Testing Galileon Gravity Using Supermassive Black Holes

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Why modified gravity?

If you aren't interested in modified gravity, you're in the wrong room — Marco Crisostomi

Why modified gravity?

- Quantum gravity
- Dark energy
- Cosmologícal constant problem
- Need alternative theories to test GR



Galileons

Newtonian gravity:

 $\nabla^2 \Phi_N = 4\pi G\rho \qquad F_N = \frac{GM}{m^2}$

New scalar graviton:

 $\nabla^2 \phi + \frac{r_c^2}{3} \left[\left(\nabla^2 \phi \right)^2 - \nabla_i \nabla_j \phi \nabla^i \nabla^j \phi \right] = 8\pi \alpha G \rho$ Poisson term galileon term coupling to matter

Galileons - Vainshtein screening $\left(\frac{F_5}{F_N}\right) + \frac{1}{2\alpha^2} \left(\frac{r_V}{r}\right)^3 \left(\frac{F_5}{F_N}\right)^2 = 2\alpha^2$ Poisson term galileon term coupling to matter $\frac{F_5}{F_M} = 2\alpha^2$ $r \gg r_V$ $\frac{F_5}{F_N} = 2\alpha^2 \left(\frac{r}{r_V}\right)^{\frac{3}{2}} \quad r \ll r_V$ $r_V^3 = \frac{4}{3} \alpha G M r_c^2$

 $\frac{F_5}{F_N}$ Unscreened Screened r_V

Galileons

- Self-acceleration (DE but does not solve CC)
- Níce UV properties
- Massíve gravíty
- Braneworld models

• Hard to test due to Vainshtein screening

Hui & Nicolis '12

No hair theorem

Black holes described by mass and spin only!

No galileon charge Q so BH does not feel galileon force

Matter has Q = M

Matter and BH fall at different rates

Violation of the strong equivalence principle



Galaxy clusters: nature's leaning towers









Future tests

This is one galaxy!

• More galaxies - SDSS, DES, Euclid + X-ray/Radio

Morphologícal distortions

Missing SMBHs!

Summary

Can test Vainshtein using SEP violation

• Expect offset black holes in cluster satellite galaxies

New constraints from Virgo cluster/M 87

Expect improvements with imaging survey data