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On the overflowing of cosmic rays from galaxies and the expansion of cosmic matter

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Particles of the cosmic radiation, electrons and nuclei, transport a dominant positive electric charge. A tiny fraction of these particles of extremely high energies in favorable conditions overflow from galaxies. The overflowing of positively charged cosmic nuclei into the intergalactic space uncovers an equal amount of negative charge in the parent galaxy. Negative charge is mainly stored by quiescent electrons. After adequate particle propagation neither the negative electric charge located in the galaxies nor the positive electric charge of the overflowed cosmic nuclei can be neutralized due to the enormous distances.

In several ways it is proved that the total electric charge retained by clusters of galaxies after an appropriate time interval generate a repulsive force between clusters which overwhelms gravity. After a few billions years of electrostatic repulsion, peripheral clusters attain relativistic velocities and their mutual distances increase accordingly. Several facts suggest that the expansion of the universe, as determined by optical observations since a century, has been caused by the electrostatic repulsion of the positively charged cosmic nuclei overflowed from galaxy clusters.

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1. Introduction

It is a fact known since 1961 that the dominant fraction of cosmic radiation, about 98 per cent of the total flux above 10-20 GeV consists of atomic nuclei which all have positive electric charge. An interesting facet of this fact is that the propagation volume of cosmic rays is permeated by a dominant fraction of positive electric charge and, consequently, cosmic-ray sources retain negative electric charge in order to preserve charge neutrality on a suitable scale length.

A second basic fact is that the nearby universe consists of many spiral galaxies whose cosmic-ray properties have to be similar to those measured in the $Milky\ Way\ Galaxy$. These properties have been measured through synchrotron radiation (hereafter curvature radiation) of cosmic electrons in the 10-100 cm radio band for more than 100 spiral galaxies. The fraction of spiral galaxies in galaxy clusters in the nearby universe is typically in the range 0.30-0.35 the rest being ellipticals and irregulars.

This study posits that disk galaxies, elliptical galaxies and irregular galaxies i.e. all galaxy categories, store cosmic rays. Support to this prerequisite comes from radio astronomy data but also from gamma-ray observations. Gamma rays from proton interactions via neutral pion decays have been observed in the $Large\ Magellanic\ Cloud$, Andromeda and $M33$ galaxy. Moreover, a tight correlation between gamma-ray emissivity and radio emissivity (curvature emission) in galaxies has been evidenced thereby testifying the presence of cosmic rays.

Quite recently in a long scientific document the electrostatic acceleration of cosmic rays has been proposed [1]. Following this work disk galaxies retain in their disks a negative electric charge of about 2-3 $\times 10^{31}$ C, order of magnitude. This conclusion entails radical changes in many areas of all macroscopic sciences as demonstrated elsewhere [2].

2. Equilibrium between gravitational and electrostatic forces

Consider two spherical objects of mass m and M, placed at the distance r (fig. 1). Assume further that the two spheres have the electric charges q and Q, respectively, both either positive or negative. The charge distributions in the two objects are such that develop the a point-like repulsive force. There exists a unique ratio between the electric charge trapped on the objects and the masses m and M for which, whatever is the distance r arbitrarily large or small, the force between the two spheres is balanced, e. g. is zero. This is the balancing condition featured by:

$$G\frac{mM}{r^2} = \frac{1}{4\pi\epsilon_0}\frac{qQ}{r^2} \tag{1}$$

The charge-mass ratio in the balancing condition is : $[(q/m)(Q/M)] = 4\pi\epsilon_0 G$.

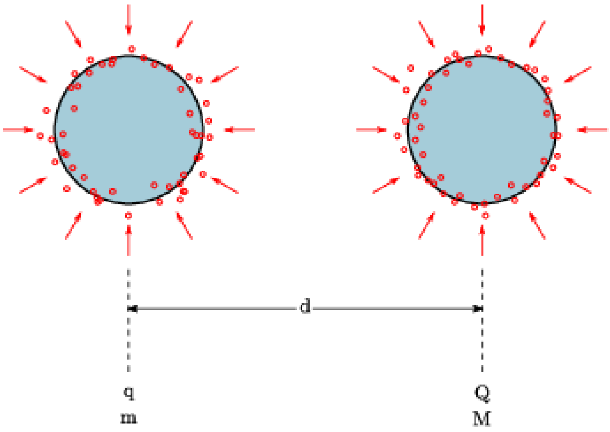

Figure 1: Competition between gravitational and electrostatic forces of two imaginary material bodies of mass m and M and electric charge q and Q placed at the arbitrary distance d. Red dots represent cosmic nuclei coming from the exterior dumped on the outer surfaces of the masses m and M as qualitatively shown in the drawing. With no positive electric charge both bodies would precipitate one another by gravity. Instead, with an extremely small amount of electric charge relative on the masses m and M, both bodies would repel. The particular amount of electric charge with q = Q which maintain equilibrium of m and $M$is designated in this work by q_b, and referred to as the balancing charge or equilibrium charge.

If, for sake of simplicity, m=M and q=Q is imposed, then the relation :

$$q/m = (4\pi\epsilon_0 G)^{1/2} \tag{2}$$

holds. The q/m ratio is $8.617508609 \times 10^{-11}$ C/kg and will be denoted by $(q/m)_b$ or q_b/m_b where b on foot designates balancing.

The equality between electrostatic and gravitational force expressed by the equations (1) and (2) is a mere definition, devoid of any subtlety, with the arbitrary conditions m=M and q=Q. The amount of electric charge Q stored in a generic macroscopic body of mass m can be also expressed by the dimensionless variable ζ which adopts as unit charge q_b. By definition it is set : $\zeta \equiv Q/q_b$ being q_b that particular amount of electric charge residing in the material body of mass m such as the electrostatic repulsive force f_e with another arbitrary material charged body equalizes the attractive gravitational force f_g.

3. Electrostatic repulsion between pairs of rich clusters

Let be r_c the typical radius of a rich galaxy cluster of mass M_c containing N_g galaxies and R_c the maximum extent of the positive charged halo of cosmic nuclei overflowed from clusters. Moreover, let be d_c the typical distance between rich galaxy clusters in the nearby Universe. The nominal negative charge stored in the disks of disk galaxies Q_w is $2.585252 \times 10^{31} C$ (see Chap.

5 of ref. [1]). This charge amount is ascribed to the cores (i.e. inner region) of other galaxies composing rich clusters.

Here it is desired to evidence that the electrostatic forces responsible of cosmic expansion around the Earth in the range 1-10 Gpc or (0.3-3) $\times\ 10^{26}$ m are generated by the electric charges stored in galaxy clusters and not by charges in isolated or sparse galaxies. This assertion is inferred only by the parameters: r_c, N_g, d_c, M_c and R_c of rich galaxy clusters. For the numerical estimates to follow the calculation assumptions are : the nominal mass of a generic rich cluster, M_c = $7.5 \times 10^{47} g$ resulting from the adopted values, $M_c = N_g \times m_g$ = 2500×3× 10^{44} g = 7.5×10^{47} g, r_c= 3 Mpc, d_c= 60 Mpc and R_c=150 Mpc justified elsewhere [2]. A useful electric charge unit for galaxy clusters, a dimensionless quantity, is $\zeta_c \equiv Q^c / Q^c_b$ where $Q^c_b = N_g Q_w$ = 6.46313 ×10^{34} C is the balancing charge and Q^c the total electric charge within the radius r_c of the cluster.

The phenomenon of electrostatic repulsion between two rich of clusters is qualitatively illustrated in fig. 2. Let us consider a rich spherical cluster denoted by A with center Ω_A which has the characteristic parameters previously mentioned and two concentric spheres with common origin Ω_A and radii r_c and R_c as shown in fig. 2. Let ξ_A be the electric charge fraction of the cosmic rays stored in the sphere of radius r_c while the rest of the charge, (1 - ξ_A) is contained in a spherical shell comprised between r_c and R_c. The positive charge of cosmic rays within r_c in the volume (4/3) $\pi\ r_c^3$ is: $Q^A_{cr}(r_c) = N_g\ Q_{cr}(r_c/R_c)^2 = N_g$ 2.5852 × 10^{31} C. The total electric charge, which is the sum of the positive $Q^A_{cr}(r_c)$ and negative charges Q_w in the spherical volume of radius r_c is : $Q^A_e = Q^A_w + Q^A_{cr}(r_c)$ = -$Q^A_{cr} + Q^A_{cr}(r_c)$ = -6.460546 × 10^{34} C called here also effective charge of the cluster A, denoted Q^A_e (e on foot for effective). The electric charge conservation implies: $Q^A_w = Q^A_{cr}$ (1- ξ_A). Numerically it is : $\xi_A = 4.0 \times 10^{-4}$ and (1- ξ_A) = 99.9599 × 10^{-2}. The charge to be taken into account in order to compute the global electrostatic force on the cluster A is Q^A_e i. e. the effective charge of the cluster A exerting a repulsive force on the cluster B.

Let designate by B a rich spherical cluster placed at distance d from the cluster A (fig. 2). For simplicity the cluster B has the same characteristic features of the cluster A, namely, $\xi^A = \xi^B$, $Q^A_{cr} = Q^B_{cr}$ and $Q^A_e = Q^B_e$. Let be $\vec{E}^A(r)$ the electric field generated by the cluster A at the generic distance expressed by the sum of two terms: $\vec{E}^A(r) = \vec{E}^A_-(r) + \vec{E}^A_+(r)$ where $\vec{E}^A_-(r)$ is the electric field generated by the negative charge Q^A_e retained within the radius r_c of the cluster A and $\vec{E}^A_+(r)$ the electric field generated by the positive charge contained in the spherical shell between r_c (see fig. 2). The repulsive force $\vec{f}^{AB}(d)$ at the distance d exerted by the cluster A on B is given by :

$$\vec{f}^{AB}(d) = Q^B_e \left[\vec{E}^A_+(d) - \vec{E}^A_-(d) \right] \tag{3}$$

where Q^B_e is the effective electric charge of the cluster B. The positive electric charge carried by cosmic nuclei residing in the spherical shell between d and R_c centered at the origin Ω_A does not exert any force due to the assumed spherical symmetry of the electrostatic structure under examination. In these conditions it is inevitable that a repulsive force sets on between the cluster A and B because: $\vec{E}^A_-(r) > \vec{E}^A_+(r)$. In fact, the field intensity $\vec{E}^A_-(r)$ beyond r_c is:

$$E^A_-(r) = \zeta_c Q^A_e/(4\pi\epsilon_0 r^2) = 5.808\times 10^{44}\zeta_c/r^2 = 0.610\zeta_c/r^2(Mpc) \quad V/m \tag{4}$$

while the intensity of the field $\vec{E}^A_+(r)$ in the range $r_c < r \le R_c$ is :

$$E^A_+(r) = (k/2\epsilon_0)\zeta_c/(1. - r^2_c/r^2) = (2.704\times 10^{-5})\zeta_c/(1. - r^2_c/r^2) \quad V/m \tag{5}$$

with k= 4.800 $\times 10^{-16}$ C/m^2. The strength of the field $\vec{E}^A_+$ expressed by equation (5) derives from the radial profile $\rho_c(r)$ of the positive charge transported by cosmic nuclei Q^A_{cr} beyond r_c. For example, with ζ_c = 150 and $r = d_c$ = 60 Mpc it is : $E^A_+(d_c)$ = 0.4056 $\times 10^{-2}$ V/m while $E^A_-(d_c)$ = 2.541 $\times$ 10^{-2} V/m, so that the intensity $E^A(d_c)$ is 2.135 $\times 10^{-2}$ V/m.

The corresponding electrostatic potential $V^A_e(r)$ of the cluster A at any arbitrary point at distance r from the origin Ω with $r_c \le r \le R_c$ is (see Chap. 5 ref. [1]):

$$V^A_e(r) = \frac{\zeta_c Q^c_b}{4\pi\epsilon_0}\left(-\frac{1}{r} - \frac{r}{R^2_c} + \frac{2}{R_c}\right) = \frac{\zeta_c N_g Q_b}{4\pi\epsilon_0}\left(-\frac{1}{r} - \frac{r}{R^2_c} + \frac{2}{R_c}\right) \tag{6}$$

For example, for $r = r_c$ = 3 Mpc it is, $V_c(3) = -2.35\times 10^{27}$ V while for r = 60 Mpc it is, $V_c(60) = -3.92\times 10^{26}$ V.

From these results it is quickly realized that the electrostatic field of the cluster $\vec{E}_c$ at distances of some dozens of $megaparsec$, is by far greater than that of isolated galaxies. Indeed, the electric field of sparse galaxies displaying spherical symmetry $\vec{E}_g$ vanishes at large distance from the galactic center as the typical value R_g (for example, R_g = 0.3 Mpc) is much less that the typical intercluster distance d_c (for example, 60 Mpc). The electric field intensities of sparse galaxies devoid of spherical symmetry at large distances r from the origin Ω, fall more rapidly than those having a quadratic dependence as they depend on multipole terms of the charge distribution. Hence, the field strength E_g, though not zero, it is certainly negligible relative to the intensities of the fields $E^A(r_c)$ and $E^B(r_c)$.

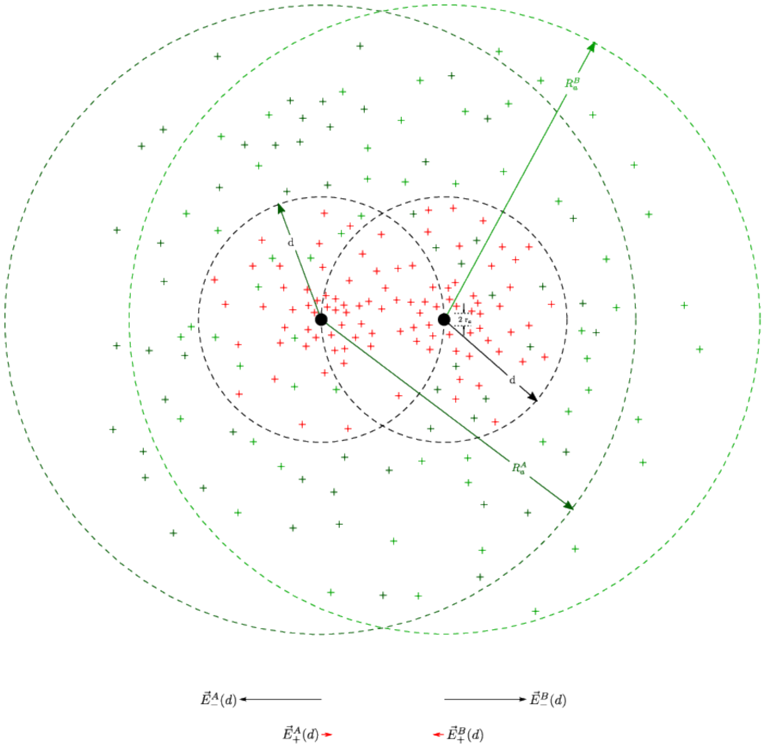

Figure 2: Two galaxy cluster A and B (black dots) set at the distance $d_c = 60\ Mpc$ with two positive charged mantels (spherical shells) of radii R_a^A and R_b^B. The fraction of electric charge that does not affect the repulsive force between between clusters A and B is represented by red crosses (dark green for the cluster A and light green for the cluster B). The positive electric charge (red crosses) in the spherical shell between r_c and d_c generates the fields $\vec{E}_+^A(d_c)$ and $\vec{E}_+^B(d_c)$ which exert the attractive force. The negative charge contained within the radii r_c of the two clusters generate the fields $\vec{E}_-^A(d_c)$ and $\vec{E}_-^B(d_c)$ which exert the repulsive force. The aforementioned fields, obtained by putting $r_c = 3\ Mpc$, $R_c = 150\ Mpc$ and $\zeta_c = 150$, are represented by vectors in the bottom of the figure.

The conclusion is that the electrostatic fields of galaxy clusters dominate the expansion of the cosmic matter.

4. Velocities of galaxy clusters and intensities of the electric fields

In the non relativistic approximation, the acceleration $\vec{a}_c$ acquired by the cluster B subject to the field $\vec{E}^A(d_c)$ with $d_c = 60\ Mpc$ as sketched in fig. 2 is given by:

$$\vec{a}_c = (Q_e^B/M_c^B)\zeta_c\vec{E}^A(d_c) = (4\pi\epsilon_0 G)^{1/2}\zeta_c\vec{E}^A(d_c) = 2.7\times10^{-10} ms^{-2} \tag{8}$$

being $\vec{E}^A(d_c) = 2.135 \times 10^{-2}\ V/m$, $\zeta_c = 150$ and $M_c^B = 7.5 \times 10^{44}\ Kg$.

An order-of-magnitude estimate of the velocity of the generic cluster residing in an ambient crowded with galaxy clusters (unlike that just considered of only two clusters) where $\overline{a}_c$ represents an average, suitable, constant value of the acceleration in the given temporal span t. For instance, with $\overline{a}_c = 2.7 \times 10^{-10}\ ms^{-2}$ in the time t of one billion years (3.155×10^{16} sec), being, $v(t) = \overline{a}_c\ t$, the velocity reached by the generic galaxy cluster is 8700 Km/s. The straight line segment traveled in the same time interval $(1/2)\ \overline{a}_c\ t^2$ is 4.2 Mpc. Yet, in the same conditions in 5 billion years, the velocity reaches 43 500 Km/s and the straight line segment 111 Mpc.

Galaxy clusters are distributed in space on *Gigaparsec* scale lengths and not in isolated pairs as shown in fig. 2. Accordingly, the illustrative but essential calculation described above has been repeated for clusters forming three dimensional arrays in space. In this case cluster velocities in the range 60000-90000 km/s (see fig. 29 of ref. [2]) are attained by peripheral clusters of the cubic array confirming the crude, oversimplified estimates of two clusters above.

5. Empirical basis of the electrostatic repulsion of galaxy clusters

A solid-rock base of this calculation derives from the observed gamma-ray fluxes in galaxy clusters. Let us remind that according to the previous calculation, only 4 protons out of ten thousand remain in the cluster volume V_c, the rest e.g. 9996 cosmic nuclei out of 10000, are outside this volume as summarized by the variable ξ_A and (1. -ξ_A) in *Section* 3.

If cosmic protons and heavier cosmic nuclei massively overflow from galaxy clusters only a negligible fraction of them will remain in the nominal cluster volume $V_c = (4/3)\pi r_c^3$. On the contrary electrons reside in the volume V_c albeit slowly dragged by the electric field $\vec{E}_c$ toward the cluster outskirts and, perhaps, sporadically recompacted to the central cluster zone by indirect gravity action. Consequently, the gamma-ray flux from the reaction, $\mathrm{p} + \mathrm{p} \rightarrow \pi^0$ + anything $\rightarrow \gamma + \gamma$ + anything, is highly suppressed, almost void. Notice that cosmic electrons in cluster volume are routinely detected in the radio band as a diffuse radio emission (see *Appendix A*.3 in ref. [2]). Thus, finite and robust emissivities of diffuse radio emission in clusters around 10^{-42} $erg/s\ cm^3 Hz$ [3] caused by cosmic electrons loudly protrude face to the inferred scarcity of gamma rays of hadronic origin.

Empirical evidence since almost two decades supports the absence of gamma-ray fluxes from galaxy clusters against the predicted rates [4]. Based on the upper limits at two standard deviations of 10^{-9} $photons/cm^2/s$ it was stated in 2003 : "In conclusion we have to await the first observational evidence of high-energy gamma-ray emission from galaxy clusters" [4]. Presently (2021) this statement is still alive and more constraining as new sensitive measurements of gamma-ray fluxes in galaxy clusters [5–10] confirm their paucity and the inferred scarcity above as well. The recent upper limit at 3 standard deviations is 2.3×10^{-11} $photons/cm^2s$ for energies in the range 0.8-100 GeV [9]. Data are summarized by others [10] as follows : "While there is yet no observational evidence for energetic protons in clusters, the presence of relativistic electrons is well established from radio observations" . In the context of this work the radio emission of cosmic electrons abounds because cosmic electrons are predominantly retained in the cluster volume permeated by the cluster magnetic field and electric fields of individual cluster galaxies while gamma-ray emission from the reaction, $\mathrm{p} + \mathrm{p} \to \pi^0 + \text{anything} \to \gamma + \gamma + \text{anything}$, is highly suppressed due to the massive overflow of cosmic protons from galaxy cluster volumes.

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