Chapter 13

ANTIGRAVITY AND SPACETIME MACHINES

13.1 THEORETICAL PREDICTIONS OF ANTIGRAVITY

13.1.1 Introduction

Antigravity is one of the most ancient dreams of mankind, that has stimulated the imagination of many researchers, from various engineering fields (see, e.g., Refs. [1,2] that also list patents), to the most advanced branches of physics (see the prediction of antigravity in supergravity theories [3,4] and proceedings [5] for other more recent approaches).

A comprehensive study of antigravity was conducted by the author in monograph [30]. In this chapter we essentially present an update of the content of Ref. [30].

An experiment on the gravity of antiparticles was considered by Fairbank and Witteborn [6] via low energy positrons in vertical motion. Unfortunately, the measurements could not conclusive because of interferences from stray fields, excessive upward kinetic energy of the positrons and other reasons.

Additional data on the gravity of antiparticles are those from the LEAR machine on antiprotons at CERN [7], although these data too are inconclusive because of the excessive energy of the antiprotons and other factors, including the care necessary to extend the gravity of antiprotons to all antiparticles pointed out in Chapter 2, the proved impossibility for quarks to experience gravity, let alone antigravity, and other factors.

Additional experiments on the gravity of antiparticles are based on neutron interferometry, such as the experiments by Testera [8], Poggiani [9] and others. These experiments are extremely sensitive and, as such, definite and conclusive results continue to be elusive. In particular, the latter experiments too deal with antiprotons, thus inheriting the ambiguities of quark conjectures with respect to gravity, problems in the extension to other antiparticles, and other open issues.

All further data on the gravity of antiparticles known to this author are of indirect nature, e.g., via arguments based the equivalence principle (see, e.g., Ref. [10] and papers quoted therein). Note that the latter arguments do not apply under isoduality and will not be considered further.

A review on the status of our knowledge prior to isodual theories is available in Ref. [11], that includes an outline of the arguments against antigravity, such as those by Morrison, Schiff and Good. As we shall see, the latter arguments too cannon even be formulated under isodualities, let alone be valid.

We can therefore conclude by stating that at this writing there exists no experimental or theoretical evidence known to this author that is resolutory and conclusive either against or in favor of antigravity.

One of the most intriguing predictions of isoduality is the existence of *antigravity* conceived as a reversal of the gravitational attraction, first theoretically submitted by Santilli in Ref. [12] of 1994.

The proposal consists of an experiment that is feasible with current technologies and permits a definite and final resolution on the existence or lack of the existence of the above defined antigravity.

These goals were achieved by proposing the test of the gravity of positrons in horizontal flight on a vacuum tube. The experiment is resolutory because, for the case of a 10 m long tube and very low kinetic energy of the positrons (of the order of μeV), the displacement of the positrons due to gravity is sufficiently large to be visible on a scintillator to the naked eye.

Santilli's proposal [12] was studied by the experimentalist Mills [13] to be indeed feasible with current technology, resolutory and conclusive.

The reader should be aware from these introductory lines that *the prediction of antigravity exists, specifically, for the isodual theory of antimatter and not for conventional treatment of antiparticles.*

For instance, no prediction of antigravity can be obtained from Dirac's hole theory or, more generally, for the treatment of antimatter prior to isoduality, that solely occurring in second quantization.

Consequently, antigravity can safely stated to be the ultimate test of the isodual theory of antimatter.

In this chapter, we study the prediction of antigravity under various profiles, we review the proposed resolutory experiment, and we outline some of the far reaching implications that would follow from the possible experimental verification of antigravity, such as the consequential existence of a fully *Causal Time Machine,* although not for ordinary matter, but for an isoselfdual combination of matter and antimatter.

13.1.2 Newtonian and Euclidean Prediction of Antigravity

It is important to show that the prediction of antigravity can be first formulated at the most primitive possible level, that of Newtonian mechanics and its isodual. All subsequent formulations will be merely consequential.

The current theoretical scene on antigravity is dominated by the fact that, as it is well known, the Euclidean, Minkowskian and Riemannian geometries offer no realistic possibility to reverse the sign of a gravitational mass or of the energy of the gravitational field.

Under these conditions, existing theories can at best predict a decrease of the gravitational force of antiparticles in the field of matter (see Ref. [11] for a review of these conventional studies). In any case the decreased interaction, as such, remains attractive.

Isodual mathematical and physical theories alter this scientific scene. In fact, antigravity is predicted by the interplay between the classical Euclidean geometry and its isodual. The resulting prediction of antigravity persists at all levels, that is, for flat and curved spaces and for classical or quantum formulations, in a fully consistent way without known internal contradictions.

Also, antigravity is a simple consequence of Corollary 2.3.1 according to which the observed trajectories of antiparticles under a magnetic field are the *projection* in our spacetime of inverted trajectories in isodual spacetime.

Once these aspects are understood, the prediction of antigravity becomes so simple to appear trivial. In fact, antigravity merely originates from the projection of the gravitational field of matter in that of antimatter and vice-versa. We therefore have the following:

PREDICTION 13.1.1 [11,15]: *The existence of antigravity, defined as a gravitational repulsion experienced by isodual elementary particles in the field of matter and vice-versa, is a necessary consequence of a consistent classical description of antimatter.*

Let us begin by studying this prediction in Euclidean and isodual Euclidean spaces. Consider the Newtonian gravitational force of two conventional (thus, positive) masses m_1 and m_2

$$F = -G \times m_1 \times m_2 / r < 0, \quad G, m_1, m_2 > 0, \tag{13.1.1}$$

where G is the gravitational constant and the minus sign has been used for similarity with the Coulomb law.

Within the context of conventional theories, the masses m_1 and m_2 remain positive irrespective of whether referred to a particle or an antiparticle. This yields the well known "universal law of Newtonian attraction", namely, the prediction that the gravitational force is attractive irrespective of whether for particle-particle, antiparticle-antiparticle or particle-antiparticle.

Again, the origin of this prediction rests in the assumption that antiparticles exist in our spacetime, thus having positive masses, energy and time. Under isoduality the situation is different. For the case of antiparticle-antiparticle under isoduality we have the different law

$$F^d = -G^d \times^d m_1^d \times^d m_2^d /^d r^d > 0, \quad G^d, m_1^d, m_2^d < 0. \qquad (13.1.2)$$

But this force exists in the different isodual space and is defined with respect to the negative unit -1. Therefore, isoduality correctly represents the *attractive* character of the gravitational force between two isodual particles.

The case of particle-antiparticle under isoduality requires the *projection* of the isodual particle in the space of the particle (or vice versa), and we have the law

$$F = -G \times m_1 \times m_2^d / r > 0, \qquad (13.1.3)$$

that now represents a *repulsion,* because it exists in our spacetime with unit $+1$, and it is opposite to force (13.1.1). This illustrates antigravity as per Prediction 13.1.1 when treated at the primitive Newtonian level.

Similarly, if we project the particle in the spacetime of the antiparticle, we have the different law

$$F^d = -G^d \times^d m_1^d \times^d m_2 /^d r^d < 0, \qquad (13.1.4)$$

that also represents *repulsion* because referred to the unit -1.

We can summarize the above results by saying that *the classical representation of antiparticles via isoduality renders gravitational interactions equivalent to the electromagnetic ones, in the sense that the Newtonian gravitational law becomes equivalent to the Coulomb law, thus necessarily including both attraction and repulsions.*

The restriction in Prediction 13.1.1 to “elementary” isodual particles will soon turn out to be crucial in separating science from its political conduct, and *de facto* restricts the experimental verification of antigravity to positrons in the field of Earth.

Note also that Prediction 13.1.1 is formulated for “isodual particles” and *not* for antiparticles. This is due to the fact indicated in preceding sections that, according to current terminologies, antiparticles are defined in our spacetime and have positive masses, energy and time. As such, no antigravity of any type is possible for antiparticles as conventionally understood.

13.1.3 Minkowskian and Riemannian Predictions of Antigravity

It is important to verify the above prediction at the classical relativistic and gravitational levels.

Let $M(x, \eta, R)$ be the conventional Minkowskian spacetime with coordinates $x = (r, t)$ (as a column) and metric $\eta = Diag.(1, 1, 1, -1)$ over the field of real numbers $R(n, +, \times)$ with unit $I = Diag.(1, 1, 1, 1)$. The *Minkowski-Santilli isodual space* [16] is given by (Section 2.2.8)

$$M^d(x^d, \eta^d, R^d), \;\; x^d = -x^t, \;\; \eta^d = Diag.(-1, -1, -1, +1), \qquad (13.1.5a)$$

$$I^d = Diag.(-1, -1, -1, -1). \qquad (13.1.5b)$$

The *isodual electromagnetic field* on $M^d(x^d, \eta^d, R^d)$ is given by

$$F^d_{\mu\nu} = \partial^d_\nu A^d_\mu - \partial^d_\mu A^d_\nu = -F^d_{\nu\mu}, \quad \mu, \nu = 1, 2, 3, 4, \qquad (13.1.6)$$

with *isodual energy-momentum tensor*

$$T^d_{\mu\nu} = (1^d/^d 4^d \times m^d) \times^d [F^{d\,\alpha}_\mu \times^d F^d_{\alpha\nu} +$$

$$+ (1^d/^d 4^d) \times^d g^d \times^d F^d_{\alpha\beta} \times^d F^{d\,\alpha\beta}] = -T^t_{\nu\mu}, \qquad (13.1.7)$$

where g is a known constant depending on the selected unit (whose explicit value is irrelevant for this study). Most importantly, the fourth component of the isodual energy-momentum tensor is negative-definite,

$$T^d_{00} < 0. \qquad (13.1.8)$$

As such, antimatter represented in isodual Minkowski geometry has negative-definite energy, and other physical characteristics, and evolves backward in time. It is an instructive exercise for the interested reader to prove that the results of the Newtonian analysis of the preceding section carry over in their entirety to the Minkowskian formulation [16].

Consider now a Riemannian space $\mathcal{R}(x, g, R)$ in (3+1)-dimensions with spacetime coordinates x and metric $g(x)$ over the reals R with basic unit $I = Diag.(1, 1, 1, 1)$ and related Riemannian geometry as presented, e.g., in Refs. [10,17]. As outlined in Section 2.1.7, the *isodual iso-Riemannian spaces* are given by

$$\mathcal{R}^d(x^d, g^d, R^d) : x^d = -x^t, \;\; g^d(x^d) = -g^t(-x^t), \qquad (13.1.9a)$$

$$I^d = Diag.(-1, -1, -1, -1). \qquad (13.1.9b)$$

Recall that a basic drawback in the use of the Riemannian geometry for the representation of antiparticles is the positive-definite character of its energy-momentum tensor.

In fact, this character causes unsolved inconsistencies at all subsequent levels of study of antimatter, such as lack of a consistent quantum image of antiparticles.

These inconsistencies are resolved *ab initio* under isoduality. In fact, the isodual Riemannian geometry is defined over the isodual field of real numbers R^d for which the norm is negative-definite (Section 2.2.1).

As a result, all quantities that are positive in Riemannian geometry become negative under isoduality, thus including the energy-momentum tensor. In particular, energy-momentum tensors in the Riemannian geometry are given by relativistic expression (2.1.49i) and, as such, they remain negative-definite when treated in a Riemannian space.

It then follows that in the isodual Riemannian treatment of the gravity of antimatter, all masses and other quantities are negative-definite, including the *isodual curvature tensor,* Eq. (2.1.49c).

Despite that, the gravitational force between antimatter and antimatter remain *attractive,* because said negative curvature is measured with a negative unit.

As it was the case at the preceding Euclidean and Minkowskian levels, the isodual treatment of the gravitation of matter-antimatter systems requires its projection *either* in our spacetime *or* in the isodual spacetime. This again implies a *negative curvature in our spacetime* [16] resulting in Prediction 13.1.1 of antigravity at the classical Riemannian level too.

13.1.4 Prediction of Antigravity from Isodual Einstein's Gravitation

Einstein's gravitation is generally defined (see, e.g., Ref. [10]) as the reduction of gravitation in the exterior problem in vacuum to pure curvature in a Riemannian space $\mathcal{R}(x, g, R)$ with local spacetime coordinates x and metric $g(x)$ over the field of real numbers R *without a source,* according to the celebrated field equations

$$G_{\mu\nu} = R_{\mu\nu} - g_{\mu\nu} \times R/2 = 0, \tag{13.1.10}$$

where $G_{\mu\nu}$ is generally referred to as the *Einstein tensor,* $R_{\mu\nu}$ is the *Ricci tensor,* and R is the *Ricci scalar.*

As it is well known, *Einstein's conception of gravitation as above identified does not permit antigravity,* and this occurrence has been a motivation for the absence of serious experimental studies in the field, as indicated in Section 1.4.1.

However, we have indicated in preceding chapters that *the problem of antigravity cannot be confidently formulated, let alone treated, in Einstein's gravitation, due to the impossibility of consistently treating antimatter.*

As indicated earlier, the only possible formulation of antimatter is that by *only* changing the sign of the charge. However, this formulation is inconsistent with quantization since it leads to particles, rather than antiparticles, with the wrong sign of the charge.

At any rate, *the most important formulation of the gravity of antimatter is that for astrophysical bodies with null total charge, as expected for an antimatter star or an antimatter neutron star.*

The impossibility for any credible treatment of antimatter is then established by the fact that *according to Einstein's conception of gravitation the gravitational fields equations for matter and antimatter stars with null total charge are identical.*

These inconsistencies are resolved by the isodual theory of antimatter because it implies the novel *isodual field equations for antimatter* defined on the isodual Riemannian space [16] $\mathcal{R}^d(x^d, g^d, R^d)$ with local isodual spacetime coordinates $x^d = -x^t$ and isodual metric $g^d(x^d) = -g^t(-x^t)$ over the isodual field of real numbers R^d

$$G^d_{\mu\nu} = R^d_{\mu\nu} - g^d_{\mu\nu} \times R^d/^d2^d = 0. \qquad (13.1.11)$$

The latter representation is based on a negative-definite energy-momentum tensor, thus having a consistent operator image, as shown in Chapter 3.

We, therefore, conclude this analysis with the following:

THEOREM 13.1.1 : Antigravity is a necessary and sufficient condition for the existence of a classical formulation of antimatter compatible with its operator counterpart.

Proof. Assume the validity of Einstein's gravitation for matter and its isodual for antimatter. Then, the former has a positive curvature tensor and the latter has a negative curvature tensor.

Therefore, the projection of the gravitational field of antimatter in the spacetime of matter implies a negative curvature tensor in our spacetime, namely, antigravity, or, vice-versa, a positive curvature tensor in the isodual spacetime, that is also repulsive, and this proves the sufficiency. The necessity comes from the fact that the only formulation of antimatter compatible with operator counterparts is that based on negative energies and masses.

In turn, geometric formulations of negative energies and masses necessarily imply, for consistency, a negative curvature tensor. Still in turn, when projected in the space of matter, a negative curvature necessarily implies antigravity and the same occurs for the projection of matter in the field of antimatter. **q.e.d.**

13.1.5 Identification of Gravitation and Electromagnetism

In addition to the above structural inability by Einstein's equations (13.1.10) to represent antimatter, Einstein's gravitation antimatter) is afflicted by a litany of inconsistencies for the treatment of *matter itself* studied in Section

1.4 whose resolution requires a number of structural revisions of general relativity.

It is important to show that the prediction of antigravity, not only persists, but it is actually reinforced for gravitational theories resolving the inconsistencies of Einstein's gravitation.

The first catastrophic inconsistency of Einstein's gravitation crucial for the problem of antigravity is that of Theorem 1.4.1 on the irreconcilable incompatibility between Einstein's lack of source in vacuum and the electromagnetic origin of mass.

As stressed in Section 1.4, this inconsistency is such that, either one assumes Einstein's gravitation as correct, in which case quantum electrodynamics must be reformulated from its foundation to prevent a first-order source in vacuum, or one assumes quantum electrodynamics to be correct, in which case Einstein's gravitation must be irreconcilably abandoned.

The second catastrophic inconsistency of Einstein's gravitation is that of Theorem 1.4.2 identifying the incompatibility of field equations (13.1.10) and the forgotten Freud identity of the Riemannian geometry,

$$R^\alpha_\beta - \frac{1}{2}\times\delta^\alpha_\beta\times R - \frac{1}{2}\times\delta^\alpha_\beta\times\Theta \; = \; U^\alpha_\beta + \partial V^{\alpha\rho}_\beta/\partial x^\rho \; = \; k\times(t^\alpha_\beta+\tau^\alpha_\beta), \quad (13.1.12)$$

where

$$\Theta \; = \; g^{\alpha\beta}g^{\gamma\delta}(\Gamma_{\rho\alpha\beta}\Gamma^\rho_{\gamma\beta} - \Gamma_{\rho\alpha\beta}\Gamma^\rho_{\gamma\delta}), \quad (13.1.13a)$$

$$U^\alpha_\beta \; = \; -\frac{1}{2}\frac{\partial\Theta}{\partial g^{\rho\alpha}_{|\rho}}g^{\gamma\beta}\uparrow_\gamma, \quad (13.1.13b)$$

$$V^{\alpha\rho}_\beta \; = \; \frac{1}{2}[g^{\gamma\delta}(\delta^\alpha_\beta\Gamma^\rho_{\alpha\gamma\delta} - \delta^\rho_\beta\Gamma^\rho_{\alpha\delta}) +$$
$$+(\delta^\rho_\beta g^{\alpha\gamma} - \delta^\alpha_\beta g^{\rho\gamma})\Gamma^\delta_{\gamma\delta} + g^{\rho\gamma}\Gamma^\alpha_{\beta\gamma} - g^{\alpha\gamma}\Gamma^\rho_{\beta\gamma}]. \quad (13.1.13c)$$

The latter inconsistency requires the addition in the right-hand-side of Eqs. (13.1.10) of *two source tensors* for astrophysical bodies with null total charge.

As stressed in Section 1.4, the above two inconsistencies are deeply interrelated because complementary to each other, since the inconsistency of Theorem 1.4.2 is the dynamical counterpart of the inconsistency of Theorem 1.4.2 on geometric grounds.

A systematic study of the resolution of these inconsistencies was conducted by Santilli [18] in 1974.

The classical gravitational formulation of antimatter can be done in the *Riemannian-Santilli isodual space* $\mathcal{R}^d(x^d, g^d, R^d)$ studied in Sections 2.1.7 and 2.2.11.

To avoid catastrophic inconsistencies, the field equations of antimatter should be compatible with the basic geometric axioms of the isodual Riemannian geometry, including, most importantly, the *isodual Freud identity* [16], that can be written

$$R^{\alpha d}_{\beta} - \frac{1}{2}^{d} \times^{d} \delta^{\alpha d}_{\beta} \times^{d} R^{d} - \frac{1}{2}^{d} \times^{d} \delta^{\alpha d}_{\beta} \times^{d} \Theta^{d} = k^{d} \times^{d} (T^{d\alpha}_{\beta} + \Upsilon^{d\alpha}_{\beta}). \quad (13.1.14)$$

with corresponding isodualities for Eqs. (13.1.13) here assumed as known.

These studies then leads to the following:

PREDICTION 13.1.2: [18] IDENTIFICATION OF GRAVITATION AND ELECTROMAGNETISM. In the exterior problem in vacuum, gravitation coincides with the electromagnetic interactions creating the gravitational mass with field equations

$$G^{Ext.}_{\mu\nu} = R_{\mu\nu} - g_{\mu\nu} \times R/2 = k \times T^{Elm}_{\mu\nu}, \quad (13.1.15)$$

where the source tensor $T^{Elm}_{\mu\nu}$ *represents the contribution of all charged elementary constituents of matter with resulting gravitational mass*

$$m^{Grav} = \int d^3x \times T^{Elm}_{00}, \quad (13.1.16)$$

while in the interior problem gravitation coincides with electromagnetic interactions plus short range weak, strong and other interactions creating the inertial mass with field equations

$$G^{Int.}_{\mu\nu} = R_{\mu\nu} - g_{\mu\nu} \times R/2 = k \times (T^{Elm}_{\mu\nu} + \Upsilon^{ShortRange}_{\mu\nu}), \quad (13.1.17)$$

where the source tensor $\Upsilon^{ShortRange}_{\mu\nu}$ *represents all possible short range interactions in the structure of matter, with inertial mass*

$$m^{Inert} = \int d^3x \times (T^{Elm}_{00} + \Upsilon^{ShortRange}_{00}), \quad (13.1.18)$$

and general law

$$m^{Inert} > m^{Grav}. \quad (13.1.19)$$

The same identification of gravitation and electromagnetism then exists for antimatter with field equations and mass expressions given by a simple isodual form of the preceding ones.

A few comments are in order. All studies on the problem of "unification" of gravitation and electromagnetism prior to Ref. [18] known to this author[1] treated the two fields as *physically distinct*, resulting in the well known historical failures to achieve a consistent *unification* dating back to Albert Einstein

[1] Again, the author would appreciate the indication of similar contributions prior to 1974.

(see next chapter for a detailed study). An axiomatically consistent theory emerges if gravitation and electromagnetism are instead "identified", as first done by Santilli [18] in 1974.

Also, Prediction 13.1.2 implies a *theory on the origin of the gravitational field,* rather than a theory providing its "description", as available in standard treatises such as [10]. This is due to the fact that in Prediction 13.1.2 *all* mass terms are completely eliminated and replaced with the fields originating mass.

In this way, the use of any mass term in any theory is an admission of our ignorance in the structure of the considered mass.

We should indicate for completeness that the identification of exterior gravitational and electromagnetic fields appears to be disproved by the assumption that quarks are physical constituents of hadrons, owing to the known large value of their "masses".

However, as indicated in Chapter 1, gravitation solely exists in our spacetime and cannot be consistently extended to mathematical unitary symmetries. Also, the only masses that can consistently create gravitation are those defined in our spacetime, thus necessarily being the eigenvalues of the second-order Casimir invariant of the Poincaré symmetry.

Since quarks cannot be defined in our spacetime, they cannot be consistently characterized by the Poincaré symmetry and their masses are not the eigenvalues of the second-order Casimir invariant of the latter symmetry, the use of quark masses has no scientific value in any gravitational profile. This is the reason why quark "masses" have been ignored in Ref. [18] as well as in this chapter.

It is well established in quantum electrodynamics that the mass of the electron is entirely of electromagnetic origin. Therefore, a gravitational theory of the electron in which the source term solely represents the charge contribution is incompatible with quantum electrodynamics. In fact, the latter requires *the entire reduction of the electron mass to electromagnetic fields* according to Eqs. (13.1.16).

Note in particular that, since the electron has a point-like charge, we have no distinction between exterior and interior problems with consequential identity

$$m^{Grav}_{Electron} \equiv m^{Inert}_{Electron}. \tag{13.1.20}$$

When considering a neutral, extended and composite particle such as the π°, the absence of a source tensor of electromagnetic nature renders gravitation, again, incompatible with quantum electrodynamics, as established in Ref. [18] and reviewed in Section 1.4.

By representing the π° as a bound state of a charged elementary particle and its antiparticle in high dynamical conditions, quantum electrodynamics establishes the existence not only of a non-null total electromagnetic tensor, but one of such a magnitude to account for the entire gravitational mass of the π° according to Eq. (13.1.16) and gravitational mass

$$m_{\pi^\circ}^{Grav} = \int d^3x \times T_{00\,\pi^\circ}^{Elm}. \tag{13.1.21}$$

Unlike the case of the electron, the π° particle has a very large charge distribution for particle standards. Moreover, the structure of the π° particle implies the additional weak and strong interactions, and their energy-momentum tensor is not traceless as it is the case for the electromagnetic energy-momentum tensor.

Therefore, for the case of the π° particle, we have a well-defined difference between exterior and interior gravitational problems, the latter characterized by Eqs. (13.1.18), i.e.,

$$m_{\pi^\circ}^{Inert} = \int d^3x \times (T_{00}^{Elm} + \Upsilon_{00}^{ShortRange}) \ > m_{\pi^\circ}^{Grav}. \tag{13.1.22}$$

The transition from the π° particle to a massive neutral star is conceptually and technically the same as that for the π°. In fact, the star itself is composed of a large number of elementary charged constituents each in highly dynamical conditions and, therefore, each implying a contribution to the total gravitational mass of the star as well as to its gravitational field.

The separation between exterior and interior problems, the presence of only one source tensor for the exterior problem and two source tensors for the interior problems, and the fact that the inertial mass is bigger than the gravitational mass is the same for both the π° and a star with null total charge.

For the case of a star we merely have an increased number of elementary charged constituents resulting in the expression [18]

$$m_{Star}^{Grav} = \Sigma_{p=1,2,3,\ldots} \int d^3x \times T_{00}^{Elem.Constit.}. \tag{13.1.23}$$

Note that when the star has a non-null total charge there is no need to change field equations (13.1.15) since the contribution from the total charge is automatically provided by the constituents.

As it is well known, there exist numerous other theories on the identity as well as the possible differentiation of gravitational and inertial masses (see, e.g., Ref. [10]). However, these theories deal with exterior gravitational problems while the studies here considered deal with the interior problem, by keeping in mind that inertial masses are a strictly *interior* problem, the exterior problem providing at best a geometric abstraction.

Nevertheless, one should remember that all these alternative theories are crucially based on Einstein's gravitation, while the theory presented in this section is based on quantum electrodynamics. Therefore, *none of the existing arguments on the differences between gravitational and inertial masses is applicable to the theory here considered.*

Note finally that conventional electromagnetism is represented by a *first-order tensor*, the electromagnetic tensor $F_{\mu\nu}$ of type (2.2.37*a*) and related first-order Maxwell's equations (2.2.37*b*) and (2.2.37*c*).

When electromagnetism is identified with exterior gravitation, it is represented with a *second-order tensor,* the energy-momentum tensor $T_{\mu\nu}$ of type (13.1.7) and related second-order field equations (13.1.15).

13.1.6 Prediction of Antigravity from the Identification of Gravitation and Electromagnetism

Another aspect important for this study is that *the identification of gravitation and electromagnetism in the exterior problem in vacuum implies the necessary existence of antigravity.*

In fact, the identification implies the necessary equivalence of the phenomenologies of gravitation and electromagnetism, both of them necessarily experiencing attraction and repulsion.

Note that this consequence is intrinsic in the identification of the two fields and does not depend on the order of the field equations (that is first order for electromagnetism and second order for gravitation as indicated earlier.

Alternatively, for the exterior problem of matter we have the field equations on $\mathcal{R}(x, g, R)$ over R

$$G^{Ext.}_{\mu\nu} = R_{\mu\nu} - g_{\mu\nu} \times R/2 = k \times T^{Elm}_{\mu\nu}, \tag{13.1.24}$$

in which *the curvature tensor is positive,* and for the exterior problem of antimatter we have the isodual equations on $\mathcal{R}^d(x^d, g^d, R^d)$ over R^d

$$G^{d,Ext.}_{\mu\nu} = R^d_{\mu\nu} - g^d_{\mu\nu} \times R^d/2 = k \times T^{d,Elm}_{\mu\nu}, \tag{13.1.25}$$

in which *the curvature tensor is negative.*

The prediction of antigravity, Prediction 13.1.1, follows as a trivial extension of that of the preceding sections and occurs when the gravitational field of antimatter is projected in that of matter, or vice-versa, since such a projection implies a negative curvature in a Riemannian space that, by definition, is antigravity.

The prediction of antigravity is so strong that it is possible to prove that *the lack of existence of antigravity would imply the impossibility of identifying gravitation and electromagnetism.*

In turn, the lack of such identification would necessary require the impossibility for masses to have appreciable electromagnetic origin, resulting in the need for a structural revision of the entire particle physics of the 20-th century.

13.1.7 Prediction of Gravitational Repulsion for Isodual Light Emitted by Antimatter

Another important implication of the isodual theory of antimatter is the prediction that antimatter emits a new light, the *isodual light,* that experiences repulsion when in the vicinity of the gravitational field of matter, or vice-versa [19], where the *isodual electromagnetic waves* emitted by antimatter are given by Eqs. (2.3.37), i.e.,

$$F^d_{\mu\nu} \ = \ \partial^d A^d_\mu /^d \partial^d x^{\nu d} - \partial^d A^d_\nu /^d \partial^d x^{d\mu}, \tag{13.1.26a}$$

$$\partial^d_\lambda F^d_{\mu\nu} + \partial^d_\mu F^d_{\nu\lambda} + \partial^d_\nu F^d_{\lambda\mu} = 0, \tag{13.1.26b}$$

$$\partial^d_\mu F^{d\mu\nu} = -J^{d\nu}. \tag{13.1.26c}$$

The gravitational repulsion then emerges from the negative energy of the above isodual waves when in the field of matter. Vice versa, electromagnetic waves emitted by matter are predicted to experience antigravity when in the gravitational field of antimatter because they have a positive energy.

Note that *isodual electromagnetic waves coincide with conventional waves under all known interactions except gravitation.* Alternatively, the isodual electromagnetic waves requires the existence of antigravity at a pure classical level for their proper identification.

In turn, the experimental confirmation of the gravitational repulsion of light emitted by antimatter would have momentous astrophysical and cosmological implications, since it would permit for the first time theoretical and experimental studies as to whether far away galaxies and quasars are made up of matter or of antimatter.

It is important in this connection to recall that all relativistic quantum field equations admit solutions with positive and negative energies. As it is the case for Dirac's equations, relativistic field equations are generally isoselfdual, thus admitting solutions with both positive and negative energies.

The former are used in numerical predictions, but the negative-energy states are generally discarded because they are believed to be "unphysical".

The isodual theory implies a significant revision of the interpretation of quantum field theory because *the solutions of relativistic equations with positive energy are defined in our spacetime and represent particles, while the joint solutions with negative energy are actually defined on the isodual spacetime and represent antiparticles.*

This re-interpretation cannot be presented in this chapter for brevity. In fact, a systematic study of isodual photons requires the formulation of *isodual quantum field theory* that would render prohibitive the length of this chapter.

It is hoped that interested colleagues will indeed work out the proposed isodual quantum field theory, with particular reference to the isodual re-interpretation of advanced and retarded solutions, Green distributions, Feynman diagrams, and all that, because of various implications, such as those in conjugation of trajectories or in the transition from particles to antiparticles.

In closing, the reader should keep in mind that the isodual theory of antimatter resolves all conventional inconsistencies on negative energies as well as against antigravity (see also Section 2.3.15).

13.2 EXPERIMENTAL VERIFICATION OF ANTIGRAVITY

13.2.1 Santilli's Proposed Test of Antigravity for Positrons in Horizontal Flight

By far the most fundamental experiment that can be realized by mankind with current technologies is the measure of the gravitation of truly elementary antiparticles, such as the positron, in the field of Earth.

Irrespective of whether the outcome is positive or negative, the experiment will simply have historical implications for virtually all of physics, from particle physics to cosmology for centuries to come.

If antigravity is experimentally established, the location of the experiment is predicted to become a place of scientific pilgrimage for centuries, due to the far reaching implications, such as the consequential existence of a Causal Time Machine outlined later on in this chapter.

An inspection of the literature soon reveals that the problem of the *gravity of antiparticles in the field of Earth is fundamentally unsettled at this writing, thus requiring an experimental resolution.*

On theoretical grounds, all arguments based on the weak equivalence principle [10] are dismissed as inconclusive by the isodual theory of antimatter, since the latter predicts that bound states of particles and their isoduals experience *attraction* in the gravitational field of Earth.

At any rate, no argument against antigravity based on general relativity can be considered scientifically valid without first the resolution of the catastrophic inconsistencies of gravitation, such as those expressed by the various inconsistency theorems of Section 1.4.

Similarly, all experiments conducted to date on the test of the *gravity of antiparticles not bounded to matter* are equally inconclusive, to the author's best knowledge.[2] A direct measurement of the gravity of positrons was considered in 1967 by Fairbanks and Witteborn [6] via electrons and positrons in a *vertical* vacuum tube.

However, the test could not be conducted because preliminary tests with electrons discouraged the use of positrons due to excessive disturbances caused

[2]The author would appreciate being kept informed by experimentalist in the field.

by stray fields, impossibility of ascertaining the maximal height of the electrons, and other problems.

Neutron interferometric measurements of the *gravity of antiprotons* have been studied by Testera [8], Poggiani [9] and others. However, these experiments are highly sophisticated, thus implying difficulties, such as those for securing antiprotons with the desired *low energies,* magnetic trapping of the antiprotons, highly sensitive interferometric measurements of displacements, and others.

A number of important proposals to text the gravity of antimatter have been submitted to CERN and at other laboratories by T. Goldman, R. J. Hughes, M. M. Nieto, et al. [22–25], although no resolutory measurement has been conducted to date to the author best knowledge, perhaps in view of the excessive ambiguities for an accurate detection of the trajectories of antiparticles under Earth-s gravitational field in existing particle accelerators (see in this respect Figure 13.2).

Additional important references are those studying the connection between antigravity and quantum gravity [26–29], although the latter should be studied by keeping in mind Theorem 1.5.2 on the catastrophic inconsistencies of quantum gravity when realized via nonunitary structures defined on conventional Hilbert spaces and fields.[3]

In view of these unsettled aspects, an experiment that can be *resolutory* with existing technologies, that is, establishing in a final form either the existence of the lack of existence of antigravity, has been proposed by Santilli in Ref. [12] of 1994.

The experiment essentially requires a *horizontal* vacuum tube ranging from 100 meters in length and 0.5 meter in diameter to 10 m in length and 1 m in diameter depending on used energies, with axial collimators at one end and a scintillator at the other end as in Figure 13.1. The proposed test then consists in:

1) Measuring the location in the scintillator of lack of gravitational displacement via a collimated photon beam (since the gravitational displacement on photons at the considered distances is ignorable);

2) Measuring on the same scintillator the downward displacement due to Earth's gravity on an electron beam passing through the same collimators, which downward displacement is visible to the naked eyes for sufficiently small electron energies (for instance, we can have a downward displacement due to gravity of 5 mm, that is visible to the naked eye, for electron kinetic energies

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[3]The author would like to express his sincere appreciation to T. Goldman for the courtesy of bringing to his attention the important references [22–29] that could not be reviewed here for brevity, but whose study is recommended as a necessary complement of the presentation of this monograph.

of 25 μeV along 100 m horizontal flight, or for electrons with 2 μeV along a 10 m horizontal flight); and

3) Measuring on the same scintillator the displacement due to Earth's gravity on a positron beam passing through the same collimators, which displacement is also visible to the naked eye for positron energies of the order of a few μeV.

If the displacement due to gravity of the positrons is downward, the test would establish the lack of existence of antigravity. On the contrary, the detection of an upward displacement of the positrons would establish the existence of antigravity.

An alternative proposal was submitted by Santilli [20] via the use of the so-called *particle decelerator* in the shape of a doughnut of a diameter of about 10 m and 50 cm in sectional diameter (Figure 13.2). The main idea is that low energy beams of electrons and positrons could be *decelerated* via the use of magnetic fields down to the energy needed to achieve a displacement due to gravity sufficiently larger than the dispersion to be visible to naked eye, at which point the particles are released into a scintillator.

We have stressed throughout this presentation that the only experimental verification of the theoretical prediction of antigravity recommendable at this writing, is that for *truly elementary antiparticles in the gravitational field of matter without any bound to other particles,* such as an isolated beam of positrons under the gravitation field of Earth.

Other tests of antigravity, if conducted before the above tests with positrons and used for general claims on antigravity, can likely lead to ambiguities or a proliferations of unnecessary controversies.

The reasons for this restriction are numerous. Firstly, the study of the gravity of particle-antiparticle systems, such as a bound state of one electron and one positron at large mutual distances according to quantum mechanics (QM),

$$Positronium = (e^-,\ e^+)_{QM}, \tag{13.2.1}$$

is *strongly discouraged* for a first "test of antigravity", because all theories, including the isodual theory, predict attraction of the positronium in the field of matter. Therefore, under no condition can any possible experimental verification of this prediction be used as a credible claim on the lack of existence of antigravity at large.

Second, the above restriction eliminates the use of muons for a first test of antigravity, because, in view of their instability and decay modes, and as studied in detail in the next chapter, hadronic mechanics (HM) predicts that muons are a bound state of electrons and positrons in conditions of total

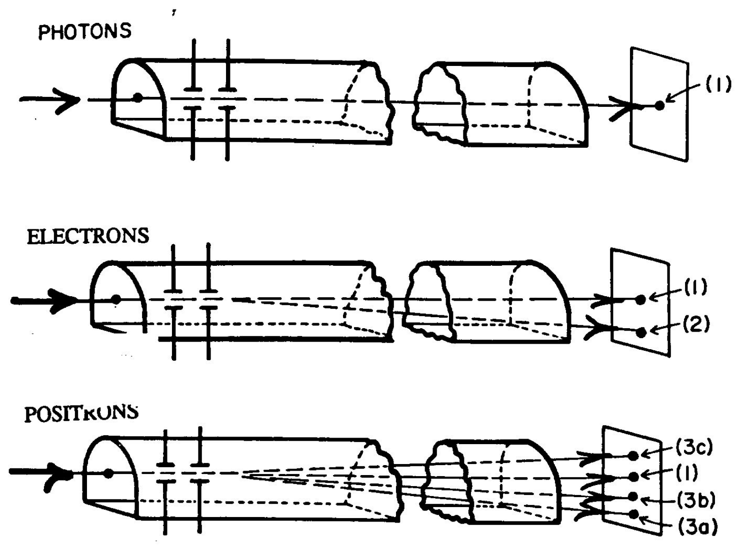

Figure 13.1. A schematic view of the proposal to test the gravity of positrons suggested by Santilli [12] in 1994 via a horizontal vacuum tube with a scintillator at the end in which a collimated beam of photons is used to identify the point in the scintillator of no displacement due to gravity, and collimated beams of very low energy electrons and, separately, positrons are used to measure displacements due to gravity. The latter are indeed visible to the naked eye for sufficiently low kinetic energy of the order of a few μeV. Santilli's proposal [12] was studied by the experimentalist J. P. Mills, jr. [13], as reviewed in the next section.

mutual penetrations of their wavepackets at very short mutual distances,

$$\mu^{\pm} = (e^{-}, e^{\pm}, e^{+})_{HM}, \qquad (13.2.2)$$

with consequential highly nonlocal effects structurally beyond any credible treatment by quantum mechanics. Under this structure, *both muons and antimuons are predicted to experience gravitational attraction only* because the possible antigravity of the positron is expected to be less than the gravity of basic electron-positron system.

A similar restriction applies against the use of mesons for first tests of antigravity because they are bound states of particles and antiparticles that, as such, are predicted not to experience antigravity in the field of matter. This is particularly the case for pions. Similarly, a first use of kaons for experiments on antigravity can only result in unnecessary controversies in view of their unsettled structure.

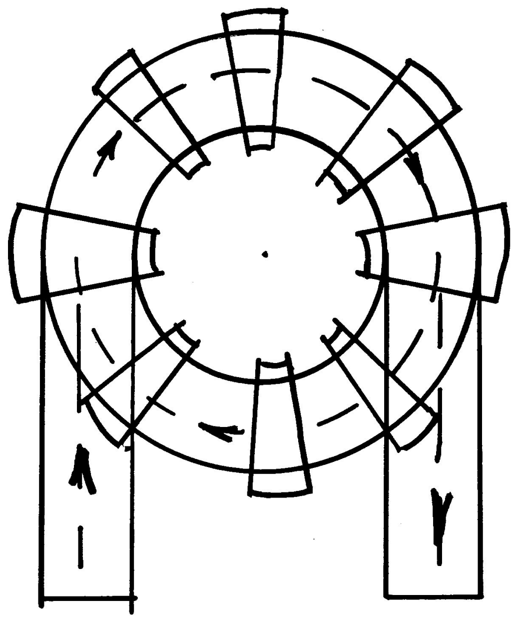

Figure 13.2. A schematic view of the alternative proposal submitted for study by the author [20] at the National High Magnetic Field Laboratory, Tallahassee, Florida, in December 1995. The main idea is to use the established techniques for "particle accelerators" for the construction of a "particle decelerator" that would slow down the initial energy of electron and positron beams down to the amounts needed to produce displacement due to gravity sufficiently bigger than the spread due to stray fields to produce a definite-resolutory answer visible to the naked eye. Suggested dimensions of the "particle decelerator" are 10 m in diameter with a sectional diameter of 0.5 m and two entrances-exits, one used for the entrance-exit of the electron beam and the other for the positron beam. The study conducted by Mills [13] for the horizontal tube indicates that the "particle decelerator" here considered is also feasible and will produce a resolutory answer.

Serious reservation also exist for the first use of antiprotons and antineutrons due to their basically unsettled structure. As stressed earlier, the use of current quark conjecture prevents antiprotons and antineutrons to have any gravity at all, let alone antigravity, as rigorously proved by the fact indicated earlier that gravity can only be defined in our physical spacetime while quarks can only be defined in their internal mathematical unitary space, as well as by the lack of credibly defines "quark masses" as inertial eigenvalues of the second order Casimir invariant of the Poincaré group (see the Appendix of Ref. [8]).

Equally equivocal can be at this stage of our knowledge the conduction of first gravitational measurements via the sole use of the antihydrogen atom for intended general results on antigravity, evidently because its nucleus, the antiproton, is believed to be a bound state of quarks for which no gravity at all can be consistently defined. Any study of antigravity under these unsettled structural conditions can only lead to un-necessary controversies, again, if used for general results on antigravity.

It is evident that, *until baryons theories are afflicted by such fundamental problematic aspects, as the inability even to define gravity in a credible way, no gravitational measurement based on antiprotons and antineutrons can be credibly used as conclusive for all of antimatter.*

After the resolution of the gravitational behavior of unbounded positrons in the field of matter, the tests for the gravitational behavior of positronium, muons, muonium, pions, pionium, antiprotons, antineutrons, antihydrogen atom, etc. become essential to acquire an experimental background sufficiently diversified for serious advances on antimatter beyond the level of personal beliefs one way or the other.

The fundamental test of the gravity of positrons here considered was proposed by the author to the following institutions:

1) Stanford Linear Acceleration Center, Stanford, USA, during and following the Seventh Marcel Grossmann Meeting on General Relativity held at Stanford University in July 1994;

2) The Joint Institute for Nuclear Research in Dubna, Russia, during the International Conference on Selected Topics in Nuclear Physics held there in August 1994;

3) The National High Magnetic Field Laboratory in Tallahassee, Florida, during a meeting there in 1996 on magnetic levitation;

4) CERN, Geneva, Switzerland, during a presentation there of hadronic mechanics;;

5) Brookhaven National Laboratories, following the participation at the Sepino meeting on antimatter of 1996 [5];

and to other laboratories as well to universities in various countries.

It is regrettable for mankind that none of these laboratories or universities expressed interest in even considering to date such a fundamental experiment, by preferring to spend much bigger public funds for esoteric experiments manifestly lesser important than that of antigravity.

13.2.2 Santilli's Proposed Tests of Antigravity for Isodual Light

Additionally, in 1997 Santilli [19] predicted that *antimatter emits a new light, the isodual light, that is predicted to be repelled by the gravitational field of matter,* and proposed its experimental verification as the only known (or even conceivable) possibility of ascertaining whether far-away galaxies and quasars are made up of matter or of antimatter.

Measurements as to whether light emitted by the antihydrogen atoms now produced at CERN are attracted or repelled by matter is predictably more delicate than the test of the gravity of the positron, evidently because gravitational displacements for photons in horizontal flight are extremely small, as well know, thus requiring very sensitive interferometric and other measurements.

The experimental detection as to whether far-away galaxies and quasars are made up of matter or of antimatter is predictably more complex and requiring longer periods of time, but with immense scientific implications whatever the outcome.

The test can be done in a variety of ways, one of which consists of measuring the deflection of light originating from far away astrophysical objects when passing near one of our planets. Comparative measurements of a sufficiently large number of galaxies and quasars should permit the detection of possible repulsions, in the event it exists.

Another test has been privately suggested by to the author by an astrophysicist and consists in reinspecting all existing astrophysical data on the deflection of light from far away galaxies and quasars when passing near-by astrophysical bodies.

In the opinion of this astrophysicist, it appears that evidence for the repulsion of light already exists in these data. Such a possible evidence has been ignored so far, and, if found, could not be admitted publicly at the moment, simply because Einstein's gravitation does not allow for any prediction of gravitational repulsion of light.

An understand is that, for these astrophysical measurements to be credible, astrophysicists must conduct the study of a vary large number of galaxies and quasars (of the order of several thousands), and the considered galaxies and quasars must be sufficiently far away to render plausible their possible antimatter structure.

13.2.3 Mills' Studies of Santilli's Proposed Tests of Antigravity

The experimentalist J. P. Mills, jr., [13] conducted a survey of all significant experiments on the gravity of antiparticles in the field of Earth, including indirect tests based on the weak equivalence principle and direct experiments with antiparticles, by concluding that the problem is basically unsettled on theoretical and experimental grounds, thus requiring an experimental resolution.

After considering all existing possible tests, Mills' conclusion is that Santilli's proposed test [12] on the measurement of the gravitational deflection of electrons and positron beams of sufficiently low energy in horizontal flight in a vacuum tube of sufficient length and shielding, is preferable over other possible tests, experimentally feasible with current technology, and providing a resolutory answer as to whether positrons experience gravity or antigravity.

As it is well known, a main technical problem in the realization of Santilli's test is the shielding of the horizontal tube from external electric and magnetic field, and then to have a tube structure in which the internal stray fields have an ignorable impact on the gravitational deflection, or electrons and positrons have such a low energy for which the gravitational deflection is much bigger than possible contributions from internal stray fields, such as the spreading of beams.

The electric field that would cancel the Earth gravitational force on an electron is given by

$$E \; = \; m_e \times g/e = 5.6 \times 10^{-11} \text{ V/m}. \tag{13.2.3}$$

As it is well known, an effective shielding from stray fields can be obtained via Cu shells. However, our current understanding of the low temperature zero electric field effect in Cu shells does not seem sufficient at this moment to guarantee perfect shielding from stray fields. Mills [13] then suggested the following conservative basic elements for shielding the horizontal tube.

Assuming that the diameter of the tube is d and the shielding enclosure is composed of randomly oriented grains of diameter λ, the statistical variation of the potential on the axis of the tube of a diameter d would then be [13]

$$\Delta V \; = \; \frac{\lambda}{d \times \sqrt{\pi}}. \tag{13.2.4}$$

As expected, *the effect of stray fields at the symmetry axis of the tube is inversely proportional to the tube diameter.* As we shall see, a tube diameter of 0.5 m is acceptable, although one with 1 m diameter would give better results.

Given a work function variation of 0.5 eV, 1 μm grains and $d = 30$ cm, we would have the following variation of the potential on the axis of the horizontal tube

$$\Delta V \; = 1 \; \mu\text{eV}. \tag{13.2.5}$$

Differences in strain or composition could cause larger variations in stray fields. To obtain significant results without ambiguities for the shielding effect of low temperature Cu shells, Mills [13] suggests *the use of electrons and positrons with kinetic energies significantly bigger than* 1 μeV. As we shall see, this condition is met for tubes with minimal length of 10 m and the diameter of 1 m, although longer tubes would evidently allow bigger accuracies.

The realization of Santilli's horizontal vacuum tube proposed by Mills [13] is the following. As shown in Figure 13.3, the tube would be a long dewar

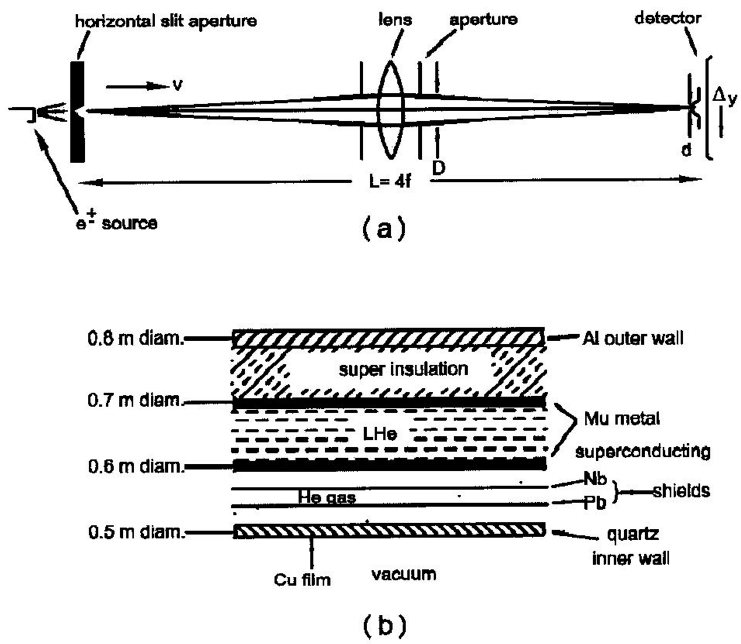

Figure 13.3. A schematic view of the realization suggested by Mills [13] of the horizontal tube proposed by Santilli [12].

tube, consisting of concentric shells of Al and Mu metals, with Pb and Nb superconducting shells and an inner surface coated with an evaporated Cu film.

There should be two superconducting shells so that they would go superconducting in sequence [Nb (9.25 K), Pb (7.196 K)], evidently for better expulsion of flux. Trim solenoids are also recommended for use within the inner shell and a multitude of connections to the Cu field for trimming electrostatic potentials.

As also shown in Figure 13.3, the flight tube should be configured with an electrostatic lens in its center for use of electron and positron beams in both horizontal directions, as well as to focus particles from a source at one end into a gravity deflection sensitive detector at the other end. The de Broglie wavelength of the particles results in the position resolution

$$d \; = \; 2.4 \times \pi \times \alpha_B \times \frac{c \times L}{v \times D}, \qquad (13.2.6)$$

where $\alpha = 1/137$ is the fine structure constant, $a_B = 0.529\,\text{Å}$ is the Bohr radius of hydrogen, c is the velocity of light, v is the electron or positron velocity, L is the length of the horizontal path, and D is the diameter of the lens aperture in the center of the flight tube.

The *vertical gravitational deflection* is given by

$$\Delta y \ = \ g \times \frac{L^2}{2 \times v^2}. \tag{13.2.7}$$

Given $L = 100\,\text{m}$, $D = 10\,\text{cm}$, $v/c = 10^{-5}$ (i.e., for 25 μeV particles), we have

$$\Delta y = 5\,\text{mm}. \tag{13.2.8}$$

For 1 meV particles the resolution becomes

$$\Delta y = 125\,\mu\text{m}. \tag{13.2.9}$$

Therefore, one should be able to observe a meaningful deflection using particles with kinetic energies well above the expected untrimmed fluctuation in the potential.

Mills also notes that the lens diameter should be such as to minimize the effect of lens aberration. This requirement, in turn, dictates the minimum inside diameter of the flight tube to be 0.5 m.

The *electron source* should have a cooled field emission tip. A sufficient *positron source* can be provided, for example, by 0.5 ci of ^{22}Na from which we expect (extrapolating to a source five times stronger) $3 \times 10^7\, e^+/\text{s}$ in a one centimeter diameter spot, namely a positron flux sufficient for the test.

Ideal results are obtained when the positrons should be bunched into pulses of 10^4 e^+ at the rate of 10^3 bunches per second. Groups of 10^3 bunches would be collected into macrobunches containing 10^6 e^+ and 20 nsec in duration. The positrons would be removed from the magnetic field and triply brightness enhanced using a final cold Ni field remoderator to give bunches with 10^4 e^+, 10 meV energy spread, an ellipsoidal emission spot 0.1 μm high and 10 μm wide and a 1 radian divergence.

However, stray fields are notoriously weak and decrease rapidly with the distance. Therefore, there is a diameter of the vacuum tube for which stray fields are expected to have value on the axis insufficient to disrupt the test via a spreading of the beams. Consequently, the proposed tests is also expected to be resolutory via the use of very low energy positrons as available, e.g., from radioactive sources.

As a matter of fact, the detection in the scintillator of the same clear gravitational deflection due to gravity by *a few* positrons would be sufficient to achieve a final resolution, provided, of course, that these few events can be systematically reproduced.

After all, the reader should compare the above setting with the fact that new particles are nowadays claimed to be discovered at high energy laboratories via the use of extremely few events out of hundreds of millions of events on record for the same test.

The beam would then be expanded to 100 μm×1 cm cross section and a 1 mrad divergence, still at 10 meV. Using a time dependent retarding potential Mills would then lower the energy spread and mean energy to 100 μeV with a 2 μs pulse width. Even assuming a factor of 1,000 loss of particles due to imperfections in this scheme, Mills' set-up would then have pulses of about 10 positrons that could be launched into the flight tube with high probability of transmissions at energy of 0 to 100 μeV.

The determination of the gravitational force would require many systematic tests. The most significant would be the measurements of the deflection as a function of the time of flight (enhance the velocity v) $\Delta v(e\pm, \pm v)$ for both positrons and elections and for both signs of the velocity relative to the lens on the axis of the tube, $v > 0$ and $v < 0$, the vertical gravitational force on a particle of charge q is

$$F_y \ = \ -m \times g + q \times E_y + q \times v_z \times B_x/c. \tag{13.2.10}$$

The deflection is then given by

$$\Delta y = \int_0^L \int_0^{z'} q \times [E(z'') + v \times B(z'')/c] \times dz'' \times dz'/(m \times v^2) - g \times z^2/2 \times v^2. \tag{13.2.11}$$

In lowest order, Mills neglects the transverse variation in E_y and B_x and writes for the average fields

$$\epsilon \ = \ \frac{1}{L^2} \int_0^L \int_0^{z'} E_y(z'') \times dz'' \times dz', \tag{13.2.12}$$

and

$$\beta \ = \ \frac{1}{L^2} \int_0^L \int_0^{z'} B_x(z'') \times dz'' \times dz'. \tag{13.2.13}$$

Note that these are not simple averages, but the averages of the running averages. They depend on the direction of the velocity. In the approximation that there are not significantly different from simple averages, the average of the four deflection Δy for both positrons and electrons and for both signs of the velocity is independent of ϵ and β and it is given by

$$< \Delta y > = \ (g^+ + g^-) \times \frac{L^2}{v^2}. \tag{13.2.14}$$

where $g^{\pm}$ refers to the gravitational acceleration of $e^{\pm}$. Since we also have the velocity dependence of the Δy's, and can manipulate E and B by means of trim adjustments, it will be possible to unravel the gravitational effect from the electromagnetic effect in this experiment.

In summary, the main features proposed by Mills [13] for Santilli's [12] horizontal vacuum tube are that:

1) The tube should be a minimum of 10 m long and 1 m in diameter, although the length of 100 m (as proposed by Santilli [12]) and 0.5 m in diameter is preferable;

2) The tube should contain shields against internal external electric and magnetic fields and internal stray fields. According to Mills [13], this can be accomplished with concentric shells made of Al, double shells of Mu metal, double shells of superconducting Nb and Pb, and a final internal evaporated layer of fine grain of Cu;

3) Use bright pulsed sources of electrons and, separately, positrons, at low temperature by means of phase space manipulation techniques including brightness enhancement;

4) Time of flight and single particle detection should be tested to determine the displacement of a trajectory from the horizontal line as a function of the particle velocity;

5) Comparison of measurements should be done using electrons and positrons traversing the flight tube in both directions.

The *use of electrons and positrons with 25 μeV kinetic energy would yield a vertical displacement of 5 mm at the end of 100 m horizontal flight, namely, a displacement that can be distinguished from displacements caused by stray fields and be visible to the naked eye,* as insisted by Santilli [12].

Mills [13] then concludes by saying that *"... an experiment to measure the gravitational deflection of electrons and positrons in horizontal flight, as suggested by R. M. Santilli, ... is indeed feasible with current technologies.... and should provide a definite resolution to the problem of the passive gravitational field of the positron".*

13.3 CAUSAL SPACETIME MACHINE

13.3.1 Introduction

In preceding sections of this monograph we have indicated the far reaching implications of a possible experimental verification of antigravity predicted for antimatter in the field of matter and vice versa, such as a necessary revision of the very theory of antimatter from its classical foundations, a structural revision of any consistent theory of gravitation, a structural revision of any operator formulation of gravitation, and others.

In this section we show that another far reaching implications of the experimental detection of antigravity is the consequential existence of a *Causal Time Machine* [14], that is the capability of moving forward or backward in time without violating the principle of causality, although, as we shall see, this capability is restricted to isoselfdual states (bound states of particles and antiparticles) and *it is not* predicted by the isodual theory to be possible for matter or, separately, for antimatter.

It should be stressed that the Causal Time Machine here considered is a *mathematical model,* rather than an actual machine. Nevertheless, science has always surpassed predictions. Therefore, we are confident that, as it has been the cases for other predictions, one the Causal Time Machine is theoretically predicted, science may indeed permits its actual construction, of course, in due time.

As we shall see, once a Causal Time Machine has been identified, the transition to a causal SpaceTime Machine with the addition of motion in space is direct and immediate.

13.3.2 Causal Time Machine

As clear from the preceding analysis, *antigravity is only possible if antiparticles in general and the gravitational field of antimatter, in particular, evolve backward in time.* A time machine is then a mere consequence.

Causality is readily verified by the isodual theory of antimatter for various reasons. Firstly, *backward time evolution measured with a negative unit of time is as causal as forward time evolution measured with a positive unit of time.* Moreover, *isoselfdual states evolve according to the time of the gravitational field in which they are immersed.* As a result, no violation of causality is conceivably possible for isoselfdual states.

Needless to say, none of these causality conditions are possible for conventional treatments of antimatter.

The reader should be aware that we are referring here to a "Time Machine," that is, to motion forward and backward in time without space displacement (Figure 13.4). The "Space-Time Machine" (that is, including motion in space as well as in time), requires the isodualities as well as isotopies of conventional geometries studied in Chapter 3 and it will be studied in the next section.

The inability to have motion backward in time can be traced back to the very foundations of special relativity, in particular, to the basic time-like interval between two points 1 and 2 in Minkowski space as a condition to verify causality

$$(x_1 - x_2)^2 + (y_1 - y_2)^2 + (z_1 - z_2)^2 - (t_1 - t_2)^2 \times c^2 < 0. \qquad (13.3.1)$$

defined on the field of real numbers $R(n, \times, I),\ I = Diag.(1, 1, 1, 1)$.

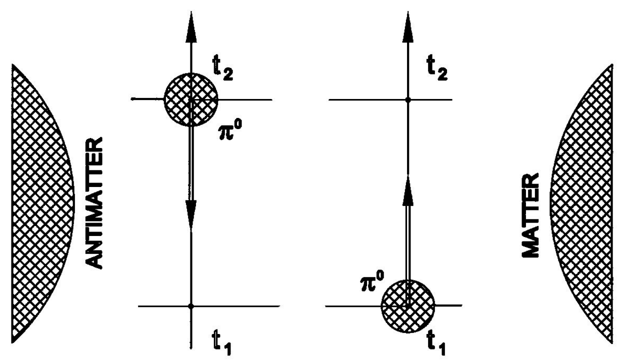

Figure 13.4. A schematic view of the simplest possible version of the "Time Machine" proposed in Ref. [14] via an isoselfdual state such as the positronium or the π° meson that are predicted to move forward (backward) in time when immersed in the gravitational field of matter (antimatter). The Time Machine then follows by a judicious immersion of the same isoselfdual state first in the fields of matter and then in that of antimatter. No causality violation is possible because of the time evolution for isoselfdual states is that of the field in which they are immersed in.

The inability to achieve motion backward in time then prevents the achievement of a *closed loop* in the forward light cone, thus including motion in space and time, since said loop would necessarily require motion backward in time.

Consider now an isoselfdual state, such as the positronium or the π° meson (Section 2.3.14). Its characteristics have the sign of the unit of the observer, that is, positive time and energy for matter observers and negative times and negative energies for antimatter observers. Then a closed loop can be achieved as follows [14]:

1) With reference to Figure 13.4, expose first the isoselfdual state to a field of matter, in which case it evolved forward in time from a point at time t_1 to a point at a later time t_2 where the spacetime coordinates verify the time-like invariant (13.3.1) with $t_2 > t_1$;

2) Subsequently, expose the same isoselfdual state to a field of antimatter in which case, with the appropriate intensity of the field and the duration of the exposure, the state moves backward in time from time t_2 to the original time t_1, where the spacetime coordinates still verify invariant (13.3.1) with $t_2 < t_1$ although in its isodual form.

We, therefore, have the following:

PREDICTION 13.3.1 [14]: Isoselfdual states can have causal motions forward and backward in time, thus performing causal closed loops in the forward light cone.

Note that the above causal Time Machine implies 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 and related unit.

Note also that the use of a particle or, separately, of an antiparticle would violate causality.

Numerous time machines exist in the literature. However, none of them appears to verify causality and, as such, they are ignored.

Other time machines are based on exiting our spacetime, entering into a mathematical space (e.g., of complex unitary character), and then returning into our spacetime to complete the loop.

Other attempts have been based on quantum tunnelling effects and other means.

By comparison, the Causal Time Machine proposed in Ref. [14] achieves a closed loop at the classical level without exiting the forward light cone and verifying causality.[4]

13.3.3 Isogeometric Propulsion

All means of locomotion developed by mankind to date, from prehistoric times all the way to current interplanetary missions, have been based on *Newtonian propulsions*, that is, propulsions all based on *Newton's principle of action and reaction.*

As an example, human walking is permitted by the action generated by leg muscles and the reaction caused by the resistance of the feet on the grounds. The same action and reaction is also the origin of *all* other available locomotions, including contemporary automobiles or rockets used for interplanetary missions.

Following the identification of the principle of propulsion, the next central issue is the displacement that is evidently characterized by the *Euclidean distance.* We are here referring to the conventional Euclidean space $E(r, \delta, R)$ over the reals R with familiar coordinates $r = (x, y, z) \times I$, metric $\delta = Diag.(1, 1, 1)$, units for the three axes $I = I_{3\times 3} = Diag(1\,\text{cm}, 1\,\text{cm}, 1\,\text{cm})$ hereon used in their dimensionless form $I = Diag.(1, 1, 1)$, and Euclidean distance that we write in the isoinvariant form

$$D^2 = r^2 \times I = (x^2 + y^2 + z^2) \times I \in R. \qquad (13.3.2)$$

The *geometric locomotion* can be defined as the *covering of distances via the alteration (also called deformation) of the Euclidean geometry without any*

[4] The indication by colleagues of other versions of the spacetime machine with a proved verification of causality without existing from our spacetime would be appreciated.

use of action and reaction . The *only* possible realization of such a geometric locomotion that avoid the theorems of catastrophic inconsistencies of Section 1.5, as well as achieves compatibility with our sensory perception (see below), is the *isogeometric locomotion* [15b] namely, that permitted by the *Euclid-Santilli isogeometry* and relative *isodistance.*

We are here referring to the Euclid-Santilli isospace (Section 3.2) $\hat{E}(\hat{r}, \hat{\delta}, \hat{R})$ over the isoreals $\hat{R}$ with isocoordinates $\hat{r} = (x, y, z) \times \hat{I}$, metric $\hat{\delta} = \hat{T}_{3\times3} \times \delta$, isounits for the three isoaxes

$$\hat{I} = \hat{I}_{3\times3} = Diag(n_1^2 \, \text{cm}, \ n_2^2 \, \text{cm}, \ n_3^2 \, \text{cm}) = 1/\hat{T}_{3\times3} > 0 \tag{13.3.3}$$

that will also be used hereon in the dimensionless form

$$\hat{I} = Diag.(n_1^2, \ n_2^2, \ n_3^2), \tag{13.3.4}$$

and *isodistance* that we write in the isoinvariant form[5]

$$\hat{D}^{\hat{2}} = \hat{r}^{\hat{2}} = (x^2/n_1^2 + y^2/n_2^2 + z^2/n_3^2) \times \hat{I} \in \hat{R}, \tag{13.3.5}$$

in which case the deformation of the geometry is called *geometric mutation.*[6]

It is evident that $\hat{D}$ can be bigger equal or smaller than D. Consequently, the isogeometric locomotion occurs when $\hat{D} < D$, as in the example below

$$\hat{I} = Diag.(n_1^2, 1, 1) \ll I = Diag.(1, 1, 1), \quad \hat{T} \gg I, \tag{13.3.6a}$$

$$\hat{D}^{\hat{2}} = (x^2/n_1^2 + y^2 + z^2) \ll D^2 = (x^2 + y^2 + z^2). \tag{13.3.6b}$$

The understanding of the above locomotion requires a knowledge of the *isobox* of Section 3.2. Consider such an isobox and assume that it is equipped with isogeometric locomotion. In this case, there is no displacement at all that can be detected by the internal observer. However, the external observer detects a displacement of the isobox the amount $x^2 - x^2/n_1^2$.

This type of locomotion is new because it is causal, invariant and occurs without any use of the principle of action and reaction and it is geometric because it occurs via the sole local mutation of the geometry.

The extension to the *Causal Spacetime Machine,* or *spacetime isogeometric locomotion* is intriguing, and can be formulated via the *Minkowski-Santilli*

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[5]By "isoinvariance" we means invariance under conventional space or spacetime symmetries plus the isotopic invariance.

[6]According to the contemporary terminology, "deformations" are alterations of the original structure although referred to the original field. As such they are afflicted by the catastrophic inconsistencies of Section 1.5. The term "mutation", first introduced by Santilli in Ref. [21] of 1967, is today referred to an alteration of the original structure under the condition of preserving the original axioms, thus requiring the formulation on isospaces over isofields that avoid said theorems of catastrophic inconsistency.

isospace of Section 3.2 with four-isodistance

$$\hat{D}^{\hat{2}} = (x^2/n_1^2 + y^2/n_2^2 + z^2/n_3^2 - c^2 \times t^2/n_4^2) \times \hat{I} \in \hat{R}, \qquad (13.3.7)$$

where $n_4 > 0$.

The main implications in this case is the emergence of the additional *time mutation* as expected to occur jointly with any *space mutation.* In turn, this implies that the *isotime* $\hat{t} = t/n_4$ (that is, the internal time) can be bigger equal or smaller than the time t (that of the external observer).

More specifically, from the preservation of the original trace of the metric, *isorelativity predicts that the mutations of space and time are inversely promotional to each others.* Therefore, jointly with the motion ahead in space there is a motion backward in time and vice versa.

Consequently, the external observer sees the object moving with his naked eye, and believes that the object evolves in his own time, while in reality the object could evolve far in the past. Alternatively, we can say that the inspection of an astrophysical object with a telescope, by no means, implies that said object evolves with our own time because it could evolve with a time dramatically different than that after adjustments due to the travel time of light because, again, light cannot carry any information on the actual time of its source.

To further clarify this important point, *light cannot possibly carry information on the time of its source because light propagates at the speed c at which there is no time evolution.*

As a concrete example, one of the consequences of interior gravitational problems treated via Santilli's isorelativity (see Section 3.5) is that *the time of interior gravitational problems,* $\hat{t} = t/n_4$*, depends on the interior density* n_4^2*, rather than the inertial mass, thus varying for astrophysical bodies with different densities.*

This implies that if two identical watches are originally synchronized with each other on Earth, and then placed in the interior gravitational field of astrophysical bodies with different densities, they will no longer be synchronized, thus evolving with different times, even though light may continue to provide the information needed for their intercommunication.

In particular, *the time evolution of astrophysical bodies slows down with the increase of the density,*

$$\hat{t}_1 < \hat{t}_2, \quad n_{41}^2 > n_{42}^2. \qquad (13.3.8)$$

It should also be noted that the above effect has no connection with similar Riemannian predictions because it is structurally dependent on the *change of the units,* rather than geometric features.

A prediction of isospecial relativity is that the bigger the density, the slower the time evolution. Thus, a watch in the interior of Jupiter is predicted to

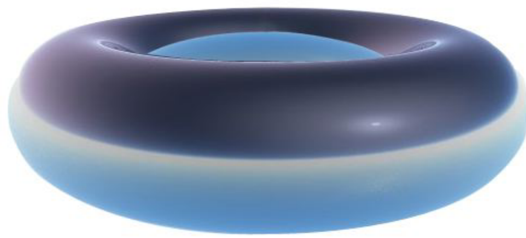

Figure 13.5. An artistic rendering of the "Space Time Machine", namely, the "mathematical" prediction of traveling in space and time permitted by the isodual theory of antimatter. The main assumption is that the aether (empty space) is a universal medium characterized by a very high density of positive and negative energies that can coexist because existing in distinct, mutually isodual spacetimes. Virtually arbitrary trajectories and speeds for iso-selfdual states (only) are then predicted from the capability of extracting from the aether very high densities of positive and negative energies in the needed sequence. Discontinuous trajectories do not violate the law of inertia, speeds much bigger than the speed of light in vacuum, and similarly apparently anomalous events, do not violate special relativity because the locomotion is caused by the change of the local geometry and not by conventional Newtonian motions.

move *slower* than its twin on Earth under the assumption that the density of Jupiter (being a gaseous body) is significantly smaller than that of Earth (that can be assumed to be solid for these aspects).

As stressed in Section 13.3.1, *the above spacetime machine is a purely mathematical model*. To render it a reality, there is the need to identify the *isogeometric propulsion*, namely a source for the geometric mutations of type (13.3.5).

Needless to say, the above problem cannot be quantitatively treated on grounds of available scientific knowledge. However, to stimulate the imagination of readers with young minds of any age, a speculation on the possible mechanism of propulsion should be here voiced.

The only source of geometric mutation conceivable today is the availability of very large energies concentrated in very small regions of space, such as energies of the order of 10^{30} ergs/cm^3. Under these conditions, isorelativity does indeed predict isogeometric locomotion because these values of energy density generate very large values of isounits $\hat{I}$, with very small values of the isotopic element $\hat{T}$, resulting in isogeometric locomotions precisely of type (13.3.5).

The only possible source of energy densities of such extreme value is empty space. In fact, according to current views, space is a superposition of positive and negative energies in equal amounts each having extreme densities precisely of the magnitude needed for isogeometric locomotion.

The speculation that should not be omitted in this section is therefore that, one day in the future, the advancement of science will indeed allow to extract from space at will all needed amounts of both positive and negative energy densities.

In the event such an extraction becomes possible in a directional way, a spaceship would be able to perform all desired types of trajectories, including trajectories with sharp discontinuities (instantaneous 90 degrees turns), instantaneous accelerations, and the like without any violation of the law of inertia because, as indicated earlier, the spaceship perceives no motion at all. It is the geometry in its surroundings that has changed.

Moreover, such a spaceship would be able to cover interstellar distances in a few of our minutes, although arriving at destination way back in the time evolution of the reached system.

Science has always surpassed science fiction and always will, because there is no limit to the advancement of scientific knowledge. On this ground it is, therefore, easy to predict that, yes, one day mankind will indeed be able to reach far away stars in minutes.

It is only hoped that, when that giant step for mankind is achieved, the theory that first achieved its quantitative and invariant prediction, Santilli isorelativity, will be remembered.

References

[1] D. H. Childress, *The Antigravity Handbook,* Network Unlimited Press, Stell, Illinois (1983).

[2] B. C. Ebershaw, *Antigravity Propulsion Devices,* D&B Associates, New York (1980).

[3] J. Sherk, Phys. Letters B **88,** 265 (1979).

[4] J. Sherk, contributed paper in *Supergravity,* P. van Neuwenhulzen and D. Z. Freedoman, Editors, North Holland, Amsterdam (1979).

[5] M. Holzscheiter, Editor, *Proceedings of the International Workshop on Antimatter Gravity*, Sepino, Molise, Italy, May 1996, Hyperfine Interactions, Vol. **109** (1997).

[6] W. M. Fairbank and F. C. Witteborn, Phys. Rev. Lett. **19**, 1049 (1967).

[7] R. E. Brown et al., Nucl. Instr. Methods, Phys. Res. B **26**, 480 (1991).

[8] G. Testera, Hyperfine Interactions **109,** 333 (1997).

[9] R. Poggiani, Hyperfine Interactions **109,** 367 (1997).

[10] C. W. Misner, K. S. Thorne and A. Wheeler, *Gravitation*, Freeman, San Francisco (1970).

[11] M. M. Nieto and T. Goldman, Phys. Reports **205,** 221 (1991), erratum **216**, 343 (1992).

[12] R. M. Santilli, Hadronic J. **17**, 257 (1994).

[13] J. P. Mills, jr., Hadronic J. **19**, 1 (1996).

[14] R. M. Santilli, Hadronic J. **17**, 285 (1994).

[15] R. M. Santilli, *Elements of Hadronic Mechanics*, Vols. I [15a] and II [15b], Ukrainian Academy of Sciences, Kiev, Second Edition (1995).

[16] R. M. Santilli, Intern. J. Modern Phys. D **7**, 351 (1998).

[17] D. Lovelock and H. Rund, *Tensors, Differential Forms and Variational Principles*, Wiley, New York (1975).

[18] R. M. Santilli, Ann. Phys. **83**, 108 (1974).

[19] R. M. Santilli, Hyperfine Interactions, **109**, 63 (1997).

[20] R. M. Santilli, contributed paper to *New Frontiers in Hadronic Mechanics*, T. L. Gill, Editor, Hadronic Press (1996), pp. 343–416.

[21] R. M. Santilli, Nuovo Cimento **51**, 570 (1967).

[22] T. Goldman and M. M. Nieto, Phys. Lett. **112B**, 437 (1982).

[23] T. Goldman, M. V. Hynes and M. M. Nieto, Gen. Rev. Grav. **18** 67 (1986).

[24] N. Beverini et al., "A Measurement of the Gravitational Acceleration of the Antiproton," LA-UR-86-260, experimental proposal submitted to CERN.

[25] T. Goldman, R. J. Hughes and M. M. Nieto, Phys. Rev. D **36**, 1254 (1987).

[26] T. Goldman, R. J. Hughes and M. M. Nieto, Phys. Lett. **171B**, 217 (1986).

[27] T. Goldman, R. J. Hughes and M. M. Nieto, in *Proceedings of the First Workshop on Antimatter Physics at Low Energy*, ed. by B. E. Bonner, and L. S. Pinsky, Fermilab (April 1986), p. 185.

[28] T. Goldman, R. J. Hughes and M. M. Nieto, in *Proceedings of Second Conf. on the Intersections Between Particle and Nuclear Physics*, (Lake Louise, May 1986), AIP Conf. Proc. 150, ed. by D. Geesaman, p. 434.

[29] T. Goldman, R. J. Hughes and M. M. Nieto, in *Proceedings of the GR11 Conference*, Stockholm July 1986.

[30] Santilli, R. M. *Isoduial Theory of Antimatter with Applications to Antigravity, Spacetime Machine and Cosmology,* Springer, in press for 2006).