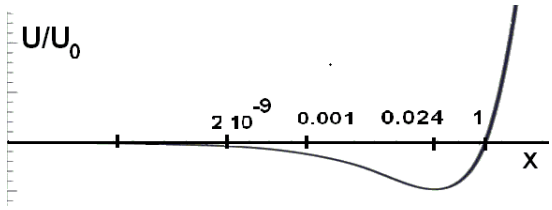

Fig. 1. Inverse Yukawa Potential in adimensional comovil scale $x = (r/50\mathrm{h}^{-1}$ Mpc).

$$F_{\rm YI}(r) \equiv -\frac{U_0(M)}{r^2} e^{-\alpha/r} \left(r^2 + \alpha\,(r - r_0)\right). \quad (2)$$

Also in the weak field approximation ($x \ll 1$) the IYF per unit mass is given by:

$$F_{\rm YI}(r \ll r_0) \approx -\frac{U_0(M)\alpha r_0}{r^2}. \quad (3)$$

But if $x \to 0$, IYF is null, in accordance to Eotvos-type experiments. Is easy to see that for r the order of a kiloparsec, we recover the MOND-Milgrom assumptions (Milgrom 2009):

$$F_{\rm YI}(r \ll r_0) \approx \frac{U_0(M) r_0}{2r + \alpha} \approx \left(\frac{U_0(M) r_0}{2}\right) r^{-1}. \quad (4)$$

Remember that the usual Newtonian gravitation acts in addition to this force. Notice that the maximun value of the force occurr at $r \approx 1.2\mathrm{h}^{-1}$ Mpc, a typical Abell radius.

3. COSMOLOGICAL CONSEQUENCES

Let us now consider a usual homogeneous and isotropic FRW metric an usual energy-momentum tensor for a perfect fluid together with $\Lambda \equiv \Lambda(r)$, as dynamic variable proportional to IYF, thus:

$$\Lambda(r) = \Lambda_0 (x - 1) e^{-\alpha_0/x}, \quad (5)$$

where Λ_0 is a coupling constant, and $\alpha_0 = 1/20$ is a dimensionless constant or $\alpha_0 = \alpha/r_0$. As before $x \equiv r/r_0$. Then $\Lambda_0 \approx 39 H_0^2/c^2$ or $\Lambda_0 \approx 0.45\mathrm{h}^2\ 10^{-50}\mathrm{m}^{-2}$. But now the definition of the critical density change is: $\rho_c \simeq 9.1 \frac{3H_0^2}{8\pi G} \approx 2.53\ 10^{12}\mathrm{h}^2\ M_{\rm sun}/\mathrm{Mpc}^3$.

When the critical density increases, because the critical mass has been underestimated in the usual definition, the IYF, must join the mass equivalent to the energy of the field, has to be taken into account. Also the central density in the core of clusters of galaxies is $3 \times 10^{15}\ M_{\rm sun}\ \mathrm{Mpc}^{-3}$. For cosmological distance ranges, at scales larger than $50\mathrm{h}^{-1}$ Mpc, the Λ variation is asymptotic (see Figure 1 for $x \gg 1$) and using equation (5) then

$$\Omega_\Lambda \cong \Lambda_0 \left(\frac{c^2}{3H_0^2}\right) \alpha_0\,(x - 1). \quad (6)$$

Also, if we define: $\Omega_{\rm YIF} \equiv -\frac{c^2 \Lambda(r = r_c)}{3H_0^2}$, then the Friedmann equation is (Falcon 2010):

$$\frac{kc^2}{R^2(t)} = H_0^2 \left[\Omega_m\,(1 + \Omega_{\rm YIF}) + \Omega_\Lambda - 1\right], \quad (7)$$

where we used the standard notation (see Peacock 1999, for details) for the dimensionless parameters of density, cosmological "constant" and deceleration. Reeplacing equation (6) into equation (7) with $x \approx 2$, like comoving distance as $100\mathrm{h}^{-1}$ Mpc, (cosmological distance range) then $\omega_\lambda \approx 0.65$ is very close to the usual value: 0.7.

4. CONCLUSION

The important result is that $k = 0$ and $\Omega_{\rm YIF} \neq 0$ do not require the nonbaryonic dark matter assumption, i.e., using equation (7) and $\Omega_\lambda \approx 0.7$ we obtain $\Omega_m \approx \Omega_b = 0.03$ as the typical value for a flat universe but without nonbaryonic dark matter. For the early stages of the Universe, we find the usual relationship between $R(t)$ and the state variables ρ and P, futhermore do not affect the decoupling time, neither the predictions of the Cosmic Microwave Background, nor the primordial nucleosynthesis. Clearly, the incompatibility between the flatness of the Universe and $\Omega \ll 1$ is removed if brigravity is assumed, maybe like the IYF proposed here, as alternative to non-baryonic dark matter, also it is concomitant with FRW cosmology. Ishak et al. (2010) have shown that Λ, is a second order factor in the angle of deflection from gravitational lenses. It is clear that IYF also leads to a similar prediction. Also the IYF can fully comply the Mach Principle, through the incorporation of the dynamic cosmological term $\Lambda(r)$, which also implies that the masses of the nuclei of galaxies (Black Holes) have been overestimated, since the scalar field contributes in addition to the gravitational potential. At large distances from the sources, the reduction in the Newtonian field with the inverse of the square would be offset by an interaction that is growing at much greater distances. These long-range interaction also could be caused by baryonic mass and therefore could be derived with usual physics.

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