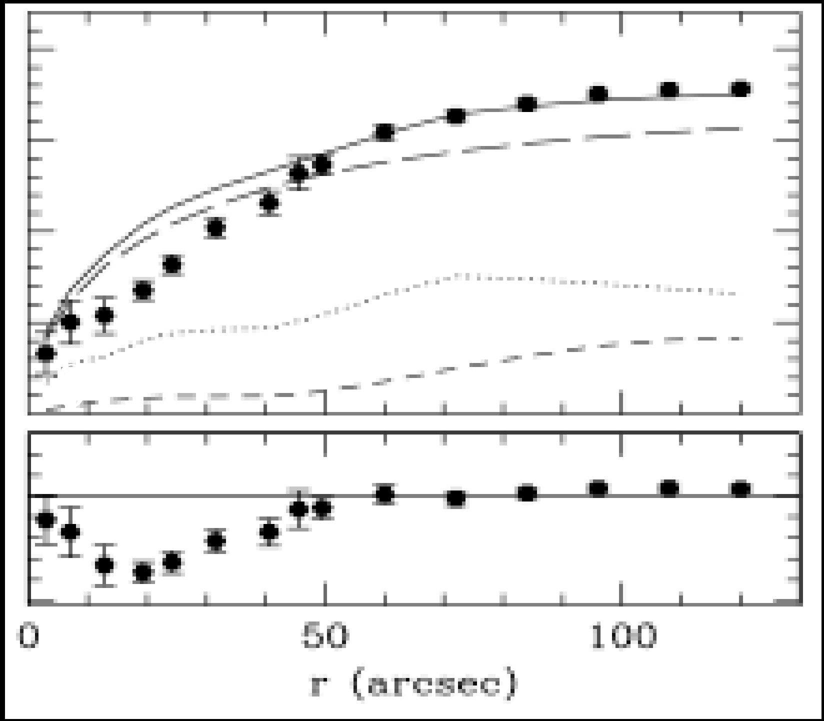
The cusp problem

- Simulations of clustering CDM halos (e.g. Diemand et al) predict a central cusp $\rho \propto r^{-\gamma}$, with $\gamma > 1$
- Feedback from the baryons makes the problem worse
- Angular momentum transfer from the bar not enough
- Bulk gas motions?
- Accretion of substructures?
- Other solutions?
- Hiding cusps by triaxiality of the halo? No

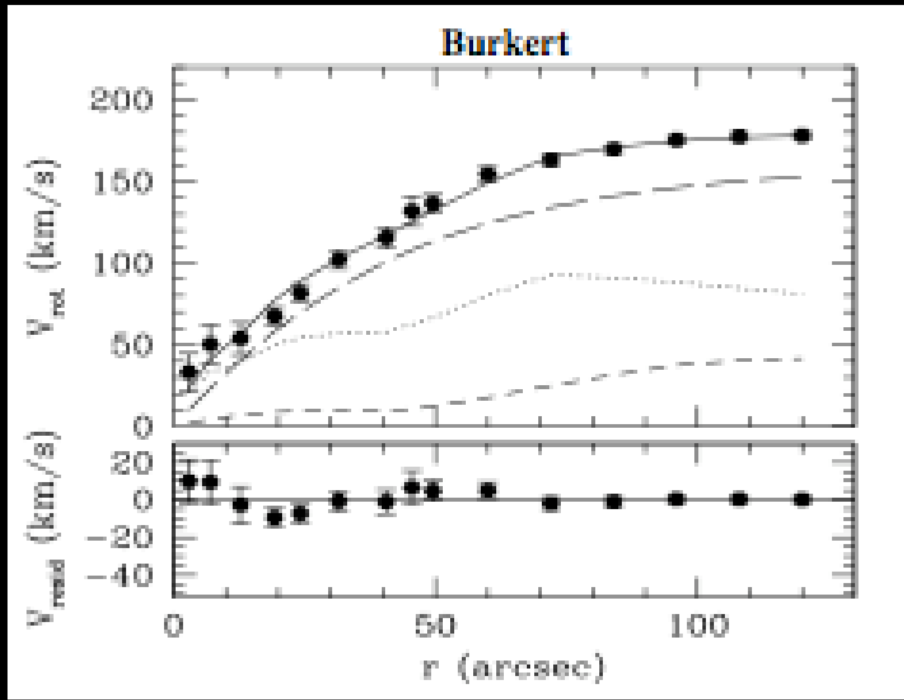


ESO79-G14 (Gentile et al. 2004)

The Burkert halo

- A halo with a central constant density core
- 2 parameters: a central density ρ_0 and a core radius r_0 at which the DM density reaches 1/4 of its central value
- Zero slope at the center and -3 log slope in the outskirts

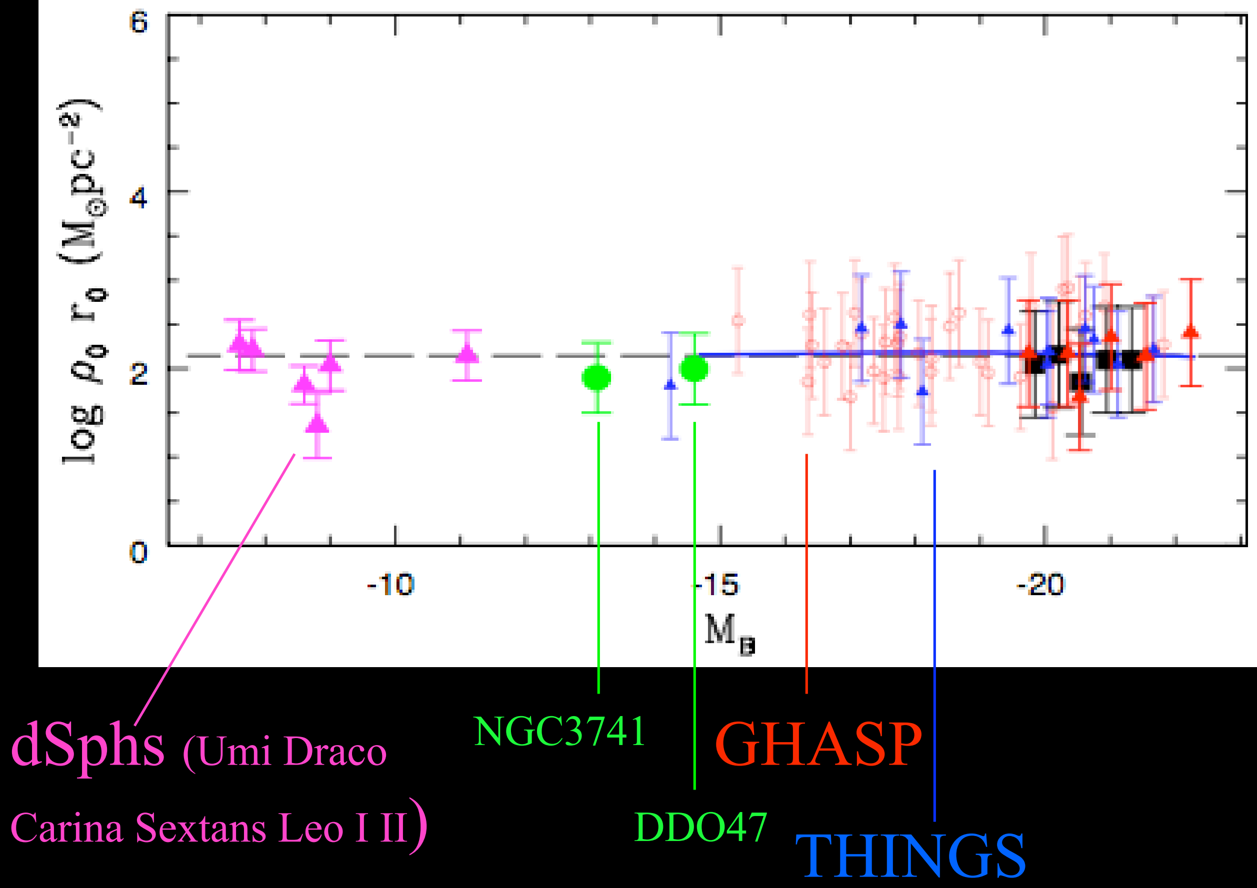
$$\rho_{dm} = \rho_0 r_0^3/[(r + r_0)(r^2 + r_0^2)]$$



A scaling relation for DM

A constant dark matter halo surface density in galaxies

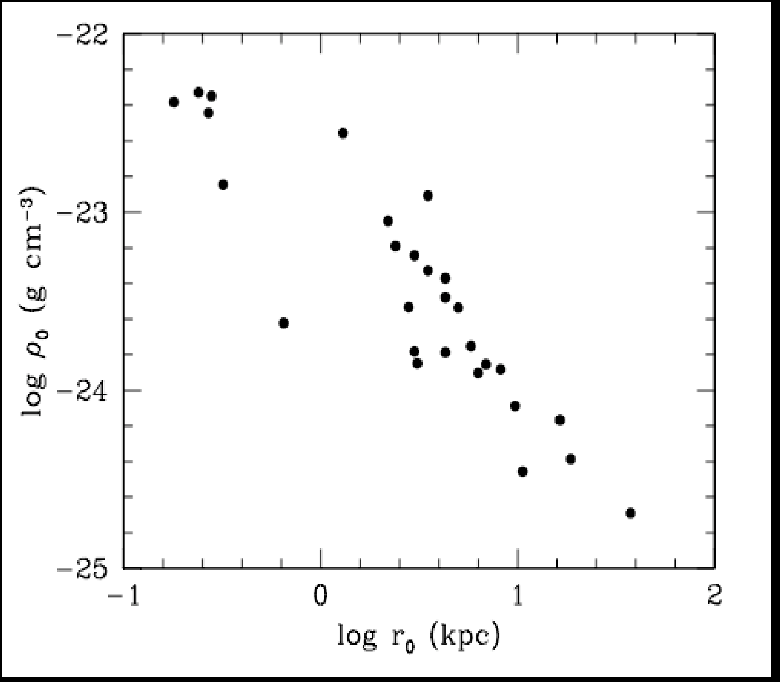
F. Donato[1*], G. Gentile[2,3], P. Salucci[4], C. Frigerio Martins[5], M. I. Wilkinson[6], G. Gilmore[7], E. K. Grebel[8], A. Koch[9], R. Wyse[10]



What does it mean?

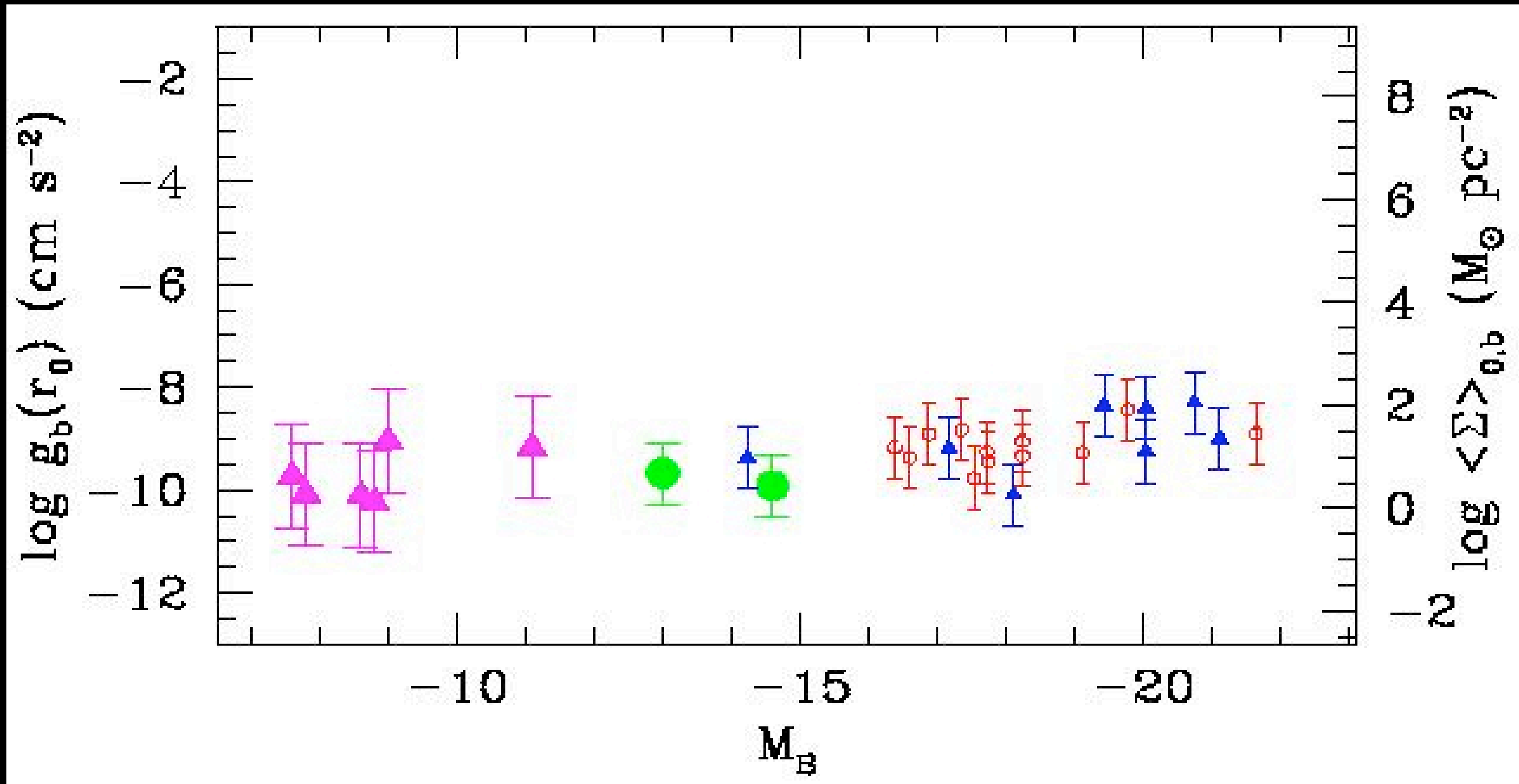
- The parameters are degenerate with the stellar M/L ratio but this is taken into account in the error bars: difficult to lower them without a better knowledge of stellar pops
- The product

  $\rho_0 r_0 = 141^{+82}_{-52}\ M_{\ast}/pc^2$
- The mean DM surface density inside $r_0 = 72^{+42}_{-27}\ M_{\ast}/pc^2$



- The gravity due to DM at $r_0 = 3.2^{+1.8}_{-1.2}\ 10^{-9}\ cm/s^2$
- Very intriguing… (see also Kormendy & Freeman 2004)

A similar relation for baryons!



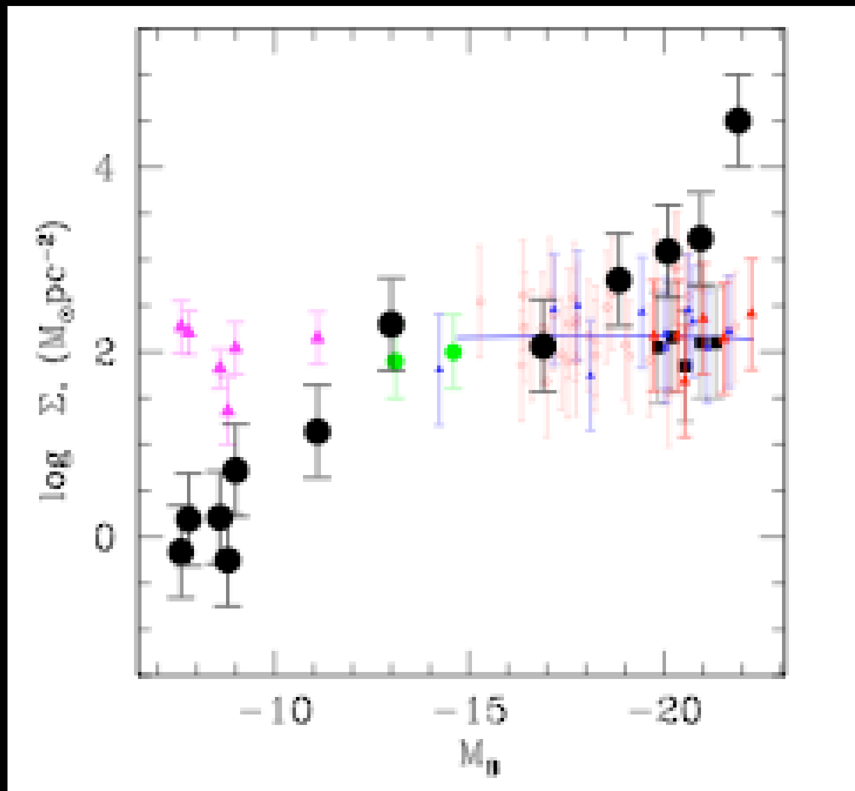
The gravity due to ***baryons*** at $r_0 = 5.7\ ^{+3.8}_{-2.8}\ 10^{-10}$ cm/s^2

or $\log g_b(r_0) = -9.24\ ^{+0.3}_{-0.22}$

Gentile, Famaey, Zhao & Salucci, Nature, 461, 627

What does it mean?

- The DM-to-baryonic ratio is universal within r_0
- It does not mean that the total ratio is universal
- It does not mean that the baryonic surface density is constant (misconception known as Freeman's law): the *central* surface density of baryons varies by 4 orders of magnitude

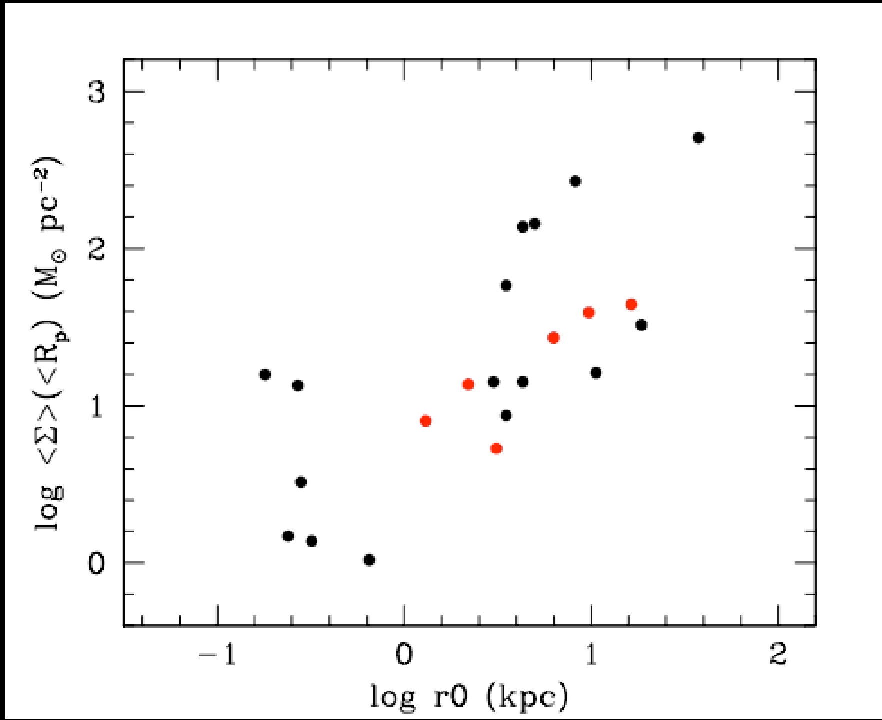


What does it mean?

- The larger r_0 of larger and more luminous galaxies compensate for their larger baryonic surface densities

- For a galaxy of a given « baryonic scale-length », the central baryonic surface density is ***correlated*** with r_0 and ***anti-correlated*** with the central DM volume density ρ_0

- Unknown fine-tuned process in galaxy formation?



Rp = maximum of the baryonic rot curve

An example

UGC 9179

Vc = 90 km/s

Baryonic surf. den. within Rp

= 8.7 M_{*} / pc^2

r_0= 3.5 kpc => log $g_b(r_0)$ = -9.27

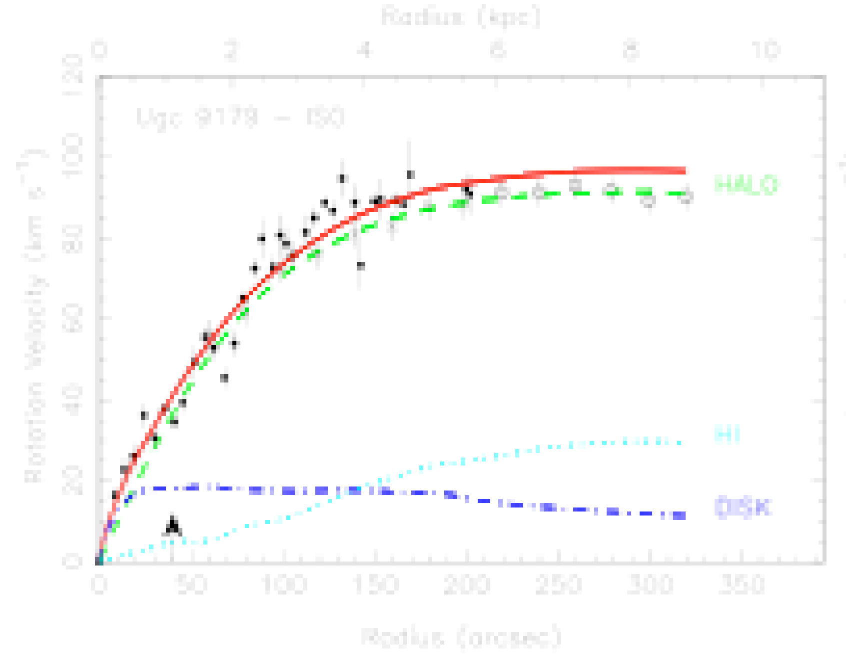
UGC 7323

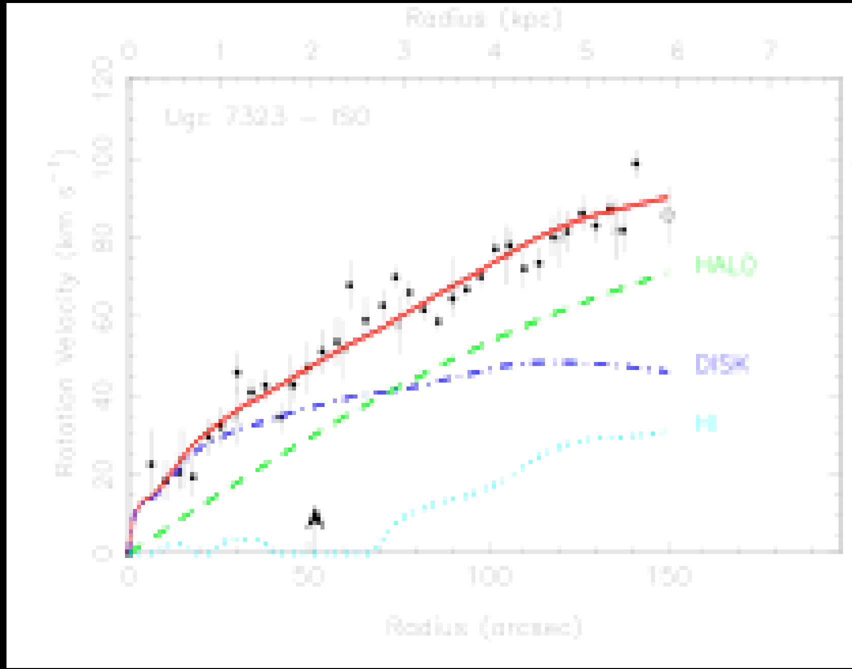
Vc = 90 km/s

Baryonic surf. den. within Rp

= 38.9 M_{*} / pc^2

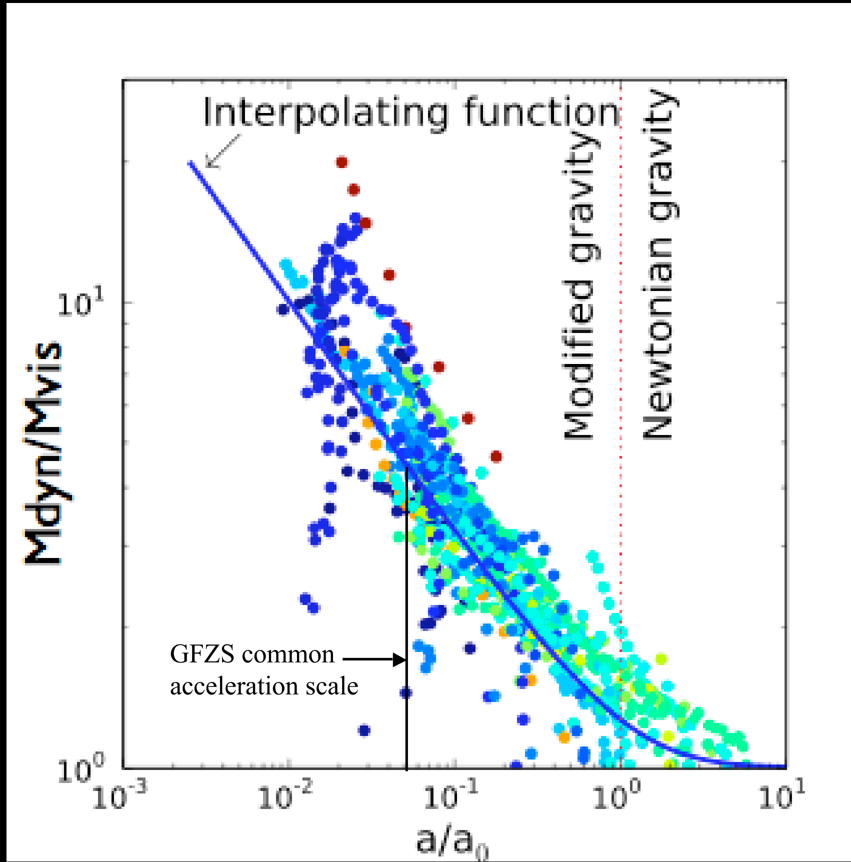
r_0= 9.7 kpc => log $g_b(r_0)$ = -9.05





Mass Discrepancy vs Acceleration

- At r_0, the acceleration from the DM is always the same: it is a natural consequence of the Mass Discrepancy-Acceleration relation that the acceleration from baryons is then the same and vice-versa



McGaugh 2004; Tiret & Combes 2008

a_0= 1.2 x 10^{-8} cm/s^2

MOND

$\mu\,(g/a_0)\,g = g_{\mathrm{N\,bar}}$ where $a_0 \sim cH_0 \sim c\Lambda^{1/2}$

$\mu\,(V^2/ra_0)\,V^2/r = g_{\mathrm{N\,bar}}$

with $\mu(x) = x$ for $x \ll 1$

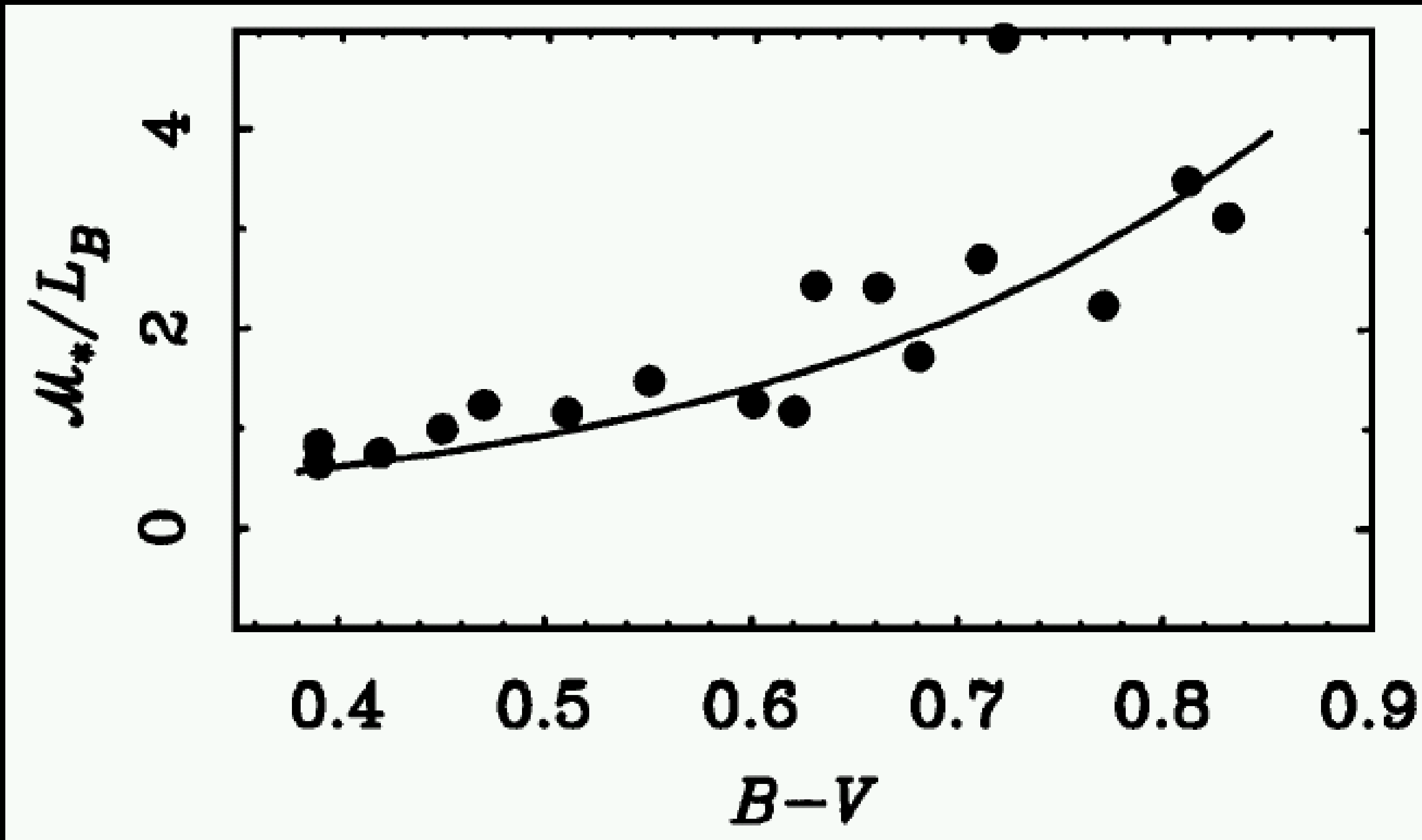
$\mu(x) = 1$ for $x \gg 1$

MOND

- OK for the Milky Way TVC (Famaey & Binney 2005, McGaugh 2008)
- No cusp problem + explains the RC wiggles following the baryons
- Tully-Fisher relation (observed with small scatter): $V_\infty^4 = GM_{bar}a_0$
- Predicts that the discrepancy always appear at $V^2/r \sim a_0$
  => in LSB where $\Sigma << a_0/G$
- Explains why young Tidal Dwarf Galaxies exhibit a Mass Discrepancy in NGC 5291 (Bournaud et al. 2007, Gentile et al. 2007)
- Predicts the correct order of magnitude for the local galactic escape speed (Famaey, Bruneton & Zhao 2007)

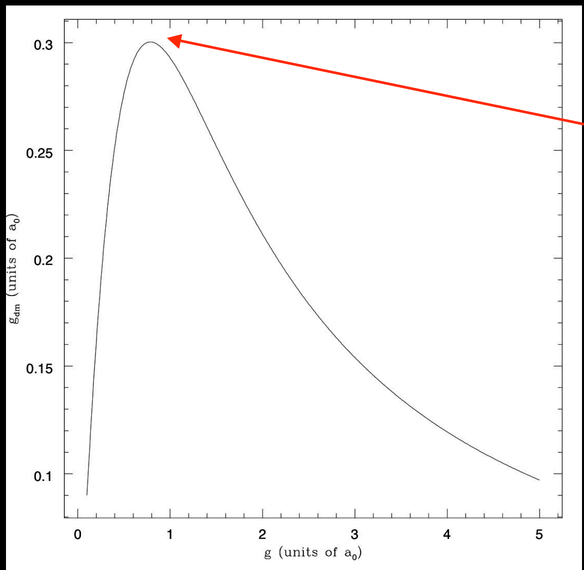
  - Could be:
    a) fundamental property of DM (e.g. Blanchet, Zhao)
    b) modification of « inertia » (Milgrom 1994)
    c) modification of gravity
    d) all of the above

MOND



MOND => acceleration due to the « dark matter » is :

$g_{dm} = [1 - \mu]\, g$ with typically a *maximum* acceleration of the order of $0.3a_0$ (depends on μ)

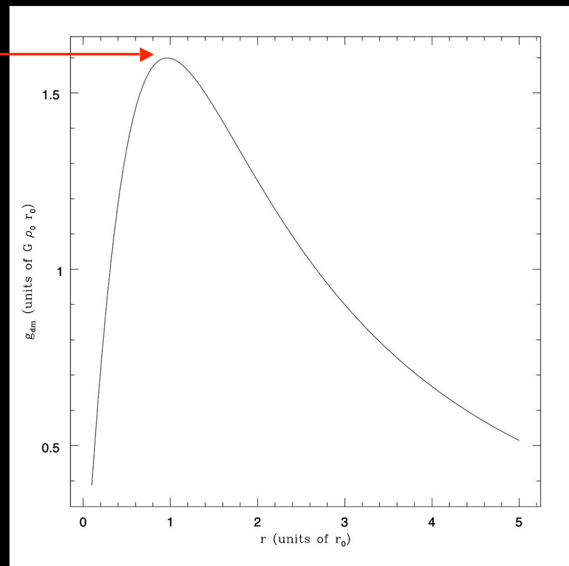


1.6 G $\rho_0 r_0$

= $0.3a_0$

$\rho_0 r_0$ =130 $M_* pc^{-2}$

(log $\rho_0 r_0$ = 2.1)



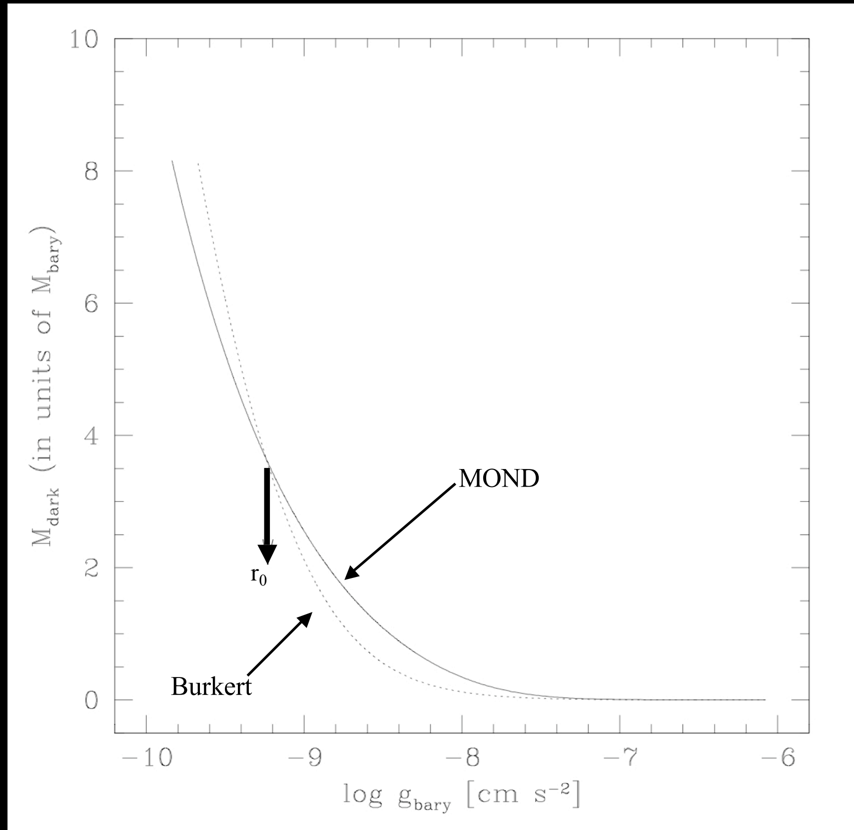
Milgrom

Burkert

- For a Burkert halo to produce the same maximum acceleration as MOND, one gets naturally the Donato scale **$g_{DM}(r_0) \sim 3 \times 10^{-9}$ cm/s^2**

- However, the MOND « DM » profile ≠ the Burkert profile, so this doesn't happen at the same baryonic gravity

- Fixing a Burkert halo such that the maximum acceleration due to DM happens at the GFZS scale **$g_{bar}(r_0) \sim 6 \times 10^{-10}$ cm/s^2** and such that the MOND mass discrepancy is reproduced at r_0 yields a very similar profile to the MOND one



Conclusion

- The core radius in any galaxy = the radius where the mass discrepancy is of the order of 5
- This always happens at the same gravity produced by the baryonic component $g_{bar} \sim 6 \times 10^{-10}$ cm/s^2
- This is linked with the success of the MOND phenomenology on galaxy scales
- The MOND phenomonelogy has to be understood (one way or the other: baryon-DM intreractions, modified gravity) in order to get a better understanding of the dark sector in galaxies