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SPACE–TIME MACHINE

Ruggero Maria Santilli
The Institute for Basic Research
P. O. Box 1577, Palm Harbor FL 34682, USA
Fax 1-813-934 9275, E-mail ibrrms@pinet.aip.org

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Abstract

The "time machine", commonly referred to a closed time-like loop in the forward light cone, has been theoretically studied by a number of authors via suitable generalizations of the Minkowskian and Riemannian spaces. Following the preceding note on antigravity, in this note we propose a new form of "space-time machine" referred to a closed, timelike, forward loop in both space and time, which is here also submitted as a scientific curiosity for young minds. The main property is the lack of *necessary* use of curvature for the characterization of gravitation, because of the existence of its *identical* representation in a flat isominkowskian space. The latter representation introduces generalized units of space and time, which therefore assume local character, that is, they depend on the gravitational field in which the test particle is immersed. While time for Einstein's relativities is *universal* in the sense that it the same for all observers throughout the Universe with the same speed with respect to an inertial system, time for our covering isorelativities is *local* in the sense that observers with the same speed but immersed in different gravitational fields have different times because of different units. Exactly the same situation occurs for lengths which, besides the Lorentz contraction, may admit locally varying units. According to these theories, the intensity of the forward motion of time can be controlled by increasing or decreasing the intensity of the gravitational field of matter in which the test particle is immersed. The isodual representation of antiparticles of the preceding note then permits the control of the intensity of the backward motion of time by decreasing or increasing the gravitational field of antimatter. A fully causal "space-time machine" then follows via a suitable interplay of matter and antimatter. Specific experiments fully feasible with current interplanetary technology are proposed to resolve the fundamental issue raised by isotopic theories: whether time for us on Earth and on other bodies with significantly different gravitational field, such as Jupiter, are the same or not.

1. INTRODUCTION

The "time machine", defined as a closed time-like loop in the forward light cone, has been studied by a number of authors (see, e.g., papers [1] and references quoted therein).

These studies have essentially indicated that closed loops *are not* possible in the Minkowskian space-time because of the time-like causality condition

$$x\,x + y\,y + z\,z - t\,c_o^2\,t < 0. \tag{1.1}$$

For this reason, studies [1] require a suitable generalization of the space-time itself, such as a *complex* extension of the Minkowski space. The possibility of reaching closed time-like loops in our physical space is then studied via quantum tunneling and other means.

The situation is topologically different in Riemannian spaces because of the curvature. In fact, studies [2] point out the possibility of reaching closed time-like loops in *conventional* Riemannian spaces by using different wormholes with higher order perturbative terms.

In this paper we submit a novel formulation of the "space-time machine" conceived for closed loops in space-time under the time-like condition of causality, which admits experimental verifications feasible with current technology submitted in Sect. 5. We then point out the existence of indirect experimental support for the basic assumptions of the proposed "space-time machine". The apparent existence in our environment of a realizations of the "time machine" of the proposed type is identified in the least expected field, that of biology.

2. ISOSPECIAL RELATIVITY

The inability to have closed time-like loops in Minkowski space can be traced back to the very foundations of the special relativity, in particular, to Einstein's **"relativity of space and time"** [3] according to the familiar expression of *time dilation* and *space contraction*

$$\Delta r' = \Delta r\,(1 - v^2/c_o^2)^{\frac{1}{2}}, \quad \Delta t' = \Delta t\,/\,(1 - v^2/c_o^2)^{\frac{1}{2}}, \tag{2.1}$$

where c_o is the speed of light in vacuum. An understanding is that, while time-dilation has been experimentally verified via NASA probes, the space-contraction is experimentally unverified and theoretically unsettled because afflicted by problematic aspects due to its evident asymmetry with respect to time, as studied by Strel'tsov [4] and others.

Laws (2.1) essentially express the lack of "absolute" character of space and time in the sense that they depend on the local speed. However, the Einsteinian notions of space time are "universal" in the sense that *they are the same for all observers throughout the Universe with the same speed relative to an inertial system.*

But the physical foundations of the special relativity, the "universal constancy of the speed of light c_o", are a philosophical abstraction because in the physical reality light has a speed which is varying with the local physical conditions. For instance, in our environment, the speed of light in our atmosphere is continuously varying with the density, and then assumes yet different values when propagating in glass, water, etc.

This note is focused on the fact that the variation of the speed of light in the physical reality implies a predictable mandatory generalization of Eq.s (2.1) with consequential generalization of the notions of space and time. The "space-time machine" submitted in this note will then be proposed within the context of such broader notions.

A generalization of the special relativity for arbitrarily varying speeds of light c has been submitted by this author in 1983 [5] and then studied in details in various publications and meetings (see monographs [6a] for the classical profile and [6b] for the operator counterpart).

The generalization is constructed via the so-called nonlinear-nonlocal-nonlagrangian *isotopies* [5,6] (see also the outline in Sect. 2 of the preceding note [7]) and, for this reason, it has been submitted under the name of *isospecial relativity*. The generalized relativity is a *covering* of the conventional one because:

1) The isorelativity is constructed with mathematical methods structurally more general than those of the conventional relativity, including new numbers, new angles, new algebras-groups-symmetries, new functional analysis, etc.;

2) The generalized relativity applies to physical conditions (interior nonlocal-nonhamiltonian systems within physical media) which are structurally more general than those of the conventional relativity (exterior local-Lagrangian systems in vacuum); and

3) The isorelativity coincides with the conventional relativity at the abstract level by construction, while admitting the latter in its entirety as a particular case.

The special relativity is constructed on the *Minkowski space* $M(x,\eta,R)$ with local coordinates $x = (r, c_o t)$ and metric $\eta = \text{diag.}\ (1, 1, 1, -1)$ over conventional fields $R(n,+,\times)$ of real numbers n with familiar addition n+m and multiplication $n \times m = nm$, $n, m \in R$. The geometric unit of the space, e.g., that of the fundamental representation of the Lorentz group, is then the familiar form $I = \text{diag.}\ (1, 1, 1, 1)$. This evidently establishes that the units of the local space and time coordinates is $I = (I_s, I_t) = (I_\mu)$ of which the unit of space is given by $I_s = (1cm, 1cm, 1cm)$ and the unit of time is the quantity $I_t = I_4 = 1sec$. Note the same value of the unit of space for each space coordinate, as requested by the isotropy of space.

By assuming a knowledge of the isotopies at least as in Sect. 2 of the preceding note [7], the covering isospecial relativity in its most general form is constructed on the so-called *isominkowskian spaces* of Class I in the diagonal form [5,6,7]

$$\hat{M}(x,\hat{\eta},\hat{R}): \ x = (r, x^4),\ \hat{\eta} = T\eta,\ \eta = \text{diag.}\ (1, 1, 1, -1),\ \hat{R} = \hat{R}(\hat{n},+,*), \tag{2.2a}$$

$$T = \text{diag.}\ (n_1^{-2}, n_2^{-2}, n_3^{-2}, n_4^{-2}) > 0, \qquad n_\mu > 0, \qquad \hat{1} = T^{-1}, \tag{2.2b}$$

$$x^{\hat{2}} = (x^1 n_1^{-2} x^1 + x^2 n_2^{-2} x^2 + x^3 n_3^{-2} x^3 - x^4 c_o^2 n_4^{-2} x^4)\,\hat{1} \in \hat{R}(\hat{n},+,*), \tag{2.2c}$$

where the n's, called *characteristic functions* of the physical medium, possess a general nonlinear-nonlocal-nonhamiltonian dependence on space-time coordinates x, velocities $\dot{x}$, accelerations $\ddot{x}$, as well as any needed additional quantity, such as local gravitational field f, the density of the medium μ in which motion occurs, its temperature τ, etc.,

$$n_\mu = n_\mu(x, \dot{x}, \ddot{x}, f, \mu, \tau, \ldots) > 0; \tag{2.3}$$

T is called the *isotopic element*, $\hat{1}$ is called the *isounit* of the $\hat{M}((x,\hat{\eta},\hat{R})$; and $\hat{R}(\hat{n},+,*)$ is the *isofield* of *isoreal numbers* $\hat{n} = n\hat{1}$ with sum $\hat{n} + \hat{m} = (n+m)\hat{1}$, isoproduct $n*m = \hat{n}T\hat{m} = (nm)\hat{1}$ and consequential isotopic operations for quotient, powers, etc.

Recall that the Minkowski space provides a direct geometrization of the constancy of the speed of light in vacuum c_o, that is, a geometrization via the metric of the space itself, Eq. (1.1). The first application of the isominkowski space (2.2) is a *direct geometrization of the locally varying speed of light* $c = c_o/n_4$ in interior physical media, that is, a geometrization also via the metric $\hat{\eta}$ of the space itself.

The first interpretation of the characteristic quantities n_4 *is therefore that of being the local index of refraction.* The space components n_k are introduced on grounds of Lorentz invariance (see [5,6] for details). However, the restriction of n_4 to the index of refraction is grossly unwarranted for the isospecial relativity because isotopies leave the functional dependence of the isotopic element T unrestricted. Our problem is is the identification of this broader physical meaning of the isotopic element T.

The multiplicative term $\hat{1}$ is introduced in Eq. (2.2c) because the isoseparation must be an isoscalar, rather than a scalar, that is, an element of the isofield $\hat{R}(\hat{n},+,*)$ rather than one of the conventional field $R(n,+,\times)$. The factor $\hat{1}$ is also introduced for additional, rather subtle geometric reasons.

In fact, *isoseparation (2.2c) coincides with the conventional separation (1.1) at the abstract level* because, jointly with the deformation of each space-time component $I_\mu \to n_\mu^2$, the corresponding unit is changed in the *inverse* amount, $I_\mu \to n_\mu^{-2}$. The deformation of the original separation (1.1) therefore exists only when the new separation is inspected in our space–time, that is, with the conventional units I_μ. The important point is that the two separations (1.1) and (2.2) coincide when each is represented in its own space.

The abstract identity of the spaces $M(x,\eta,R)$ and $\hat{M}(x,\hat{\eta},\hat{R})$ ensure the preservation of causality. In particular, the time–like condition reads

$$x^{\hat{2}} = (x\, n_1^{-2} x + y\, n_2^{-2} y + z\, n_3^{-2} z - t\, c_o^2\, n_4^{-2} t)\,\hat{1} < 0 . \qquad (2.4)$$

and it is fully equivalent to the conventional condition (1.1).

Also, when the speed of light is no longer c_o, the lack of applicability of conventional time–dilation and space–contraction (2.1) is established by clear experimental evidence. In this case the isospecial relativity replaces them with the covering isotopic laws

$$\Delta r' = \Delta r\,(1 - v^k n_k^{-2} v^k / c_o\, n_4^{-2} c_o)^{\frac{1}{2}}, \qquad (2.5a)$$

$$\Delta t' = \Delta t\,/\,(1 - v^k n_k^{-2} v^k / c_o\, n_4^{-2} c_o)^{\frac{1}{2}}, \qquad (2.5b)$$

which have been proved by Aringazin [8] to be "directly universal", that is, admitting as particular cases all possible generalized laws without changing the coordinates of the observer via different expansions in terms of different parameters and with different truncations. Equivalently, one can see the direct universality of laws (2.5) from the fact that the isominkowski space unifies all infinitely possible signature–preserving deformations $\hat{\eta} = T\eta$ of the Minkowski metric η.

The quantity $\hat{1} = \text{diag.}\,(n_1^2, n_2^2, n_3^2, n_4^2)$ is *the isounit of the isospace* $\hat{M}(x,\hat{\eta},\hat{R})$ or, equivalently, of the isofield $\hat{R}(\hat{n},+,*)$ in which it is defined or, equivalently, the isounit of the fundamental isorep of the isolorentz symmetry $\hat{O}(3.1)$ [5,6].

It is easy to see that *the isounits of the space and time coordinates* are different and given by

$$\hat{1} = (\hat{1}_s, \hat{1}_t) = (\hat{1}_\mu) = ((n_1, n_2, n_3), n_4), \qquad (2.6)$$

where the *isounit of space* is given by $\hat{1}_s = (n_1, n_2, n_3)$ and the *isounit of time* is given by $\hat{1}_t = n_4$. Note the general existence of different isounits of space for different directions. Note that this implies the use of isofields $\hat{R}_s$ and $\hat{R}_t$ different than that of the isospace, which are hereon assumed.

In fact, the assumptions $\bar{x}_\mu = x_\mu n_\mu$ (no sum) turn the conventional separation into the isotopic one

$$\bar{x}^1 \bar{x}^1 + \bar{x}^2 \bar{x}^2 + \bar{x}^3 \bar{x}^3 - \bar{x}^4 \bar{x}^4 \equiv x^1 n_1^{-2} x^1 + x^2 n_2^{-2} x^2 + x^3 n_3^{-2} x^3 - x^4 c_o^2 n_4^{-2} x^4. \qquad (2.7)$$

Equivalently, the abstract identity of the special and isospecial relativities can be seen from the values $x_\mu = \bar{x}_\mu \hat{1}_\mu$ (no sum) under which the isotopic separation is turned into the conventional one.

What we have learned until now is therefore the following:

a) By no means the geometric axioms of the Minkowski space solely admit the conventional separation (1.1), because an infinite class of structurally more general separations (2.2) are admitted;

b) A necessary condition to preserve the abstract identity of the generalized and conventional separations is the change of the units of space–time from the trivial values $I = (I_s, I_t) = ((1, 1, 1), 1)$ to the generalized quantities called isounits $\hat{1} = (\hat{1}_s, \hat{1}_t) = ((n_1, n_2, n_3), n_4), n_\mu > 0$;

c) The conventional units (I_s, I_t) of the special relativity are subjected to time–dilation and space–contractions (2.1) but are otherwise "universal" in the sense indicated earlier. On the contrary, the isounits $(\hat{1}_s, \hat{1}_t)$ are "local" quantities, that is, they depend on the local physical conditions in addition to speed and, as such, are generally different for different observers with the same speed relative to an inertial frame.

Note that the transition from the conventional (1.1) to the isotopic line element (2.4) resolves all conventional difficulties for a closed–time–like loop, thus avoiding any need to pass to complex extensions [1]. This is evidently due to the unrestricted time dependence of the isotopic elements n_μ.

Such a possibility is however *insufficient* for our objectives. In fact, we want to identify a "space–time machine" which is testable with current technology and actually realizable in case of positive tests. Such objectives are evidently not allowed by a mere theoretical capability of closed loops in the line element.

In order to proceed further, we have to identify the physical meaning of the remaining functional dependence of the isounits at least for the simpler case of exterior problems in vacuum. This problem is resolved by the fact that *the isotopies permit, first, a geometric unification of the special and general relativities in vacuum and, second, their unification with the corresponding interior nonlocal–nonlagrangian generalizations* [6].

Until now we have considered the isospecial relativity within physical media with variable speed of light c in which the differences $(1_s, 1_t) \neq (\hat{1}_s, \hat{1}_t)$ are transparent. Let us perform now the transition to the exterior dynamical problem in vacuum as represented by a (locally Minkowskian) Riemannian space $\Re(x,g,R)$ with nowhere degenerate and symmetric metric g(x) over the reals $R(n,+,\times)$.

Because of the local Minkowskian and nondegenerate conditions, all possible Riemannian metrics admit the decomposition

$$g(x) = T(x)\,\eta, \quad T(x) > 0. \tag{2.8}$$

As a result, the Riemannian space $\Re(x,g,R)$ can be reinterpreted as an isominkowskian space $\hat{M}(x,\hat{\eta},\hat{R})$ with exactly the same metric $g(x) = T(x)\eta \equiv \hat{\eta}(x)$, but now formulated over the isofields $\hat{R}(\hat{n},+,*)$ with *gravitational isounit* $\hat{1}(x) = [T(x)]^{-1}$. We therefore have the local isomorphism

$$\Re(x,g,R) \sim \hat{M}(x,\hat{\eta},\hat{R}), \qquad g(x) = T_g(x)\,\eta \equiv \hat{\eta}, \quad \hat{1}_g(x) = [\,T_g(x)\,]^{-1}. \tag{2.9}$$

Note the isotopic equivalence of Riemannian and Minkowskian space permit the abstract unification of the general and special relativities [6]. Note also the novelty given by the *lack of axiomatic character of curvature*. In fact, the Riemannian metric can be *identically* assumed in a *flat* isominkowskian space, where the latter space preserves by construction the original axiom of flatness.

The above result is achieved by embedding the component T(x) of the Riemannian metric $g(x) = T(x)\eta$ truly representing curvature in the isounit $\hat{1}(x) = [T(x)]^{-1}$ of the theory. The local isomorphism with the conventional, flat Minkowski space $M(x,\eta,R)$ then follows from the positive-definiteness of T(x) or $\hat{1}(x)$.

We learn in this way that, when passing to the exterior motion in vacuum, there is no need to have the isounits recover the conventional values, because the isospecial relativity contains in its structure the totality of gravitation in vacuum.

But, again, the restriction of the Riemannian metric g to a sole dependence on the local coordinates x is grossly unwarranted under isotopies. In fact, the Riemannian space itself can be subjected to the isotopies

$$\hat{\Re}(x,\hat{g},\hat{R}): \quad \hat{g} = \hat{g}(x, \dot{x}, \ddot{x}, \ldots) = T'(x, \dot{x}, \ddot{x}, \ldots)\, g(x), \quad \hat{1}' = T'^{-1} > 0, \tag{2.10}$$

which, by construction, is locally isomorphic to the original space $\Re(x,g,R)$ for all positive-definite isounits $\hat{1}'$. Note the arbitrary nonlinearity in the *velocities* as well as the nonlocality and non-Lagrangian character from the unrestricted functional dependence of the isotopic element T'.

The physical relevance of the lifting $\Re(x,g,R) \rightarrow \hat{\Re}(x,\hat{g},\hat{R})$ is evident because

it permits, apparently for the first time, a direct representation within a fully gravitational context of the locally varying speed of light in interior conditions, or a more accurate study of "gravitational collapse", "black holes", "big bang" and all that [6].

As recalled in the introduction of note [7], the latter systems are not composed of ideal isolated points, but rather of extended hadrons in conditions of mutual penetration of their charge distributions/wavepackets/wavelengths in large numbers into small regions of space. Under these conditions, the lack of exact character of the local-differential Riemannian geometry, and the consequential need for a nonlocal-integral geometry is then beyond scientific doubts.

The aspect important for this note is that the interior nonlocal-integral isoriemannian spaces $\hat{\Re}(x,\hat{g},\hat{R})$ can themselves be reduced to an equivalent isominkowskian form via the decomposition

$$\hat{g}(x, \dot{x}, \ddot{x}, \ldots) = T_{\hat{g}}(x, \dot{x}, \ddot{x}, \ldots)\,\eta \equiv \hat{\eta}, \quad \hat{1}_g(x, \dot{x}, \ddot{x}, \ldots) = [\,T_{\hat{g}}(x, \dot{x}, \ddot{x}, \ldots)\,]^{-1}. \tag{2.11}$$

and the referral of the space to the isofield $\hat{R}(\hat{n},+,*)$ with interior gravitational isounit $\hat{1}_{\hat{g}}$.

In summary, we have the chain of isotopic equivalences

$$\hat{\Re}(x,\hat{g},R) \sim \hat{\Re}(x,\hat{g},\hat{R}) \sim \Re(x,g,R) \sim \hat{M}(x,\hat{\eta},\hat{R}) \sim M(x,\eta,R). \tag{2.12}$$

We can also say that the isominkowskian spaces unifies the Riemannian spaces as well as their most general possible nonlocal-integral generalizations for interior conditions, which all result to be equivalent to the conventional Minkowski space.

We therefore have the following:

Proposition 2.1: *The isounits* $\hat{1}$ *for the characterization of particles (matter) in the isominkowski space* $\hat{M}(x,\hat{\eta},\hat{R})$ *are the gravitational isounits.*

The above property implies that **for the exterior case in vacuum** the isounit $\hat{1}$ is the exterior gravitational isounit

$$\hat{1}_g(x) = [\,T_g(x)\,]^{-1}, \qquad g(x) = T_g(x)\,\eta; \tag{2.13}$$

while **for the interior case within physical media** the isounit $\hat{1}$ is the interior gravitational isounit

$$\hat{1}_{\hat{g}}(x, \dot{x}, \ddot{x}, \ldots) = [\,T_{\hat{g}}(x, \dot{x}, \ddot{x}, \ldots)\,]^{-1}, \quad \hat{g}(x, \dot{x}, \ddot{x}, \ldots) = T_{\hat{g}}(x, \dot{x}, \ddot{x}, \ldots)\,\eta, \tag{2.14}$$

(see [6] for details).

Corollary 2.1.A: *The isounits $(\hat{1}_s, \hat{1}_t)$ of the local space and time coordinates of particles (matter) can assume the values* $\hat{1}_\mu = (\hat{1}_{\mu\mu})^{1/2}$.

Since all interior conditions are generally tested in the outside, the interior isounits can be averaged into constants when studied from the outside. This point has important implications for the tests of Sect. 5.

As an example for the exterior case in vacuum, the assumption of Schwartzchild's geometry in spherical coordinates $((r, \theta, \phi), t)$ [3] implies the space- and time isounits in the equivalent isominkowskian formulation

$$\hat{1}_s = \{(1 - 2M/r)^{1/2}, 1, 1\}, \quad \hat{1}_t = (1 - 2M/r)^{-1/2}, \quad r > 2M, \qquad (2.15)$$

A similar occurrence evidently holds for other gravitational models in vacuum.

Recall the following notions from the preceding note [7]: 1) *particles*, which are represented with isospaces; 2) *antiparticles*, which are represented with isodual isospaces; and 3) *isoselfdual particles*, which are represented with the tensorial product of isospaces and their isoduals, thus being invariant under isoduality. The latter states are given by bound states of particles and their antiparticles such as the π° and have positive-definite (negative-definite) energy and time when represented in our (the isodual) space-time.

Consider now a particle and an isoselfdual particle in the absence of gravitational field as conventional represented in a Minkowski space $M(x,\eta,R)$ with unit $I = \text{diag.}(1, 1, 1, 1)$. When exposed to a gravitational field of matter, both the particle and the isoselfdual particle experience the conventional gravitational attraction under forward motion to future time.

The latter occurrence is conventionally represented via the generalization of the Minkowskian to the Riemannian space $\mathfrak{R}(x,g,R)$, namely, via the curvature $g(x) = T(x)$ under the same unit I.

In this note we have shown that the same numerical results can be obtained by generalizing the Minkowskian space into the isominkowskian form $\hat{M}(x,\hat{\eta},\hat{R})$, $\hat{\eta}(x) = T_g(x)\eta \equiv g(x)$, in which case there is no curvature, but the original unit is generalized to the form $\hat{1}_g(x) = [T_g(x)]^{-1}$. This implies that a particle and an isoselfdual particle, when immersed in a gravitational field, experience an alteration of their units of space and time given by (2.15).

The numerical identity of the representations of the same reality via Riemannian or isominkowskian spaces and the emergence of the isounits of space and time can also be seen via a direct transition from the coordinates in $\mathfrak{R}(x,g,R)$ to those in $\hat{M}(x,\hat{\eta},\hat{R})$. Recall that under isotopies we have no actual change of the numerical value of the Minkowskian separation because the deformation of a coordinate $I_\mu \to n_\mu^{-2}$ is compensated by the inverse deformation of the related unit $I_\mu \to n_\mu^2$. We can therefore write $(x^t\eta x)I \equiv (x'^t\hat{\eta}x')\hat{1}$, $x \in M$, $x' \in \hat{M}$. Consider now the coordinates x'' in a Riemannian space which is such to yield the numerical identity $(x^t\eta x)I \equiv (x''gx'')I$. We can then write the chains of identities

$$(x^t \eta x) I \equiv (x'^t \hat{\eta}(x') x')\hat{1} \equiv (x''^t g(x) x'') I, \qquad (2.16a)$$

$$x_{|\text{unit } I} \equiv x'_{|\text{unit } \hat{1} = [T(x)]^{-1/2}} \equiv x'' [T(x)]^{1/2}{}_{|\text{unit } I}. \qquad (2.16b)$$

This confirms the fundamental alternative of representing gravitation submitted in this note,m that via the change of the unit in the *Minkowski space*.

The corresponding interior situation is considerably beyond the elementary character of this note because gravitational models are now nonlinear in the velocities as well as nonlocal and non-Lagrangians. As such, the "space-time machine" will be studied below solely for the exterior case.

Note for future use the *physical necessity* of using the isospecial relativity (or some other formulation) for the representation of the local variation of the speed of light in flat interior conditions. By comparison, the isounits of exterior space and time and their dependence on the local gravitational field are a *mathematical possibility* offered by the isospecial relativity without experimental support at this writing.

3. ISODUAL ISOSPECIAL RELATIVITY

Another necessary element of the "space-time machine" submitted in this note is the *isodual isospecial relativity* for the characterization of antiparticles [5,6]. It is essentially the antiautomorphic image of the isospecial relativity under the conjugations

$$\hat{1} \to \hat{1}^d = -\hat{1}, \quad (\hat{1}_s, \hat{1}_t) \to (\hat{1}_s^d, \hat{1}_t^d) = (-\hat{1}_s - \hat{1}_t) \qquad (3.1a)$$

$$n_\mu^2 \to n_\mu^{2d} = -n_\mu^2, \quad n_\mu \to n_\mu^d = -n_\mu. \qquad (3.1b)$$

The isodual isospecial relativity is constructed over *isodual isofields* $\hat{R}^d(\hat{n}^d, +, \hat{\times}^d)$ with *isodual isonumbers* $\hat{n}^d = -\hat{n}$, and isodual isomultiplication $\hat{n}^d \hat{\times}^d \hat{m}^d = -\hat{n}\hat{\times}\hat{m}$ (see the preceding note [7] and references quoted therein). In particular, the *isodual isonorm is negative-definite*, $|\hat{n}^d|^d = |n|\hat{1}^d < 0$. This implies that *all physical quantities of the isodual isospecial relativity are negative definite*, that is, all physical characteristics generally assumed to be positive-definite for ordinary particles, such as energy, time, charge, etc., become negative-definite.

The isodual isospecial relativity is then constructed on the *isodual isominkowski space* $\hat{M}^d(x,\hat{\eta}^d,\hat{R}^d)$ which is the antiautomorphic image of $\hat{M}(x,\hat{\eta},\hat{R})$ under maps (3.1). In particular, the *isodual isoseparation* is given by [6] (see also the recent article [9])

$$x^{\hat{2}d} = (-x\,n_1^{-2}x - y\,n_2^{-2}y - z\,n_3^{-2}z + t\,c_0^2\,n_4^{-2}t)\hat{1}^d \in \hat{R}^d < 0\,. \quad (3.2)$$

Note that *the isodual separation coincides with the isotopic one,* $x^{\hat{2}d} \equiv x^{\hat{2}}$. A property of isodualities with fundamental significance for the causality of the "space-time machine" proposed in this note is that *all separations, whether conventional or isotopic, are invariant under isoduality* [6] (see also the preceding note [7]).

To be more specific on this crucial point, the isodual isominkowski space $\hat{M}^d(x,\hat{\eta}^d,\hat{R}^d)$ contains as particular case the *isodual Minkowski space* $M^d(x,\eta^d,R^d)$, $\eta^d = -\eta$, $I^d = -I$. The conventional time-like condition (1.1) can be *identically* reinterpreted as expressing the isodual time-like separation,

$$(xx + yy + zz - t\,c_0^2\,t)\,I \equiv (-xx - yy - zz + t\,c_0^2\,t)\,I^d < 0\,. \quad (3.3)$$

Note that, despite the internal changes of signs, the latter separation is still *time-like* because referred to negative-definite units.

This implies that we have no theoretical or experimental way of establishing whether a given *conventional* separation holds for motion forward in time and unit +1, or motion backward in time and unit −1, because these two separations coincide when properly written in their respective spaces.

Exactly the same situation occurs under isotopies and we shall write

$$(x\,n_1^{-2}x + y\,n_2^{-2}y + z\,n_3^{-2}z - t\,c^2\,t)\hat{1}^d \equiv$$

$$\equiv (-x\,n_1^{-2}x - y\,n_2^{-2}y - z\,n_3^{-2}z + t\,c^2\,t)\hat{1}^d < 0\,.\ c = c_0 / n_4\,. \quad (3.4)$$

Identities (3.3) and (3.4) then resolve known causality arguments against motion backward in time. To be specific, conventional objections against motion backward in time are inapplicable under isodualities because they would imply *exactly the same causality problems* for motion forward in time. In the final analysis, one should remembers that a negative time $t^d = -t$ referred to a negative unit −1 is fully equivalent to our conventional positive time t referred to the positive unit +1.

Isodualities also apply to gravitational studies via isoriemannian spaces, thus implying the identical reformulation of their metrics in terms of isodual

isominkowski spaces (see [6] for brevity).

We therefore have the following

Proposition 3.1: *The isodual isounits* $\hat{1}^d$ *for the characterization of antiparticles (antimatter) in isodual isominkowski spaces* $\hat{M}^d(x,\eta^d,\hat{R}^d)$ *are the isodual gravitational isounits.*

The above property implies the *isodual isounits for the exterior problem* $\hat{1}_g^{\,d}(x) = -\hat{1}_g(x)$ and the *isodual isounits for the interior problem* $\hat{1}_{\hat{g}}^{\,d}(x, \dot{x}, \ddot{x}, \ldots) = -\hat{1}_{\hat{g}}(x, \dot{x}, \ddot{x}, \ldots)$ [5,6].

Corollary 3.1.A: *The isodual isounits* $(\hat{1}_s^{\,d}, \hat{1}_t^{\,d}) = (-\hat{1}_s, -\hat{1}_t)$ *of the local space and time coordinates of antiparticles (antimatter) assume the values* $\hat{1}_\mu^{\,d} = -(\hat{1}_{\mu\mu})^{1/2}$.

As an example for the exterior case in vacuum, the assumption of the *isodual Schwartzchild's geometry* in spherical coordinates ((r,θ, φ), t) [6] implies the space and time isodual isounits

$$\hat{1}_s^{\,d} = -\left((1 - 2M/r)^{1/2}, 1, 1\right), \quad \hat{1}_t^{\,d} = -(1 - 2M/r)^{-1/2}, \quad r > 2M, \quad (3.5)$$

This implies that, when immersed in the gravitational field of antimatter, an antiparticle or an isoselfdual particle have isounits of space and time of type (3.5). Note also that an isoselfdual particle can reverse the sign of its time evolution via merely passing from the field of matter to that of antimatter.

Note that, in our notation, the space and time coordinates do not change under isoduality. Only their units change sign.

Needless to say, there exist a rather vast literature on negative energy and negative time and their interpretation for the characterization of antiparticles. We here bring to the reader's attention the systematic studies by E. Recami in Minkowski space [10a] and those by Italiano [10b] on a Riemannian space.

The latter studies have essentially shown that the *joint* use of negatives energies and negative times is sufficient to provide a physically consistent interpretation of antiparticles when defined on *a convention al Minkowski space* M(x,η,R) over *a conventional field of numbers* R(n,+,×) in which the fundamental units are positive-definite.

The sole novelty of the studies of this note is that physical consistency for antiparticles is achieved by defining negative energies and negative times on an *isodual Minkowski space* $M^d(x,\eta^d,R^d)$ over an *isodual field of numbers* $R^d(n^d,+,\times^d)$ in which the fundamental units are negative-definite.

4. PROPOSED "SPACE–TIME MACHINE"

Our main idea of the "space–time machine" is its conception via motion in isospace and isotime, rather than in conventional space and time. In fact, as shown in the preceding sections, ordinary units of space and time $(1_s, 1_t)$ are universal, while the corresponding isounits $(\hat{1}_s, \hat{1}_t)$ can be altered in value by a sufficient gravitational field of matter, and can then be reversed in sign via the field of antimatter.

The most elementary form of the ensuing "space–time machines" can be formulated as follows:

BASIC HYPOTHESIS: The "space-time machine" here submitted consists of an isoselfdual particle such as the π° which:

STEP 1: Starts at a given space-time point P;

STEP 2: Is immersed in a sufficiently intense gravitational field of antimatter which causes motion in space as well as motion backward in time, and then

STEP 3: Is immersed in a gravitational field of matter in a location and with intensity such to permit the return to the original space-time point P via motion forward in time.

As one can see, the above sequence is a consequence of the isospecial relativity and its isodual in their *exterior* formulation unifying the special and general relativities, i.e., representing the gravitational field in the isounit (see Figure 1).

Note also the preservation of the causal time–like condition throughout the entire process,

$$\text{Step 1: } (x\,x + y\,y + z\,z - t\,c_0^2\,t)(+1) < 0,$$
$$\text{Step 2: } (-x\,n_1^{-2}x - y\,n_2^{-2}y - z\,n_3^{-2}z + t\,c_0^2\,n_4^{-2}\,t)\hat{1}^d < 0, \qquad (4.1)$$
$$\text{Step 3: } (x\,n_1^{-2}x + y\,n_2^{-2}y + z\,n_3^{-2}z - t\,c_0^2\,n_4^{-2}\,t)\hat{1} < 0.$$

To put it clearly, the Einsteinian axioms are preserved in their entirety throughout the complete loop and only realized in different forms. Note also the preservation of causality, specifically, during the motion backward in time, evidently because referred to a negative isounit of time.

Note that the above "space–time machine" implies the gravitational attraction for both fields of matter and antimatter, owing to the use of an isoselfdual test particle, in which case we only have the reversal of the sign of

time.

More general realizations of the "space–time machine" via the use of a particle or an antiparticle and the reversal of both gravitation and time will be studied in some future paper.

A SCHEMATIC VIEW OF THE PROPOSED "SPACE–TIME MACHINE"

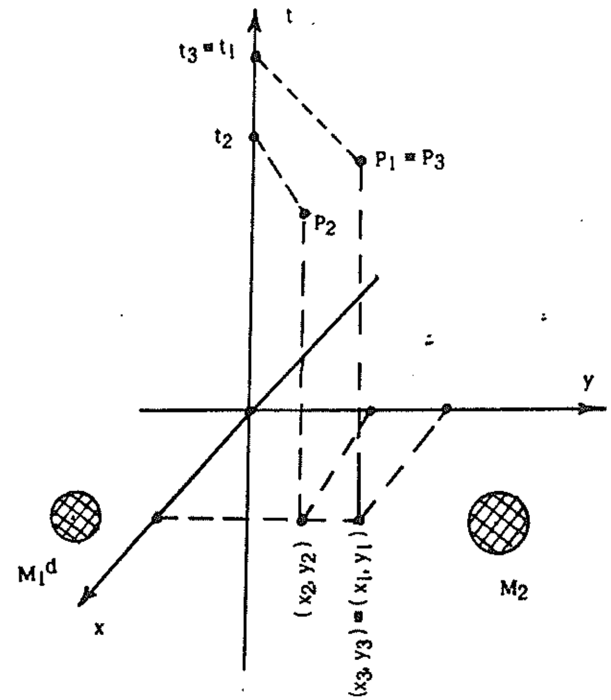

FIGURE 1: A schematic view of the simplest possible version of the proposed "space–time machine" via a neutral particle such as the π° which is expected to move back in time when immersed in the gravitational field of antimatterM_1^d and then return to the original time via immersion in the gravitational field of matter M_2. In this simplest possible case motion in space is attractive under both fields because the π° is isoselfdual.

5. EXPERIMENTAL VERIFICATIONS

The first fundamental experimental question raised in this note is *whether we evolve in conventional time or in isotime.*

Stated in different terms, the question is whether the units of space and time (I_s, I_t) are universal all over the Universe, or they have the isotopic structure $(\hat{1}_s, \hat{1}_t)$ with a functional dependence on the local gravitational field, e.g., as in Eq.s (2.15).

Note that, by no means, the possible experimental disproof of the latter case would invalidate the isotopic theories. In fact, it would merely establish that the *physical description* of gravitation is that in a curved space with universal units (I_s, I_t), while the equivalent formulation in isominkowski space is merely a *mathematical description.*

Similarly, the possible experimental verification of the local character of the space and time units cannot possibly disprove the Riemannian description of gravitation, because such description would remain fully valid on mathematical grounds.

In different terms, the first fundamental experimental question raised in this note is: *which of the two possible identical representations of gravitation, the Riemannian and the isominkowskian representation, is the physical one.*

The possible argument that the latter case is not confirmed by available experimental data in gravitation would miss the point. In fact, such data cannot possibly have a bearing on their own units.

The second fundamental experimental question raised in this note is *whether antiparticles evolve in conventional time, as currently believed, or they evolve in isodual isotime.*

The third fundamental question needed for the "space–time machine" is that raised in the preceding note [7], namely, *whether a particle (antiparticle) in the gravitational field of antimatter (matter) experiences a repulsion or an attraction.* Specific experiments for the resolution of this latter question has been submitted at the end of note [7]. In this note we shall therefore consider only possible tests for the first two issues.

To illustrate the first issue, suppose that we do evolve according to isotime. This would have no visible consequences here on Earth, and only imply that the quantity $\hat{1}_t$ has been scaled to 1sec, the quantity $\hat{1}_s$ has been scaled to 1cm, while the spherical symmetry of Earth implies the identity of the space isounits along different space axis. However, under the same isounits, deviations would exist in our time evolution at sufficient distance from Earth, as illustrated by the Schwartzchild case (2.15).

Equivalently, one note that at sufficient large distance from Earth, both the space and time isounits (2.15) have the conventional value 1,

$$\mathrm{Lim}_{r\to\infty}\, \hat{1}_t = \mathrm{Lim}_{r\to\infty} (1 - 2M/r)^{-1/2} =$$

$$= \mathrm{Lim}_{r\to\infty}\, \hat{1}_s = \mathrm{Lim}_{r\to\infty} (1 - 2M/r)^{1/2} = 1 . \qquad (5.1)$$

which essentially implies that isospace and isotime coincide with conventional space and time, respectively, or that Riemannian and Minkowskian descriptions coincide in empty space, as expected.

Note that, besides a dependence on the distance from a gravitational field, the isounits also show a perhaps more important dependence on the intensity of the gravitational field itself, e.g., on the mass M.

The issue whether we evolve in conventional, time or in isotime can therefore be resolved with currently feasible experiments in a variety of ways, e.g., via the following:

Proposed experiment: *Beginning with two synchronous clocks on Earth, send one of them via an interplanetary probe in the Jovian upper atmosphere and verify whether or not such a synchronous character is preserved.*

By recalling the difference in mass between Earth and Jupiter, the comparison should last for a period of time of the order of weeks, which would in turn require the probe to be equipped with suitable floating devices to remain in the upper Jovian atmosphere (for better communications with Earth) which are also feasible with current technology.

Note that the possible measure of a difference in time would be of particular value to resolve the problematic aspects underlying the Schwartzchild metric because of its derivation from the controversial sourceless character of Einstein's gravitation in vacuum [6].

Note finally that the formulation of independent tests on the possible isounit of space are considerably more involved and they will be studied at a future time.

The experiment proposed above (or numerous other which can be similarly formulated) would resolve the first assumption of our "space–time machine", the possibility of altering the unit of time via a sufficiently intense gravitational field. The experimental verification of the second question, the reversal of the sign of time, will be considered later on.

It is intriguing to note that there exist a number of indirect experimental measures in particle physics supporting the apparent change of the isounit of time. These verifications essentially deal with the deformation of the Minkowskian space–time expected in the *interior* of hadrons from the conditions of total mutual penetration and overlapping of the wavepackets of the constituents [6]. This results in the densest known nonlinear–nonlocal–nonhamiltonian conditions with evident geometric departures from empty space. The applicability of the isominkowskian geometrization then follows from its direct universality [8] mentioned in Sect. 2. The emergence of the isounits of space and time is then unavoidable in these studies as shown below.

One should keep in mind that in all particle experiments considered below, the interior structure is evidently studied from the outside in empty space-time. This requires the averaging of the interior isounits to constants as indicated in Sect. 2.

The first proposals for the internal nonlocality of hadrons can be traced back to Blochintsev [11] who conjectured that such internal nonlocality could manifest itself via a deviation from the behaviour of the meanlife of unstable hadrons with speed, with the understanding that its center-of-mass behaviour is fully Einsteinian.

These lines were studies also by other authors, such as Redei [12], Kim [13] and others. All these authors essentially identified different generalizations of time dilation (2.1) with nonlinear terms. The advent of the isospecial relativity unified all these possible different laws into the unique isolaw (2.5b), with evident facilitation of the experimental task.

The first phenomenological verification was provided by Nielsen and Picek [14] who computed deviations from the Minkowskian geometry inside pions and kaons via standard gauge models in the Higgs sector. These phenomenological studies resulted in a deformed Minkowski metric inside pions and kaons of the type

$$\hat{\eta} = \text{diag.}\,\{ (1-\alpha/3), (1-\alpha/3), (1-\alpha/3), -(1-\alpha) \}, \quad (5.2)$$

which is precisely of the isominkowskian type with numerical values

$$\text{PIONS } \pi^{\pm}: \; n_1^{-2} = n_2^{-2} = n_3^{-2} \cong 1 + 1.2\times 10^{-3},\; n_4^{-2} \cong 1 - 3.79\times 10^{-3}, \quad (5.3a)$$

$$\text{KAONS } K^{\pm}: \; n_1^{-2} = n_2^{-2} = n_3^{-2} \cong 1 - 2\times 10^{-4},\; n_4^{-2} \cong 1 + 6.1\times 10^{-4}. \quad (5.3b)$$

A study of the above data via the isominkowskian geometry [6] indicates that the preservation of the original Einsteinian axioms for the deformed metric requires the necessary change of the conventional time t into the isotime $\hat{t} = t\hat{1}_t$ with numerical value of the time isounit for the pions

$$\hat{1}_t(\pi^-) \approx 1.0004. \quad (5.4)$$

The transition to the antiparticle then implies the negative isounit of time

$$\hat{1}^d_t(\pi^-) = \hat{1}_t(\pi^+) \approx -1.0004. \quad (5.5)$$

Note that the preservation of the conventional notion of time for data (5.3) is faced with rather serious problems of consistency. To begin, such preservation implies the adoption of interior hadronic conditions structurally incompatible with the Einsteinian axioms, as evident from the deformed Minkowskian metric (5.2). Assuming that new axioms replacing those of the special relativity are identified and, after that, proved to be experimentally valid, one would still remain with the "discontinuity at the boundary", that is, the discontinuity in the transition from the exact Einsteinian axioms in the outside of the particles to structurally different axioms in the inside.

The isominkowskian geometrization resolves these problems. In fact, it permits the Einsteinian axioms to be valid everywhere in space-time, and only being subject to different *realizations* for the interior and exterior dynamics. This permits a unity of physical and mathematical thought for the interior and exterior problems as well as a smooth continuity in the transition from the interior to the exterior problem. The generalization of the unit of time is an evident necessary pre-requisite for such unity.

The first direct experimental verification of deviations from the Einsteinian behaviour of the meanlife of unstable particles with speed was reached by Aronson et al. [15] who measured a noneinsteinian behaviour of the meanlife of the K° in the energy range 30-100 GeV. Subsequent experiments conducted by Grossman et al. [16] confirmed the Einsteinian behaviour of the meanlife of the same particle in the *different* energy range 100-350 GeV, although tests [16] are based on a number of questionable theoretical assumptions, such as a frame in which there is no PC violation while the asymmetry in time behaviour is known to be *dependent* on the PC asymmetry [13].

Assuming that measures (16] will pass the test of time, the seemingly discordant experimental measures [15,16] were proved to be unified by the isominkowskian geometrization of the K°-particle by Cardone et al. [17] via phenomenological plots in the range 30-350 GeV resulting in the following experimental values for the characteristic n-quantities

$$n_1^{-2} = n_2^{-2} = n_3^{-2} \approx 0.909080 \pm 0.0004, \qquad n_4^{-2} \approx 1.002 \pm 0.007, \quad (5.6a)$$

$$\Delta n_k^{-2} \cong 0.007, \qquad \Delta n_4^{-2} \cong 0.001, \quad (5.6b)$$

which are of the same order of magnitude of values (5.3b).

Measures (5.6b) also confirm the prediction of the isominkowskian geometry in the range 30-350 GeV that the n_4 quantity is a geometrization of the density, and therefore it is constant for the particle considered (although varying from hadron to hadron with the density), while the dependence in the velocities rests with the n_k-quantities.

A reinspection of the results of plots [17] conducted in [6] has shown that data (5.6a) also imply the redefinition of the time for the K° particle into the isotime $\hat{t}$ with value

$$\hat{1}_t(\text{kaons}) \approx 0.998 \qquad (5.7)$$

ISOMINKOWSKIAN BEHAVIOUR OF THE MEANLIFE OF THE K° PARTICLE WITH SPEED

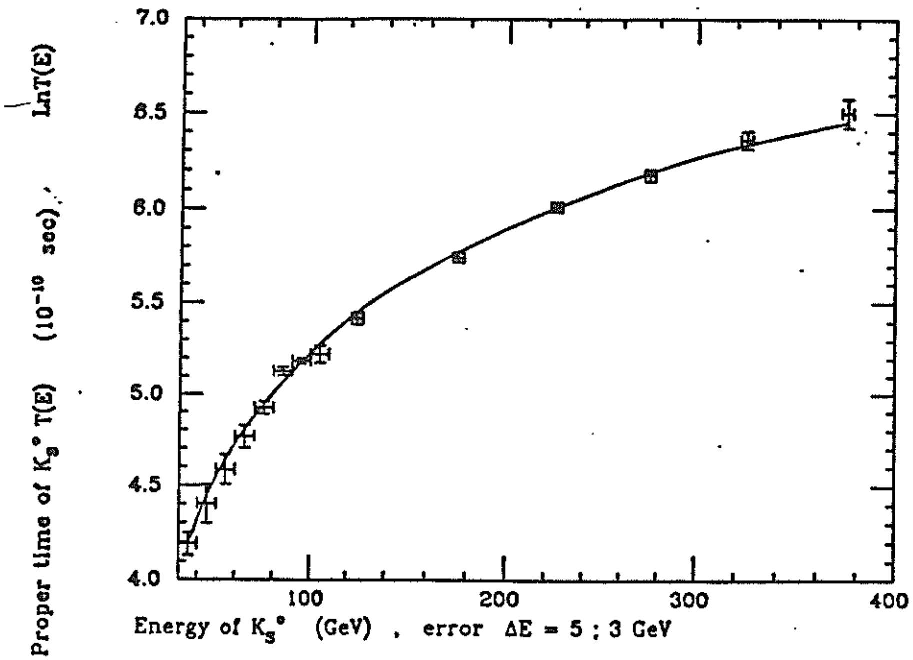

FIGURE 2: This figure presents a verification of the isotopic law (2.5b) on the time dilation in particle physics via a joint fit of the seemingly different data [15] and [16] done in ref. [17].

Note the change of the numerical value of the isounit in the transition from pions to kaons which provides preliminary confirmation of the apparent dependence of time from the local interior conditions of density, temperature,

etc.

A fundamental assumption of the isospecial relativity is the nonlocal-integral character of the interior problem. The most fundamental verifications are therefore those testing such nonlocal structure of matter, evidently because it mandates a suitable generalization of both the special and general relativity, i.e., a nonlocal-integral generalization of the local-differential Minkowskian and Riemannian geometries.

Among all possible experimental verifications in particle physics of this class, those most direct are the tests of the *Bose-Einstein correlation*. We are here referring to the collision of protons and antiproton at very high energy, their annihilation (forming the so-called *fireball*), and the subsequent emission of a number of unstable massive particles whose final product is a set of correlated pions.

A number of direct and indirect arguments (see [18] for brevity) points toward the fact that such correlation is ultimately due to the nonlocal-integral effects expected in the deep mutual penetration of the charge-distributions of the proton and antiproton. At any rate, there is a general agreement on the fact that no correlation is possible for particles in strict local-differential, point-like approximation.

The experimental verification of the nonlocal nature of the Bose-Einstein correlation is therefore of clear fundamental character, not only for particle physics (because it implies a necessary generalization of quantum mechanics owing to its local-differential character), but also of gravitation, cosmology and other fields.

It is rewarding for this author to report that studies in this field appear to confirm, not only the ultimate nonlocality of the structure of matter, but also the effectiveness of the Isospecial relativity and related isominkowskian spaces. In fact, theoretical studies conducted by this author [18] with isorelativistic operator methods for the interior of the p-$\bar{p}$ fireball result in the two-point Boson isocorrelation function on $\hat{M}(x,\hat{\eta},\hat{R})$ [18, Equation (10.8), p. 122]

$$\hat{C}_{(2)} = 1 + \frac{K^2}{3}\sum_\mu \hat{\eta}_{\mu\mu}\,(e^{-q_t^2 n_\mu^{-2}}, \quad \hat{\eta} = \text{Diag.}\,(n_1^{-2}, n_2^{-2}, n_3^{-2}, -n_4^{-2}), \qquad (5.8)$$

where q_t is the momentum transfer and the term $K = n_1^{-2} + n_2^{-2} + n_3^{-2}$ is normalized to 3.

The above results are achieved from first isotopic axioms under the sole approximation (also assumed in conventional treatments) that the longitudinal and fourth components of the momentum transfer are very small [6,15].

The comparison of isobehaviour (5.8) with experimental data was conducted by Cardone and Mignani [19] via the UA1 data at CERN with results beyond the best expectations of this author, as reported in Figure 3. In particular, studies [19] resulted in the following experimental values of the characteristic n-quantities for densities of the order of that of the p-$\bar{p}$ fireball

$$n_1^{-1} = 0.267 \pm 0.054, \qquad n_2^{-1} = 0.437 \pm 0.035, \tag{5.9a}$$

$$n_3^{-1} = 1.661 \pm 0.013, \qquad n_4^{-1} = 1.653 \pm 0.015. \tag{5.9b}$$

ISOMINKOWSKIAN BEHAVIOUR OF THE BOSE-EINSTEIN CORRELATION

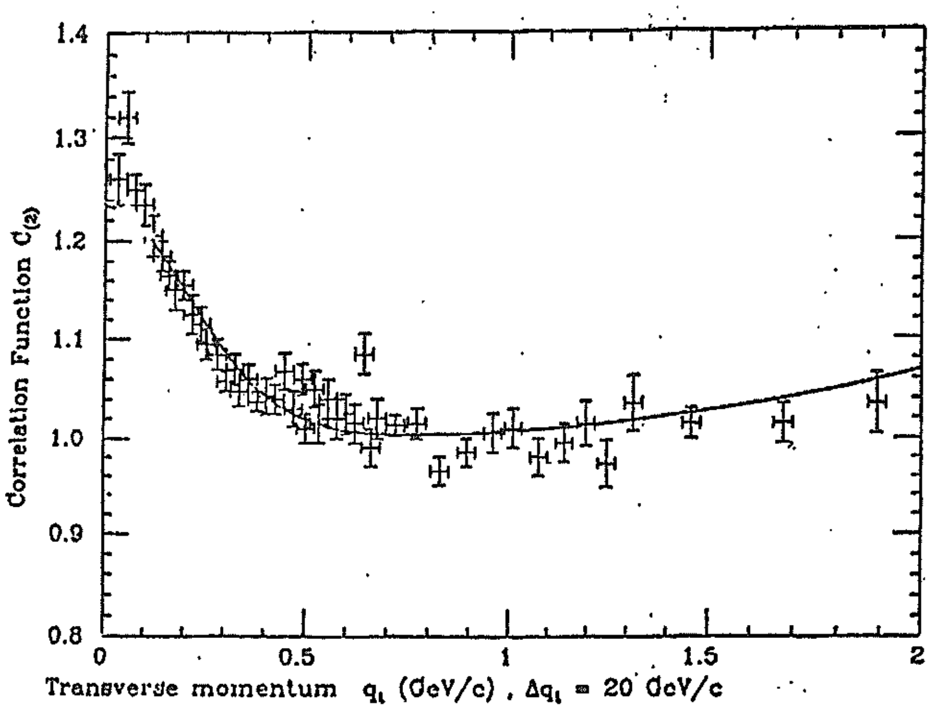

FIGURE 3: A reproduction of the fit of the two-point isocorrelation function (5.8) of [18] done in [19] with the experimental data on the Bose-Einstein correlation from the UA1 experiments at CERN. As one can see, the fit is a clear confirmation of the isominkowskian character of the event. The fit reproduced in this figure may well result to be, in due time, the first experimental evidence on the ultimate nonlocality of the

structure of the Universe, with consequential needs for a suitable generalization of contemporary local-differential geometries, relativities and mechanics.

It is easy to see that the treatment of the Bose-Einstein correlation along the lines indicated earlier (preservation of the abstract Einsteinian axioms, smooth connection between interior and exterior problems, etc.) requires a necessary transition in the interior of the fireball from the conventional time t to the isotime $\hat{t}$ with isounit for all hadrons with a density of the order of that of the proton, which is introduced in this paper apparently for the first time

$$\hat{1}_t(p^+) \approx 0.429, \tag{5.10}$$

with related value for the antiparticle

$$\hat{1}^d(p^-) \approx -0429. \tag{5.11}$$

Annihilation of proton-antiproton and related fireball result precisely from the opposite character of the evolution of time of the two particles according to a rather old hypothesis.

Other *indirect* verifications of the relativity of the unit of time exist in astrophysics, nuclear physics, superconductivity, and other fields. They are not reported here for brevity (see [6] for details).

The above experimental information regards the apparent verification of the isounit of *time* via different values for different particles. In regard to possible verifications of the isounit of *space* we outline below one in the least expected field, that of conchology. In essence studies conducted by Illert [20] have established that that sea shells with a minimum of complexity (e.g., one bifurcation) crack during their growth if assumed to strictly obey the axioms of conventional geometries, that is, of strictly having the trivial unit +1. This author then showed in [9] that sea shells grow normally when considered in the covering isogeometry, that is, when possessing a generalized unit of space $\hat{1}_s$.

Sea shell growth is best studied via discrete mathematics owing to their typical growth in small finite increments $\Delta\xi$. Quantitative mathematical studies conducted by Illert [loc. cit.] indicate that such growth can be represented via a Lagrangian of the type

$$L = \tfrac{1}{2} K_1 \frac{\Delta\xi}{\Delta t} \cdot \frac{\Delta\xi}{\Delta t} + \tfrac{1}{2} K_2 \Delta\xi \cdot \Delta\xi, \tag{5.12}$$

where K_1 and K_2 are constants. The intriguing property is that the shells crack if the scalar product in the above Lagrangian is that of the Euclidean space, while the growth is normal if the *same* Lagrangian is written in isoeuclidean space $\hat{E}(r,\hat{\delta},\hat{R})$ with $\hat{\delta} = T\delta$, $\delta = \text{diag.}(1, 1, 1)$ [9]

$$L = \tfrac{1}{2} K_1 \frac{\Delta\xi}{\Delta t} \hat{\times} \frac{\Delta\xi}{\Delta t} + \tfrac{1}{2} K_2 \Delta\xi \hat{\times} \Delta\xi, \qquad \hat{1} = K_3 e^{-\Omega(\phi)} = T^{-1}, \qquad (5.13)$$

where $A \hat{\times} B = ATB$ and $\Omega(\phi)$ is a function of the characteristic spiral angle ϕ varying from shell to shell [20].

But this is only the beginning of the fascinating properties of the evolution of sea shells. In fact, such evolution provides an apparent first realization of the "time machine" (but not of the "space-time machine" along the lines of this note.

ISOEUCLIDEAN GROWTH OF SEA SHELLS

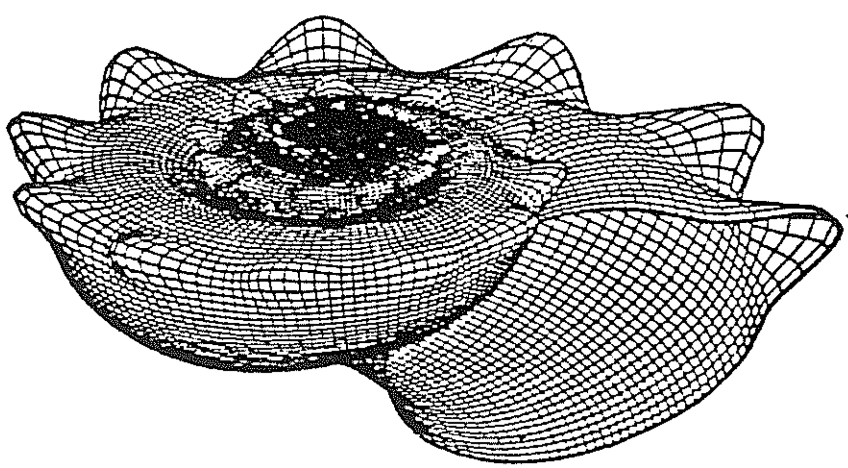

FIGURE 4: A computer simulation of the growth of an *Angaria Delphinius* from Illert [20, p. 64] based on a generalized unit $\hat{1} = K^{-1}{}_3\exp[-\Omega(\phi)]$ where ϕ is the characteristic angle of the basic spiral. Illert's analytic results are reinterpreted in [9] as being characterized by a new geometry of the isotopic type. This implies the far reaching possibility that, to our perception, sea shells *appear* to evolve in our Euclidean space, while in reality they evolve in a more general space. Note that the generalization does not implies changes in dimension or in curvature, but a deeper generalization in the very structure of the geometry.

Deeper topological studies indicate an apparent reversal of the direction of time at bifurcations [20]. More specifically, no quantitative interpretation of the growth at bifurcations is possible without three contributions: (1) a normal evolution forward in our time, (2) a forward evolution in future time, and (3) an evolution backward from future time (see Illert [20, p. 95].

The representation of this behaviour is quantitatively possible by assuming that [9] *sea shells evolve in an isotime of Class* III (union of positive and negative times). In different terms, it is not sufficient to assume a numerical value of the unit $\hat{1}$ different than the trivial number 1. It is necessary instead that the isounit has a structure with an appropriate functional dependence on time to permit the above indicated three contributions without loss of continuity.

SEA SHELLS AS A REALIZATION OF THE "TIME MACHINE"

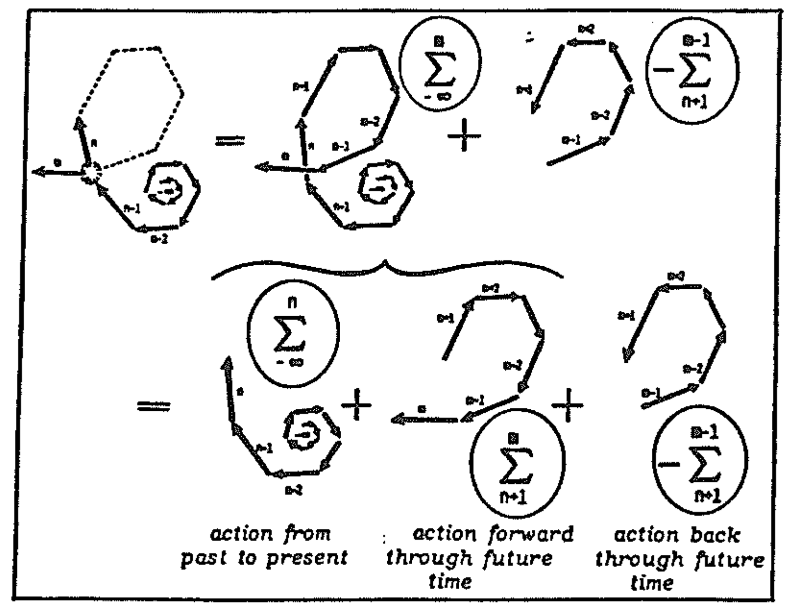

FIGURE 5: A reproduction of the table from Illert's [20, p. 95] showing the three contributions which are necessary for a quantitative representation of the growth of sea shells at bifurcations. The interpretation in Euclidean, Minkowskian or Riemannian spaces would evidently be discontinuous. At any rate, conventional spaces lack the necessary

technical means for the description of motion backward in time. The same description is instead smooth under an isotopic generalization of the unit of time [9]. As a result, *sea shells do constitute one form of the "time machines" proposed in this paper.* In reality, the latter has been submitted by this author after the identification and along the characteristics of the former.

Sea shells evolution therefore appear to be one (among several possible) explicit realization of the "time machine" already existing in our environment.

Note that particles or antiparticles appear to master only *one* direction of time. On the contrary, it appears that sea shells have the capability of mastering *both* directions of time in a rather complex, joint way.

We can therefore conclude this note by saying that, despite majestic advances occurred during this century, our knowledge of space and time is only at its first infancy.

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