Possible explanation of the critical acceleration in galaxies by subatomic building blocks

Hans Peter Good
Sargans, Switzerland
e-mail: hp.good at catv.rol.ch

March 30, 2022

Abstract

It is hypothesized that the characteristic acceleration scale (g_c) seen in galaxies can be interpreted as the effect of a subatomic structure of the vacuum space. As a consequence, the characteristic mass surface density associated with g_c defines the breakdown of classical gravity for gravitationally bound systems beyond a baryonic mass scale of $\approx 1.8\ 10^4\ M_{sun}$. Both characteristic scales can be expressed in terms of two number constants, the natural constants G_{Newton}, m_e, c and the reduced Planck constant h_{bar}.

Keywords: Critical acceleration, galaxy dynamics, gravity, MOND phenomenology, subatomic building blocks, number constants, natural constants

It is an experimental fact that rotational velocities of stars in orbit about their galactic centre deviate at low accelerations from Newton's law if the total gravitational mass is based on the amount of luminous matter. Observations also reveal that rotational velocities flatten out to a constant value v_{flat} in the outer part of galaxies. The effects become important not at some characteristic radius, nor some characteristic galaxy mass, but there appears a characteristic acceleration scale $g_\dagger$ in the data which is independent of any model. A one parameter ($g_\dagger$) fit function to the data yields [1]

$g_\dagger = 1.20 \pm 0.02(\text{random}, 1\sigma) \pm 0.24(\text{systematic}) \times 10^{-10}$ m/s^2.

The characteristic acceleration $g_\dagger$ manifests itself in other empirical laws such as the Faber-Jackson relation and the Baryonic Tully-Fisher relation, and corresponds to a_0 of the MOND phenomenology [2]. The physical cause of the characteristic acceleration scale in galaxy dynamics is unknown. There need be no such scale at all, but it is clearly present. In the following, the author proposes a microscopic mechanism that could set the observed characteristic acceleration scale $g_\dagger$.

Consider a gravitationally bound binary system where two masses m are at a distance 2a from each other and orbit around its common centre of mass. Assuming equilibrium between the radial component of the gravitational force and the centripetal force, the radial acceleration g is given by

$$g \equiv \frac{v^2}{a} = G_{Newton} \frac{m}{(2a)^2} \qquad (1)$$

The author speculated [3a] that the mass of a baryonic particle can be understood as a bound state of the subatomic building blocks m_{grav} and $h_{bar}/c/L_2(\Lambda)$. The mass m_{grav} equals $2^{-3}\pi^{25/3}$ or ≈1737.1 in units of m_e [3b] and the length $L_2(\Lambda)$ is equivalent to $2^{-14}\pi^{17/3}$ in units of λ_{e_bar} or ≈ 15.5 fm [3a].

Setting $m \equiv m_{grav}$, $a \equiv L_2(\Lambda)$ and using CODATA values for Newton's gravitational constant G_{Newton}, the electron mass m_e and the reduced Compton wavelength of the electron λ_{e_bar}, the characteristic acceleration g_c, according to equation 1, becomes $\mathbf{g_c \approx 1.10\ 10^{-10}\ m/s^2}$, which is within the error limits of $g_\dagger$. The result maps very well to the acceleration seen in galaxies and strongly suggests an interplay between micro-scale nuclear physics and astrophysical observations [3c].

The quotient g_c/G_{Newton} defines a characteristic surface density of ≈ 1.65 kg/m^2 or equivalently ≈ 791 M_{sun}/pc^2. The author conjectured that the kilogram is a redundant unit and that it can be replaced by ms^2, that is $kg = ms^2 \rightarrow m^3/c^2$ [3d]. This allows units of the MKS system to be solely defined as powers of the meter [3e]. In this view, according to $kg/m^2 \rightarrow m/c^2$, the characteristic surface density g_c/G_{Newton} corresponds to ≈ 4.8 pc. The transformation is accomplished by multiplication of g_c/G_{Newton} with c^2 and suggests that the length R_c of ≈ 4.8 pc could represent a characteristic astrophysical scale of gravity.

The length R_c enables to estimate a critical mass scale $M_c \equiv (g_c/G_N)\, R_c^2 \approx 1.8\ 10^4\ M_{sun}$ that can be interpreted as a boundary where one gravitational regime gives way to another. Is M_c the minimum mass needed to form a luminous galaxy with a flat rotation curve? If M_c is combined with the empirical Baryonic Tully-Fisher law $(g_c\, G_N)\, M_c = v_{c\_flat}^4$, a critical asymptotic speed v_{c_flat} of ≈ 4.0 km/s can be calculated.

All characteristic scales thus far calculated can be expressed in terms of two number constants, the natural constants G_N, m_e, c and the reduced Planck constant h_{bar}, and are therefore universal. It is an experimental fact, that effects of Newton's law in the very large as well as on the level of the elementary particles are unknown, and a change in the gravitational regime at either scale cannot be ruled out. But, more galaxies have to be studied with less systematic errors to ensure that the proposed microscopic concept, i.e., a subatomic structure of the vacuum space, is responsible for the experimentally observed characteristic acceleration scale in galaxies.

References

[1] Stacy S. McGaugh, Federico Lelli, and James M. Schombert,
Phys. Rev. Lett. 117(2016), 201101

[2] M. Milgrom
The Astrophysical Journal, 270(1983), 365–370

[3] Hans Peter Good, On the Origin of Natural Constants, De Gruyter 2018.
a) p. 154, b) p. 67, c) p. 81, d) p. 4, e) p. 48