Modified Gravity or Dark Matter and Dark Energy ?

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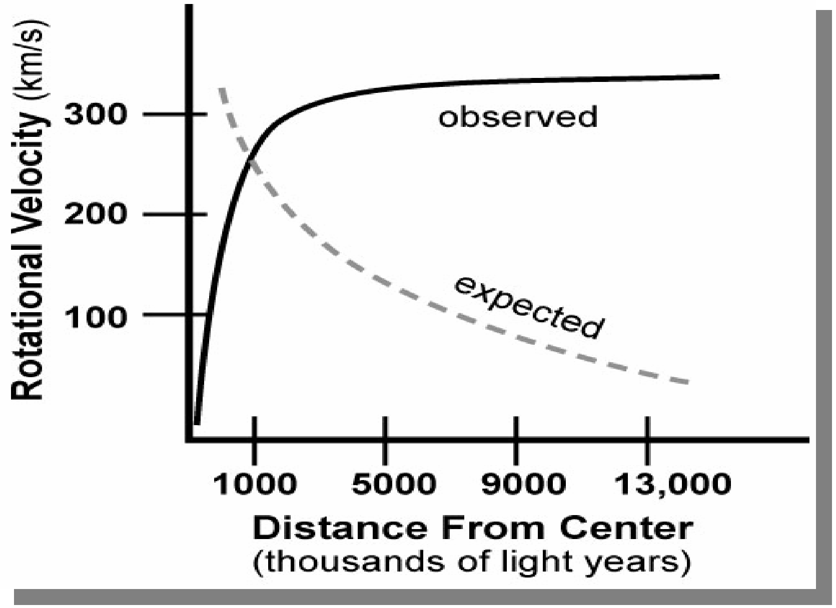
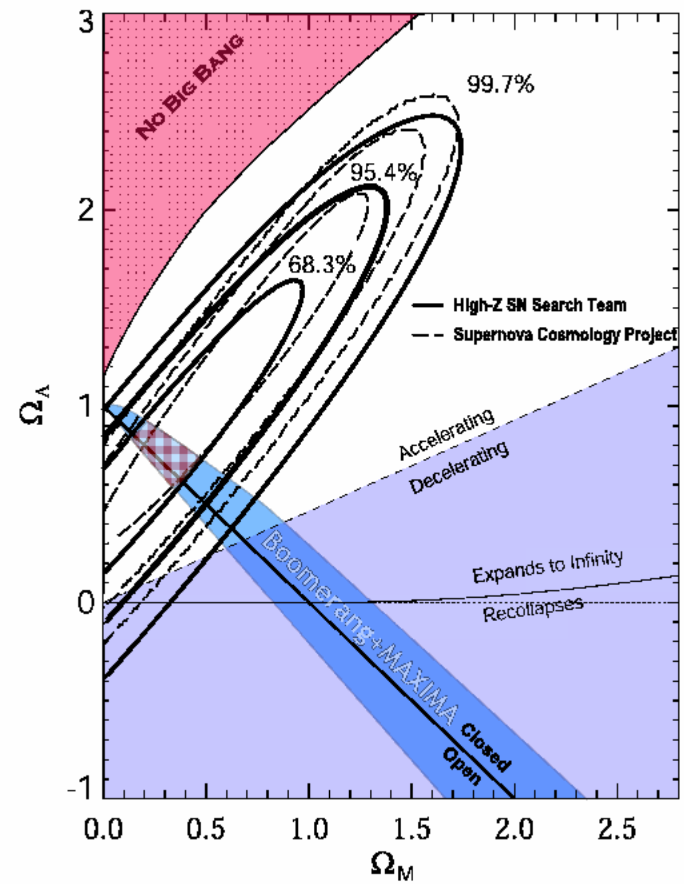
Dark Matter inside the Spiral Galaxies

One of the Candidates is MACHOs. Those objects could be brown dwarfs, faint white dwarf and black holes



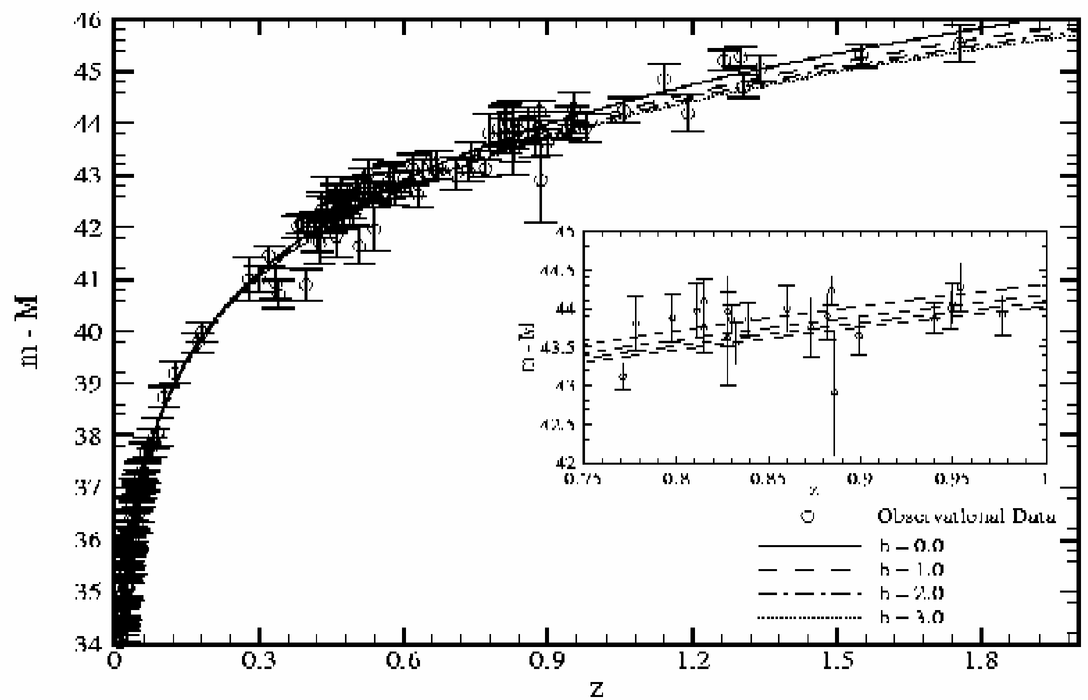
Evidence for Dark Energy

- ⌖☹ 🕔 0.7
- ⌖m 🕔 0.3



Experiments on Dark Matter

1. Microlensing experiments -> We failed (there is no dark Compact object at the Galactic halo)
2. WIMPs (up to now there is no significant signals)
3. In near future Baryonic matter search through scintillation experiment of Large Magellanic Clouds (OSER Project, M. Moniez & F. Habibi)



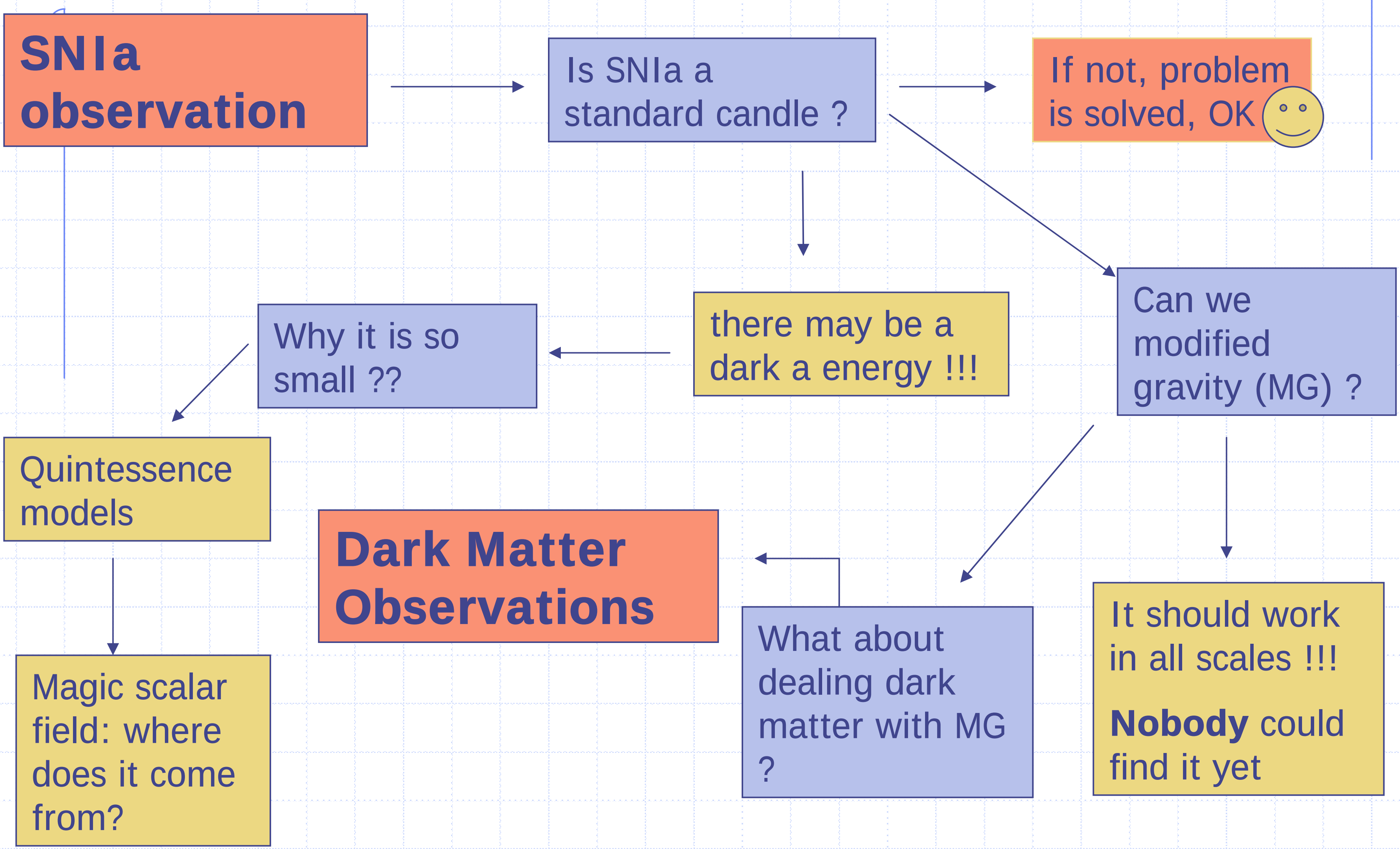
M.S. Movahed & S.R,
Phys.Rev. D73 (2006) 083518

$\Omega_\Lambda \simeq 0.7$

$\Omega_m \simeq 0.3$

It seems that the main energy-momentum of universe is in dark energy form !!!

How we can deal with this messy problem ?



Starting from the bottom of the flow-chart

- Modified gravity (MG) in small scale ?
- We can start from the modified dynamics (MOND).
- It is not difficult to show that MOND dynamically is equal to a MG

MOND

For small accelerations a<10^{-10} m/sec^2:

$$F = m\mu(a/a_0)a$$ (Milgrom M., 1983, ApJ,)

Assuming equality of inertial and gravitating mass:

$$-\nabla\varphi_N = \mu(a/a_0)a$$

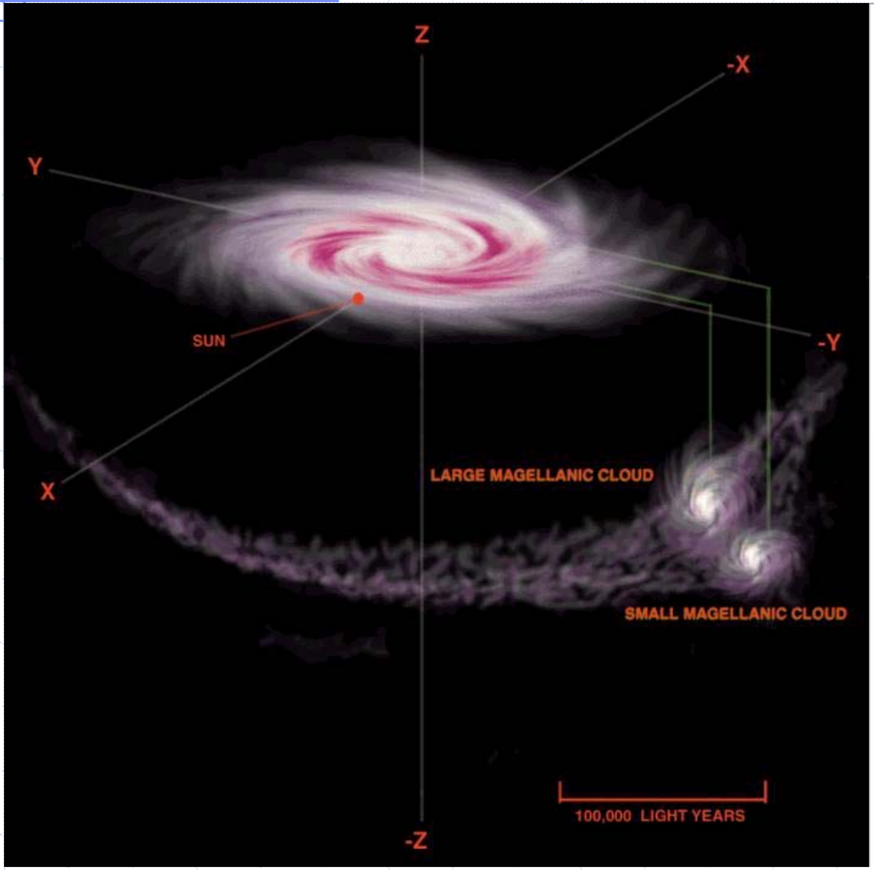
$$\mu(x) = x/\sqrt{1+x^2}$$

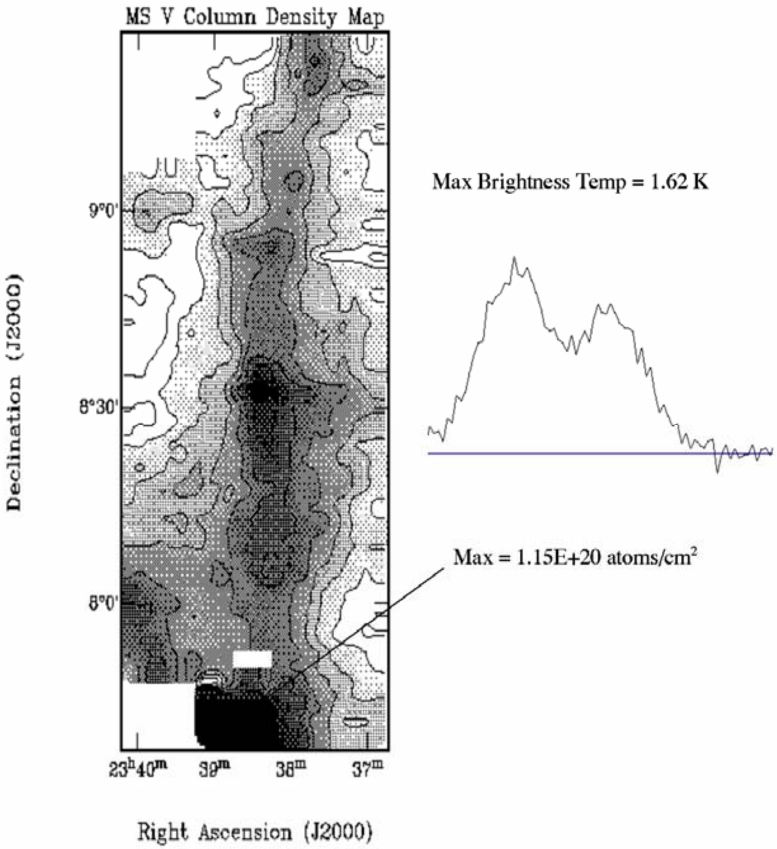
It is not difficult to show the physical acceleration is gradient of a scalar field, which we call it as the modified gravity

Testing MOND

- Using the rotation curve of Spiral Galaxies
- Using the dynamics of satelite galaxies
- Looking to the dynamcis of elliptical galaxies
- Cluster of galaxies

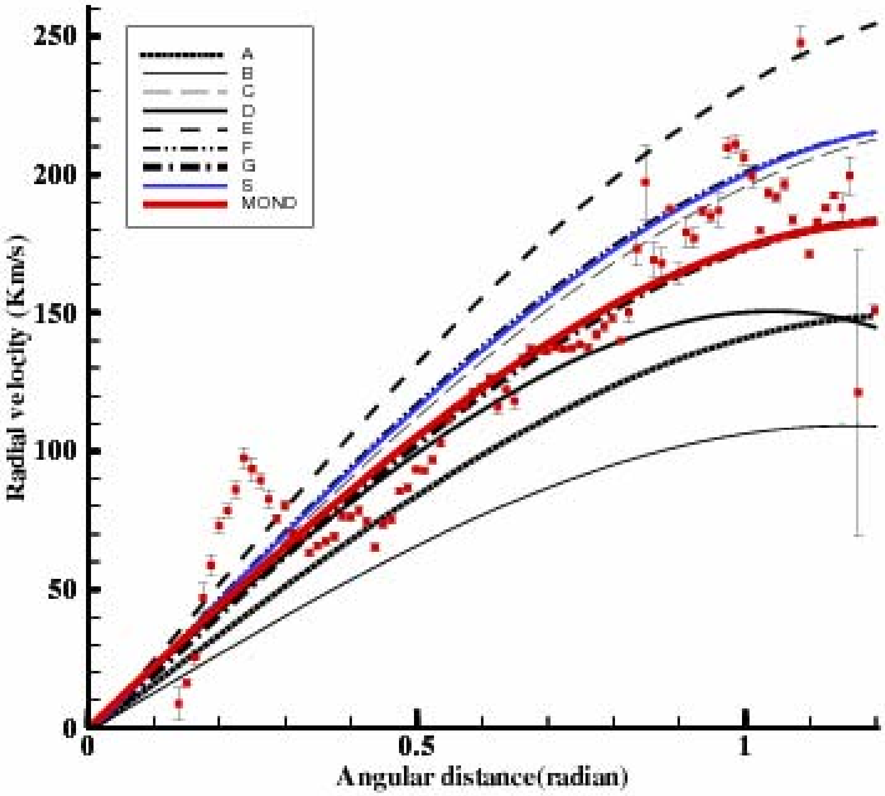
Using the dynamics of Magellanic Stream





Data from Brunes et al (2005) A&A
(Parkres Observatory)

Results:



MOND has good agreement with the Dynamics Of MS, comparable to CDM halo models

H. Haghi, A. Hassani-zonoz and S.R, (2006) ApJ (submitted)

Relativistic approach:

$$s = \int f(R)\sqrt{-g}\,dx^4 + \kappa \int L_M \sqrt{-g}\,dx^4$$

$$f(R)' R_{\mu\nu} - \frac{1}{2} f(R) g_{\mu\nu} - \nabla_\mu \nabla_\nu f(R)' + g_{\mu\nu} \nabla_\alpha \nabla^\alpha f(R)' = \kappa T_{\mu\nu}$$

Are there any $f(R)$ which generate a MOND like potential ?

Problems:

We have fourth order differential equation in constrast to the second order equation as the equation of motion !

The cosmological solution is very difficult even numerically and it makes difficult for comparing with the observations

(e.g. $f(R) = (R^n - R_0^n)^{1/n}$)

Sh. Baghramian, M. Farhang, Sh. Sheik-Jabari and S.R, (2006)

Some interesting properties of f(R) Lagrangian

Start with f(R)

(Jordan frame)

Use an auxiliary scalar field

A Brans-Dicke gravity !

Do conformal transformation

(Einstein frame) + scalar field

Which one is the physical frame, it seems that there is no observational test ??

Thanks for attention