Hiding gravitationally coupled scalars through local symmetry restoration (after arxiv:1001.4525)

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In the work is considered the scalar field, which is coupled with gravitation and the matter. The coupling is such that the field evolves in effective potential

$$V_{eff}(\phi) = -\mu^2\phi^2 + \lambda\phi^4 + \frac{\rho\phi^2}{M^2} \tag{1}$$

where ρ is the density of matter and μ, λ, M are the parameters of the theory. When $\rho \leq \mu^2 M^2$, the symmetry is broken, but in dense environments, $\rho > \mu^2 M^2$, the symmetry is restored. The interaction between matter and the field is proportional to the local average value of the field, and then in dense environments there is no interaction between matter and the field.
The action of the theory states:

$$S = \int d^4x\sqrt(-g)(\frac{M_{PL}^2}{2}R - \frac{1}{2}(\partial\phi)^2 - V(\phi)) + \int d^4x L_m[\tilde{g}] \tag{2}$$

where

$$\tilde{g}_{\mu\nu} = A^2(\phi)g_{\mu\nu}, \quad A(\phi) = 1 + \frac{\phi^2}{2M^2} \tag{3}$$

$$V(\phi) = -\frac{1}{2}\mu^2\phi^2 + \frac{1}{4}\lambda\phi^4 \tag{4}$$

$$\tag{5}$$

The existing limits:

$$H_0^2 M_{PL}^2 \approx \mu^2 M^2 \tag{6}$$

$$M \lesssim 10^{-3} M_{PL} \tag{7}$$

$$\phi_0 \equiv \frac{\mu}{\sqrt{\lambda}} \approx \frac{M^2}{M_{PL}} \tag{8}$$

Static equation on the field ϕ:

$$\phi'' + \frac{2}{r}\phi' = V_{,\phi} + A_{,\phi}\rho \tag{9}$$

The prime denotes the derivative wrt r. we consider the case of homogeneous object of radius R and density ρ. Approximate solution can be obtained by linearising the potential around the corresponding minima. The solution:

$$\phi_{in} = A\frac{R}{r}\sinh\left(r\sqrt{\frac{\rho}{M^2} - \mu^2}\right) \tag{10}$$

$$\phi_{out} = B\frac{R}{r}e^{-\sqrt{2}\mu r} + \phi_0 \tag{11}$$

There are three dimensionless parameters in this solutions: $\mu R, \frac{\rho}{\mu^2 M^2}, \rho R^2/M^2$. In the situation under consideration $\mu R \ll 1$, $\frac{\rho}{\mu^2 M^2} \gg 1$. The third parameter, α can be either great or small.
The equations of gravitational field in the cases:

$$R_{\mu\nu} - \frac{1}{2}g_{\mu\nu}R = 8\pi G A(\phi)T_{\mu\nu} + 8\pi G T_{\mu\nu}^{(\phi)} \tag{12}$$

where $T^{(\phi)}_{\mu\nu}$ is stress-energy tensor of the field ϕ, and $T_{\mu\nu}$ is stress-energy tensor of the rest matter. The linearised Einstein equations state in this case:

$$R_{\mu\nu} = \frac{1}{2}\delta h_{\mu} \tag{13}$$

$$\Delta h_{00} = \frac{8\pi G}{c^2}(T_{00} - T_{11}) \tag{14}$$

$$\Delta h_{11} = \frac{8\pi G}{c^2}(T_{00} + 3T_{11}) \tag{15}$$

We assumed, that $h_{11} = h_{22} = h_{33}, h_{0i} = 0, h_{ij} = 0$ if $i \neq j$ - this is indeed the case in Cartesian coordinates. Gauge-fixing condition for this case states: $\partial^{\mu}(h_{\mu\nu} - \frac{1}{2}hg^{\mu\nu})$ For light deflection and time delay experiments matters only one PPN parameter,

$$\gamma - 1 = \frac{h_{11} - h_{00}}{h_{11} + h_{00}} = \frac{4\int_0^R T_{11} r^2 dr}{\int_0^R T_{00} r^2 dr} = \frac{1}{\rho R^3} \tag{16}$$