VARYING SPEED OF LIGHT IN AN ANISOTROPIC FOUR-DIMENSIONAL SPACE

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−Simplified version of original paper in Spanish−

ABSTRACT: We show how the theory of relativity disagrees with the isotropy of the expanding universe and with the experimental arguments in favour of the existence of a preferred frame. We postulate a new heuristic principle, the invariance of the radius of the universe, deriving new transformation equations. Then we develop the geometric scenario and we prove how the universe equals an anisotropic inhomogeneous hyperboloid in four-space. The new model quite naturally incorporates the expanding universe, solves the cosmological horizon problem, explains the asymmetrical time dilation effect (for example, in the twin paradox) and describes the Big Bang in an original way by reducing the radius of the hypersphere to zero. The speed of light acquires a new geometrical meaning that justifies a varying speed of light (VSL) theory and clarifies unsolved problems in physics as the Pioneer anomaly, cosmological puzzles, the dark energy and the Loschmidt paradox.

1. INTRODUCTION

> "The most important result of our reflections is, however, *that precisely the apparently simplest mechanical principles are of a very complicated character; that these principles are founded on uncompleted experiences, even on experiences that never can be fully completed; that practically, indeed, they are sufficiently secured, in view of the tolerable stability of our environment, to serve as the foundation of mathematical deduction; but that they can by ho means themselves be regarded as mathematically established truths, but only as principles that not only admit of constant control by experience but actually require it*." Ernst Mach [1]

1.1. The Lorentz transformation versus the expanding universe

1. **Lorentz transformation for frames in standard configuration.** Two observers O and O' use their own coordinate system to measure space-time intervals. The x_1-axis and the x'_1-axis are collinear, the x'_2-axis is parallel to the x'_2-axis and the x_3-axis is parallel to the x'_3-axis. The relative velocity between the two observers is V along the common x_1-x'_1 axis. O measures (x_1, x_2, x_3, x_4) and O' measures (x'_1, x'_2, x'_3, x'_4), where x_4 = ct and x'_4 = ct'. At time t = t' = 0 the observers O and O' coincide. The Lorentz transformation (LT) for frames in standard configuration can be shown to be:

$$x_1 = \gamma(x'_1 + \beta\, ct') \qquad x_2 = x'_2 \qquad x_3 = x'_3 \qquad x_4 = \gamma(x'_4 + \beta\, x'_1) \tag{1}$$

where $\beta = V/c$, $\gamma = 1/(1 - \beta^2)^{1/2}$ and c is the speed of light.

The two postulates of special relativity require that the four-velocities (U_1, U_2, U_3, U_4) and (U'_1, U'_2, U'_3, U'_4) as measured by O and O' respectively, are connected by the same transformation:

$$U_1 = \gamma(U'_1 + \beta\, U'_4) \qquad U_2 = U'_2 \qquad U_3 = U'_3 \qquad U_4 = \gamma(U'_4 + \beta\, U'_1) \tag{2}$$

The classical velocities (v_1, v_2, v_3) and the four-velocities (U_1, U_2, U_3, U_4) are related by

$$U_1 = \frac{v_1}{\sqrt{1-\frac{V^2}{c^2}}} \qquad U_2 = \frac{v_2}{\sqrt{1-\frac{V^2}{c^2}}} \qquad U_3 = \frac{v_3}{\sqrt{1-\frac{V^2}{c^2}}} \qquad U_4 = \frac{ic}{\sqrt{1-\frac{V^2}{c^2}}} \tag{3}$$

where $\beta = v/c$, $\gamma = 1/(1 - v^2/c^2)^{1/2}$, $V = (v^2_1 + v^2_2 + v^2_3)^{1/2}$ and i is the imaginary unit.

2. **The expanding universe as measured by two frames in standard configuration.** Two observers O and O' measure the correlation between the distance to a galaxy and its recessional velocity along the common x_1-x'_1 axis, v_1/x_1 and v'_1/x'_1 respectively. The LT implies

$$x_1 = \gamma(x'_1 + \beta\, ct') \tag{4}$$

and

$$U_1 = \gamma(U'_1 + \beta\, U'_4) \tag{5}$$

that is

$$U_1/x_1 = (U'_1 + \beta\, U'_4)/(x'_1 + \beta\, ct') \tag{6}$$

3. Self-refutation of special relativity. According to (6), in the most general case, the expansion rate of the universe is different in the common x_1-x'_1 axis ($v_1/x_1 \neq v'_1/x'_1$) but is the same in perpendicular directions ($v_2/x_2 = v'_2/x'_1$ and $v_3/x_3 = v'_3/x'_3$). In other words, if the observer O sees an isotropic expansion, the observer O' sees an anisotropic one. All inertial frames are not equivalent.

The same reasoning holds even in a static universe. If the observer O sees a uniform distribution of matter, the observer O' sees a bigger density of matter in the common x_1-x'_1 axis. The problem does not lie in the expanding universe, but in the LT itself. Einstein's theory of relativity is logically contradictory.

4. Meaning of anisotropy of space. As Einstein wrote [4]: *"If the principle of relativity (in the restricted sense) does not hold, then the Galileian coordinate systems K, K', K'', etc., which are moving uniformly relative to each other, will not be equivalent for the description of natural phenomena. In this case we should be constrained to believe that natural laws are capable of being formulated in a particularly simple manner, and of course only on condition that, from amongst all possible Galileian coordinate systems, we should have chosen one (K_0) of a particular state of motion as our body of reference. We should then be justified (because of its merits for the description of natural phenomena) in calling this system 'absolutely at rest' and all other Galileian system K 'in motion.' […] In the general laws of nature which have been formulated with reference to K, the magnitude and direction of the velocity of the carriage would necessarily play a part."*

1.2. The isotropy of space versus the empirical evidences

5. The absence of evidence is the evidence of absence!? Einstein concluded that the failure to observe anisotropy favours the isotropy hypothesis [4]: "*However, the most careful observations have never revealed such anisotropic properties in terrestrial physical space, i.e. a physical non-equivalence of different directions. This is very powerful argument in favour of the principle of relativity."*

6. Empirical evidence of anisotropy. Against Einstein's assertion, modern authors like Wilheim [5], Wesley [6] or Levy [7] consider that the anisotropy of the one way speed of light can be indirectly established by measuring the absolute velocity of the solar system using different methods: Vaucouleurs & Peters [8], Rubin [9], Conklin [10], Henry [11], Smoot et al [12], Gorenstein & Smoot [13], Partridge [14], Monstein & Wesley [15], Marinov [16-17], Torr and Kolen [18], DeWitte [19] or Cahill & Kitto [20-21].

Fundamental tests of special relativity theory purporting to demonstrate the invariance of the speed of light were based on erroneous ideas. Múnera [22] shown that Michelson interferometers reveal small but significant effects of the Earth's absolute motion, but only when they are operated in a dielectric. Cahill & Kitto analysed the old results from gas-mode interferometers and revealed an absolute speed of 369 ± 123 km/s. A more recent evaluation by Cahill yielded 420 ± 30 km/s, in excellent agreement with the cited experiments [8-21] and with the speed of 365 ± 18 km/s determined by the COBE satellite [23].

The empirical results [7-21, 23] provide weighty arguments in favour of the anisotropy of space. The small quantity v/c derived from the absolute speed of the Earth is compatible with the classical experiments: Michelson & Morley (1887), Miller (1925/26), Illingworth (1927), Joos (1930), Jaseja et al (1964), etc. Indeed, the space is quasi-isotropic.

7. The existence of an absolute and preferred frame of reference. The aether ideas of Lorentz & Fitzgerald [24-25], Poincaré [26], Larmor [27], Dirac [28] or even Dingle [29], are presented in a modern approach by Bell [30-31]. Today a remarkable number of researchers like Demjanov [32-34], Dmitriyev [35], Niayesh [36-37], Jacobson [38] or Cahill & Kitto [20-21] support the concept of an absolute frame under the influence of earlier works [39-47]. As a remedy for difficulties of relativistic quantum mechanic, a preferred frame was also treated by Dirac [28], Bohm [48], Bell [31] and, more recently, by Hardy [49] and Percival [50].

8. Different interpretations, similar predictions. Length contraction and time dilation have two different interpretations, that of Einstein (relative to the observer) and that of Lorentz (relative to the aether). But the predictions coincide in both cases. According to Bell [30], it is not so simple to distinguish experimentally between the two alternatives. There are no strong experimental arguments to refuse the aether; on the contrary, a number of arguments led support to the anisotropy of the one way speed of light.

2. GEOMETRICAL PART

"The concept 'true' does not tally with the assertions of pure geometry, because by the word 'true' we are eventually in the habit of designating always the correspondence with a 'real' object; geometry, however, is not concerned with the relation of the ideas involved in it to objects of experience, but only with the logical connection of these ideas among themselves." Albert Einstein [4]

2.1. The invariance of the radius of the universe

9. Two kinds of relativistic transformations. The special relativity cannot be completely rejected. First, the theory is very successful; second, the empirical evidences [7-21,23] suggest the quasi-isotropy of space. Then the relativistic transformations (1) and (2) accurately describe the natural phenomena in a wide range of situations.

If we compare (1) and (2), there are similarities and differences. Every term in (2) is a velocity, while the terms in (1) are both positions and velocities. The transformation (2) distinguish between the components of the classical velocity (v_1, v_2, v_3) and the components of the four-dimensional velocity (U_1, U_2, U_3, U_4) because, in the general case, $v_1 \neq U_1$, $v_2 \neq U_2$ and $v_3 \neq U_3$. On the contrary, the transformation (1) identifies the components of the classical distance (x_1, x_2, x_3) with the respective components of the four-position (x_1, x_2, x_3, ict).

10. The third and non-Einsteinian transformation. What happen if we apply the transformation (2) to distances instead of velocities? We look for a new transformation that includes the two relativistic transformations as a particular case and also ensures the isotropy of the space in preferred reference frames (see 2.2 section).

Two observers O and O' use their own coordinate system to measure space-time intervals. The χ_1-axis and the χ'_1-axis are collinear, the χ'_2-axis is parallel to the χ'_2-axis and the χ_3-axis parallel to the χ'_3-axis. The relative distance between the two observers is r along the common χ_1-χ'_1 axis. O measures (χ_1, χ_2, χ_3, χ_4) and O' measures (χ'_1, χ'_2, χ'_3, χ'_4). The new transformation is a hyperbolic rotation:

$$\chi_1 = \gamma_r(\chi'_1 + \beta_r\, \chi'_4) \qquad \chi_2 = \chi'_2 \qquad \chi_3 = \chi'_3 \qquad \chi_4 = \gamma_r(\chi'_4 + \beta_r\, \chi'_1) \tag{7}$$

where $\beta_r = r/R$, $\gamma_r = 1/(1 - r^2/R^2)^{1/2}$ and $r = (x^2_1 + x^2_2 + x^2_3)^{1/2}$.

The classical positions (x_1, x_2, x_3) and the four-positions (χ_1, χ_2, χ_3, χ_4) are related by

$$\chi_1 = \frac{x_1}{\sqrt{1-\frac{r^2}{R^2}}} \qquad \chi_2 = \frac{x_2}{\sqrt{1-\frac{r^2}{R^2}}} \qquad \chi_3 = \frac{x_3}{\sqrt{1-\frac{r^2}{R^2}}} \qquad \chi_4 = \frac{iR}{\sqrt{1-\frac{r^2}{R^2}}} \tag{8}$$

The new transformation does not identify the components of the classical distance (x_1, x_2, x_3) with the respective components of the four-position (χ_1, χ_2, χ_3, χ_4) because, in the general case, $x_1 \neq \chi_1$, $x_2 \neq \chi_2$ and $x_3 \neq \chi_3$. The distance R ensures the homogeneity of all components of the equation and the parameters β_r and γ_r are function of distances as well. ¿Which is the meaning of R? The sum of the square of the components of the four-position is

$$\chi^2_1 + \chi^2_2 + \chi^2_3 + \chi^2_4 = -R^2 \tag{9}$$

that correspond to a four-dimensional hyperboloid or quasi-sphere of radius R.

An observer does not directly measures the four-dimensional position (χ_1, χ_2, χ_3, χ_4) but the classical position (x_1, x_2, x_3). Substituting (8) in (9) gives:

$$x^2_1 + x^2_2 + x^2_3 \leq R^2 \tag{10}$$

that correspond to a ball of radius R. If the transformation (7) holds, then four-positions define a hypersurface in four-dimensional space as expressed in (9), while classical positions define a closed ball as expressed in (10). The evident meaning of R is the radius of the universe.

¿Can Einsteinian physics be expressed as a particular case of hyperbolic physics? The answer is yes (see section 2.2).

11. Hyperbolic geometry. The 4D hyperboloid offers a perfect scenario to develop an anisotropic model of the universe because there is an obvious preferred frame: the centre of the hyperboloid C. With respect to C, natural laws are capable of being formulated in a particularly simple manner. We should then be justified (because of its merits for the description of natural phenomena) in calling this system 'absolutely at rest' and all other system 'in motion.' In the general laws of nature which have been formulated with reference to C, the magnitude and direction of the position and the velocity of the frame would necessarily play a part.

The relativistic velocity addition theorem is:

$$v_1 = \frac{v_1' + V}{\left(1 + \frac{V v_1'}{c^2}\right)} \qquad v_2 = \frac{v_2'}{\gamma\left(1 + \frac{V v_1'}{c^2}\right)} \qquad v_3 = \frac{v_3'}{\gamma\left(1 + \frac{V v_1'}{c^2}\right)} \tag{11}$$

If the velocity between the two observers is very small compared with the speed of light ($V << c$), the theorem (11) easily reduces to the Galilean law: $v_1 \approx v'_1 + V$, $v_2 \approx v'_2$ and $v_3 \approx v'_3$. The velocity addition formula shows that c is a limiting velocity: in the extreme case where both v'_1 and V equal to c, then $v_1 = (c + c)/[1 + (c^2/c^2)] = c$. Nothing is faster than light.

In the 4D hyperboloid, the distance addition theorem is derived from (7):

$$x_1 = \frac{x_1' + r}{\left(1 + \frac{r \cdot x_1'}{R^2}\right)} \qquad x_2 = \frac{x_2'}{\gamma_r\left(1 + \frac{r \cdot x_1'}{R^2}\right)} \qquad x_3 = \frac{x_3'}{\gamma_r\left(1 + \frac{r \cdot x_1'}{R^2}\right)} \tag{12}$$

If the distance between the two observers is very small compared with the radius of the universe ($r << R$), the theorem (12) reduces to the Euclidean law: $x_1 \approx x'_1 + r$, $x_2 \approx x'_2$ y $x_3 \approx x'_3$. The distance addition formula shows that R is a limiting distance: in the extreme case where both x'_1 and r equal to R, then $x_1 = (R + R)/[1 + (R^2/R^2)] = R$. Nothing is further than the radius of the universe.

There is a total analogy between the relativistic limiting velocity c and the hyperbolic limiting distance R. Nothing can travel faster than light and nothing can be further than the radius of the universe.

The invariance of R (*the radius of the universe R is the same in all reference frames, independent of the location of the observer*) can be seen as a principle of impotence (*nothing is further than R*) in analogy with the first and second laws of thermodynamics (*it is impossible to construct a perpetuum mobile of the first and second kind*) and with the invariance of c (*nothing is faster than light*).

In Figure 1, the distance between O and O' is r and the distance from the observer O to the edge of the universe is the same in every direction: OL = OL' = R. Which are the distances from O' to L and L' as measured in the reference system S'?

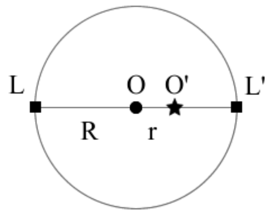

Figure 1. The universe as observed from O is a sphere of radius R. The distance between O and O' is r. The distances between the limits points and the observer are OL = OL' = R.

The distances must verify the theorem (12):

$$O'L = (O'O + OL)/(1 + O'O \cdot OL/R^2) = (r + R)/(1 + r \cdot R/R^2) = R \tag{13}$$

$$OL' = (OO' + O'L')/(1 + OO' \cdot O'L'/R^2) \tag{14}$$

so that

$$R = (r + O'L')/(1 + r \cdot O'L'/R^2) \tag{15}$$

The only value of O'L' that satisfies (15) for all values of $r \leq R$ is O'L' = R. Then O'L = O'L' = R, and the observer O' sees itself as the centre of the universe (Figure 2 right):

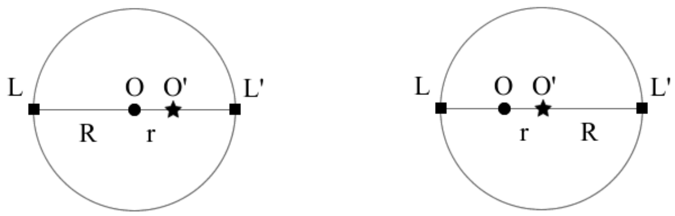

Figure 2. The universe as observed from O (left) and O' (right). The universe from O' is a sphere of radius R. The distances between the limits points and the observer are O'L = O'L' = R.

As well as the observers O and O', any other observer sees itself as the centre of the universe. It is easiest to imagine a picture of a four-dimensional spacetime if we start with a two dimensional space:

$$\chi^2_1 + \chi^2_4 = -R^2 \tag{16}$$

The square of χ_4 is negative, then (16) is the equation of a hyperbola in the two-dimensional Minkowski space (Figure 3 left). As observed from O, the universe is a hyperbola in Minkowski space defined by the centre C, the vertex O and the points at infinity L and L'. Actually, the observer O does not directly measures χ_1 but the real coordinate x_1. According to (8), a hyperbola of radius R in Minkowski space (Figure 3 left) implies a line segment of length 2R in real space (Figure 3 top centre).

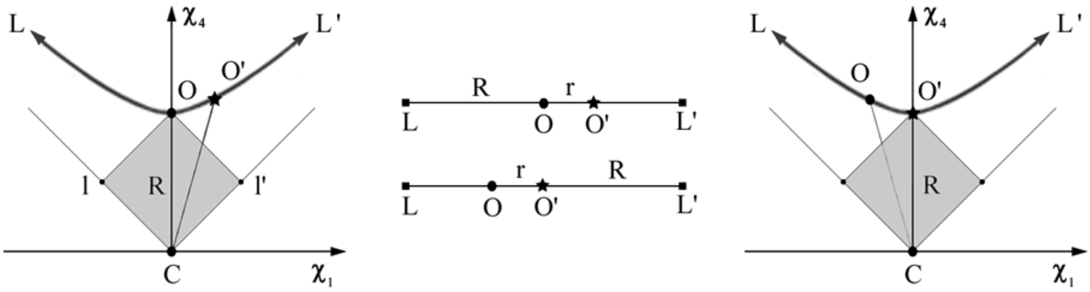

Figure 3. The Minkowski space as observed from O (left) and O' (right). The real space as observed from O' (top centre) and O' (bottom centre).

The observer O is situated at a distance R from L, but O cannot reduce (nor increase) the distance to L because it is a point at infinity in Minkowski space. That the radius of the universe is the same for all observers, regardless of the observer's position, is extraordinary enough: as extraordinary as the special relativity itself (the speed of light in vacuum is the same for all observers, regardless of the light source's motion). The *invariance of the radius of the universe* and the *distance addition theorem* express a new geometry: the *hyperbolic geometry*.

As observed from O, the universe is not a Euclidean sphere, but a three-dimensional projection of a four-dimensional hyperboloid. The hyperbolic sphere has *more than a centre*; actually, an *infinite number of centres*.

2.2. Einsteinian physics as a particular case of hyperbolic physics

11. The expanding 4D hyperboloid. We live in an expanding universe and the radius of the hyperboloid increases with time according to (17).

$$\chi^2_1 + \chi^2_2 + \chi^2_3 + \chi^2_4 = -R^2(t) \tag{17}$$

Positions and velocities of observers in radial motion (like O and O' in Figure 4) have the same direction and define constant angles with respect to the axis χ_1 and χ_4.

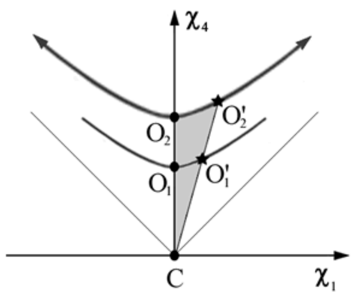

Figure 4. Expanding universe. Observers O_1 and O'_1 in the bottom hyperbola respectively move to O_2 and O'_2 in the top hyperbola. The angle between any two vectors remains unchanged.

In radial motion, the distance coefficient β_r equals to the velocity coefficient β:

$$\beta_r = r/R = v/c = \beta \tag{18}$$

and

$$\gamma_r = 1/(1 - \beta_r^2)^{1/2} = 1/(1 - \beta^2)^{1/2} = \gamma \tag{19}$$

12. Einsteinian physics as a particular case of hyperbolic physics. The hyperbolic transformation (7) can be more elegantly expressed using the matrix form (20). Using (18) and (19), the matrix form (20) equals to (21) in radial motion.

$$\begin{bmatrix} \chi'_1 \\ \chi'_2 \\ \chi'_3 \\ i\chi'_4 \end{bmatrix} = \begin{bmatrix} \gamma_r & 0 & 0 & i\gamma_r\beta_r \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ -i\gamma_r\beta_r & 0 & 0 & \gamma_r \end{bmatrix} \begin{bmatrix} \chi_1 \\ \chi_2 \\ \chi_3 \\ i\chi_4 \end{bmatrix} \tag{20}$$

$$\begin{bmatrix} \chi'_1 \\ \chi'_2 \\ \chi'_3 \\ i\chi'_4 \end{bmatrix} = \begin{bmatrix} \gamma & 0 & 0 & i\gamma\beta \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ -i\gamma\beta & 0 & 0 & \gamma \end{bmatrix} \begin{bmatrix} \chi_1 \\ \chi_2 \\ \chi_3 \\ i\chi_4 \end{bmatrix} \tag{21}$$

If the distance between the two observers is very small compared with the radius of the universe (r << R), the real components of the four-position reduce to the classical positions ($\chi_1 \approx x_1$, $\chi_2 \approx x_2$, $\chi_3 \approx x_3$) and the hyperbolic transformation (21) in radial motion equals to the Lorentz transformation (1). As well as Einsteinian laws reduce to Newtonian laws in the limit v << c, hyperbolic laws reduce to Einsteinian laws in the limit r << R in radial motion.

13. Hubble's law and radius of the 4D hyperboloid. Observers in radial motion see an isotropic expansion and describe the cosmological expansion by the Hubble's law. In radial motion, the distance coefficient β_r equals to the velocity coefficient β:

$$v/c = r/R \tag{22}$$

that is

$$v = (c/R)\ r = H\ r \tag{23}$$

Galaxies in radial motion in the expanding 4D hyperboloid verify that the recession velocity is approximately proportional to the distance, according to (23). Hubble's law is shown to be a geometrical necessity in the hyperboloid and the Hubble constant is given by:

$$H = c/R \tag{24}$$

The observed value of the Hubble constant is $H = 70.8$ (km/s)/Mpc $= 2.18 \cdot 10^{-18}\ s^{-1}$ as measured by the NASA (2007). Then the radius of the universe is given by:

$$R = c/H = 1.37 \cdot 10^{26}\ \text{m} \approx 14.5 \text{ millions of light years} \tag{25}$$

Not surprisingly, the estimation (25) disagrees with the estimation of the radius of the observable universe under the assumption of the standard cosmological model. Hyperbolic physics has been developed on the basis of the invariance of the radius of the universe, then verifies the theorems of hyperbolic geometry and makes its own estimations.

14. The logical inconsistencies of special relativity. The hyperbolic transformation (8) is naturally a function of position ($\beta_r = r/R$) while the Lorentz transformation (1) is function of velocities ($\beta = v/c$). This key difference dissipates in the particular case of radial motion, where the distance coefficient β_r equals to the velocity coefficient β, and both transformations are the same as shown in (20) and (21). But in non-radial motion the Lorentz transformation can imply inaccurate and even contradictory results as relativistic paradoxes.

Hyperbolic physics shares the ideas of those who claimed that the relativity principles reveal a logical inconsistency (Bergson [51], Lovejoy [52], Ives [53] or Essen [54], amongst others) or that the concept of asymmetrical clock dilation is contradictory to the mathematical formalism of relativity (Dingle [29]).

The equations (20) and (21) literally describe two hyperbolic rotations and prove the anisotropic character of the LT beyond reasonable doubt: every rotation has a centre, the only fixed point of the transformation. We should then be justified (because of its merits for the description of natural phenomena) in calling this point "absolutely at rest" and all other points "in motion:" the principle of relativity (in the restricted sense) does not hold.

2.3. Transformation equations of non-radial motion

15. Proper time in the hyperboloid. Let us consider the matrix form (20) expressed as $\boldsymbol{\chi}' = [\theta]\boldsymbol{\chi}$. The time derivative of the hyperbolic transformation (20) with respect to the time gives the expressions of velocities **U** and accelerations $\boldsymbol{\alpha}$ in the four-space. Of course, the non-invariant local time t must be replaced by an invariant interval time in the hyperboloid, the hyperbolic proper time T, which is not function of the velocities but of the distances:

$$dT = dt\ (1 - r^2/R^2)^{1/2} = dt'\ (1 - r'^2/R^2)^{1/2} \tag{26}$$

Then the transformation equations are given by:

$$\chi' = [\theta]\,\chi$$
$$U' = [\theta]\,U + [\Omega]\,\chi$$
$$\alpha' = [\theta]\,\alpha + 2[\Omega]\,U + [\dot{\Omega}]\,\chi \tag{27}$$

where **U** = d$\boldsymbol{\chi}$/dT and **U**' = d$\boldsymbol{\chi}$'/dT are the four-velocities in S and S'; $\boldsymbol{\alpha}$ = d**U**/dT and $\boldsymbol{\alpha}$' = d**U**'/dT are the four-accelerations in S and S'; [θ] is the matrix transformation; [Ω] the time derivative of [θ], that is the angular velocity matrix; and [α] the time derivative of [Ω], that is the angular acceleration matrix.

In radial motion (r/R = v/c), the infinitesimal change in the hyperbolic proper time $dT = dt\,(1 - r^2/R^2)^{1/2}$ equals to the infinitesimal change in the relativistic proper time $dT = dt\,(1 - v^2/c^2)^{1/2}$. Both [Ω] and [$\dot{\Omega}$] are nulls in radial motion, so the hyperbolic transformation reduces to the Lorentz transformation. The hyperbolic proper time is the age of the universe and has an absolute character.

16. Relation between velocities and accelerations in different frames of reference. Classical physics perfectly states the relation between velocities and accelerations in two rotating reference systems S and S'. The velocities are given by

$$\mathbf{V}' = \mathbf{V} + \mathbf{V}_{\mathbf{euler}} \tag{28}$$

and the accelerations by

$$\mathbf{a}' = \mathbf{a} + \mathbf{a}_{\mathbf{coriolis}} + \mathbf{a}_{\mathbf{euler}} \tag{29}$$

The analogy between (27) and (30-31) suggests in calling the term [$\dot{\Omega}$]χ *Euler four-acceleration* and the term 2[Ω]**U** *Coriolis four-acceleration.*

17. Preferred frame of reference. Euler and Coriolis accelerations (that is, fictitious forces) are null for observers in radial motion that constitute true preferred frames in which the CMBR (cosmic microwave background radiation) uniformly fills the universe at a temperature of 2.725 K in all directions. Marinov [17], Weisskopf [55], Wesley [6], Wilheim [5] or Levy [7] pointed out the absolute character of the velocities measured with respect of the CMBR although they did not identify the preferred reference frame with the 4D hyperboloid.

2.4. Hyperbolic Big Bang

18. Hyperbolic Big Bang. In the hyperboloid, the condition R = 0 describes the Big Bang as a hypercone in four-space or, equivalently, as a primordial light cone:

$$\chi^2_1 + \chi^2_2 + \chi^2_3 + \chi^2_4 = 0 \tag{30}$$

19. Evolution of the hyperbolic universe. Ignoring the third spatial dimension, the hyperbolic Big Bang reduces to a three-dimensional cone (Figure 5 left). Just as the Dirac equation of the electron has two solutions (one for matter and one for antimatter), the hyperbolic Big Bang theoretically can give rise to several causally disconnected universes (perhaps some of matter and some of antimatter). In Figure 5, the space-time diagram helps to visualize the scenario: when the Big Bang happens, the cone breaks in two sheets facing each other, the two causally disconnected sheets of the double-sheeted hyperboloid (Figure 5 centre). Furthermore, we cannot rule out the positive value of R^2, that is, the role played at the Big Bang by the single-sheeted hyperboloid (Figure 5 right).

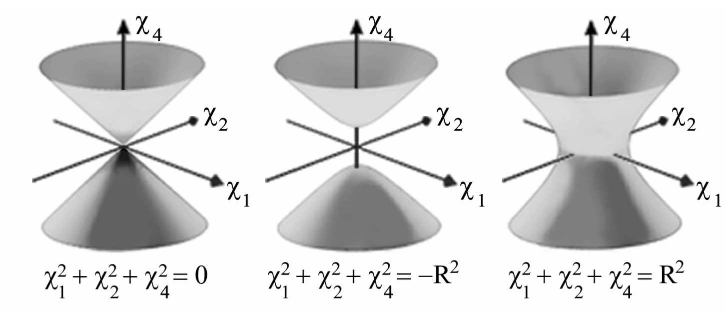

Figura 5. Hyperbolic Big Bang. Ignoring the third spatial dimension, the hyperbolic Big Bang reduces to a cone (left); the negative value of R^2 reduces to the upper and lower sheets of a double-sheeted hyperboloid (centre); and the positive value of R^2 reduces to a single-sheeted hyperboloid (right).

20. The identity of indiscernibles. Taking R = 0, equation (10) is now:

$$x_1 = x_2 = x_3 = 0 \qquad (31)$$

The equation (31) is valid both in the standard Big Bang and in the hyperbolic Big Bang.

- All points of the standard Big Bang have the same classical coordinates (x = y = z = 0) and, according to the ontological principle of the identity of indiscernibles, the universe reduces to a single point. The standard Big Bang theory defies physical laws by postulating a state of infinite density, temperature and pressure. Energy, matter, space and time exist after the Big Bang, nothing exists during or before it.

- All points of the hyperbolic Big Bang have the same classical coordinates (x = y = z = 0) but, disagreeing with the ontological principle of the identity of indiscernibles, the universe does not reduces to a single point. The classical coordinates do not constitute a complete description of the universe: the true description is the 4D hypercone $\chi^2_1 + \chi^2_2 + \chi^2_3 + \chi^2_4 = 0$ where every point has its own four-dimensional coordinates (χ_1, χ_2, χ_3, χ_4). The hyperbolic Big Bang does not necessarily defy physical laws by postulating a state of infinite density, temperature and pressure. Energy, matter, space and time exist after and during the hyperbolic Big Bang, maybe before the Big Bang itself.

21. In the beginning was the light. Only massless particles can travel along a light cone. It is possible to state that *all is light* in the hyperbolic Big Bang, an aesthetically moving idea.

22. Horizon problem. The Figure 6 shows how the hyperbolic Big Bang solves de horizon problem. At the standard model, different regions of the universe are causally disconnected due to the great distances between them (Figure 6 left). In the hyperboloid, all regions remain causally connected (Figure 6 right) because the hyperbolic Big Bang (light at 45º) defines the limits of the observable universe.

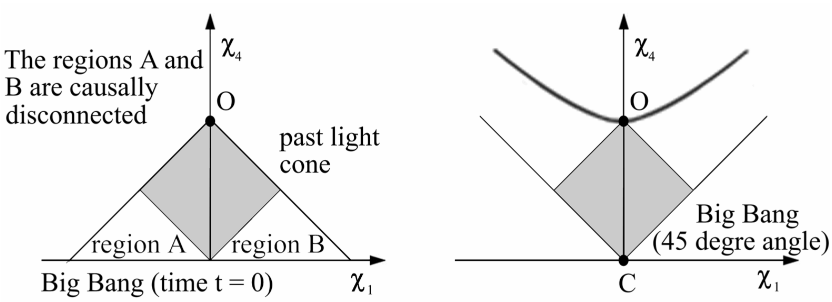

Figura 6. Horizon problem. At the standard model, different regions of the universe are causally disconnected due to the great distances between them (Figure 6 left). In the hyperboloid, all regions remain causally connected (Figure 6 right).

In Figure 3 left (page 5), the hyperbola L-O-L' is the set of events that are simultaneous with respect to the preferred reference frame (absolute simultaneity), while the past light cone l-O-l' is the set of events that are simultaneous with respect to the observer O (relative simultaneity).

3. PHYSICAL PART

"Don't ask me any questions. I've seen how things that seek their way find their void instead." F. G. Lorca

3.1. Varying speed of light

23. Geometric meaning of the speed of light in the hyperboloid. If R is large enough, the infinitesimal change of R is given by $dR \approx c\,dt$, then the speed of expansion of the hyperboloid V_{hip} is approximately equal to the speed of light:

$$V_{hip}(t) = \frac{d}{dt}R(t) = c(t) \tag{32}$$

The speed of expansion of the hyperboloid and the speed of light are mutually dependent. The time variation of c can be induced if the radius R is not a linear function of time.

24. Varying speed of light theories. Since the pioneering works of Mitchell [56], Thompson (Lord Kelvin) & Tait [57], Einstein [58] or Dirac [59], new theories with a time-variable speed of light have been investigated. One may categorize VSL theories according to the mechanisms in which they induce the variation of c:

- Breakdown of Lorentz invariance: Models proposed by Moffat [60-61] and Albrecht & Magueijo [62] postulate a possible alternative to inflationary cosmology and involve the breakdown of covariance and Lorentz invariance. This line of work may solve cosmological problems (the flatness, entropy, homogeneity, isotropy and cosmological constant problems of Big Bang cosmology). Einstein's field equations in the VSL theory have been solved by Barrow [63-64] under the strong assumption that a c variable does not introduce any corrections into the curvature tensor.

- Modification of the curvature tensor: Models proposed by Harko & Mak [65], Avelino & Martins [66] or Shojaie & Farhoudi [67] allow both covariance and Lorentz invariance in such a way that variations in the speed of light introduce corrections to the curvature tensor in the Einstein equations.

- Addition of extra dimensions (Strings/M-theory): Kiritsis [68] and Alexander [69] realize VSL on a brane-world scenario with a larger number of dimensions.

- Addition of extra metrics: Bimetric theories proposed by Moffat & Clayton [70-72] and Drummond [73] do not sacrifice the first principle of special relativity. These theories are implemented by introducing two metrics, one for gravity and one for matter. The speeds of the various massless species may be different.

- Deformation of the special relativity: Deformed special relativity (DSR) theories by Amelino-Camelia [74-75] and Ellis [76-77] introduce a non-linear realization of the Lorentz group and postulate an energy dependent speed of light.

- Deduction from field theories: Drummond & Hathrell [78] pointed out that quantum field theory in curved space-time predicts superluminal photon propagation.

A more extensive catalogue of recent VSL theories can be found at [79].

25. Varying speed of light in the hyperboloid. Only empirical evidences can determine the exact formulation of the velocity of expansion of the hyperboloid, but a theoretical hypothesis is to be preferred to anyone else: that the product of the radius of the universe and the speed of light equals to a constant K.

$$R(t)\,c(t) = K \tag{33}$$

The equation (33) is derived from electromagnetic fields theory, thus a charged particle will verify the Lorenz condition (see section 3.7). Free photons travel with speed

$$c(t) = K/R(t) \tag{34}$$

and acceleration

$$a_\gamma(t) = \frac{d}{dt}c(t) = -\frac{c^2(t)}{R(t)} \tag{35}$$

The minus sign means that free photons decelerate with time. According to (24), the Hubble constant is $H = c/R$ where c and R are functions of time, then H varies with time as well:

$$H(t) = c(t)/R(t) = K/R^2(t) \tag{36}$$

Equations (34) and (35) imply that the free photon acceleration a_γ equals to the product of c and H. The current values $a_{\gamma 0}$, c_0 and H_0 verify:

$$a_{\gamma 0} = -H_0\,c_0 = -6.54 \cdot 10^{-10}\ \text{m/s}^2 \tag{37}$$

and the constant K

$$K = R(t)\,c(t) = R_0\,c_0 = 4.11 \cdot 10^{34}\,m^2/s \qquad (38)$$

According to (37), the speed of light barely decreases a centimetre per second every year. Although this variation is on the threshold of the current technology, Sanejouand [80] examines some indirect empirical evidences in favour of a varying c: the time taken by light to go to the Moon and back to Earth [81], the Pioneer anomaly [82], the time dilation of remote events [83-84], the supernovae redshifts [85-86] and the fine-structure constant measurements [87]. The acceleration (37) agrees with the rate of change of c obtained through the cited evidences.

Integrating (33) with respect to time and taking the origin (t = 0) at the Big Bang (R = 0) we obtain

$$t = R^2(t)/2K = 1/[2H(t)] \qquad (39)$$

and the age of the universe is

$$T_0 = R_0^{\,2}/2K = 2.29 \cdot 10^{17}\ s \approx 7250 \cdot 10^6\ years \qquad (40)$$

Not surprisingly, the estimation (40) disagrees with the estimation of the age of the universe under the standard cosmological model assumptions. Hyperbolic physics refuses the postulate of homogeneous time, so different laws of physics should govern the universe at different time instants. In comparison with the standard model, interactions between particles occur in greater number and with greater power, because the greater value of the speed of light and the greater energy ($E = mc^2$) of the particles in the hyperboloid.

Is the infinite value of the speed of light at the Big Bang itself to be taken literally or ideally? The answer is elusive. In any case, the hyperbolic Big Bang is more intelligible than the impossible singularity of the standard Big Bang.

3.2. The law of inertia

26. Law of inertia. If the speed of light decreases, free photons do not move at constant speed, so the law of inertia does not hold in the expanding hyperboloid. Because of the small value of $a_{\gamma 0}$, the behaviour of free photons is quasi-inertial when the motion involves small distances compared with the radius of the universe and short periods of time compared with the age of the universe.

A free material particle does not move at constant speed either. Material particles in motion at speed v suffer an acceleration a(t) expressed as

$$a(t) = \frac{d}{dt} v(t) \approx -\beta a_{\gamma 0}(t) \qquad (41)$$

The acceleration a(t) is always smaller than $a_{\gamma 0}$, then free material particles correspond with the inertia law even better than photons. Despite of the quasi-inertial behaviour of free photons and material particles, inertia law is abolished in the hyperboloid. The classical equivalence of inertial system must be replaced by the existence of preferred free systems (observers in radial motion).

3.3. The non-relativistic flight of the photon

27. Photon motion in the hyperboloid. The photon energy E can be expressed both in function of the mass m_γ and of the frequency υ:

$$E = m_\gamma c^2 = h\upsilon \qquad (42)$$

Free photons do not verify the law of inertia, the energy varies in time as well as other properties (frequency, wavelength, etc.). If the Planck's constant h and the mass m_γ do not vary much over a short time, the time derivative of the equation (42) is:

$$\frac{dE}{dt} = 2m_\gamma c \frac{dc}{dt} = h \frac{d\upsilon}{dt} \qquad (43)$$

and then

$$\frac{d\upsilon}{dt} = \frac{2m_\gamma c}{h} \frac{dc}{dt} = \frac{2\upsilon}{c} a_\gamma \qquad (44)$$

28. Pioneer anomaly. The equation (44) is exactly the expression of the anomalous acceleration of the Pioneer spacecraft, estimated to be $a_p = -(8.74 \pm 1.33) \cdot 10^{-10}\ m/s^2$ according to [82]. This value agrees with (37), the photon acceleration $a_{\gamma 0} = -6.54 \cdot 10^{-10}\,m/s^2$.

29. Analogy between the properties of free photons and the properties of the hyperboloid itself. The product of the radius and the expanding velocity of the universe is constant, as well as the product of the wavelength and the velocity of free photons. In addition, the wavelength and the period of free photons are directly proportional to the radius and the age of the universe respectively.

3.4. Cosmology

30. Cosmological puzzles. Taking R = 0 in equation (33), the speed of light becomes virtually infinite at the Big Bang itself. It solves important cosmological problems:

- Why was the early universe so hot?
- Why is the temperature of the microwave background radiation so nearly the same in different directions?
- Why is the universe so uniform on a large scale?

The virtually infinite speed of light at the Big Bang explains in an obvious way the high temperatures of the primordial universe. And it also explains the homogeneity and uniformity on a large scale because light signals have time to get from one distant region to another.

31. Dark energy. When the source is moving away from the observer, the Doppler effect formula becomes:

$$\frac{v}{c} = \frac{(z+1)^2 - 1}{(z+1)^2 + 1} \tag{45}$$

In radial motion (v/c = r/R)

$$\frac{r}{R} = \frac{(z+1)^2 - 1}{(z+1)^2 + 1} \tag{46}$$

that is

$$z = 1 - \sqrt{1 - \frac{2r/R}{1 - r/R}} = 1 - \sqrt{1 - \frac{2ra_\gamma/c^2}{1 - ra_\gamma/c^2}} \tag{47}$$

The equation (47) explains the nonlinearity of Hubble's law (Riess [85], Perlmutter [86]) without dark energy. The result is essentially the same as that of Sanejouand [80], although in the hyperboloid both speed of light c and acceleration a_γ vary in time. The problems of the rotational speeds of galaxies can be satisfactorily solved in the expanding hyperboloid without dark energy.

3.5. The second law of thermodynamics

32. Emission of energy. The equivalence of energy E and mass m is described by the Einstein's equation $E = mc^2$. If the speed of light c decreases, the energy of a particle with rest mass m_0 must decrease as well.

$$\frac{dE}{dt} = 2m_0 c(t)\cdot a_\gamma(t) \tag{48}$$

$$\frac{dE}{E} = 2\frac{a_\gamma(t)}{c(t)}dt \tag{49}$$

In the hyperboloid, the famous equation $E = mc^2$ must be complemented with the equation that describes the variation of E with time, more elegantly expressed in terms of the Hubble's constant:

$$\frac{dE}{dt} = 2H\cdot mc^2 \tag{50}$$

According to (50), any free particle emits a small fraction of its energy. Such emitted energy is so small that it cannot be experimentally detected, although the emission can be theoretically justified from a thermodynamic point of view.

33. The second law of thermodynamics. The second law states that heat spontaneously flows from hot regions to cold regions and that gases spontaneously expand to occupy all the volume accessible to them. In Mach words [1]: "*In all the processes of nature the differences of certain quantities u play a determinative role. Differences of temperature, of potential function, and so forth, induce the natural processes, which consist in the equalisation of these differences.*" Taking the second law to its logical conclusions, the difference of energy between a particle and the empty space must induce the emission of a fraction of the relativistic energy ($E = mc^2$) from the particle to the surrounding space. There are two mechanisms by which the energy can be emitted: firstly, the reduction of the rest mass, and secondly, the reduction of the speed of light. This second mechanism is the link between the thermodynamics laws and the expanding hyperboloid.

34. The Loschmidt paradox. One of the major unsolved problems in physics is the Loschmidt paradox, the dilemma that it should not be possible to infer irreversible processes from time-symmetric dynamics like Newtonian or Einsteinian laws. The equation (33) is a time-irreversible law according which free particles must emit a fraction of their relativistic energy. For the first time, a law of dynamics introduces time-irreversible processes in natural phenomena and justifies the second law of thermodynamics.

Thermodynamic helps to justify the variation of the speed of light, while the expanding hyperboloid helps to justify the irreversibility of thermodynamics processes.

3.6. Relativity theory

35. Halfway between Einsteinian and Newtonian physics. Hyperbolic physics shares with Einsteinian physics the four-dimensional description of the universe, the relative character of simultaneity and the limiting speed c; and it shares with Newtonian physics the existence of a preferred system that Newton looked for but failed to find [89]: "*It is possible that in the remote regions of the fixed stars, or perhaps far beyond them, there may be some body absolutely at rest.*"

36. Reference system versus observer. The concepts of reference system and observer are very different. The center C of the hyperboloid is the origin of a reference system, but it is not an observer. It is possible to state that "*there is a reference system in absolute rest*" in the expanding hyperboloid. On the other hand, observers share the expanding motion of the hyperboloid, then "*there are not observers in absolute rest*" in the expanding hyperboloid.

37. General theory. A varying speed of light modifies the general theory in two ways: first, the speed o light is not a constant but a variable; second, it arises the question of the possible variation of the universal gravitational constant G, as Dirac proposed. Einstein field equations can be compatible with variable values of c and G, but it is hard to guess the abolition of the relativity principle without the abolition of the field equations.

3.7. Electromagnetic theory

38. The four-potential A of a charged particle. If μ_0 is the permeability of free space, q the electric charge, **U** the four-velocity and r the distance, the four-potential of a charged particle is given by:

$$\mathrm{A} = \frac{\mu_0 \mathrm{q}}{4\pi \cdot \mathrm{r}} \mathrm{U} \tag{51}$$

¿Which is the four-potential of an electrically charged particle with respect to the preferred reference frame (the centre C of the hyperboloid)? The distance r becomes the radius of the universe R:

$$\mathrm{A}_C = \frac{\mu_0 \mathrm{q}}{4\pi \cdot \mathrm{R}} \mathrm{U} \tag{52}$$

39. The Lorenz condition. A free charged particle in radial motion verify that $\mathbf{U} = \mathrm{K}\boldsymbol{\chi}/\chi^2$. If the permeability of free space and the electron charge remain constant, the Lorenz condition $\Box\mathbf{A_C} = 0$ is automatically verified as well. This is the reason why the equation (33) was postulated to describe the dynamics of the expanding hyperboloid.

4. CONCLUSIONS

"A great orator must be a good man." *M. F. Quintilian*

I. Empirical and theoretical status of relativity. Almost without exceptions, physics textbooks detail the great success of relativity in terms of its agreement with experimental test. What is not sufficiently emphasized in textbooks is that experiments measures some effects like the time dilation (the most revolutionary discovery of relativity), but cannot directly measure the length contraction (because the standard used to measure the length of a moving body is contracted in the same ratio as the body itself). In addition, the existence of the so called "relativistic" effects could be determined by the absolute motion of systems through space. Experiments do not indisputably support the theory of relativity; indeed, the empirical results [7] provide weighty arguments in favour of the anisotropy of space.

There are strong arguments against relativity. Experiments in favour of the isotropy of space are questioned by Builder [91], Prokhovnik [39], Múnera [22], Anderson et al [90] or Cahill & Kitto [20-21] between others, while empirical evidences points clearly, if not definitively, to the anisotropy of the space (Levi [7]). In opposition to the invariance of c, varying speed of light theories (VSL) could provide original solutions to important cosmological puzzles (Magueijo [79]). The Lorentz transformation was early called into question, first by pointing out the logical paradoxes (twin paradox, ladder paradox, Bell paradox, etc.) and second by claiming the concept of an absolute frame (Larmor [27], Lorentz [24], Bell [30-31], etc.). Breaking of Lorentz symmetry becomes a useful line of work in VSL theories (Moffat [60-61], Albrecht & Magueijo [62]) and in quantum mechanics (Horava [92]). Singularity theorems (Hawking & Penrose [93]) mean that general relativity predicts its own demise. General relativity is difficult, even impossible, to quantize. The cosmological constant problem can be divided into three problems: the old cosmological problem, the new cosmological problem and the coincidence problem (Niayesh [36-37]). General relativity agrees with cosmological data if dark matter dominates at galactic scales and dark energy dominates at the largest scales. Of course, Einsteinian physics is incompatible with the quantum uncertainty and with the irreversibility of the physical phenomena.

Einsteinian relativity is a self-refuting theory: the Lorentz transformation implies the negation of the principle of relativity (see section 1.1).

Mueller [94] has documented the existence of 3789 publications criticizing relativity and has recommended the 14 most important publications [29,53-54,95-105]. These titles have been excluded and silenced by academic physics.

II. Invariance of the radius of the universe. The invariance of R is a heuristic principle that serves as a core of inductive reasoning and as a criterion for its validity. New transformation equations can be derived in such a way that includes the Lorentz transformation as a particular case. The new geometric scenario means a new cosmological model, the expanding 4D hyperboloid. Hyperbolic physics has been developed on the basis of the invariance of the radius of the universe and verifies the theorems of hyperbolic geometry. In addition, the expanding hyperboloid helps to explain problems like:

- the asymmetrical time dilation effect (for example, in the twin paradox),
- the cosmological expansion,
- the horizon problem and
- the Big Bang.

III. Varying speed of light. A varying speed of light induced by the expanding hyperboloid helps to explain:

- the pioneer anomaly,
- cosmological problems (why was the early universe so hot, why is the temperature of the microwave background radiation so nearly the same in different directions and why is the universe so uniform on a large scale),
- the dark energy and
- the irreversibility of physics phenomena.

On the contrary, basic principles like the law of inertia, the relativity principle and the invariance of the speed of light are not completely valid in the hyperboloid.

IV. Empirical status of hyperbolic physics. There are indirect empirical evidences in favour of the hypothesis that the speed of light decreases by about a few centimetres per second each year [80-86], but direct empirical evidences are not easily accessible to experiments since the acceleration (18) is on the threshold of the current technology.

V. Irreversibility. The expanding hyperboloid completely agrees with the irreversibility of physics phenomena.

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