Probing Gravity in the Low Acceleration Regime with Globular Clusters

By

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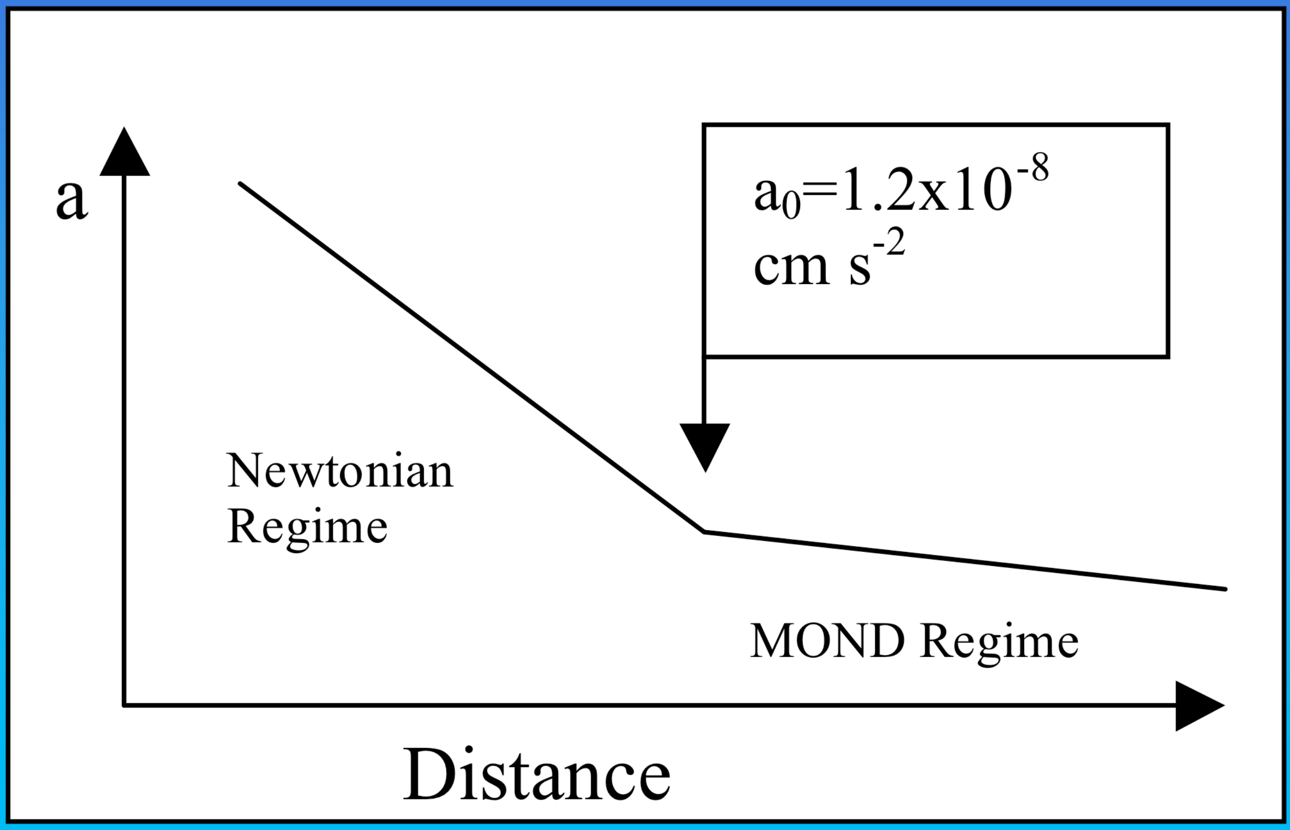
The idea of this study sparked from the following facts:

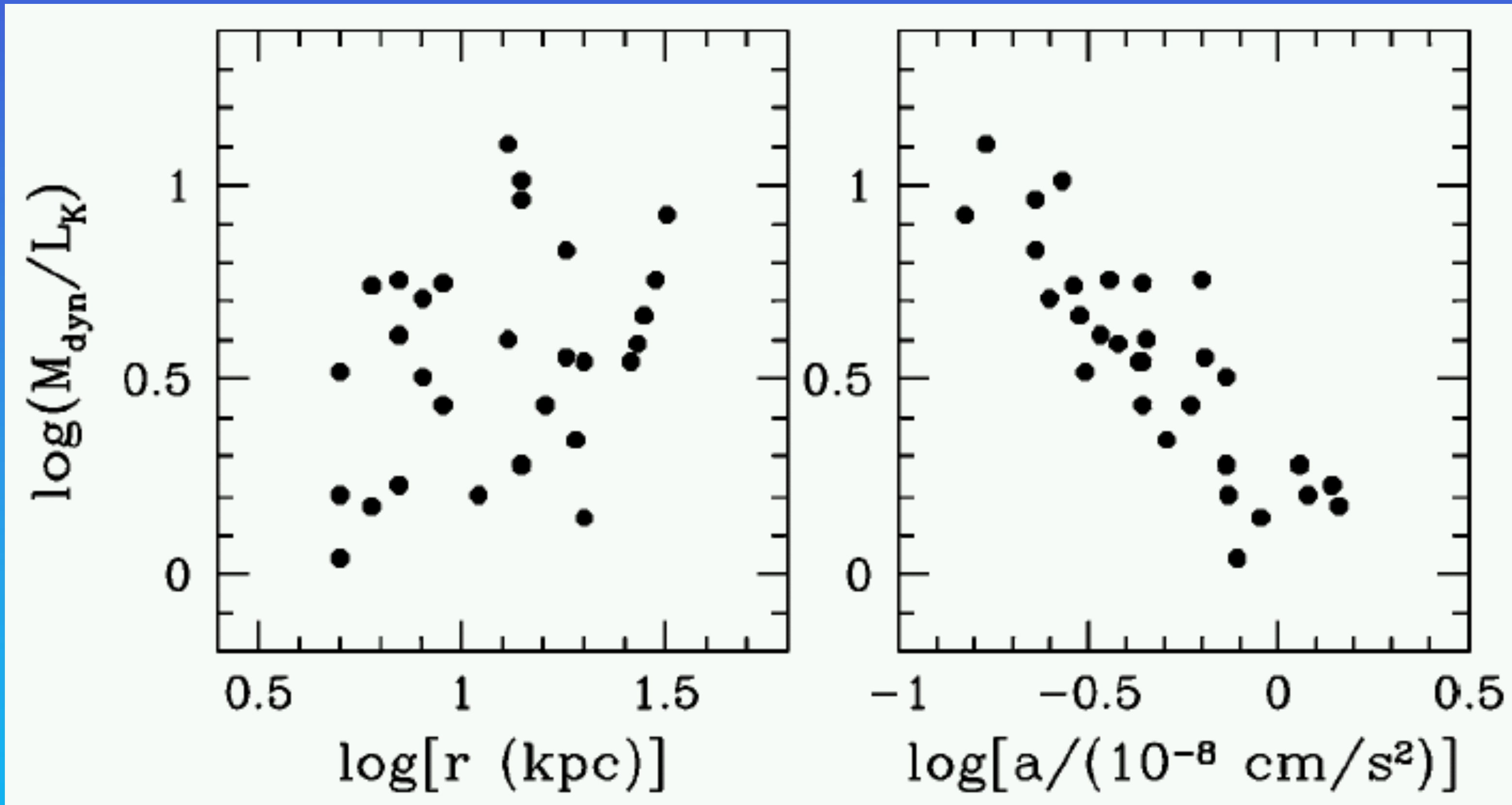
The alleged effects of dark matter appears *when and only when* the acceleration of gravity goes below ~10^{-8} cm s^{-2}, as computed considering only baryons (e.g., Binney 2004)

MOND succeeds in explaining observations without the needs for dark matter, with less free parameters and at least as well as dark-matter based models.

Proposed by M. Milgrom in 1983, MOND introduces a new constant of physics: a_0



Distance doesn't matter!



What matters is the strength of the acceleration, not distance/size of objects (though for any given object low accelerations are reached at correspondingly large distances).

Few more facts:

- When applied to galaxies, dark matter and MOND provide *alternative but generally indistinguishable* descriptions of the data.

- These two alternatives can be differentiate studying the dynamics of objects UNQUESTIONABLY free from the effects of dark-matter.

- For instance, the dynamic of objects in a laboratory IS NOT affected by dark matter. However, the strong gravitation field on the earth makes it difficult to probe accelerations <10^{-8} cm s^{-2}.

There is one astrophysical option: Globular Clusters

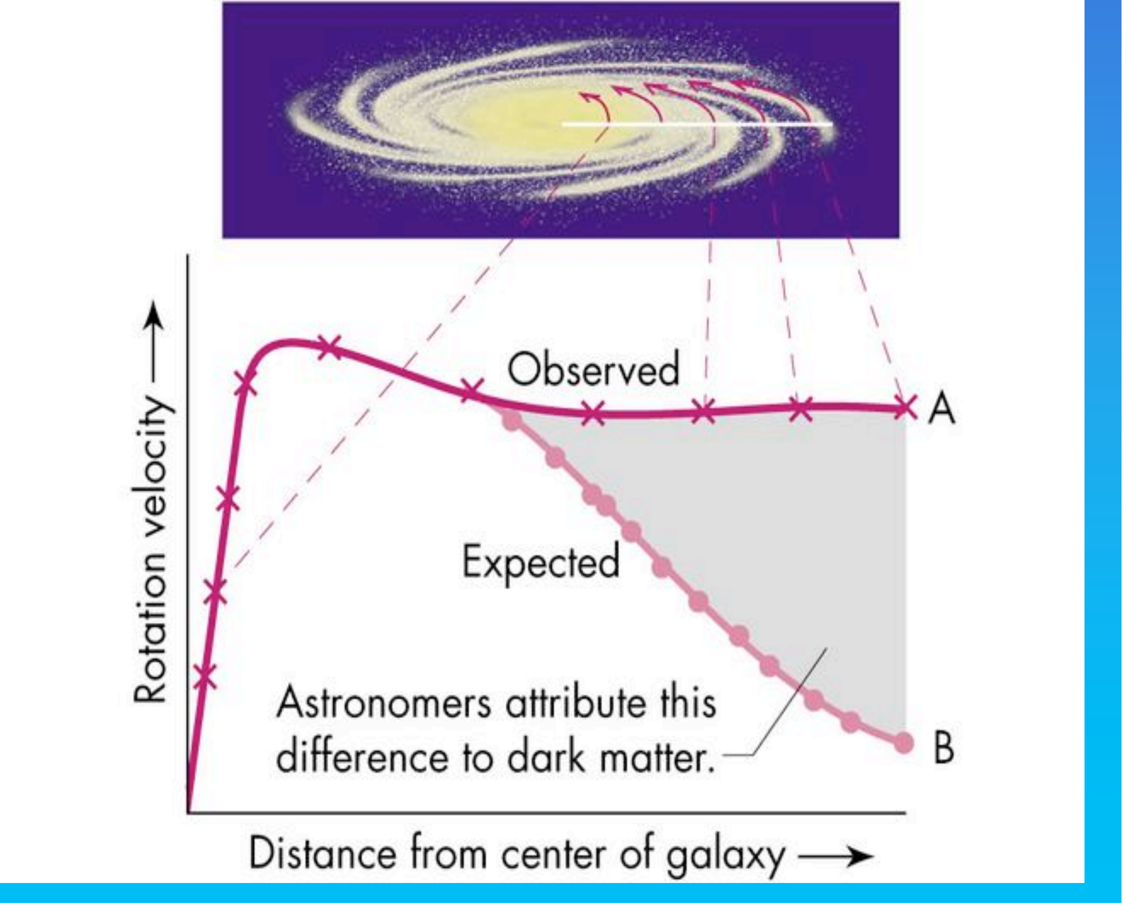
GCs are believed to be free from large amount of Dark Matter for various reasons:

- dark matter, being non-collisional, does not form compact structures.
- Luminous and dynamical masses of GCs are in good agreement.
- Tidal stripping should effectively remove any possible dark-matter halo surrounding GCs.
- At most, GCs are filled by the dark matter of the galactic halo. Dynamically negligible for such small structures.

Therefore: stars in GCs should follow Newtonian dynamics down to whatever weak acceleration

To verify whether this is the case, we started a program to study the dynamics of the external part of globular cluster.

Novelty: we probe the same accelerations of the flat part of galaxies rotation curves.

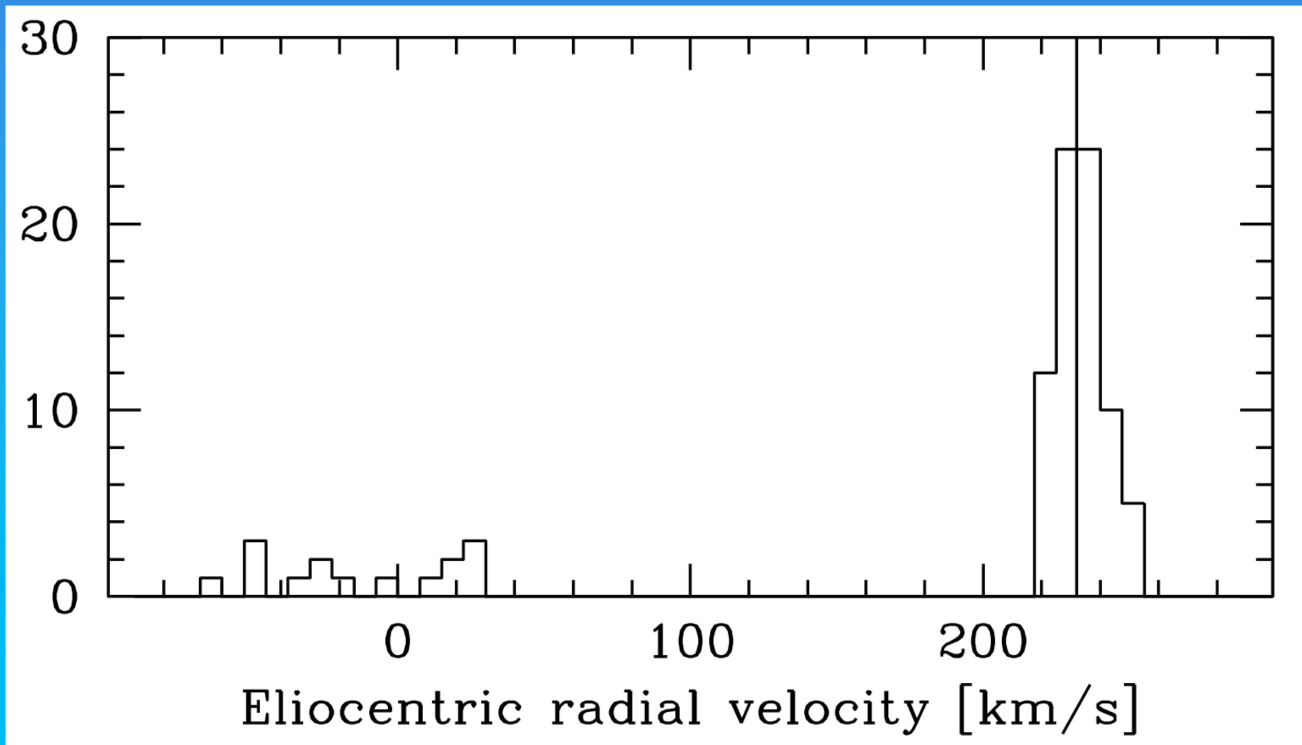


So far, results obtained for:

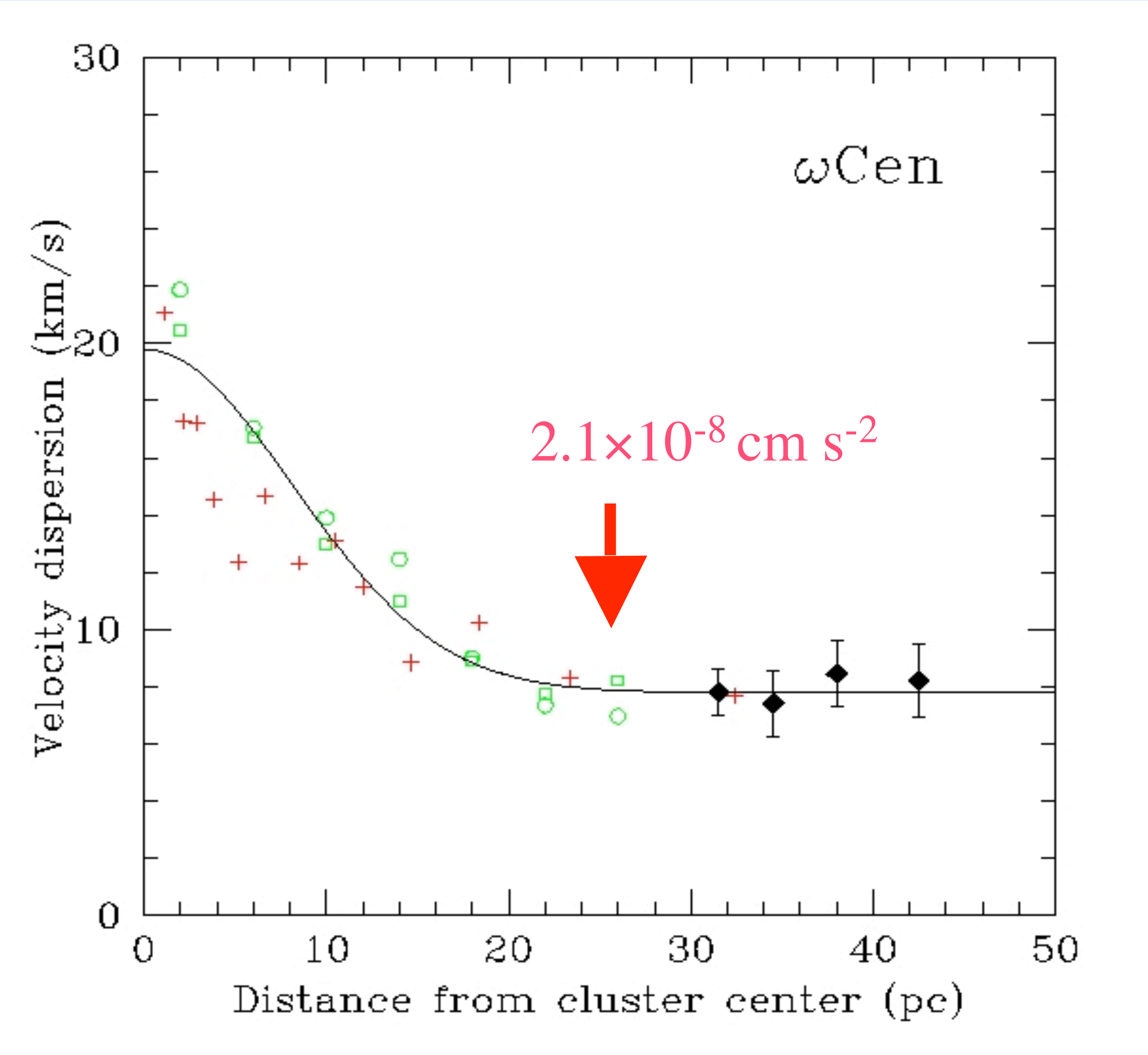
- ω Centauri: selected because of proper motion data
- M15: data available from the literature
- NGC 6171: Selected because of position relative to the Milky Way

ω Centauri

- Largest globular cluster known with $M > 10^6$ solar masses and tidal radius 70 pc.
- Observations of 90 stars at r>30 pc obtained with VLT + UVES.
- Radial velocity accuracy better than 1km/s.
- Based on radial velocity, 75 stars found to be members.



ω Centauri: velocity dispersion constant at large radii.

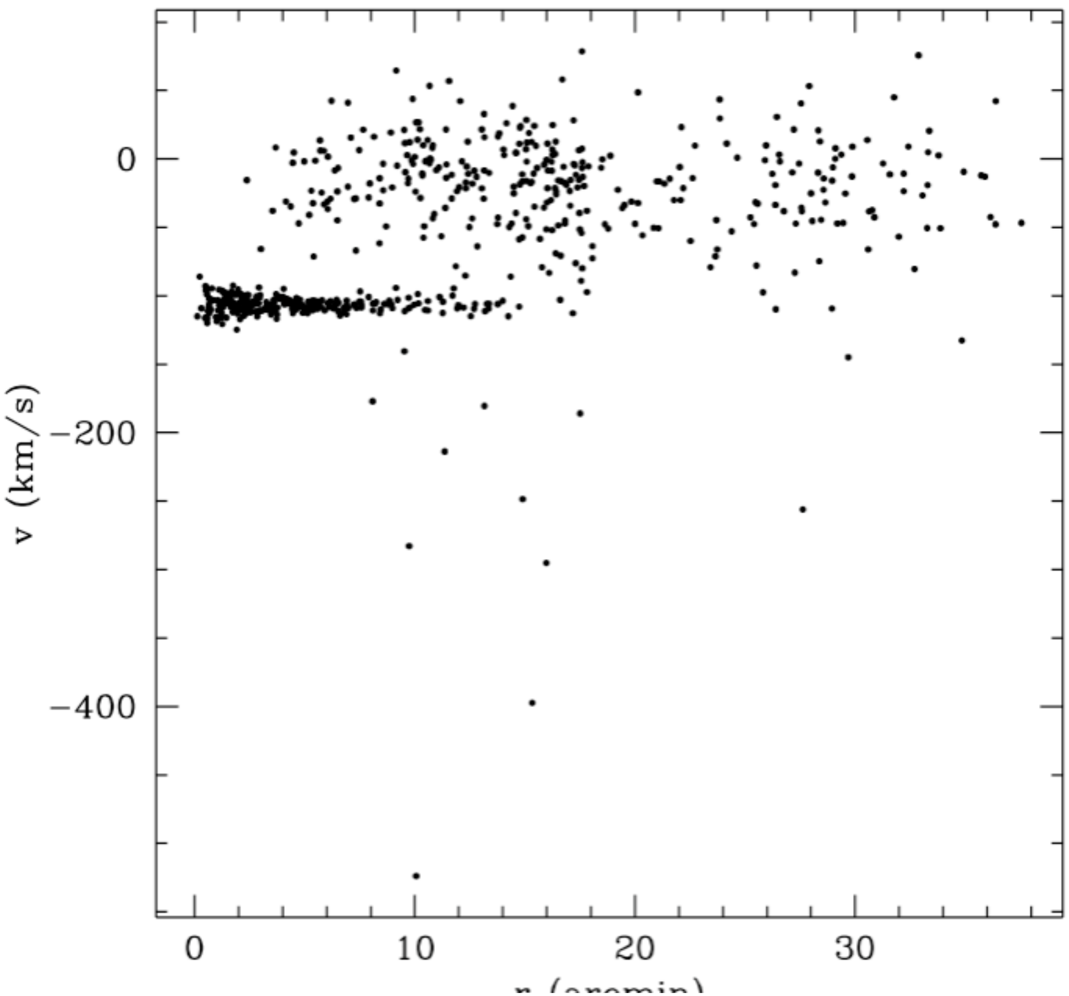


Milky Way external Field for $M=10^{11}M_{sun}$:

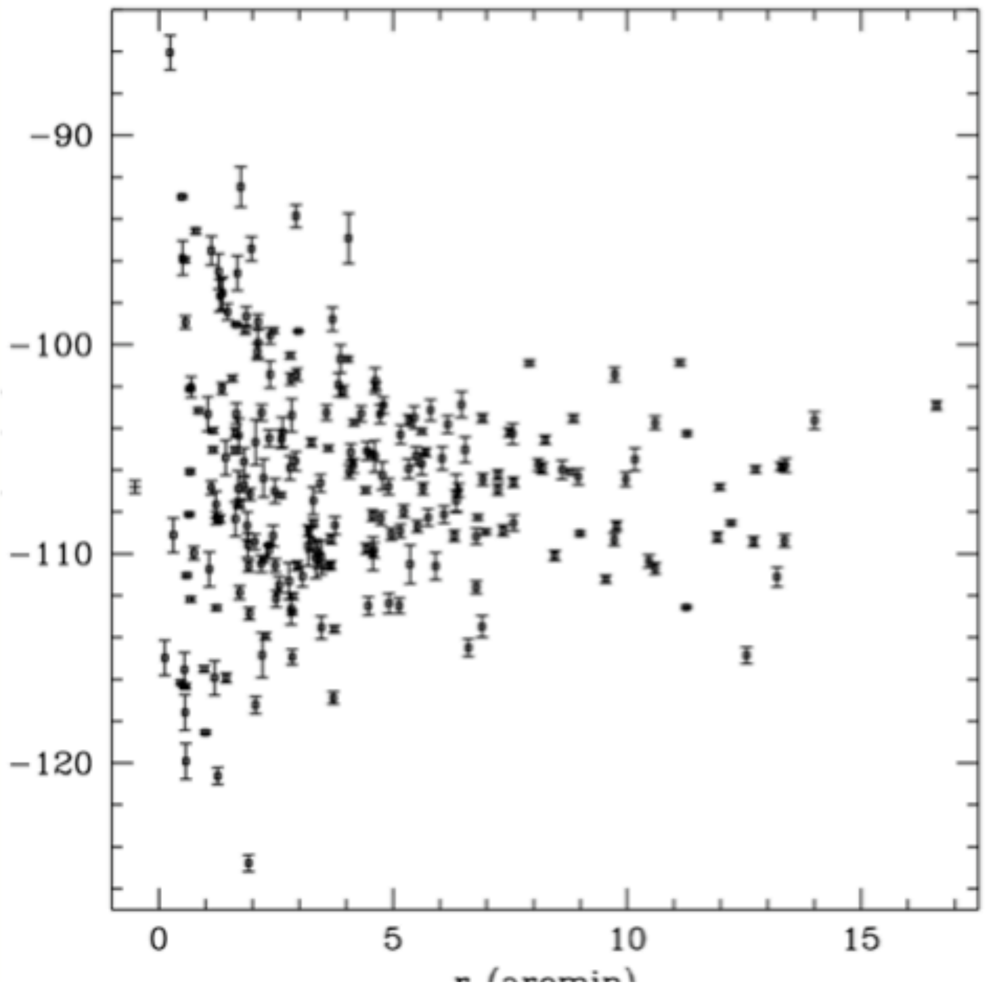
$GM/r^2=3.6x10^{-8}$ cm s^{-2}

M 15 (From data by Drukier et al 1998)

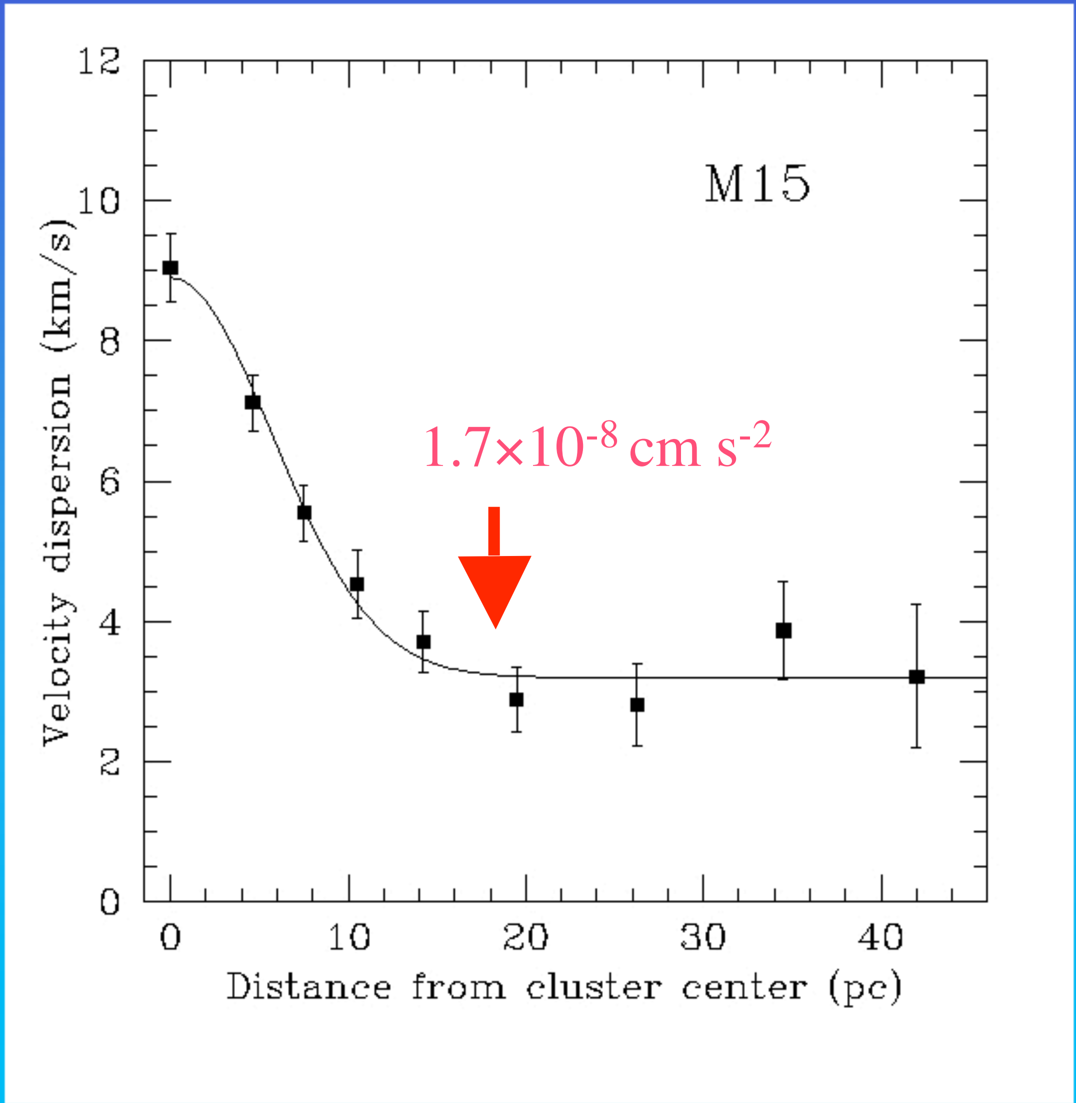
All data



230 Members

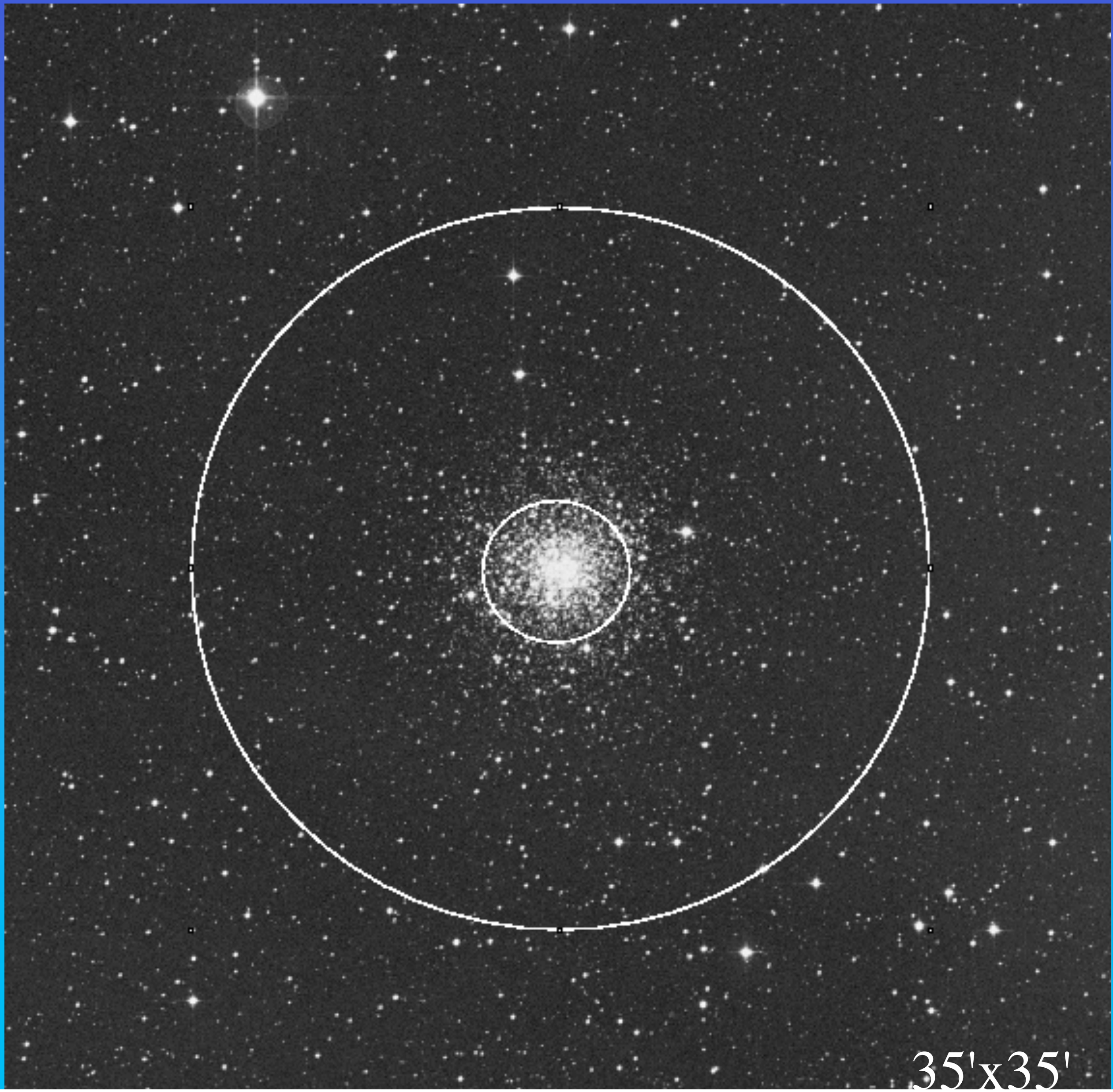


M 15 confirms what found for ω Cen



Milky Way external field =1.4x10^{-8} cm s^{-2}

NGC 6171



VLT + FLAMES
Multi-object fiber spectrograph

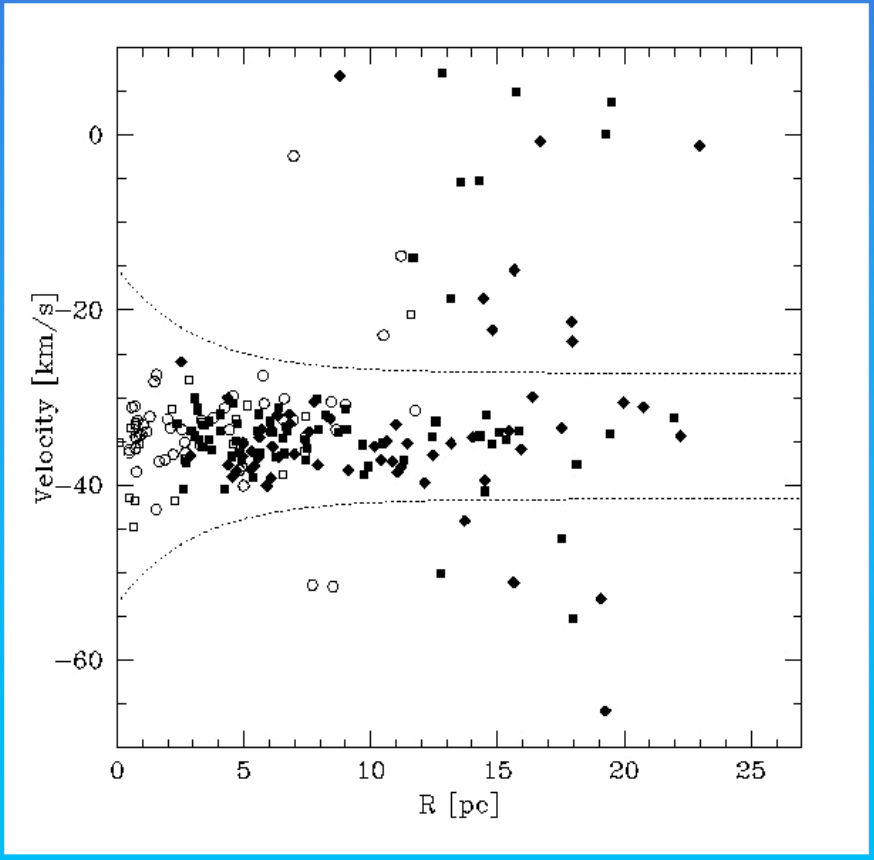
170 stars selected based on HR diagram

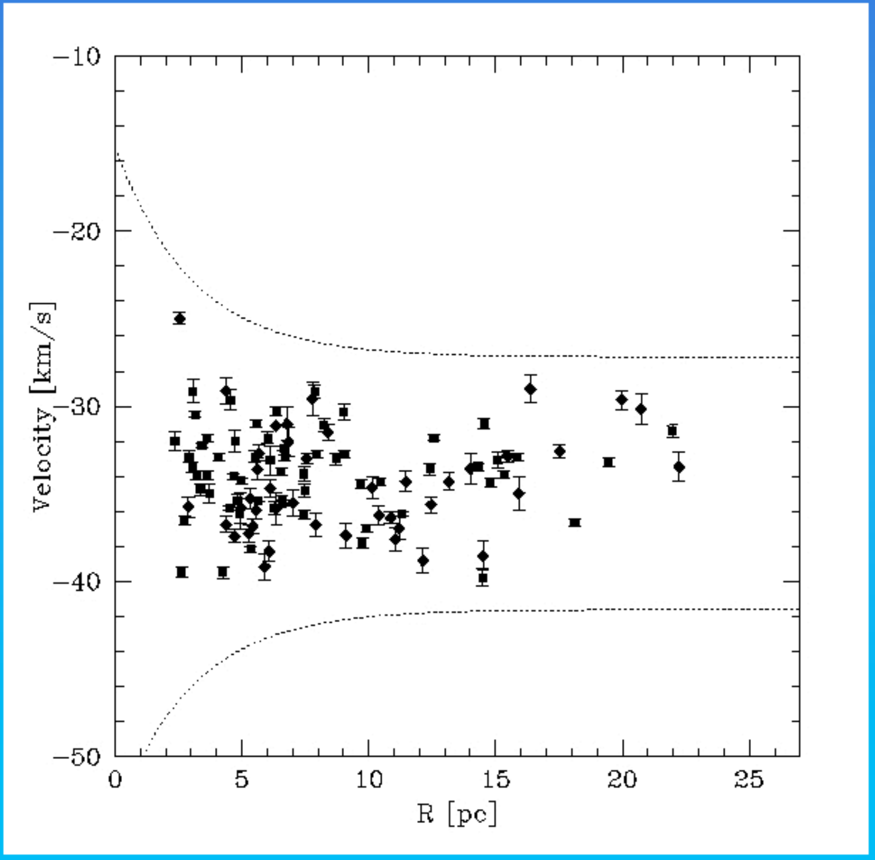
Stars located between 6 and 23 pc from center
Still inside the tidal radius

Spectra cover $4225<\lambda<6345$ Å, R~ 26000.

NGC 6171: 131 stars with radial velocity accuracy better than 1.25 km/s

Also available 75 velocities from Piateck et al. 1994



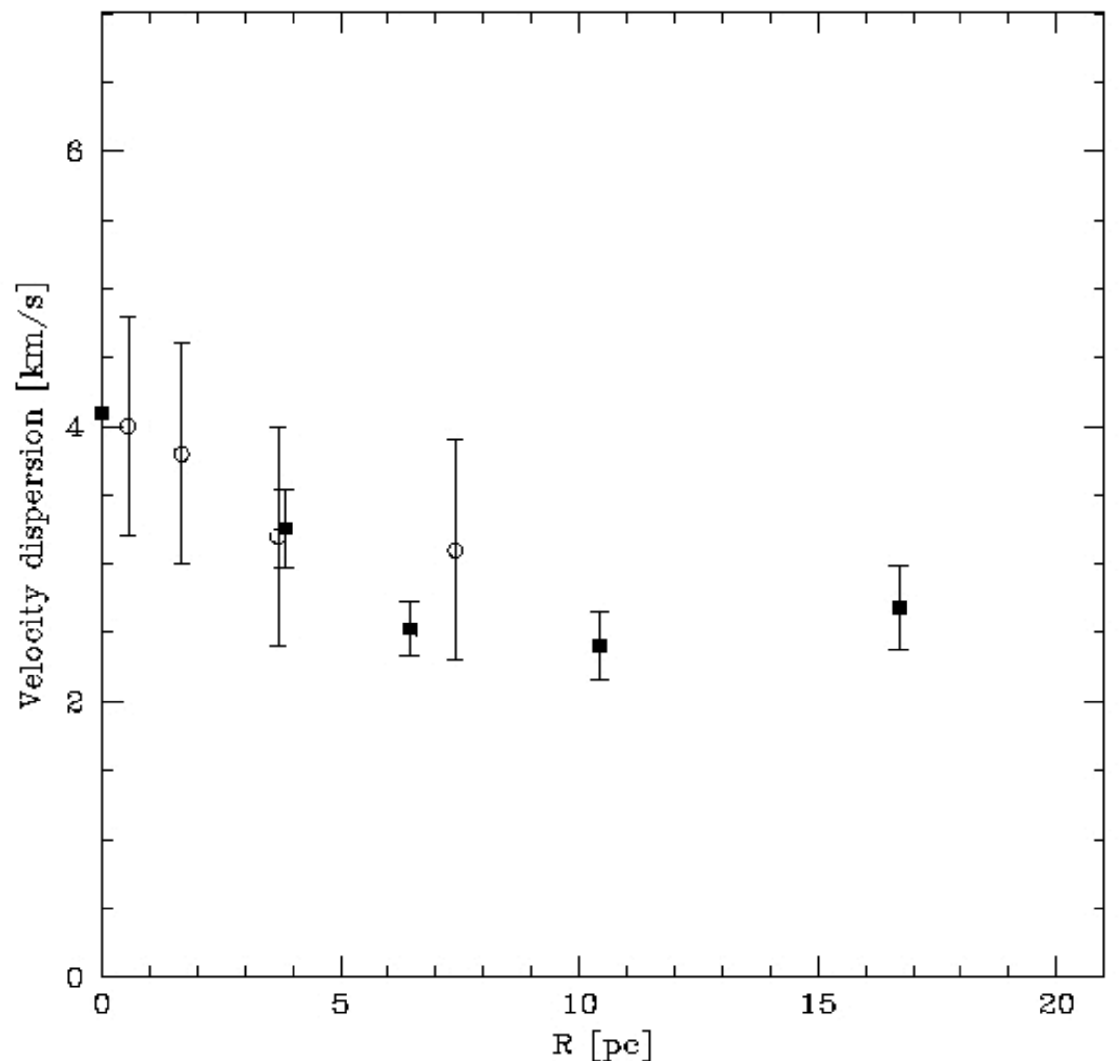


Dispersion in agreement with Piateck et al. 1994 values

In Total: 206 stars

Solid symbols:
Our VLT data

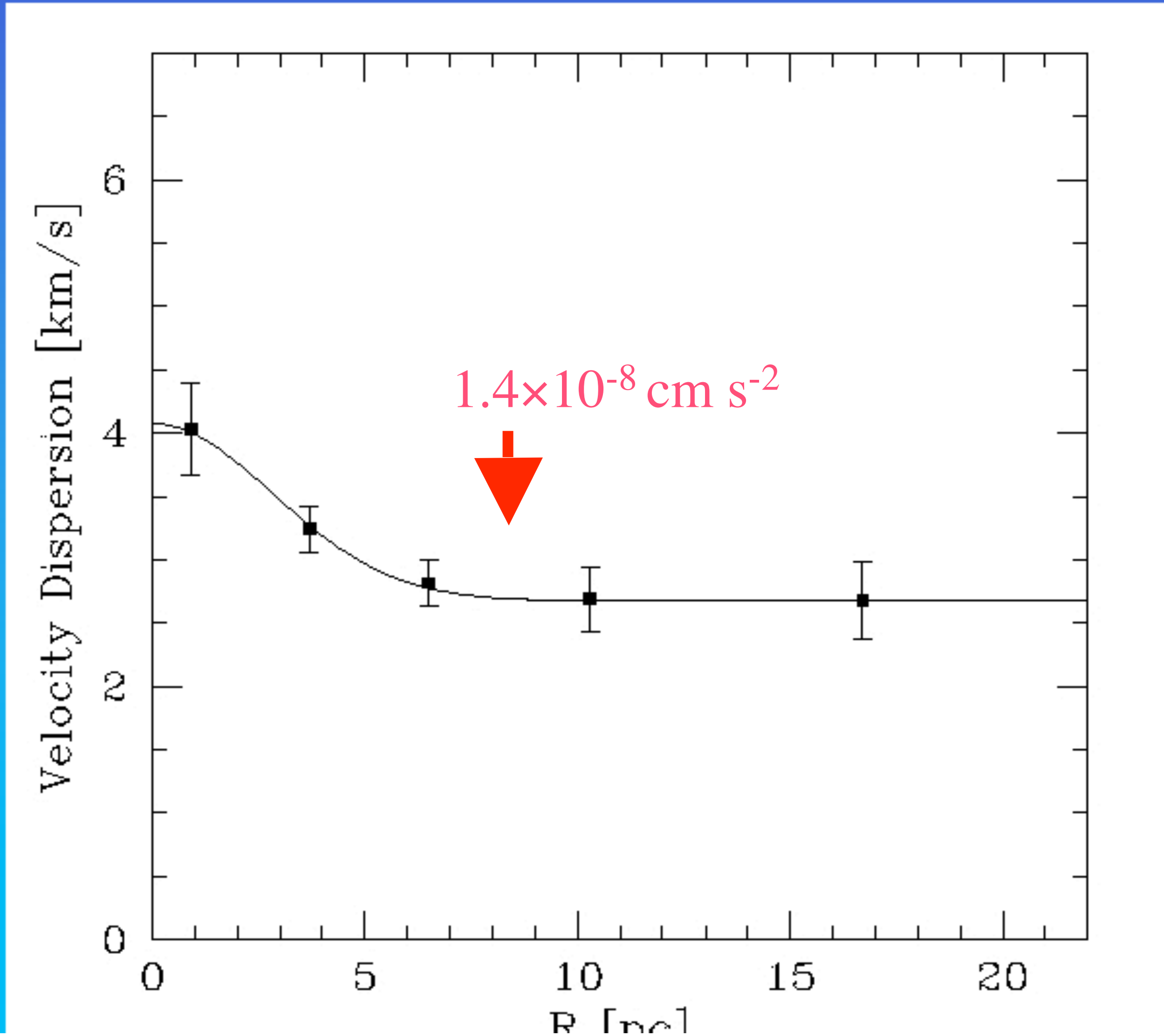
Open symbol:
Drukier et al 1994



Also in NGC 6171 the velocity dispersion profile flattens out at large radii

All data together
206 stars

Milky Way external field =1.4x10^{-8} cm s^{-2}



Global result:

Dispersion profile of globular clusters found to be flat at large radii in 3 out of 3 clusters studied

Assuming M/L=1, flattening occurs at similar accelerations (the same within uncertainties)

M15	$1.7 \pm 0.6 \times 10^{-8}$ cm s^{-2}	Average 1.78 ± 0.4
ω Cen	$2.1 \pm 0.5 \times 10^{-8}$ cm s^{-2}	
NGC 6171	$1.4 \pm 0.6 \times 10^{-8}$ cm s^{-2}	

Classical explanation based on tidal heating are less and less viable.

Results consistent with MOND expectations 1.2×10^{-8} cm s^{-2}

Omega Cen and NGC 6171 interesting because total field > a_0

Milgrom claims that MOND effects appear when and only when the TOTAL field is < a_0.

Our result seems to disagree with Milgrom claim.

If confirmed, then experiment within the solar system and in particular on the earth should probe MOND.

Future developments:

More FLAMES+VLT data have be collected on August 2005 in order to enlarge the number of cluster studied.

Our target is to have a sample of 10 clusters

However

I warmly invite everybody to perform independently similar observation to confirm the flattening of the dispersion profile.
If confirmed:

- non-baryonic dark matter gone once and far all

- a new theory of gravity to be found.