One of the causes of the acceleration of the Universe

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April 26, 2023

ABSTRACT

It is shown that a galaxy inside a cosmic void close to a wall between two cosmic voids is attracted towards the wall by a Hooke's law force. It is also shown that the duration of the universal expansion is about 100 billion years.

Key words. accelerated Universe – cosmic web – universal expansion

1. Introduction

The first paper that proposed that the expansion of the Universe is accelerating was the paper by Riess et al. (1998) from 1998 whose work was based on the observation of supernovae Ia. Then, in 1999, came the paper by Perlmutter et al. (1999), also based on observations of Ia supernovae. The accelerated expansion was soon after confirmed in 2014 by Betoule et al. (2014) also using supernova data. Other confirmations were made by Jimenez & Loeb (2002) and Eisenstein et al. (2005) using other astronomical data. Nielsen et al. (2016) used a modified statistical model for the analysis of the supernova JLA dataset (Betoule et al. (2014)) and claimed that the evidence for the accelerated expansion is only below three sigma. However, Haridasu et al. (2017) conducted a deeper analysis of the Ia supernovae data and claim that the evidence is strong for an accelerating Universe.

On the other hand, Chincarini (1978), Gregory & Thompson (1978) and Einasto et al. (1978) reported the first cosmic voids among galactic clusters. And Huchra et al. (1986) clearly showed a mapped slice of the local Universe containing cosmic voids, galactic walls and galactic sheets. And Broadhurst et al. (1990) showed that at least half of the observable Universe is formed by a foam-like structure which is constituted of voids, walls and sheets. This foam-like structure of the Universe has been confirmed and expanded by the redshift maps of the 2dF-GRS (Colles (2003)) and SDSS (Tegmark et al., SDSS Collab. (2004)) surveys.They have established that galactic clusters, cosmic voids, galactic walls and galactic sheets are integral components of the Cosmic Web. Inside voids the number of galaxies decreases significantly and inside walls and sheets the number of galaxies is much larger than in voids. According to Giovanelli (2010) the mean density within voids is only about 10% of the cosmic density.

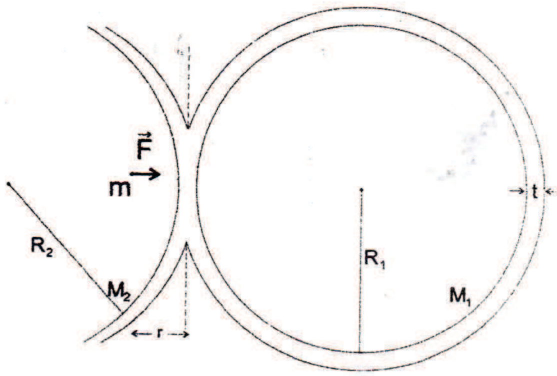

Fig. 1. A galaxy of mass m inside a void of radius R_2 close to a wall between two voids. The right void has radius R_1.

2. Galaxies close to walls are attracted by means of a Hooke's law force

Let us analyze the motion of a galaxy of mass m inside a void at a distance r from the wall between two neighboring voids, as shown in Fig. 1 above

Taking into account results from a couple of articles Ceccarelli et al. (2013) have stated that "Voids in the galaxy distribution, in a first approximation, can be described as simple underdense regions which have nearly spherical shapes and isotropic expansion motions". Hence, let us consider two spherical voids with approximately the same size, with radii R_1 and R_2, and with masses M_1 and M_2. Each mass is distributed along the wall that surrounds each void, that is, each mass M_i is equal to $4\pi R_i^2 t\rho$ where ρ is the approximate mass density in the wall ant t is the wall thickness. Taking the origin of r at the wall, the gravitational potential energy of the galaxy for r close to the wall is given by

$$U(r) = -\frac{GmM_1}{R_1 + |r|} - \frac{GmM_2}{R_2} \quad (1)$$

which is larger than its potential energy when it is at the wall which is given by

$$U(0) = -\frac{GmM_1}{R_1} - \frac{GmM_2}{R_2} \qquad (2)$$

Therefore, the galaxy is attracted by the wall to lower its potential energy. From the power series expansion of $U(r)$ to second order in $|r|$, for $|r| \ll R_1$, we find that the force is given by

$$F(r) = \frac{2GmM_1|r|}{R_1{}^3} \qquad (3)$$

if we consider that the rate of expansion of voids, that is, of their radii, is much slower than speeds of galaxies inside voids. This appears to be, indeed, the case simply because the density inside voids is very low. That is, most galaxies that in the past were further from the walls, got closer to the walls over time or just got inside the walls. The force $F(r)$ is a Hooke's law force with k equal to

$$k = \frac{2GmM_1}{R_1{}^3} \qquad (4)$$

Dropping the subscript and making use of $M = 4\pi R^2 t\rho$ we obtain

$$k = \frac{2GmM}{R^3} = \frac{8\pi Gmt\rho}{R} \qquad (5)$$

If the galaxy completed the whole periodic motion we would obtain a period given by

$$T = \left(\frac{\pi R}{2Gt\rho}\right)^{1/2} \qquad (6)$$

Of course, the galaxy will not make the whole periodic motion, but only a part of it, which is the part of the motion up to reaching the wall. It will last a time of the order of T/4.

It is important to notice that for r far away from the wall the above calculation is not valid because in this case we would have to include many neighboring voids.

3. The duration of the universal expansion

With equation 6 we can calculate an approximate value for the duration of the universal expansion with the present data for ρ, t and R. Pan et al. (2012) have thoroughly analyzed the structure of voids in the Sloan Digital Sky Survey Data Release 7 and have found that most of their radii are comprised between 13 and 23 Mpc (on Fig. 2 of their paper). The density in walls is of the order of $3\times10^{-28}kgm^{-3}$ according to Berry (1991) and t is about 7.1 Mpc according to Roos (1994). When we insert these data into equation 6 we obtain $\frac{T}{4} = (0.3-0.39)\times10^{19}s =$ (90 - 120) billion years which is much longer than the duration of the expansion up to now. This figure should be taken with caution as a first and crude approximation because R, t and ρ change with time.

4. The anisotropy of the universal acceleration

Colin et al. (2019) have reported that the universal acceleration is anisotropic. Let us show why this is true, indeed, for galaxies close to void walls. As shown in Fig. 1, r is negative. Let us make $-r = d$ which is positive and is the distance between the galaxy and the wall. Therefore, from 2nd. Newton's law we obtain

$$ma = k|r| = kd \qquad (7)$$

and, thus, using Equation 6 above, we get

$$a = \frac{8\pi Gtd\rho}{R} \qquad (8)$$

which means

$$a \propto \frac{d}{R} \qquad (9)$$

This equation shows that the galaxy acceleration depends on the location of the galaxy with respect to the wall of a void as well as on the size of the void. There are, thus, two kinds of observations to be carried out. We can measure galaxies accelerations at different distances d from the wall in the same void and we can measure galaxies accelerations with the same d in different voids with very different radii. Of course, the above formula for the acceleration is very approximate and, obviously, it is not valid close to clusters because close to them both ρ and t increase a lot in comparision with their values in other regions of the same wall.

5. Conclusion

It is shown above that galaxies close to voids walls and far from clusters are attracted to the walls by a Hooke's law force, from which we obtain a rough number for the duration of the universal expansion and are able to understand a part of the acceleration of the Universe and its anisotropy. We still have to understand the universal acceleration among clusters.

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