Can we Measure the Effect of Compactified Extra Dimension by a Gravitational Wave Detectors?

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Annual NewCompStar Conference 2016

28th April 2016 Istanbul, Turkey

Possible experiments to test...

- Without violating the theories:

  Looking for deviant Newtonian motion

  Certainly NOT in the standard regime

- Where can we test this?

  Search for extra dimensions at the LHC

  Maximal LHC energy just reach the LXD regime

  GW detectors might have the sensitivity too

How the modified gravitation looks

- Modified GR potential in different ways:

Perturbation to the power of the distance

$$F(r) = G\frac{m_1\ m_2}{r^{2+\epsilon}}$$

$$V(r) = -G\frac{m_1\ m_2}{r}\left[1 + \alpha_N \left(\frac{r_0}{r}\right)^{N-1}\right]$$

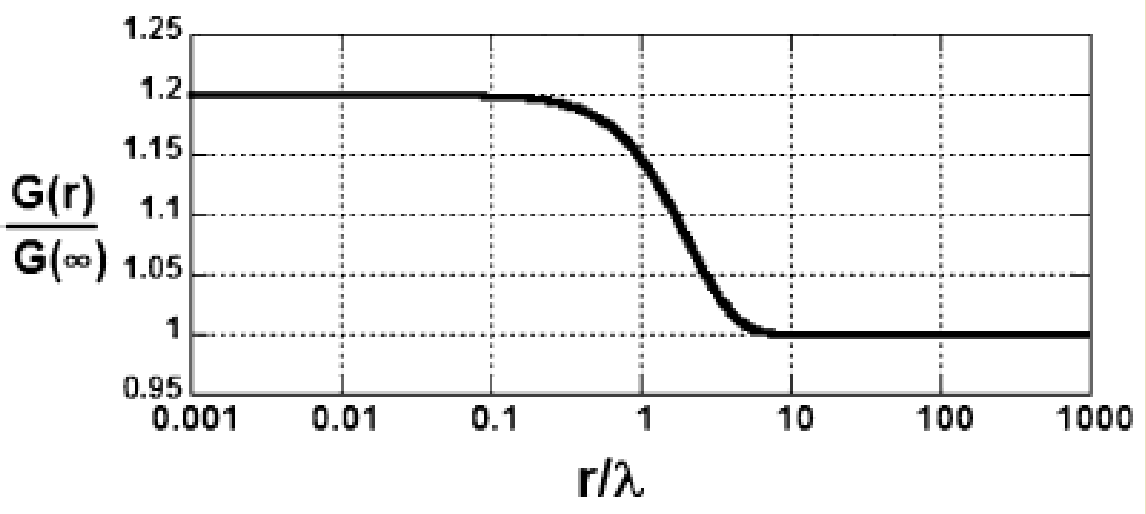
Problem: we should see it at any distance

How the modified gravitation looks

- Modified GR potential in different ways:

  Yukawa-like term as a correction

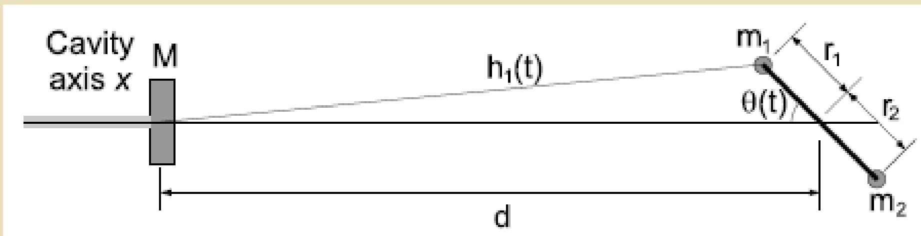
$$F(r) = \frac{Gm_1m_2}{r^2}\left(1+\alpha\left(1+\frac{r}{\lambda}\right)e^{-r/\lambda}\right) = \frac{G(r)m_1m_2}{r^2}$$

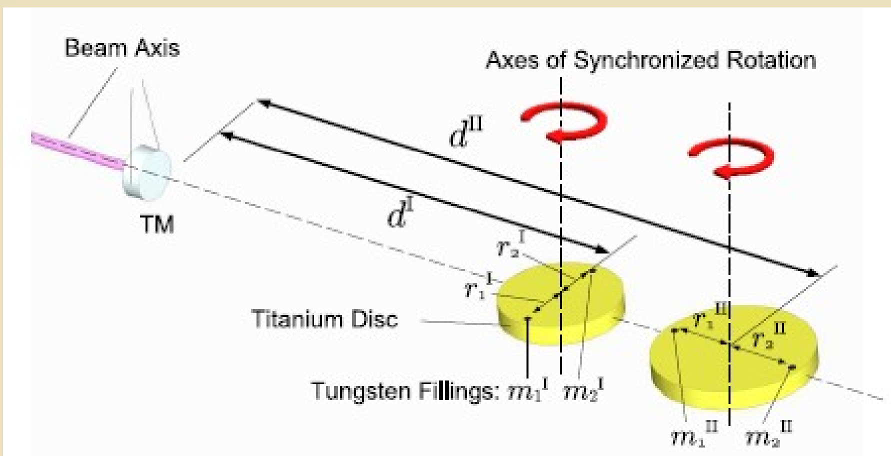


How the modified gravitation looks

A suggested measurement for GR corrections:

DFG: Dynamic gravity Field Generator@aLiGO





P. Raffai et al. PRD84 082002 (2011)

How the modified gravitation looks

A suggested measurement for GR corrections:

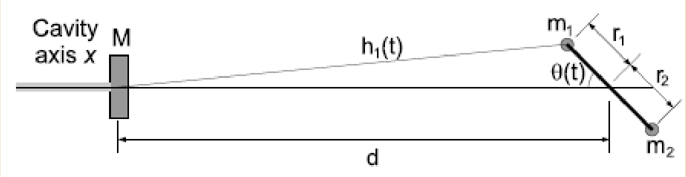
DFG: Dynamic gravity Field Generator@aLiGO

$$V(r) = V^{\mathrm{N}}(r) + V^{\mathrm{Y}}(r) = -G\,\frac{mM}{r}\,[1 + \alpha e^{-r/\lambda}]$$

$$V^{\mathrm{N}} = \sum_{i=1}^{2} V_{\mathrm{i}}^{\mathrm{N}} = -GM \sum_{i=1}^{2} \frac{m_{\mathrm{i}}}{h_{\mathrm{i}}}.$$

$$V^{\mathrm{Y}} = \sum_{i=1}^{2} V_{\mathrm{i}}^{\mathrm{Y}} = -\alpha GM \sum_{i=1}^{2} \frac{m_{\mathrm{i}}}{h_{\mathrm{i}}} e^{-h_{\mathrm{i}}/\lambda}$$

$$h_{\mathrm{i}}(t) = d\,\sqrt{1 + R_{\mathrm{i}}^2 - 2R_{\mathrm{i}}\cos\theta(t)}$$



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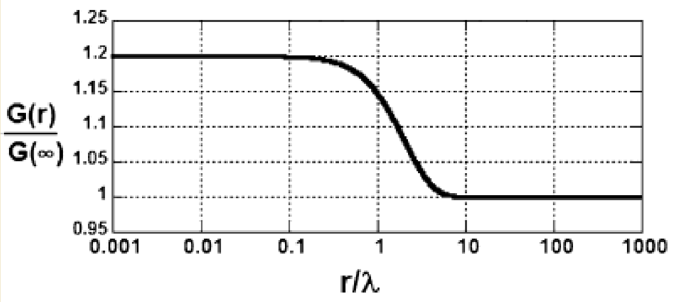
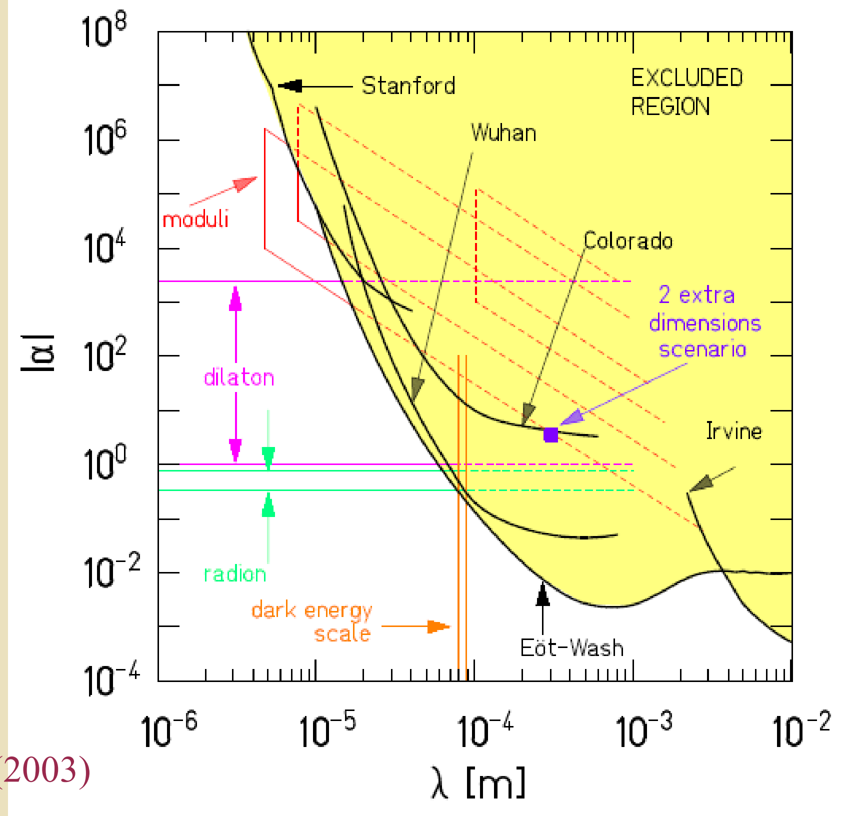
Possible experiments to test...

- Excluded regions by gravitational experiments:

$$F(r) = \frac{Gm_1m_2}{r^2}\left(1+\alpha\left(1+\frac{r}{\lambda}\right)e^{-r/\lambda}\right) = \frac{G(r)m_1m_2}{r^2}$$





See more in Refs:

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E.G. Adelberger: Ann. Rev. Nucl. Part. Sci. 53. 77 (2003)

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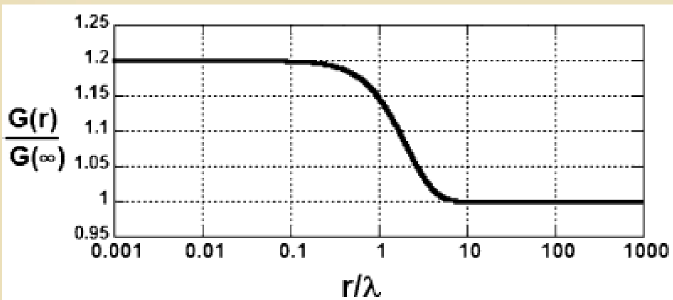

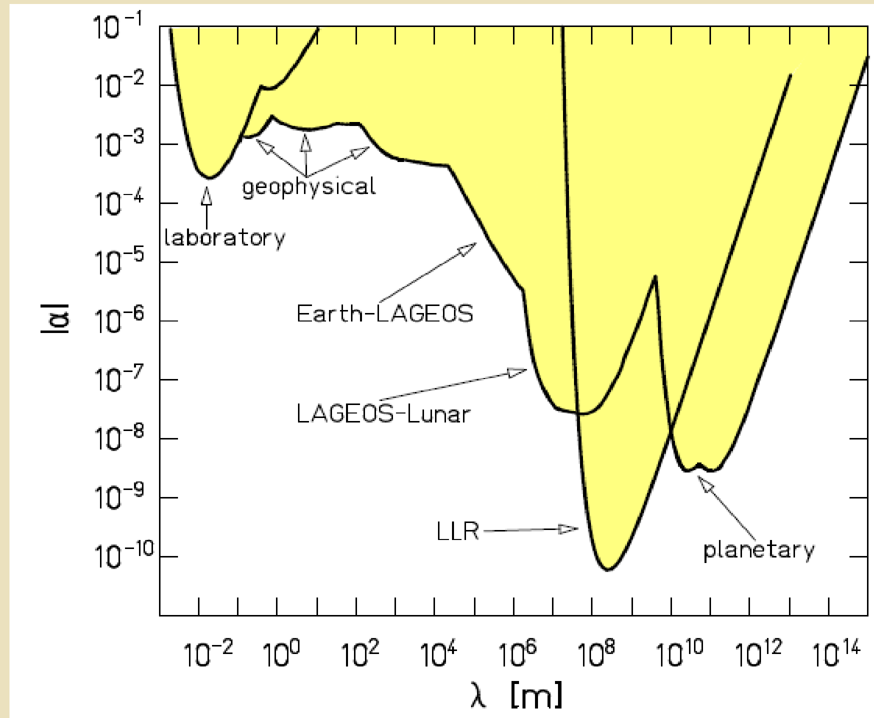

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Construction of KK stars

1. The space-time has $(3 + m_c) + 1$ dimensions; and except for the last one, they are space-like, while the last is time-like.

2. The structure of general relativity is just as we have learnt in $3 + 1$ dimensions; especially the form of the *Equivalence Principle* is unchanged.

3. All causality postulates, including lightcone structure, are as they were in the $3 + 1$ case.

4. The m_c extra space-like dimensions are microscopical, i.e. they are all compact with microscopical circumferences.

5. There is complete Killing symmetry in the m_c-dimensional microscopical subspace.

Connection to KK stars

- Construction of a KK star in $1+3+1_c$ spacetime

  General metric:

  $$ds^2 = -\Phi^{2/3}(d\Psi + A_r dx^r)^2 + \Phi^{-1/3} g_{rs} dx^r dx^s$$

  Lagrangian (Brans-Dicke):

  $$\mathcal{L} = R^{(5)} = R^{(4)} + \frac{\Phi}{4} F^{rs} F_{rs} + \frac{g^{rs}}{6} \cdot \frac{\Phi_{,r} \Phi_{,s}}{\Phi^2}$$

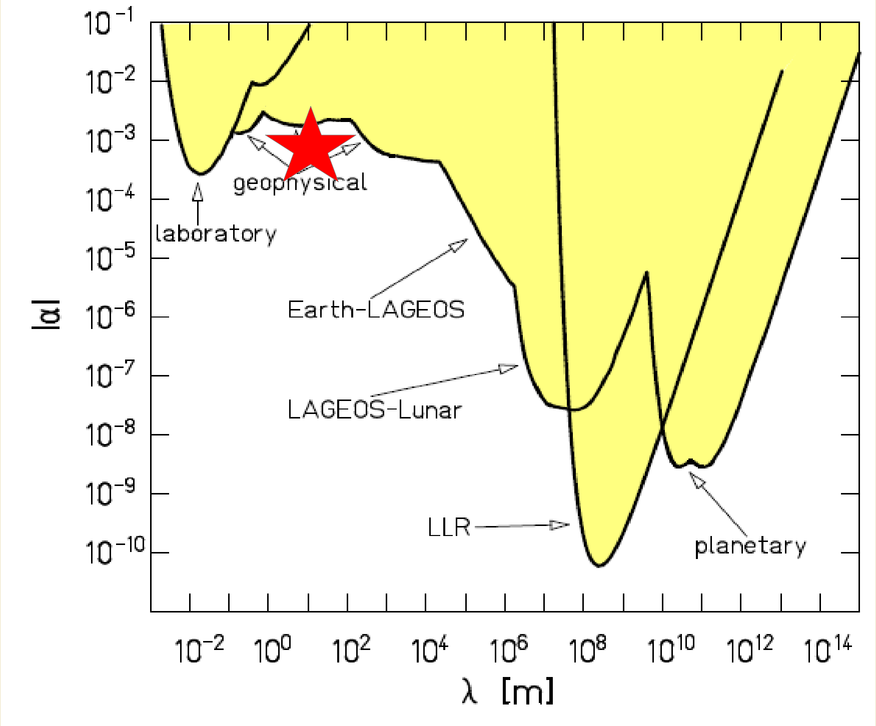
  This can appeared as correction to GR potential

  $$V(r) = -G_\infty \frac{m_1 m_2}{r} \left(1 + \alpha \cdot e^{-r/\lambda}\right)$$

KK stars vs. experiments

- Excluded regions by gravitational experiments:

  Take extraD effects as perturbation will not rule out the theory for the non-interacting case

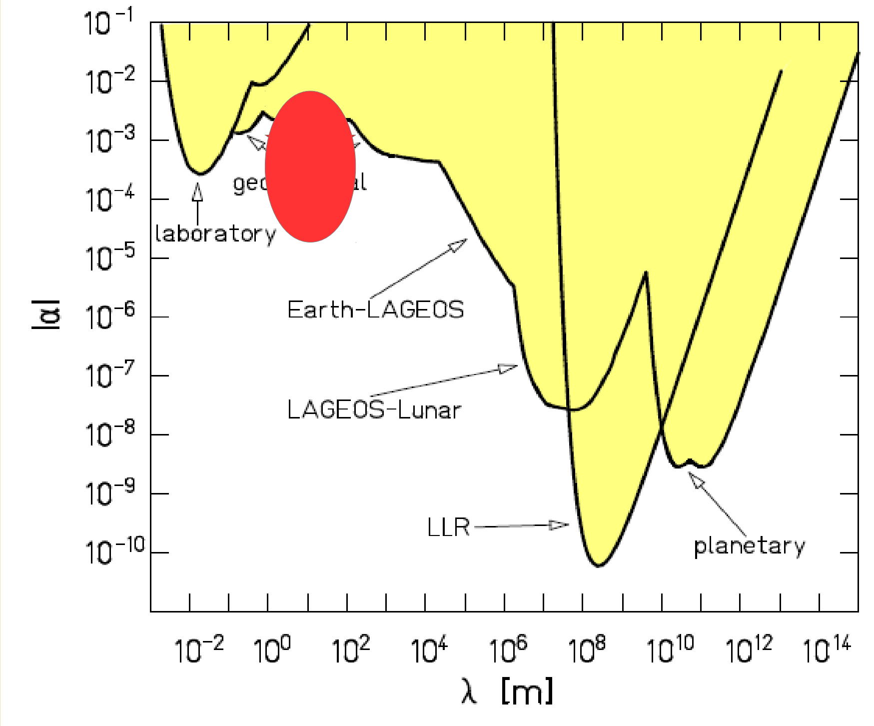


KK stars vs. experiments

- Excluded regions by gravitational experiments:

Take extraD effects as perturbation will not rule out the theory for the non-interacting case

Including interaction is much more better



Summary

- Compact stars in $1+3+1_C\, D$ were analyzed:

  Static, spherical Schwarzschild-like space-time

  TOV-like eqs. with specific, but exact (stable) solution

  Solutions overlap with strange star models if R_C is set to the mass of strangeness: 10^{-13} cm < R_C < 10^{-9} cm

  Mass limits: Determinate by R_C , D and the μ & larger the R_C result more compact compact star

- Possible ongoing tests:

  Might see a signal for *D*s at the LHC: $hc/E_{beam} \sim 10^{-18}$ cm

  Compact Stars or GW detectors: deviation from GR potential. Still in the non-exclusion regime.