An alternative model, explaining the VLS, due to the gravitational interaction of two populations, one composed by positive mass and the second by negative mass.

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Abstract :

Negative mass 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 mass cannot interact through virtual photons, they only interact through gravitational force. Two particules whose mass own same sign attract each other through Newton law. Two particles whose mass own opposite signs repel through « anti-Newton » law. Then the two populations tend to separate. If the mass density of the negative material is much larger, this last first form clusters by gravitational instability. Then the positive matte ris repelled in the remnant place, shaping like joined bubble, which looks like VLS. To illustrate this schema, we give 2d simulation results. In addition this model provides a new insight on the galaxies' birth mechanism.

1 – Introduction

Negative mass arise naturally from dynamic groups, as shown in 1970 by the french mathematician Jean-Marie Souriau. Let us write the element of the Poincaré group, which is the isometry group of the Minkowski space, in its (5,5) matrix representation :

(1)

$$g = \begin{pmatrix} L & C \\ 0 & 1 \end{pmatrix}$$

L is the (4,4) matrix element of the Lorentz group, axiomatically defined by :

(2)

$$G = \begin{pmatrix} 1 & 0 & 0 & 0 \\ 0 & -1 & 0 & 0 \\ 0 & 0 & -1 & 0 \\ 0 & 0 & 0 & -1 \end{pmatrix} \qquad {}^{t}L\,G\,L = G$$

(3)

$$C = \begin{pmatrix} \Delta x \\ \Delta y \\ \Delta z \end{pmatrix}$$

The Poincaré group acts on the ten components of its momentum : energy E , impulsion $\boldsymbol{p}$, passage $\boldsymbol{p}$ and spin $\boldsymbol{s}$. The number of the components of the momentum is equal to the dimension of the group (ten).

(4)

$$J = \{\ E\ , p\ , f\ , s\ \}$$

Souriau introduces the following matrix notation :
(5)

$$M = \begin{pmatrix} 0 & -s_z & s_y & f_x \\ s_z & 0 & -s_x & f_y \\ -s_y & s_x & 0 & f_z \\ -f_x & -f_y & -f_z & 0 \end{pmatrix} \qquad P = \begin{pmatrix} E \\ p_x \\ p_y \\ p_z \end{pmatrix} \qquad J = \begin{pmatrix} M & P \\ {}^tP & 0 \end{pmatrix}$$

Following, the momentum of the Poincaré group, written as an antisymmetrix matrix :
(6)

$$J = \begin{pmatrix} 0 & -s_z & s_y & f_x & E \\ s_z & 0 & -s_x & f_y & p_x \\ -s_y & s_x & 0 & f_z & p_y \\ -f_x & -f_y & -f_z & 0 & p_z \\ -E & -p_x & -p_y & -p_z & 0 \end{pmatrix}$$

As shown by J.M.Souriau the coadjoint action of the group on its momentum can be written
(7)

$$J' = g\, J\, {}^t g$$

Or, explicitely :
(8)

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

(9)

$$P' = L\, P$$

This group owns four connex components, forming two subsets : the orthochron one and the antichron one. As shown by Souriau in 1970 any element of antichron subset transforms any orthochron movement into an antichron movement (implying a T-symmetry). It can be shown simply, using the element L_o of the orthochron subset of the Lorentz group, and writing the complete Lorentz group as :
(10)

$$L = \lambda L_o \qquad with \quad \lambda = \pm 1$$

$\lambda = -1$ refers to the antichron elements, implying a *T*-symmetry.
Then the complete Poincaré group element, in its matrix représentation, can be writen :
(11)

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

The coadjoint ation of the group on its momentum can be written :

(12)

$$M' = L_o \, M \, {}^t L_o + \lambda C \, {}^t P \, L_o - \lambda L_o \, P \, {}^t C$$

(13)

$$P' = \lambda L_o \, P$$

which shows explicitely how a *T*-symmetry (λ = - 1) goes with the inversion of the energy *E*. Then this movement refers to a mass whose energy and mass are negative. In addition, if we consider the complete Poincaré group we must think about negative energy photons.

2 – Electrically charged particle description

As shown by J.M.Souriau (ref) an electric charge can be added to the particle, considering its movement as inscribed in a 5d Kaluza space

(14)

$$t \; , \; x \; , \; y \; , \; z \; , \; \zeta$$

with signature (+ - - - -). Then the dynamic group is the central extension of the Poincaré group :
(15)

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

Its dimension is 11. This adds an extra scalar q to the momentum :
(16)

$$J = \{ \, E \, , p \, , f \, , s \, , q \, \}$$

identified to the electric charge. The associated relation in the coadjoint action of the group ont its momentum is simply :
(17)

$$q' = q$$

The extended group still holds four connex components, with its two subsets, orthochron and antichron.

3 - Geometrical description of matter-antimatter duality.

As shown by Souriau, in (reference Geometrie et Relativité, chapter 5) the charge conjugation goes with the inversion of the fifth dimension ζ , the Kaluza dimension. This is phrased through the following matrix representation of an extended group :
(18)

$$\begin{pmatrix} \mu & 0 & \mu\theta \\ 0 & \lambda L_o & C \\ 0 & 0 & 1 \end{pmatrix} \quad with \quad \lambda = \pm 1 \quad and \quad \mu = \pm 1$$

Then, as first suggested by Kaluza, antimatter is a peculiar movement of the charged mass point in a five dimensional space. The associated coadjoint action of the group on its momentum space is

(19)

$$M' = L_o M\, {}^t L_o + \lambda C\, {}^t P L_o - \lambda L_o P\, {}^t C$$

(20)

$$P' = \lambda L_o P$$

(21)

$$q' = \lambda \mu q$$

The equation (18) shows that the ζ-symmetry ($\zeta \rightarrow - \zeta$) goes with a C-symmetry ($q \rightarrow - q$). This is the goemetrical interpretation of the matter-antimatter symmetry.

4) **Could positive and negative energy particles co-exist in the same space ?**

Is it possible to imagine the Universe as a mixture of positive and negative energy matters ? Would'nt the result of a collision should be a complete annihilation ? Oppositely, in the so-called matter-antimatter annihilation, if the mass disappears, the energy is conserved.
First remark : could we see some assembly made of negative mass ? This last would emit negative energy photons. As far as we know our eyes, or optical devices do not react to such negative energy light. So that we could not observe such structures with our telescopes.
Can electrically charged positive energy matter interact with electrically charged negative energy matter ? In QCM the electromagnetic interaction is phrased in terms of virtual photons exchange. If positive energy (and positive mass) particles cannot exchange virtual photons with negative energy (and negative mass) particles, the interaction becomes impossible. Then the two subsets only interact through the gravitational force :

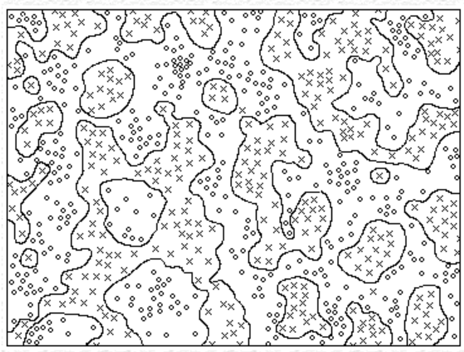
(22)

$$F = \frac{G\, m\, m'}{d^2}$$

The result depends on the observer. We consider we belong to the positive mass and energy world. If two positive mass attract each other through Newton's law, positive mass is repelled by a negative mass, through « anti-Newton law ». The action reaction principle implies that, with respect to an observer made of positive matter, this last repels negative matter. In addition, two negative mass attract each other through Newton law. We will consider in the following the observational consequences of such dynamics through numerical simulations.

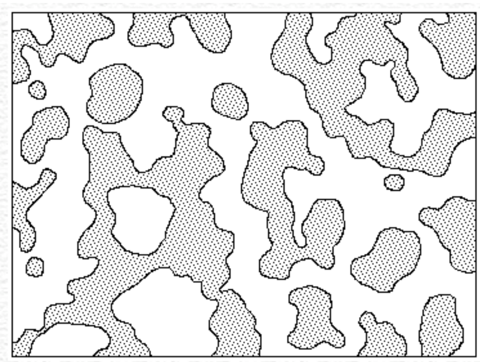
5) **Opposite mass particles interacting. Numerical results.**

Consider 2d simulations. If we put two sets of positive and negative particles, with same average random velocity and same numbers of density, we get a percolation phenomenon, with the following result :



2d simulation. Cross : positive mass, circles : negative mass
Same initial uniform numbers of density and random velocities
and : $m^- = - m^+$

In the next figure, we use grey and white colors.



Percolation phenomenon : the opposite mass separate

Now, assume that :
(23)

$$- m^- > m^+$$

It means that
(24)

$$\left|\rho^-\right| > \rho^+$$

Considering the gravitational instability process, the characteristic (accretion) time for formation of clusters, in a given uniform medium, with positive mass density ρ is :
(25)

$$t_a = \frac{1}{\sqrt{4\pi G \rho}}$$

From (21) we have :
(26)

$$t_a^- < t_a^+$$

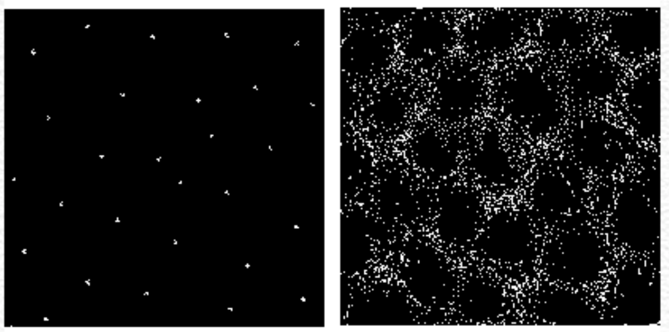
Assume that :
(27)

$$- m^{-} >> m^{+}$$

Then :
(28)

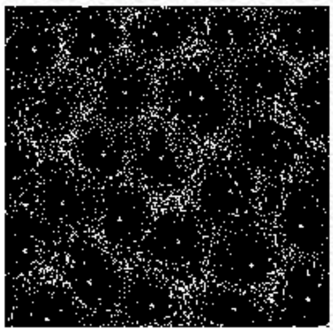
$$\left|\rho^{-}\right| \gg \rho^{+} \qquad and \qquad t_a^{-} \ll t_a^{+}$$

The negative mass clusters first form, by gravitational instability, and repel the remnant material, the positive mass matter in the remnant space. Let us illustrate this idea through a 2d numerical simulation :



Result of joint gravitational instabilities with

$$\left|\rho^{-}\right| = 50\,\rho^{+} \qquad and \qquad t_a^{-} = 0.14\ t_a^{+}$$



The two species, superimposed

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 this joined soap bubbles like positive structure

6) **Some insight on the galaxies' birth problem.**

To get condensed matter objects, initially formed by gravitational instability, the problem is to evacuate heat by radiation emission. In proto stars, the radiation is due to their surface. Then the larger is the proto star the longer is the cooling time.

Gravitational instability creates spherical negative clusters, with huge mass and dimension. Then, if the physics of negative material is similar to ours, the associated cooling time could be larger than de age of the Univers. Even if we basically could not have optical information of such structures, emitting negative energy photons, we can try to have some idea about what going on there. These big clusters would emit large wavelength radiations (reddish, infrared). They would ressemble proto stars that would never ignite. Subsequently the negative world would not have stars, heavy atoms, planets and … life.

Oppositely, when negative clusters first form, for their Jeans time is smaller, they repel and compression the positive matter, forming soap bubbles like pattern. This is optimum for energy dissipation by radiative process and triggers, promote galaxies' formation. Later, negative matter could play a role in galaxies confinement.

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