Is there really such a thing as dark matter?

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“We habitually act upon hypotheses, but not precisely as we act upon what we consider certainties; for when we act upon an hypothesis we keep our eyes open for fresh evidence”

-Bertrand Russel-

“The difficulty lies not
in the new ideas, but
in escaping from the
old ones”

-John Maynard Keynes-

.

Spiral Rotation Curves

Surface density mass distribution follows $\Sigma(r) = \Sigma_0 e^{-R}$,

with $R = r/r_s$.

Integral Mass distribution hence given by: $M_D(< R) = M_D \left[1 - e^{-R}(R+1)\right]$

Mass converges rapidly, over 90% within $R = 4$ yet, rotation curves remain flat always at $V(R) = V_{\rm inf}$, out to last measured point, sometimes $R > 25$.

No Kepplerian fall off has ever been measured! end up with $M_{Tot} \sim 20 M_D$

$V_{\rm inf}$ and r_s range from 10-300 km/s and 0.2-5 kpc.

.

Galaxy cluster dynamics

Radial Velocity of each individual galaxy measured, giving a velocity dispersion for the cluster, σ

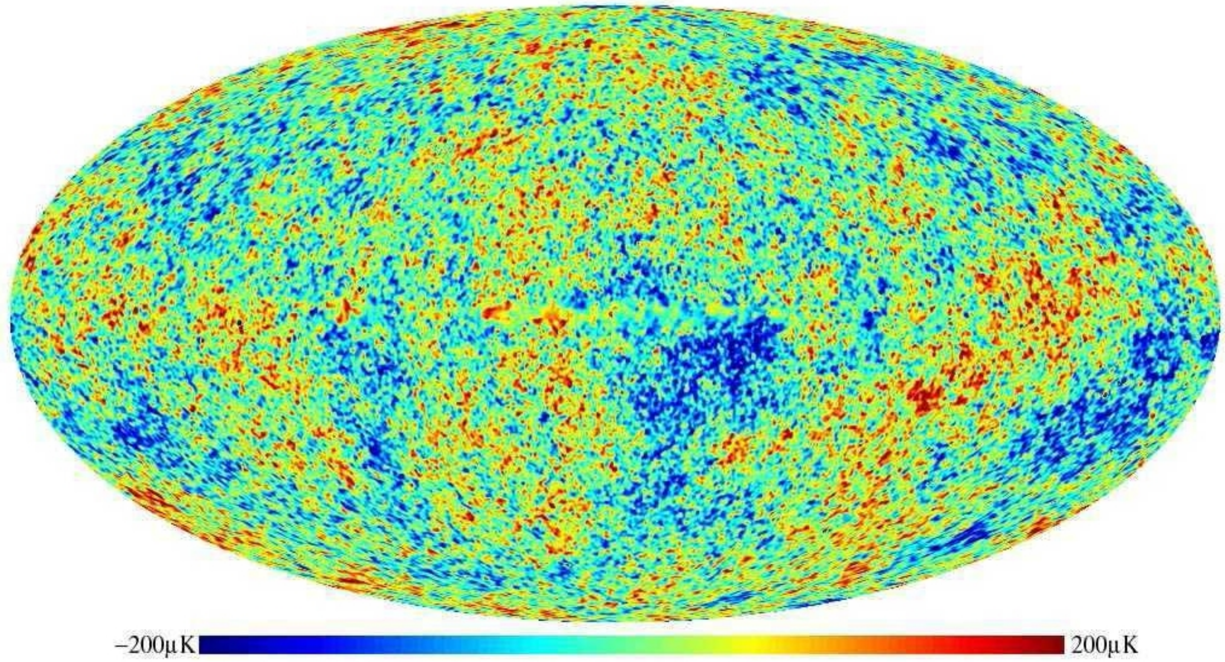
Total size (or half-light radius, R_{hl}), hence yields total cluster mass M_C from virial equilibrium, $2T + W = 0$:

$$M_C \sigma^2 = \frac{G M_C^2}{0.5 R_{hl}}$$

End up again with $M_{Tot} \sim 20 M_{Vis}$

.

Structure Formation



Linearised expansion law, fluctuations grow as $\delta\rho \propto (1+z)^{-1}$

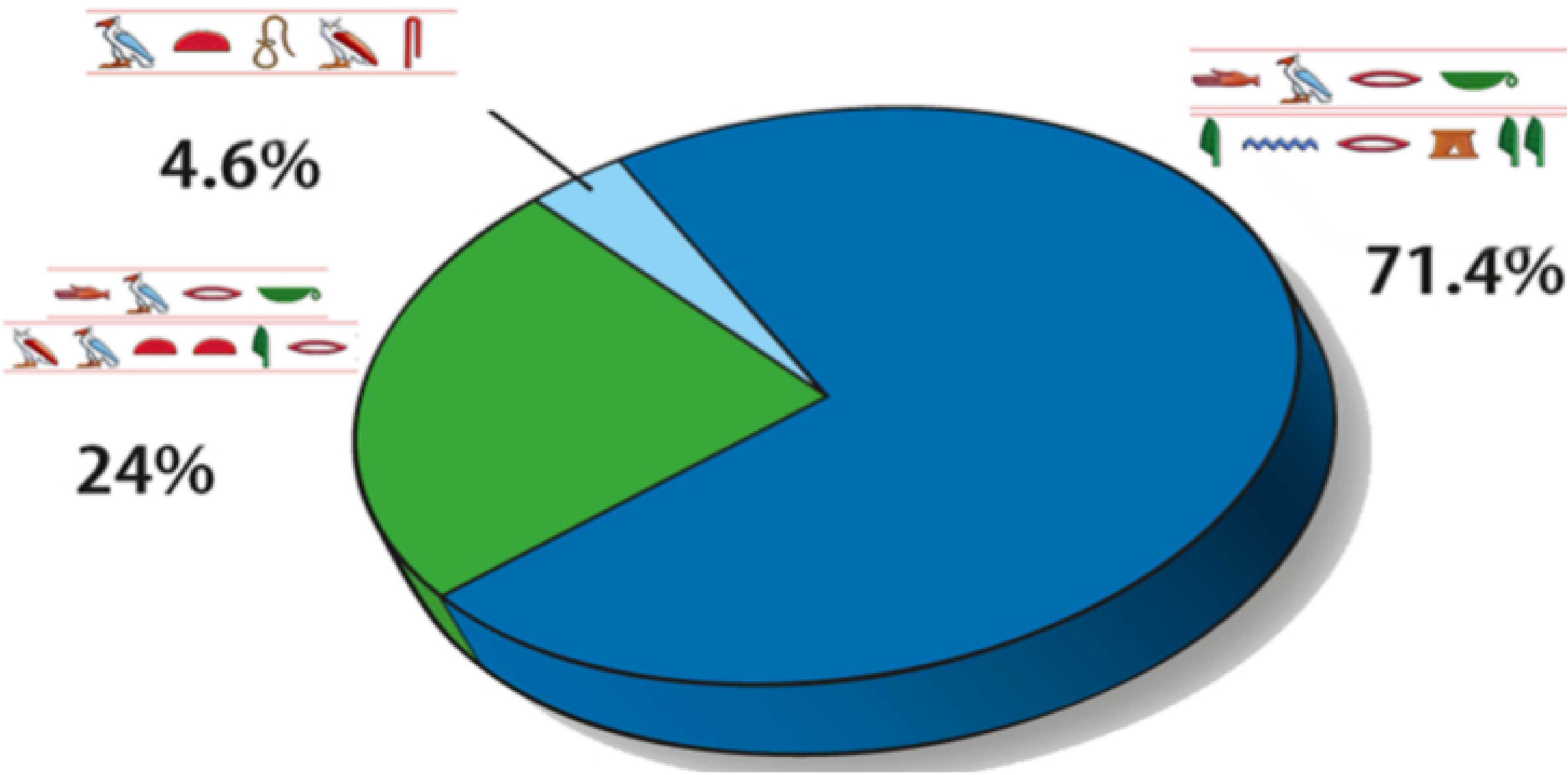
Since γ field energy density scales with $\rho_\gamma \propto (1+z)^4$ and ρ_γ scales with T_γ^4, Temperature scales with (1+z)

Therefore, present temperature of 2.7K and 13.6 ev H ionisation potential $\Rightarrow$ CMB emitted at z=1000.

Since δT (and hence $\delta\rho$) only of 1 part in 10^{4-5}, we should still be in the linear regime!

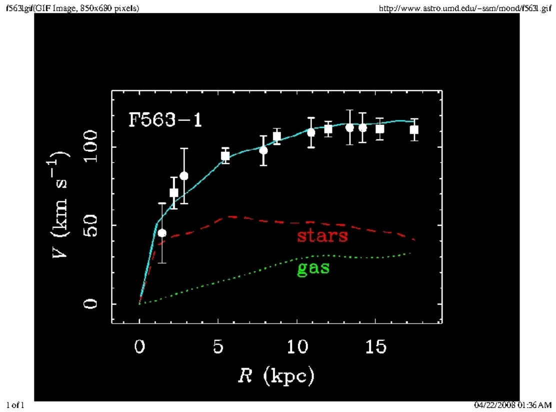
Need to boost gravity effect again, e.g. $M_{Tot} \sim 20 M_{Vis}$

So then what is the universe made up of?

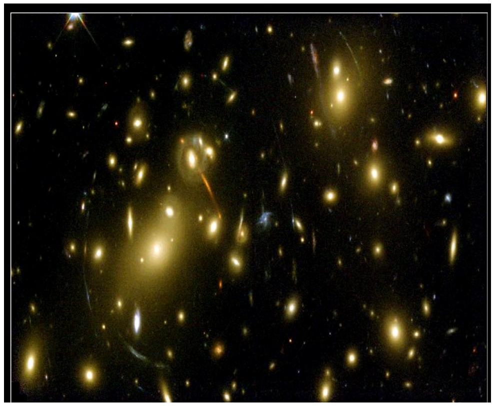


Indirect evidence for Dark Matter?

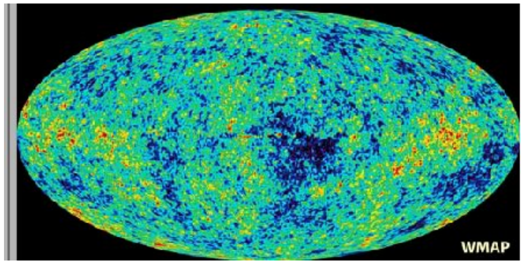
Rotation Curves of Large Spirals
(1-10 kpc)



Dynamics and Lensing of Galaxy Clusters
(1-5 Mpc)



Cosmological Matter Determinations
($>$ 50 Mpc)



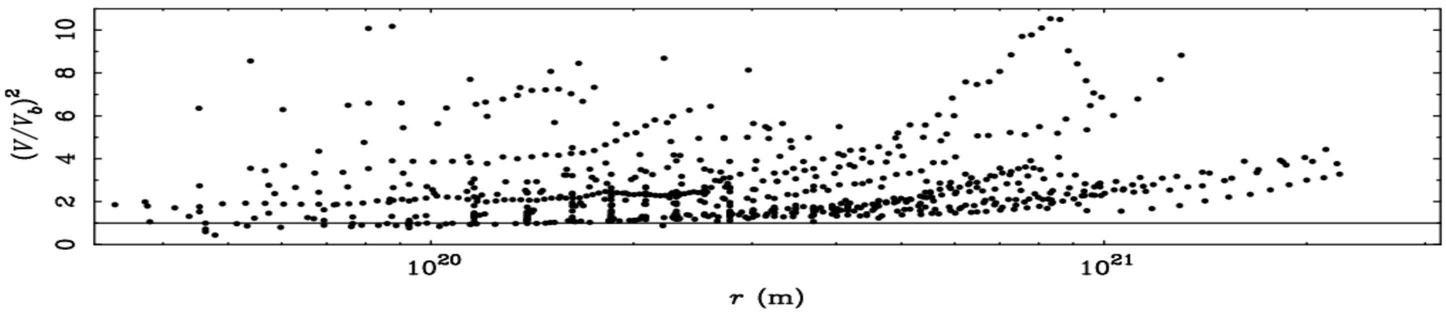
...or direct evidence for the failure of standard Gravity at large scales?

-Direct proof of the law of Gravity exists only for $R < 0.001pc$

-Direct proof of the existence of Dark Matter is still missing

Detailed Dynamics of Disk Galaxies

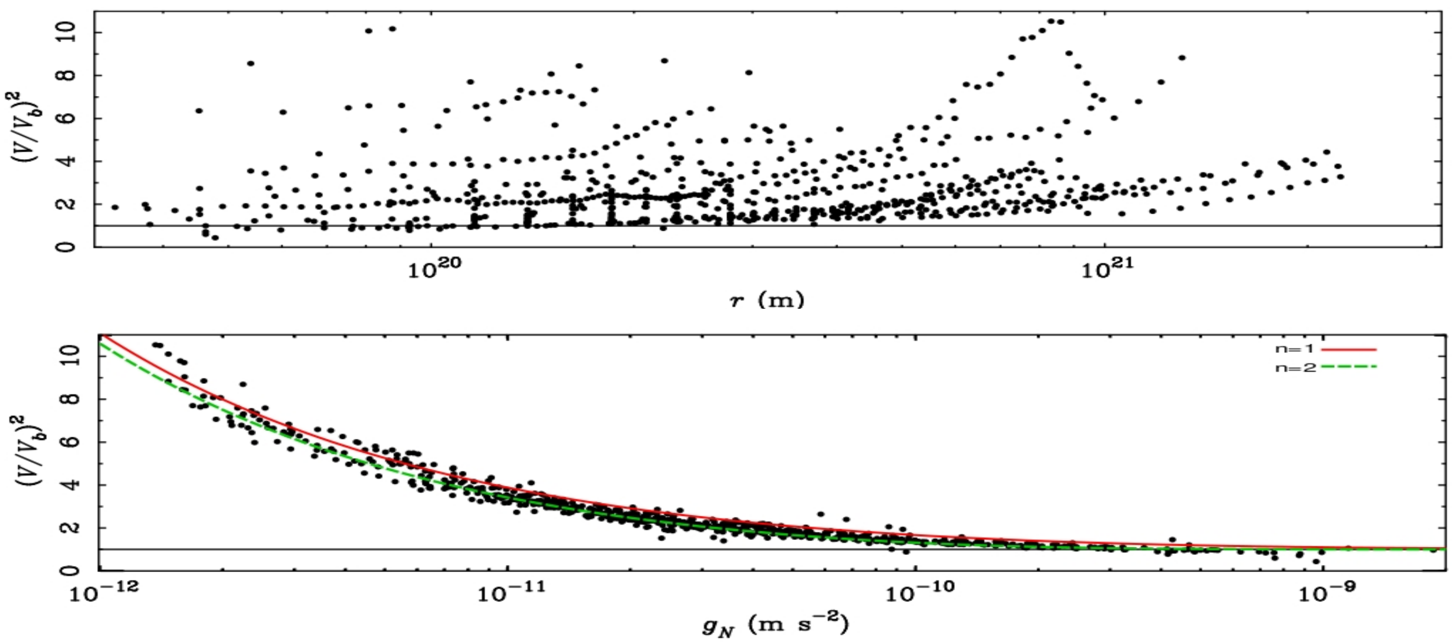
"Dark matter fraction" does not show any clear correlation with integral or differential Galactic properties.



Famaey & McGaugh (2012), Living Rev. Relativity, 15, 10

Detailed Dynamics of Disk Galaxies

“Dark matter fraction” does not show any clear correlation with integral or differential Galactic properties.
However, mass discrepancy tightly correlates with acceleration, at all radii, for all galactic types.



Distribution of baryonic mass uniquely determines total rotation!

Famaey & McGaugh (2012), Living Rev. Relativity, 15, 10

What would Newton have done?

Since $F = ma$, and for centrifugal equilibrium orbits $a = V^2/r$,

Given the Solar System rotation curve $V = \left(\frac{GM}{r}\right)^{1/2}$,

Gravitational force per unit mass is inferred to be: $\frac{GM}{r^2}$.

Take now the empirical rotation curves of galaxies, $V = (GMa_0)^{1/4}$,

Gravitational force per unit mass is inferred to be: $\frac{(GMa_0)^{1/2}}{r}$.

We can therefore write the dimensionless force per unit mass F/a_0 as:

$$\frac{F_N}{a_0} = \left(\frac{GM}{a_0}\right)\frac{1}{r^2} \qquad \frac{F_M}{a_0} = \left(\frac{GM}{a_0}\right)^{1/2}\frac{1}{r}$$

choosing $x = \left(\frac{GM}{a_0}\right)^{1/2}\frac{1}{r}$ gives:

$$\frac{F_N}{a_0} = x^2 \qquad \frac{F_M}{a_0} = x$$

Perhaps $\frac{F}{a_0} = ... + x^2 + x + ...$?

Generic modified gravity predictions

1) All $a > a_0$ systems in the low velocity regime should appear as purely Newtonian, without requiring any dark matter.
-Indeed, no counterexamples to this prediction exist.

2) All $a < a_0$ systems in the low velocity regime should appear as purely "MONDian", requiring substantial dark matter if interpreted under Newtonian Gravity.
-All known "dark matter" presenting systems neatly fall into this category.
-A definitive prediction appears for the outskirts of globular clusters and wide binaries

3) In the $a < a_0$ regime, equilibrium velocities become flat, with systems exhibiting a "Tully-Fisher" relation for $V_{MG}^2 \propto (MGa_0)^{1/2}$

X. Hernandez, S. Mendoza, T. Suarez & T. Bernal (2010), A&A 514, A101
S. Mendoza, X. Hernandez, J.C. Hidalgo & T. Bernal (2011), MNRAS 411, 226
T. Bernal, S. Capozziello, J.C. Hidalgo, S. Mendoza (2011), EPJC 71, 1794
X. Hernandez (2012), Entropy, 14, 484

Wide binaries as a critical experiment for gravity

A test particle orbiting a $1M_\odot$ star in a circular orbit of radius s, will have an acceleration that falls below $a_0 = 1.2 \times 10^{-10} m/s$ for: $s > 7000AU = 3.4 \times 10^{-2} pc$.

Therefore, relative velocities of binaries wider than $7000AU$ are predicted to be qualitatively and quantitatively very different under Newtonian Gravity and generically under modified gravity theories.

Which scaling will wide binaries show?

$$\Delta V_N = 2\left(\frac{GM}{s}\right)^{1/2} \quad or \quad \Delta V_{MG} = 2(Ga_0 M)^{1/4} \ ?$$

A large survey of relative proper motions and separations for wide binaries should yield a conclusive answer.

X. Hernandez, M. A. Jimenez & C. Allen (2012) EPJC, 72, 1884

Newtonian prediction for wide binary samples

Predicted projected RMS 1D ΔV vs. s relation.

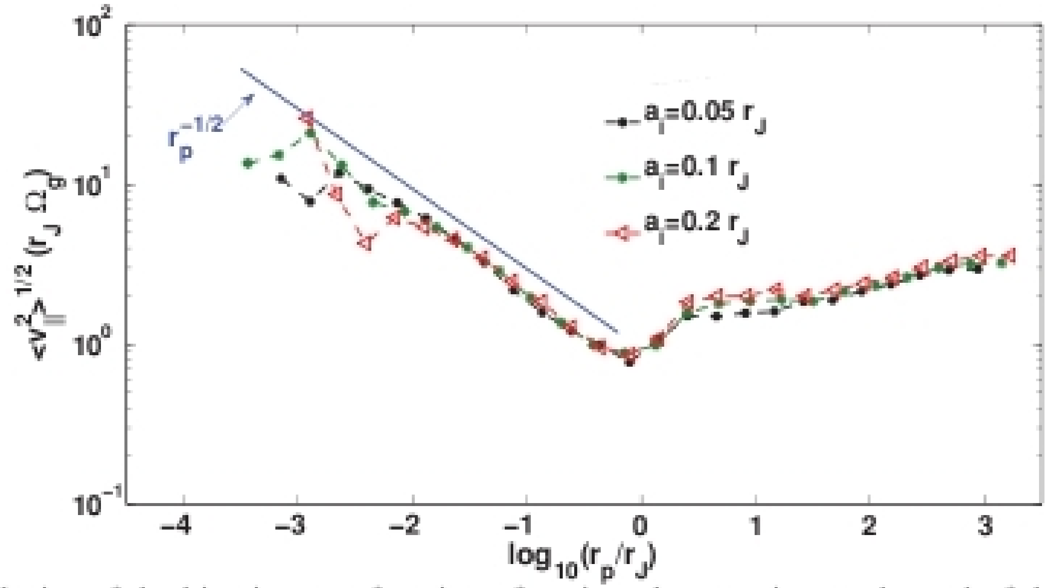


Figure 7. RMS line-of-sight relative velocity of the binaries as a function of projected separation, at the end of the simulations. The horizonta projected separation normal to a randomly chosen line of sight, while the vertical axis is the rms line-of-sight relative velocity in each separ Keplerian motion we expect $\langle v_{||}^2 \rangle^{1/2} \propto r_p^{-1/2}$, shown by the straight line. The relation between the line-of-sight relative velocity and the projecte deviates from the Keplerian relation for $r_p \gtrsim r_J$.

- Below $s = r_J = 1.7pc$, curve closely follows Kepler's law.

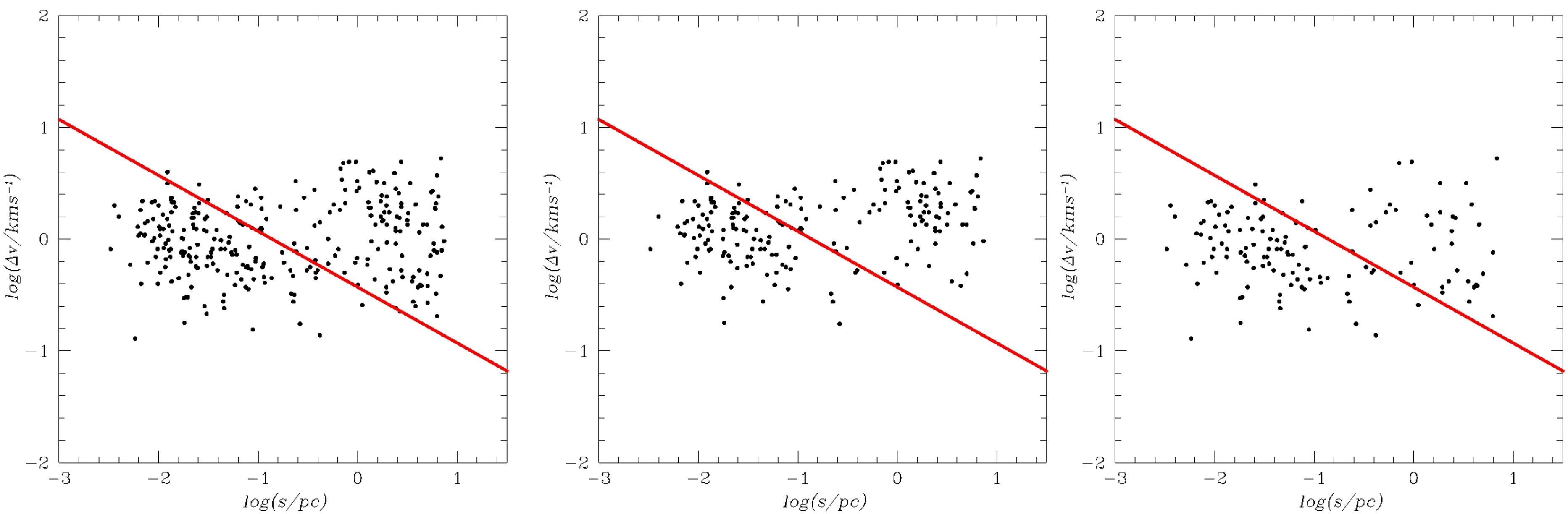
- Mostly, disruption occurs for $s > r_J$, the tidal radius of the problem.
$\Rightarrow$ a definitive feature expected at $s = r_J = 1.7pc$

- Unbound stars continue to drift along very similar orbits and will show up in observational samples.

Y. Jiang & S. Tremaine (2010), MNRAS 401, 977

Wide binary catalogues -2) *Hipparcos*

From a catalogue of $\sim$ 280 carefully selected wide binaries we obtain relative velocities on the plane of the sky and projected separations, average S/N=2.0.



- The upper envelope clearly defines a horizontal line, showing the "flat rotation curve" of modified gravity, and not the Kepplerian decline of Newtonian gravity.

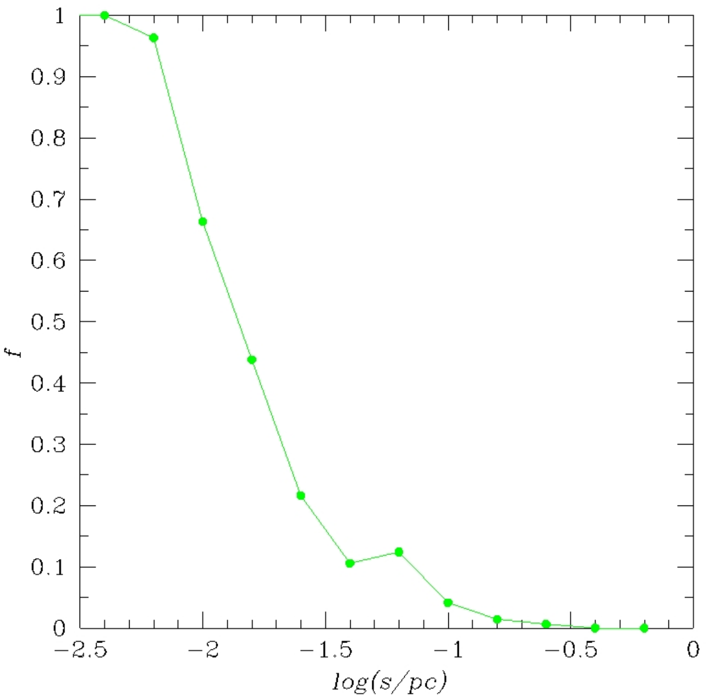
- It can be shown that results are not driven by errors or catalogue selection cuts.

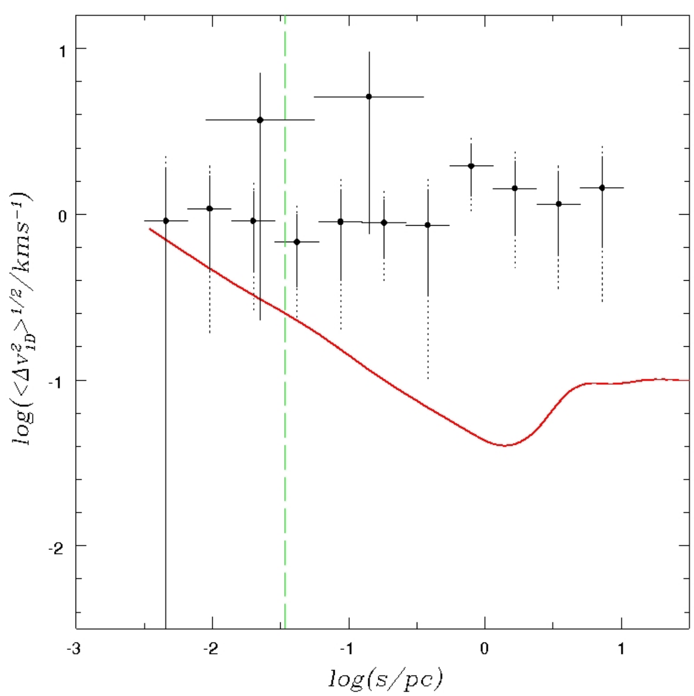
-The data show no feature of any kind on crossing the Newtonian tidal radius at 1.7pc.

E. J. Shaya & R. P. Olling (2011), ApJS, 192, 2

Wide Binary conclusions

Quantitative comparison with full Newtonian prediction:





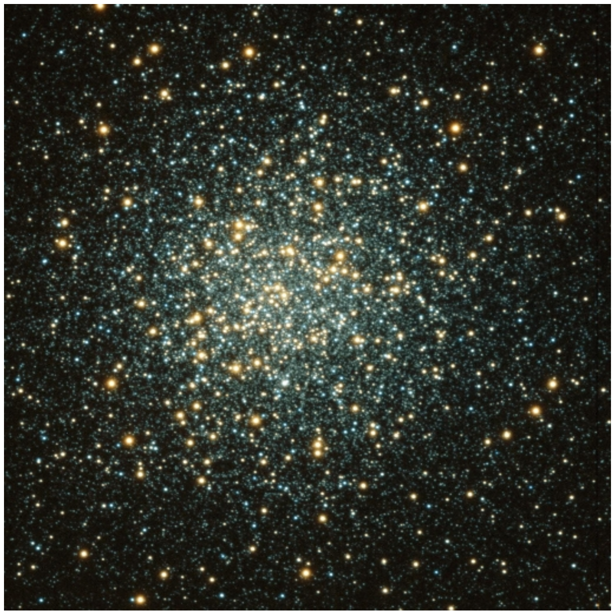
- The trends shown by the data are clearly defining the modified gravity phenomenology, Newtonian Gravity is only consistent with the data with a probability $< 3 \times 10^{-5}$.

- The two completely independent catalogues yield fully consistent results.

- The data rule out the Newtonian model at a 4σ level.

X. Hernandez, M. A. Jimenez & C. Allen (2012) EPJC, 72, 1884

Surprising New GC Results:



Total masses $\sim 10^5 - 10^6 M_\odot$

Half mass radii $\sim 20pc$

Up to now, with stellar velocity dispersion profiles measured towards the core regions, well modelled as purely Newtonian equilibrium strictures, without any Dark Matter.

The outskirts of GCs

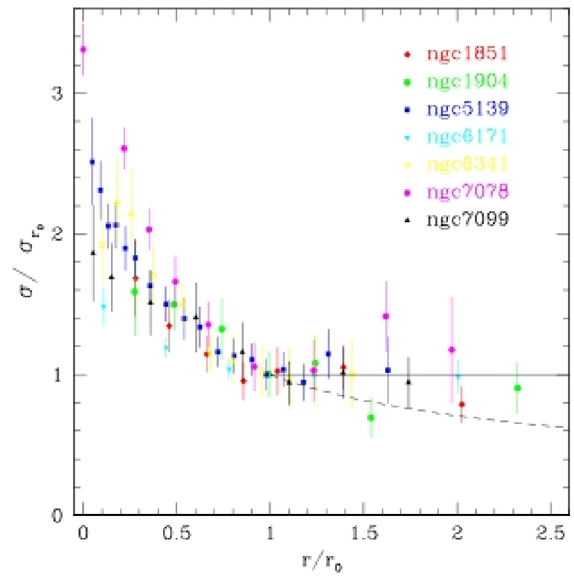
Astronomy & Astrophysics manuscript no. ms˙revised2
August 23, 2010

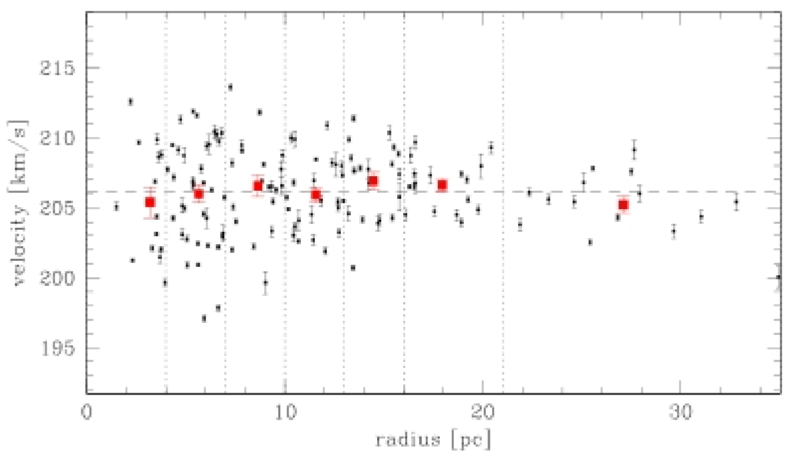
Testing Newtonian gravity with distant globular clusters: NGC1851 and NGC1904⋆

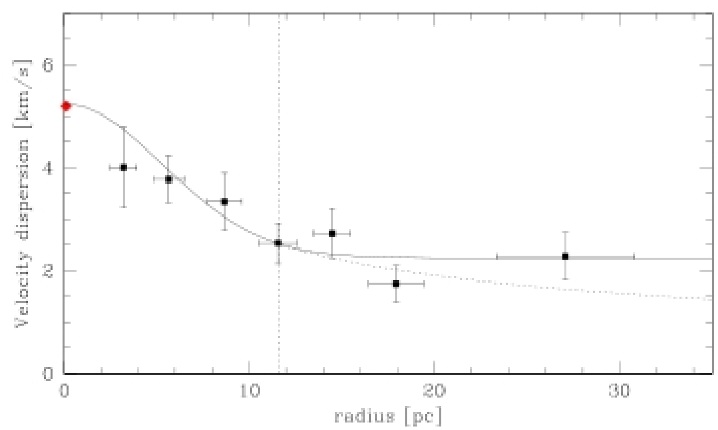
R. Scarpa[1], G. Marconi[2], G. Carraro[2], R. Falomo[3], and S. Villanova[4]

[1] Instituto de Astrofísica de Canarias, Spain
[2] European Southern Observatory, Chile
[3] Osservatorio Astonomico di Padova, Italy
[4] Universidad de Concepcion, Departamento de Astronomia, Concepcion, Chile

August 23, 2010







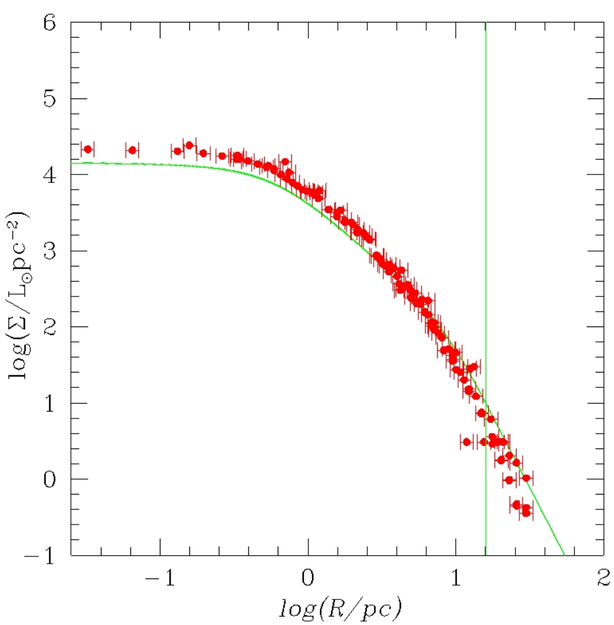
The outskirts of GCs

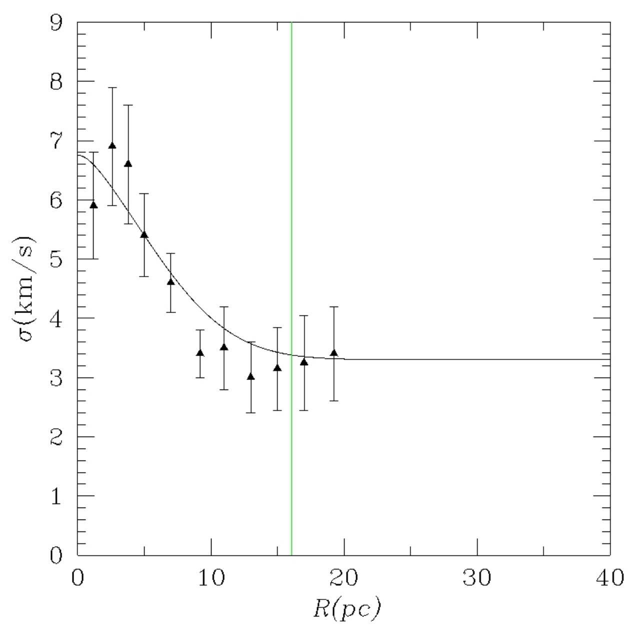
Using the modified force model, we solve equation:

$$\sigma(r)\frac{d\sigma(r)}{dr} + \sigma(r)^2\left[\left(\frac{\mathrm{d}M}{\mathrm{d}r}\right)^{-1}\frac{d^2M}{dr^2} - \frac{2}{r}\right] = F\left(GM(r)/a_0 r^2\right)$$

with $F(X) = X\left(\frac{1-X^{10}}{1-X^9}\right)$

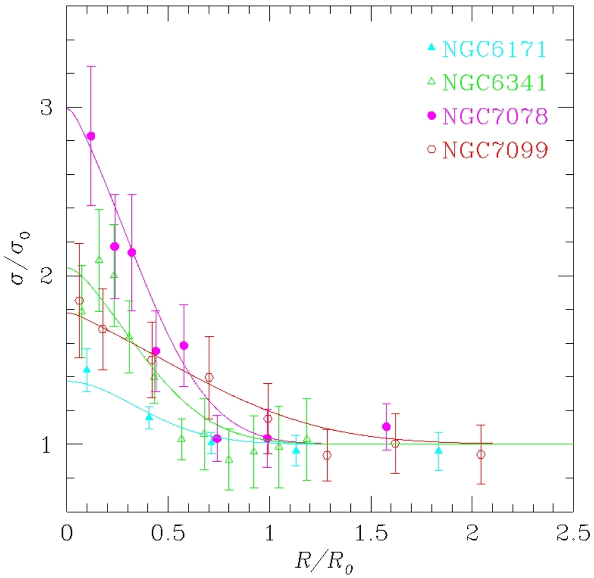
Constrained to give measured total mass, half mass radius, central stellar volume density and observed projected velocity dispersion and brightness profiles. Model for NGC 6341.

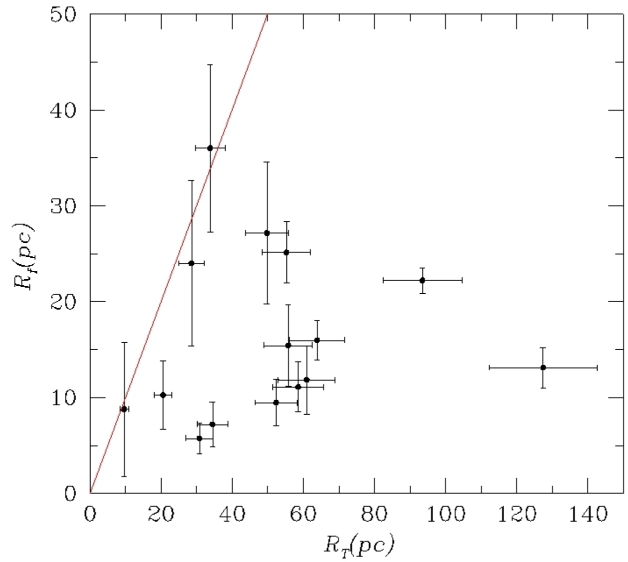


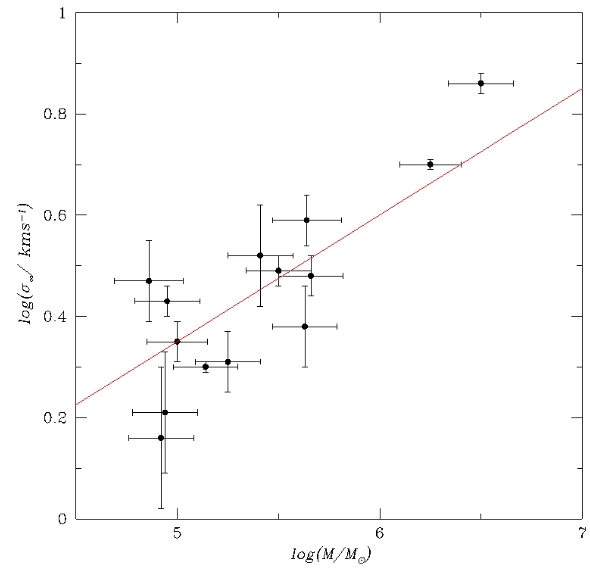


All observational parameters are fitted simultaneously. Vertical line gives point at which $X = 1$

GC conclusions







Flattening of the velocity dispersion profile closely coincides with $a = a_0$ threshold

Using total masses from detailed stellar population modelling tuned to each individual GC,
Even at perigalacticon, all the GC in the sample are smaller than their Newtonian tidal radii.

Fractional fall in σ correlates with fraction of the GC within $a < a_0$.

σ vs. Mass relation compatible with expected "Tully-Fisher" a_0 relation.

X. Hernandez & M. A. Jimenez (2012), ApJ, 750, 9
X. Hernandez, M. A. Jmenez & C. Allen (2013), MNRAS, 428, 3196

What about the periodic DM detection claims ?

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Annihilation “signal” towards the galactic centre?

Journal of Cosmology and Astroparticle Physics

Journal of Cosmology and Astroparticle Physics > Volume 2012 > July 2012

Torsten Bringmann *et al* JCAP07(2012)054 doi:10.1088/1475-7516/2012/07/054

Fermi LAT search for internal bremsstrahlung signatures from dark matter annihilation

Torsten Bringmann[a], Xiaoyuan Huang[b], Alejandro Ibarra[c], Stefan Vogl[c] and Christoph Weniger[d]

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Tag this article PDF (641 KB)

Abstract | References | Cited By

A commonly encountered obstacle in indirect searches for galactic dark matter is how to disentangle possible signals from astrophysical backgrounds. Given that such signals are most likely subdominant, the search for pronounced spectral features plays a key role for indirect detection experiments; monochromatic gamma-ray lines or similar features related to internal bremsstrahlung, in particular, provide smoking gun signatures. We perform a dedicated search for the latter in the data taken by the Fermi gamma-ray space telescope during its first 43 months. To this end, we use a new adaptive procedure to select optimal target regions that takes into account both standard and contracted dark matter profiles. The behaviour of our statistical method is tested by a subsampling analysis of the full sky data and found to reproduce the theoretical expectations very well. The limits on the dark matter annihilation cross-section that we derive are stronger than what can be obtained from the observation of dwarf galaxies and, at least for the model considered here, collider searches. While these limits are still not quite strong enough to probe annihilation rates expected for thermally produced dark matter, future prospects to do so are very good. In fact, we already find a weak indication, with a significance of 3.1σ (4.3σ) when (not) taking into account the look-elsewhere effect, for an internal bremsstrahlung-like signal that would correspond to a dark matter mass of ~150 GeV; the same signal is also well fitted by a gamma-ray line at around 130 GeV. Although this would be a fascinating possibility, we caution that a much more dedicated analysis and additional data will be necessary to rule out or confirm this option.

...Merely a slight excess towards a high Baryonic matter density region of poorly constrained high energy photons....

If really an DM signal, more such expected towards other high “dark matter” density regions, after years of searches, none detected....

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Journal of Cosmology and Astroparticle Physics
An IOP and SISSA journal

Fermi-LAT γ-ray anisotropy and intensity explained by unresolved radio-loud active galactic nuclei

Mattia Di Mauro,[a,b,c] **Alessandro Cuoco,**[a,b] **Fiorenza Donato**[a,b] **and Jennifer M. Siegal-Gaskins**[d]

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[b]Istituto Nazionale di Fisica Nucleare, Sezione di Torino, via P. Giuria 1, Torino, 10125 Italy
[c]LAPTh, Université de Savoie, CNRS, 9 Chemin de Bellevue, B.P. 110, Annecy-le-Vieux, F-74941 France
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Abstract. Radio-loud active galactic nuclei (AGN) are expected to contribute substantially to both the intensity and anisotropy of the isotropic γ-ray background (IGRB). In turn, the measured properties of the IGRB can be used to constrain the characteristics of proposed contributing source classes. We consider individual subclasses of radio-loud AGN, including low-, intermediate-, and high-synchrotron-peaked BL Lacertae objects, flat-spectrum radio quasars, and misaligned AGN. Using updated models of the γ-ray luminosity functions of these populations, we evaluate the energy-dependent contribution of each source class to the intensity and anisotropy of the IGRB. We find that collectively radio-loud AGN can account for the entirety of the IGRB intensity and anisotropy as measured by the *Fermi* Large Area Telescope (LAT). Misaligned AGN provide the bulk of the measured intensity but a negligible

...Merely a slight excess towards a high Baryonic matter density region of poorly constrained high energy photons.... which has now completely gone away...

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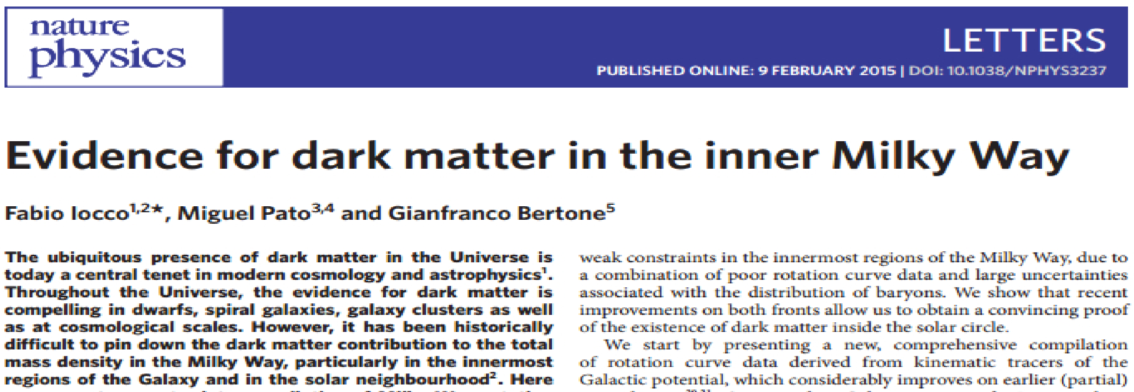
DM "detection" towards the galactic centre?



nature physics

LETTERS

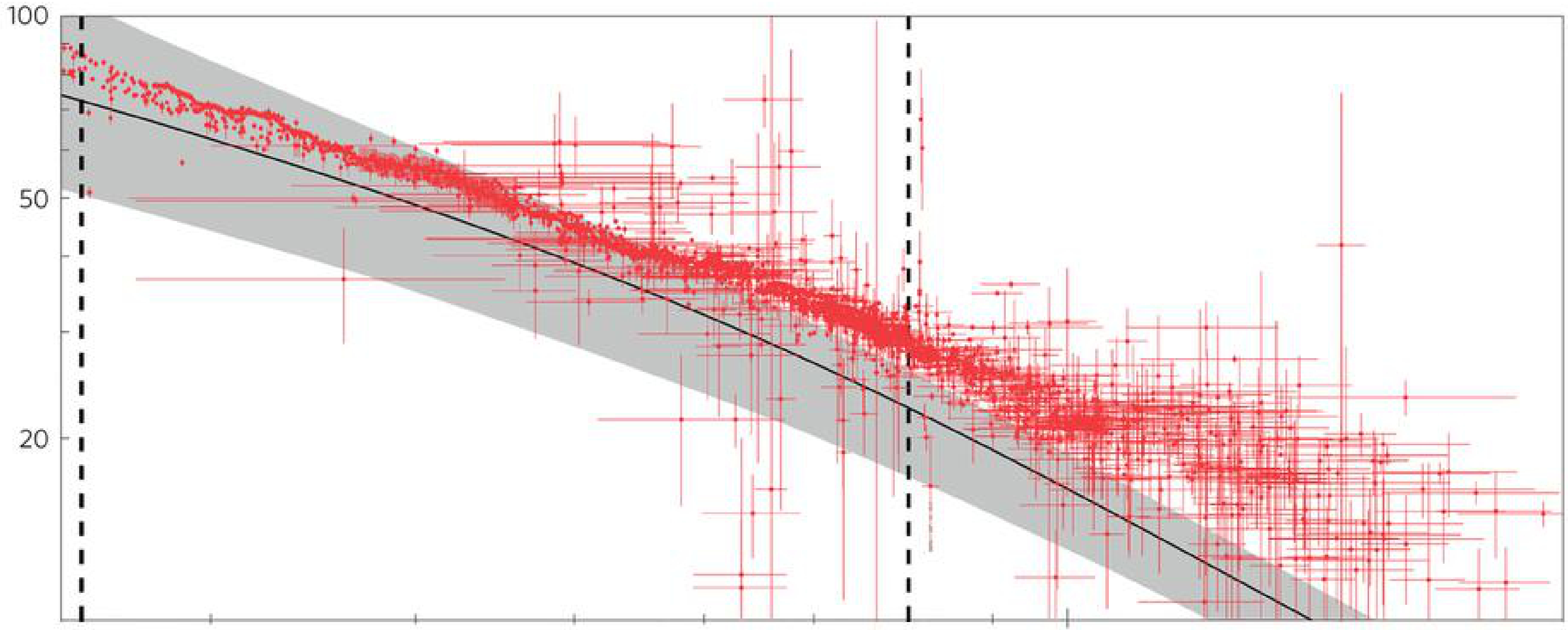
PUBLISHED ONLINE: 9 FEBRUARY 2015 | DOI: 10.1038/NPHYS3237

Evidence for dark matter in the inner Milky Way

Fabio Iocco[1,2]*, Miguel Pato[3,4] and Gianfranco Bertone[5]

The ubiquitous presence of dark matter in the Universe is today a central tenet in modern cosmology and astrophysics[1]. Throughout the Universe, the evidence for dark matter is compelling in dwarfs, spiral galaxies, galaxy clusters as well as at cosmological scales. However, it has been historically difficult to pin down the dark matter contribution to the total mass density in the Milky Way, particularly in the innermost regions of the Galaxy and in the solar neighbourhood[2]. Here weak constraints in the innermost regions of the Milky Way, due to a combination of poor rotation curve data and large uncertainties associated with the distribution of baryons. We show that recent improvements on both fronts allow us to obtain a convincing proof of the existence of dark matter inside the solar circle.

We start by presenting a new, comprehensive compilation of rotation curve data derived from kinematic tracers of the Galactic potential, which considerably improves on earlier (partial)



...a dynamical anomaly detected in rotation curve data...

What about the periodic DM detection claims?

DM “detection” towards the galactic centre?

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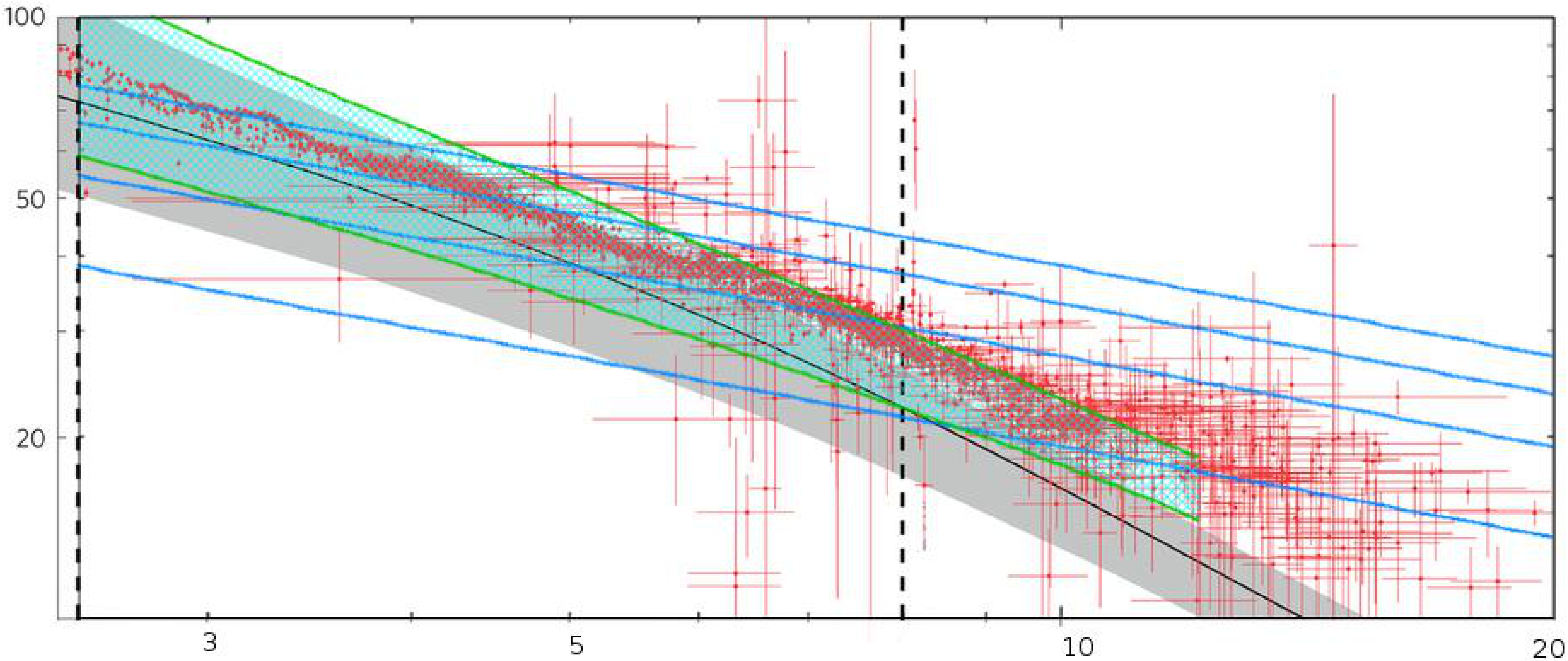

... precisely at a_0 acceleration scales, and in accordance with extended gravity ideas....

What about the bullet cluster?

.

Originally touted as a proof of the existence of dark matter

What does it really show?

X-ray/Optical Composite of 1E 0657-56

...merely that the gas has been subject to classical hydrodynamical effects, showing the encounter to have been strongly supersonic, and that the gravitational signal is centred not on the diffuse gas, but on the 'point like" baryonic galaxies...

.

What about the bullet cluster?

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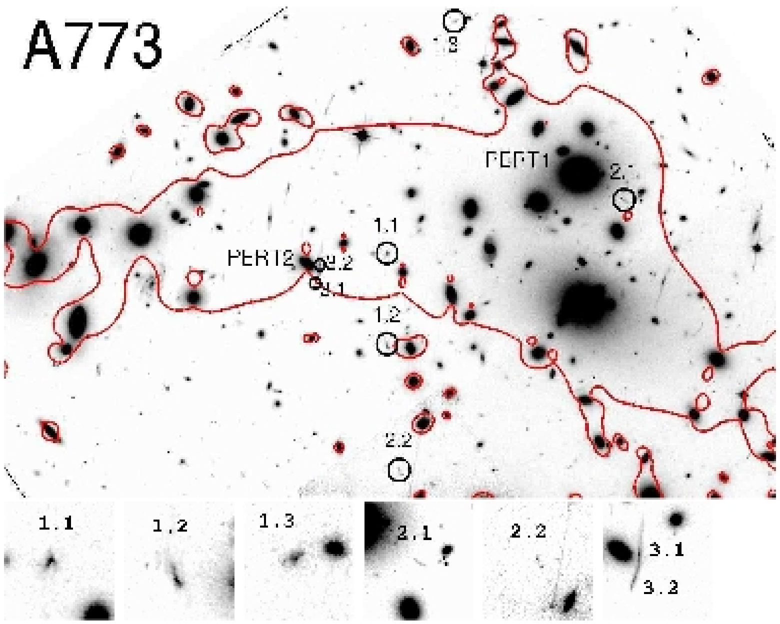
Originally touted as proof of the existence of dark matter

What does it really show?

X-ray/Optical Composite of 1E 0657-56



...as would be expected in any normal or modified gravity model.

To first order, the observation is compatible under both points of view, ...only to first order!

.

What about the bullet cluster?

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Detailed hydrodynamical modelling has shown the encounter velocity to have been $> 3500 km/s$, significantly larger that the escape velocity of the cluster!

970 C. Mastropietro and A. Burkert

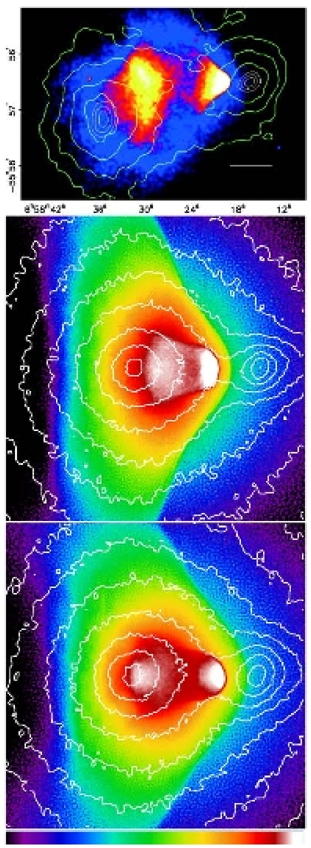


Figure 1. Upper panel: 500-ks *Chandra* image of the system with weak lensing k reconstruction shown in green (courtesy of D. Clowe and reproduced by permission of the AAS). Central and bottom panels: 0.8–4 keV surface brightness maps of runs 6:vb0 and 6:v3000b0. Logarithmic colour scaling is indicated by the key at the bottom of the figure with violet corresponding to 10^{38} erg s^{-1} kpc^{-2} and white to 2×10^{41} erg s^{-1} kpc^{-2}. White contours trace the total surface mass density of the system within 2.3×10^5 and $2.3 \times 10^8 M_\odot$ kpc^{-2}. The box size is 1800 kpc.

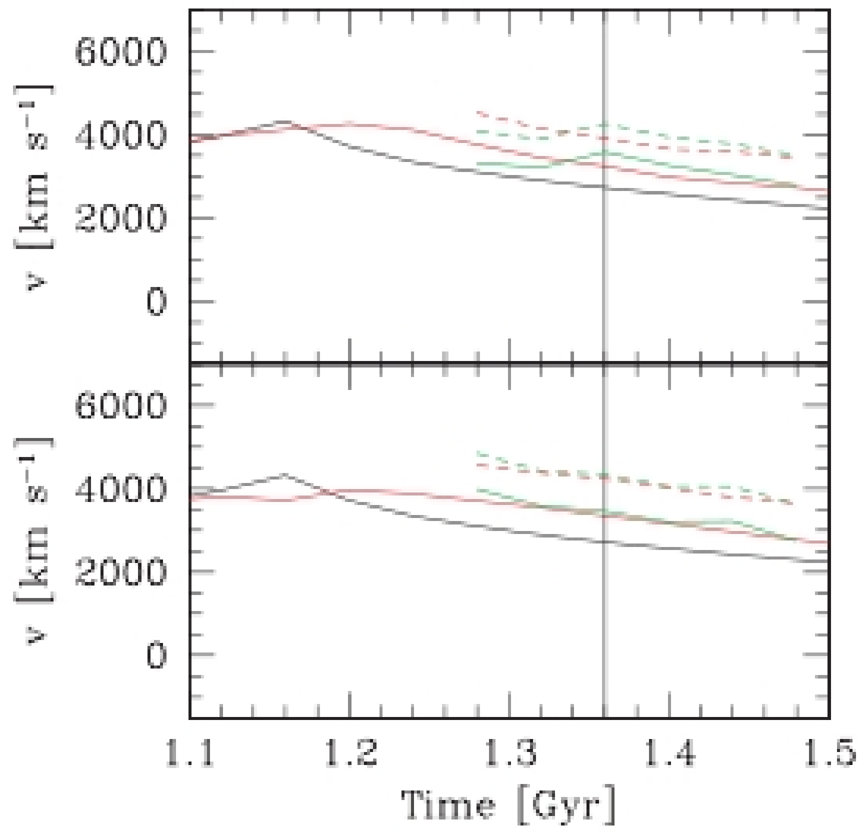


Figure 16. Run 10:1vb0c2 (top panel) and 10:1vb0c2nfw (bottom panel). Same as in Fig. 14.

This essentially rules out Classical gravity at this scale!

Mastropietro & Burkert (2008), MNRAS, 389, 976

What about the bullet cluster?

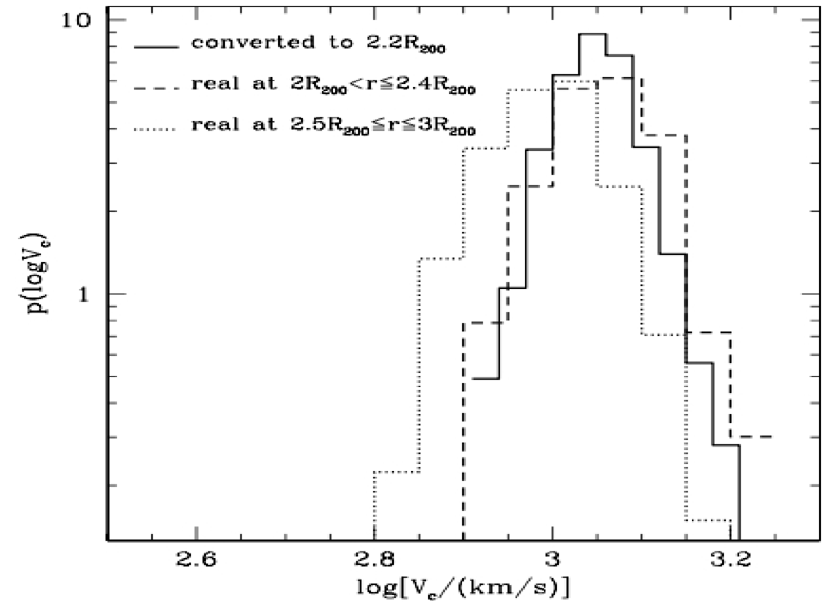


Figure 6. Testing Equation (1). The dashed line shows the distribution of $\log V_c$ in $2 \leqslant r/R_{200} \leqslant 2.4$ measured from the simulation, while the solid line shows the distribution of $\log V_c$ at $r_{\rm in} = 2.2 R_{200}$ calculated from the measured distribution in $2.5 \leqslant r_{\rm out}/R_{200} \leqslant 3$ (dotted line) and Equation (1).

also has to be excluded because it cannot reproduce the observed X-ray brightness ratio of the main and subcluster or the X-ray morphology of the main cluster.

In this paper, we have shown that such a high velocity at 5 Mpc, which is about two times R_{200} of the main cluster, is incompatible with the prediction of a ΛCDM model. Using the results at $z = 0$ and $M_{\rm main} \geqslant 0.7 \times 10^{15}\, h^{-1}\, M_\odot$, ΛCDM is excluded by more than 99.91% confidence level (none of the 1135 subclusters have $V_c \geqslant 2000$ km s^{-1} in $2 \leqslant r/R_{200} \leqslant 3$). For a lower minimum main cluster mass, $M_{\rm main} \geqslant 0.5 \times 10^{15}\, h^{-1}\, M_\odot$, ΛCDM is excluded by more than 99.95% confidence level (none of the 2189 subclusters have $V_c \geqslant 2000$ km s^{-1} in $2 \leqslant r/R_{200} \leqslant 3$).

X-ray/Optical Composite of 1E 0657-56

Encounter velocity necessary to obtain hydrodynamical signature is incompatible with classical gravity.

Lee & Komatsu (2010), ApJ, 718, 60

A recent independent confirmation

Detailed cosmological modelling has shown the encounter velocity to be outright incompatible with standard ΛCDM structure formation scenarios.

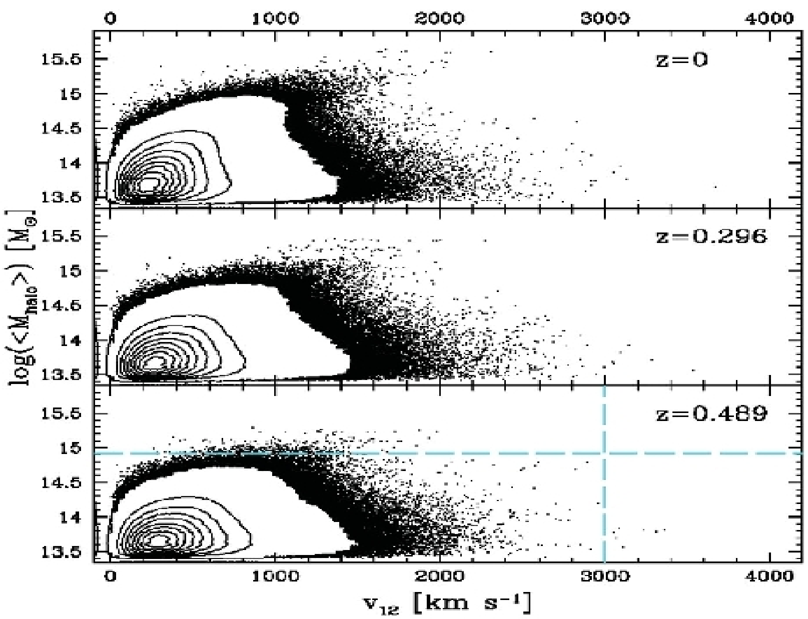


Figure 13. Average mass of halo pairs versus their pairwise velocity for the L2016N1008 run at $z = 0.0$, 0.296 and 0.489. In the bottom panel ($z = 0.489$), the horizontal dashed line represents an average pair mass of $8.25 \times 10^{14}\,M_\odot$ for 1E 0657−56, and the vertical dashed line represents a pairwise velocity of $3000\,\mathrm{km\,s^{-1}}$ suggested by Mastropietro & Burkert (2008).

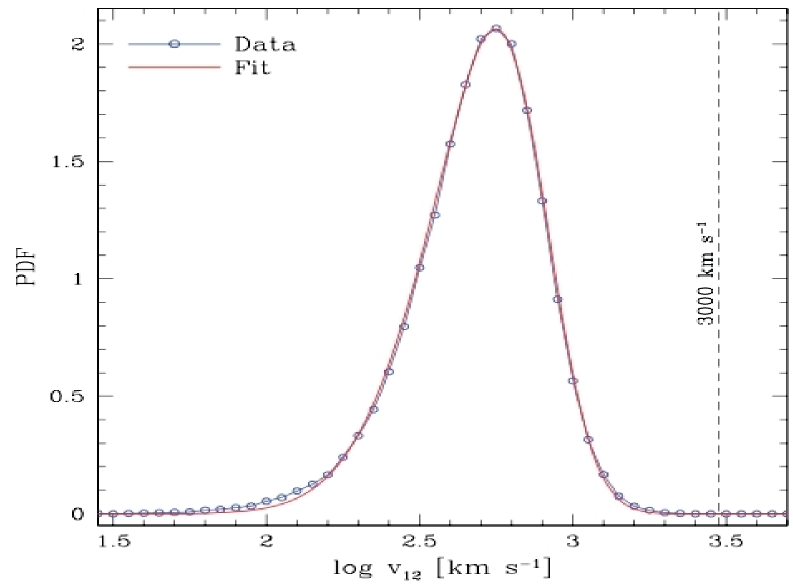


Figure 15. Pairwise velocity PDF for halo pairs with masses above $10^{14}\,M_\odot$ in our L2016N1008 run. The blue circles represent v_{12} binned PDF data, the blue curve is the linearly interpolated values, and the red curve is the best-fitting skew normal distribution (Azzalini & Capitanio 2010). Integrating the fit from $v_{12} = 3000\,\mathrm{km\,s^{-1}}$ to infinity gives $P(>3000\,\mathrm{km\,s^{-1}}) = 2.8 \times 10^{-8}$. This very low probability suggests that it is very difficult to produce a halo pair with high mass and high v_{12} as the observed 1E 0657−56.

This essentially rules out Classical gravity at this scale!

Thompson & Nagamine (2012), MNRAS 419, 3560

Understanding the impossibility of the bullet cluster under standard gravity

The sound speed for a gas in equilibrium with a dark halo having DM velocity dispersion σ is: $c = \sigma$.

The rotation velocity of this halo will be $V_R = 2^{1/2}\sigma$.
The escape velocity will therefore be $V_e = 2^{1/2} V_R = 2c$.
Releasing the "bullet" from infinity will therefore yield a maximum Mach number for the collision of $V_e/c \Rightarrow \boxed{M_{max} = 2}$

From looking at the picture it is evident the collision resulted in a strong shock with $\boxed{M_{obs} \approx 3 \text{ or above}}$.

Within a cosmological scenario, one has to start by overcoming the (accelerated!) expansion, which results in maximum Mach numbers $\boxed{\text{even smaller than } 2}$.

No amount on DM helps, as adding DM increases both V_e and c in the same proportion.

Under standard gravity it is $\boxed{\text{impossible}}$ to produce Mach numbers as required to obtain the observed hydrodynamical signal, which explains the results of Lee & Komatsu (2010) and Thompson & Nagamine (2012).

Understanding the bullet cluster under extended gravity

We can get the collision velocity to first order from:

$$F = \frac{(GMa_0)^{1/2}}{r} = \frac{dV}{dt} = \frac{dV}{dr}V$$

$$V\,dV = (GMa_0)^{1/2} ln(r)$$

releasing the "bullet" from rest at a distance r_0, we see that V impact at r=5 Mpc implies:

$$\frac{V^2}{2} = (GMa_0)^{1/2} ln(r_0/5Mpc)$$

for a total baryonic mass of 3×10^{14}, obtaining V impact= 3,000 km/s requires:

$$3000 = 0.5(3 \times 10^{14})^{1/4} \left[ln(r_0/5Mpc)\right]^{1/2}$$

which yields, $r_0 = 8.33 \times 5Mpc.$

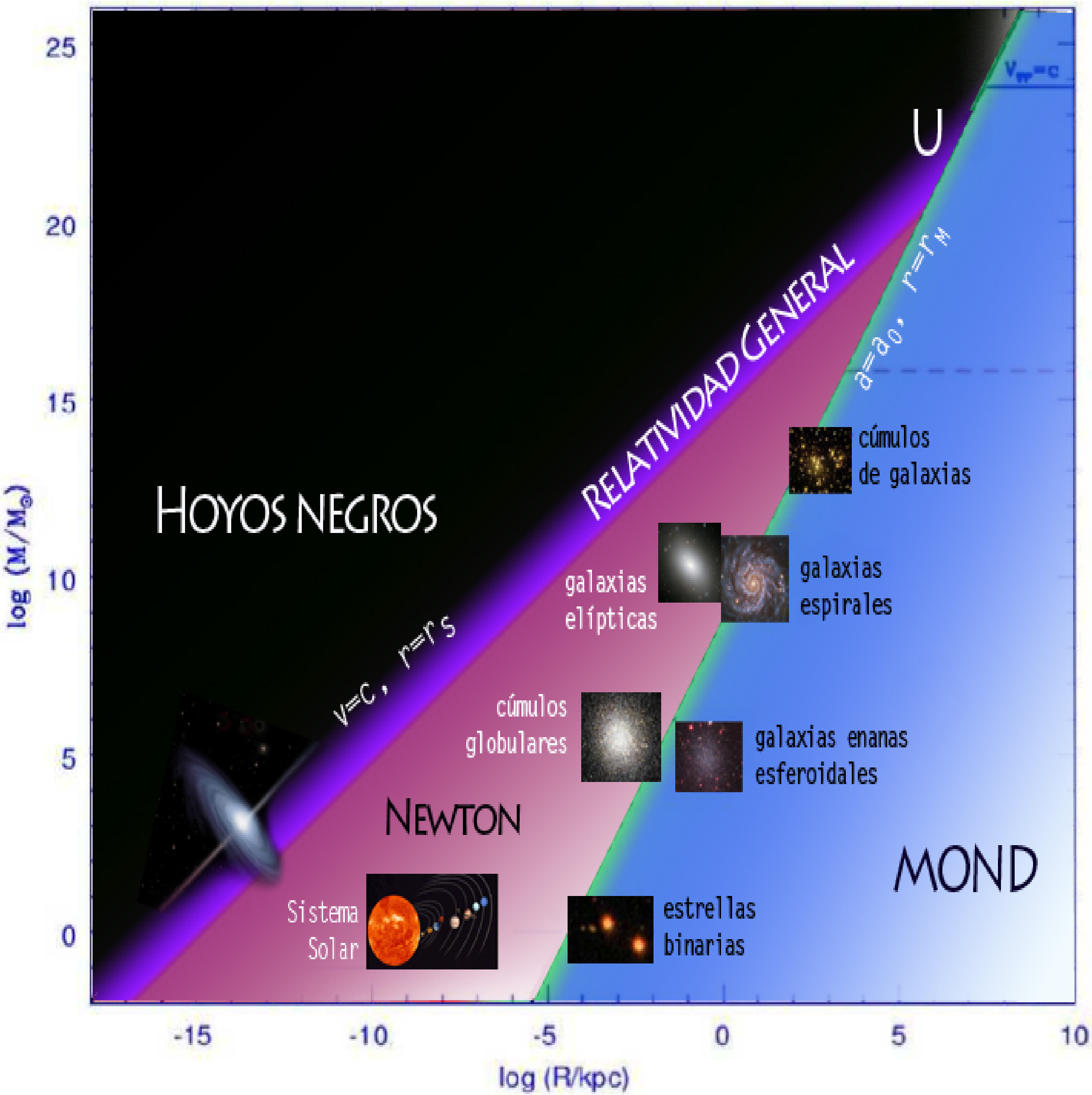
By comparison, the Newtonian escape velocity of the system,

including hypothetical DM, at 5 Mpc is of only $\sim$ 1,000 km/s.

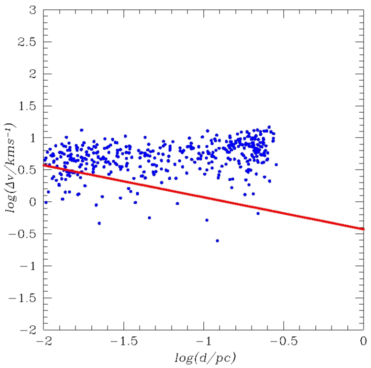
Under extended gravity schemes, starting from merely $\sim$ 10 times the observed size of the system, one can easily obtain impact velocities as required to obtain the observed hydrodynamical signal.

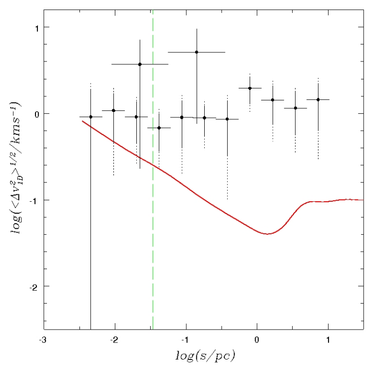
e.g. Moffat & Toth (2010), arXiv:1005.2685

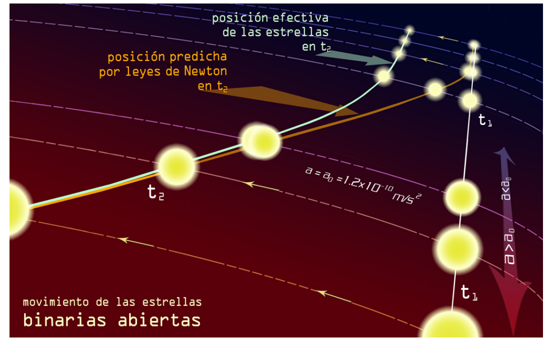
Overall scalings:



The relative velocities of observed Wide binaries are inconsistent with Newtonian Gravity and GR







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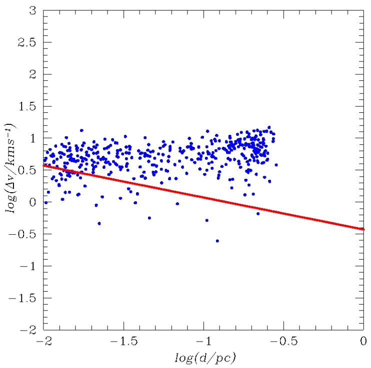
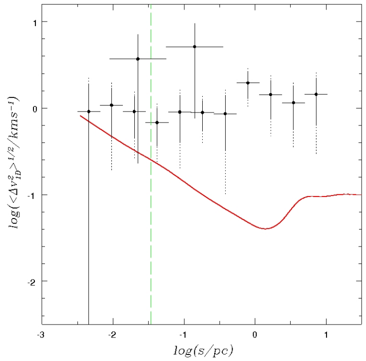
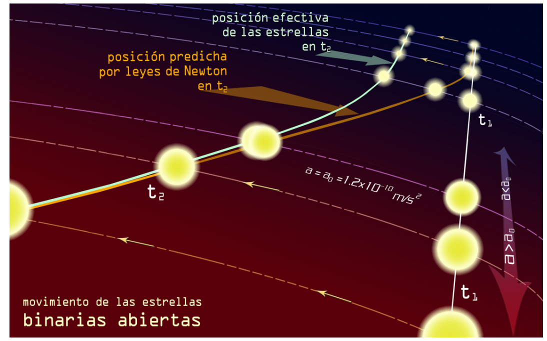
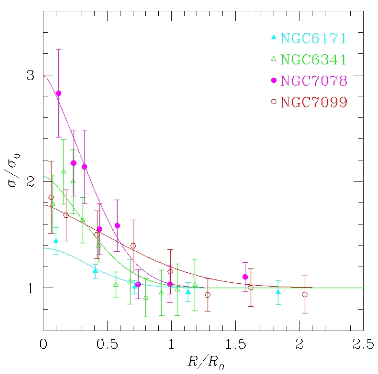
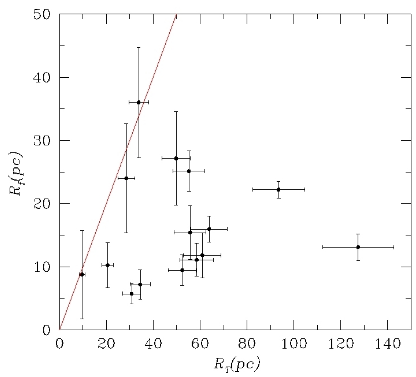


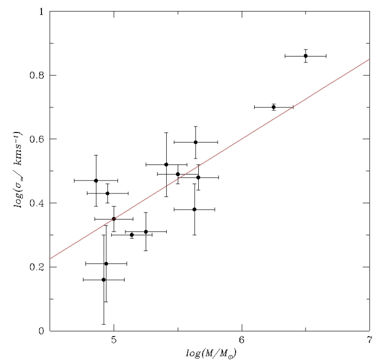




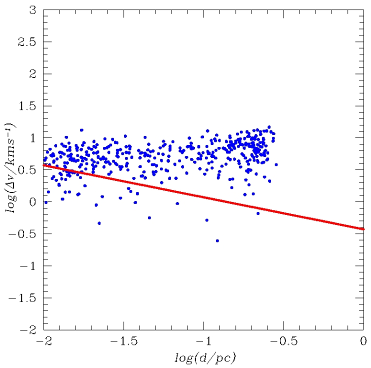
Outer velocity dispersions of globular clusters become flat and show the same galactic $\sigma \propto M^{1/4}$ TF scaling

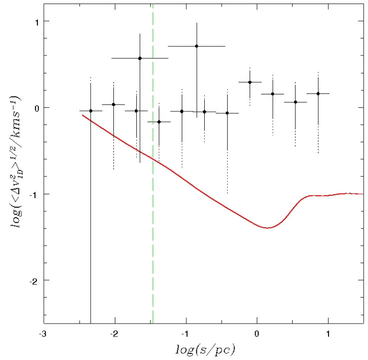


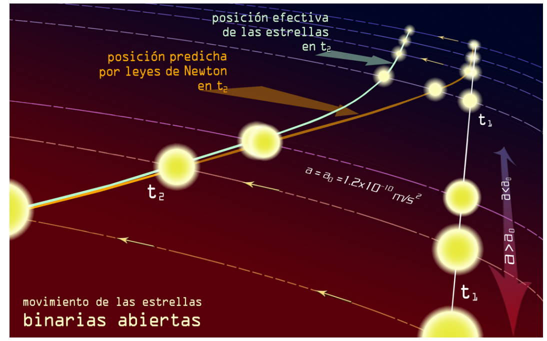




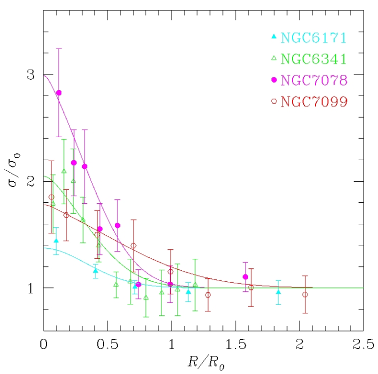
The relative velocities of observed Wide binaries are inconsistent with Newtonian Gravity and GR

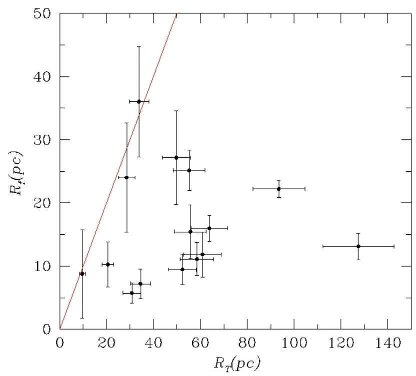


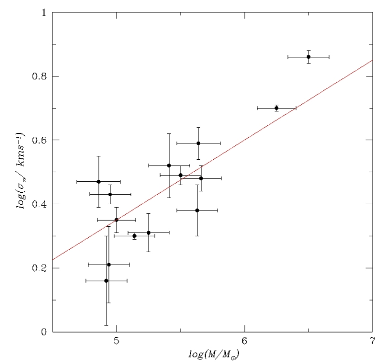




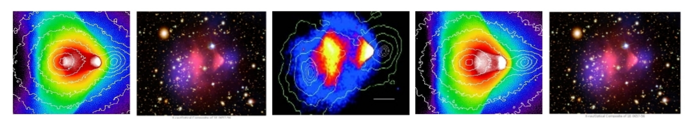
Outer velocity dispersions of globular clusters become flat and show the same galactic $\sigma \propto M^{1/4}$ TF scaling

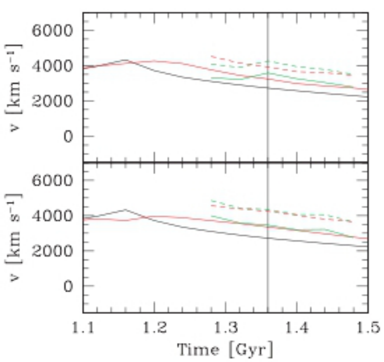


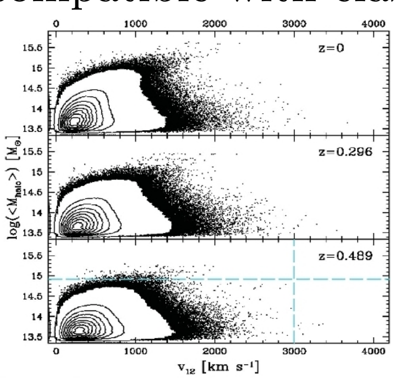


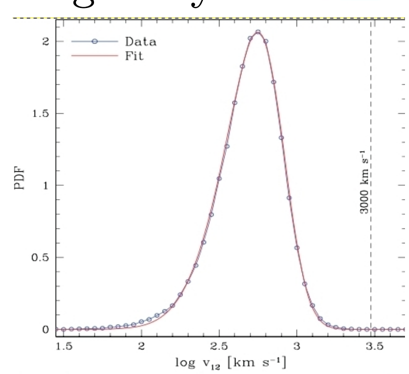


Infall velocity of the Bullet Cluster is larger than escape velocity, and hence incompatible with classical gravity





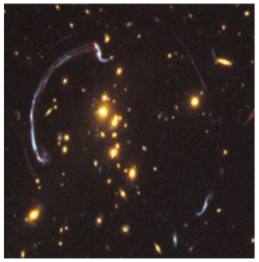
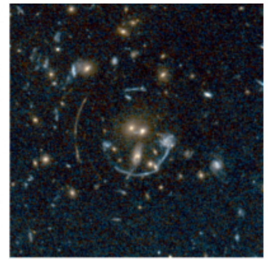
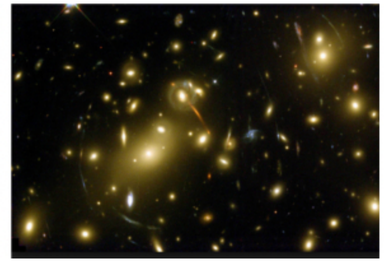
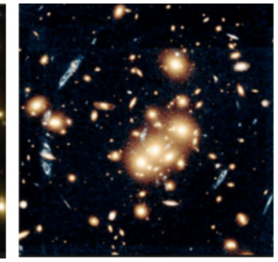


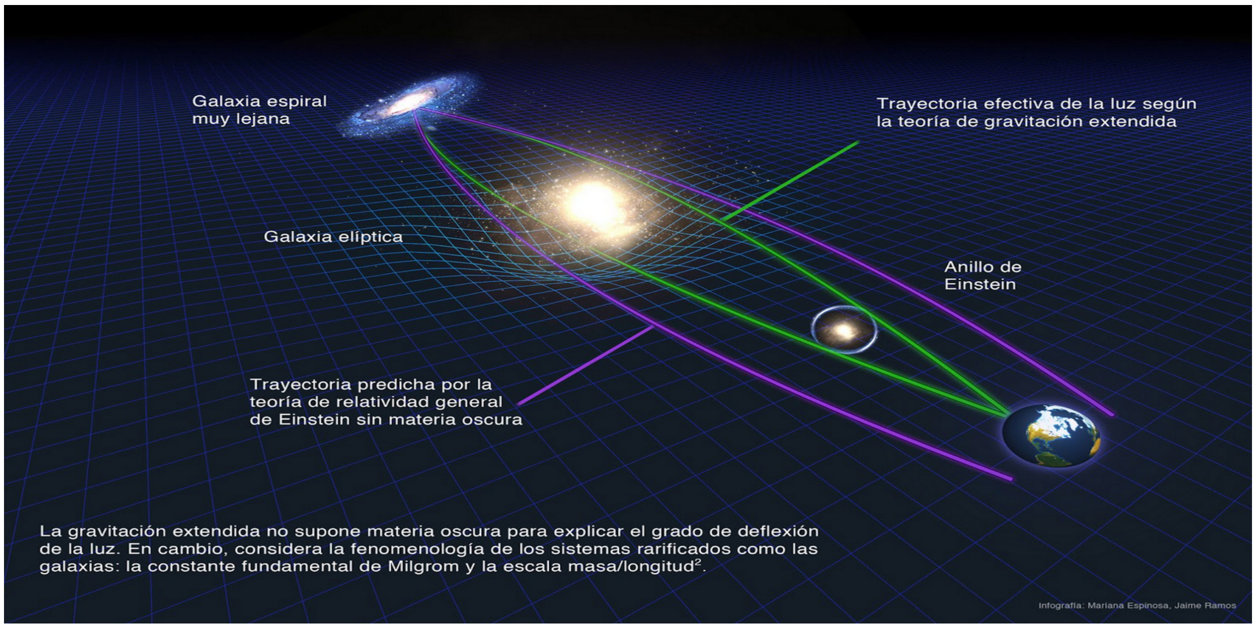


Conclusion:

The end of the validity regime
for Newtonian gravity and GR
has now been observed in a variety
of low acceleration astrophysical systems.

Gravitational lenses as a critical experiment



-While the orbits of material particles (e.g. stars) depend only on the distortions on the flow of time ($g_{00} = 1 + 2\phi/c^2$) as a function of position, the trajectories of light rays depend also upon distortions in the measure of space, g_{11}.

-We presented the only modified gravity theory to date to explain both stellar movements in galaxies and gravitational lensing, without requiring any dark matter.

S. Mendoza, T. Bernal, X. Hernandez, J.C. Hidalgo & L. A. Torres (2013) MNRAS 433, 1802

ariſe from the particular natures of thoſe bodies. But whence it is that bodies derive thoſe natures they don't tell us; and therefore they tell us nothing. And being entirely employed in giving names to things, and not in ſearching into things themſelves, we may ſay that they have invented a philoſophical way of ſpeaking, but not that they have made known to us true philoſophy.

Others therefore by laying aſide that uſeleſs heap of words, thought to employ their pains to better purpoſe. Theſe ſuppoſed all matter homogeneous, and that the variety of forms which is ſeen in bodies ariſes from ſome very plain and ſimple affections of the component particles. And by going on from ſimple things to thoſe which are more compounded they certainly proceed right; if they attribute no other properties to thoſe primary affections of the particles than Nature has done. But when they take a liberty of imagining at pleaſure unknown figures and magnitudes, and uncertain ſituations and motions of the parts; and moreover of ſuppoſing occult fluids, freely pervading the pores of bodies, endued with an all-performing ſubtilty, and agitated with occult motions; they now run out into dreams and chimera's, and neglect the true conſtitution of things; which certainly is not to be expected from fallacious conjectures, when we can ſcarce reach it by the moſt certain obſervations. Thoſe who fetch from hypotheſes the foundation on which they build their ſpeculations, may form indeed an ingenious romance, but a romance it will ſtill be.

There is left then the third claſs, which profeſs experimental philoſophy. Theſe indeed derive the cauſes of all things from the moſt ſimple principles poſſible;

poſſible; but then they aſſume nothing as a principle, that is not proved by phænomena. They frame no hypotheſes, nor receive them into philoſophy otherwiſe than as queſtions whoſe truth may be diſputed. They proceed therefore in a twofold method, ſynthetical and analytical. From ſome ſelect phænomena they deduce by analyſis the forces of nature, and the more ſimple laws of forces; and from thence by ſyntheſis ſhew the conſtitution of the reſt. This is that incomparably beſt way of philoſophizing, which our renowned author moſt juſtly embraced before the reſt; and thought alone worthy to be cultivated and adorned by his excellent labours. Of this he has given us a moſt illuſtrious example, by the explication of the Sy-
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