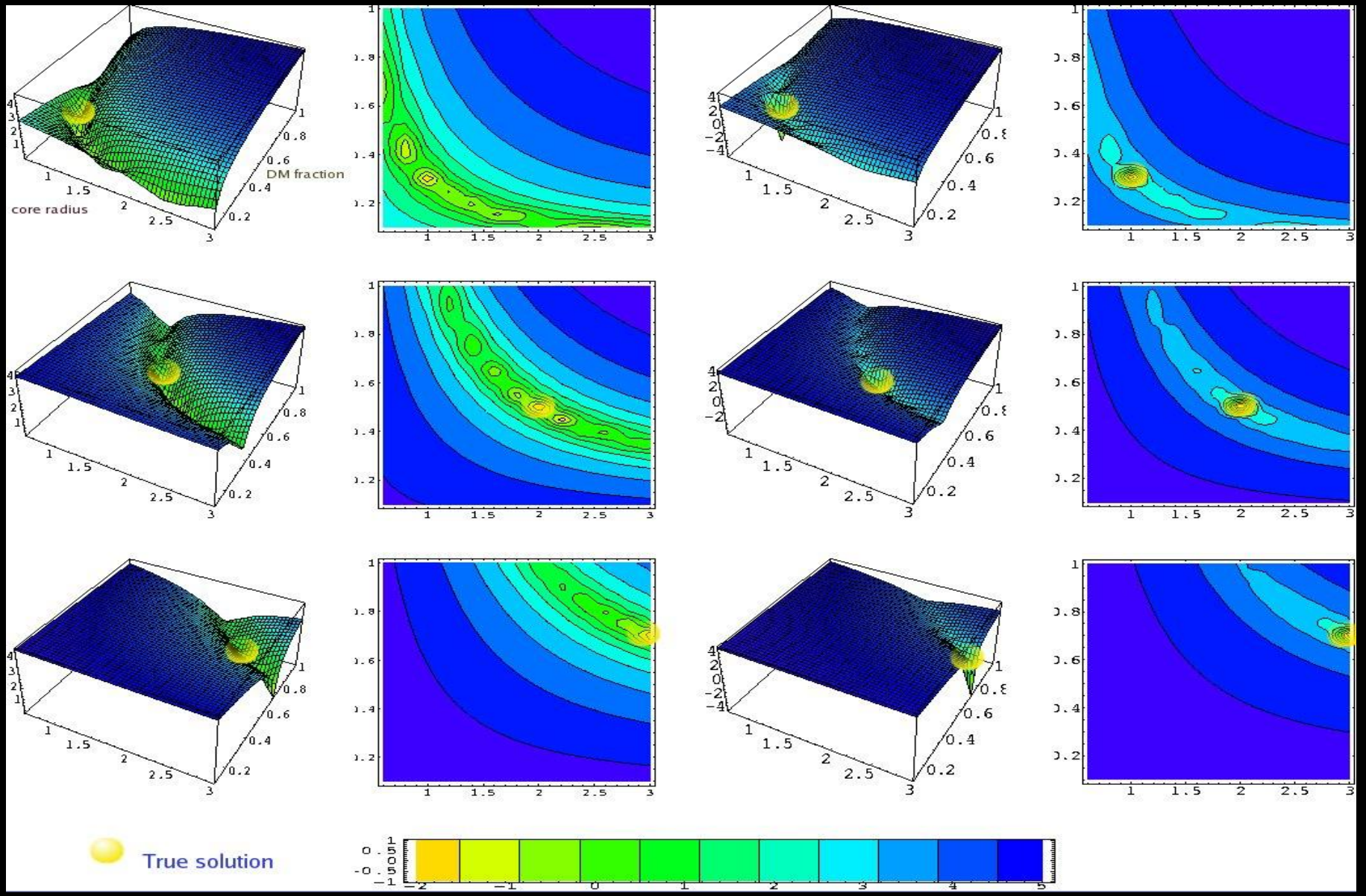
Tonini Lapi Salucci




DARK MATTER IS PRESENT IN GALAXIES
IT IS STRONGLY RELATED TO THE LUMINOUS MATTER
THERE IS A SOLID EMPIRICAL SCENARIO

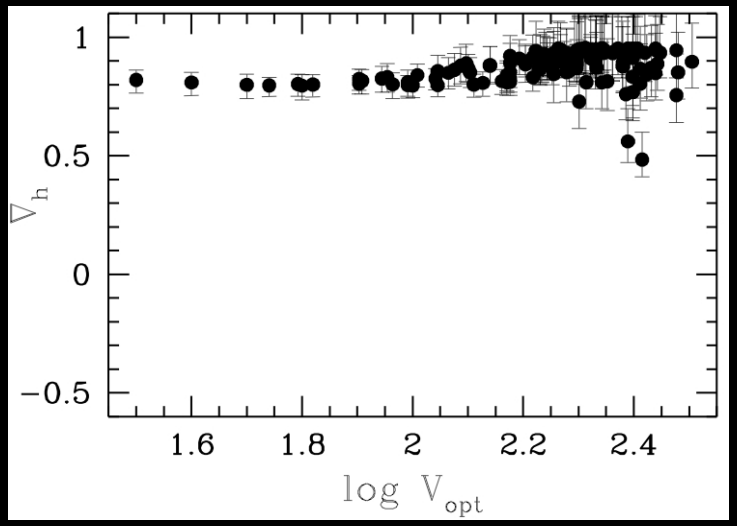
# We can uniquely mass model a RC

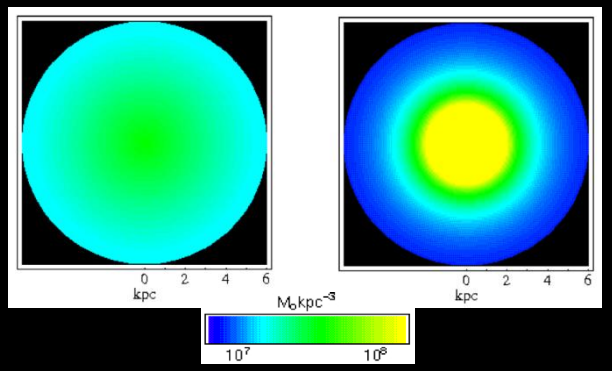
**disk-halo components, known surf phot, reliable V(R) and dV/dR, resolution ~ 0.3 $R_D$**



# Results from Trieste: analysis of high quality RCs

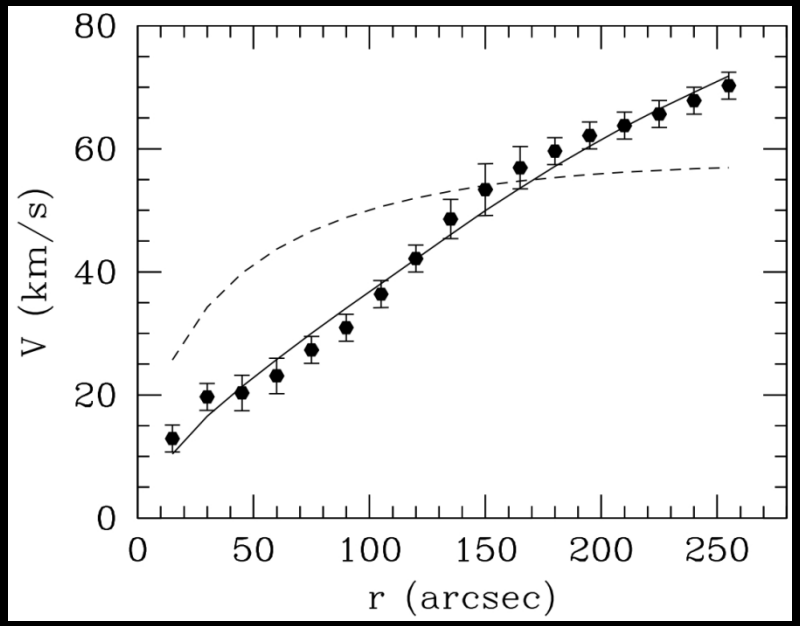
**URC fits to RCs**



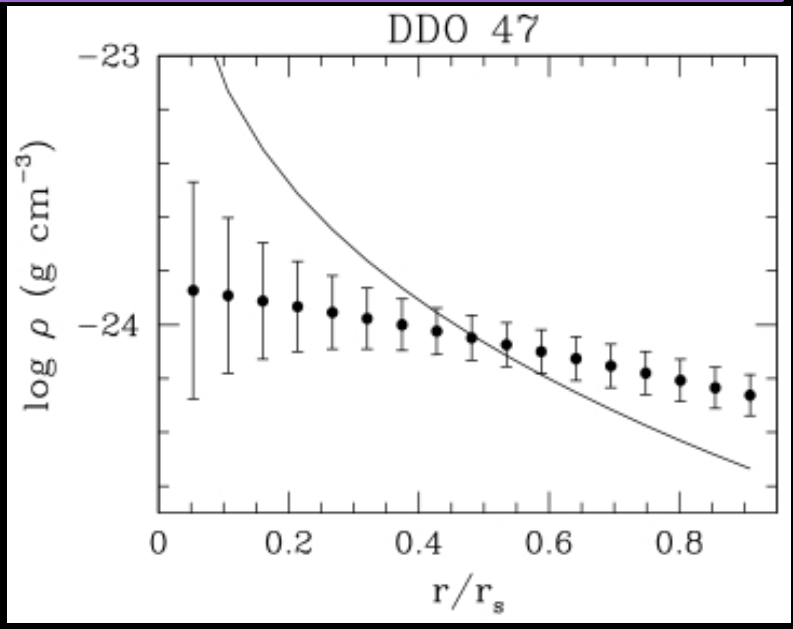




Borriello & Salucci, MNRAS 323, 285 (2001)

**DDO 47**




Gentile et al., ApJ 634, L145 (2005)




Gentile, Tonini & Salucci, A&A 467, 925 (2007)

# ΛCDM Universal Rotation Curve from NFW profile and MMW theory