

Gravitational repulsion of spherical Voids (MOGA-model with large-scale force $1/R$)

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Flat rotation curves of galaxies suggest extra gravity at galactic scales, which is usually explained by dark matter (DM). However, astrophysicists (P. Kroupa et al) point to facts and data that contradict the DM hypothesis. Instead, the MOND model is advocated. The baryonic Tully–Fisher relation $\log M_{\text{bar}} = c + b \log V_{\text{flat}}$ links the baryonic mass of spiral galaxies with their asymptotic velocity. MOND requires $b = 4$. The M_{bar} includes stars, atomic and molecular gas (i.e. HI/HeI/H2; for dwarfs, HII component is important because intergalactic radiation ionizes HI, as N.Gnedin noted). Conducting calculations is hard and requires assumptions and/or modeling. In [1] slope $b \approx 3$ was obtained for 32 spirals ($V_{\text{flat}} \approx 45 \dots 280$ km/s; HII mass was not estimated). Slope $b = 2$ appears in modeling [2; App.G] (luminosity is square of mass, $L_{\text{gal}} \approx M_{\text{gal}}^2$, except for dwarfs). This slope prefers (large scale) gravity force $F \sim M_{\text{bar}}/R$; some authors called it MOGA, MODified Gravity Attraction, [3]. MOGA appears also in one 5D-variant of Teleparallelism with 4th-order gravity and expanding brane-universe [4]: Newton's law turns to $F(R) = GMm/(LR)$ when $R > L$ (L is the brane co-moving thickness along the extra-dimension). As it is stated in [3], MOGA, unlike MOND, preserves the momentum and angular momentum, as well as stability of three-body systems.

Let's consider large scales, $R > L$. For thin disks (SO₂-symmetry; plain $1/R$ -model), the force in the disk plane at radius R , $F(R)$, depends on the mass M_R inside this radius: $F = GmM_R/(LR)$; on the axis Z (uniform disc of radius a ; 'test-mass' m) the attraction force is $F(Z) = GmM_a Z \ln(1 + a^2/Z^2)/(La^2)$.

For uniform spherical balls (bulges; radius a), we find: $F(R) = GmM/(La) f(R/a)$, where

$$f(x) = \frac{3}{8} \{1/x + x - \frac{1}{2}(1/x - x)^2 \ln[(x+1)/|x-1|]\}; \text{ it is maximal at } x = 1, f(1) = 3/4.$$

This function is symmetrical for the substitution $x \rightarrow 1/x$, so similar series exist for small and large x :

$$f(x) = x\{1 - x^2/5 - \dots - 3x^{2n}/[(2n-1)(2n+1)(2n+3)] - \dots\} = 1/x\{1 - 1/(5x^2) - \dots\}.$$

One can further integrate (in parts) this function and find the potential:

$$u(x) = \int f(y) dy = \frac{1}{2} \ln|x^2-1| + \frac{x^2}{8} - \frac{x^4-6x^2-3}{16x} \ln \frac{x+1}{|x-1|} + C.$$

Logarithmic potential growth stops when «underdensities» appear, and cosmic voids should be objects with negative masses. Our MW galaxy resides in the KBC void (one among the largest – redshift z is small) with a shift from its center. Defocusing caused by the KBC void provides some extra-dipoles (redshift dependent). Further we are considering a simple model of spherical voids with a massive shell, which consists of two co-centered uniform balls with positive and negative densities, ρ_b and $-\rho_a$, of radius b and a , respectively. Let the total shell mass is $M_S = \rho_b V_b - \rho_a V_a = \rho_0 V_b$, where $\rho_0 \sim 0.04\rho_c$ is the mean baryonic density of the Universe. And take, for simplicity, $\rho_b = \rho_a$ (an absolutely empty void), and $b = \varepsilon a$ (with, say, $\varepsilon = 1.1$). One can find the following void potential (again, $x = r/a$) $U(x) = GM_S L^{-1} u^*(x)$, where $u^*(x) = [u(x/\varepsilon) - u(x)]/(\varepsilon^3 - 1)$. We took into account that the uniform density ρ_0 gives no gravity, no potential (the case $a \rightarrow 0$). For very thin shells, $a \rightarrow b$ and $\varepsilon \rightarrow 1$, we find $u^*(x) \rightarrow -xf(x)/3$ and repulsion is $\propto (xf' + f)/3$.

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