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An alternative model, explaining the VLS, created by the gravitational interaction of two matter populations, one composed of positive mass and the other of negative mass.

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Abstract. Negative masses arise naturally from dynamic groups, as shown in 1970 by the French mathematician Jean-Marie Souriau. We recall this, based on the coadjoint action of the Poincaré group on its momentum. Negative populations include negative energy photons. If we admit that positive and negative masses cannot interact through virtual photons, they only interact through gravitational force. Two particles whose masses display the same sign attract each other through Newton law. Two particles of opposite signs repel each-other through «anti-Newton» law. Then the two populations tend to separate. If the mass density of the negative material is much larger, it first forms clusters by gravitational instability. Then the positive matter is repelled in the remnant place, shaped like adjoining bubbles, which looks like VLS. To illustrate this scheme, we provide 2D simulation results. In addition this model provides a new insight on the galaxies' birth mechanism.

1. Introduction

The French mathematician Jean-Marie Souriau writes the momentum of the Poincaré group in the following matrix notation and calls "passage" the vector f and "whirstling" the vector l. Then the coadjoint action of the group has the following simple form :

$$g=\begin{pmatrix} L & C \\ 0 & 1 \end{pmatrix} \quad C=\begin{pmatrix} \Delta t \\ \Delta x \\ \Delta y \\ \Delta z \end{pmatrix} \quad J=\begin{pmatrix} 0 & -l_z & l_y & f_x & E \\ l_z & 0 & -l_x & f_y & p_x \\ -l_y & l_x & 0 & f_z & p_y \\ -f_x & -f_y & -f_z & 0 & p_z \\ -E & -p_x & -p_y & -p_z & 0 \end{pmatrix} \quad P=\begin{pmatrix} E \\ p_x \\ p_y \\ p_z \end{pmatrix} \quad J=\begin{pmatrix} M & P \\ {}^tP & 0 \end{pmatrix}$$

$$J' = g\, J\, {}^tg \qquad M' = L\, M\, {}^tL + C\, {}^tP\, L - L\, P\, {}^tC \qquad P' = L\, P$$

If one chooses a coordinate system relative to the particle, the passage vector f becomes zero, and the l vector becomes the kinetic momentum associated to the mass-point particle. In his book [1], Souriau, developing geometrical method for quantization shows that this vector is quantized and becomes the spin (but this extension to quantum world is out of the scope of the present paper). The Poincaré group is built around the Lorentz group, which owns four connex components, forming two subsets : the orthochron one (L_o matrixes) and the antichron one (L_a matrixes). It inherits this property and can be written :

$$g=\begin{pmatrix} L & C \\ 0 & 1 \end{pmatrix}=\begin{pmatrix} \lambda L_o & C \\ 0 & 1 \end{pmatrix} \quad with \quad \lambda=\pm 1 \quad \Rightarrow \quad P=\lambda L_o P$$

The (λ = - 1) terms implies *T*-symmetry and subsequently the inversion of the energy *E*. Then these movements refer to matter whose energy and mass are negative [1]. In addition, if we consider the complete Poincaré group we must take into account negative energy photons. In addition, Souriau shows that an electric charge can be added to the particle, considering its movement as inscribed in a 5D Kaluza (t , x , y , z , ζ) space with signature (+ - - - -). Moreover he showed [2] that the charge conjugation ($q \rightarrow -q$) goes with the inversion of the fifth dimension ($\zeta \rightarrow -\zeta$), the Kaluza dimension, which can be expressed through the following matrix representation of the extended group :

$$\begin{pmatrix} \mu & 0 & \mu\theta \\ 0 & \lambda L_o & C \\ 0 & 0 & 1 \end{pmatrix} \quad \begin{matrix} with \quad \lambda=\pm 1 \\ and \ \mu=\pm 1 \end{matrix} \qquad \begin{matrix} M'=L_o M' L_o + \lambda C' P L_o - \lambda L_o P' C \\ P'=\lambda L_o P \qquad q'=\lambda \mu q \end{matrix}$$

According to this vision, among others things, classical antimatter corresponds to a peculiar movement of the charged mass point in a five dimensions space. This shows that the ζ-symmetry (μ = -1 ; $\zeta \rightarrow -\zeta$) goes hand in hand with a *C*-symmetry ($q \rightarrow -q$) which is a geometrical interpretation of the matter-antimatter symmetry through an extension of the Poincaré dynamic group. As derived from such dynamic groups, built with real components, the representation of matter becomes somewhat different. Given the *T*-symmetry, the *CPT*-symmetric and *PT*-symmetric of a particle refer to a negative energy and negative mass objects. A negative world arises, where the matter antimatter duality holds.

2. Could positive and negative energy particles co-exist in the same space ?

Negative mass problem was investigated by H.Bondi [3] and W.B.Bonnor [4]. In 1967 A.Sakharov proposed a twin universe model, with a time inversion [5]. Adding the Souriau's 1970 theorem we built a new dynamical system, ruled by gravitationally interacting masses, of opposite signs, represented as two interacting field equations [6]. The solution of such system is a pair of non-independent metrics g+ and g-. Newtonian approximation provides Poisson equation and interaction laws. Particles whose masses own the same signs mutually attract through Newton's law. When these signs are opposite they repel each other according to "anti-Newton's law". What would be an Universe made of positive and negative masses? The latter would emit negative energy photons. Neither our eyes, nor our optical devices react to such negative energy light. Therefore we cannot observe such structures with our telescopes. Negative mass structures would be perfectly invisible to us. As shown in reference [7] exact (bimetric) solutions, Schwarzschild type, of the system presented in [6] can be built. If, for example, we look at the external Schwarzschild metric, in its classical expression (m is a length, not a mass) :

$$ds^2 = (1-\frac{2m}{r})c^2\,dt^2 - \frac{dr^2}{(1-\frac{2m}{r})} - r^2(d\theta^2+\sin^2\theta\, d\varphi^2) \qquad M=\frac{mc^2}{G}$$

m is nothing but an integration constant, which can be chosen positive or negative. The equations of geodesics, (where φ is the polar angle and $u = 1/r$) is the following (right : null geodesics) :

$$\varphi = \varphi_o + \int_{u_o}^{u} \frac{du}{\sqrt{\frac{c^2 a^2 - 1}{h^2} + \frac{2m}{h^2} u - u^2 + 2mu^3}} \qquad \varphi = \varphi_o + \int_{u_o}^{u} \frac{du}{\sqrt{\frac{c^2 a^2}{h^2} - u^2 + 2mu^3}}$$

and similar for the "internal" Schwarzschild solutions. On the following figures photon's trajectories around a positive and negative mass M. Notice that a positive energy photon can experience negative lensing due to "antigravitational effect", when encountering a cluster of negative mass, for it does not interact with negative material through electromagnetic force, so that it cannot collide with any negative mass particle.

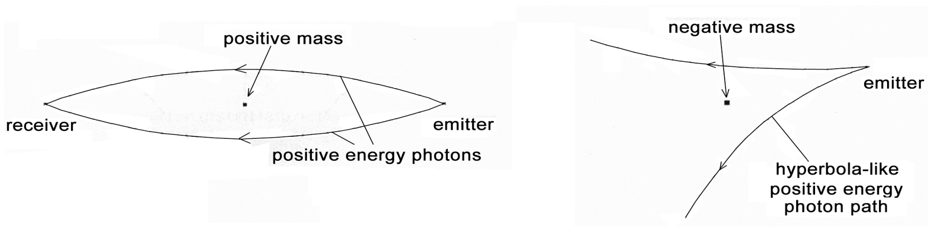

Figure 1. : Positive and negative gravitational lensing effect

As a conclusion, although invisible, negative material clusters would induce negative gravitational lensing effect, reducing the apparent magnitude of large redshift galaxies, which fits observational data [8]. Combining Euler and Poisson equations we get Jeans' like joint gravitational instability equations [9] :

$$\Delta \delta n + \frac{\delta n}{L_j^2} - \frac{m}{kT}\frac{\partial^2 \delta n}{\partial t^2} = 0 \quad (Jeans) \quad \rightarrow \quad \begin{aligned} &\Delta \delta n^+ + \frac{1}{L_j^{+2}}(\delta n^+ + \frac{m^-}{m^+}\delta n^-) - \frac{1}{n^+}\frac{\partial^2 \delta n^+}{\partial t^2} = 0 \\ &\Delta \delta n^- - \frac{1}{(L_j^-)^2}(\delta n^- + \frac{m^+}{m^-}\delta n^+) - \frac{1}{n^-}\frac{\partial^2 \delta n^-}{\partial t^2} = 0 \end{aligned}$$

A spherically symmetric non-linear steady state exact solution can be built, corresponding to a Maxwellian velocity distribution function in both systems. Hereafter: when the absolute values of the densities ρ^+ and ρ^- are equal at infinite, and absolute values of temperatures T^+ and T^- are constant (in time and space), we get the following figures:

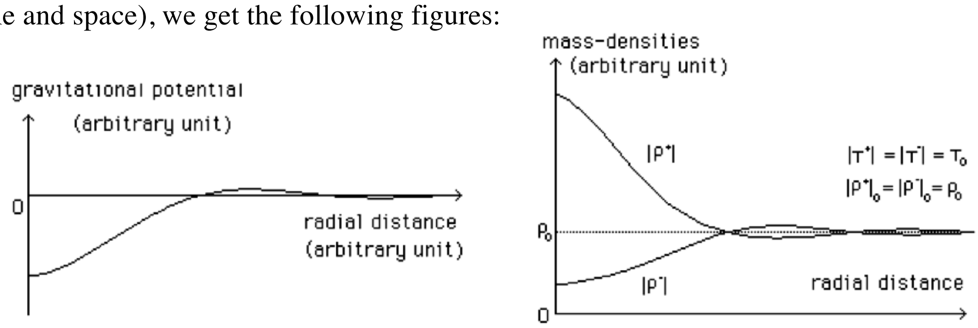

Figure 2. : Spherically symmetric cluster nested in negative material [9]

This is similar, with two interacting populations to the model presented in 1942 by S. Chandrasekhar [10]. Now, assume that the absolute value of the negative mass density is 50 times higher than the one of the positive mass. Then its associated Jeans times are such as:

$$t_J^- = \frac{1}{\sqrt{4\pi G|\rho^-|}} \quad << \quad t_J^+ = \frac{1}{\sqrt{4\pi G\rho^+}}$$

Hereafter the result of 2D numerical simulations [7]. Negative species forms clusters in Figure 3(a) and repels the positive mass in the remnant space in Figure 3(b). In Figure 3(c) the two species, are superimposed.

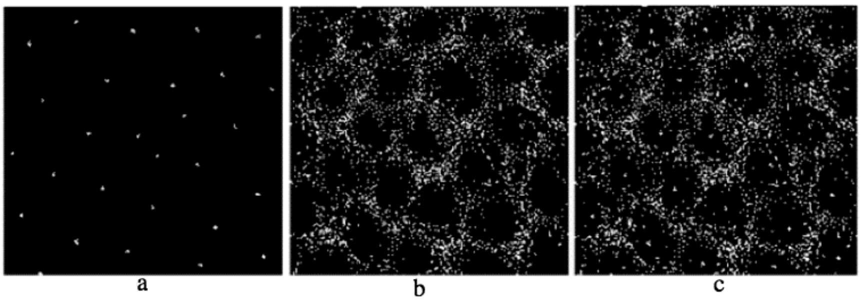

Figure 3. : Results of 2D numerical simulations [7]

This global pattern is stable in time. The cellular structure keeps the negative clusters in place. These negative clusters behave like anchors with respects to the positive matter structure which looks like joined soap bubbles. In 3D it would be similar to VLS.

3. Some insight on the galaxies' birth problem.

To get condensed matter objects, initially formed by gravitational instability, the problem is to evacuate the heat by emission of radiation. In proto stars, their radiatizve cooling is due their spherical surface. The larger the proto star the longer its cooling time. 3D gravitational instability creates spherical negative clusters, with huge mass and dimensions. Then, if the physics of negative matter is similar to ours, the associated cooling time could be larger than the age of the Universe. Even if we fundamentally cannot have optical information on such structures, as they emit negative energy photons, we can try to have some idea about what is going on there. These big clusters would emit long wavelength radiations (reddish, infrared). They would resemble to proto stars that would never ignite. Subsequently the negative world would not have stars, no heavy atoms, planets nor … life.

On the contrary, when negative clusters first form, for their Jeans time is smaller, they repel and compress the positive matter, forming soap bubbles like pattern. This is optimum for energy dissipation by a radiative process and triggers, promotes galaxies' formation. Later, negative matter could also play a role in galaxies' confinement. In addition, this invisible and negative energy content could be the searched so-called "dark energy".

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