Cosmologic Model with m>O and m<0 interacting masses

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Retired

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Complement to my presentation at the 2013 international meeting on mathematical physics, held in Praga, on september the 2nd.

The allowed time for oral (15 minuts) was quite shot to present my work. Same thing for the allowed pages (four) of the paper, to be published in the proceedings, that holds a different title :

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.

If the reader is interested, I will give more information there.

1) Why the scientific community was not really interested in negative matter since decades.

They are several reasons. The first is related to the energy. If a particle owns a negative mass

$$m < 0$$

If its energy can be written :

$$E = m c^2$$

then this corresponding energy would be negative :

$$E < 0$$

Immediatly, a physicist would ask :

- If two particles meet, with opposite energies, the result of such collision would be ... perfectly nothing !

As everybody know, matter and antimatter have positive masses. When such particles collide, a so-called "annihilation" occurs, which is not really a true annihilation, because the energy is conserved. This couple is transformed into positive energy photons.

Just notice that " nihil " means " nothing " in latin.

If the universe would be a mixture fifty-fifty of positive energy particles and negative energy particles, all that content would be annihilated.

If these amounts would be different a certain amount of positive or negative matter would survive. The behaviour of an universe filled by negative matter was investigated by W.Bonnor in 1998. I will give some comments about his paper further.

The second argument comes from quantum mechanics. Let us quote some pages of the famous book of Steven Weinberg, entitled :

Quantum theory of fields

Issued in 2005, Cambridge University Press

Page 74, Weinberg introduces space and time inversions operators :

2.6 Space Inversion and Time-Reversal

We saw in Section 2.3 that any homogeneous Lorentz transformation is either proper and orthochronous (i.e., $\text{Det}\Lambda = +1$ and $\Lambda^0{}_0 \geq +1$) or else equal to a proper orthochronous transformation times either $\mathscr{P}$ or $\mathscr{T}$ or $\mathscr{P}\mathscr{T}$, where $\mathscr{P}$ and $\mathscr{T}$ are the space inversion and time-reversal transformations

$$\mathscr{P}^\mu{}_\nu = \begin{bmatrix} -1 & 0 & 0 & 0 \\ 0 & -1 & 0 & 0 \\ 0 & 0 & -1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}, \quad \mathscr{T}^\mu{}_\nu = \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & -1 \end{bmatrix}.$$

It used to be thought self-evident that the fundamental multiplication rule of the Poincaré group

$$U(\bar{\Lambda}, \bar{a})\, U(\Lambda, a) = U(\bar{\Lambda}\Lambda, \bar{\Lambda}a + \bar{a})$$

Pages 75 and 76 he deal with time inversion problem. I am not familiar with quantum mechanics, but it seems that, from the beginning, an arbitrary choice is decided about the nature of the T operator : to be anti-linear and anti-unitary. If not " "the consequences would be disastrous" , as noted by Weinberg. I quote :

coefficients of $\omega_{\rho\sigma}$ and ϵ_ρ in Eqs. (2.6.1) and (2.6.2), we obtain the P and T transformation properties of the Poincaré generators

$$\mathsf{P}\, i J^{\rho\sigma} \mathsf{P}^{-1} = i \mathscr{P}_\mu{}^\rho \mathscr{P}_\nu{}^\sigma J^{\mu\nu} , \tag{2.6.3}$$

$$\mathsf{P}\, i P^\rho \mathsf{P}^{-1} = i \mathscr{P}_\mu{}^\rho P^\mu , \tag{2.6.4}$$

$$\mathsf{T}\, i J^{\rho\sigma} \mathsf{T}^{-1} = i \mathscr{T}_\mu{}^\rho \mathscr{T}_\nu{}^\sigma J^{\mu\nu} , \tag{2.6.5}$$

$$\mathsf{T}\, i P^\rho \mathsf{T}^{-1} = i \mathscr{T}_\mu{}^\rho P^\mu . \tag{2.6.6}$$

This is much like Eqs. (2.4.8) and (2.4.9), except that we have not cancelled factors of i on both sides of these equations, because at this point we have not yet decided whether P and T are linear and unitary or antilinear and antiunitary.

The decision is an easy one. Setting $\rho = 0$ in Eq. (2.6.4) gives

$$\mathsf{P}\, i H \mathsf{P}^{-1} = i H ,$$

where $H \equiv P^0$ is the energy operator. If P were antiunitary and antilinear then it would anticommute with i, so $\mathsf{P} H \mathsf{P}^{-1} = -H$. But then for any state Ψ of energy $E > 0$, there would have to be another state $\mathsf{P}^{-1}\Psi$ of

energy $-E < 0$. There are no states of negative energy (energy less than that of the vacuum), so we are forced to choose the other alternative: P *is linear and unitary, and commutes rather than anticommutes with* H.

On the other hand, setting $\rho = 0$ in Eq. (2.6.6) yields

$$\mathsf{T}\, i H \mathsf{T}^{-1} = -i H .$$

If we supposed that T is linear and unitary then we could simply cancel the is, and find $\mathsf{T} H \mathsf{T}^{-1} = -H$, with the again disastrous conclusion that for any state Ψ of energy E there is another state $\mathsf{T}^{-1}\Psi$ of energy $-E$. To avoid this, we are forced here to conclude that T *is antilinear and antiunitary*.

Now that we have decided that P is linear and T is antilinear, we can conveniently rewrite Eqs. (2.6.3)–(2.6.6) in terms of the generators (2.4.15)–(2.4.17) in a three-dimensional notation

$$\mathsf{P}\mathbf{J}\mathsf{P}^{-1} = +\mathbf{J} , \tag{2.6.7}$$

$$\mathsf{P}\mathbf{K}\mathsf{P}^{-1} = -\mathbf{K} , \tag{2.6.8}$$

$$\mathsf{P}\mathbf{P}\mathsf{P}^{-1} = -\mathbf{P} , \tag{2.6.9}$$

$$\mathsf{T}\mathbf{J}\mathsf{T}^{-1} = -\mathbf{J} , \tag{2.6.10}$$

$$\mathsf{T}\mathbf{K}\mathsf{T}^{-1} = +\mathbf{K} , \tag{2.6.11}$$

$$\mathsf{T}\mathbf{P}\mathsf{T}^{-1} = -\mathbf{P} , \tag{2.6.12}$$

and, as shown before,

$$\mathsf{P} H \mathsf{P}^{-1} = \mathsf{T} H \mathsf{T}^{-1} = H . \tag{2.6.13}$$

In effect the action of the T operator, which implies time-inversion, would give energy inversion and open the road to negative energy particles.

Page 104, Weinberg writes :

" No examples are known of particles that furnish unconventional representations of inversions, so that theses possibilities will not be purshed further here. "

In effect, that was true until an unsuspected discovery : recent measurements showed that the universe was accelerating.

Even if a suitable arrangement of the T operator makes possible to avoid the "disastrous" negative energie, some said that the fact that particles could cruise backwards in time violated the causality principle.

Main precedent works :

In a paper published in 1957, entitled "Negative mass and General Relativity" H.Bondi [1]. writes :

We can distinguish between three kinds of mass according to the measurement by which it is defined :

- *Inertial mass* m_i
- *Passive gravitational mass* m_p
- *Active gravitational mass* m_a

Inertial mass is the quantity that enters (and is defined by) Newton's second law. Passive gravitational mass on which the gravitational field acts. Active gravitational mass is the mass that is the source of gravitational fields and hence the mass that enters Poisson's equation and Gauss'law.

This can we written, in Newtonian approximation :

$$m_i^{(1)}\ddot{\vec{r}}_1 = \frac{G(\vec{r}_2 - \vec{r}_1)m_p^{(1)}m_a^{(2)}}{|\vec{r}_2 - \vec{r}_1|^3} \quad \text{action of } m_2 \text{ on } m_1$$

$$m_i^{(2)}\ddot{\vec{r}}_1 = \frac{G(\vec{r}_1 - \vec{r}_2)m_p^{(2)}m_a^{(1)}}{|\vec{r}_1 - \vec{r}_2|^3} \quad \text{action of } m_1 \text{ on } m_2$$

Then Bondi writes :

In general relativity the principle of equivalence is not a separate fact but is basic to the theory. Accordingly the ratio of inertial and passive gravitational masses is the same for all bodies.

$$m_i = m_p$$

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[1] Review of Modern Physics, Vol 29, Number 3, july 1957, entitled "Negative mass in General Relativity".

The equations become :

$$\ddot{r}_1 = \frac{G(\vec{r}_2 - \vec{r}_1)\, m_a^{(2)}}{|\vec{r}_2 - \vec{r}_1|^3} \quad action\ de\ (2)\ sur\ (1)$$

$$\ddot{r}_2 = \frac{G(\vec{r}_1 - \vec{r}\,2)\, m_a^{(1)}}{|\vec{r}_1 - \vec{r}\,2|^3} \quad action\ de\ (1)\ sur\ (2)$$

The direction of the action only depends on the sign of the active gravitational mass.

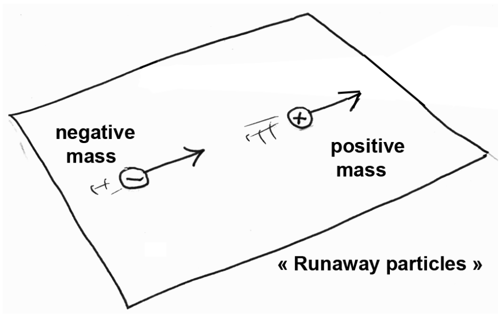
- If $m_a^{(2)} > 0$ the mass (2) attracts the mass (1) whatever its inertial mass is positive or negative.

- If $m_a^{(2)} < 0$ the mass (2) repels the mass (1) whatever its inertial mass is positive or negative.

Page 424 of his 1957 paper Bondi writes :

To use the language of Newtonian approximation, the positive body will attract the negative one (***since all bodies are attracted by it****), while the negative body will repel the positive body (****since all bodies are attracted by it****). If the motion is confined to the line of centers, then one would expect the pair to move off with uniform acceleration (...). This rather surprising result clearly requires confirmation by the complete construction of the model in general relativity.*

This corresponds to the following schema :

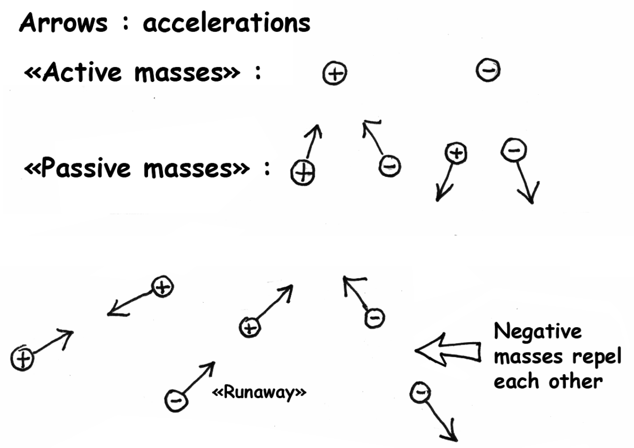


corresponding to " *Runaway motion* ".

Bondi :

We now return to the task of constructing a model in general relativity whose masses have opposite signs ....

The next schema gives a better vision of this strange cosmological mechanics :



Dynamics of a mixture of positive and negative masses

Fourty one years years after (1998) W. Bonnor publishes a paper " Negative Mass in General Relativity"[2]. He decides to remove positive masses, in order to prevent this strange runaway effect, although he notes that :

The two particles, starting from rest, will follow each other with constant acceleration to infinity. The velocities increase without limit but the momentum and energy are conserved because the inertial masses are equal and opposite (...).

And he considers a universe filled by negative masses, with :

$$m_i = m_p < 0 \quad m_a < 0$$

At the begining of his paper he writes, I quote :

" *At this point it becomes clear that the universe I am considering has no practical relation to the one we live in. Indeed, when I am writing may be called science fantasy, and the busy reader is fully entitled to turn the page. My reason for continuing is to see wether the properties of the hypothetical universe suggest why the real universe contains only positive mass* (...). *My intention is well summarized by Einstein's metaphorical phrase "What interests me is whether God had any choice in the creation of the world*".

Then he studies the dynamics of such Universe, with a zero cosmological constant and a "dust universe" ($p = 0$) . He finds :

$k = -1$ (curvature index)

$\rho R^3 = Cst$ (conservation of this negative matter)

$R^2 R'' = Constant$ (positive, while this one is negative in the Friedman solutions).

So that $R'' < 0$

The Bonnor's solution is :

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[2] General Relativity and Gravitation, Vol.11 N° 11, 1989

$$R(u) = \alpha^2 \; ch^2 u$$

$$t(u) + t_o = \alpha^2 \; (\; 1 + \frac{sh 2u}{2} + u \;)$$

t grows with *u*. When *u* = 0 , R gets a minimum value (exit the singularity). When *t* tends to infinite, *R*' becomes constant.

As a conclusion, Bonner writes at the end of his paper :

" *Pursuing Einstein's theological metaphor, mentioned in the introduction, one can say that the result of this paper do not reveal why God chose matter to have positive rather that negative mass* (...)"

2) **A completely different approach.**

We concentrate on group theory. First consider the 3d euclidean space. In such space we can experience rotations and translations. These fits the *physical reality*. It can be phrased through the following matrix group :

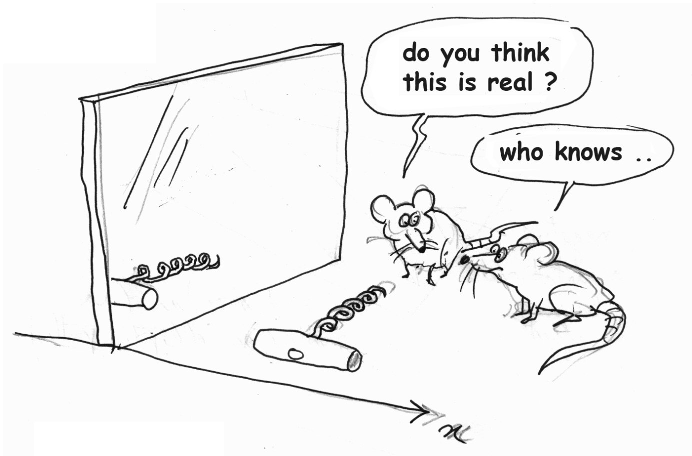
$$g = \begin{pmatrix} a & C \\ 0 & 1 \end{pmatrix} \qquad C = \begin{pmatrix} \Delta x \\ \Delta y \\ \Delta z \end{pmatrix} \qquad {}^t a = a^{-1} \qquad \det(a) = +1$$

This is a subgroup of the isometry group of the Euclidean space, this last being :

$$g = \begin{pmatrix} a & C \\ 0 & 1 \end{pmatrix} \qquad C = \begin{pmatrix} \Delta x \\ \Delta y \\ \Delta z \end{pmatrix} \qquad {}^t a = a^{-1} \; (\; or \quad {}^t a \; I \; a = I \;) \qquad \det(a) = \pm 1$$

so that this euclidean group owns two connex components. The first, corresponding to det(a) = + 1 preserves the orientation of the objects, the second, corresponding to det(a) = - 1 operates a "mirror transformation", transforms a "right object" into a "left object".

The definition of the orientation is somewhat arbitrary. We consider our kitchen's corkscrew as "right corkscrew". From a mathematical point of view, the complete euclidean group can transform a right corkscrew into a left corkscrew : Does it fits the physical reality ? Do left corkscrews ... exist (except as images in a mirror)?



The physical transformation of a right corkscrew into a left corkscrew would be rather tedious, if you would ask a smith to do it.

We could decide that left corkscrews do not belong to "our real world". But we know that we can find some in tricks and jokes shops.

Let's shift to 4d world, to Minkowski space time we are supposed to live in. In such space we can perform "relativistic rotations", using Lorentz matrix, space and time symmetries, and space time translation, defined by :

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

Introduce the following metric matrix (Gramm matrix) :

$$G = \begin{pmatrix} -1 & 0 & 0 & 0 \\ 0 & -1 & 0 & 0 \\ 0 & 0 & -1 & 0 \\ 0 & 0 & 0 & 1 \end{pmatrix}$$

Combining relativistic rotation, symmetries and space-time translations we get :

$$g = \begin{pmatrix} L & C \\ 0 & 1 \end{pmatrix}^t \quad with \quad L\,G\,L = G \quad \det(L) = \pm 1$$

which is the complete Poincaré group.

Let us start from a movement oriented from the past to the future. Let an element of the Poincaré group act on it.

Some will not reverse space and time, for example the neutral element :

$$\begin{pmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{pmatrix}$$

Call L_n the elements that do not reverse space and time.

We can find elements that produce a space inversion but not a time inversion. Example :

$$\begin{pmatrix} -1 & 0 & 0 & 0 \\ 0 & -1 & 0 & 0 \\ 0 & 0 & -1 & 0 \\ 0 & 0 & 0 & 1 \end{pmatrix}$$

Such elements form the subset L_s

Another elements produce a time inversion, but not a space inversion. Example :

$$\begin{pmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & -1 \end{pmatrix}$$

They will form the L_t subset

And, finally, some elements produce inversion of space and time. Example :

$$\begin{pmatrix} -1 & 0 & 0 & 0 \\ 0 & -1 & 0 & 0 \\ 0 & 0 & -1 & 0 \\ 0 & 0 & 0 & -1 \end{pmatrix}$$

They form the fourth subset L_{st}

The complete Lorentz group owns four connex components :

$$L = \{ L_n , L_s , L_t , L_{st} \}$$

The first two form the *orthochron* subgroup, whose elements do not inverse time :

$$L_o = \{ L_n , L_s \}$$

The next two, whose elements inverse time form the *antichron* subset :

$$L_a = \{ L_t , L_{st} \}$$

The orthochron subgroup is also called the *restricted* Lorentz group, the complete Lorentz group being :

$$L = L_o \cup L_a$$

If we form the Poincaré matrix with the restricted Lorentz group we get the restricted Poincaré group (or "orthochron Poincaré group")

$$\textit{restricted Poincaré group} \quad g_o = \begin{pmatrix} L_o & C \\ 0 & 1 \end{pmatrix}$$

The Poincaré group inherits the properties of the Lorentz group. It owns four connex components :

$$\{ g \}_{Poincaré} = \{ g_n \} \cup \{ g_s \} \cup \{ g_t \} \cup \{ g_{st} \}$$

With :

Its orthochron subgroup (restricted Poincaré Group -

$$\{ g_o \}_{Poincaré} = \{ g_n \} \cup \{ g_s \}$$

Its antichron subset

$$\{ g_a \}_{Poincaré} = \{ g_t \} \cup \{ g_{st} \}$$

The Poincaré group is a *dynamical group*, which acts on movements. We shall consider movement of a mass-point particle, following a geodesic of the Minkowski space. In this space we have two kinds of geodesics :

- Non-null geodesics, associated to massive particles
- Null-geodesics (whose lenght is zero) associated to photons

We consider that particles' paths identify to geodesics.

Do the g_s elements have physical meaning ?

They produce a space inversion. The reader could ask :

- *What is the meaning of space inversion, if particle description is limited to straight lines ?*

The photons owns an *helicity*, so there are “right” and “left” photons. This corresponds to the polarization phenomenon.

Now, do the L_a elements have physical meaning ?

3) **Negative energy particles from action of a dynamic group on its momentum.**

In the sixties the mathematician Kostant, Kirilov and Souriau developed independently a new tool : the coadjoint action of a group on its momentum. The dimension of the momentum is equal to the dimension of the group (10 for the Poincaré group).

Consider a movement of a particle in the Minkowski space. Its movement is defined by a certain number of parameters, the components of the momentum.

An element *g* of the group acts on this movement. How its changes the components of the momentum.

Souriau arranges these 10 components, introducing an antisymmetric (4,4) matrix *M* and a 4-vector *P*. This last is well-known among physicists. It is the impulsion energy four vector :

$$P = \begin{pmatrix} p_x \\ p_y \\ p_z \\ E \end{pmatrix}$$

The (4,4) *M* matrix depends on 6 components. The momentum is written as the following antisymmetric (5,5) matrix :

$$J = \begin{pmatrix} M & P \\ {}^tP & 0 \end{pmatrix}$$

The action of the group on its momentum, after calculation, is :

$$J' = g\,J\,{}^tg$$

which gives :

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

$$P' = L\,P$$

We will concentrate on the second equation. In 1970 Souriau[3] was the first to show the purely geometric nature of the spin (as a component of the momentum, and more precisely of the *M* matrix).

We have :

$$L_{st} = - L_n$$

$$L_t = - L_s$$

So that we can build the complete Poincaré group, writing :

$$L_a = - L_o$$

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

$$g_{Poincaré} = \begin{pmatrix} \lambda L_o & C \\ 0 & 1 \end{pmatrix}$$

$$\begin{pmatrix} p'_x \\ p'_y \\ p'_z \\ E' \end{pmatrix} = \lambda \, L_o \begin{pmatrix} p_x \\ p_y \\ p_z \\ E' \end{pmatrix}$$

In particular :

$$E' = \lambda \, E$$

For E = m c^2 such antichron particles also own a *negative mass.*

Notice this holds for photons too.

If negative masses exist they should emit and capture negative energy photons.

The inversion of the energy goes with the inversion of the time.

Like with the corkscrew problem, we have to face a new problem :

- *What is the physical meaning of such movements of particles going backwards in time and owing negative energy ?*

3) **The cosmologic Sakharov's model, 1967.**

In 1967 Sakharov published a paper[4] in which he suggested that the universe, for sake of symmetry, could composed by two "twin universes" with opposite arrows of time". He

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[3] Jean-Marie Souriau : Structure des Systèmes Dynamiques, Ed. Dunod, 1970, France
Jean-Marie Souriau : Structure of Dynamic Systems, Ed. Birkhauser

called these two " twin universes ". In the second universe, the particles would cruise backwards in time. Those two universes would be linked by a singularity, he called ϕ.

In 1977, ignoring this work, I published a first paper entitled :

Univers enantiomorphes à flèches du temps opposées

in the french Compte Rendus de l'Académie des Sciences de Paris[5].

Later I used Souriau's tools to set that this second model, T-symmetric, should be inhabited by negative Energy particles, and negative mass if the had one

4) **A bimetric cosmologic model**

What is " a universe " ?

A manifold, plus a metric.

Leaving Sakharov, I no longer think that there are two distinct universes, two twin universes, but a single one, a manifold *with two metrics*.

The first, g^+ refers to positive energy particles

The second, g^- refers to negative energy particles

This give a new general relativity, which makes possible to host positive and negative masses.

Each metric gives its own system of geodesics. They form two distinct families. So that positive energy particles and negative energy particles cannot meet, collide.

- Positive energy photons follow null geodesics, associated to the metric g^+

- Negative energy photons follow null geodesics, associated to the metric g^-

We, as positive energy particle assemblies, cannot receive negative energy photons. Same thing for our telescope.

The negative energy particles are invisible for us.

If an observer would be made of negative energy particles, he could not receive photons emitted from our positive energy world.

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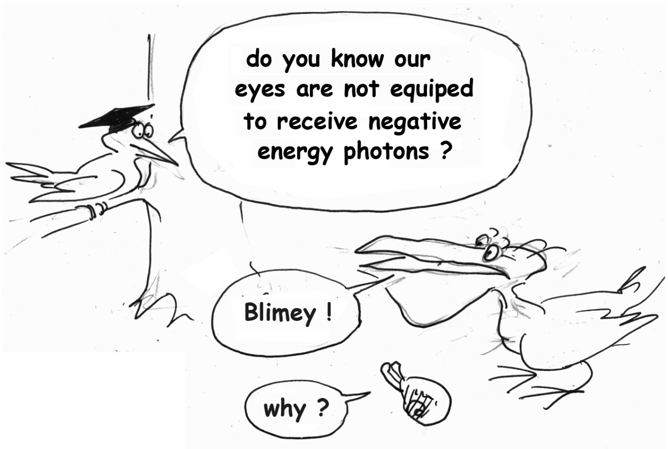
[4] A.Sakharov : CP violation and baryonic asymetry of the Universe. ZhETF Pis'ma 5, 32- (JETP Letters 5, 24-27) And 1980 Cosmological model of the Universe with time vector inversion. JETP 52, 349-351

[5] Jean-Pierre Petit : Enantiomorphic Universes with opposite time arrows. CRAS t. 263 May 1977 pages 1315-1318

On pure geometric grounds



Until somebody would build a model of electromagnetic interaction of particles owing energies with opposite signs, we can assert that the electromagnetic interaction between these two world is impossible. A positive energy particle or assembly of positive energy particle can cross a cloud, or a cluster of negative material, without any electromagnetic interaction.

And vice-versa.

This will become important later.

5) **A system of coupled field equation.**

Bondi and Bonnor studied other visions of the universe, making different choices for their parameters m_i, m_a , m_p . Here we consider two coupled field equations.

I published that in 1994 in Nuevo Cimento[6] in a paper entitled : The missing mass effect. I don't believe in dark matter. In this paper I considered that the two matters contributed to the energy-matter tensor, to the field :

$$T_{\mu\nu} = T^{+}_{\mu\nu} + T^{-}_{\mu\nu}$$

$T^{+}_{\mu\nu}$ *refers to the positive energy content*

$T^{-}_{\mu\nu}$ *refers to the negative energy content*

Then, in 1994 I introduced the following system, restricted to time independant solutions :

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[6] Jean-Pierre Petit : The missing mass effect. Il Nuovo Cimento, B , vol. 109, july 1994, pp. 697-710

$$R^{+\mu\nu} + \frac{1}{2} R^{+} g^{+\mu\nu} = T^{\mu\nu} = T^{+\mu\nu} + T^{-\mu\nu}$$

$$R^{-\mu\nu} + \frac{1}{2} R^{-} g^{-\mu\nu} = - T^{\mu\nu} = - (T^{+\mu\nu} + T^{-\mu\nu})$$

This system couples the metrics $g^{+\mu\nu}$ and $g^{-\mu\nu}$ through the Ricci tensors $R^{+\mu\nu}$ and $R^{-\mu\nu}$

This system, through a bivariational technique, can be derived from the Lagrangian :

$$L = \int_{D4} \left\{ \sqrt{-g^{+}} \left[R^{+}_{\mu\nu} - \chi (T^{+}_{\mu\nu} + T^{-}_{\mu\nu}) \right] g^{+\mu\nu} + \sqrt{-g^{-}} \left[R^{-}_{\mu\nu} + \chi (T^{+}_{\mu\nu} + T^{-}_{\mu\nu}) \right] g^{-\mu\nu} \right\} d^4 x$$

The Einstein tensor is, classically :

$$G^{\mu\nu} = R^{\mu\nu} + \frac{1}{2} R \, g^{\mu\nu}$$

From the above system, we have :

$$G^{-\mu\nu} = - G^{+\mu\nu}$$

The Einstein tensor derives from a Hilbert functional, defined in the so called hyperespace, the metric space :

$$H_{(g)} = \int_M a \, R_{(g)} \, dV_g$$

R being the scalar curvature.

(g^+ , g^-) defines *coupled geometries*, corresponding to :

$$H^{-}_{(g)} = - H^{+}_{(g)}$$

6) **Exact coupled metric solution (g^+ , g^-)**

If

$$T^{+\mu\nu} = 0 \qquad T^{-\mu\nu} = 0 \quad \text{(empty space)}$$

or

$$T^{+\mu\nu} + T^{-\mu\nu} = 0$$

the Lorentz metrics :

$$\eta^{+\mu\nu} \qquad \textit{and} \qquad \eta^{-\mu\nu}$$

form a solution of the system of coupled field equations.

Consider now that the universe is empty, except a in a sphere, whose radius is r_o, filled by constant density ρ^+ of positive matter.

Then :

$$T^{-\mu\nu} = 0$$

The system becomes :

$$R^{+}_{\mu\nu} + \frac{1}{2} R^{+} g^{+\mu\nu} = \chi T^{+}_{\mu\nu}$$

$$R^{-}_{\mu\nu} + \frac{1}{2} R^{-} g^{-\mu\nu} = -\chi T^{+}_{\mu\nu}$$

With $p+ = 0$ we can write :

$$T^{+\mu\nu} = \begin{pmatrix} \rho^{+} & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \end{pmatrix}$$

The first metric $g+$ corresponds to the "posi-Schwarzschild's solutions" (internal and external, see annex).

But the coupled solution $g-$ is different. It corresponds to "nega-Schwarschild solutions" (see annex 1). The associated geodesics describe the movement of a negative matter test particle. It is repelled by the sphere filled by positive material.

So that positive matter repels negative matter.

Conversely, imagine a large portion of the universe that is empty, except in a sphere whose radius is r_0, filled by constant density ρ^- of negative matter.

Then the system becomes :

$$R^{+}_{\mu\nu} + \frac{1}{2} R^{+} g^{+\mu\nu} = \chi T^{-}_{\mu\nu}$$

$$R^{-}_{\mu\nu} + \frac{1}{2} R^{-} g^{-\mu\nu} = -\chi T^{-}_{\mu\nu}$$

We can write, with $p^- = 0$:

$$T^{-\mu\nu} = \begin{pmatrix} \rho^{-} & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \end{pmatrix} \qquad \rho^{-} < 0$$

The two metric solutions are just exchanged.

$g+$ becomes "nega-Schwarzschild"

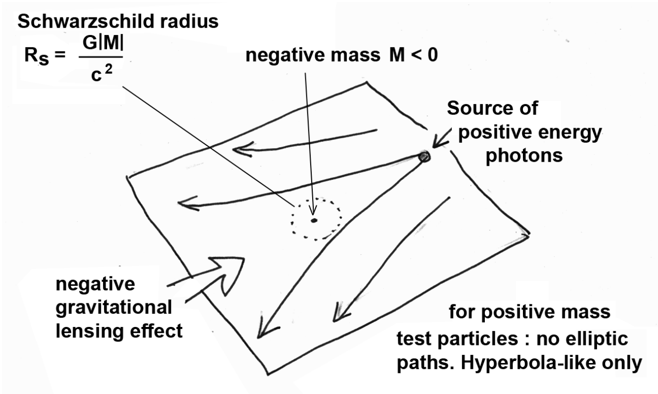
$g-$ becomes "posi-Schwarzschild" (see annex)

As a conclusion, negative matter repels positive matter

Anticipating, consider a light source, made of positive matter, emitting positive energy photons, received by an observer, obviously made of positive material.

Suppose these light rays pass through a sphere filled by negative matter.

- For those photons, this sphere is perfectly transparent.
- It produces a negative gravitational lensing effect :



7) **Newtonian approximation**

We start from a following steady state solution :

Lorentz metrics :

$$\eta^{+\mu\nu} \qquad and \qquad \eta^{-\mu\nu}$$

and we write :

$$g^{+\mu\nu} = \eta^{+\mu\nu} + \varepsilon\,\gamma^{+\mu\nu} \qquad and \qquad g^{-\mu\nu} = \eta^{-\mu\nu} + \varepsilon\,\gamma^{-\mu\nu}$$

the two perturbations are assumed to be time-independent tensors. We introduce in the system of coupled field equation and develop into a series. We obtain[7] :

$$\varepsilon\left(\frac{\partial^2 \gamma^+_{00}}{\partial x^2} + \frac{\partial^2 \gamma^+_{00}}{\partial y^2} + \frac{\partial^2 \gamma^+_{00}}{\partial z^2}\right) = -\,\chi\,(\rho^+ + \rho^-)$$
$$\varepsilon\left(\frac{\partial^2 \gamma^-_{00}}{\partial x^2} + \frac{\partial^2 \gamma^-_{00}}{\partial y^2} + \frac{\partial^2 \gamma -}{\partial z^2}\right) = \chi\,(\rho^+ + \rho^-)$$

with

[7] Adler, Schiffer et Bazin : Introduction to general Relativity. Mc Graw Hill 1965, 10.5

$$\chi = -\frac{8\pi G}{c^2}$$

We can define a gravitational potential :

$$\Psi^+ = \frac{c^2}{2}\varepsilon\gamma^+_{00}$$

and have the Poisson equation :

$$\Delta\Psi^+ = 4\pi G(\rho^+ + \rho^-)$$

8) **The Newton's law** :

Let

$$\Psi = \Psi^+$$

$$\gamma^-_{00} = -\gamma^+_{00}$$

Differential equations for geodesics are :

$$\frac{d^2x^{(+)i}}{dt^2} + \begin{pmatrix} & i & \\ 0 & & 0 \end{pmatrix}^+ c^2 = 0$$

$$\frac{d^2x^{(-)i}}{dt^2} + \begin{pmatrix} & i & \\ 0 & & 0 \end{pmatrix}^- c^2 = 0$$

$$\begin{pmatrix} & i & \\ 0 & & 0 \end{pmatrix}^+ = \frac{1}{2}\varepsilon\frac{\partial\gamma^+_{00}}{\partial x^i}$$

$$\begin{pmatrix} & i & \\ 0 & & 0 \end{pmatrix}^- = \frac{1}{2}\varepsilon\frac{\partial\gamma^-_{00}}{\partial x^i}$$

Newton's law :

$$\frac{d^2 x^{(+)i}}{dt^2} = -\frac{\partial \Psi}{\partial x^i}$$

$$\frac{d^2 x^{(-)i}}{dt^2} = +\frac{\partial \Psi}{\partial x^i}$$

The things are cleared :

- Two positive matter particles attract each other through Newton's law
- Two negative matter particles attract each other through Newton's law
- A particle of positive matter and a particle of negative matter repel each other through "anti-Newton's law".

H. Bondi and W. Bonnor could not find such result with *one* metric description. A bimetric hypersurface was needed, plus a system of coupled field equations.

9**) Antimatter geometrization**

Consider the following extended group :

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

It acts on 5-dimensional Kaluza space.

$$\begin{pmatrix} \varsigma \\ x \\ y \\ z \\ t \end{pmatrix}$$

ζ is the fifth dimension, the Kaluza dimension. According to Emmy Noether's theorem the new symmetry

$$\mu = -1 \Rightarrow \zeta' = -\zeta$$

introduces an additional scalar *q*, the electric charge.

This can also be deduces from the new dimension of the group : 11, which adds a scalar to its momentum.

The calculation of the action of the group on its moment gives :

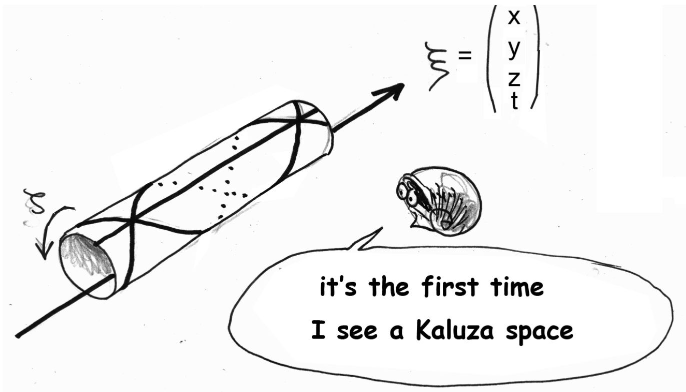
$$E' = \lambda E$$

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

$\mu = -1$ changes q into $-q$ and ζ into $-\zeta$.

The charge conjugation (C-symmetry) goes with the inversion of the fifth dimension[8].

After Souriau (geometrical quantization method), if ζ is closed the electric charge is quantized. If we figure the Minkowski space as a straight line we can give the following image of fifth dimensional inversion :



10) **Adding closed dimensions and new quantum numbers.**

Let :

$$\xi = \begin{pmatrix} x \\ y \\ z \\ t \end{pmatrix}$$

Consider the following extended group :

[8] Jean-Marie Souriau, "Géométrie et relativité ", Herman Editor, 1964

$$\begin{pmatrix} \mu & 0 & 0 & \phi_1 \\ 0 & \mu & 0 & \phi_2 \\ 0 & 0 & \lambda L & C \\ 0 & 0 & 0 & 1 \end{pmatrix} \quad acting\ on \begin{pmatrix} \varsigma_1 \\ \varsigma_2 \\ \xi \\ 1 \end{pmatrix} \quad with \quad \mu = \pm 1 \quad and \quad \lambda = \pm 1$$

ζ_1 and ζ_1 are additional closed dimensions. We have two additional scalars q_1 and q_2 :

$\mu = -1$ changes

$$q_1 \text{ into } - q_1 \text{ and } \zeta_1 \text{ into } - \zeta_1$$

$$q_2 \text{ into } - q_2 \text{ and } \zeta_2 \text{ into } - \zeta_2$$

We could add as many additional closed dimensions ζ_i as we want, and get the corresponding quantized quantum numbers q_i

In any case $\mu = -1$ would produce charge conjugation. This group provides a general geometrical interpretation of charge conjugation and C-symmetry.

10) **Back to CPT theorem**

The group can be modified as follows :

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

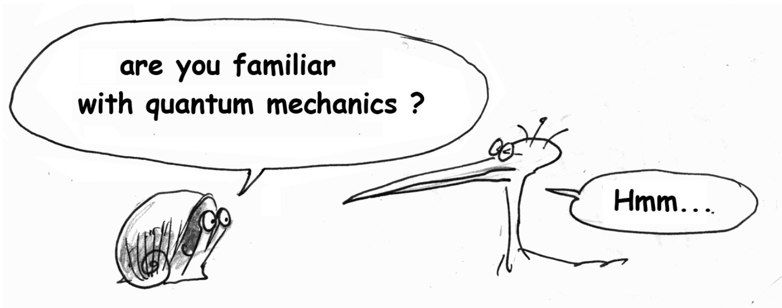
The action of the group on its momentum becomes :

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

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

Then $\lambda = -1$ achieves a C P T symmetry.

In Quantum Theory of Fields, as far as I know (I am not familiar to quantum mechanics)



the CPT symmetry does not change the sign of the energy (CPT is antiunitary[9]). If we apply a CPT symmetry, as derived from Dynamic Groups Theory on a movement inscribed in a five-dimensional space, we get a new movement, corresponding to negative energy particle.

In this negative world the matter-antimatter duality holds. So that we get the following set of particles :

Positive species (with positive energies and masses) :

Protons, neutrons, electrons and their antiparticles

Positive energy photons

Negative species (with negative energies and masses)

Nega-protons, nega-neutrons, nega-electrons and their antiparticles

Negative energy photons

We saw that, after Souriau's theorem, the time-inversion goes with energy-inversion.

In 1967 A. Sakharov suggested that the universe could be splitted into two twin universes. His underlying idea was to explain why there was no cosmological antimatter in our universe. He suggested the "twin universe" would experience a symetrical symmetry, were antimatter would remain, after mutual annihilation. This could be the same in this "negative world".

In any condition the remnant negative matter owns negative mass and can play a role in cosmic evolution.

9) **Results of numerical simulations of Very Large Structure.**

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[9] Weinberg : Quantum Theory of Field, page 345

The complete description of this bimetric model, including non steady solutions is out of the scope of the present paper. We will just consider that the absolute values of positive matter and negative matter densities, just after discoupling, are fairly different.
Say :

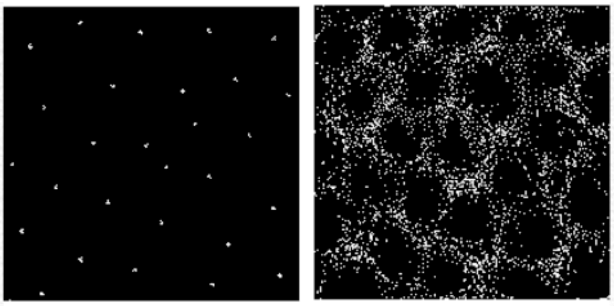
$$|\rho^-| = 50 |\rho^+|$$

We know that the Jeans'time, associated to Jeans instability is :

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

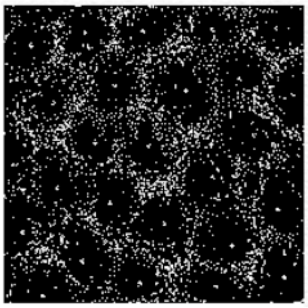
$$t_J^- = 0.14 \ t_J^+$$

The negative matter forms spherical clusters. The positive matter is pushed in the remnant place, forming a foam-like structure, comparable to joint soap bubbles. Following, 2d numerical simulations published in 1995 in Astrophysics and Space Science[10].



Result of joint gravitational instabilities

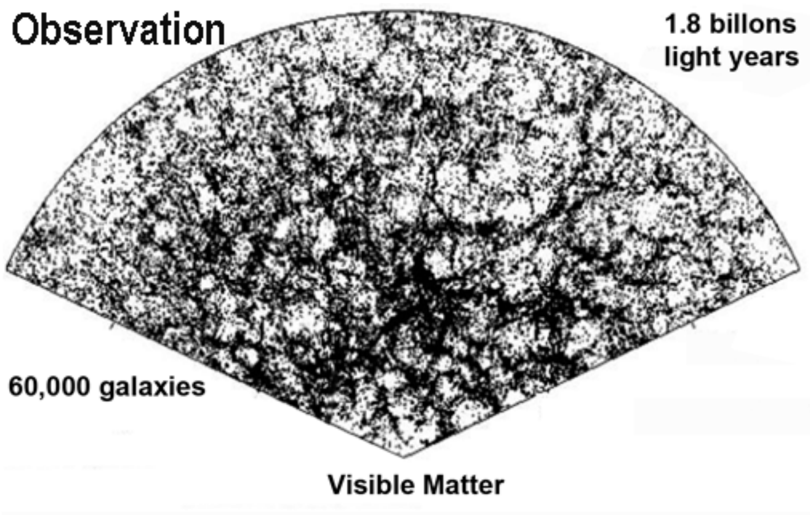
$|\rho^-| = 50\,\rho^+$ *and* $t_a^- = 0.14 \ t_a^+$



The two species, superimposed

This is similar to the observed Very Large Structure :

[10] Jean-Pierre Petit : Twin universe cosmology. Astrophysics and Space Science. 226 : 273-307 1995



The positive matter is arranged around large voids, 100 millions light years large, in average. At the center of each void lies a spheroidal cluster of negative matter, which keeps matter at distance. This structure is remarkably stable. The "bubbles" of matter confine the negative cluster and prevent their meeting with neighbour clusters. These cluster behave like anchors, with respect to the positive matter structure.

This structure appears very early, immediatly after the discoupling. When negative clusters form, they repel violently the positive matter along flate plates. This enhances its radiative cooling and triggers the galaxies-formation. The galaxies, just after their formation tend to migrate on lines, common to three neighbour "bubbles". Each set of three lines converges towards a point. Galaxies tend to migrate towards this point. Each of them becomes a cluster of galaxies.

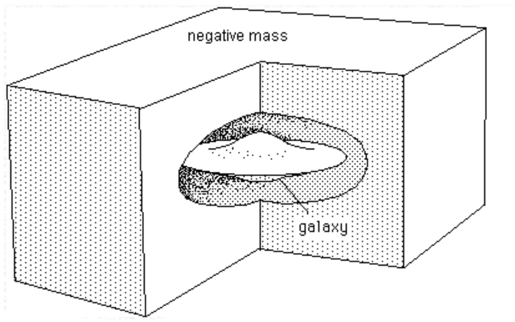
The big clusters of negative matter resemble huge proto-stars. Gravitational energy is converted into thermal energy. The larger is the proto star, the longer is their cooling time. These cluster have cooling times larger that the age of the universe. They slowly cool, emitting thermal negative energy photons, whose wavelengths correspond to (invisible) red and infrared light.

Negative matter does not form galaxies or star, nor heavy species, so that there is no life in this negative world.

The light sent by distant, large redshift galaxies is weaked by negative gravitational lensing effect (see annex), due to presence of negative cluster on their paths. So that these distant galaxies look like dwarfs, that is observed.

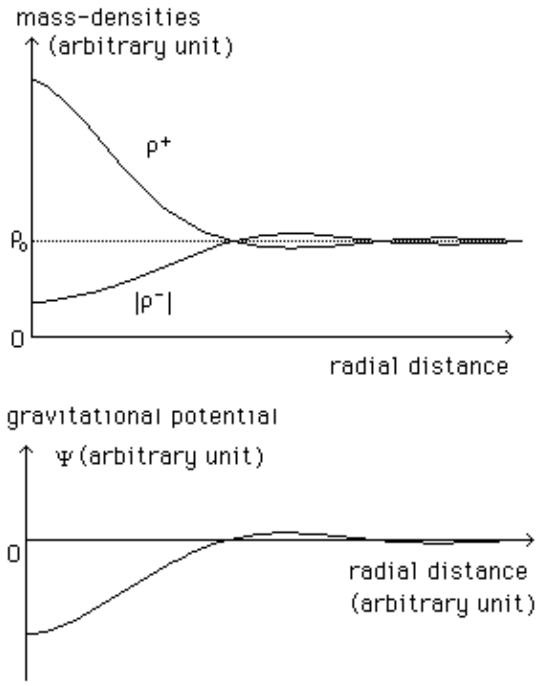
10) **Joint gravitational instability.**

When the galaxies form, the negative matter infiltrate space between them, exerts a counterpressure to them, which confines them, producing a "missing mass effect".



At the border of the galaxies this counterpressure explains the flatness of their rotation curves. We can illustrate this confinement effect, building a non-linear solution where matter nests in some sort of hole.

This can be illustrated by results of spherically symmetric calculations, done twenty five years ago. Following, how negative material helps to confine positive one. The two species were supposed to be described by Mawxellian distributions of velocities, associated to temperature T^+ and T^-, constant in space.



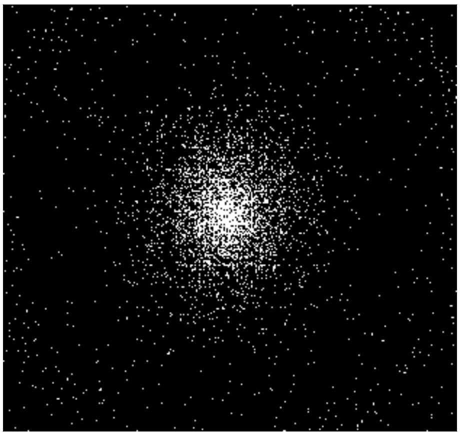
Steady spherically symmetric non-linear Maxwellian solution.

11) **Spiral structure**

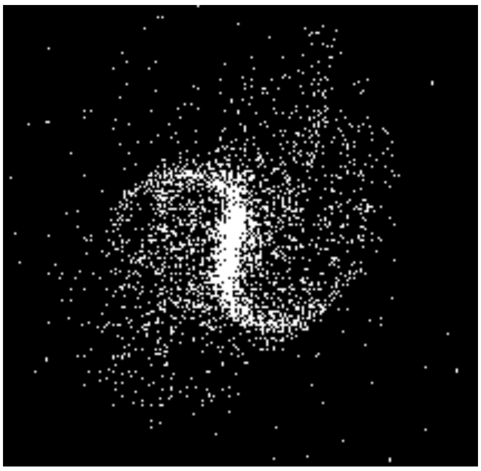
Many attempts were done in the past to try to simulate spiral structures in galaxies. In general researchers easily obtained a "bar", but spiral arms tend to evaporate. Later different approach was based on the fall of cold hydrogen on a rotating galaxy. The nice looking spiral pattern could be obtained. But, rapidly, this hydrogen was warmed and the arms evaporate again, after a very few number of turns.

By the way, the presence of cold hydrogen was never evidenced in space, between galaxies. If some gas was present, after such a long time, the thermal velocity of the atoms should be close to the escape velocity of the galaxies : in average 1000 km/s. This corresponds to tens thousand degrees. In effect, the signal coming from this intergalactic medium corresponds to X-ray emission.

Following, the results of numerical 2d simulations, showing a cluster of positive masses rotating in some sort of hole in a cloud of surrounding negative masses.



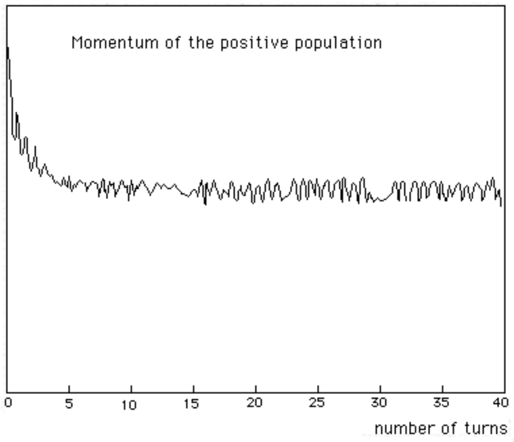
Rapidly, a good looking spiral galaxy formed, stable, that stayed 20 turns.



Stable barred spiral, 1992 **numerical simulations.**
5000 + 5000 **interacting mass-points**

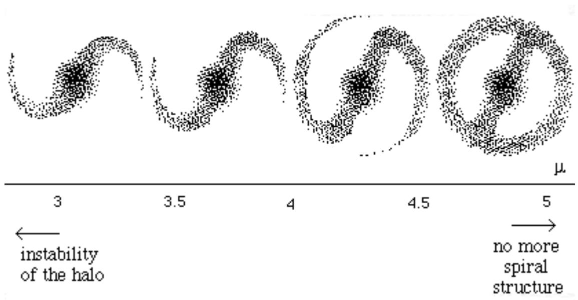
This barred galaxy keeps its arms, due to the presence of repulsive material all around, creating a potential barrier.

It appears that when the spiral was formed, the momentum of the galaxy was reduced by dynamical friction. Then, after some turns this reduction became insensitive.



The pattern depends on the ratio (with same number of mass-points for each species)

$$\mu = m^{-}/m^{+}$$



Conclusion

There are several model suggested by astrophysicists to rebuild a "standard model".

In the MOND theory, Milgrom suggests that the Newton's law must be modified at distance, in order to fit the observational data. In effect, most galaxies have rotation curves which tend to a constant value at distance.

If V is the circular orbitation velocity, it goes with a centrifugal acceleration :

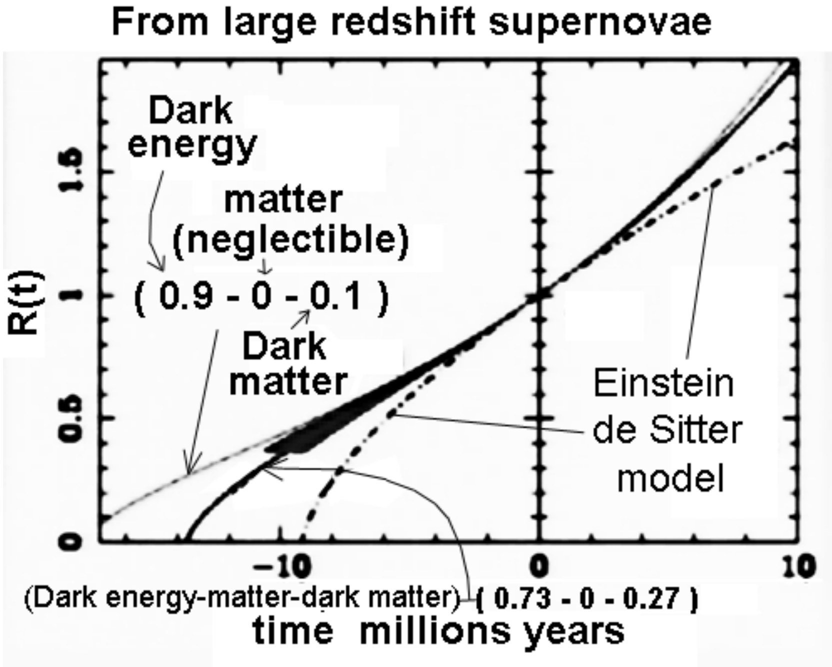
$$\frac{V^2}{r}$$

A gravitational potential $\Psi \sim Log\, r$ gives a gravitational acceleration $-\frac{\partial\, Log\, r}{\partial r} = \frac{1}{r}$

So that Milgrom suggests that the Newton's law could be arranged in order to create such potential the the acceleration is higher that a certain value a_o.

His predictions fit more or less the observational curves. But when applied to clusters of galaxies, the model fails and needs to add 15 % of ... neutrinos.

Today, the majority of astrophysicists believe that only ad hoc dark matter can ensure the confinement of galaxies and clusters of galaxies and the flatness of rotation curves at distance from the center. Only large amounts of dark matter can produce observed gravitational lensing effects. The acceleration of the universe is “explained” by the presence of some unknown “dark energy”. These who prefer to invoke the cosmological constant Λ try to promote a new “standard model”, called ΛCDM (CDM for cold dark matter).



From the 2007 conference given by the astrophysicist and academician Françoise Combes at the French Academy of Science of Paris.

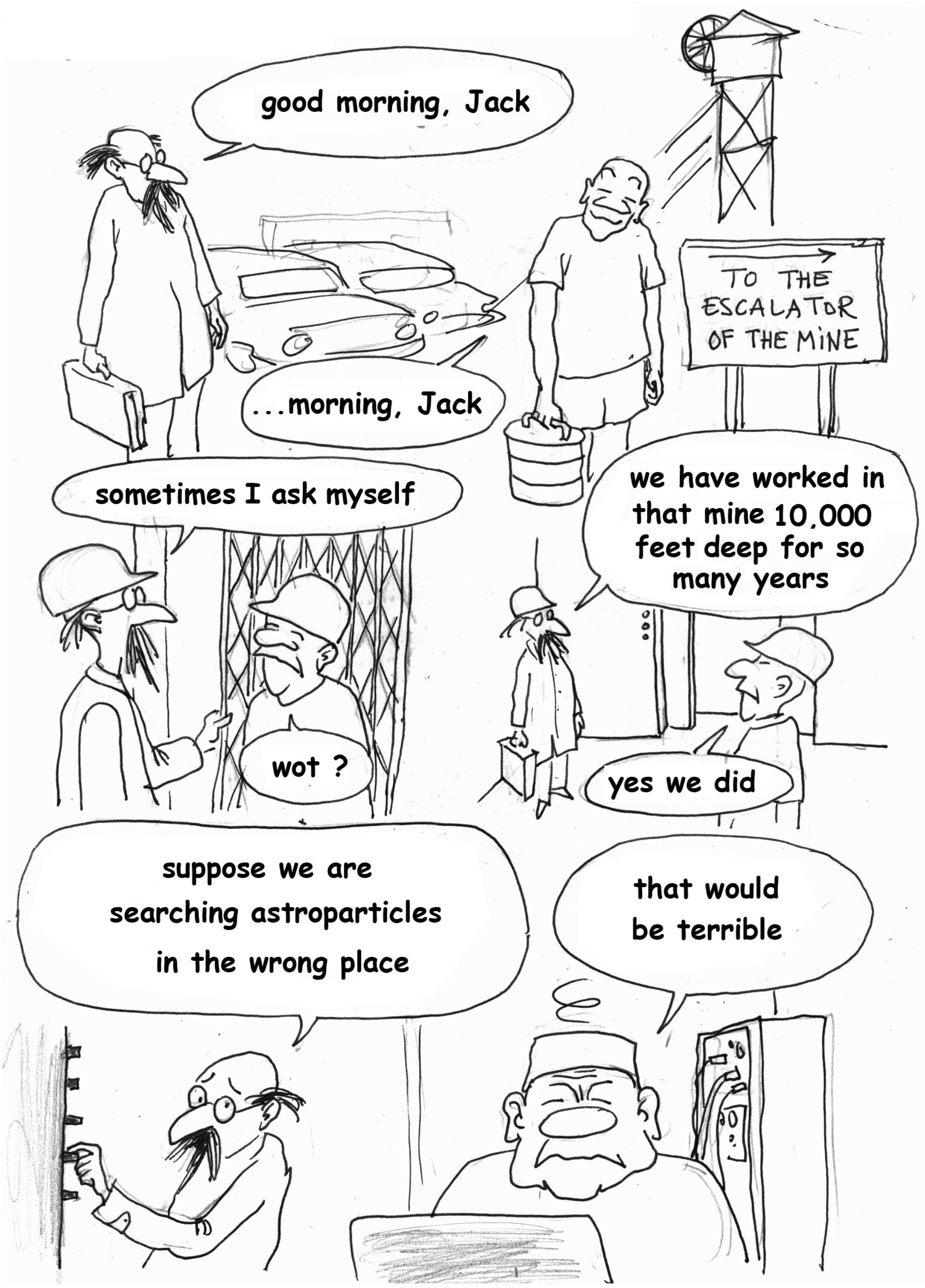
Dotted line : the Einstein de Sitter Model (one of the three Friedman’s models, when the curvature indix k is zero). Dark line : 73 % of “dark energy” plus 27 % of cold dark matter. The contribution of visible matter was neglected.

There is an alternative. If galaxies, and clusters of galaxies are surrounded by negative matter, all these effects can be evidenced, including the negative lensing effect, due to the surrounding negative matter effect (a hole in a negative matter field behaves like a cluster of positive matter.

A model combining positive and negative masses explains the VLS, the confinement of galaxies and clusters of galaxies, the flatness of the rotation curves, the origin of the spiral structure, the observed acceleration of the universe, the fact that distant galaxies look like dwarfs.

The nature of this invisible material becomes clear. It is nothing but all that we already know, with negative mass and energy.

The evolution in time of the universe, as a whole, is out of the scope of this presentation.


good morning, Jack
...morning, Jack
TO THE ESCALATOR OF THE MINE
sometimes I ask myself
wot ?
we have worked in that mine 10.000 feet deep for so many years
yes we did
suppose we are searching astroparticles in the wrong place
that would be terrible

Annex

External and internal Schwarzschild solutions

Consider the Einstein Field equation (written with a zero cosmological constant):

$$R_{\mu\nu} + \frac{1}{2} R\, g_{\mu\nu} = \chi\, T_{\mu\nu}$$

The Schwarzschild solution corresponds to a null second member.

$$R_{\mu\nu} + \frac{1}{2} R\, g_{\mu\nu} = 0$$

It refers to a portion of space where the density of energy-matter is zero.

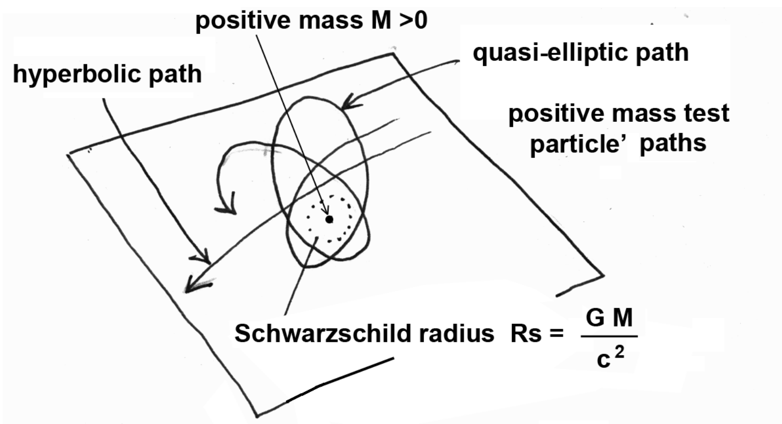
In the books the external Schwarzschild solution is classically written as : .

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

where m is definitively not a mass. It's a simple integration constant, that can be chosen either positive or negative. It is better to introduce the mass M that is supposed to be the source of this local geometry :

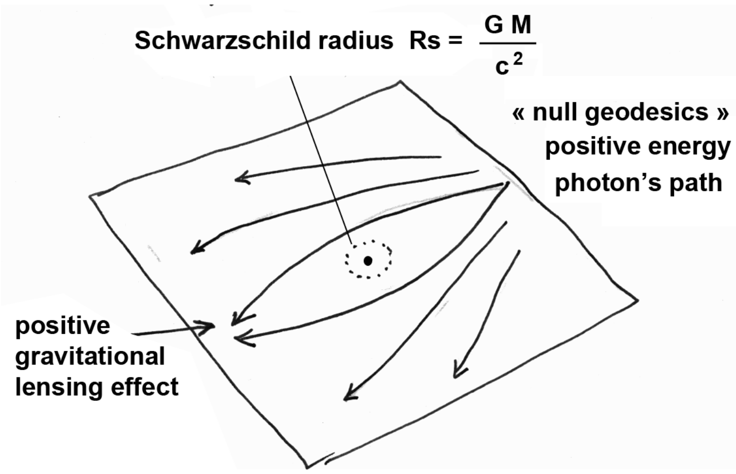
$$ds^2 = c^2 dt^2 (1 - \frac{2GM}{c^2 r}) - \frac{dr^2}{(1 - \frac{2GM}{c^2 r})} - r^2 (d\theta^2 + \sin^2\theta\, d\varphi^2)$$

From the classical solution, with M positive, one can compute the (plane) geodesic system, with two families. One corresponds to the massive particles :



When the test particle cruises far from the Schwarzschild sphere the paths tends asymptotically to Kepler paths.

The other, called “null geodesics” correspond to photons :



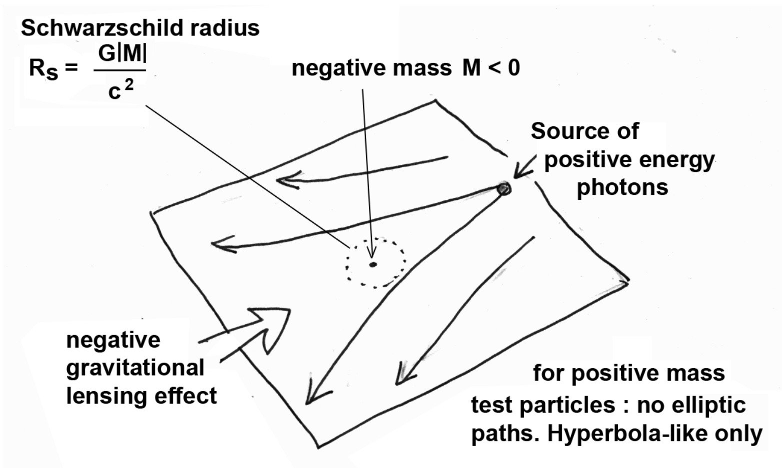
Far away from the Schwarzschild sphere the photons go along straigt lines.

Il we take M < 0 we get that :

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

The pattern of geodesics is completely différent. It evokes the behaviour of a test particles reppeled by thi negative mass M < 0

Photons are repelled too, which gives a *negative gravitational lensing effect.*



In 1917 the mathematician Karl Schwarzchild, student of Hilbert, built also the solution with a non-second second member :

$$R_{\mu\nu} + \frac{1}{2} R g_{\mu\nu} = \chi T_{\mu\nu}$$

Assumptions : spherical symmetry, steady state. Study of geodesic system insides a sphere filled by constant density matter, with density ρ.

His finds :

$$ds^2 = \left[\frac{3}{2}\sqrt{1 - \frac{r_o^2}{\hat{R}^2}} - \frac{1}{2}\sqrt{1 - \frac{r^2}{\hat{R}^2}} \right]^2 c^2 dt^2 - \frac{dr^3}{1 - \frac{r^2}{\hat{R}^2}} - r^2 (d\theta^2 + \sin^2\theta \, d\varphi^2)$$

$$for \quad r \geq r_o \quad and \quad \hat{R}^2 = \frac{3c^2}{8\pi G \rho}$$

This is restrictive. It is easy to show that a solution with negative ρ holds too :

$$ds^2 = \left[\frac{3}{2}\sqrt{1 + \frac{r_o^2}{\hat{R}^2}} - \frac{1}{2}\sqrt{1 + \frac{r^2}{\hat{R}^2}} \right]^2 c^2 dt^2 - \frac{dr^3}{1 + \frac{r^2}{\hat{R}^2}} - r^2 (d\theta^2 + \sin^2\theta \, d\varphi^2)$$

$$for \quad r \geq r_o \quad and \quad \hat{R}^2 = \frac{3c^2}{8\pi G |\rho|}$$

The link, in both cases, between the external geodesics and the internal geodesics is easy to ensure. Just take :

$$M = \frac{4}{3} \pi r_o^3 \rho \quad (\textit{ positive or negative })$$

The reader would tend to say :

- Why did Schwarzschild built this internal geodesic system ? Photon cannot cross matter ? (neutrinos were not known in 1917).

Schwarzschild was a mathematician and a geometer. He did not like the internal solution. In effect, if $r < R_s$ the signature of the metric is changed :

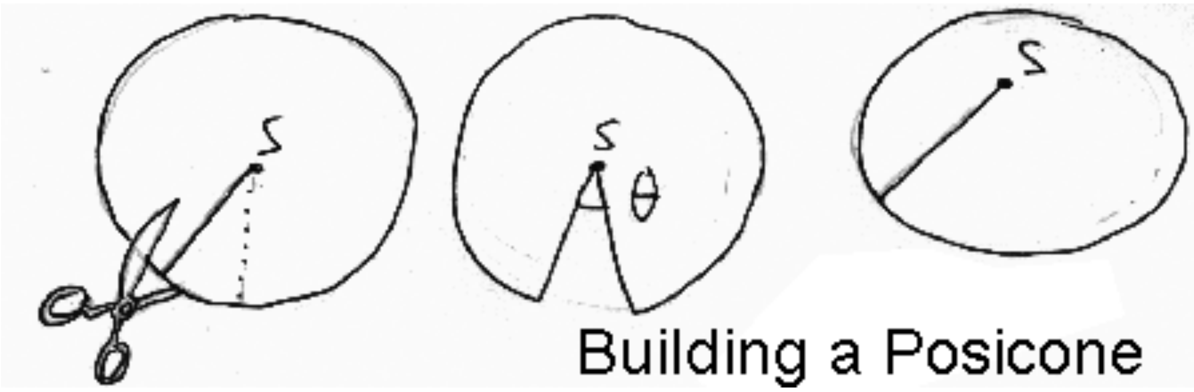
Outsides : (+ - - -)

Insides : (- + - -)

For a geometer the signature is a characteristic of an hypersurface, an invariant. Any change of this signature is a violation of geometric rules. So that Schwarzschild just tried to complete the solution, adding a sphere filled with constant density matter.

Didactic image of coupled geometries

Consider a cone. This is a “flat” surface, an euclidean surface. It is built as the following.



This angle θ can is an "amount of angular curvature". In the cone, this curvature is concentrated in a point, the summit of the cone. We can smooth is, transforming this summit into a portion of a sphere. So we link two surfaces. One has zero curvature density, the other (the sphere) has a constant (angular) curvature density. The portion of the sphere contains a certain "amount of curvature", proportional to its area.

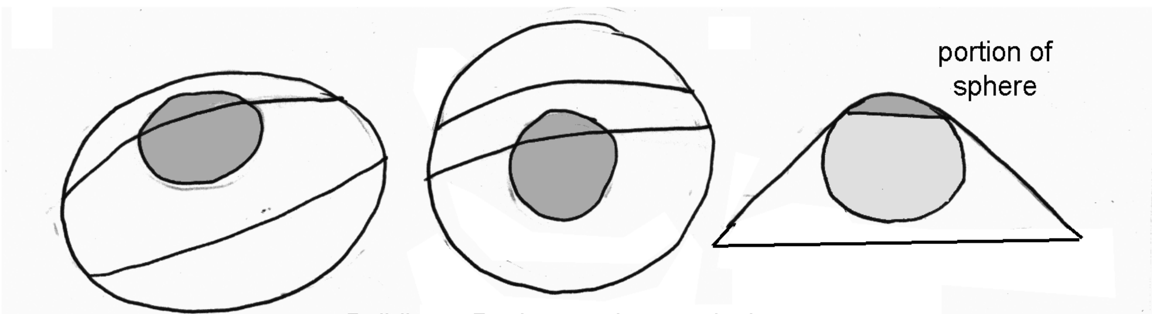
The total angular curvature of a sphere is 4π. Call s the surface of the portion of sphere, whose total surface is :

$$S = 4\pi R^2$$

The amount of angular curvature contained in the portion of sphere is :

$$4\pi \frac{s}{S}$$

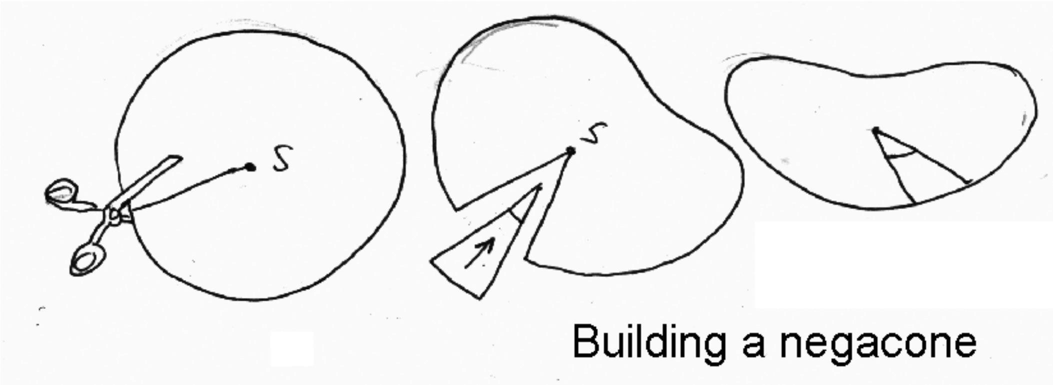
If this quantity is equal to θ , the continuity of the geodesics will me ensured.



Building a Posicone, plus geodesics

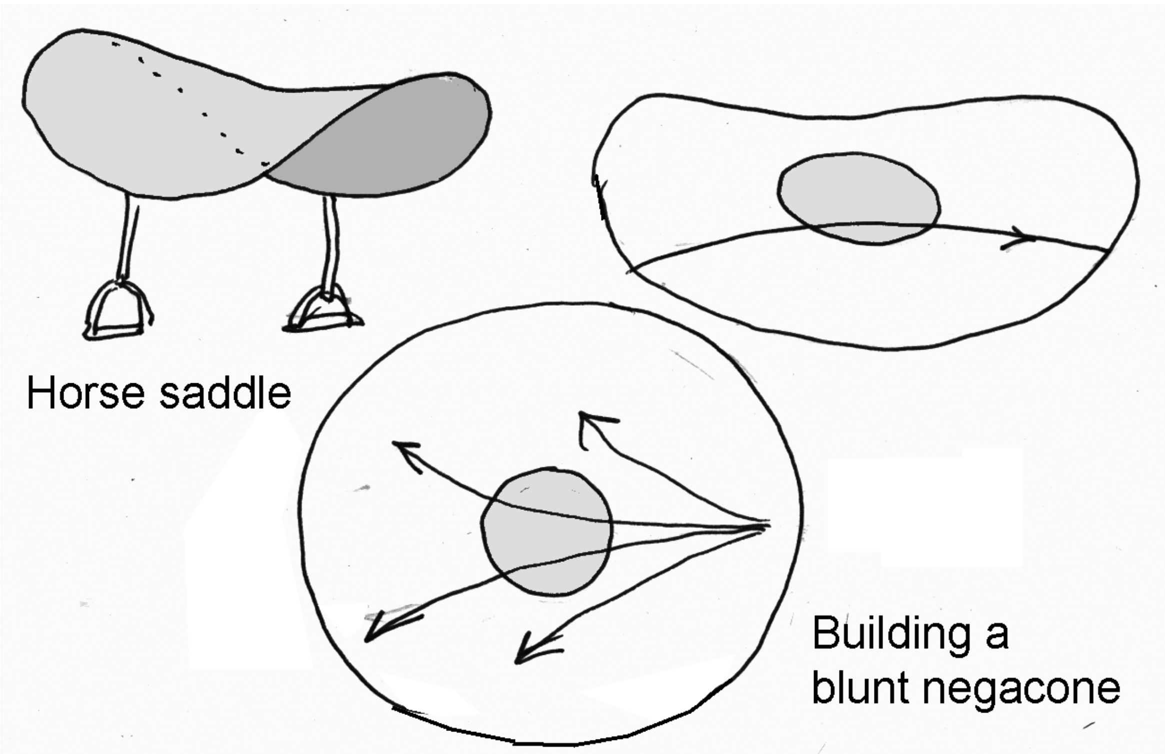
This blunt cone is the 2d analog of the 4d Schwarzschild hypersurface.

Now, look on negative curvature. We can build a " negacone ":

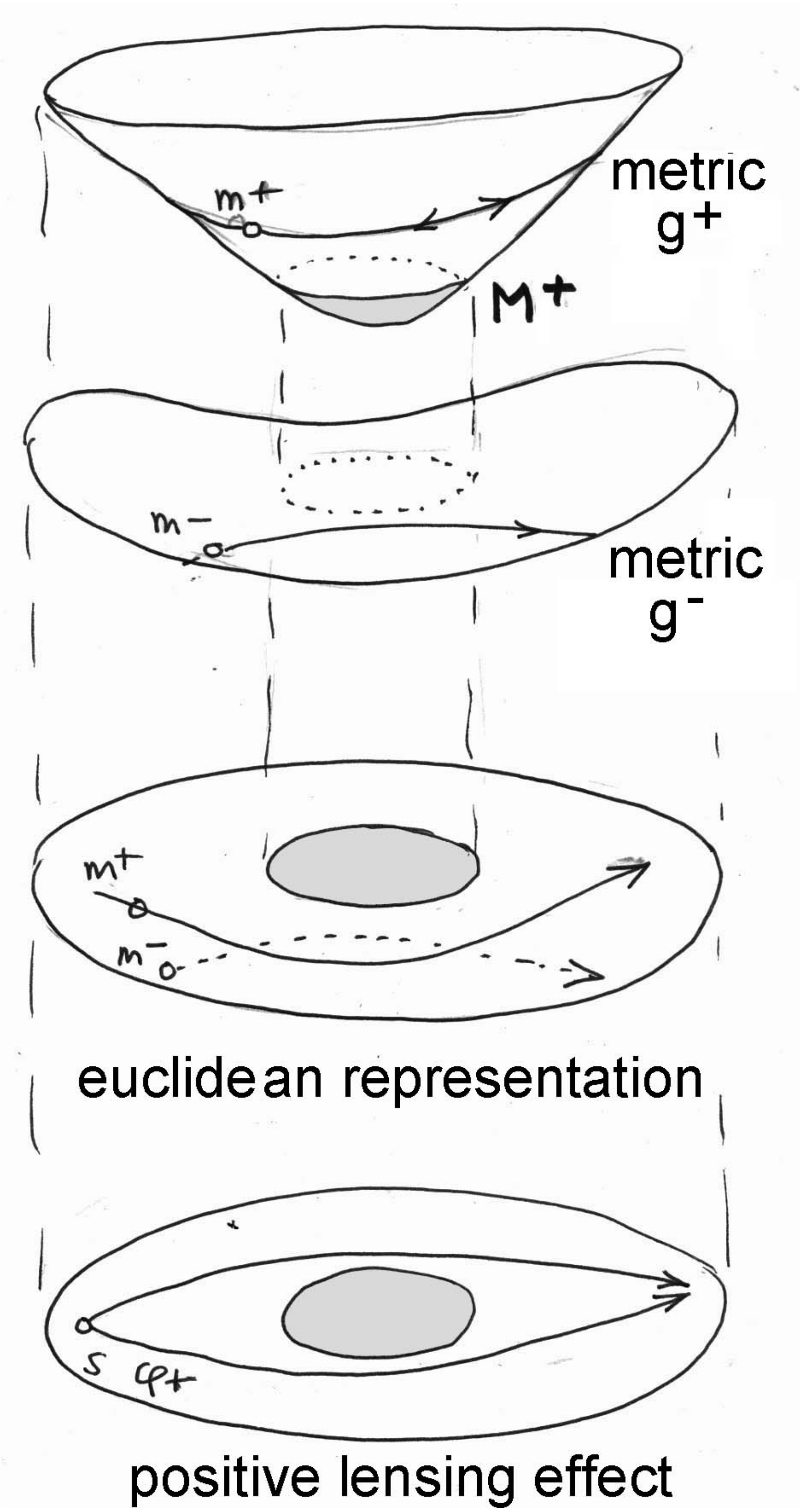


A negative angular curvature is concentrated in the summit of this negacone.

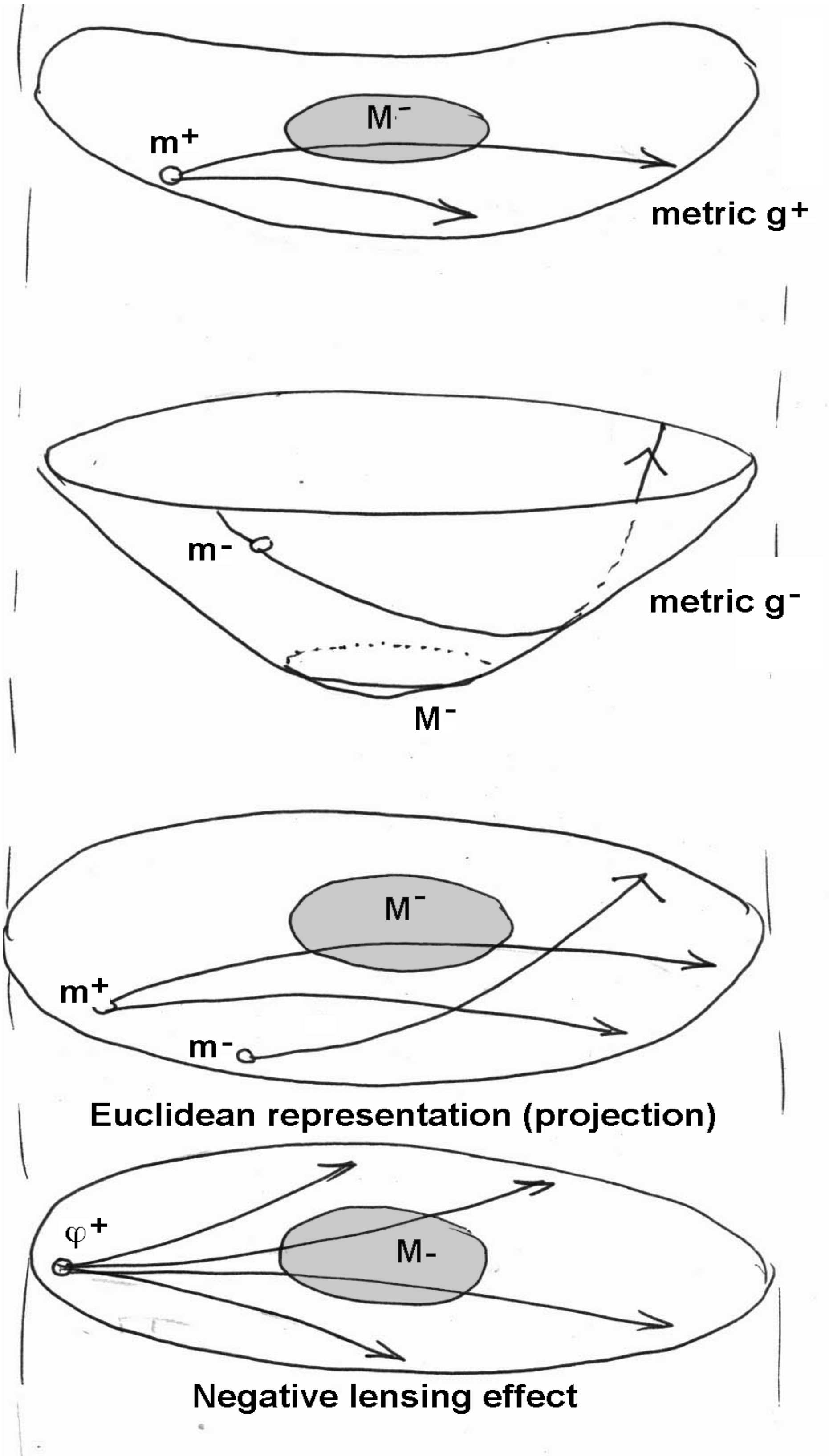
A horse saddle is the image of a constant (negative) angular curvature 2d surface. We can build a “blunt negacone”, introducing a hole in our negacone and gluing along the circular border a portion of horse saddle. If the amount of (negative) angular curvature contained in this element is equal to the one we used to build our negacone the continuity of the geodesics will be ensured.



Using those blunt posicone and negacone models we illustrates the concept of **coupled geometries**. In the first image we find a flat disk which evokes a manifold M2 with an euclidean metric.



On the top we find a portion of positive curvature (positive mass M^+), shaping a surface as a blunt posicone, with associated geodesic (path of a test particle m^+). Above, the same manifold, with opposite local curvature density. The associated geodesic is figured (a mass m^- is "repelled"). On the flat discs : the projections of the two geodesics,. And at the bottom of the figure the didactic image of a "positive lensing effect".



On the precedent image the metric g^+ is associated to a blunt negacone, didactic image of a local distribution of negative mass (a portion of horse saddle), surrounded by truncated negacone. The corresponding geodesic shows a positive mass repelled by this "mass M^-".

Abobe, the associated *coupled geometry*, represented by a blunt posicone. On this surface, following the corresponding geodesic, a negative mass m- is attracted by this mass M^-

The angular curvature densities of those coupled surfaces are opposite.

On the euclidean representation (projection of the different geodesics) we illustrate a negative lensing effect : the negative mass M- repel the positive energy photons φ^+

Those photons can cross the negative mass cluster for there is no electromagnetic interaction between positive energy objects and negative energy objects.