A new Paradigm for the Dark Matter Phenomenon.

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SIGRAV, Trieste 5/9/23

This talk is not:

-a review of the properties of the dark and luminous matter in galaxies of the problems of the ΛCDM scenario at galactic scale

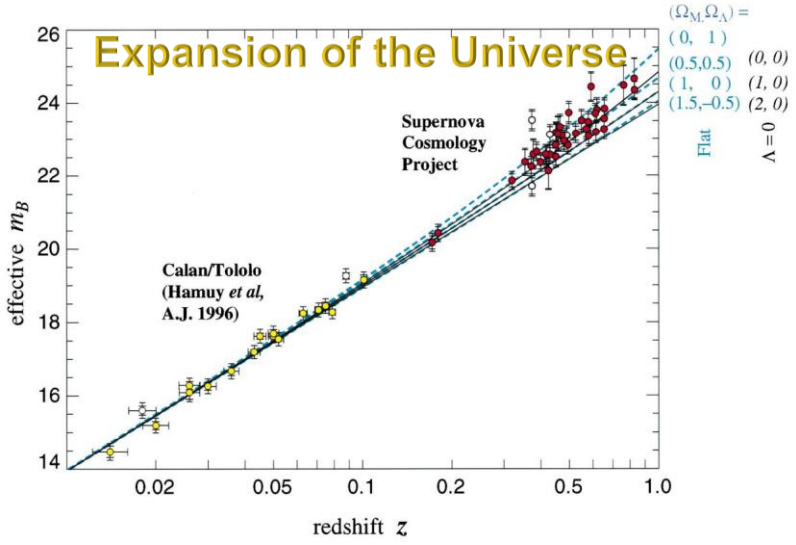
-a support for some new Scenario for the DM Phenomenon

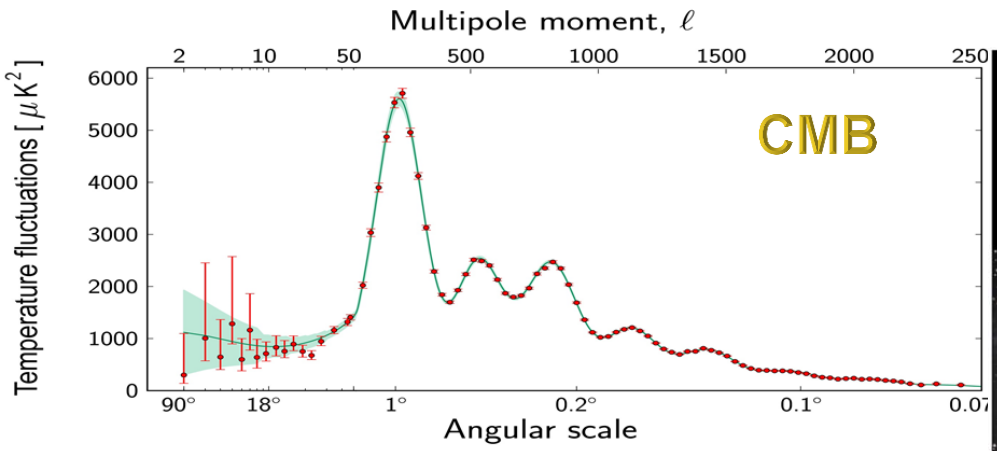
It is instead:

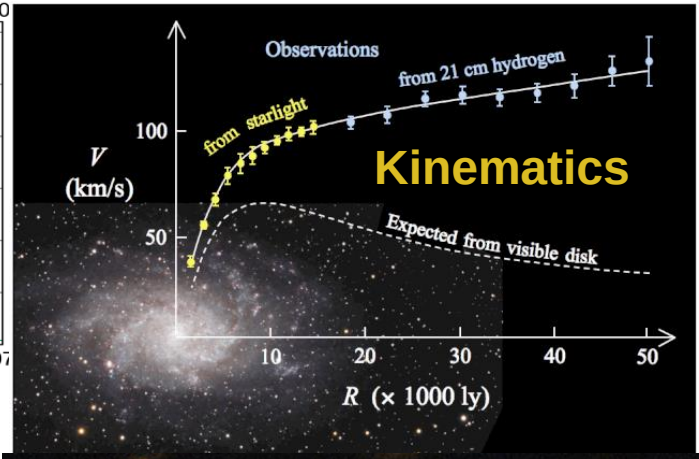
-a coming out on the DM issue, motivated by its observational properties emerged in the past 20 years.

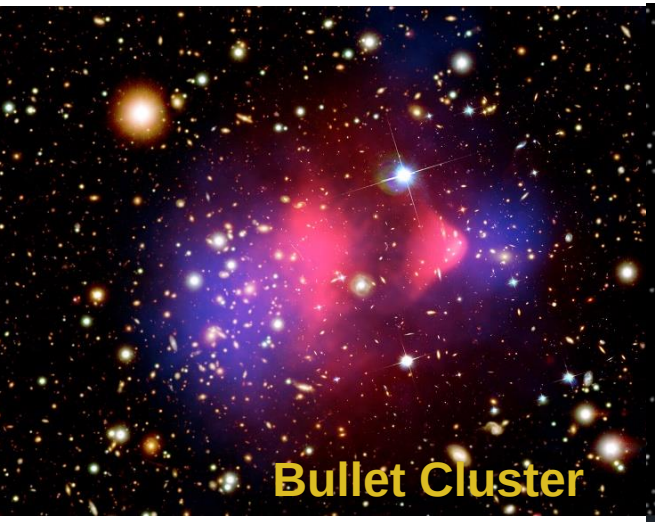
Given the DMP(2024) we need to abandon not only the currently favoured scenario, but also its generating Paradigm and to substitute it with a specific one.

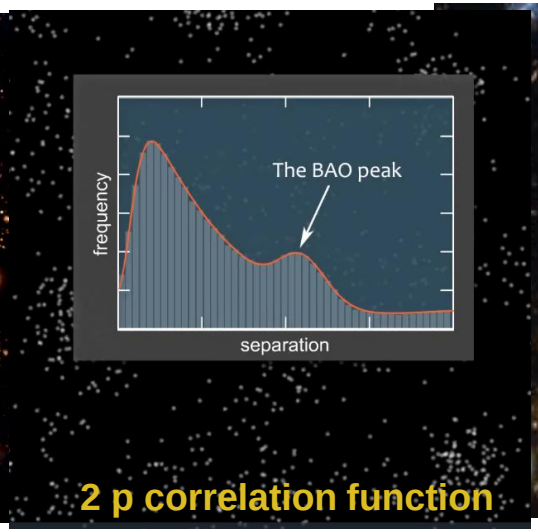
Dark Matter emerges to account for effects that appear to be the result of invisible mass











DM PHENOMENON

Dark Matter **IS NOT:**
-a particle
-a tension in Physics
-the outcome of a theory/scenario.

DM **IS:**
-a phenomenon. Multiple evidence at different scales of the Universe unexplained without postulating the existence of a dark massive BSM component.

-DMP(year): it has rapidly increased with time in quantity and in complexity.

The (true) theorethical scenario
emerges from a suitable Paradigm

Since 1990: the Apollonion Paradigm

The true scenario for the particle is the most beautiful one, so:

1) it connects the (new) Dark Matter physics with the (known) physics of the Early Universe.
2) it sheds light on open issues of the Standard Model particle physics and even on long standing big issues of Physics
3) it has a (unique) underlying dark particle which can be detected by experiments and observations with the present technology
4) it introduces the particle in a natural and simple way and its interactions with the rest of the Universe are linked to the cosmological matter density.
5) it is mathematically described by a very small number of parameters and by unique and known initial conditions
6) It has a strong predictive power on the evolution of the structures of the Universe whose evolution can be fully followed by suitable numerical simulations.
7) The scenario crystallizes with the original DMP

BEAUTY= SIMPLICITY, NATURALNESS, USEFULNESS, ACHIEVING EXPECTATIONS, OPTIMISM, HARMONICALLY EXTENDING OUR KNOWLEDGE

From the Apollonian DM Paradigm: a specific scenario reverse engeniered by DMP(1990).

Cold, collisionless WIMP (Weakly interacting massive dark particle)

Relic DM particle from the early Universe, possibly from SuperSymmetric extensions of the standard model of particle physics
Just the existence of such particle entirely defines the scenario.

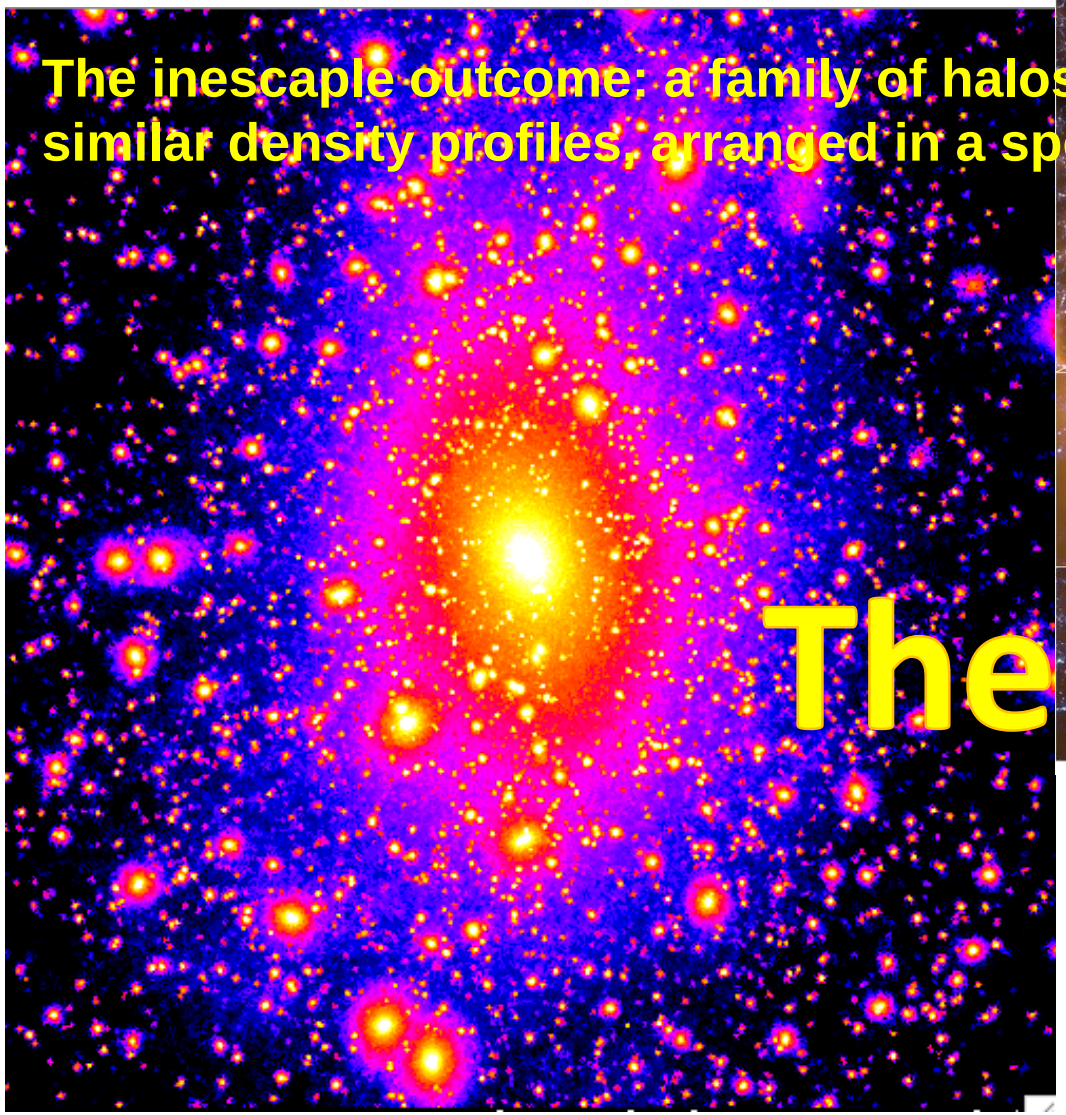
The assumed Weak Interaction naturally leads to the correct cosmological DM abundance and to its cold and collisionless status.

Density perturbations arise naturally with specific (and known) initial conditions and no free parameters to be fixed and proceed by means of an also specific (and known) bottom up merger-dominated process.

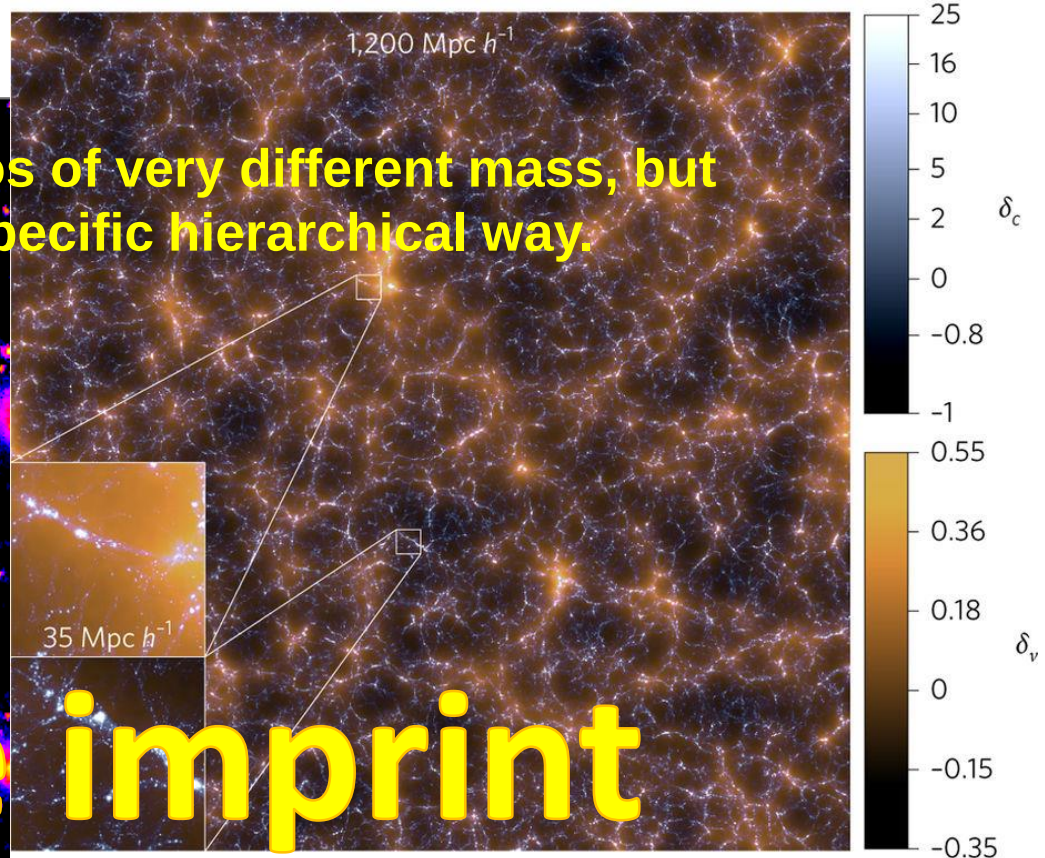
Gravitational interaction is the only actor for the dark component, numerical simulations with known baryonic physics are able to reproduce the evolving universe.

ΛCDM Scenario is fully falsiable by observations, experiments and theorethical arguments a
- needs only DMP(1990)
- is set to reproduce any DMP(XXXX) with the help of « dirty » baryonic physics

N-body simulations



The inescaple outcome: a family of halos of very different mass, but similar density profiles, arranged in a specific hierarchical way.



The imprint

ΛCDM scenario: the density profile

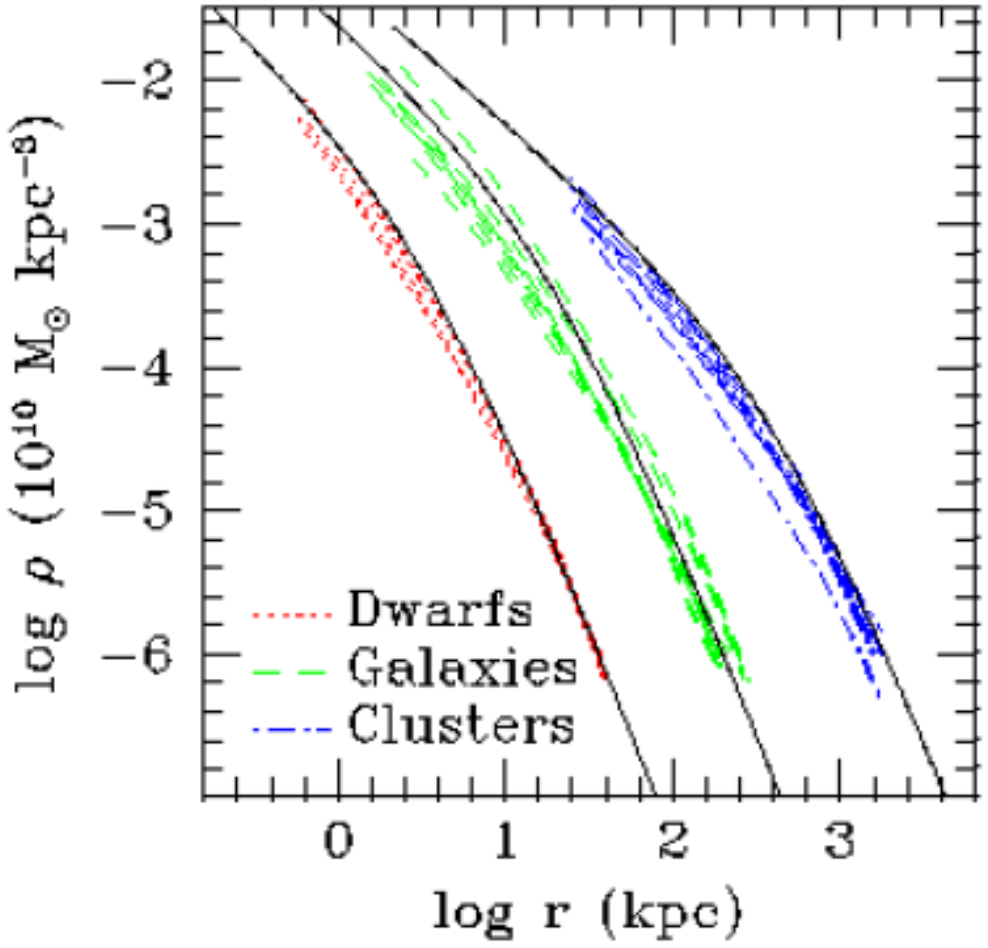
$$\rho_{NFW}(r) = \delta\rho_c \frac{r_s}{r} \frac{1}{(1+r/r_s)^2}$$

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

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

Density Profiles

N-body simulations (1996)



25 YEARS LATER:

Universal structure of dark matter haloes over a mass range of 20 orders of magnitude

J. Wang, S. Bose, C. S. Frenk, L. Gao, A. Jenkins, V. Springel & S. D. M. White

Nature **585**, 39–42 (2020) | Cite this article

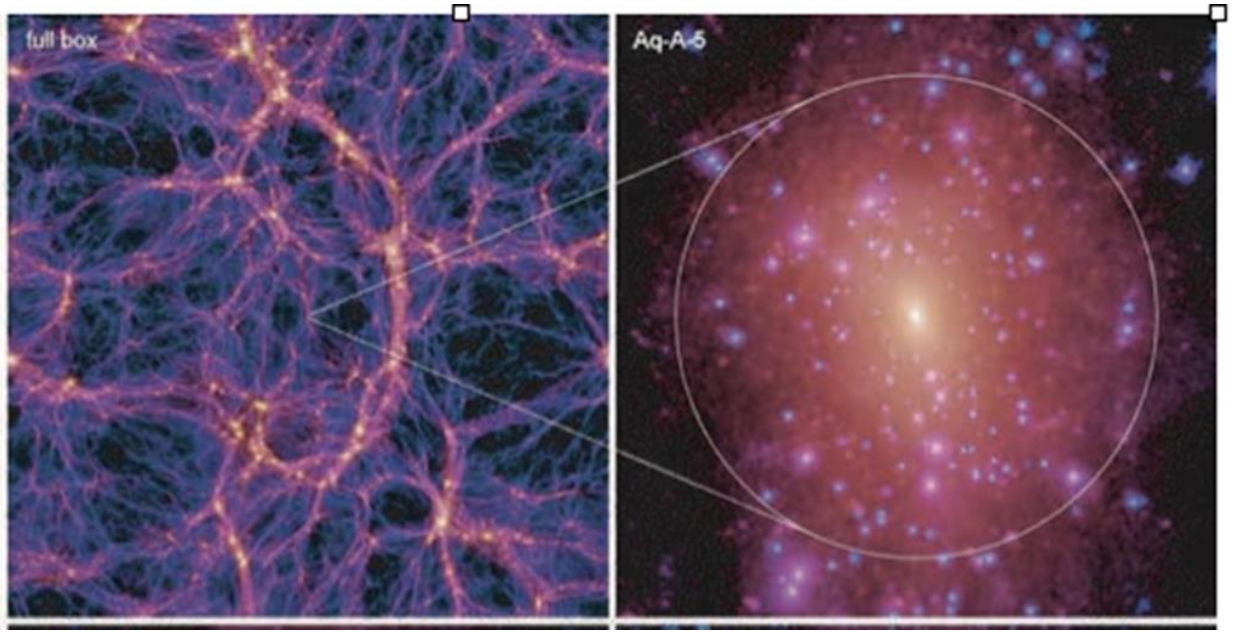
ΛCDM scenario for the DMP is uniquely beautiful and this has been the main motivation for

-35.000 published works

-90% of cosmologists has worked in it

- Experiments ~ several BN $ in 30 years

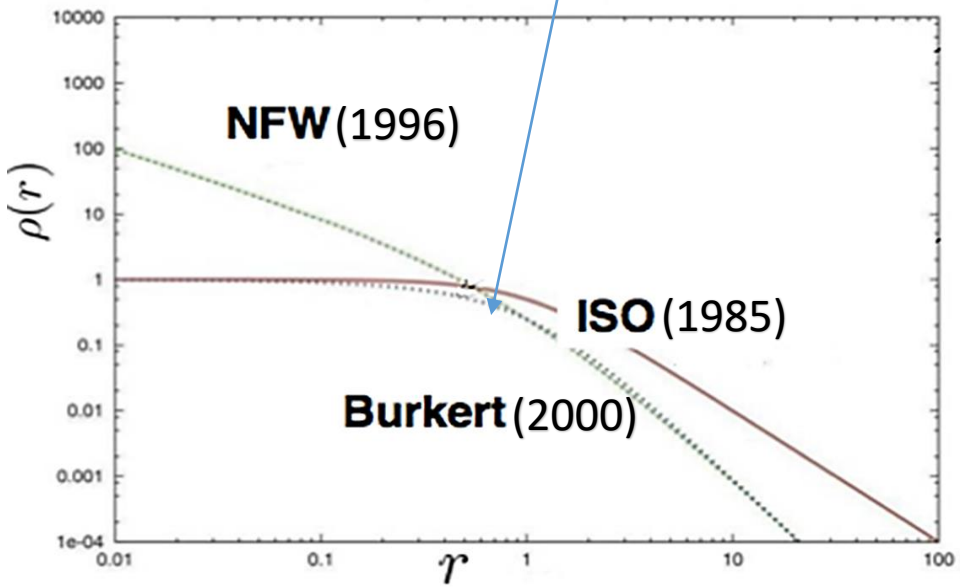
N-body simulations ΛCDM

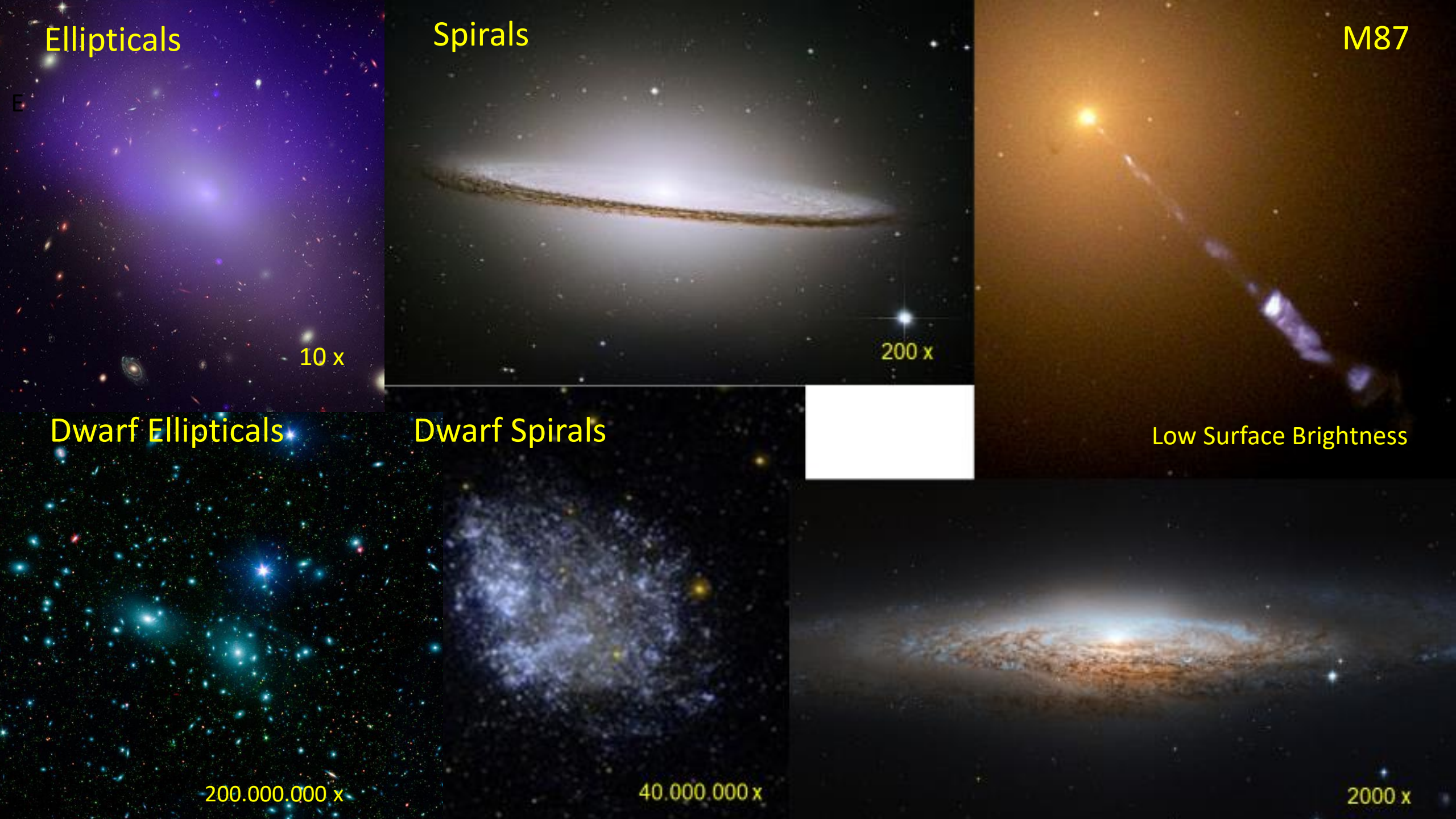


$$\rho(r) = \frac{\rho_0}{(1 + r/r_0)(1 + (r/r_0)^2)}$$

- ΛCDM → **cusp** $\rho(r) \sim r^{-1}$

- **Observations** → **core** $\rho(r) = const.$

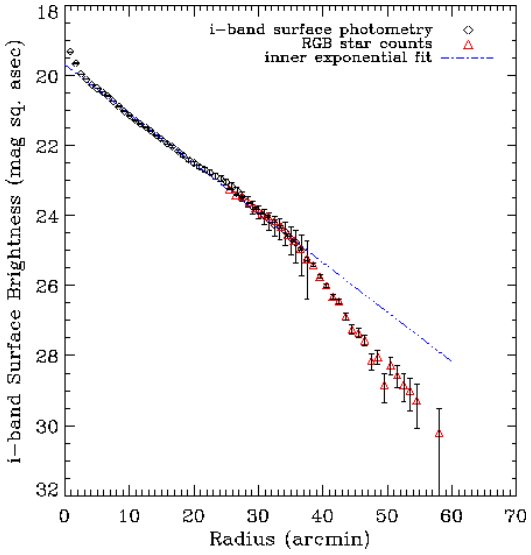



Ellipticals
E
10 x
Spirals
200 x
M87
Dwarf Ellipticals
200.000.000 x
Dwarf Spirals
40.000.000 x
Low Surface Brightness
2000 x

The Distribution of stars in galaxies

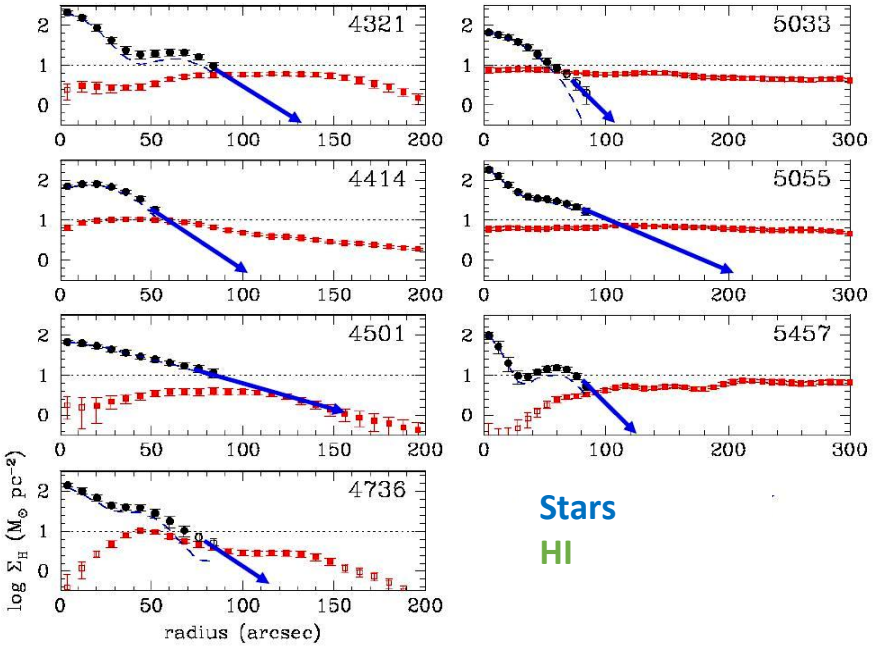
R_D lenght scale of the 2D disk
R_e lenght scale of the 3D spheroid

The Distribution of HI in disk galaxies

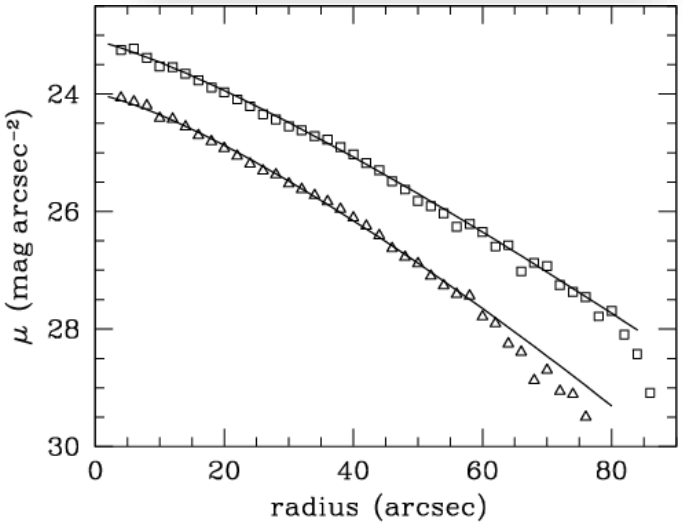


$$I(r) = I_0 e^{-r/R_D}$$

Freeman



Stars
HI



$$I(R) = I_e e^{-b_n[(R/R_e)^{1/n}-1]}$$

Sersic

From the Gravitational Potential to the mass distribution

$$\phi_{\rm tot} = \phi_b + \phi_{\rm H} + \phi_{\rm disk} + \phi_{\rm HI}$$

Gravitational Potential

$$\nabla^2 \Phi_i = 4\pi G \rho_i$$

Poisson Equation

$$V_{\rm tot}^2(r) = r\frac{\mathrm{d}}{\mathrm{d}r}\phi_{\rm tot} = V_b^2 + V_{\rm H}^2 + V_{\rm disk}^2 + V_{\rm HI}^2.$$

Rotating systems

$$\sigma_r^2(r) = \frac{1}{\nu_\star(r)}\int_r^\infty \nu_\star(r')\left(\frac{r'}{r}\right)^{2\beta}\frac{GM(r')}{r'^2}\,\mathrm{d}r'.$$

Pressure dominated systems

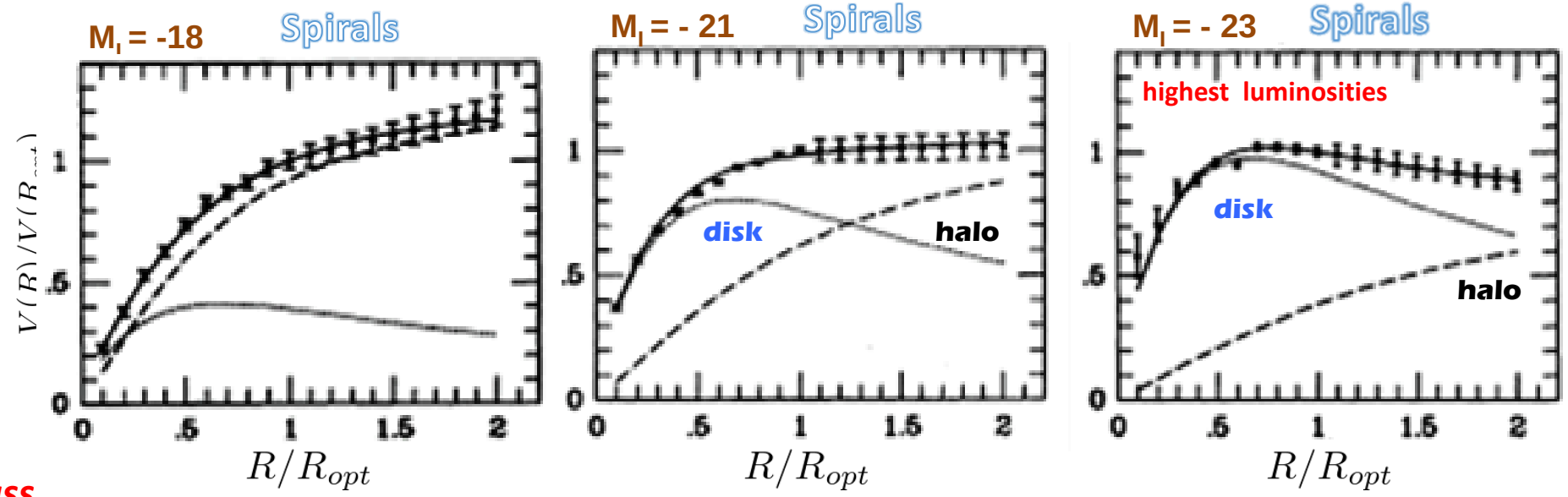
$$\Sigma_{\rm c} = \frac{c^2}{4\pi G}\frac{D_{\rm s}}{D_{\rm l}D_{\rm ls}} \qquad \gamma_t(R) = (\bar{\Sigma}(R) - \Sigma(R))/\Sigma_{\rm c}$$

Weak lensing

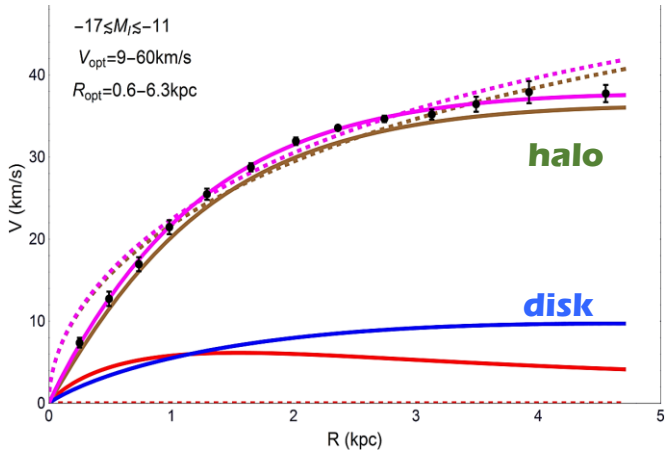
$$M(<r) = \frac{kT_{\rm g}(r)r}{G\mu\, m_{\rm p}}\left(\frac{\mathrm{d}\,\log\rho_{\rm g}(r)}{\mathrm{d}\,\log r} + \frac{\mathrm{d}\,\log T_{\rm g}(r)}{\mathrm{d}\,\log r}\right)$$

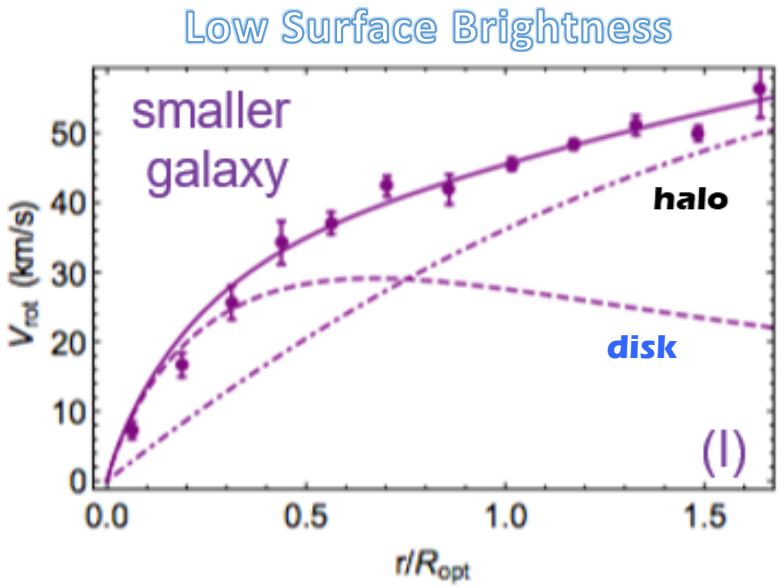
X-Ray emitting gas

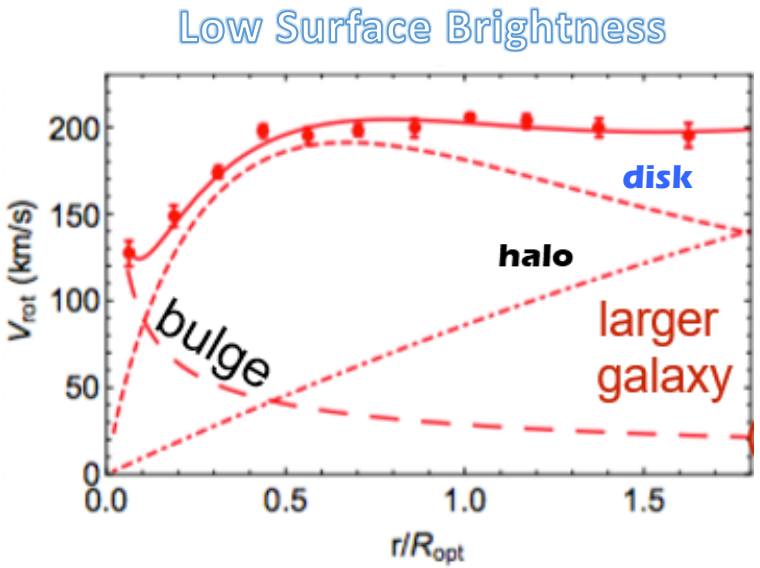
MASS MODELLING



1 par-stellar mass
2 par-halo central density
3 par-halo core radius
1 fun-ϱ_H(r, 2 free pars) CORED







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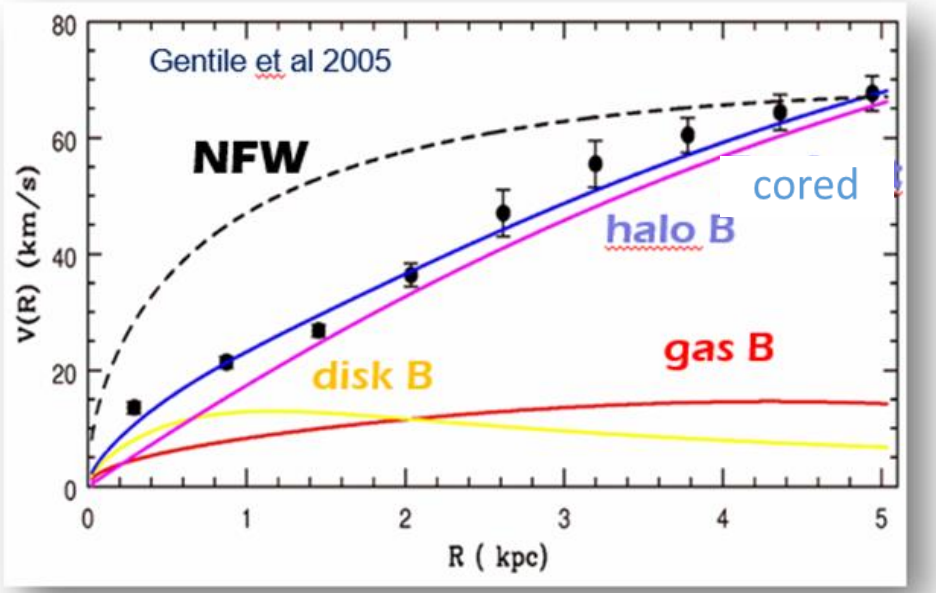
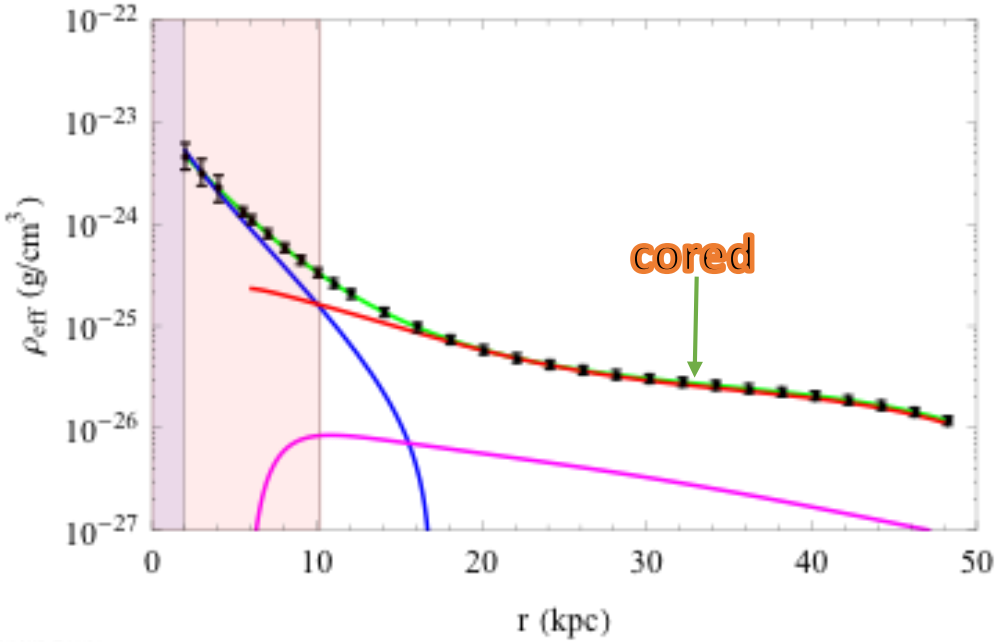
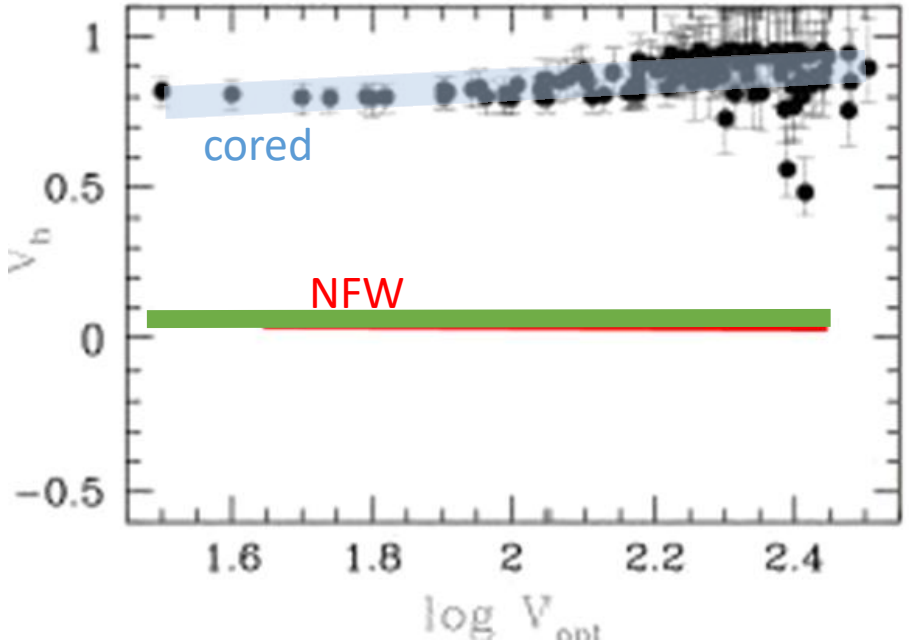


NGC 3198



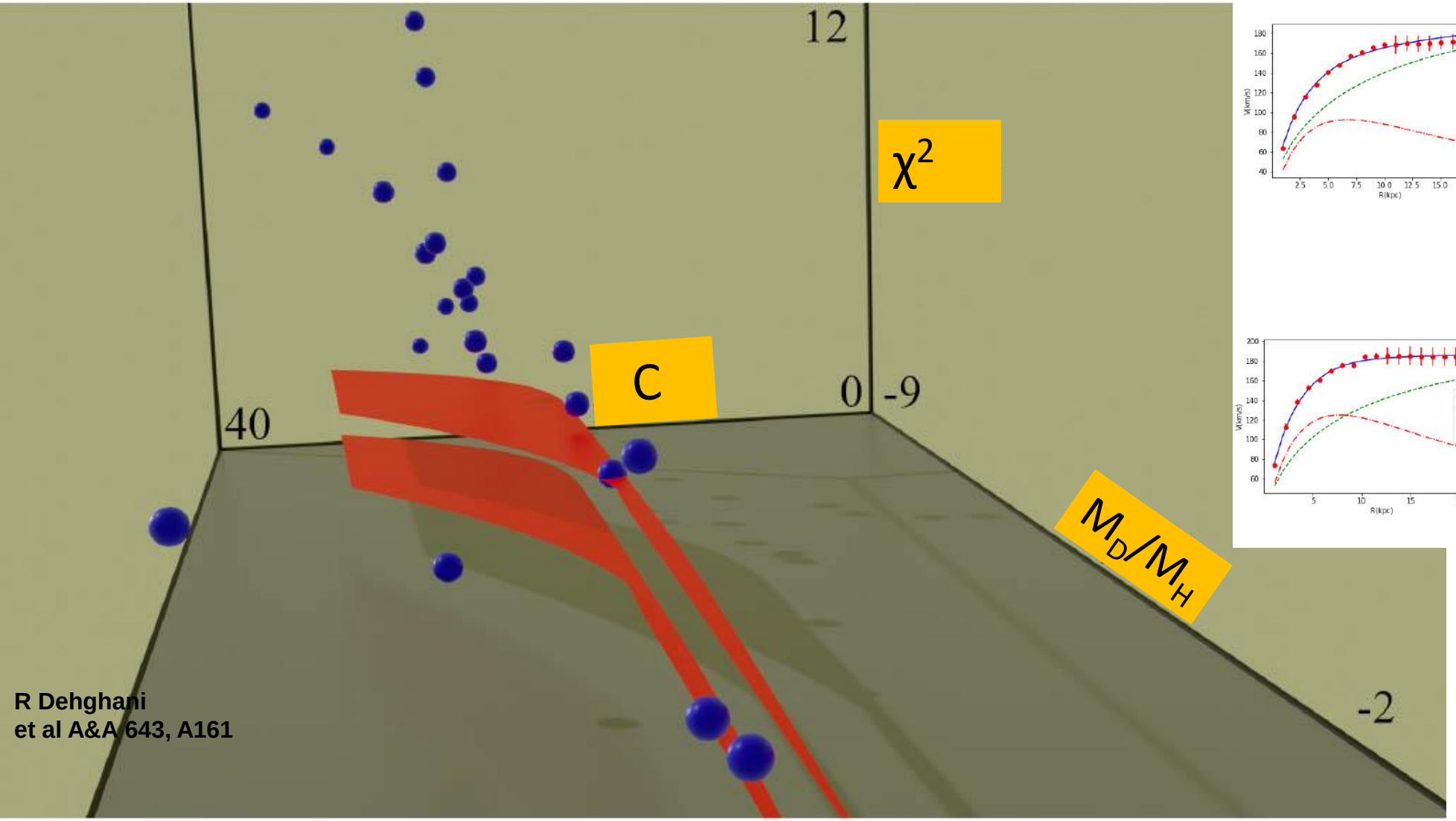
100 Spirals



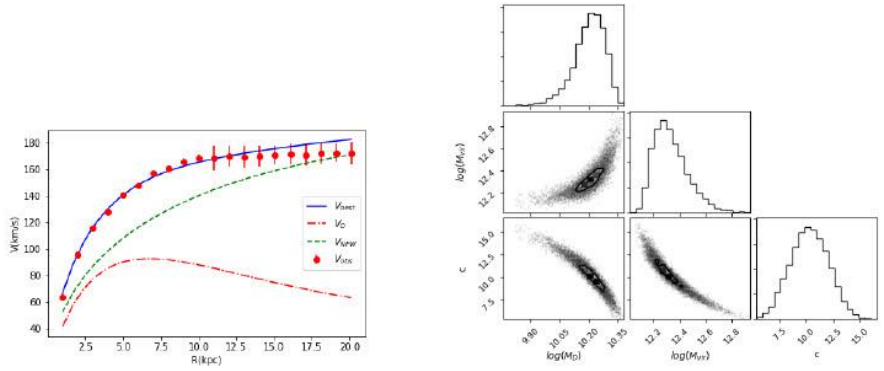
Kinematics of individual objects inconsistent with the presence of a NFW halo.

A complete study of the NFW modeling of disc systems.
26 coadded RCs from 3100 individual RCs of S, LSB and dwarf S

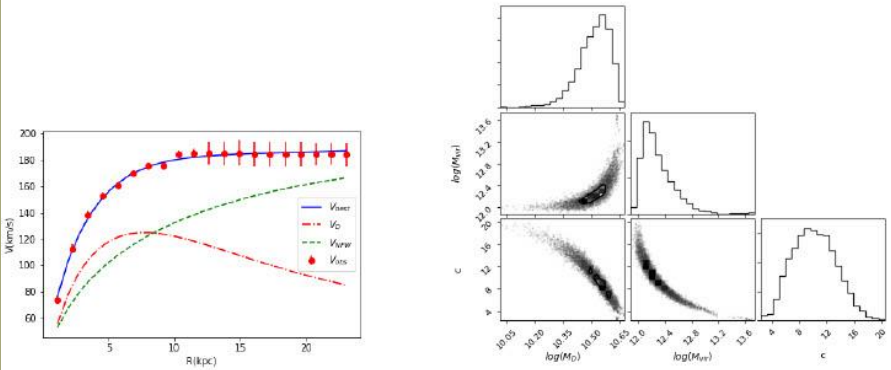
No collisionless behavior in any galaxy.



R Dehghani
et al A&A 643, A161



(f) PSS96, bin 6



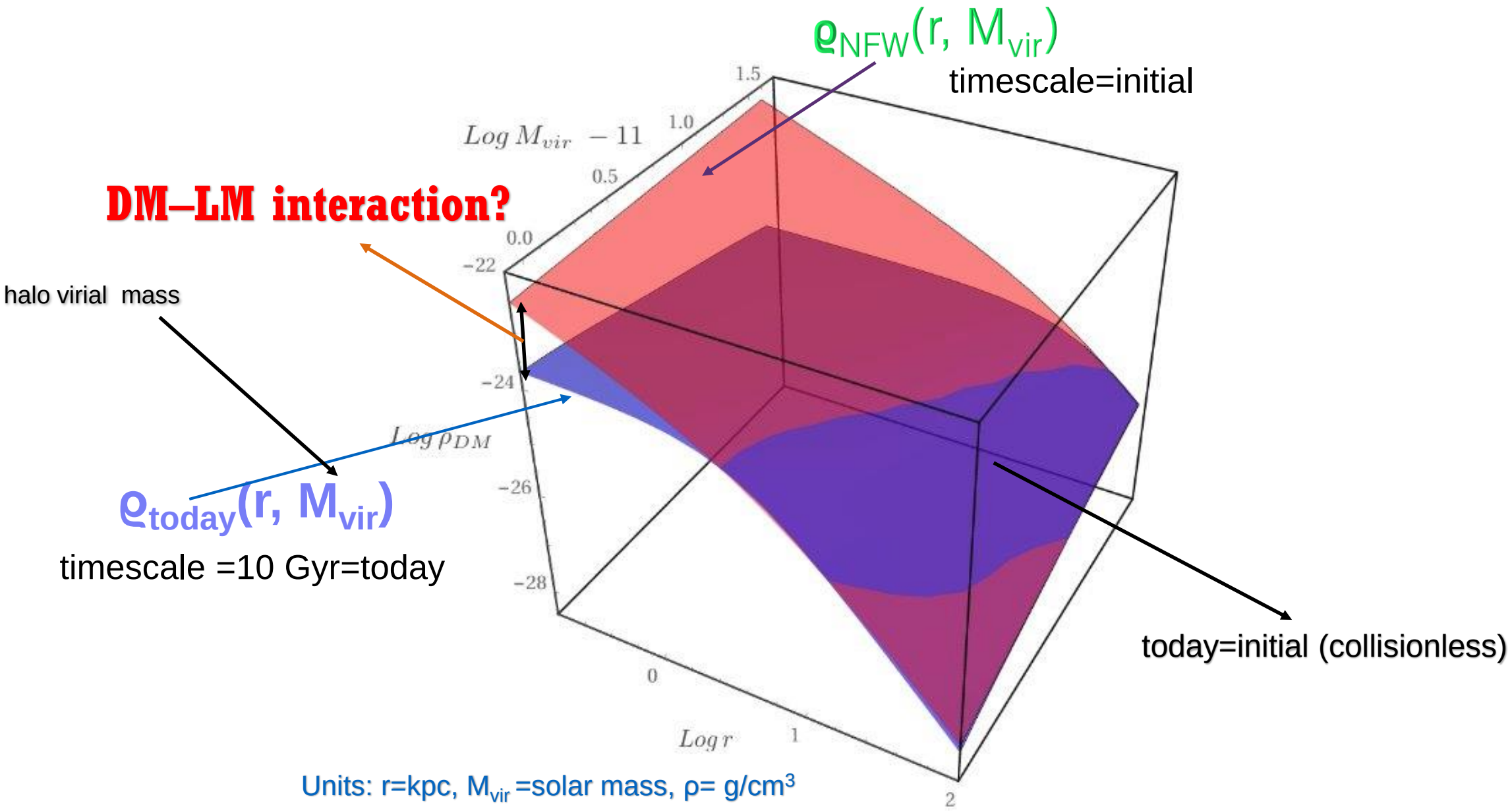
(g) PSS96, bin 7

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

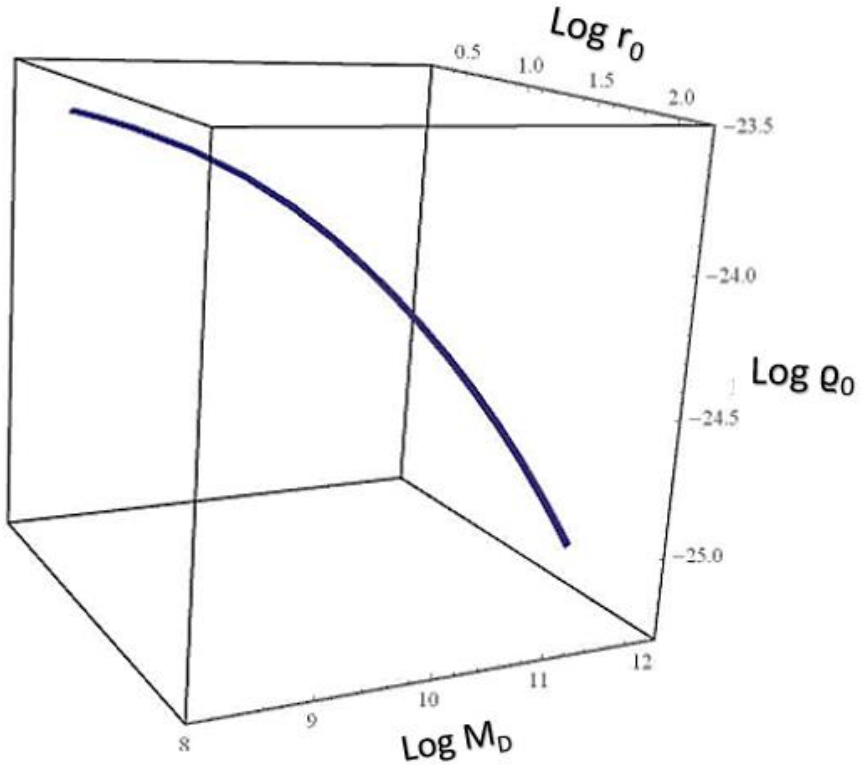
$$c = \frac{R_{vir}}{r_s}$$

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

Initial and present day DM halos density profiles



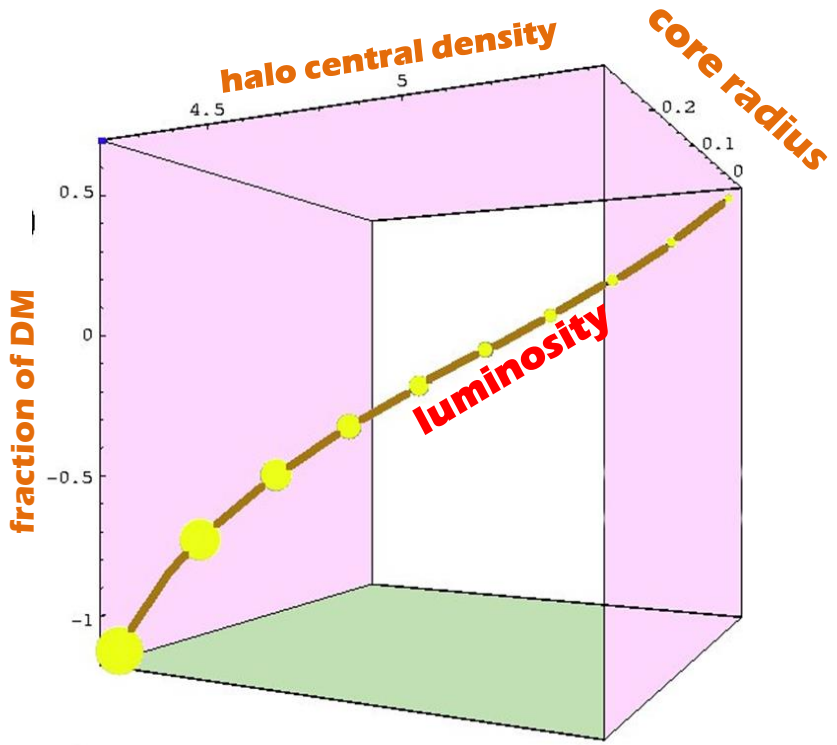
Units: r=kpc, M_{vir} =solar mass, ρ= g/cm^3



The structural DM and LM parameters are related among themselves and with luminosity.

-Baryonic feedback

-no modification of the DM scenario (inside the Apollonian DM Paradigm)

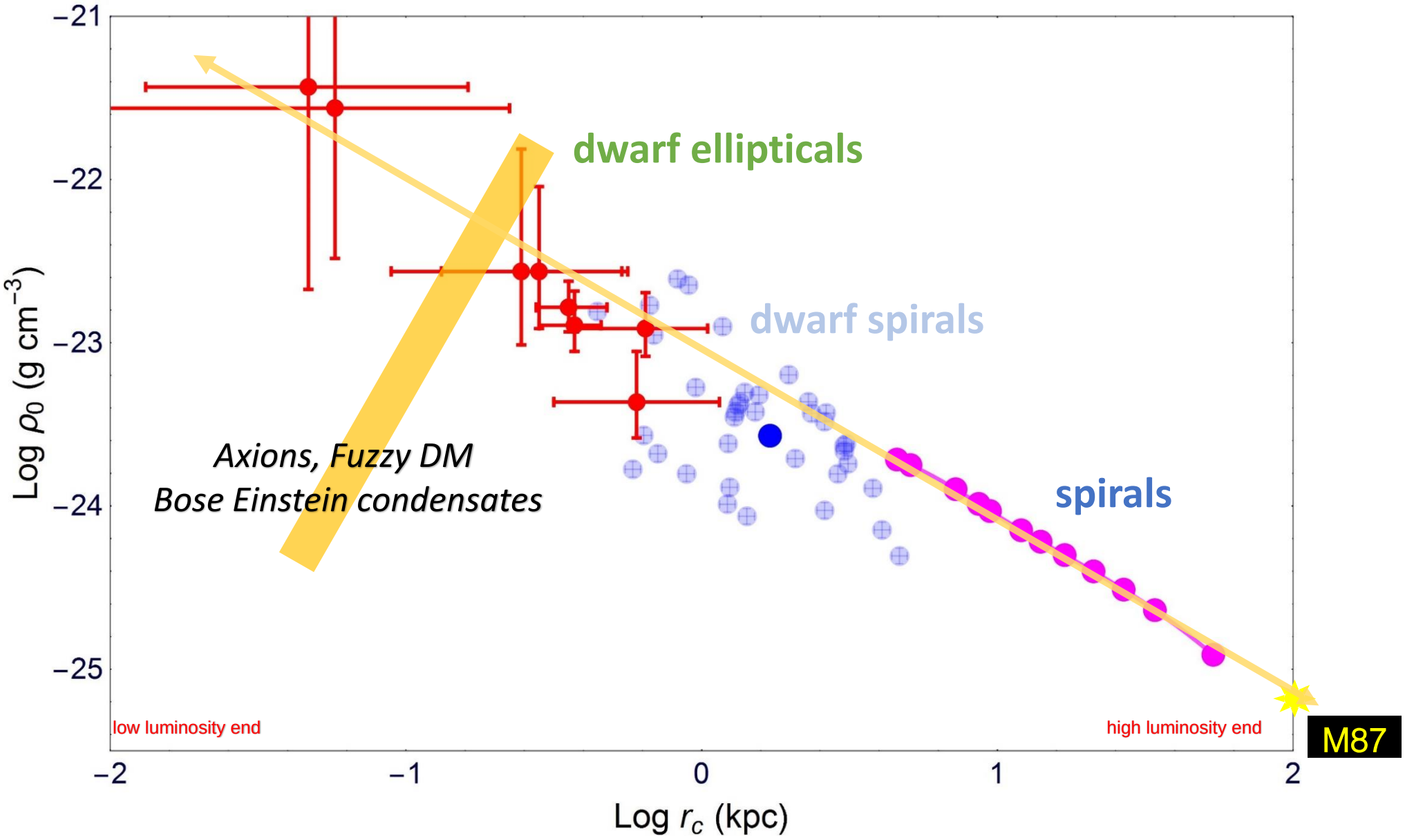


ΛCDM

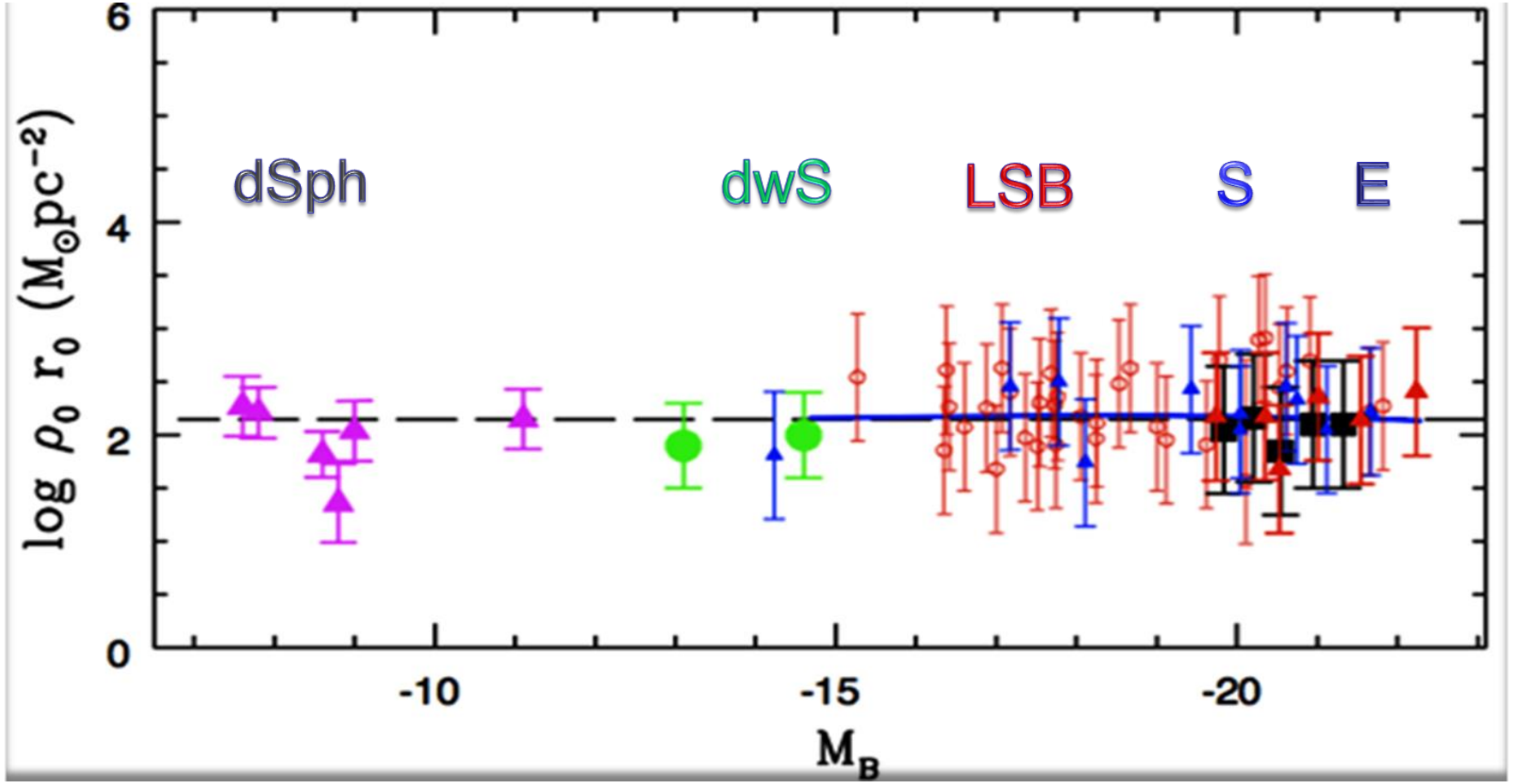
-8

-8

Central DM halo density vs. core radius



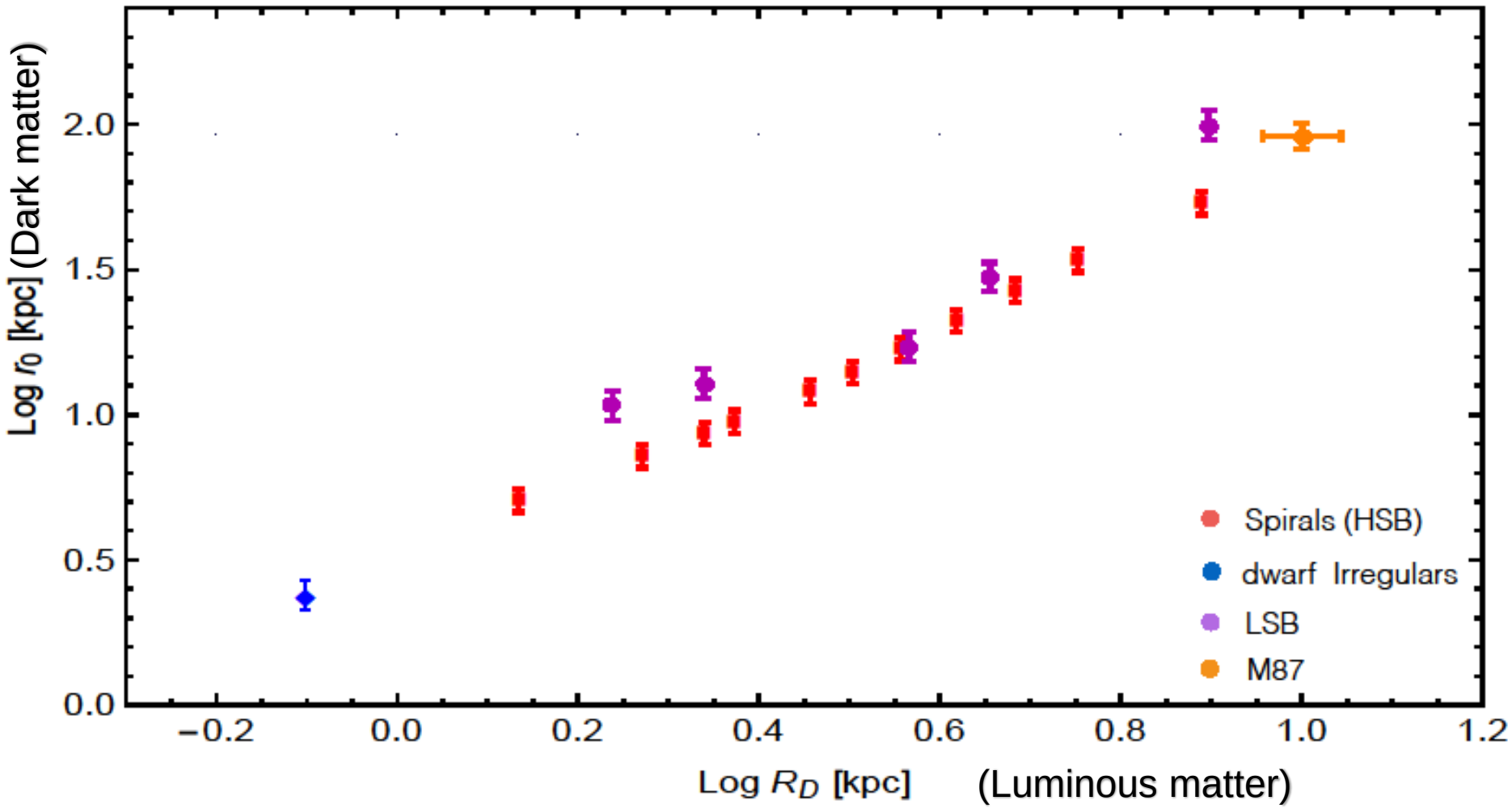
DM HALO CENTRAL SURFACE DENSITY



M87

Core radii between 0.1 kpc to 100 kpc

Stellar (disk) length scales vs halo core radii



The log derivative of the stellar surface density vs. that of the dark halo density

DMP(2023) ≠ DMP(1990)

ΛCDM scenario today suffers by:

- Anomalies, on scales > Mpc
- Inconsistencies, on scales < 0.1 Mpc

The disagreement is now so deep and wide that concerns also the paradigm itself generating this scenario

The wide disagreement between DMP(2023) and the CDM scenario
-Affects also its generating Apollonian paradigm: its defining criteria are intrinsically incompatible with the observational evidence.
-The failure of the scenario stems from its automatic adhesion to criteria of scientific beauty in all its various aspects

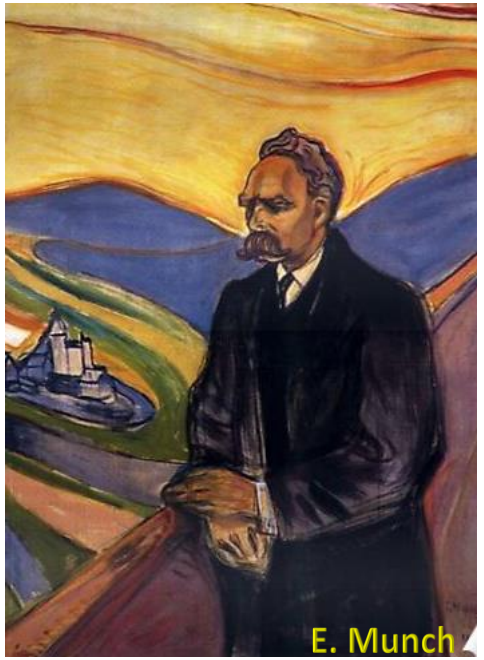
The philosopher Nietzsche, not the first, but obsessed with idea:

Beauty ⟹ Truth

False ⟹ Ugly

NIETZSCHEAN Paradigm

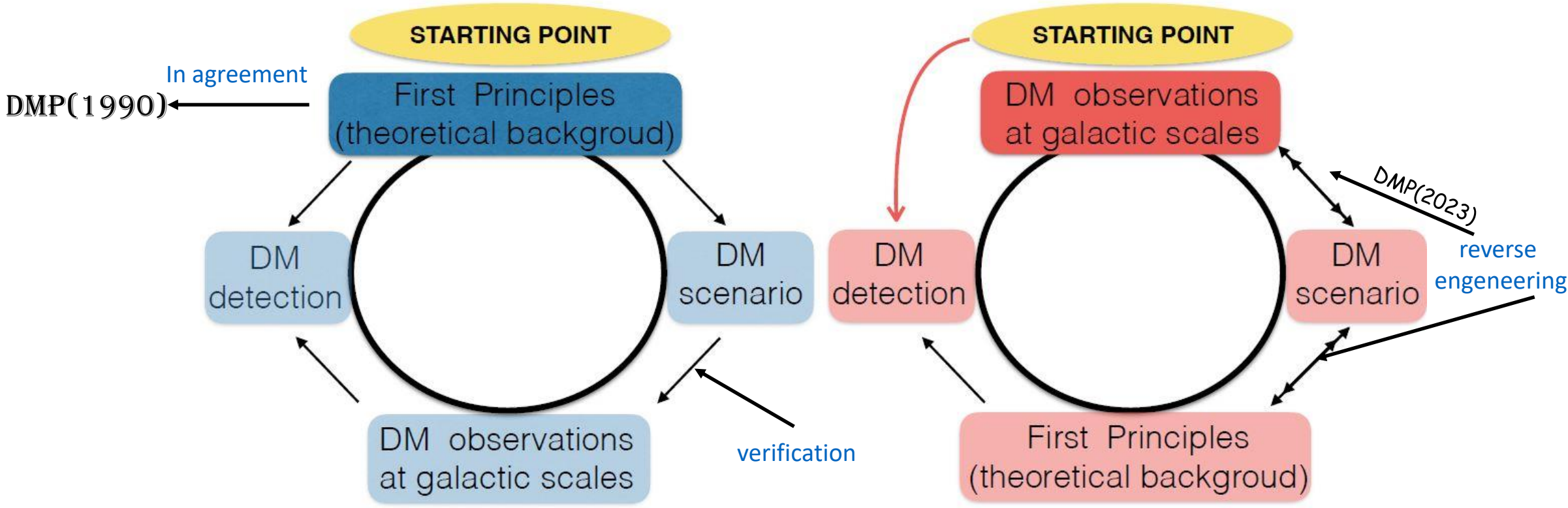
to search for the actual DM particle scenario



-The DM scenario is primarily built by reverse engineering the full DMP(XXXX) whatever it takes
-Its theorethical foundation needs not to comply with the canon of scientific beauty, naturalness or usefulness in shedding light on known issues of SM EP.
-What, for a scenario, in the Apollonion paradigm is considered as a constraint, now is instead an -opportunity- in building it.
- scenarios that appear to our “scientific senses” ugly, ad hoc and anti-Occam are allowed

PARADIGM SHIFT

Apollonian → NIETZSCHEAN



Salucci et al Universe, 2020, 6, 118

SCENARIOS

A new physical interaction create the DM cores and it is the cause of the most fascinating aspects of the DMP(2023) Notice:

$$d\rho_{DM}(r,t)/dt = k < \sigma V_r > \rho_{DM}(r,t)\rho_{LM}(r); \;\; \rho_{DM}(r,0) = \rho_{NFW}(r)$$

explains naturally the formation of cores and several of the above relationships

Direct DM-SM particle interaction. Dynamical state of the DM particle
Scattering, absorption and emission, capture, resonance.
Multiple location of the interactions.

DM-DM interaction enhanced by local baryonic excess

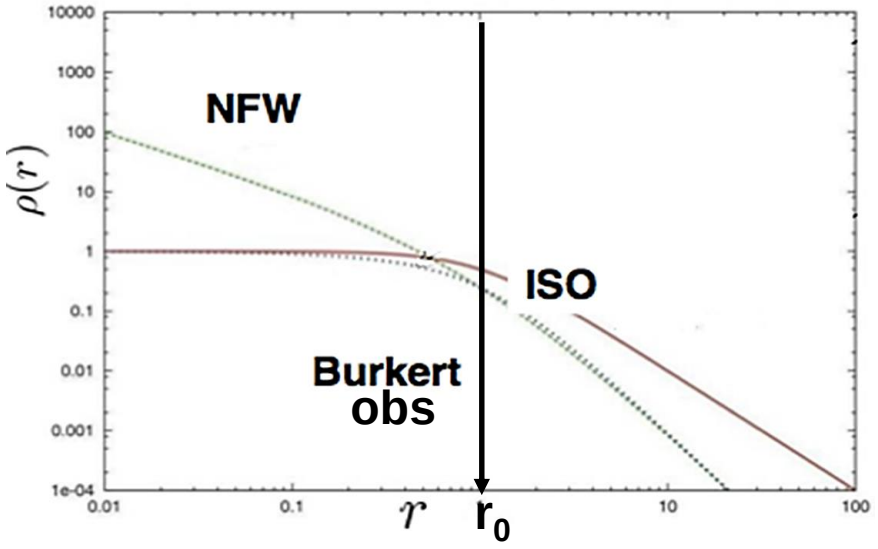
A Nietzchean scenario with:

Modified gravity and Dark Matter
baryonic feedback on a standard CDM Particle halo,
Multiple dark components

The quantity: $\rho_{DM}(R)\rho_{\star}(R)$

varies by up to 1000 at different radii and in different galaxies

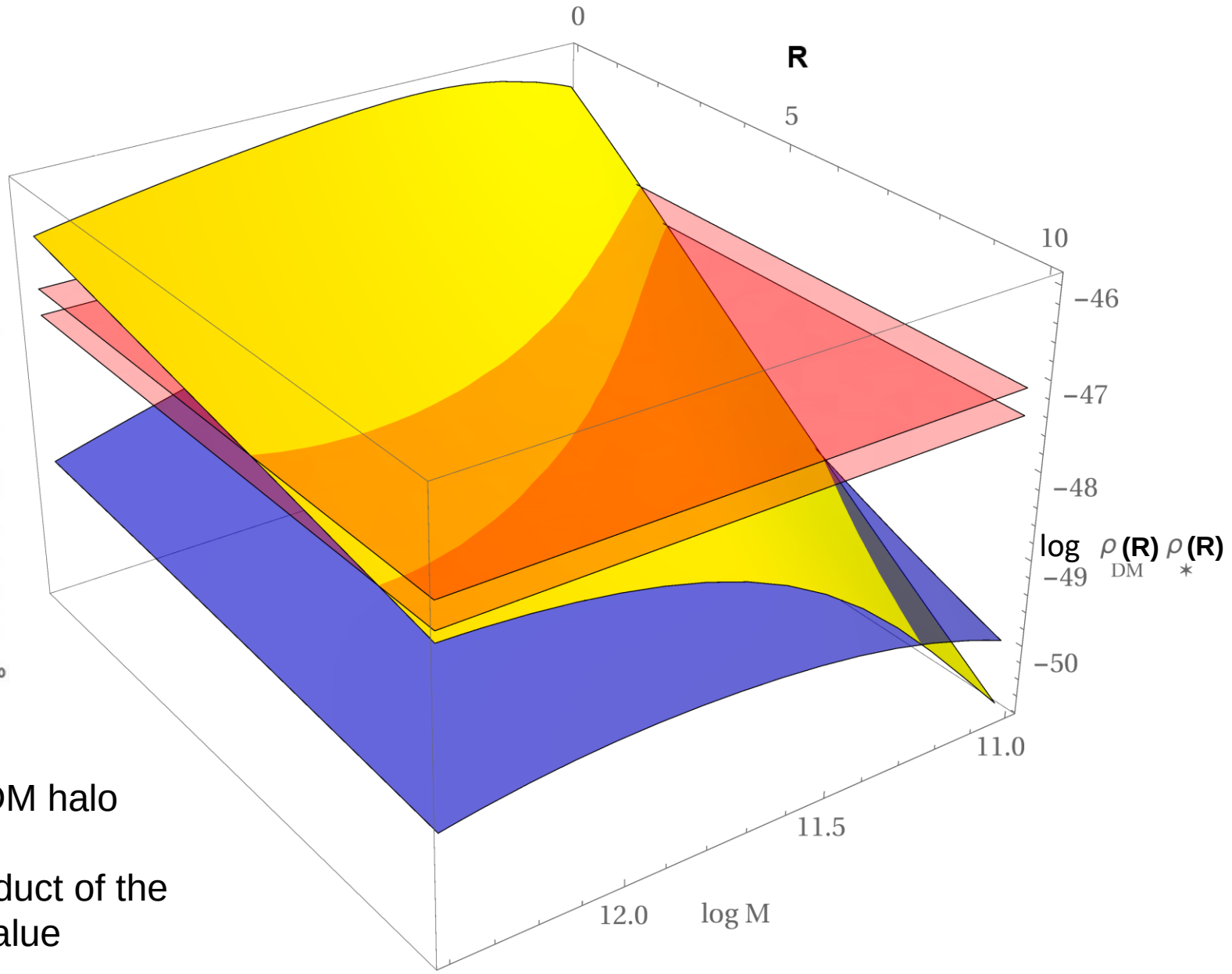
$= 10^{-47.5\pm0.3} g^2 cm^{-6}$ at r_0 in any galaxy

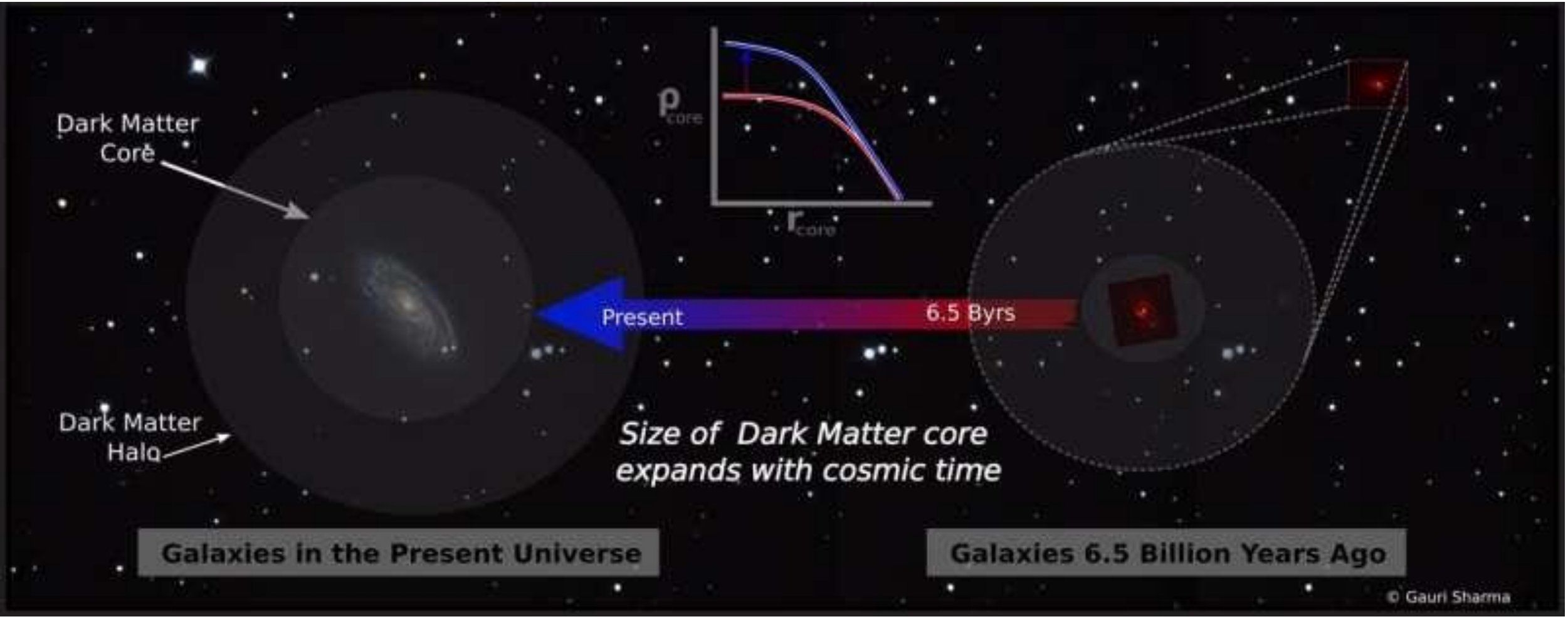


r_0

-is the size of the region in which the DM halo density is constant

-marks the radius inside which the product of the two density, in all galaxies, is a fixed value



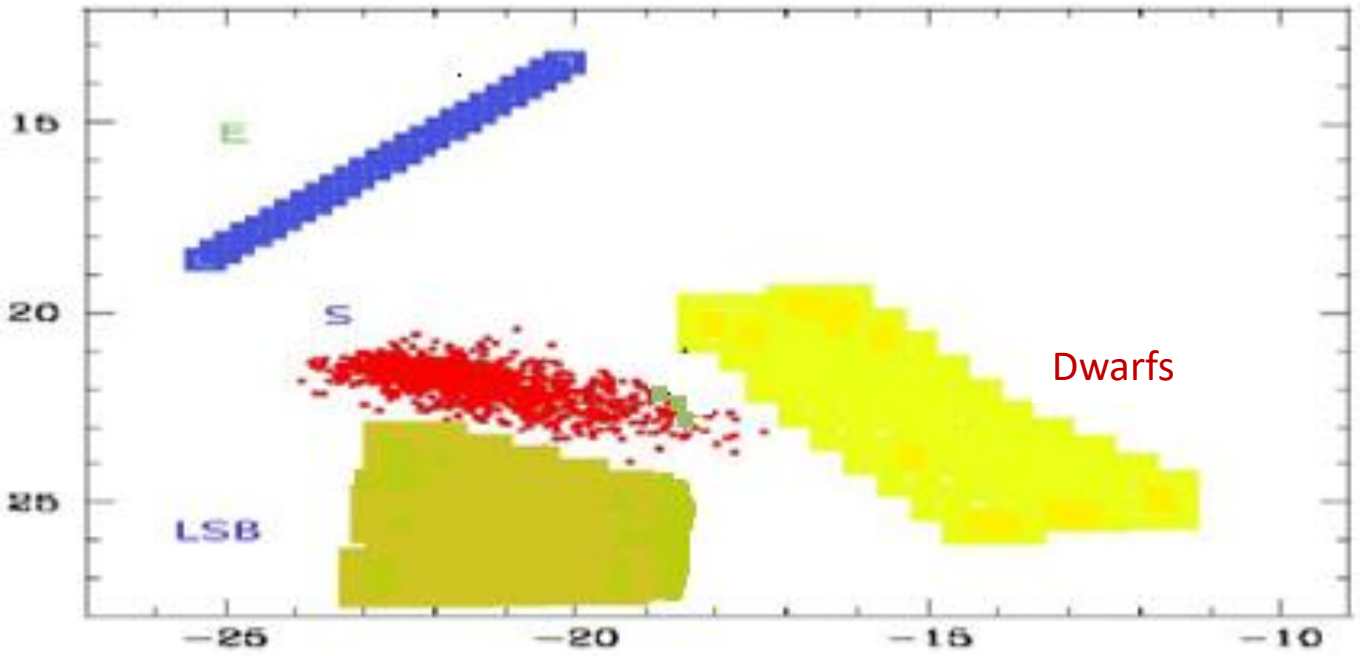


G. Sharma 2022

Galaxies

Among galaxies, the range in magnitude, type and central surface brightness
15 mag, 4 types, 16 mag arsec^{-2}

Central surface brightness vs galaxy magnitude



The distribution of luminous matter :

Spirals, dwarf S & LSB : stellar disk +bulge +HI disk
Ellipticals & dwarf E : stellar spheroid

The g g_b y relationship, not existing for a dark collisionless particle

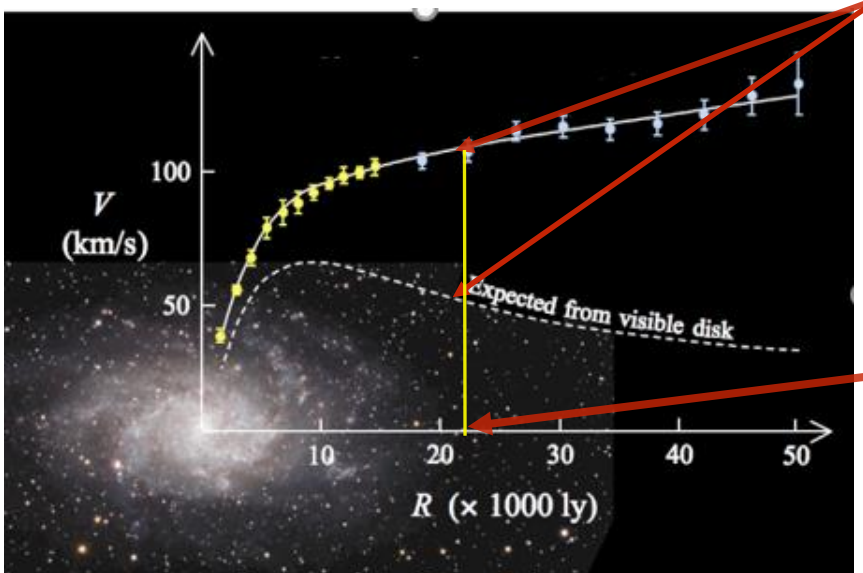
The sample: 72 LSB of all luminosities + 36 dwarf Spirals

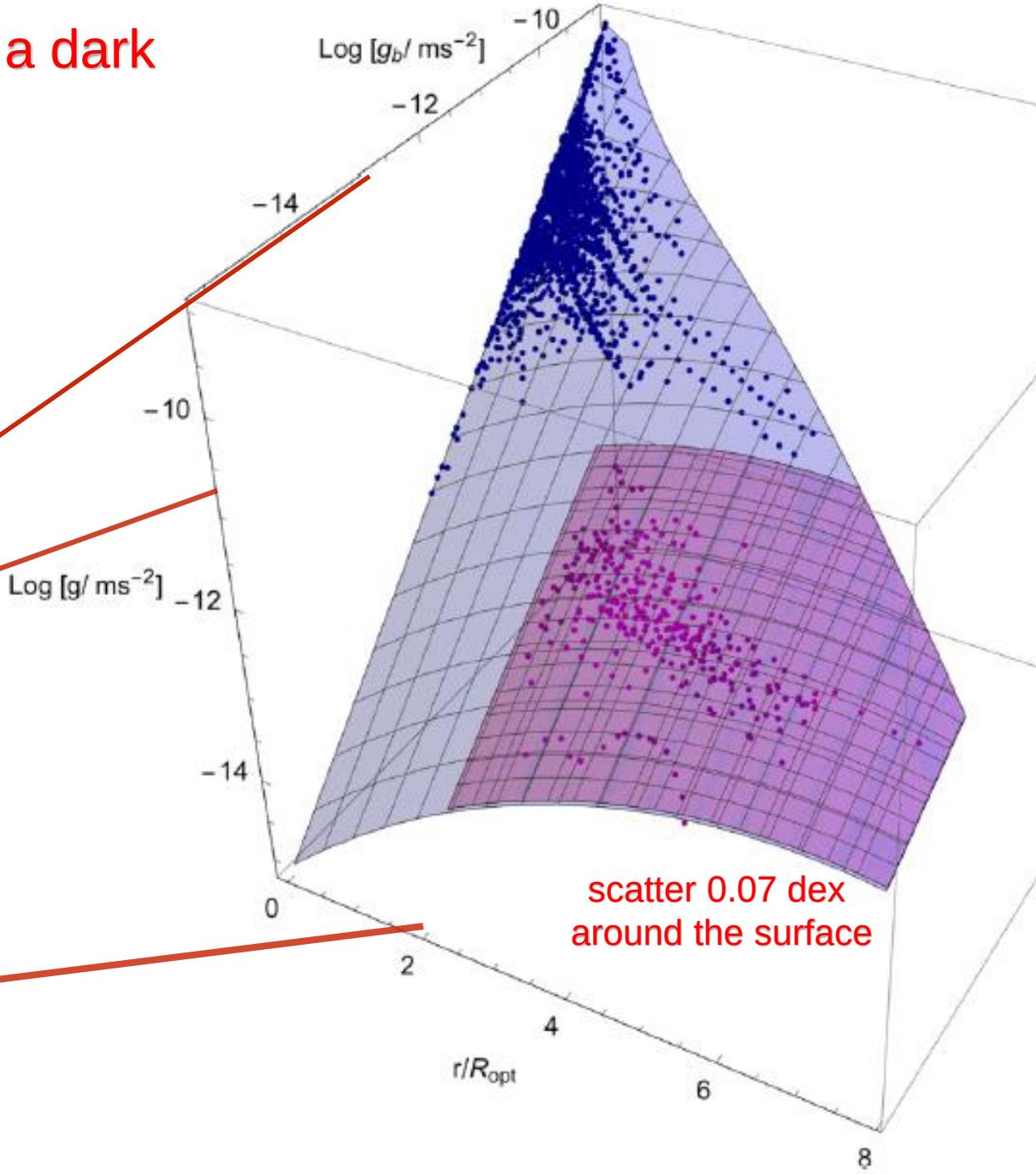
R_{opt} is the size of the stellar disk

$y = R/R_{opt}$ radius in normalised units

$V^2(y)/y \equiv g$ acceleration a $y=R/R_{opt}$

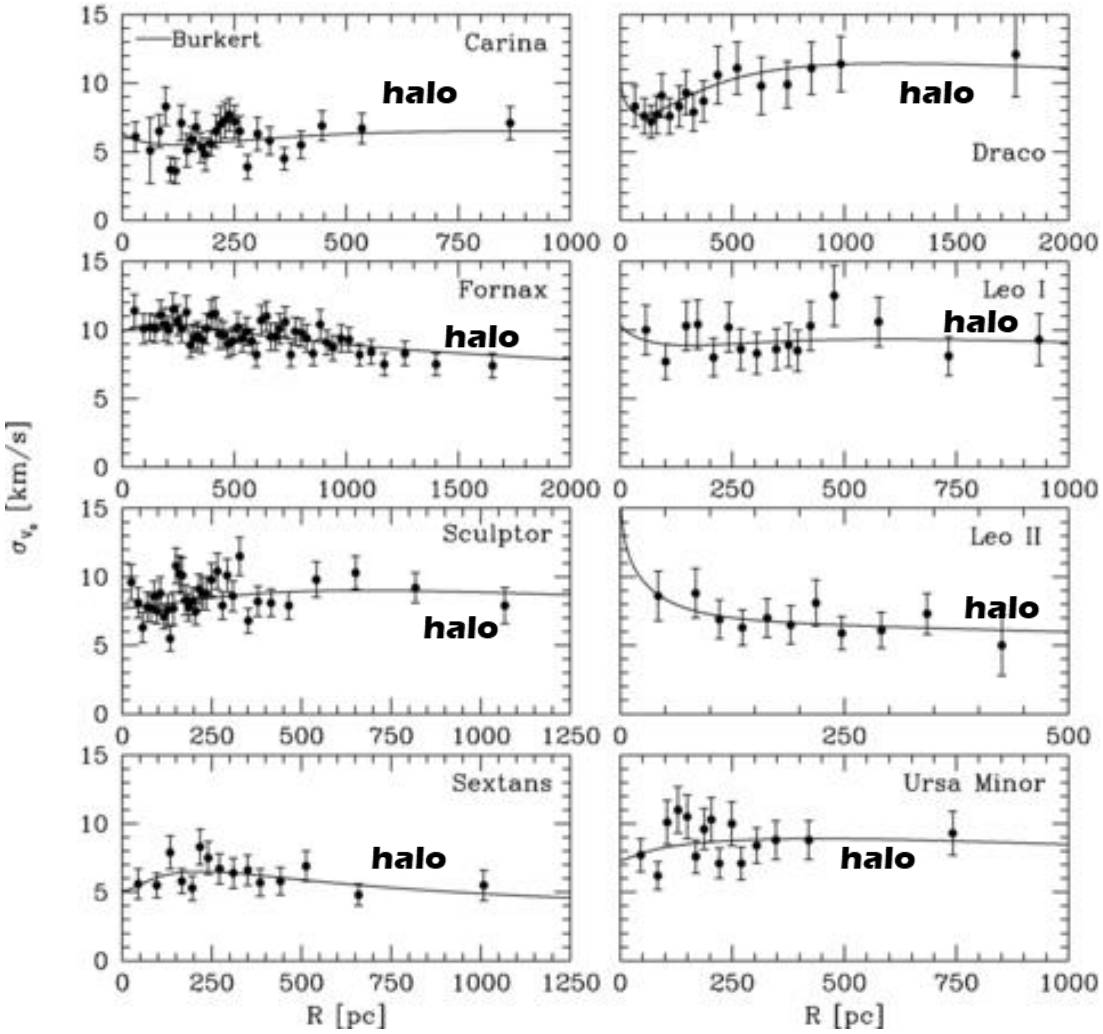
$V_b^2(y)/y = g_b$ baryonic component of g



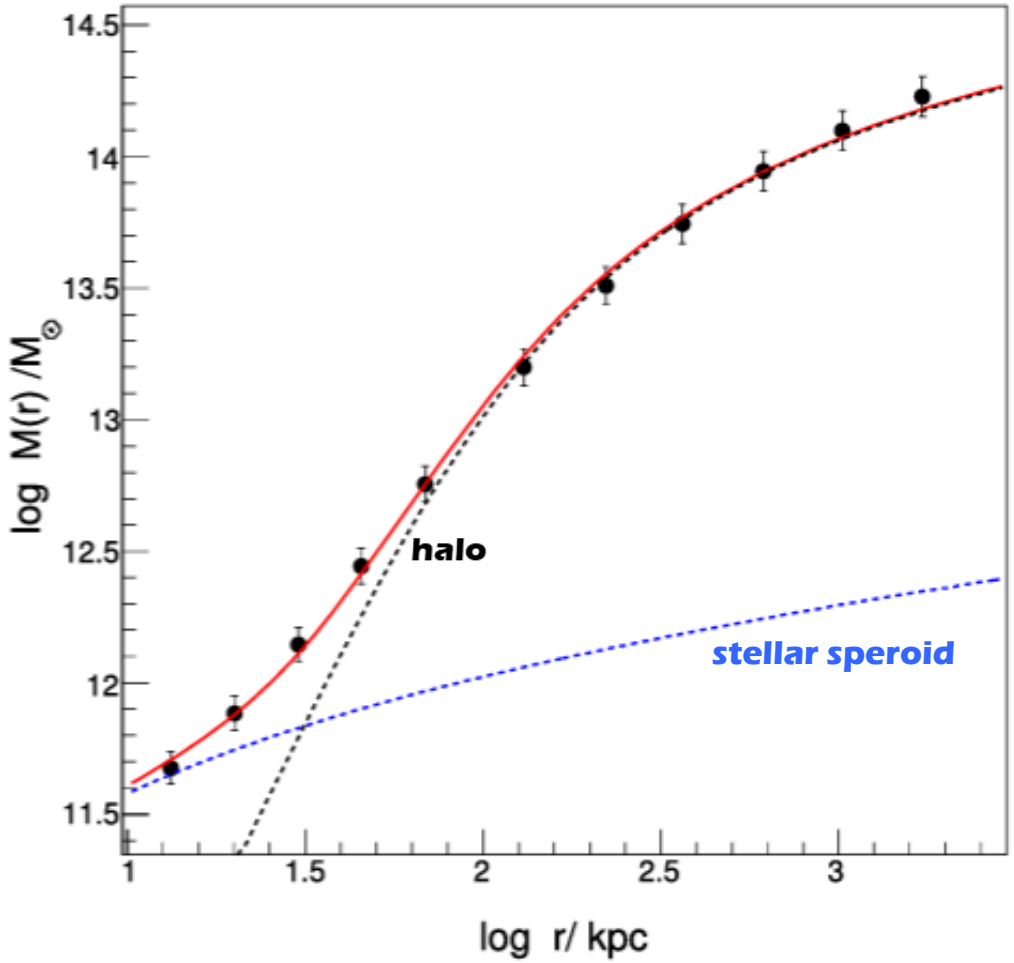


MASS MODELLING-2

Dwarf Ellipticals

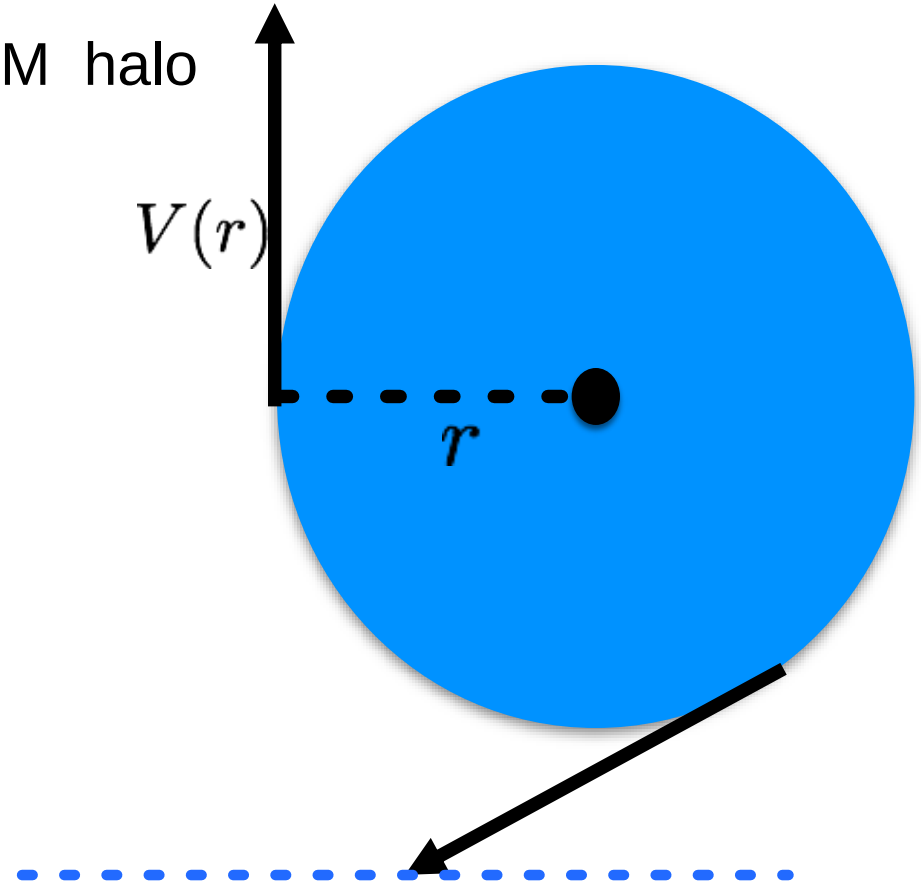


M 87



Gravitational acceleration Rotating systems

stellar disc bulge HI gaseous disc DM halo



Gravitational (radial) acceleration :

$$g(r) = \frac{V^2(r)}{r} = \left| -\frac{d\Phi}{dr} \right| = G\frac{M(r)}{r^2}$$

$$M(r) = M_d(r) + M_{bu}(r) + M_{HI}(r) + M_h(r)$$

Baryonic component :

$$g_b(r) = \frac{V_b^2(r)}{r} = \left| -\frac{d\Phi_b}{dr} \right| = G\frac{M_b(r)}{r^2}$$

$$M_b(r) = M_d(r) + M_{bu}(r) + M_{HI}(r)$$

$$V_b^2(r) = V_d^2(r) + V_{bu}^2(r) + V_{HI}^2(r)$$

DM and LM compactnesses

$M_D(R_D)$, R_D; $M_H(r_0)$, r_0

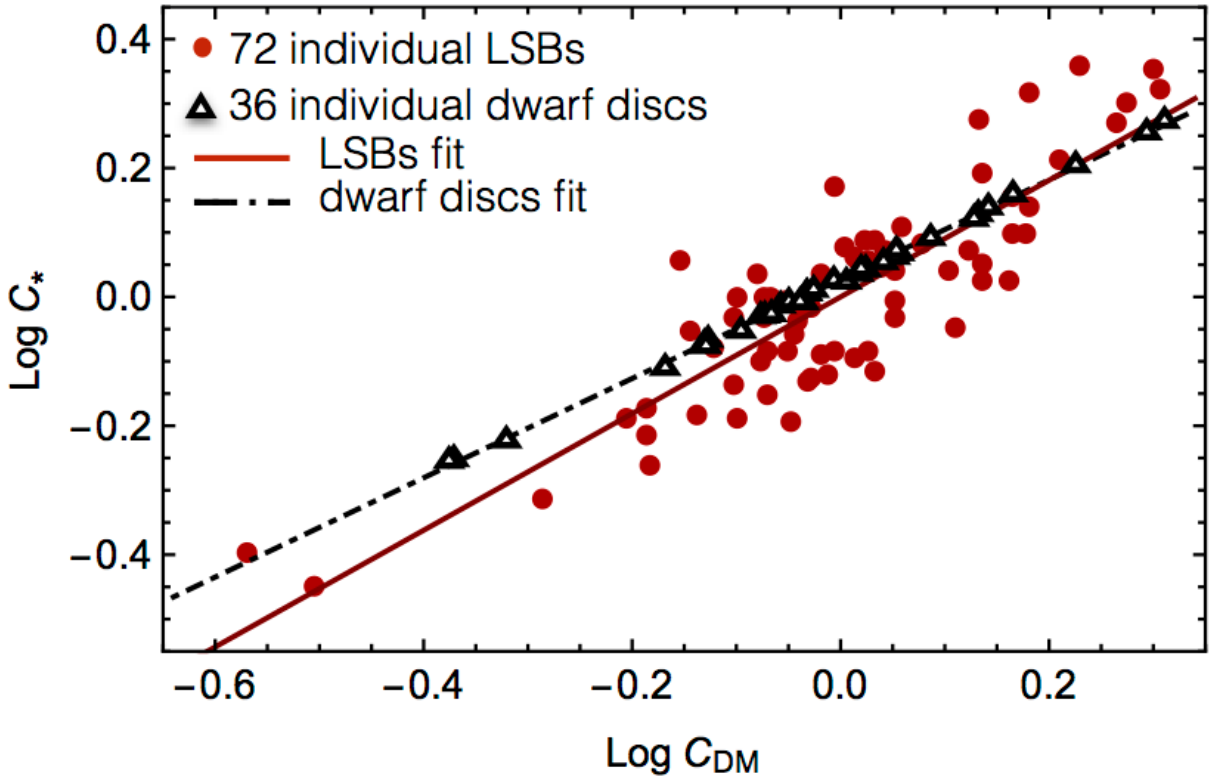
$$C_\star = \frac{(M_D(R_D)/R_D^2)}{<(M_D(R_D)/R_D^2)>}$$ same $M_D(R_D)$

$$C_{DM} = \frac{(M_H(r_0)/r_0^2)}{<(M_H(r_0)/r_0^2)>}$$ same $M_H(r_0)$

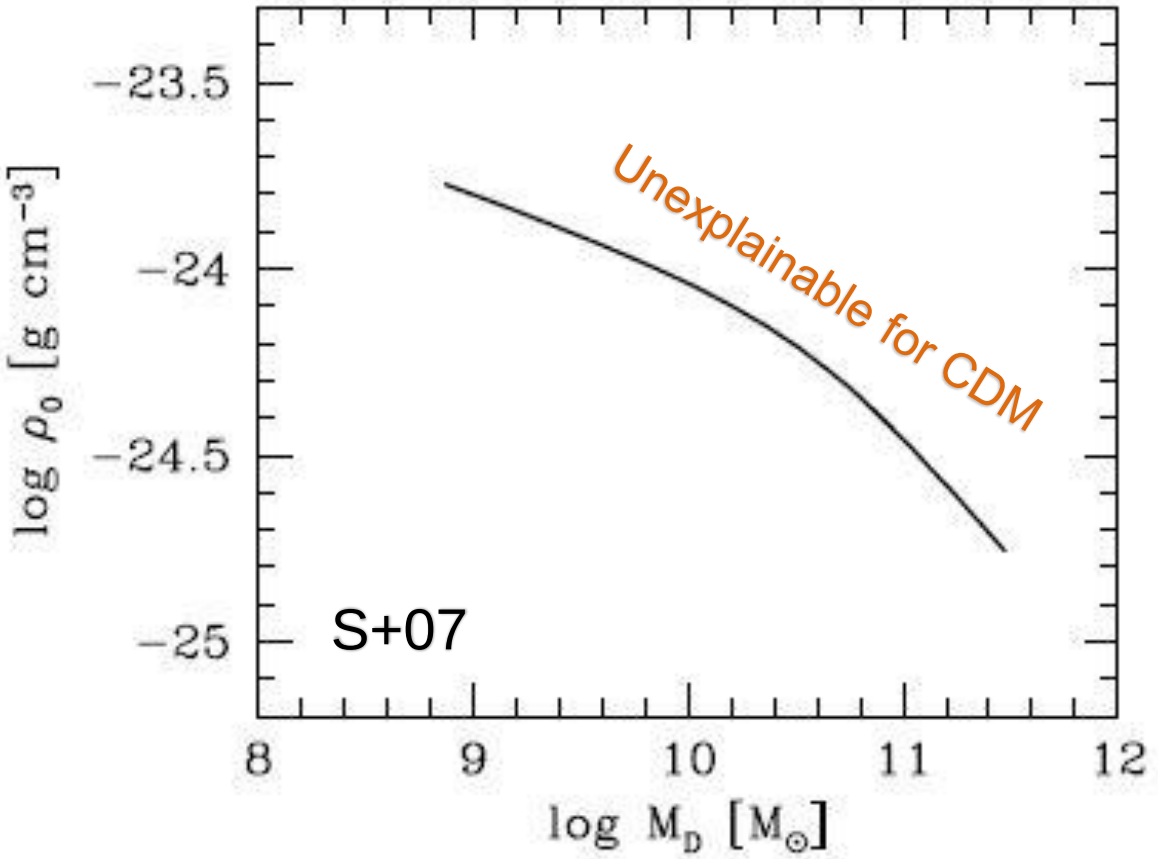
Formation of the stellar disks

Formation of the const density region in dark halos

$$Log\ C_* = 0.00 + 0.90\ Log\ C_{DM}$$



DM central density correlates with the disk mass



The Evolution of the Dark Matter Phenomenon

DMP(1980) *dark component in several Spirals*

DMP(1995) *dark component in all Spirals and in several galaxies of other Hubble types. Global DM and LM properties are linked.* 

DMP(2000) *collisionless cold dark matter halos: anomalies in several Spirals*

DMP(2010) *dark component in all galaxies out to virial radius. An inner region of constant density in objects of different L and T. Few parameters describe the mass distribution of 10^11 objects.*

DMP(2023) *The distributions of dark and luminous matter in galaxies result entangled and described by a wide and complex scenario.*