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The Misleading Acceleration of the Universe, the Galactic Potential Well and the Duration of the Universal Expansion

Mario Everaldo de Souza[1]

[1]Departamento de Física, Universidade Federal de Sergipe, São Cristovão, 49100-000, Brazil

Abstract It is shown that galaxies close to galactic sheets are attracted towards them with an approximate Hooke's law force. Thus, as they get closer to the sheets, the more their velocities increase, and the more the magnitude of their accelerations decrease. Therefore, the so-called acceleration of the Universe is completely misleading. A sort of molecular potential exists for galaxies inside voids. It is suggested that the Universe is a new kind of amorphous solid. For the first time it is estimated that the universal expansion is of the order of one trillion years.

Keywords Dark energy, universal acceleration, universal expansion, galactic potential well, amorphous solids

1. Introduction

There have been contradictory reports concerning the acceleration of the Universe. Studies of type Ia supernovae in the late 1990s showed that the Universe is accelerating and that the Universal expansion is driven by a cosmological constant [1,2,3]. But in 2016 a report found that the Universe is accelerating at a slower and constant rate [4]. In 2017 two contradictory reports were published. One of them presented a new model in which there is no acceleration [5] and the other one presented a strong evidence for an accelerating Universe [6] within the framework of the LCDM model.

On the other hand since the pioneering work of Geller, Huchra and de Lapparent in 1986 [7], it has become clear that the Universe on large scale is formed by a foam-like structure which contains enormous regions almost devoid of galaxies surrounded by filaments and sheets in which galaxies are concentrated [8,9]. Therefore, as the Universe expands voids increase in size and their centers get farther away from each other. This means that the universal expansion happens by means of voids and hence the overall expansion of the Universe in **volume** is the result of the expansions of voids **surfaces (sheets)**. Therefore, the overall homogeneous volumetric expansion does not happen in the true Universe.

*Corresponding author:
mariodesouza.ufs@gmail.com

Taking into account that the expansion of the Universe takes place by means of voids surfaces, De Souza [10] has shown in a recent paper that the baryonic mass in galaxies is sufficient for closing the Universe, and thus, there is no need to have mysterious (and ethereal) kinds of matter such as dark matter.

2. Back to Basic Classical Mechanics

In Classical Mechanics the acceleration of a particle is defined as $\vec{a} = \frac{d}{dt}\vec{v}$ and this equation does not mean that when $\vec{v}$ increases in magnitude, the absolute value of the particle's acceleration also increases in magnitude. A simple system that shows this fact is the spring-mass system in which as $|\vec{v}|$ increases when the particle gets closer to equilibrium, its acceleration decreases in magnitude.

3. The Galactic Potential Well

Let us analyze the motion of a galaxy of mass *m* inside a void at a distance *r* from the wall between two neighboring bubbles. Of course, the galactic sheet is formed by two neighboring bubbles (voids) of galaxies, as shown below in Fig. 1.

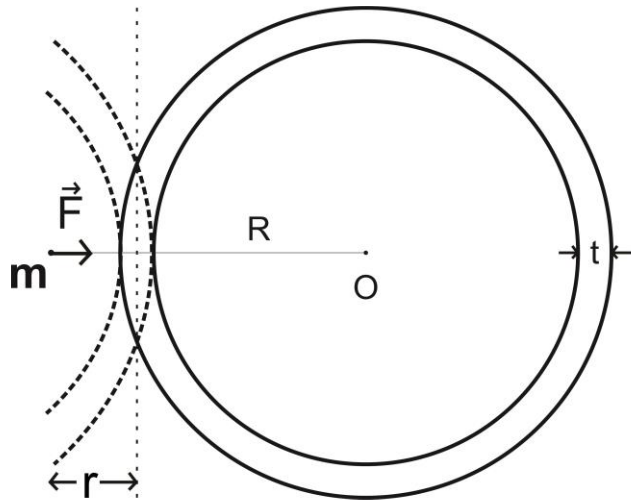

Fig. 1. A galaxy of mass *m* close to a sheet formed by two neighboring bubbles.

Let us consider that the right bubble is spherical and has radius *R*, and let us place the reference frame fixed at point O at the center of the right void. Taking into account that the density inside voids is small compared to the density in sheets, we can disregard the small gravitational field inside the void generated by it. Whence, the galaxy is attracted by the right bubble with a force given by

$$F(r) = -\frac{G4\pi R^2 t\rho m}{(R+r)^2} \qquad (1)$$

in which ρ is the density of matter in the bubble wall (sheet) and *t* is the thickness of the wall (sheet). When expanded in powers of *r/R* up to r^2 the expression becomes

$$\mathrm{F}(r) = -G4\pi\rho mt + 2\frac{G4\pi\rho tm}{R}r - 3\frac{G4\pi\rho tm}{R^2}r^2. \qquad (2)$$

Up to first order in *r* we have

$$\mathrm{F}(r) = -G4\pi\rho mt + 2\frac{G4\pi\rho tm}{R}r \qquad (3)$$

in which we clearly see that the second term is a spring-like force (Hooke's Law force). We unravel this in a better way by placing a reference frame at the galactic sheet, as in Fig. 2.

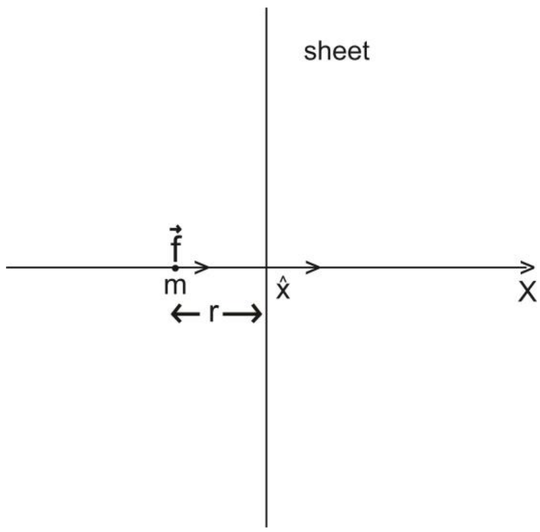

Fig. 2. The galaxy is attracted by the sheet with a Hooke's law force.

Thus, the second term can be written as

$$\mathrm{f}(r) = -\frac{G8\pi\rho tm}{R}(-r) = -\mathrm{k}(-\mathrm{r}) \qquad (4)$$

and corresponds to the left portion (positive force) of Fig. 3 below of the simple spring-mass system. From Eq. 4 we obtain the effective spring constant

$$k = \frac{G8\pi\rho tm}{R}. \qquad (5)$$

This equation yields the time

$$T = \sqrt{\frac{\pi R}{2G\rho t}} \quad (6)$$

which is not really a period because ρ, t and R change with time.

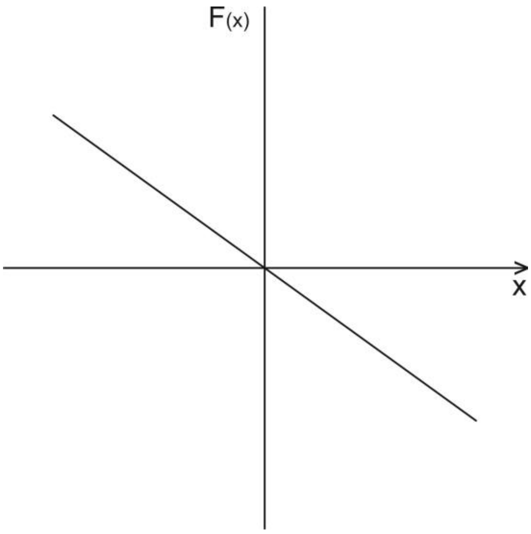

Fig. 3. Hooke's law force. The force $f(r)$ that acts on the galaxy corresponds to the left portion of the above force.

We can also express T only in terms of R if we consider that, as found by Giovanelli [11], the density inside voids is much smaller than the density in sheets, and thus as the mass in the spherical shell(bubble) is approximately constant and given by

$$M = 4\pi R^2 t\rho \quad (7)$$

T becomes

$$T = \sqrt{\frac{2\pi^2 R^3}{GM}} \quad (8)$$

which clearly shows that

$$T \propto R^{3/2} \quad (9)$$

approximately.

Let us have in mind that the galaxy does not complete its whole harmonic oscillating motion because voids will reach radii at which the Universe will begin shrinking and bubbles will disappear [10]. But in the light of the features of the spring-mass system, we can say that the time that a galaxy, at a certain initial position, would take to reach the sheet is approximately equal to *T/4*. As *R* increases with time, we can calculate a lower bound for *T/4* by using the present values of ρ, *t*, and *R*. El-Ad et al. [12] have reported an approximate diameter of 57 Mpc (for h=0.7) for voids and according to Berry [13], the density in sheets is about 3×10^{-28} kg/m^3, and *t* is about 7.1 Mpc according to Roos [14]. Thus, we obtain that *T/4* is about $0.45\times10^{19}\,s$, that is, about one trillion years. Let us recall that this is a lower bound, and thus, the Universe will continue expanding for at least this time.

With respect to the galactic sheet, taking into account Eq. 2, the galaxy is subject to a gravitational potential well given by

$$\mathrm{U}(r) = \frac{G4\pi\rho tm}{R} r^2 + \frac{G4\pi\rho tm}{R^2} r^3 \quad (10)$$

up to r^3, which is a sort of molecular potential.

Let us now consider a galaxy at an initial position $-r_i$ from the wall with velocity v_i (perpendicular to the wall) which is of the order of its peculiar velocity. For these initial conditions at *t=0*, the harmonic motion is described by

$$x(t) = r_m \sin(\omega t + \phi) \quad (11)$$

from which we obtain

$$-r_i = r_m \sin\phi$$
$$v_i = \omega r_m \cos\phi \quad (12)$$

and thus, the elipse

$$\left(\frac{r_i}{r_m}\right)^2 + \left(\frac{v_i}{\omega r_m}\right)^2 = 1. \quad (13)$$

Therefore, we have the major and minor axes $a = r_m$ and $b = \omega r_m$ whose ratio $b/a = 2\pi/T$. Thus, we obtain the important relation

$$T = 2\pi\frac{a}{b} \quad (14)$$

which shows that T can be determined from the observations of the initial positions and velocities of galaxies close to a galactic sheet.

4. The Universe is an Amorphous Solid

As said above, in 1986 Geller, Huchra and de Lapparent [7] found the bubbles formed by galaxies enclosing enormous regions almost devoid of matter in a slice of the local Universe. This foam-like structure was confirmed in 1989 by Geller and Huchra [8] that unraveled large-scale clustering of galaxies stretching in the form of gigantic filaments and sheets over 170 Mpc by about 15 Mpc. Broadhurst et al. [9] extended the observation of this foam-like large-scale structure to higher redshifts. Their observations revealed regularly spaced voids covering a distance of 2000 h-1 Mpc in each direction of the north and south galactic poles. All these works also found that voids do not have the same size and El-Ad et al have reported an average diameter of about 57 Mpc (for h=0.7) for voids.

As voids have different diameters we can state that the Universe lacks translational periodicity, that is, long-range order. On the other hand, as shown above in section 3, galaxies inside voids are subject to a potential well and that is why galaxies inside voids move out towards the walls. In regular amorphous solids the interaction between two atoms (or molecules) can be modeled with the use of molecular potentials (potential wells), such as the Lennard-Jones potential [15]. Hence, we can say that the Universe is an amorphous solid because galaxies inside voids are subject to a sort of molecular potential. However, it is a new kind of amorphous solid because in regular amorphous solids there is short-range order due to atomic bonds. But in the case of galaxies there is no short-range order. And because of the regularity of voids (with different sizes), the Universe is a galactic amorphous solid with a structure of a continuous random-network. Fig. 4 below shows the local Universe according to the Sloan Digital Sky Survey [16]. We clearly see the continuous network of voids across different redshifts.

For comparison we present below in Fig 5 a regular amorphous solid with a continuous network (in 2 dimensions) which has short-range order due to atomic triangular bonds [17].

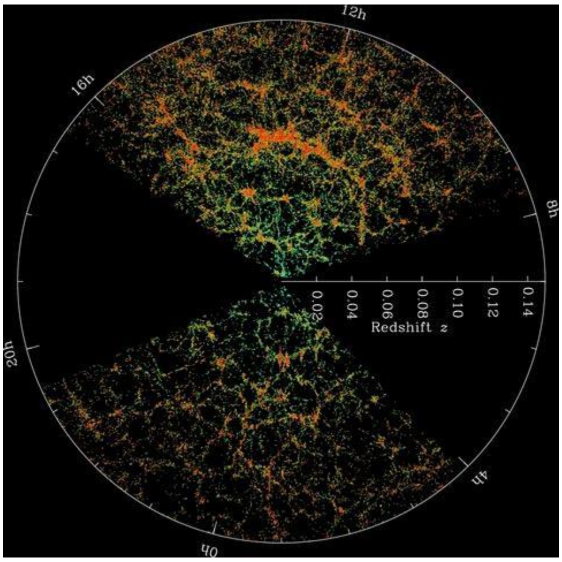

Fig. 4. A map of the local Universe according to the Sloan Digital Survey in which we clearly see voids, sheets and filaments in a continuous network.

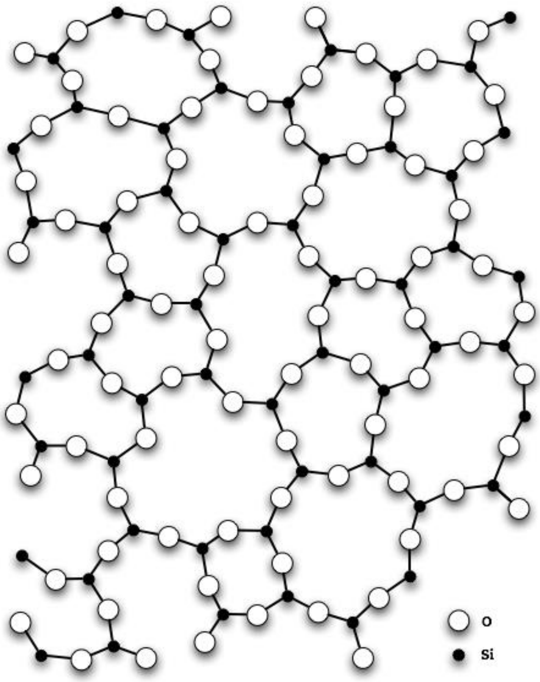

Fig. 5. Amorphous silica. It exhibits no long-range order, but it has short-range order due to the atomic bonds (triangular bonds with a silicon atom around which there are 3 oxygen atoms).

5. Conclusion

It is shown that the supposed acceleration of the Universe is completely misleading because the increase in galaxies velocities towards the galactic sheets does not mean at all that such increase is caused by an increase in magnitude of their accelerations. Actually, it is the other way around because such galaxies are trapped in local approximate potential wells, and thus, their accelerations decrease in magnitude as they approach the sheets. For each galaxy close to a sheet there should exist a relation between its velocity and its position with respect to the wall. Such a relation, which yields an important time parameter, can be found from observations.

For the first time a galactic potential well is proposed for galaxies inside voids which resembles a molecular potential and, thus, its concluded that the Universe is an amorphous solid.

We can also conclude that the samples of galaxies for accelerations analyses have to carefully take into account which types of galaxies are being considered, that is, if they are right at the sheets of close to them. And all this means that dark energy does not exist at all which is an expected result, because dark energy would mean a dynamical vacuum field without its corresponding particles. And this is not physically plausible.

For the first time we grasp that the order of magnitude of the duration of the Universal expansion is above one trillion years.

Acknowledgements

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