The Need for Dark Matter in MOND on Galactic Scales

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As presented by I. Ferreras, M. Sakelleriadou, M. F. Yusaf, [arXiv:0709.3189]

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Introduction: Rotation Curves and the Call for Dark Matter

The Observations:

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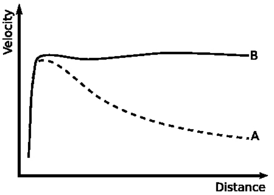

- Line A - The Keplerian Prediction

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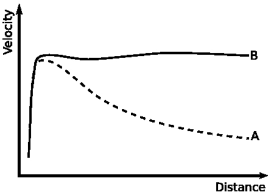

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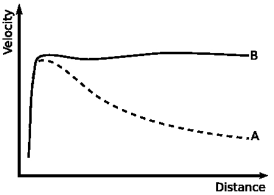

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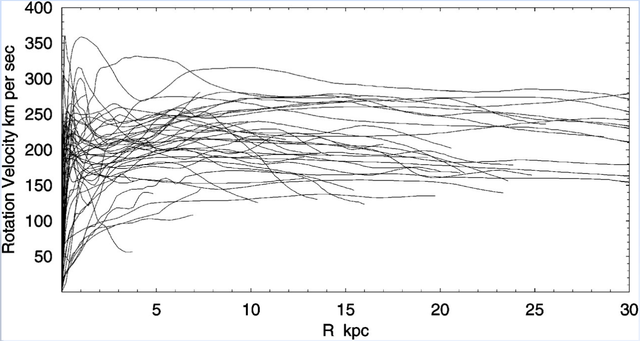

The observed results from many galaxies.

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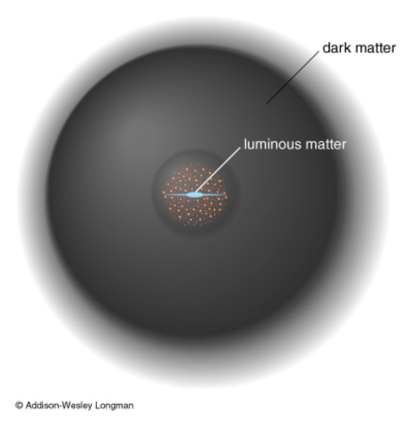

Introduce large quantities of invisible massive matter in a halo around galaxies.

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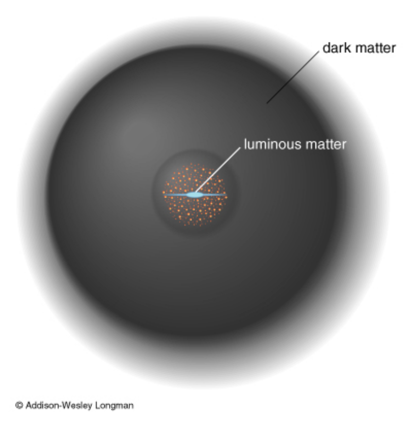

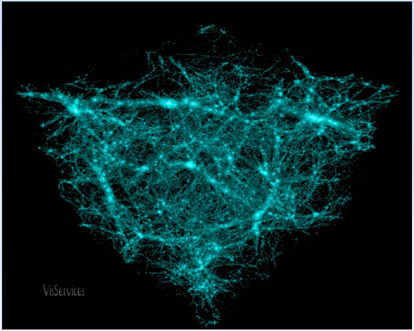

A numerical simulation showing clumping strands of dark matter.

Introduce large quantities of invisible massive matter in a halo around galaxies.

Cosmological Structure and Dark Matter

The Density Parameters:

Three types of energy density observed in the Universe.

These densities are related by $\Omega_m + \Omega_\Lambda + \Omega_k = 1$. Big Bang Nucleosynthesis constrains the Baryonic component of Ω_m to be approximately 0.03. Other constraints on these parameters come from observations of supernovas and the cosmic microwave background.

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$(\Omega_m, \Omega_\Lambda, \Omega_k) = (0.25, 0.75, 0)$

This configuration fits the CMB and Supernova data well. The extra non-baryonic contribution to Ω_m is dark matter, which helps also explain early structure formation.

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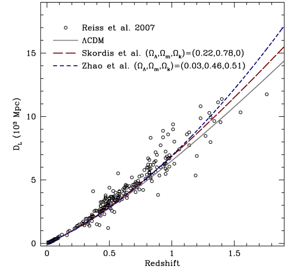

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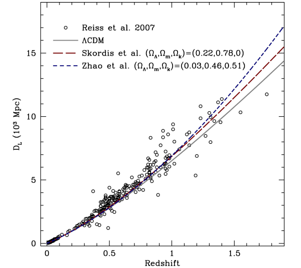

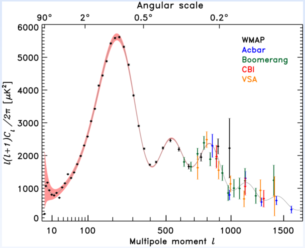

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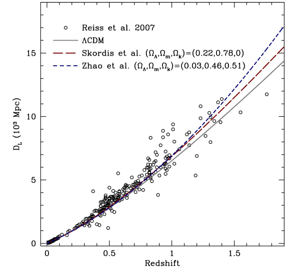

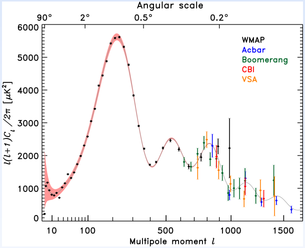

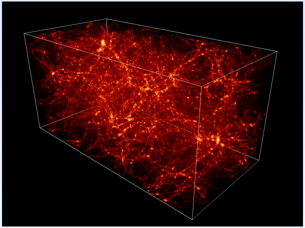

Modified Newtonian Dynamics

Objections and Alternatives:

The Objections

- Dark Matter has yet to be directly observed (LHC?)
- Tully-Fisher relation
- Fine tuning

An Alternative

- Modified Newtonian Dynamics (M. Milgrom, [Astrophys. J. **270** (1983) 365.])

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- MOND insensitive to exact form of $f(x)$ function.

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- In the Newtonian limit, TeVeS reproduces MOND. TeVeS very complex, and lensing results from simpler MOND can be extended to TeVeS.

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Modified Newtonian Dynamics

Testing MOND:

MOND shows very good fit to the rotation curves of spiral galaxies. There is some debate over dwarf galaxies and galactic clusters, but there is some evidence that MOND can even work in some of these cases.

Results taken from R. Bottema, J. L. G. Pestaa, B. Rothberg, R. H. Sanders
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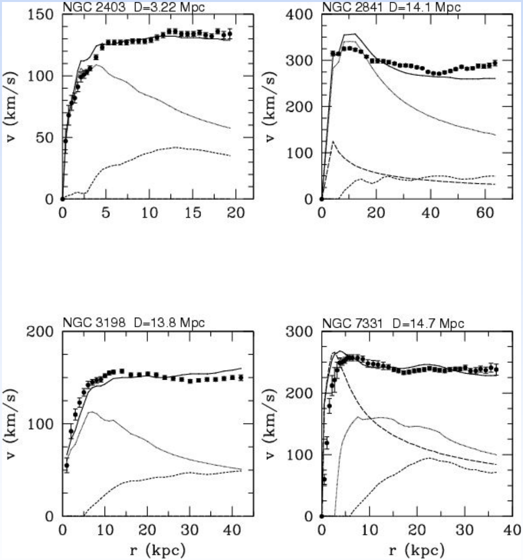

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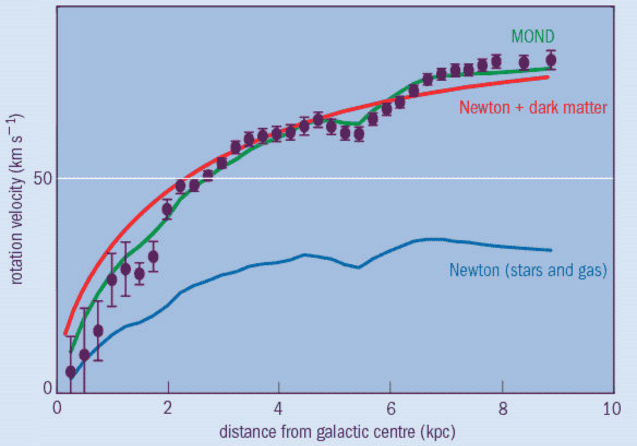

Figure: Taken from [Astrophys. J. 634 70]

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Gravitational lensing provides a way to probe the matter distribution of galaxies.

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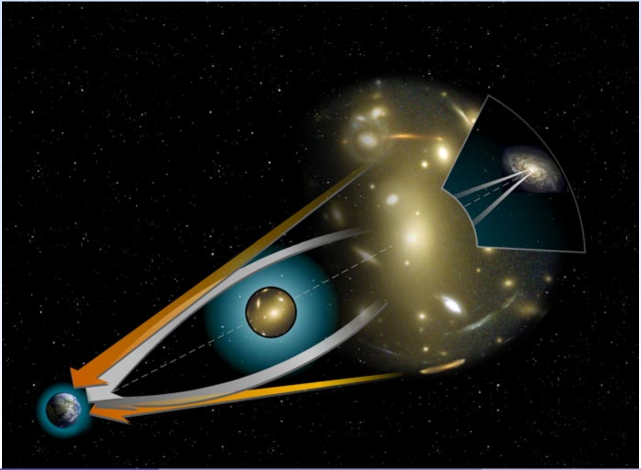

Lensing in MOND

The Deflection Angle:

The Deflection Equation

$$\alpha(b) = -\frac{4Gb}{c^2} \int_0^\infty f^{-1/2} \left[\frac{GM(<\sqrt{b^2+z^2})}{(b^2+z^2)a_0} \right] \frac{M(<\sqrt{b^2+z^2})}{(b^2+z^2)^{3/2}} \, \mathrm{d}z \ .$$

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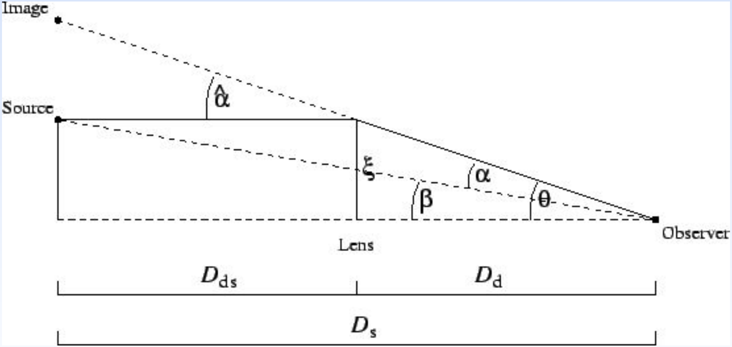

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Point mass and SIS

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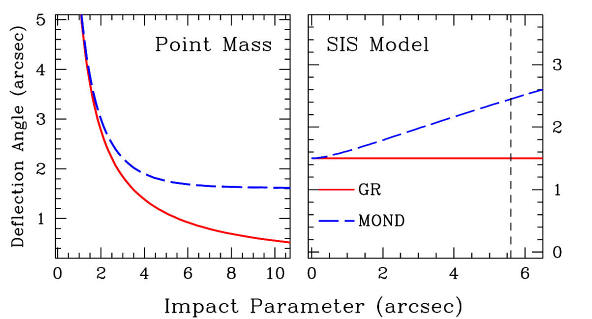

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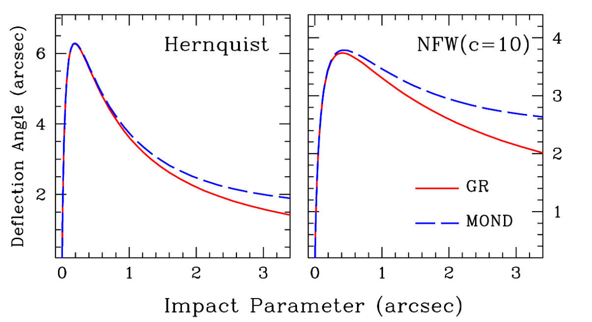

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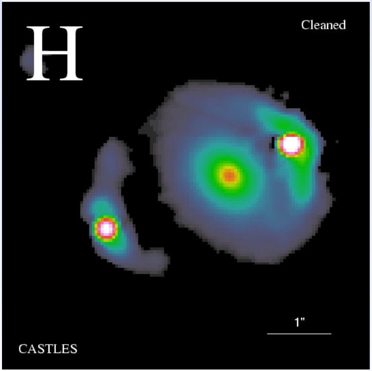
The Lensing Equation:

The Geometric Lens Equation

$$\beta = \theta - \alpha(\beta, \theta, M)\frac{D_{\mathrm{LS}}}{D_{\mathrm{S}}}$$



cfa-www.harvard.edu/castles/

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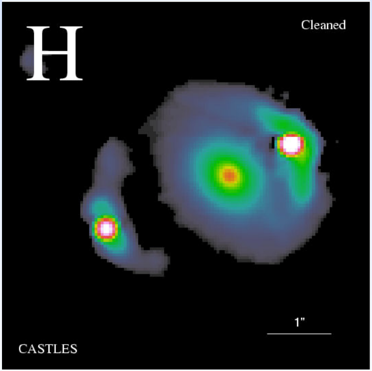

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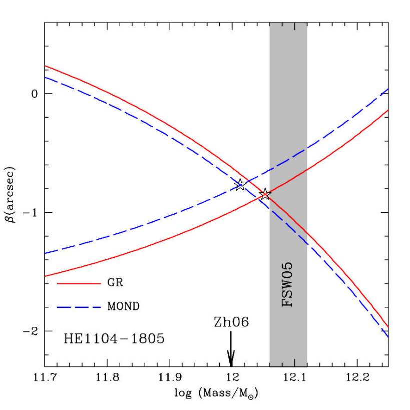

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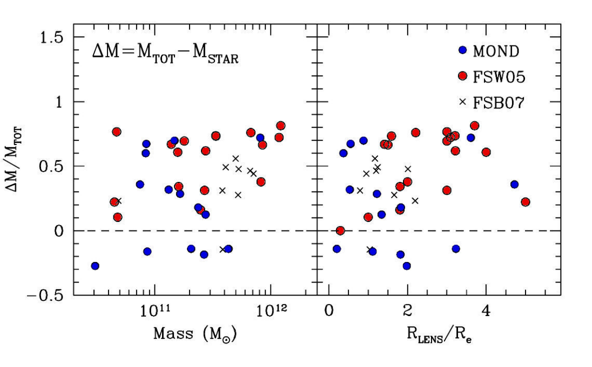
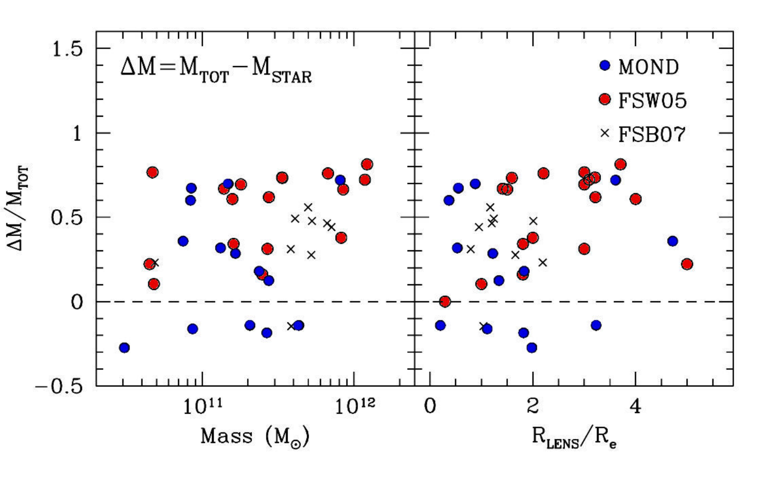
Solving The Lens Equation:



FSB07: I. Ferreras, P. Saha., L. L. R. Williams and S. Burles [astro-ph/0708.2151]

FSW05: I. Ferreras, P. Saha and L. L. R. Williams, [Astrophys. J. **623** (2005) L5.]

Conclusion



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