ORBITAL THEORY IN TERMS OF THE LORENTZ TRANSFORM OF THE ECE2 FIELD TENSOR.

by

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ABSTRACT

A new and original theory of orbits is developed from the Lorentz transform of the field tensor of ECE2 gravitomagnetic and dynamic theories. The concept of the Lorentz transform is extended to a Lorentz transform of frames. ECE2 is a generally covariant unified field theory in which the general transform reduces to a Lorentz transform, so the Lorentz transform becomes a transform of general rather than special relativity. The new theory is applied to the a priori calculation of the precession of the perihelion in terms of the gravitomagnetic field

Keywords: ECE2, Lorentz transformation, general dynamics, orbital precession.

UFT 323

1. INTRODUCTION

In recent papers of this series {1 - 12} the second Bianchi identity has been corrected in UFT313 for spacetime torsion, a series of papers developed in vector notation. These are papers of the ECE2 theory, in which the concepts of both torsion and curvature are fully utilized. The field tensors of ECE2 have been defined both for electromagnetism and gravitomagnetism, and an initial development made of the application of ECE2 to the theory of orbits. In this paper ECE2 is applied in an a priori theory of orbits based on the general Lorentz boost with any velocity $\underline{v}$. The new theory of orbits is therefore a theory of general relativity in which one frame can move in any way with respect to another.

A usual this paper should be read together with its background notes which are posted with UFT323 on www.aias.us. Note 323(1) derives the non Newtonian forces of Coriolis (1835) from a rotational Lorentz transform of the unit vector in four dimensions. The rotational Lorentz transform is defined as a rotation in a circle about the Z axis perpendicular to the plane of the plane polar coordinates. Such a transform defines the plane polar coordinates and cylindrical polar coordinates. The velocity and acceleration in these coordinates contain a Newtonian term and non Newtonian terms such as the centripetal and Coriolis accelerations. The field tensor is rotated giving self consistent results as described in the note. In note 323(2) a new theory of dynamics is developed based on the homogeneous and inhomogeneous field equations of ECE2 gravitomagnetism. The acceleration due to gravity $\underline{g}$ is generalized to any acceleration $\underline{a}$ and the new equations of dynamics, the field equations, developed in vector notation. The fundamental law of conservation of matter is derived as the continuity equation. The general Lorentz transform of this theory develops the 1835 Coriolis theory into a theory of general relativity in which one frame moves with any velocity $\underline{v}$ with respect to another. Therefore this theory applies the concept of the Lorentz transform to frames rather than particles. The primed frame is the Newtonian or inertial frame whose axes are not moving. The unprimed frame is the observer frame whose axes are moving. For example Note 323(1) deals with the case of axes rotating in a circle, this defining the cylindrical polar coordinates. Notes 323(3) and 323(4) define the Lorentz boost in Z, and also the general Lorentz boost. The results are checked rigorously with computer algebra. Since ECE2 is part of a generally covariant unified field theory, the general Lorentz boost is also a theory of general relativity in which one frame can move with respect to another with any $\underline{v}$. The latter can be an orbital linear velocity.

Section 2 of this paper is based on Notes 323(5) and 323(6) in which an a priori and generally covariant theory of orbits is developed using the general transformation of the ECE2 field tensor. In this theory the primed frame is the Newtonian frame defined as a frame in which the coordinate axes are at rest. However, in contrast to the usual concept of the Lorentz transform in special relativity, a particle may move in this rest frame. For example the acceleration of the particle in this rest frame is the Newtonian acceleration. In the original theory by Lorentz, the particle is at rest in its own frame of reference, known as "the rest frame". Therefore this theory is the general boost of the coordinate system. In note 323(1) a Lorentz rotation of the coordinate system was described. In other words Notes 323(5) and 323(6) generalize Note 323(1) to a frame moving at any $\underline{v}$ with respect to another, and therefore develop the 1835 theory of Coriolis into a theory of general relativity. As shown in Note 323(1) the latter is defined by a Lorentz rotation.

Section 3 is a graphical analysis and discussion.

2. THEORY OF ORBITS.

The general equations of the theory are defined in Note 323(5). The relevant force equation for orbits is the precise analogy of the Lorentz force equation in classical electrodynamics but with the key changes of concept described in the introduction:

$$\underline{F} = m\left(\gamma\left(\underline{g} + \underline{v} \times \underline{\Omega}\right) - \frac{\gamma^2}{1+\gamma}\,\frac{\underline{v}}{c}\left(\frac{\underline{v}}{c}\cdot\underline{g}\right)\right) = -\frac{mMG}{r^2}\,\underline{e}_r \quad -(1)$$

This equation also develops the 1689 Leibnitz orbital equation into a theory of general relativity. It can describe non Newtonian effects in astronomy, notably the precession of the perihelion. In Eq. (1) $\underline{F}$ is the total force between an object of mass m orbiting a mass M, where m and M are a distance r apart. For an inverse square law central force:

$$\underline{F} = -\frac{mMG}{r^2}\,\underline{e}_r \quad -(2)$$

where G is the Newton constant and $\underline{e}_r$ the radial unit vector. The acceleration $\underline{g}$ is the Newtonian acceleration:

$$\underline{g} = \frac{d^2 r}{dt^2}\,\underline{e}_r = -\frac{MG}{r^2}\,\underline{e}_r \quad -(3)$$

of a frame defined by axes that are not moving, known as the inertial frame. The gravitomagnetic field is $\underline{\Omega}$, and the Lorentz factor is:

$$\gamma = \left(1 - \frac{v^2}{c^2}\right)^{-1/2} \quad -(4)$$

The velocity of one frame with respect to the other is $\underline{v}$. The derivation of Eq. (1) is given in detail in Notes 323(3) and 323(4). Finally c is the speed of light in vacuo, regarded as a universal constant.

The 1835 Coriolis theory is recovered in the limit:

$$\gamma \rightarrow 1, \; v \ll c \quad -(5)$$

which gives:

$$\underline{F} = m(\underline{g} + \underline{v} \times \underline{\Omega}) = -\frac{mMG}{r^2}\underline{e}_r. \quad -(6)$$

The well known Coriolis theory in plane polar coordinates (r , θ) in conventional notation gives:

$$\underline{F} = m\left((\ddot{r} - r\dot{\theta}^2)\underline{e}_r + (r\ddot{\theta} + 2\dot{r}\dot{\theta})\underline{e}_\theta\right) = -\frac{mMG}{r^2}\underline{e}_r. \quad -(7)$$

It has been shown in previous work {1 - 12} that for planar orbits:

$$r\ddot{\theta} + 2\dot{r}\dot{\theta} = 0. \quad -(8)$$

So for planar orbits:

$$\underline{F} = m(\ddot{r} - r\dot{\theta}^2)\underline{e}_r = -\frac{mMG}{r^2}\underline{e}_r. \quad -(9)$$

The 1689 Leibnitz orbital equation is:

$$m\ddot{r} = r\dot{\theta}^2 - \frac{mMG}{r^2} \quad -(10)$$

which is recovered from the general theory using:

$$\underline{v} = \underline{\omega} \times \underline{r}, \quad \underline{\Omega} = -\underline{\omega}. \quad -(11)$$

Therefore in the Leibnitz orbital equation one frame moves with respect to another with the circular part of the orbital linear velocity:

$$\underline{v} = \underline{\omega} \times \underline{r}. \quad -(12)$$

This is the angular part of the total orbital velocity:

$$\underline{v} = \dot{r}\,\underline{e}_r + \omega r\,\underline{e}_\theta, \quad -(13)$$

$$v^2 = \dot{r}^2 + \omega^2 r^2. \quad -(14)$$

The Leibnitz orbital equation gives the conic section orbit:

$$r = \frac{\alpha}{1+\epsilon\cos\theta} \quad -(15)$$

where α is the half right latitude and ϵ the eccentricity.

The observed orbit is however precessing:

$$r = \frac{\alpha}{1+\epsilon\cos(x\theta)} \quad -(16)$$

and so the precession is due to the generalization of Eq. (9) to Eq. (1). In the Coriolis limit, the gravitomagnetic field is given by Eq. (11), so Eq. (1) becomes:

$$\underline{F} = m\left(\gamma\left(\frac{d^2r}{dt^2} - \Omega^2 r\right)\right)\underline{e}_r. \quad -(17)$$

Using the following expressions for the velocity $\underline{v}$ of the Lorentz boost and the acceleration g:

$$\underline{v} = \omega r\,\underline{e}_\theta = \underline{\omega}\times\underline{r}, \quad -(18)$$

$$\underline{g} = -\frac{MG}{r^2}\,\underline{e}_r. \quad -(19)$$

Eq. (1) reduces to:

$$\underline{F} = m\gamma\left(\frac{d^2r}{dt^2} + \underline{v}\times\underline{\Omega}\right)\underline{e}_r. \quad -(20)$$

From Eq. (14), the Lagrangian is:

$$\mathcal{L} = \frac{1}{2}mv^2 - U(r) \quad -(21)$$

The Euler Lagrange equation:

$$\frac{\partial \mathcal{L}}{\partial r} = \frac{d}{dt}\frac{\partial \mathcal{L}}{\partial \dot{r}} \quad -(22)$$

gives:

$$m(\ddot{r} - r\dot{\theta}^2) = -\frac{\partial U}{\partial r} = F(r) \quad -(23)$$

and the Binet equation:

$$F(r) = -\frac{L^2}{mr^2}\left(\frac{d^2}{d\theta^2}\left(\frac{1}{r}\right) + \frac{1}{r}\right). \quad -(24)$$

The relativistic correction is therefore due to an effective potential V defined by:

$$F(r) = -\frac{\partial V}{\partial r} = m(\ddot{r} - \Omega^2 r) = -\frac{mMG}{\gamma r^2} \quad -(25)$$

From Eqs. (16) and (24) the orbit due to Eq. (25) is given by:

$$\frac{d^2}{d\theta^2}\left(\frac{1}{r}\right) + \frac{1}{r} = \frac{1}{\gamma\alpha} \quad -(26)$$

in which the Lorentz factor is defined by:

$$\gamma = \left(1 - \frac{v^2}{c^2}\right)^{-1/2}. \quad -(27)$$

In the Coriolis limit the Binet Equation is the well known {1 - 12}:

$$F(r) = -\alpha\frac{mMG}{r^2}\left(\frac{d^2}{d\theta^2}\left(\frac{1}{r}\right) + \frac{1}{r}\right) \quad -(28)$$

where L is the angular velocity, a constant of motion. For small x as in the solar system:

$$L^2 = m^2 MG\alpha. \quad -(29)$$

The Binet equation (28) is derived with an angular velocity ω , and shows that the force needed for a precessing orbit (16) is {1 - 12}:

$$F = mMG\left(-\frac{x^2}{r^2} + (x^2-1)\frac{\alpha}{r^3} \right). \quad -(30)$$

This must be the same as the force (25) in order to give the same orbit (16). So:

$$x^2 + (x^2-1)\frac{\alpha}{r} = \frac{1}{\gamma}. \quad -(31)$$

At the perihelion:

$$r = \frac{\alpha}{1+\epsilon} \quad -(32)$$

so:

$$x^2 + (x^2-1)(1+\epsilon) = \frac{1}{\gamma}. \quad -(33)$$

This equation is solved by computer algebra in Section 3 to give x in terms of γ.

The velocity of the Lorentz transform is defined as:

$$v_\Omega = \Omega r \quad -(34)$$

so:

$$x^2 + (x^2-1)(1+\epsilon) = \left(1 - \frac{v_\Omega^2}{c^2}\right)^{1/2}. \quad -(35)$$

As in note 323(6) and Section 3, the precession is worked out in terms of v_Ω for the orbit of the earth about the sun.

Orbital theory in terms of the Lorentz transform of the ECE2 field tensor

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3 Numerical analysis and discussion

We give an example for the calculation of x and $v_{\mathbf{\Omega}}$ for the orbit of the earth. We can resolve Eq.(33) for γ, obtaining the positive solution:

$$x = \sqrt{\frac{\frac{1}{\gamma} + \epsilon + 1}{\epsilon + 2}}. \tag{36}$$

For $\gamma \to 1$, x approaches unity as expected. Identifying the local velocity v by $v_{\mathbf{\Omega}}$, where $\mathbf{\Omega}$ denotes the velocity due to the gravitomagnetic field of the sun, we obtain for the modulus of this velocity:

$$v_{\mathbf{\Omega}} \approx \Omega r \approx \omega r \tag{37}$$

where ω is the angular frequency of the earth orbit. With $v_{\mathbf{\Omega}} << c$:

$$\gamma \approx \frac{1}{\sqrt{1 - \frac{v_{\mathbf{\Omega}}^2}{c^2}}} \approx 1 - \frac{v_{\mathbf{\Omega}}^2}{2c^2}. \tag{38}$$

The eccentricity ϵ and perihelion precession are

$$\epsilon = 0.01671123, \tag{39}$$

$$\Delta\theta = 2\pi(1 - x) = 5.551 \cdot 10^{-5}, \tag{40}$$

leading to

$$x = 0.999991165. \tag{41}$$

From (36) and (38) we obtain

$$\frac{v_\Omega}{c} = 0.00844 \tag{42}$$

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and

$$v_\Omega = 2.5309 \cdot 10^6 \text{ m/s}. \tag{43}$$

This is significantly larger than the experimentally determined orbital velocity of earth, $v = 3 \cdot 10^4$ m/s. The calculation is quite rough. This can also be seen when looking at the dependence $x(v/c)$ derived from Eq.(36), see Fig. 1. x should increase rather than decrease from unity for a growing ratio v/c. However the order of magnitude $x \approx 1$ is correct for the earth orbit.

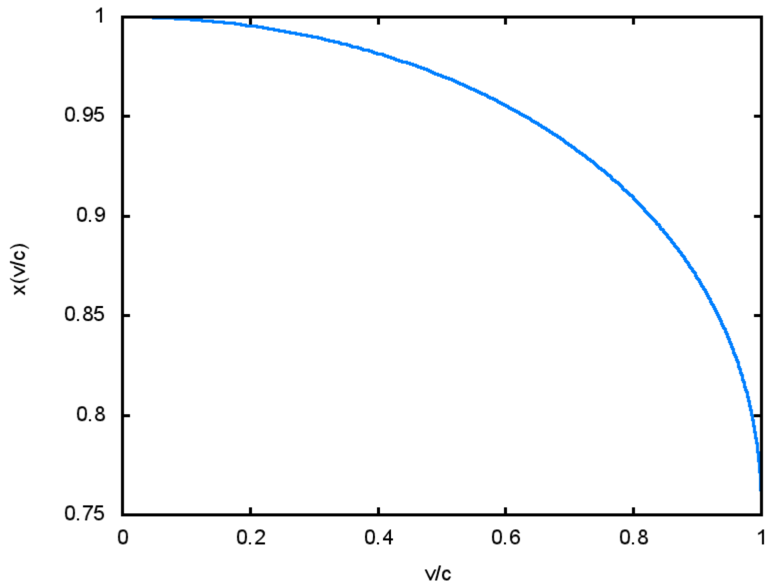

Figure 1: Precession factor x in dependence of velocity ratio v/c.

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