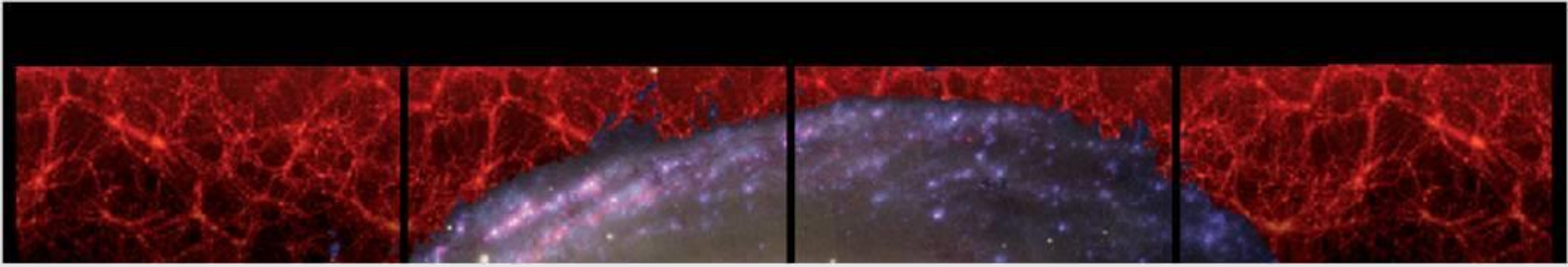


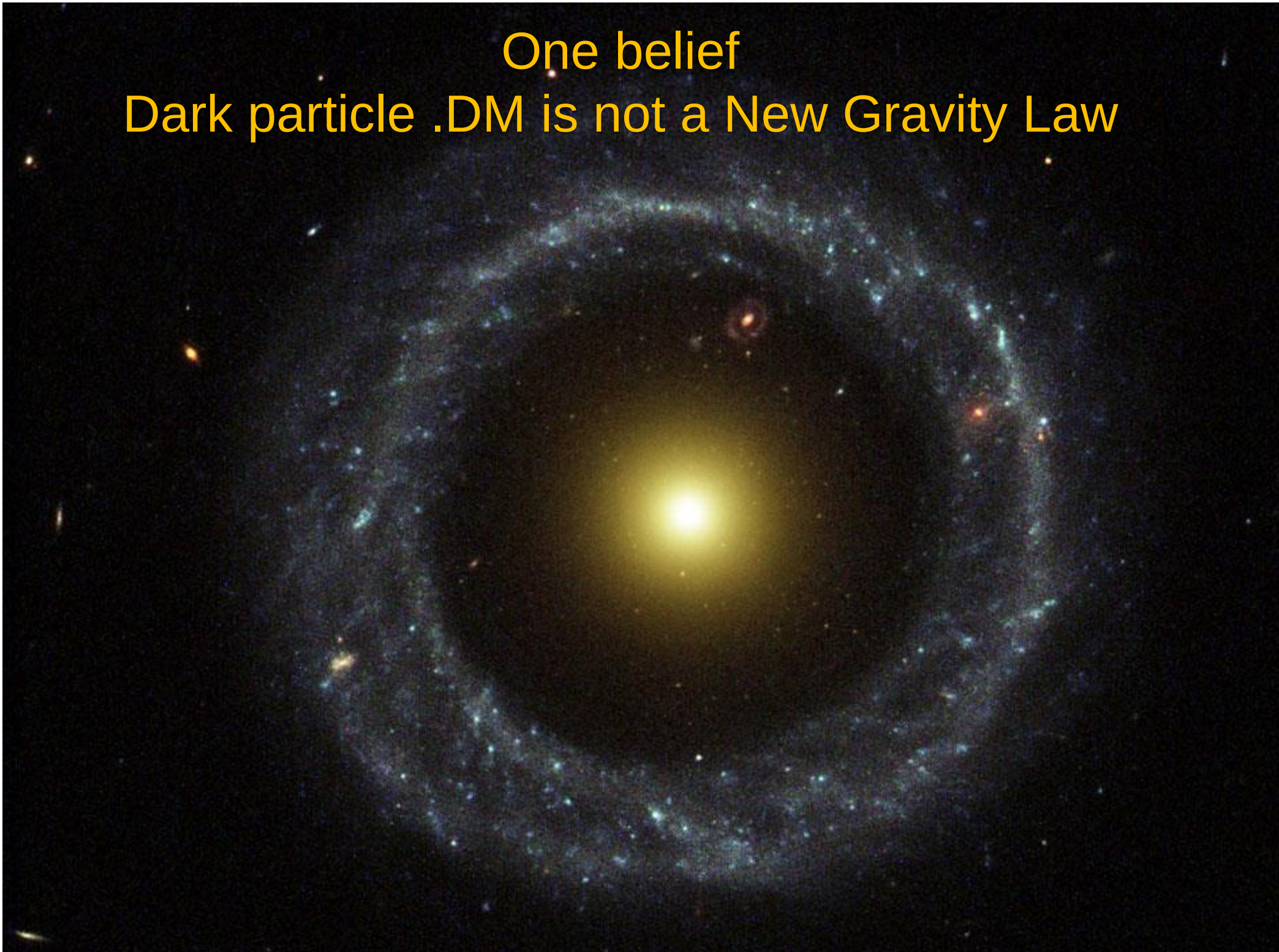
Paradigms and Scenarios for Dark Matter

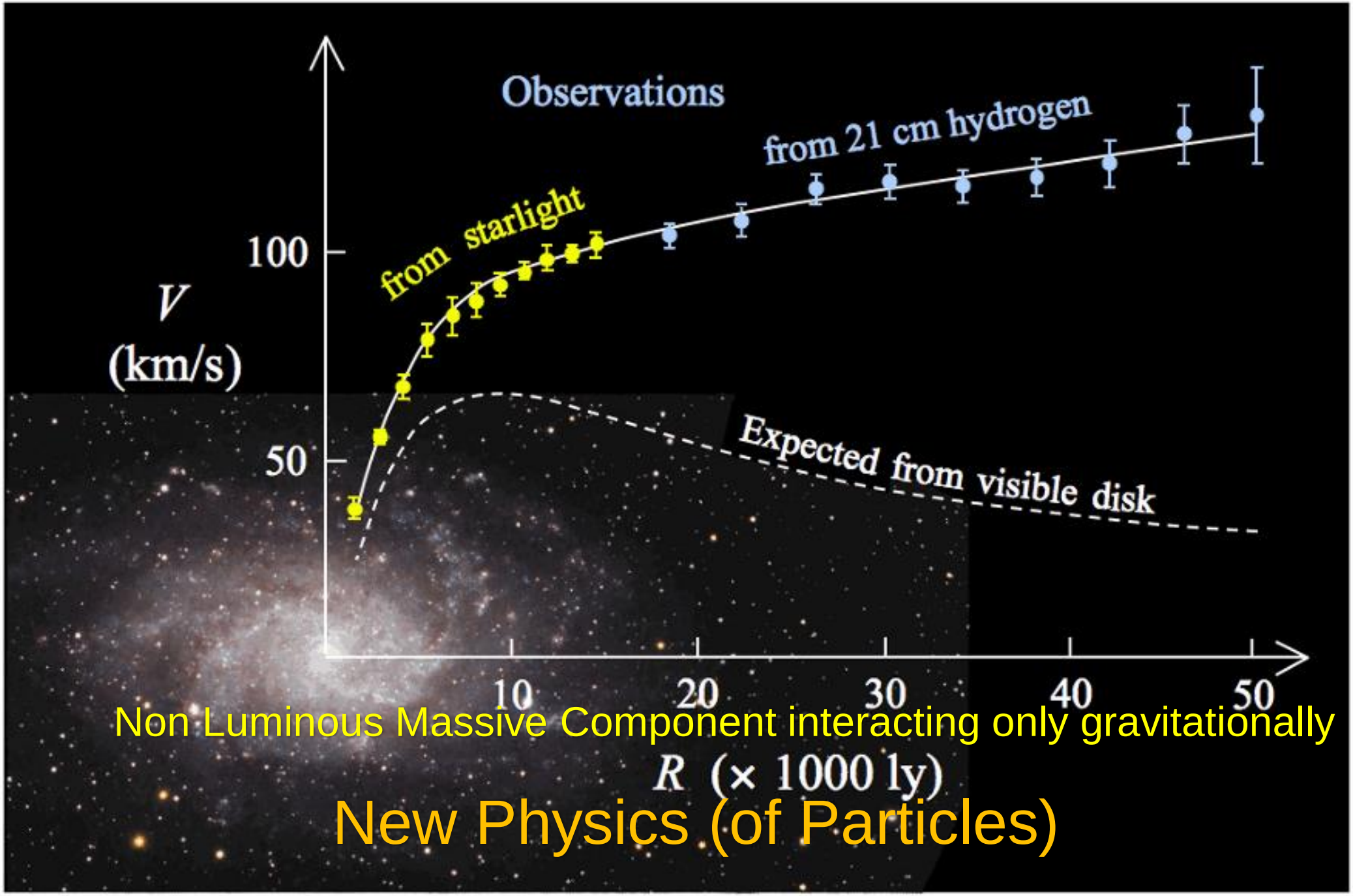
PAOLO SALUCCI

SISSA, INFN

IARD 2020 (online) 1-4 June 2020

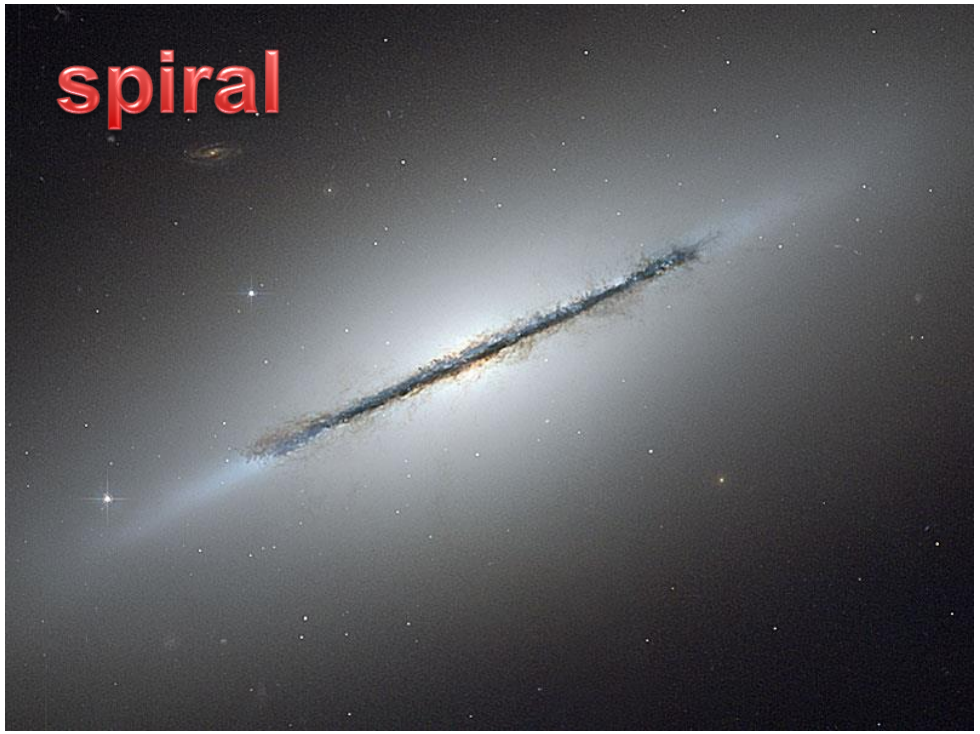
One belief
Dark particle .DM is not a New Gravity Law

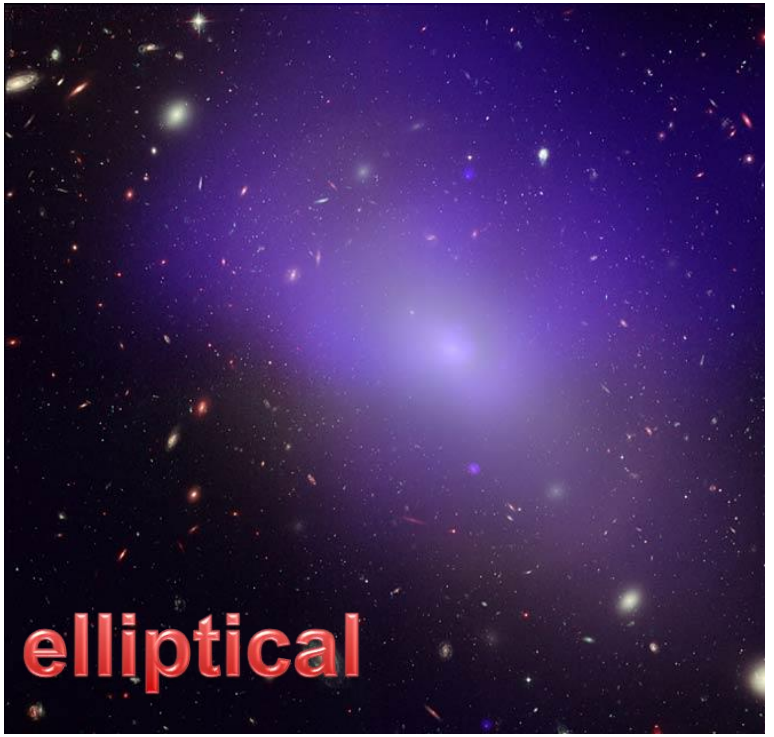




Non Luminous Massive Component interacting only gravitationally

New Physics (of Particles)





Size of stellar component

Stellar Disks

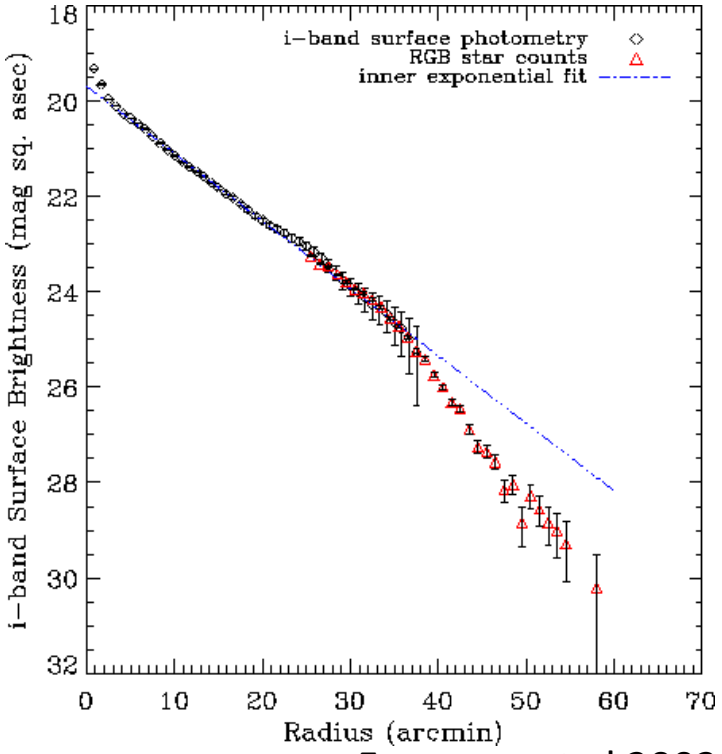
M33 disk very smooth, truncated at 4 scale-lengths

NGC 300 exponential disk for at least 10 scale-lengths

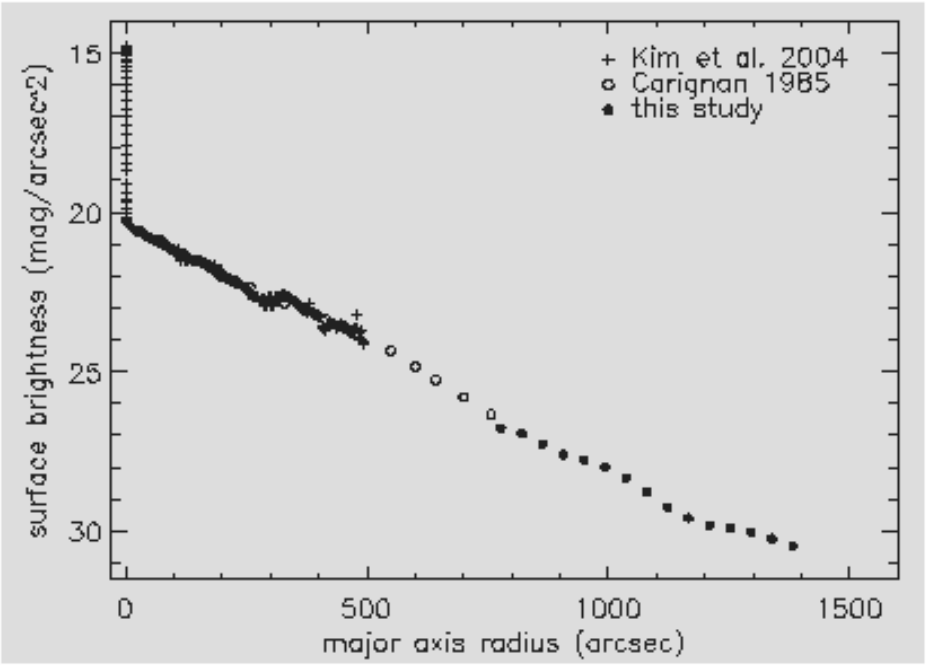
$$I(r) = I_0 e^{-r/R_D}$$

R_D lenght scale of the disk

Freeman, 1970



Ferguson et al 2003

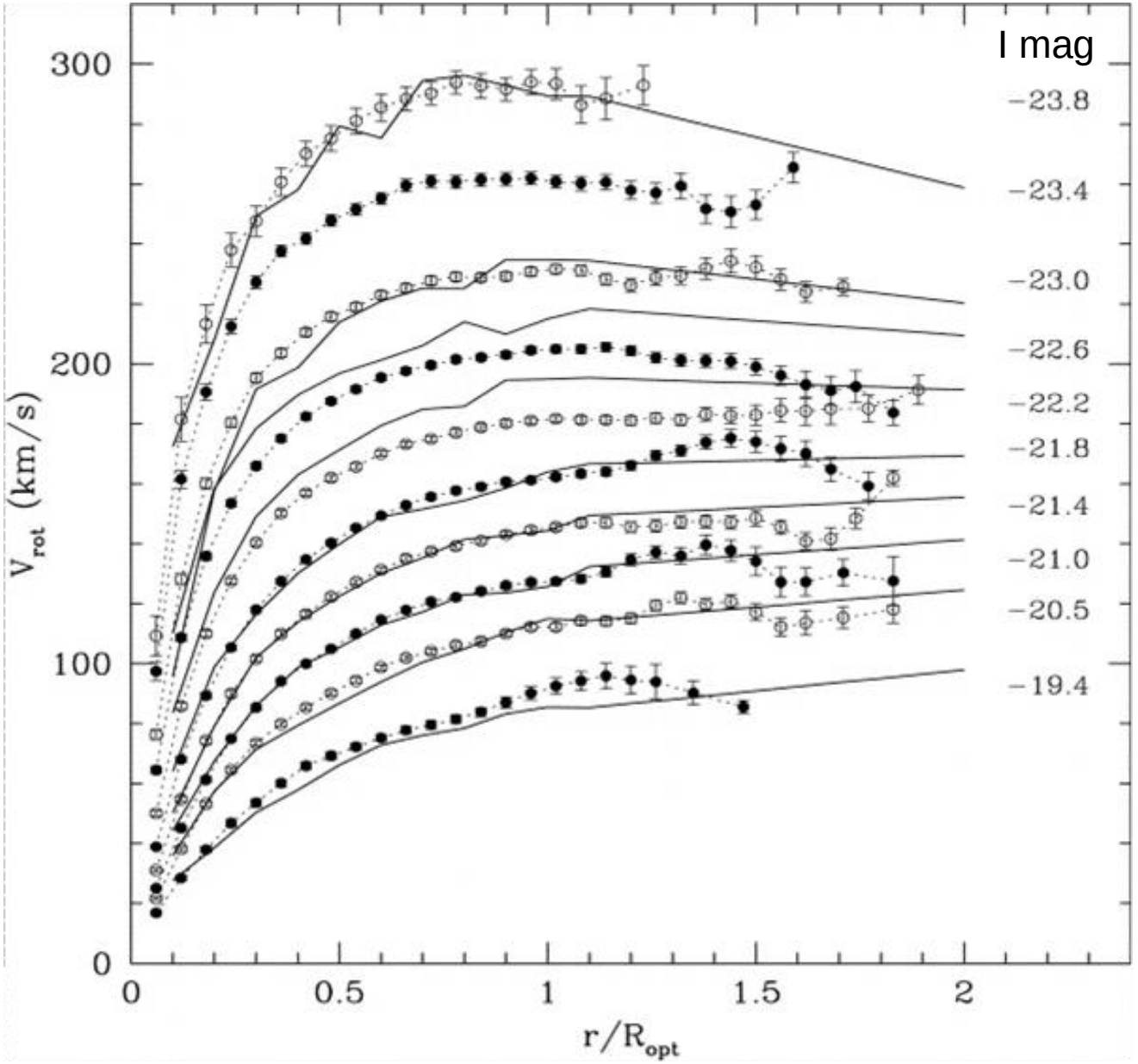


Bland-Hawthorn et al 2005

SPIRALS Rotation Curves

Coadded from 3200 individual RCs

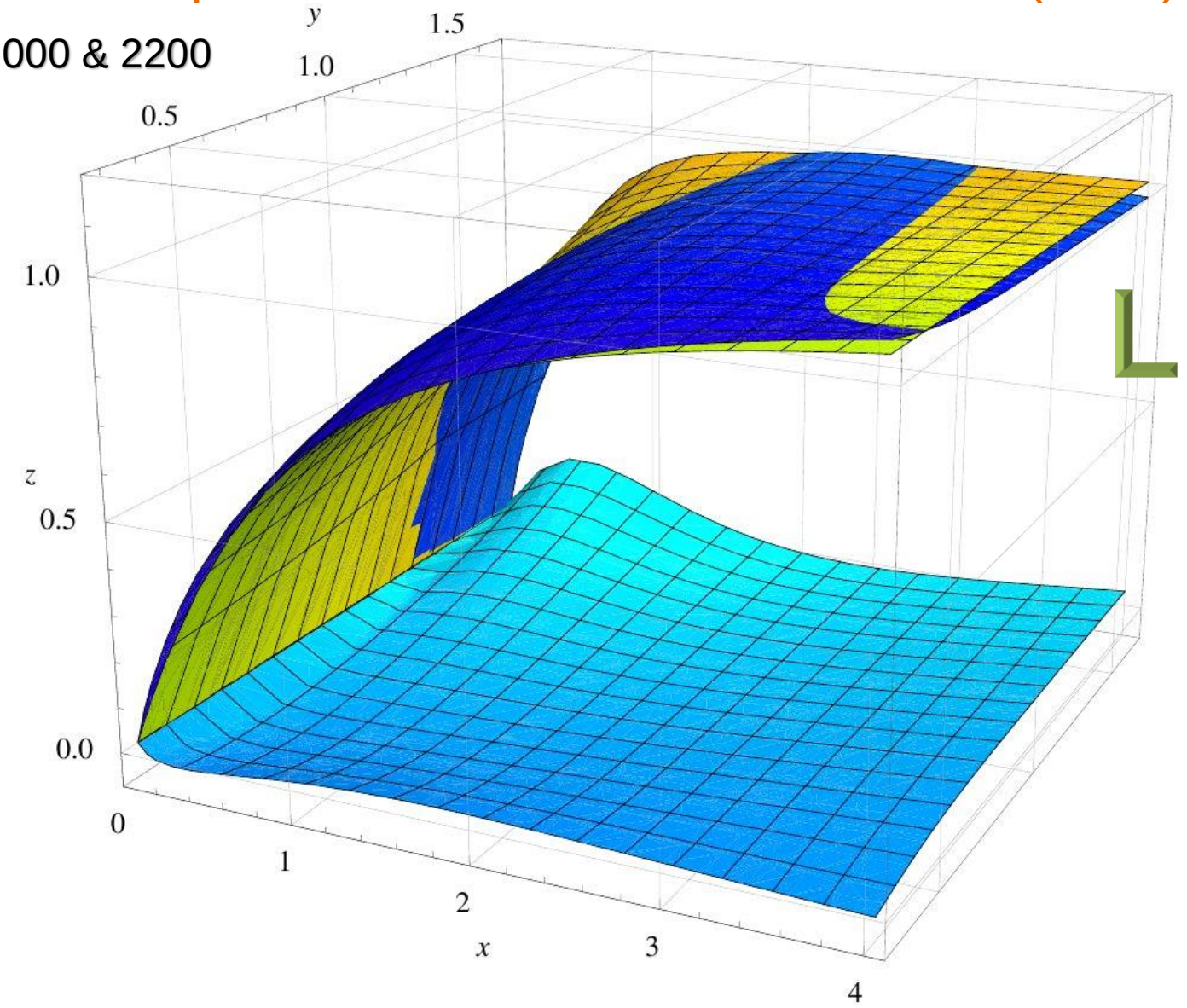
Salucci+07



The Concept of the Universal Rotation Curve (URC)

Two samples 1000 & 2200

V/V_{opt}



L

R/R_D

Density Profiles (N-body simulations almost 10^10 particles)LCDM and collisionless particles

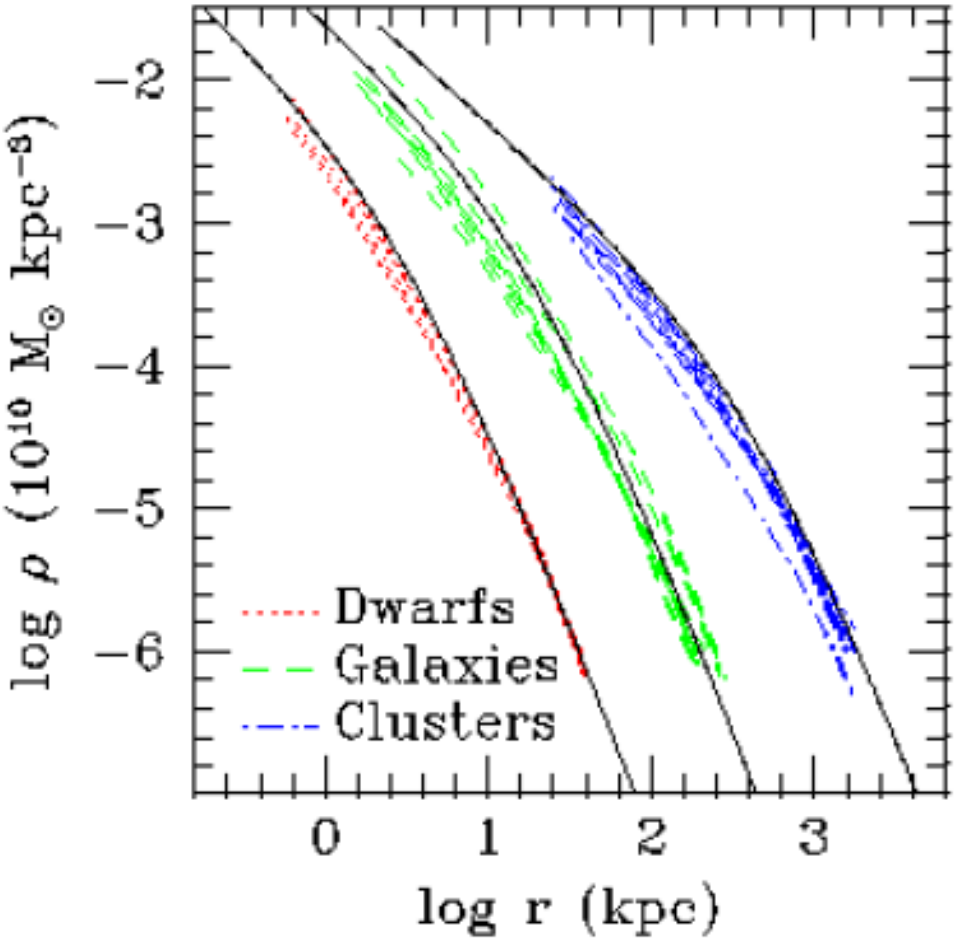
$$\rho_{NFW}(r) = \delta\rho_c \frac{r_s}{r} \frac{1}{(1 + r/r_s)^2}$$

$$c = \frac{R_{vir}}{r_s}$$

$$R_{vir} = 260 \left(\frac{M_{vir}}{10^{12}\ M_\odot} \right)^{1/3} kpc$$

$$c(M_{vir}) = 9.35 \left(\frac{M_{vir}}{10^{12}\ M_\odot} \right)^{-0.09}$$

Klypin, 2010



From first principles neutralino

PHYSICALLY DIFFERENT DM HALOS each from its first principle Empirical profile is to decide among them?

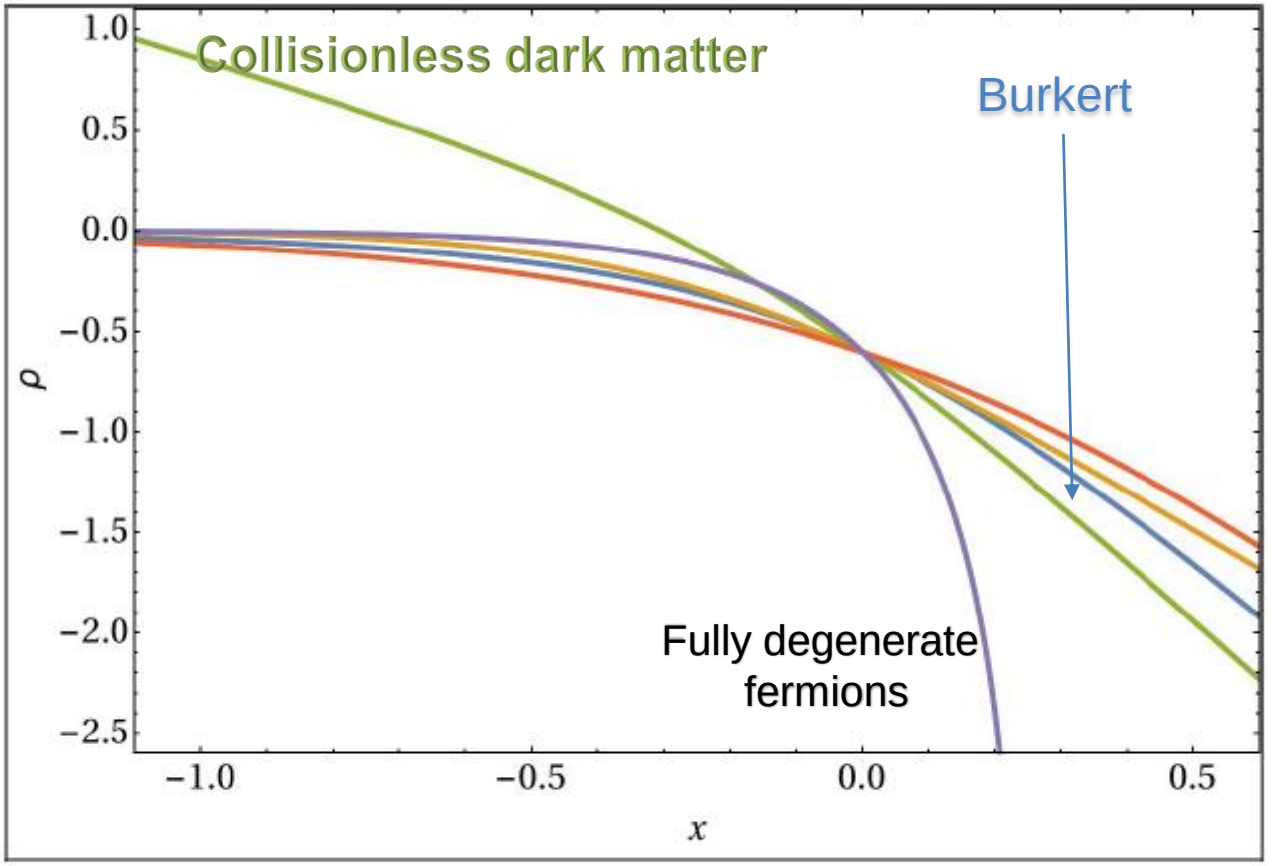


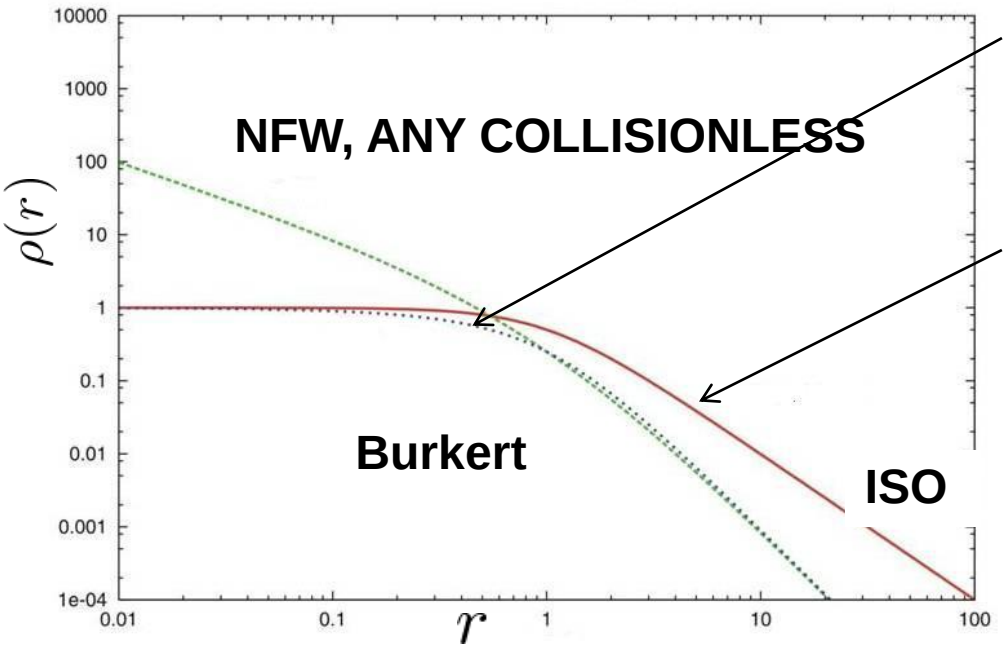
Fig. 7 Density profiles. NFW (red line), Burkert (blu line), fermionic degenerate (violet line), pseudo isothermal: $\rho_{PI}(r) \propto (r^2 + a^2)^{-1}$ with a the core radius (green line).

Rotation curve analysis

$$V^2(R) = V^2_{halo}(R) + V^2_{HI}(R) + V^2_{disk}(R) \text{ + dP/dR}$$

observations = model

- V^2_{disk} **from I-band photometry**
- V^2_{HI} **from HI observations**
- V^2_{halo} **1) collisionless dark matter 2) empirical 3) no Newtonian dark matter**

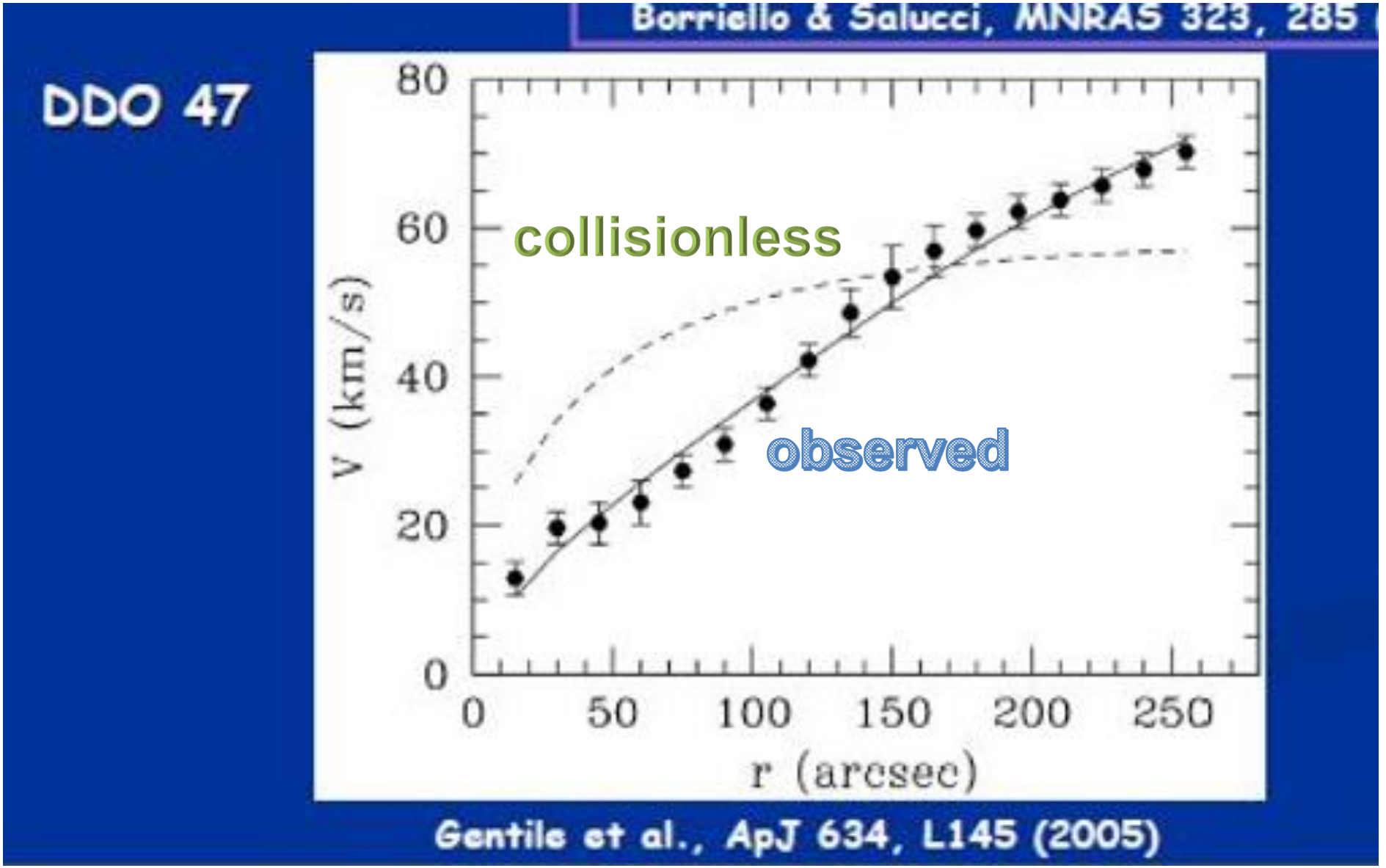


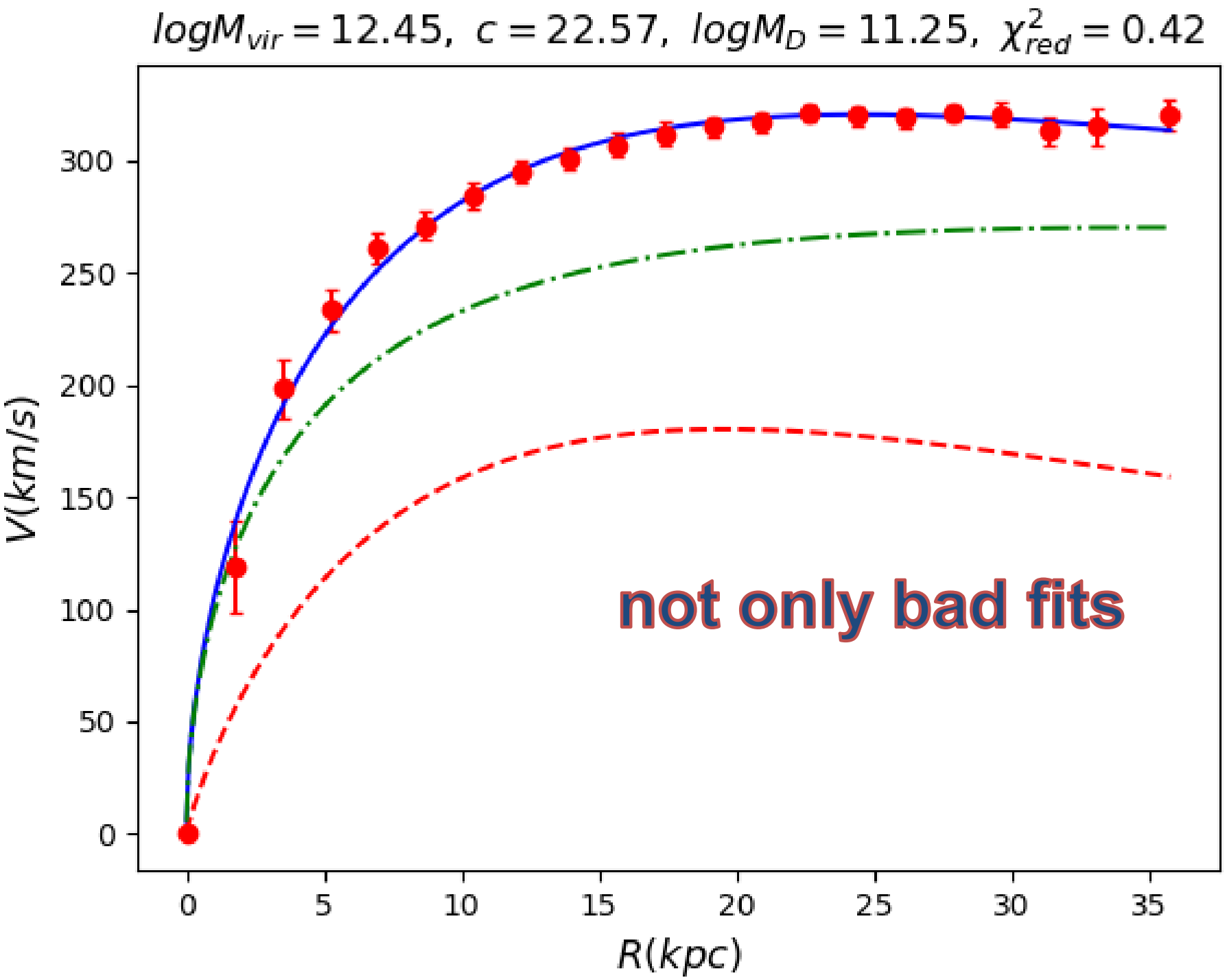
$$\rho(r) = \frac{\rho_0}{(1 + r/r_0)(1 + (r/r_0)^2)}$$

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

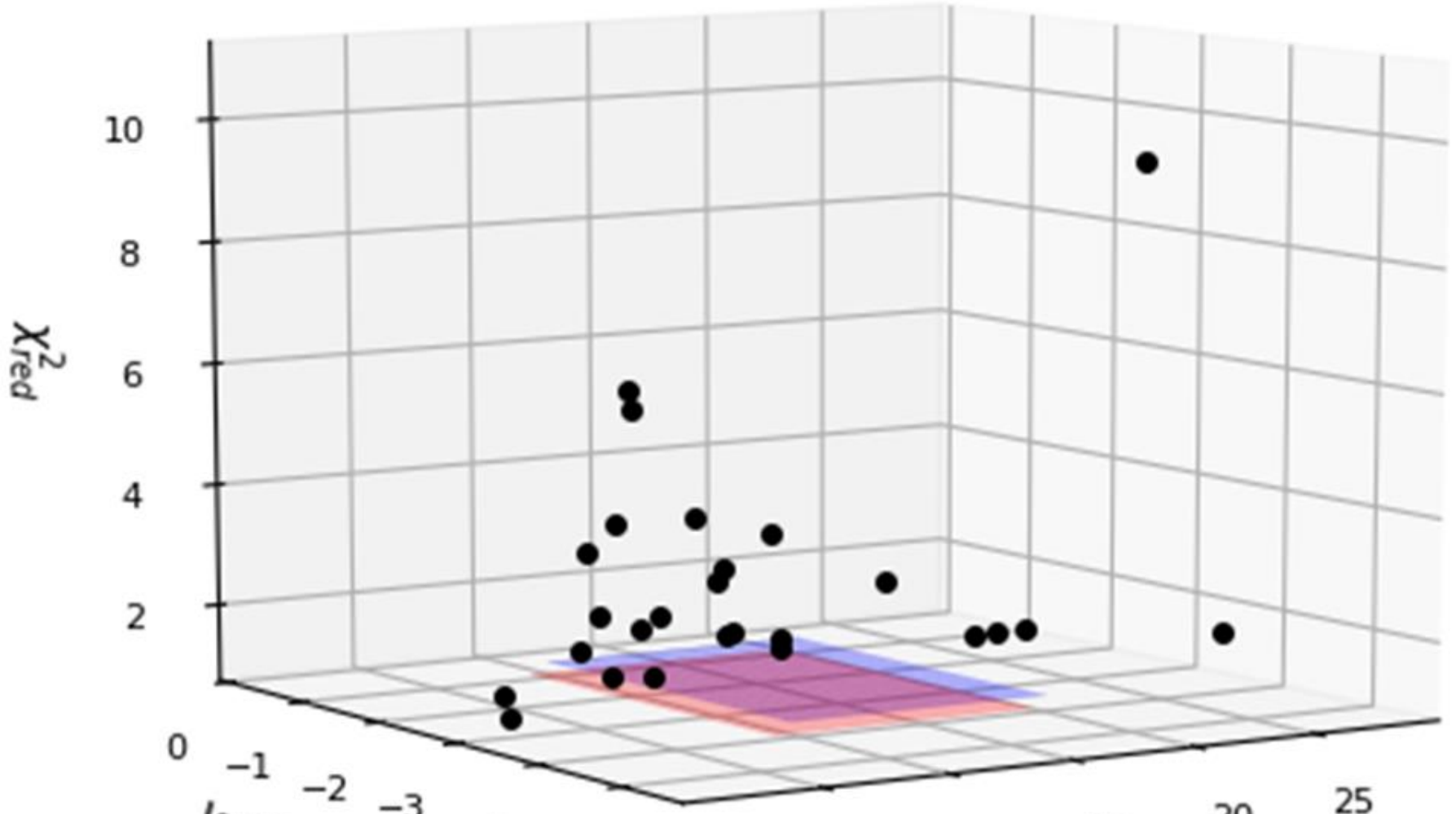
The mass model has 3 free parameters:
disk mass
halo central density
Halo core radius (length-scale)

Core vs. cusp

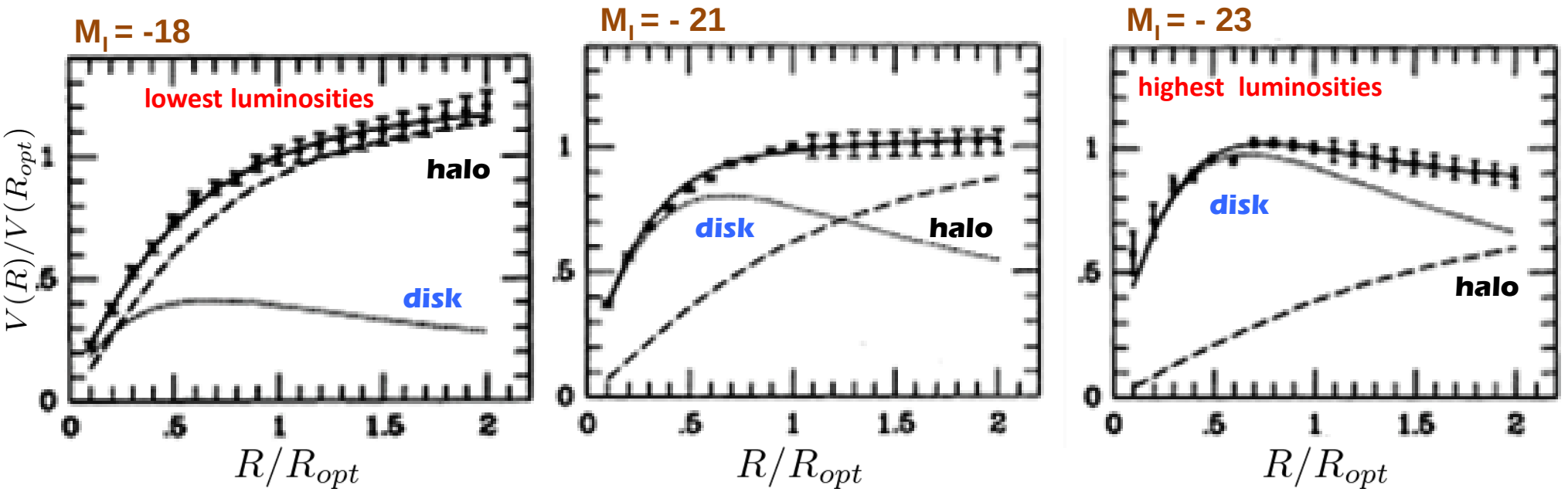

Borriello & Salucci, MNRAS 323, 285
DDO 47
collisionless
observed
V (km/s)
r (arcsec)
0
20
40
60
80
0
50
100
150
200
250
Gentile et al., ApJ 634, L145 (2005)


$logM_{vir} = 12.45,\ c = 22.57,\ logM_D = 11.25,\ \chi^2_{red} = 0.42$
$V(km/s)$
$R(kpc)$
0
50
100
150
200
250
300
0
5
10
15
20
25
30
35
not only bad fits

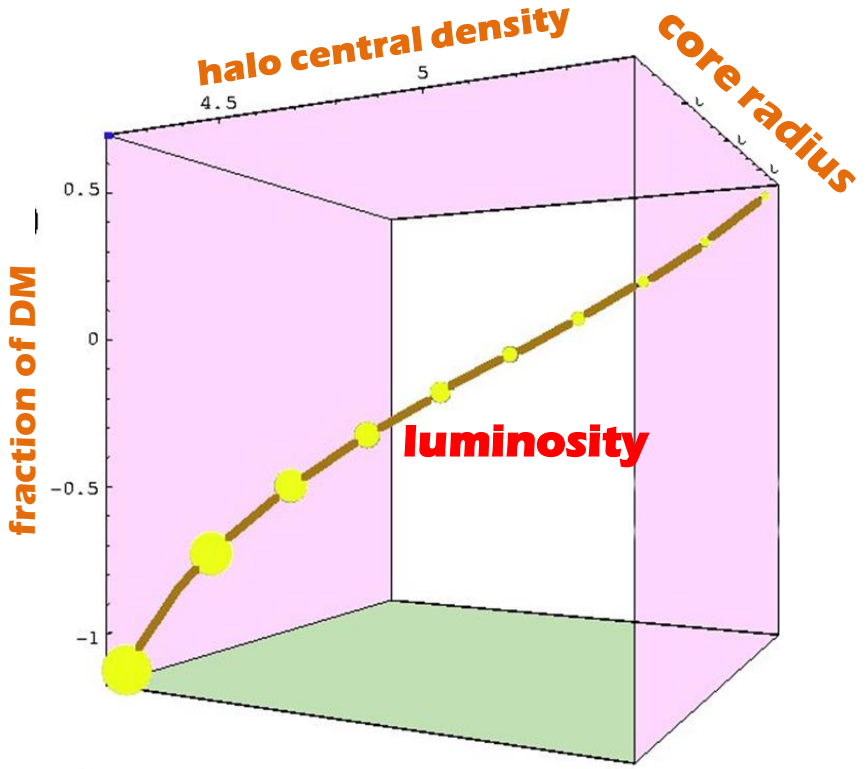
NFW modeling disc systems 26 coadded RCs from 3100



MASS MODELLING RESULTS

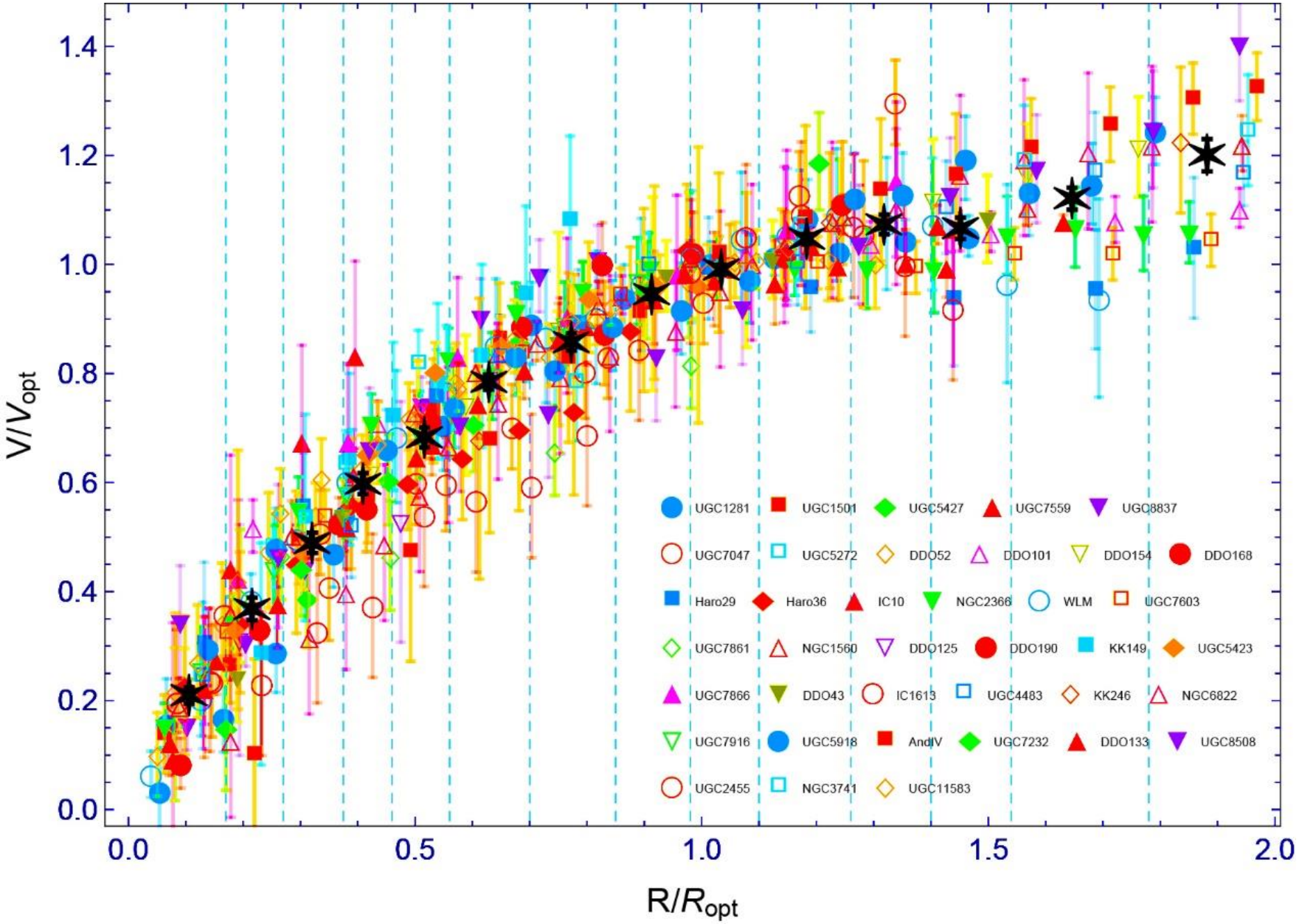


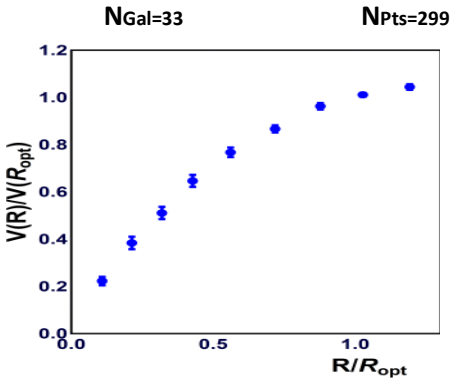
All structural DM and LM parameters are related

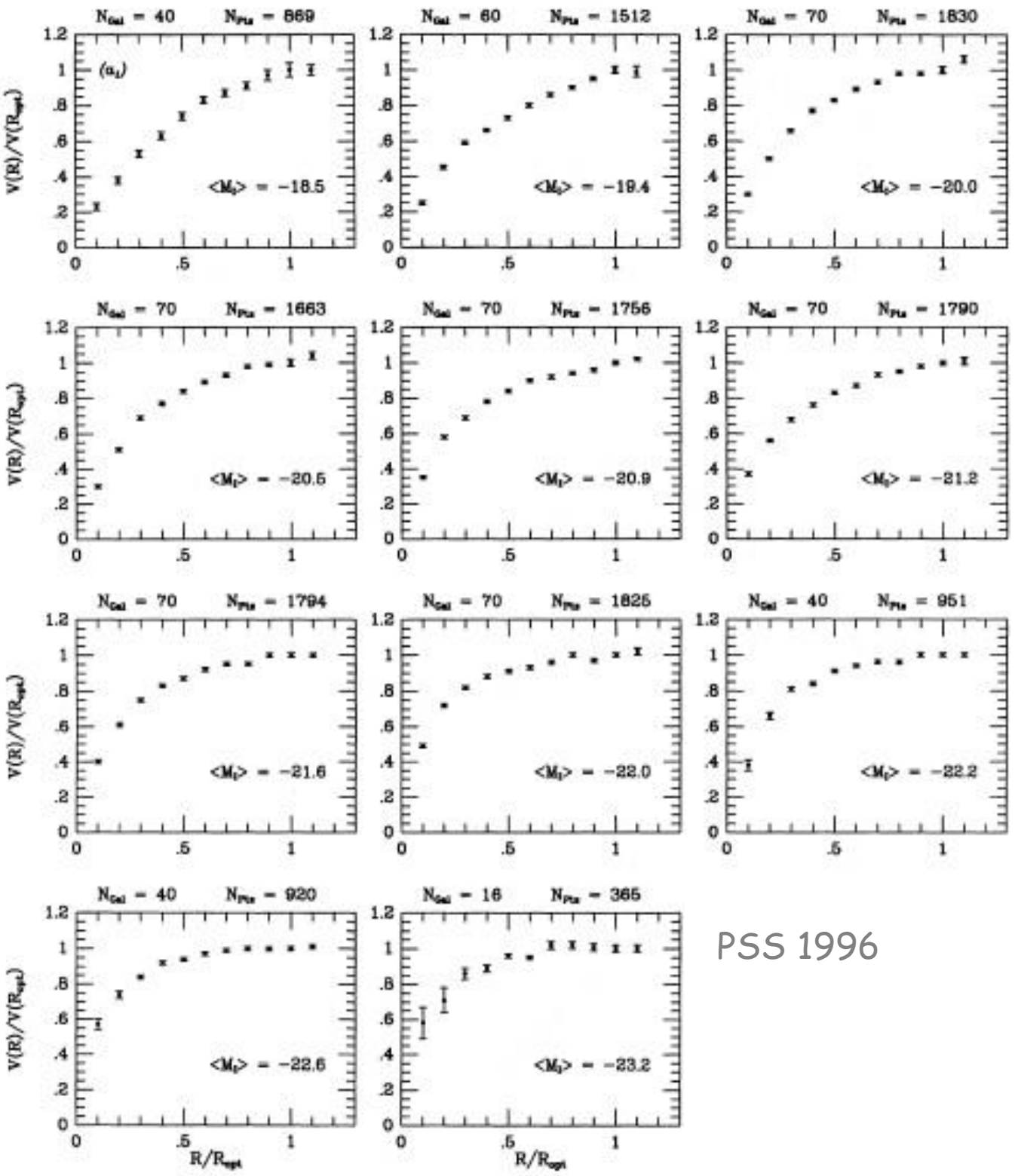


Dwarf irregular disks: minispirals. Completely DM dominated.

Universal Rotation Curve of Dwarfs

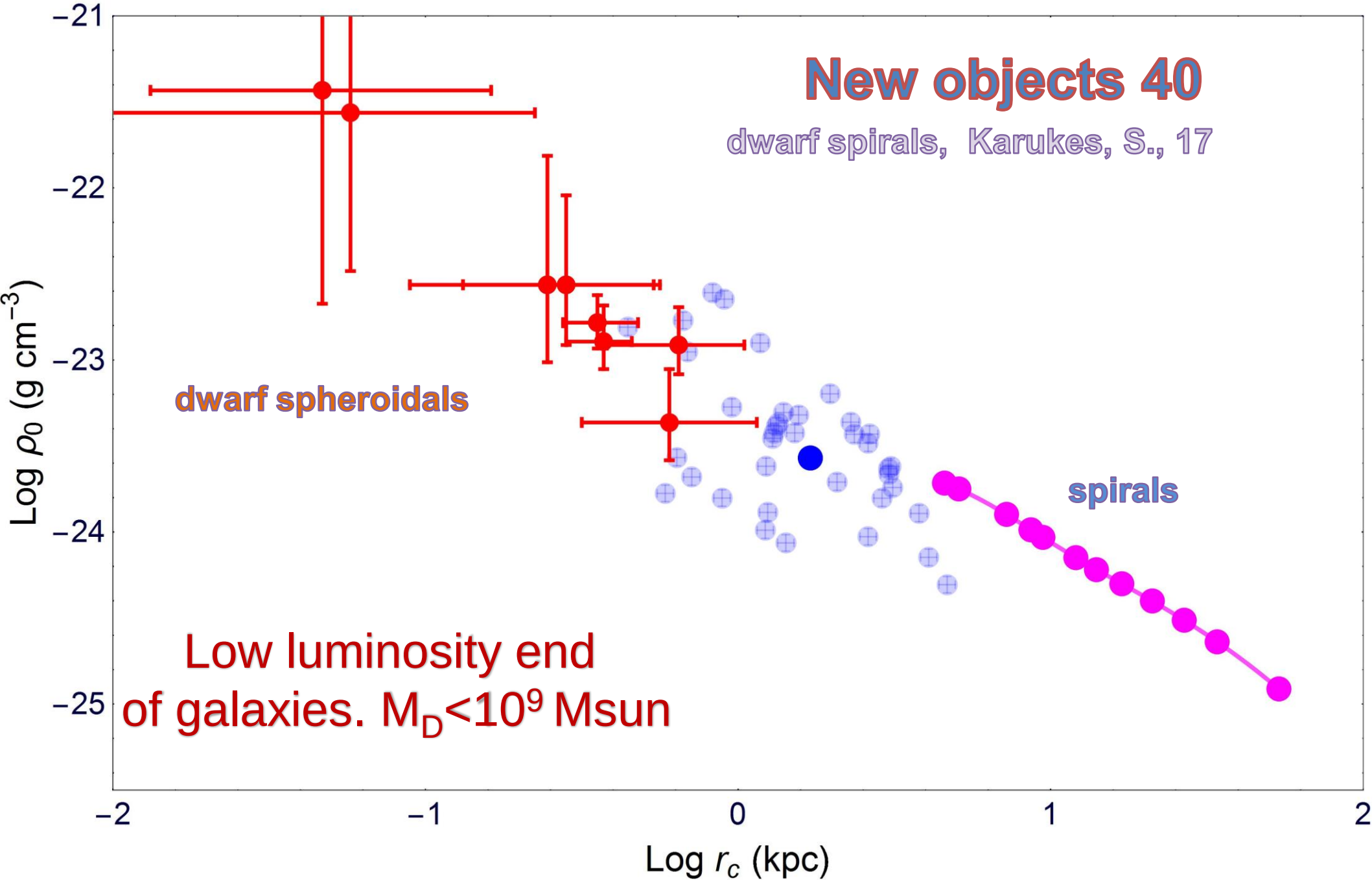






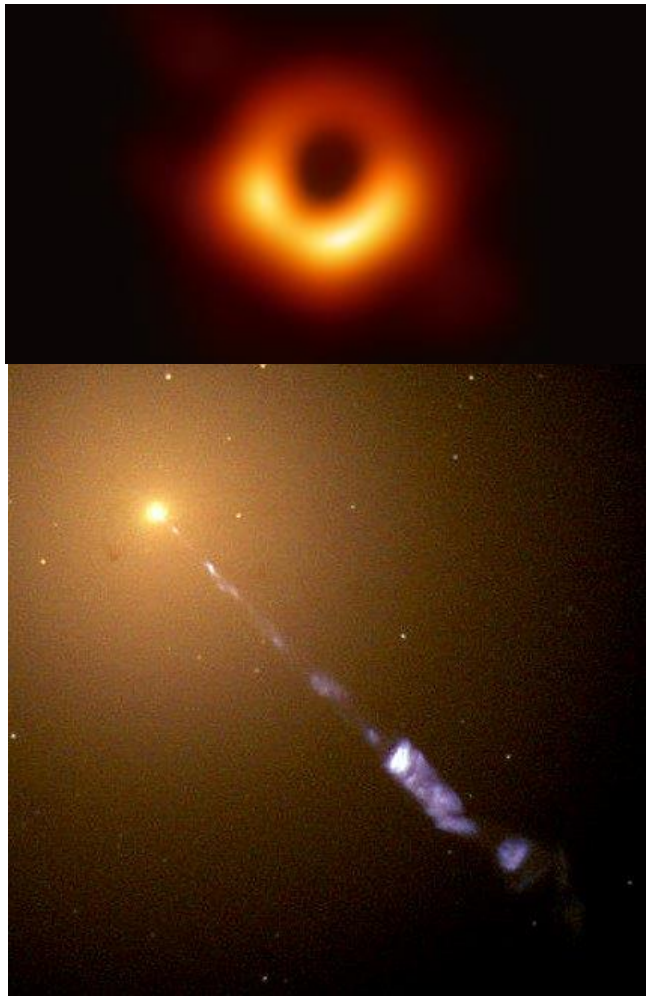
PSS 1996

Disk Dwarf Galaxies

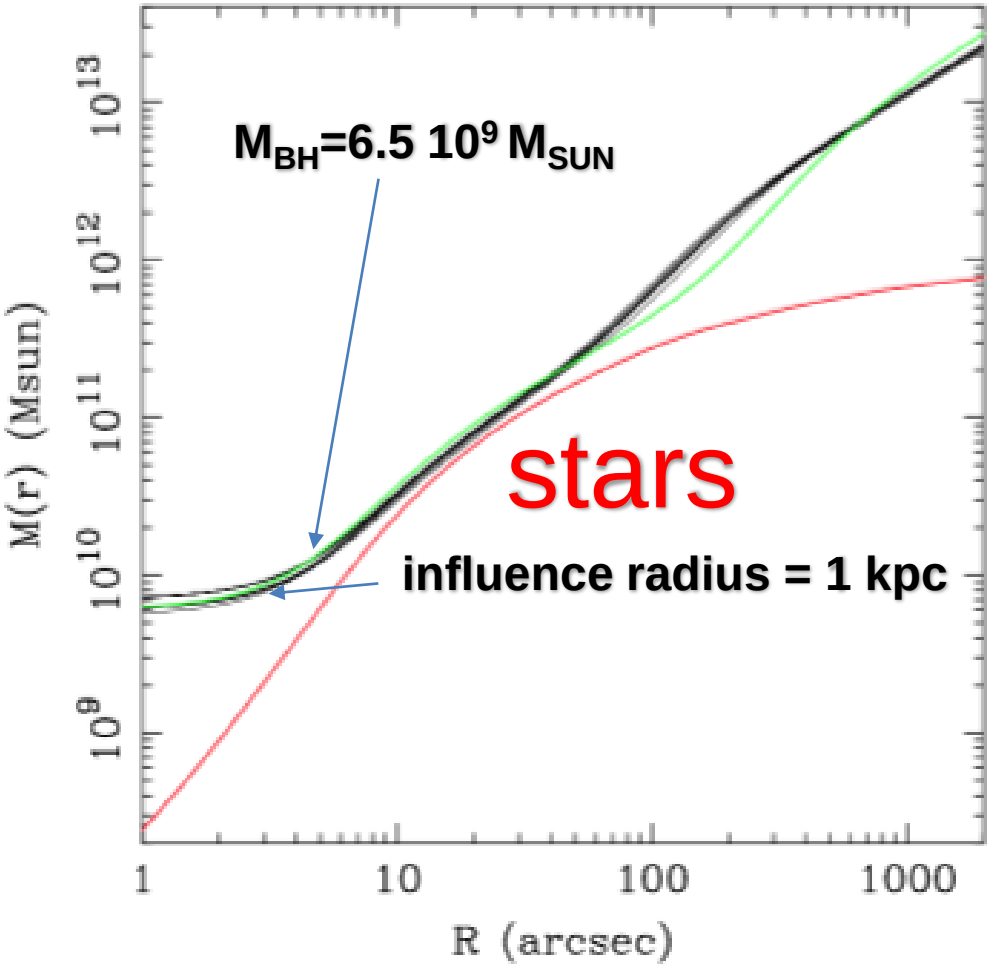

New objects 40
dwarf spirals, Karukes, S., 17
dwarf spheroidals
spirals
Low luminosity end
of galaxies. $M_D<10^9$ Msun
Log ρ_0 (g cm^{-3})
Log r_c (kpc)
−21
−22
−23
−24
−25
−2
−1
0
1
2

M87

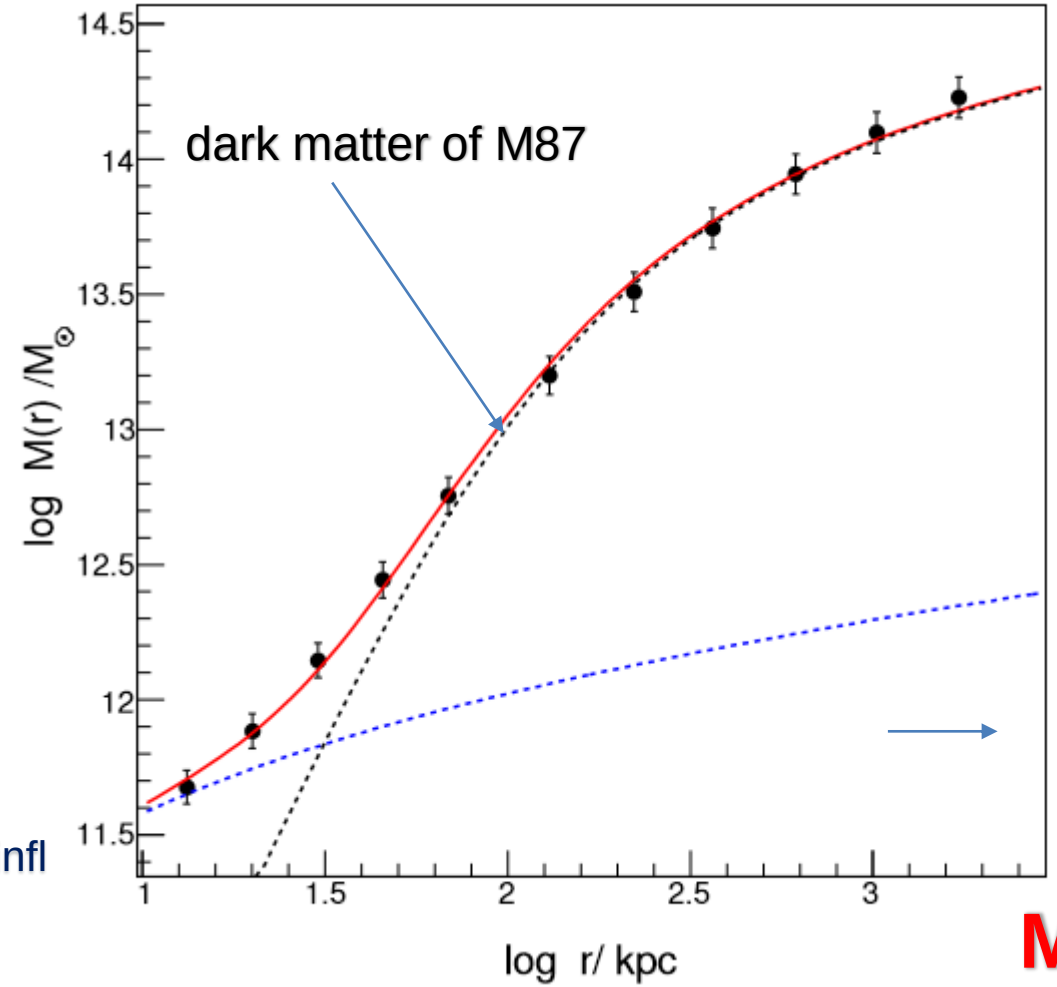
Million times bigger the Smallest dwarf



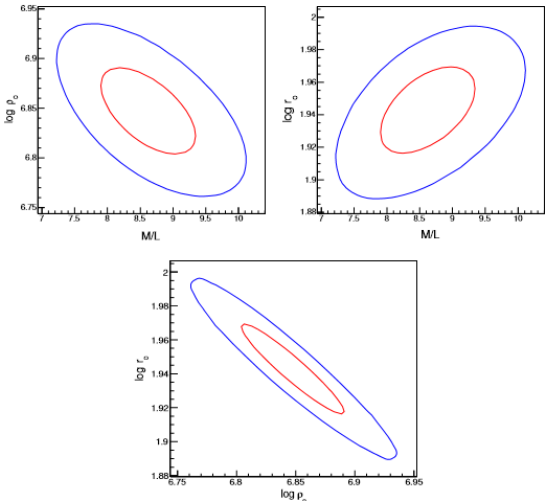
$$\rho = \gamma_v + M_{BH}\delta(r)$$



The Mass Model of M87



r_{infl}



$r0 = (91.2 \pm 9.0)\ \mathrm{kpc}$

$M_{sph} = (1.3 \pm 0.1) \times 10^{12} M_\odot$

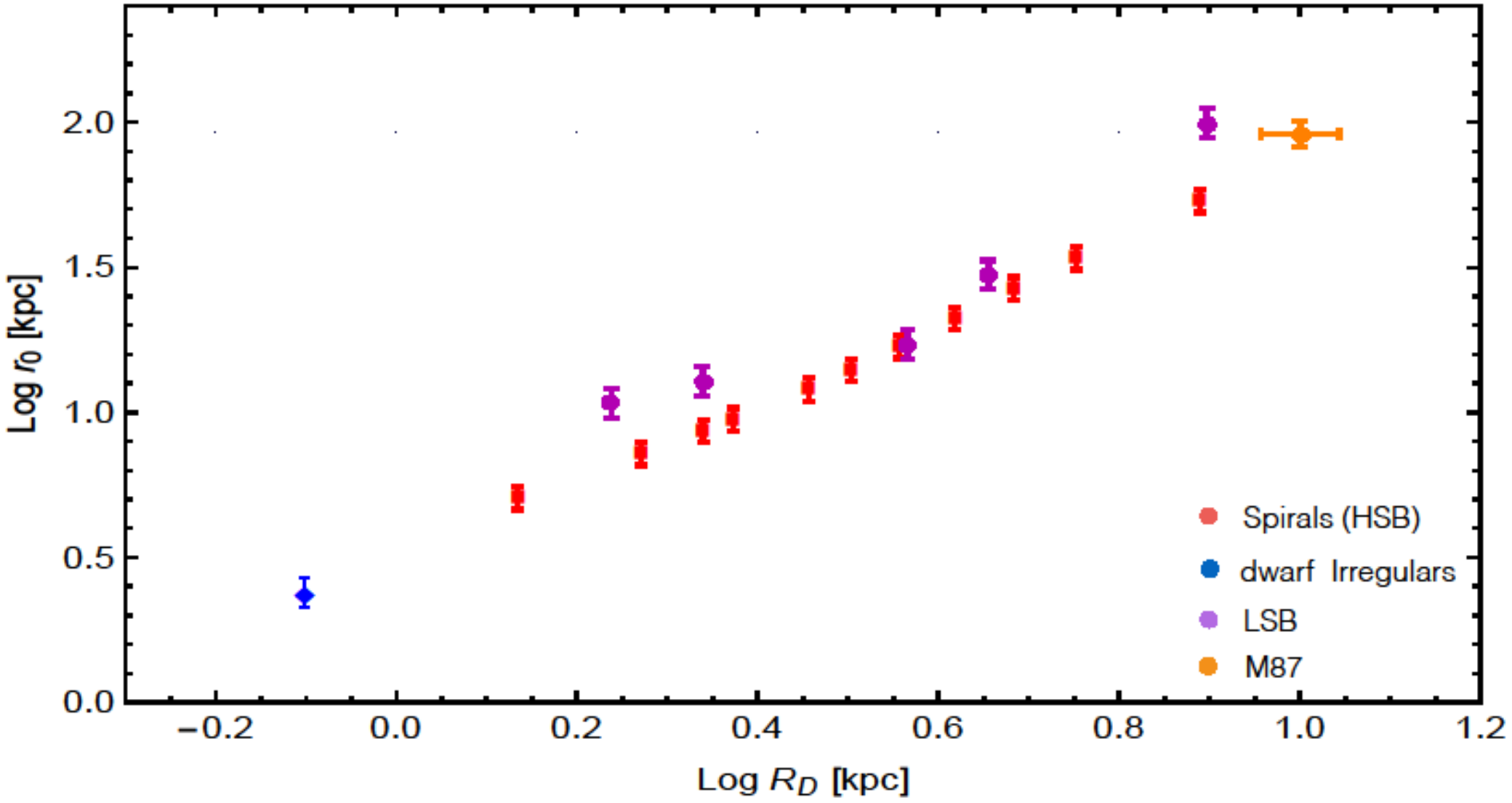
$M/L_V = (8.6 \pm 1.2) M_\odot L_\odot^{-1}.^r$

log Mvir/Msun=14.0

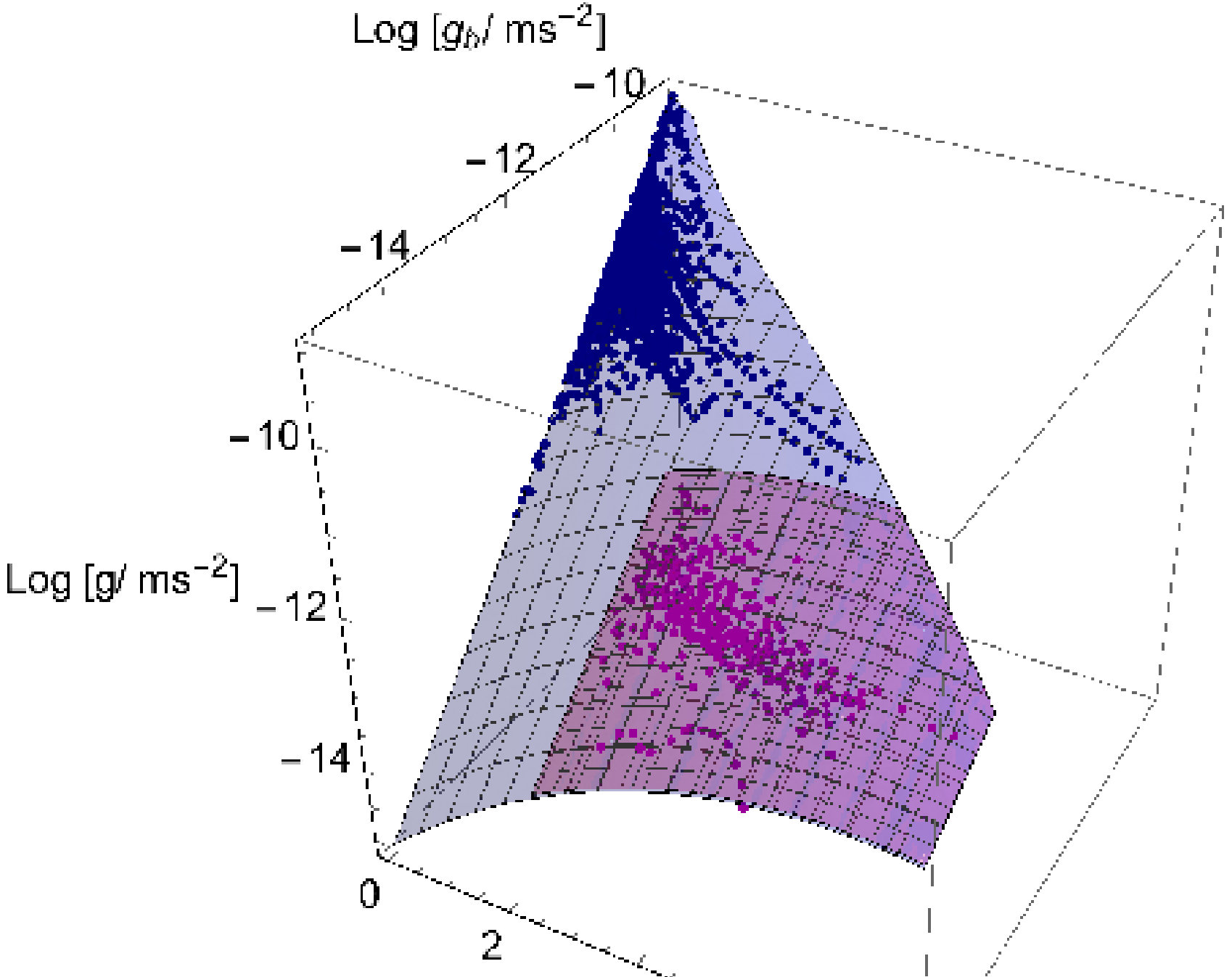
$rho_0 = (6.9 \pm 1.4) \times 10^6 M_\odot / kpc^3$

Strong anomalous Relationships

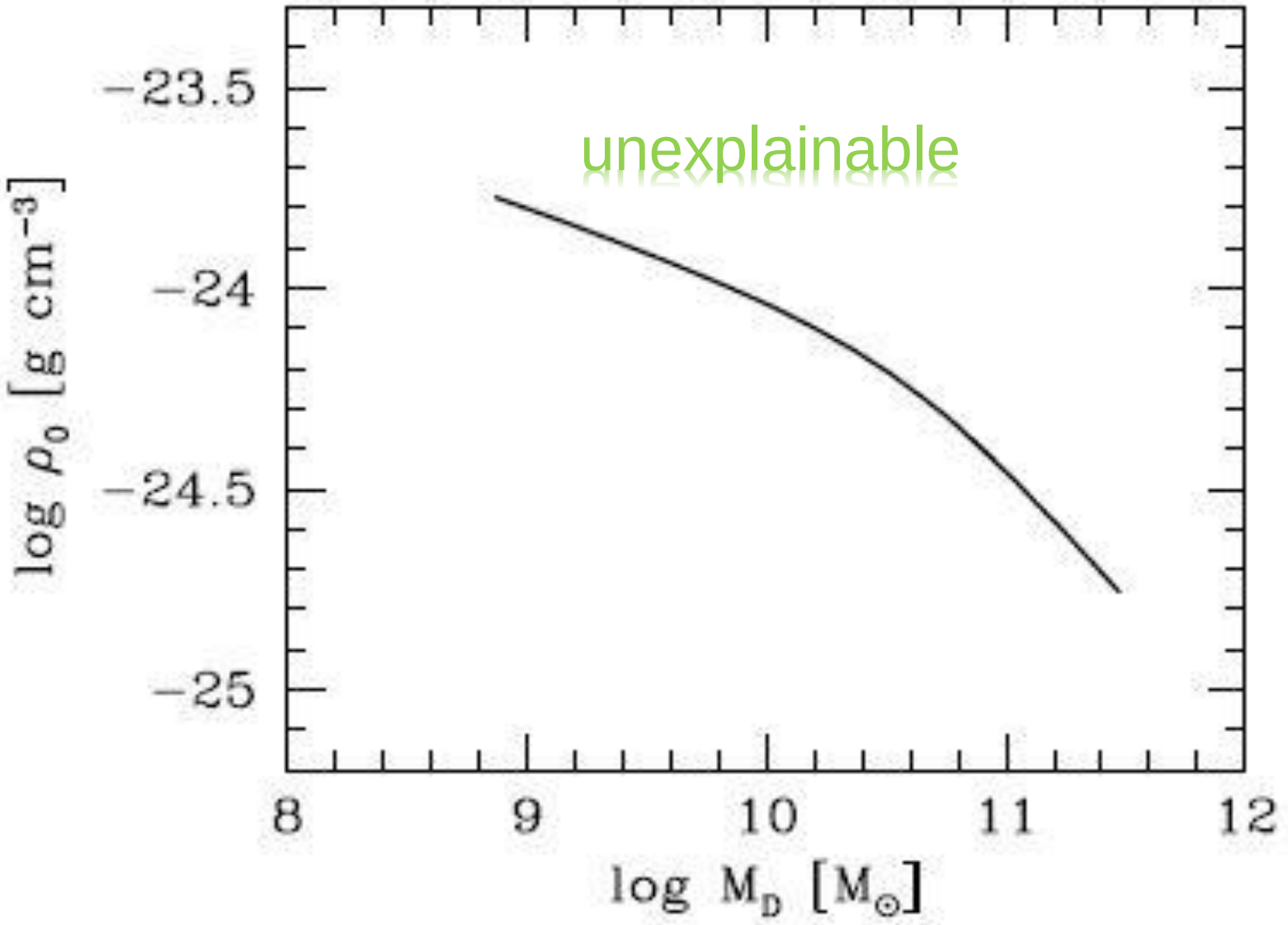
disk vs halo length scales



g/gb/x



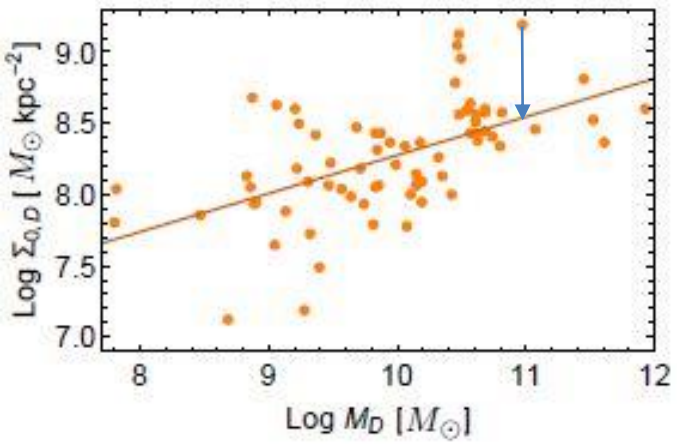
Spirals hybrid relationship



Dark/Luminous interaction 2.0

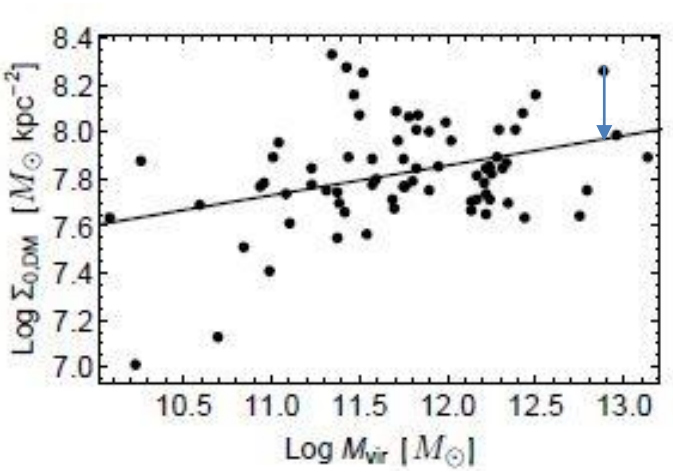
72 low surface brightness Spirals

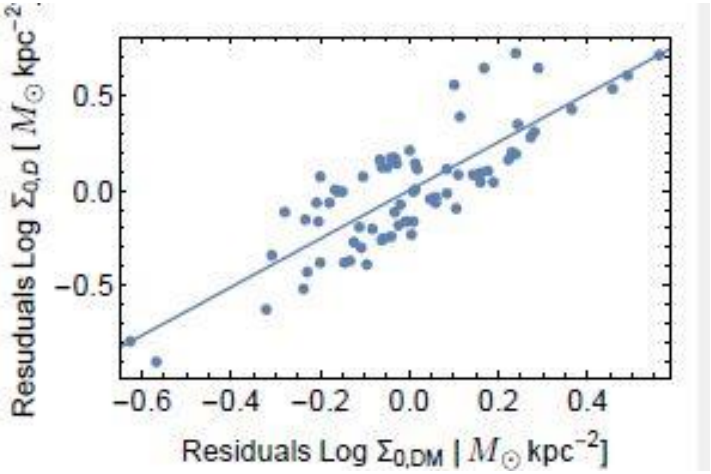
residual lum/lum relation



entral value of the disk surface density vs halo mass

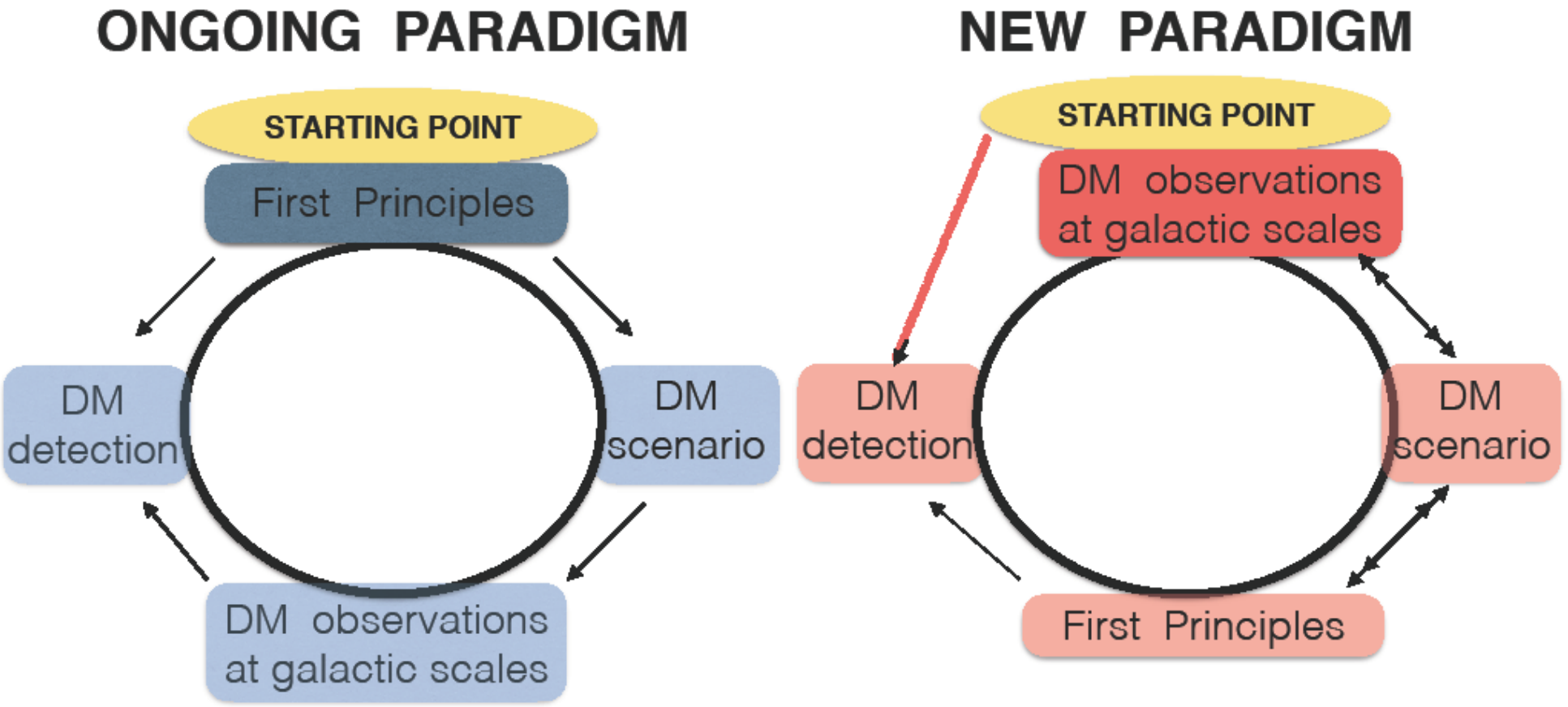
Residual Dark/Dark Relation





central value of the halo surface density vs halo mass

Situation requires more than a change of scenario



unwavering

Current paradigm

We know the Dark Matter Particle from fi rst Principles or from Strongly unwavering beliefs
We can make definite predictions also by means of proper simulations and explain all the properties of the objects of the Universe We can detect the particle, that is the real stuff. All the previous work serves to enliven the long waiting.

FAILURE forces one to take the view that observations or predictions are wrong. Or that a further standard physics phenomenon has occurred.

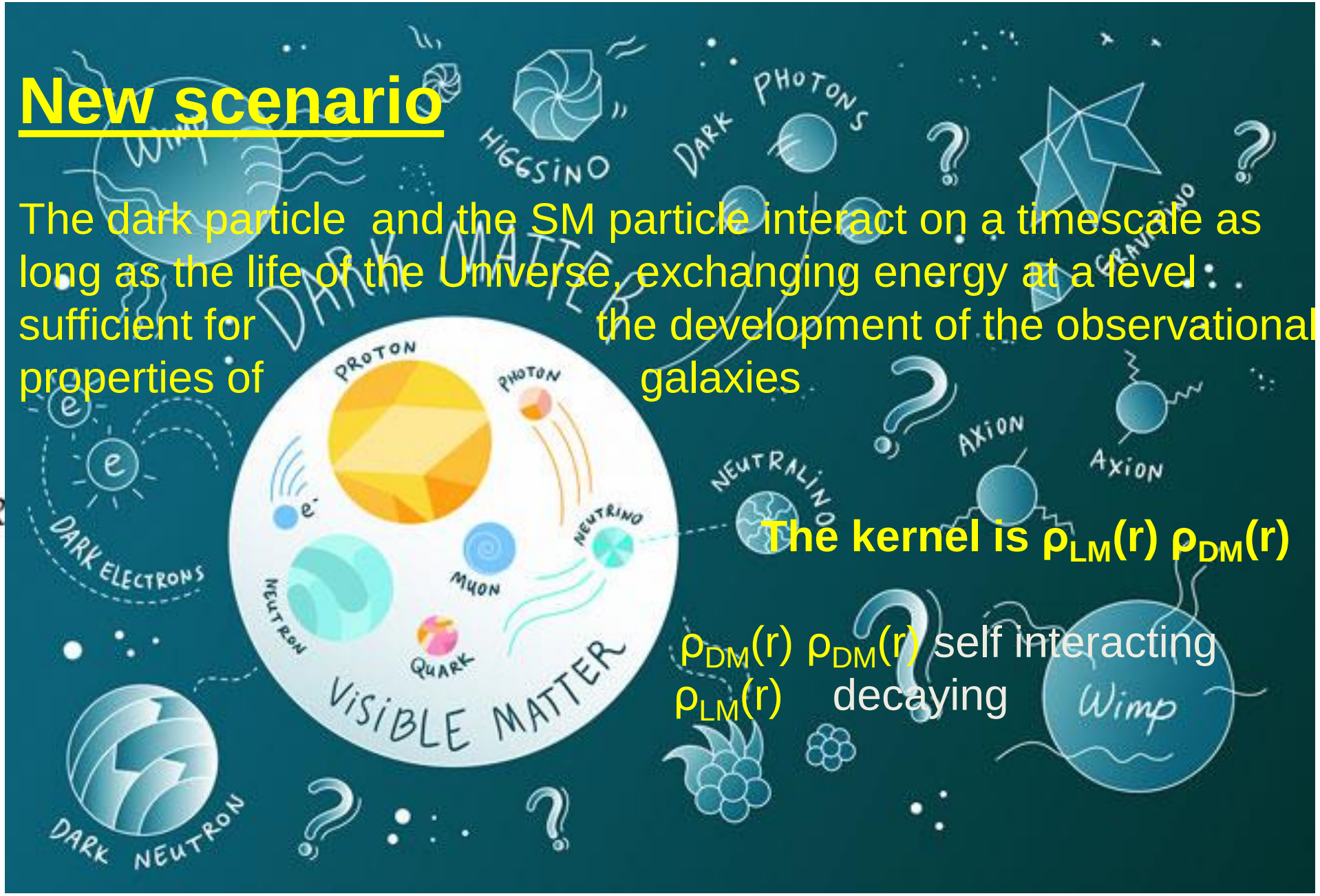
Scenarios WIMPS, AXIONS, WDMs,ULA

New paradigm

No way that we can, at this present time, deduce the nature of the particle from first principles.
On the other hand, the complex, tangled and currently unexplainable properties of distribution of dark and the luminous components in bound systems could lead to the nature of the dark particle otherwise not reacheable

New scenario

The dark particle and the SM particle interact on a timescale as long as the life of the Universe, exchanging energy at a level sufficient for the development of the observational properties of galaxies



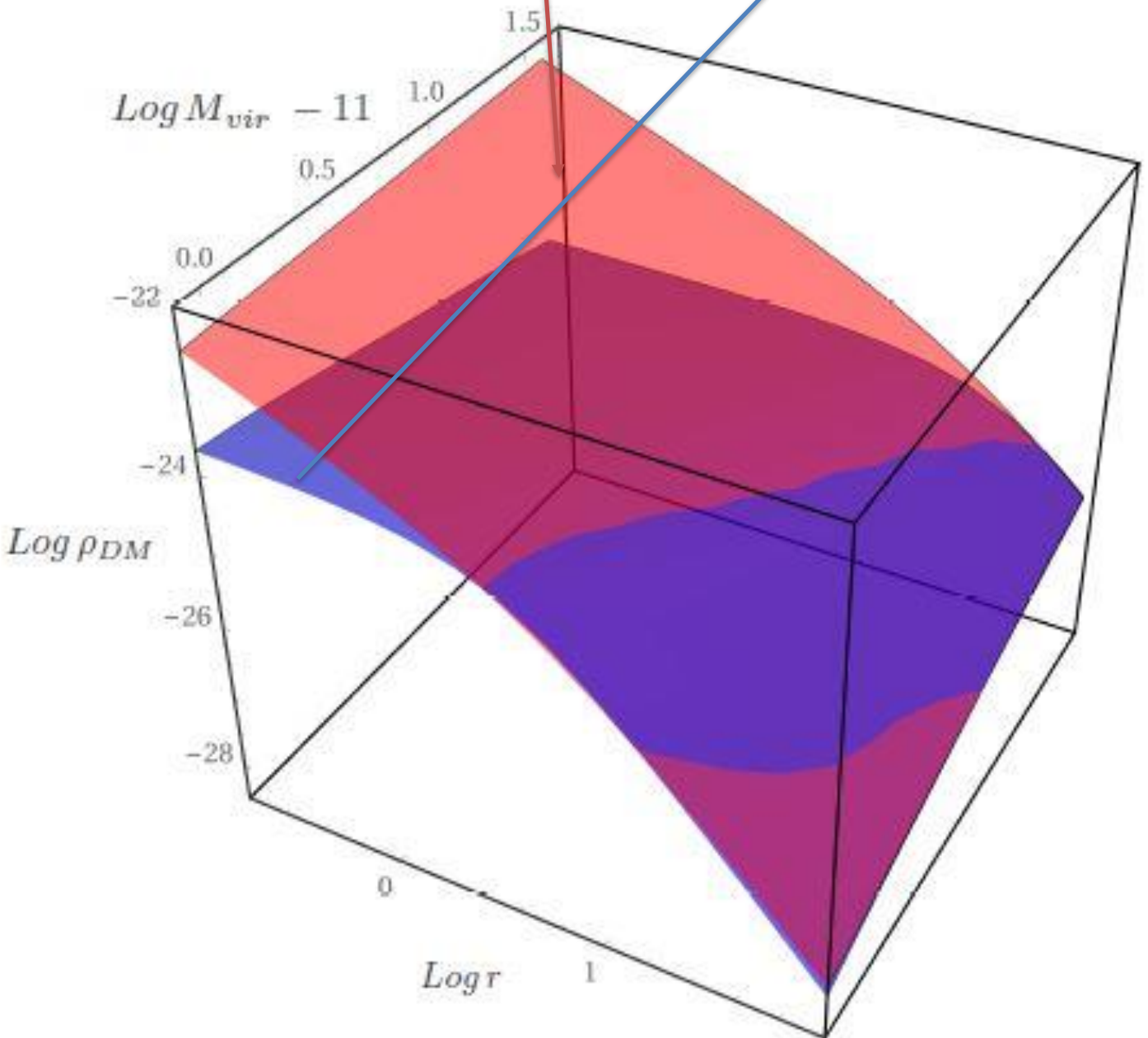
The kernel is $\rho_{LM}(r)\ \rho_{DM}(r)$

$\rho_{DM}(r)\ \rho_{DM}(r)$ self interacting

$\rho_{LM}(r)$ decaying

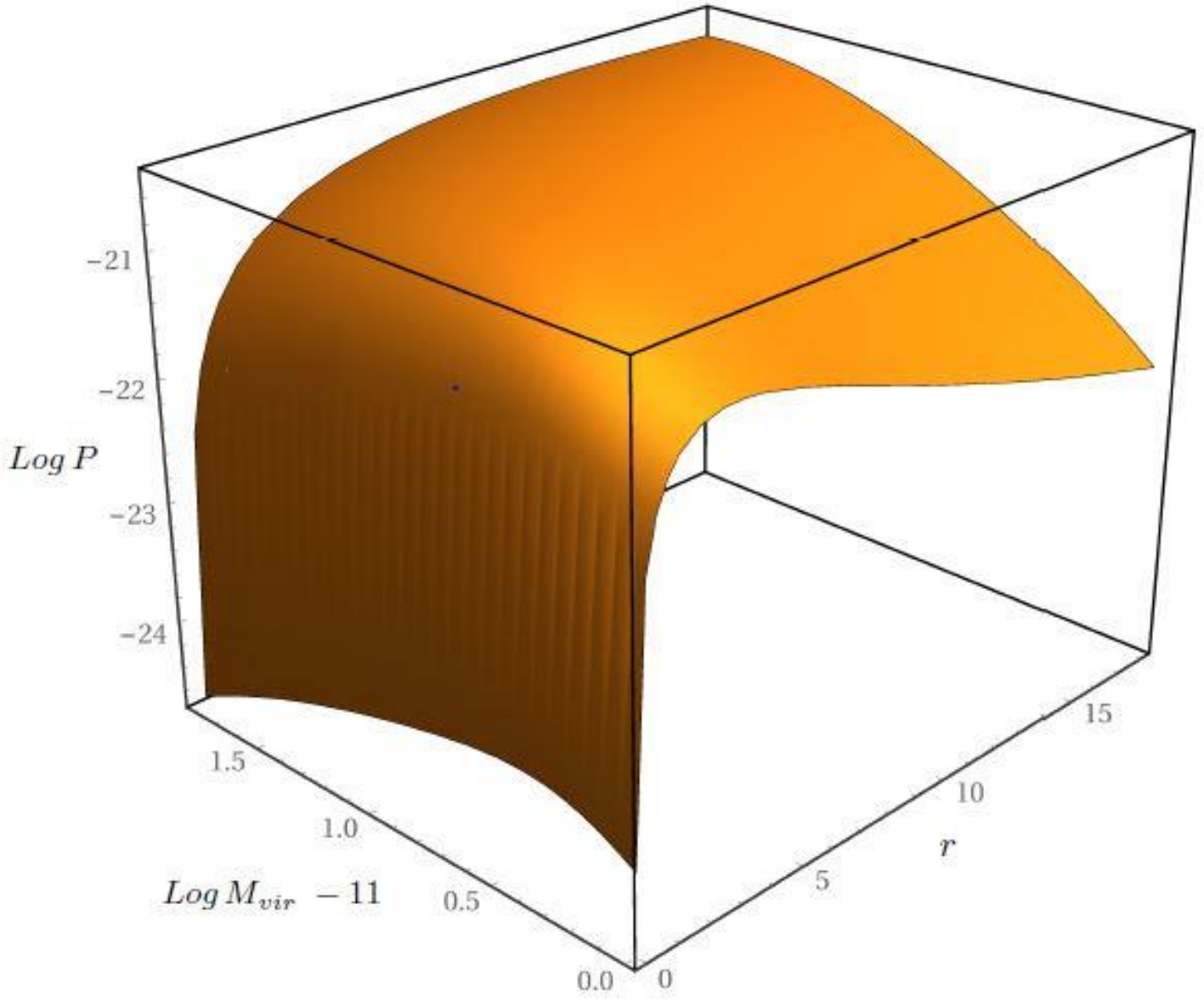
Primordial collisionless halo

Present day halo after collisions

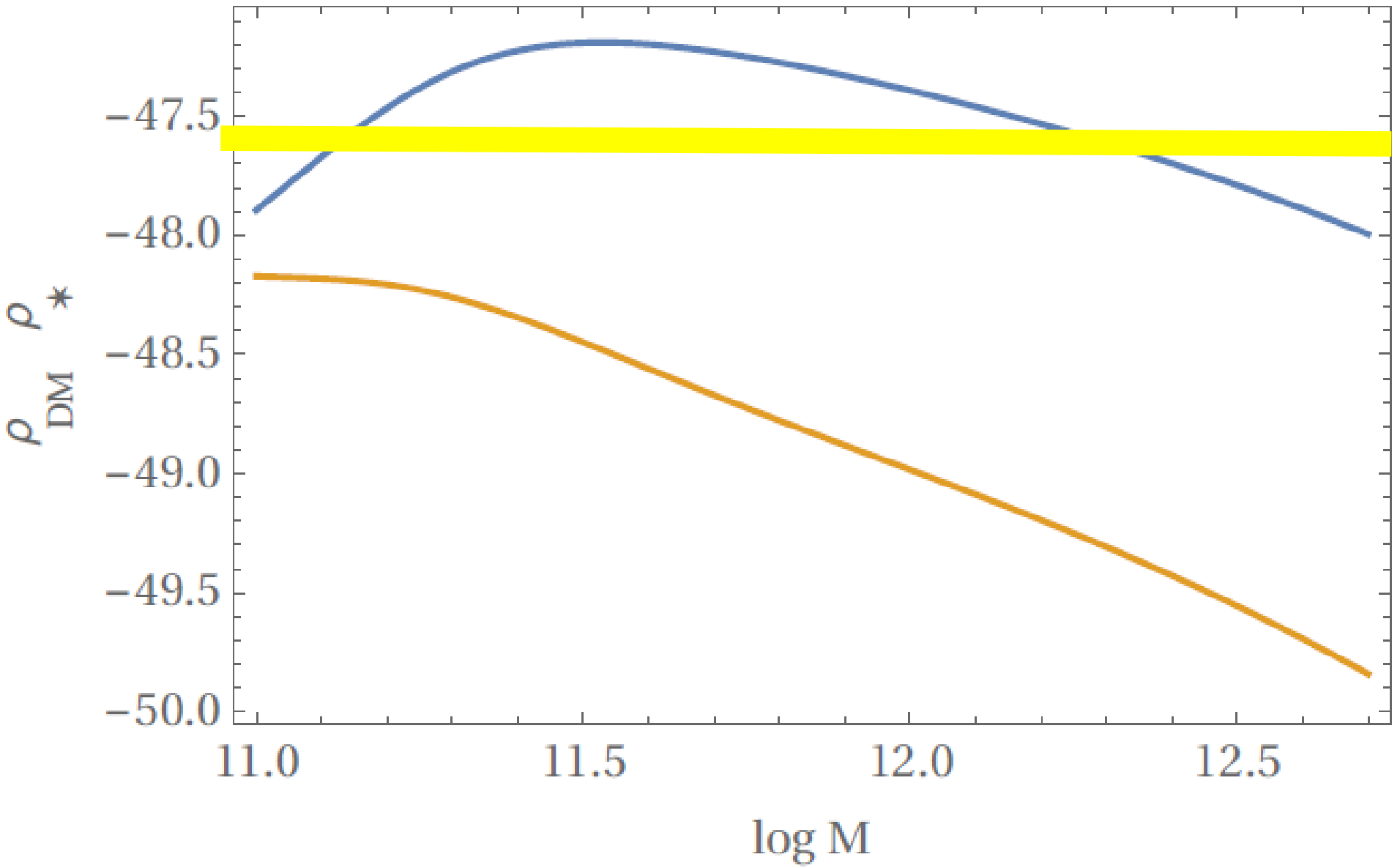


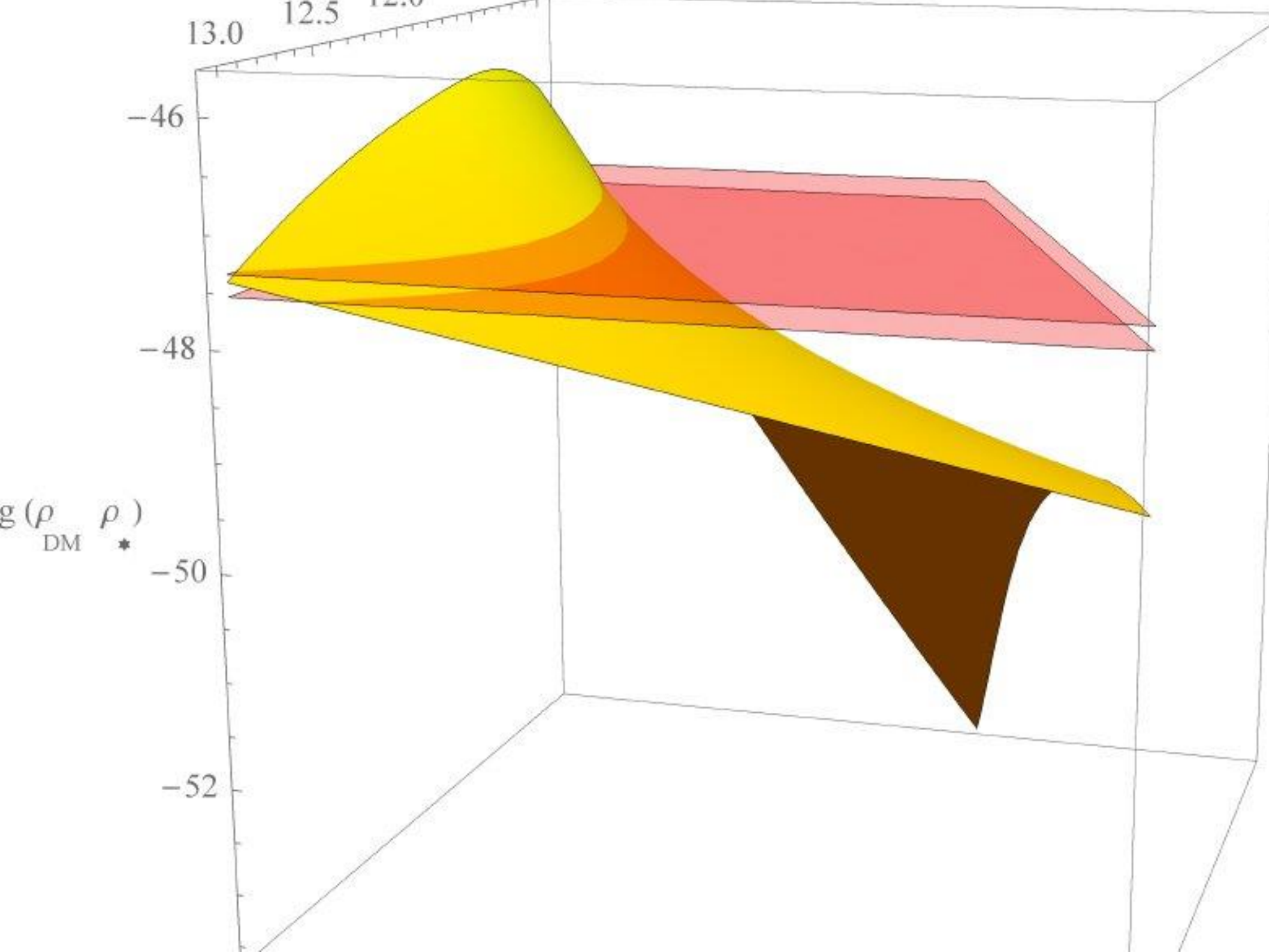
DM pressure is $\rho_{DM}(r)\ V^2(r)$

constant with radius at r_0



Product of DM and LM densities at core radius




13.0
12.5
−46
−48
−50
−52
g (ρ ρ)
DM *

Observational support for the Interacting dark matter Scenario

Following the DM core production

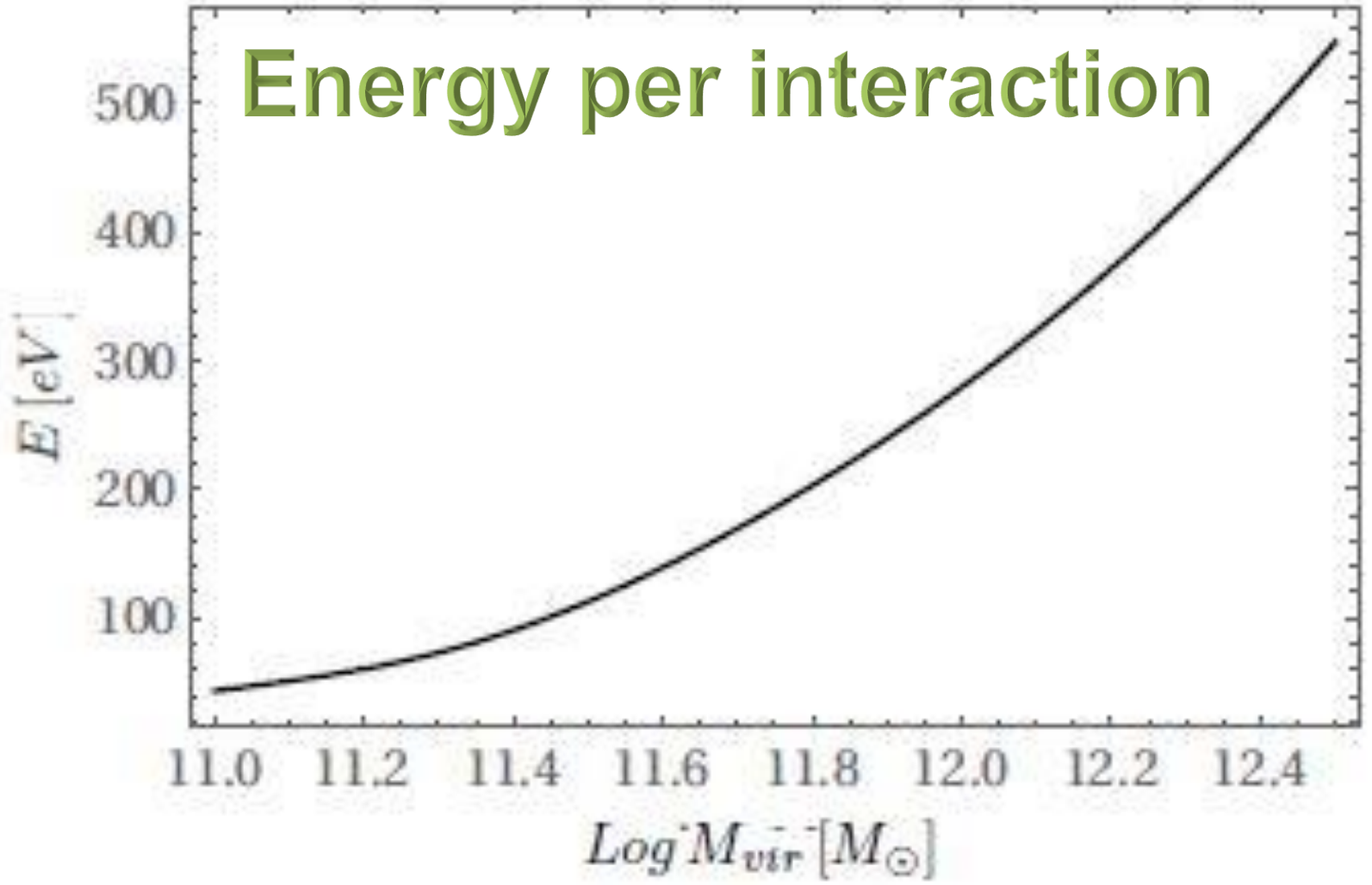
Compute the mass removed and the energy needed to form cores

$$W = \int_0^{1.2R_{cp}(M_{vir})} \rho_{DM,cusp}(r, M_{vir}) M_{cusp}(r, M_{vir})\, 4\pi r\, dr - \int_0^{1.2R_{cp}(M_{vir})} \rho_{DM}(r, M_{vir}) M(r, M_{vir})\, 4\pi r\, dr$$

The interaction can occur only when dark and SM particles are ***both*** numerous

This ***triggers*** all the strange relationships found

Number of interactions : $\Delta M_H/m_{part}$_



CONCLUSIONS

New Paradigm. The scenario and the DM nature obtained by reverse engineering the observations

New scenario. Direct interaction between dark and SM particles, likely occurring in bound system as stars