

# SELF CONSISTENCY OF THE ECE2 COVARIANT ORBITAL EQUATIONS.

by

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Civil List and AIAS / UPITEC

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## ABSTRACT

The relativistic orbital equations of ECE2 theory are derived and checked for self consistency using three methods: the kinematic, Lagrangian and Hamiltonian. Having derived the equations in the observer frame the de Sitter rotation method is applied to find the spin connection and vacuum force. The orbital equations with and without de Sitter rotation are solved numerically. The infinitesimal line element of the ECE2 theory is used to derive an orbit equation, and this is shown to be the trajectory of a free particle. More generally, the infinitesimal line element can be developed in the most general spherically symmetric spacetime, the  $m$  theory of previous UFT papers.

Keywords: ECE2 covariant orbital equations, frame rotation and  $m$  theories

UFT 414



## 1. INTRODUCTION

In immediately preceding UFT papers ([www.aias.us](http://www.aias.us)) {1 - 41} frame rotation has been shown to result in several advances in understanding, for example frame rotation produces the spin connection, the vacuum force, precessing and retrograde orbits. The spin connection can be expressed in terms of isotropically averaged vacuum fluctuations of the type used in the well known Lamb shift theory. These advances go well beyond the standard model's Einsteinian general relativity (EGR), which cannot produce retrograde precession and which has recently been refuted experimentally by an order of magnitude in S star systems. ECE2 is able to describe S star systems to any degree of accuracy by using the relevant angular velocity of frame rotation. In Section 2 of this paper the ECE2 covariant orbital equations are derived in three ways, giving the same result. This is a triple cross check of the theory using kinematic, Lagrangian and Hamiltonian methods, both in the observer frame and rotated frame. The resulting equations of motion are solved numerically to give the relativistic orbit. In UFT413, the orbit was derived in a well defined classical limit. The ECE2 covariant infinitesimal line element corresponding to the orbital equations is used to derive the relativistic equation of motion of a free particle. This method is checked using the relativistic hamiltonian of a free particle, giving the same result and a double cross check. Section 3 is a discussion of the numerical results accompanied by graphics.

This paper is a brief synopsis of extensive calculations posted in the background notes accompanying UFT414 on [www.aias.us](http://www.aias.us). Note 414(1) is a summary of orbital equations derived in UFT413 on the classical level. Eq. 414(2) describes the hamiltonian method on the classical level. Eq. 414(3) develops the relativistic hamiltonian method. Note 414(4) is the basis for Section 2 and uses the fundamental kinematic and Lagrangian methods to give the same relativistic orbital equations, providing a cross check on all concepts and calculations. Note 414(5) uses the hamiltonian method to give a triple cross check of the derivation of the

relativistic orbital equations, with and without frame rotation. Note 414(6) summarizes the relativistic orbital equations. Note 414(7) calculates the spin connection due to the transition from the classical to the relativistic theory. Note 414(8) calculates the relativistic spin connection due to frame rotation, and Note 414(9) calculates the relativistic trajectory of a free particle in two ways: using the ECE2 covariant infinitesimal line element and using the relativistic hamiltonian of a free particle. Both methods give precisely the same result, giving another double cross check.

## 2. SELF CONSISTENT DERIVATIONS THE RELATIVISTIC ORBITAL EQUATIONS.

Consider the relativistic velocity in any coordinate system {1 - 41}:

$$\underline{v} = \gamma \dot{\underline{r}} \quad \text{--- (1)}$$

where  $\gamma$  is the Lorentz factor and where  $\underline{r}$  is the position vector. The relativistic acceleration is

$$\underline{a} = \frac{d\underline{v}}{dt} = \frac{d}{dt} (\gamma \dot{\underline{r}}) = \frac{d\gamma}{dt} \dot{\underline{r}} + \gamma \ddot{\underline{r}} \quad \text{--- (2)}$$

In the plane polar system  $(r, \phi)$ :

$$\dot{\underline{r}} = \dot{r} \underline{e}_r + r \dot{\phi} \underline{e}_\phi \quad \text{--- (3)}$$

and

$$\ddot{\underline{r}} = (\ddot{r} - r \dot{\phi}^2) \underline{e}_r + (r \ddot{\phi} + 2 \dot{r} \dot{\phi}) \underline{e}_\phi \quad \text{--- (4)}$$

in which  $\underline{e}_r$  and  $\underline{e}_\phi$  are the unit vectors of the plane polar system.

It follows that the relativistic orbital equation for a mass  $m$  orbiting a mass  $M$  is:

$$\underline{g} = \frac{d\gamma}{dt} (\dot{r} \underline{e}_r + r \dot{\phi} \underline{e}_\phi) + \gamma \left( (\ddot{r} - r \dot{\phi}^2) \underline{e}_r + (r \ddot{\phi} + 2 \dot{r} \dot{\phi}) \underline{e}_\phi \right)$$

$$= - \frac{mG}{r^2} \underline{e}_r \quad \text{--- (5)}$$

where G is Newton's constant. The relativistic force equation is:

$$\underline{F} = m \underline{g} = - \frac{m m G}{r^2} \underline{e}_r. \quad \text{--- (6)}$$

Eq. ( 5 ) gives two simultaneous equations:

$$\frac{d\gamma}{dt} \dot{r} + \gamma (\ddot{r} - r \dot{\phi}^2) = - \frac{mG}{r^2} \quad \text{--- (7)}$$

and

$$\frac{d\gamma}{dt} r \dot{\phi} + \gamma (r \ddot{\phi} + 2 \dot{r} \dot{\phi}) = 0 \quad \text{--- (8)}$$

which can be solved numerically using the methods developed in previous UFT papers. The

Lorentz factor in these equations is:

$$\gamma = \left( 1 - \frac{v^2}{c^2} \right)^{-1/2} \quad \text{--- (9)}$$

in which the Newtonian velocity is:

$$v^2 = \dot{r}^2 + r^2 \dot{\phi}^2. \quad \text{--- (10)}$$

Eq. ( 7 ) is the relativistic Leibniz equation and Eq. ( 8 ) is the conservation of relativistic angular momentum L:

$$\frac{dL}{dt} = 0 \quad \text{--- (11)}$$

where

$$L = \gamma m r^2 \dot{\phi} \quad - (12)$$

is a constant of motion. The other constant of motion is the relativistic hamiltonian H.

Using the frame rotation of immediately preceding UFT papers:

$$\phi' = \phi + \omega_1 t \quad - (13)$$

Eqs. ( 7 ) and ( 8 ) become:

$$\frac{d\gamma}{dt} \dot{r} + \gamma (\ddot{r} - r \dot{\phi}'^2) = -\frac{MG}{r^2} \quad - (14)$$

and

$$\frac{d\gamma}{dt} r \dot{\phi}' + \gamma (r \ddot{\phi}' + 2 \dot{r} \dot{\phi}') = 0 \quad - (15)$$

and the Lorentz factor becomes:

$$\gamma = \left( 1 - \frac{1}{c^2} (\dot{r}^2 + r^2 \dot{\phi}'^2) \right)^{-1/2} \quad - (16)$$

These relativistic orbits go well beyond the standard model's EGR.

The orbital equations can also be derived using the ECE2 covariant Lagrangian:

$$\mathcal{L} = -\frac{mc^2}{\gamma} + \frac{mMG}{r} \quad - (17)$$

where the Lorentz factor is given by Eq. ( 9 ). Use the Lagrange variables  $r$  and  $\phi$

to find the two relevant Euler Lagrange equations:

$$\frac{\partial \mathcal{L}}{\partial r} = \frac{d}{dt} \frac{\partial \mathcal{L}}{\partial \dot{r}} \quad - (18)$$

and

$$\frac{\partial \mathcal{L}}{\partial \phi} = \frac{d}{dt} \frac{\partial \mathcal{L}}{\partial \dot{\phi}} \quad - (19)$$

As shown in Note 414(4) Eq. ( 18 ) produces

$$\frac{d\gamma}{dt} r + \gamma (\ddot{r} - r\dot{\phi}^2) = -\frac{m\gamma}{r^2} \quad - (20)$$

which is Eq. ( 7 ) Q. E. D.

The Lagrangian and kinematic methods give the same results, giving a double cross check on concepts, Q. E. D.

Eq. ( 19 ) gives

$$\frac{dL}{dt} = 0 \quad - (21)$$

where

$$L = \gamma m r^2 \dot{\phi} \quad - (22)$$

i.e. Eq. ( 19 ) gives Eq. ( 8 ), Q. E. D. This is another double cross check. It can be shown straightforwardly as in Note 414(4) that:

$$\frac{d}{dt} (\gamma m r^2 \dot{\phi}) = r^2 \dot{\phi} \frac{d\gamma}{dt} + \gamma (2r\dot{r}\dot{\phi} + r^2 \ddot{\phi}) = 0 \quad - (23)$$

which is Eq. ( 8 ), Q. E. D.

Eqs. ( 14 ) and ( 15 ) are obtained with the Lagrange variables  $r$  and  $\phi'$  :

$$\frac{\partial \mathcal{L}}{\partial r} = \frac{d}{dt} \frac{\partial \mathcal{L}}{\partial \dot{r}} \quad - (24)$$

and

$$\frac{\partial \mathcal{L}}{\partial \phi'} = \frac{d}{dt} \frac{\partial \mathcal{L}}{\partial \dot{\phi}}, \quad - (25)$$

giving another cross check, Q. E. D.

In Eq. ( 7 )

$$\dot{r} = v \quad - (26)$$

and

$$\frac{dv}{dt} = \ddot{r} - r \dot{\phi}^2 \quad - (27)$$

so Eq. ( 7 ) is:

$$F = \frac{d}{dt} (\gamma m v) = m \left( v \frac{d\gamma}{dt} + \gamma \frac{dv}{dt} \right) = - \frac{m M G}{r^2} \quad \therefore (28)$$

Write Eq. ( 28 ) as:

$$F = m \frac{dv}{dt} \left( v \frac{d\gamma}{dv} + \gamma \right) \quad - (29)$$

where

$$\frac{d\gamma}{dt} = \frac{d\gamma}{dv} \frac{dv}{dt} \quad - (30)$$

has been used. In Eq. ( 29 ):

$$\frac{d\gamma}{dv} = \gamma^3 \frac{v}{c^2} \quad - (31)$$

so the magnitude F of the orbital force is:

$$F = m \gamma \frac{dv}{dt} \left( 1 + \gamma^3 \frac{v^2}{c^2} \right)$$

$$= m \gamma \frac{dv}{dt} \left( 1 + \frac{v^2}{c^2 \left( 1 - \frac{v^2}{c^2} \right)} \right)$$

$$= m \gamma^3 \frac{dv}{dt} \quad - (32)$$

which is the relativistic second law of Newton. Therefore the relativistic Leibniz equation is:

$$F = m \gamma^3 \frac{dv}{dt} = - \frac{m M G}{r^2} \quad - (33)$$

It has been shown that:

$$\frac{d\gamma}{dt} \dot{r} + \gamma (\ddot{r} - r \dot{\phi}^2) = \gamma^3 \frac{dv}{dt} \quad - (34)$$

where:

$$v = \dot{r} \quad - (35)$$

and

$$\frac{dv}{dt} = \ddot{r} - r \dot{\phi}^2 \quad - (36)$$

Therefore the relativistic orbit in frame  $(r, \phi)$  is given by simultaneous solution of:

$$F = m \gamma^3 \frac{dv}{dt} = - \frac{m M G}{r^2} \quad - (37)$$

and

$$L = \gamma m r^2 \dot{\phi}, \quad \frac{dL}{dt} = 0 \quad - (38)$$

The results are discussed in Section 3.

A triple cross check of the orbital equations is possible using the relativistic hamiltonian:

$$H = \gamma m c^2 - \frac{m M G}{r} \quad - (39)$$

This is a constant of motion, so:

$$\frac{dH}{dt} = 0 \quad - (40)$$

It follows as in Note 414(5) that:

$$c^2 \frac{d\gamma}{dt} = -v \frac{M G}{r^2} \quad - (41)$$

The relativistic force magnitude is:

$$F = \frac{d}{dt} (\gamma m v) = m v \frac{d\gamma}{dt} + m \gamma \frac{dv}{dt} \quad - (42)$$

so

$$v \frac{d\gamma}{dt} + \gamma \frac{dv}{dt} = - \frac{M G}{r^2} \quad - (43)$$

Using Eq. (41):

$$- \frac{v^2}{c^2} \frac{M G}{r^2} + \gamma \frac{dv}{dt} = - \frac{M G}{r^2} \quad - (44)$$

and

$$\gamma \frac{dv}{dt} = - \frac{M G}{r^2} \left( 1 - \frac{v^2}{c^2} \right) \quad - (45)$$

so

$$\gamma^3 \frac{dv}{dt} = - \frac{M G}{r^2} \quad - (46)$$

which is Eq. (37), Q. E. D.

With reference to Note 414(8) consider the effect of the frame rotation:

$$\phi' = \phi + \omega_1 t \quad (47)$$

on the relativistic orbit equations ( 37 ) and ( 38 ). From Eq. ( 47 ):

$$\dot{\phi}' = \dot{\phi} + \omega_1 + t \frac{d\omega_1}{dt} \quad (48)$$

and the orbit equations in frame ( r ,  $\phi'$  ) are:

$$F = m \gamma'^3 (\ddot{r} - r \phi'^2) = -\frac{m M G}{r^2} \quad (49)$$

and

$$\frac{dL}{dt} = 0, \quad L = \gamma' m r^2 \dot{\phi}' \quad (50)$$

in which the cube of the rotated Lorentz factor is:

$$\gamma'^3 = \left( 1 - \frac{1}{c^2} (\dot{r}^2 + r^2 \dot{\phi}'^2) \right)^{-3/2} \quad (51)$$

It follows as in Note 414(8) that the orbital field equations are

$$F = m \gamma^3 (\ddot{r} - r \dot{\phi}^2) = -\frac{m M G}{r^2} + \Omega_r \Phi \quad (52)$$

and

$$\frac{dL}{dt} = \frac{d}{dt} \left( \gamma m r^2 \left( \dot{\phi} + \phi_1 + t \frac{d\phi_1}{dt} \right) \right) = 0 \quad (53)$$

where the spin connection produced by the frame rotation ( 47 ) is:

$$\Omega_r = \frac{1}{r} \left( 1 + \gamma^2 A \right)^{3/2} - \frac{c^2}{M G} \gamma^3 A - \frac{1}{r} \quad (54)$$

Here:

$$A = \frac{r^2}{c^2} \left( \omega_1 + t \frac{d\omega_1}{dt} \right) \left( \omega_1 + t \frac{d\omega_1}{dt} + 2\dot{\phi} \right) - (55)$$

and

$$\gamma = \left( 1 - \frac{1}{c^2} \left( \dot{r}^2 + r^2 \dot{\phi}^2 \right) \right)^{-1/2} - (56)$$

The orbit produced by Eqs. ( 52 ) and ( 53 ) is discussed in Section 3. The vacuum force due to frame rotation is:

$$F(\text{vac}) = \Omega_r \frac{\Phi}{r} = -\frac{mMG}{r} \Omega_r - (57)$$

and the correctly covariant total force is:

$$F = -\frac{mMG}{r^2} + F(\text{vac}) - (58)$$

as in immediately preceding UFT papers.

The ECE2 covariant infinitesimal line element corresponding to the orbit equations ( 37 ) and ( 38 ) is

$$ds^2 = c^2 d\tau^2 = (c^2 - v_N^2) dt^2 - (59)$$

where  $\tau$  is the proper time and  $v_N$  is the Newtonian velocity. It follows as in papers such as UFT106 and UFT192 that:

$$mc^2 = mc^2 \left( \frac{dt}{d\tau} \right)^2 - m v_N^2 \left( \frac{dt}{d\tau} \right)^2 - (60)$$

The Lorentz factor follows directly from Eq. ( 59 ):

$$\gamma = \frac{dt}{d\tau} = \left( 1 - \frac{v_N^2}{c^2} \right)^{-1/2} - (61)$$

Therefore the infinitesimal line element immediately gives the Einstein energy equation:

$$E^2 = c^2 p^2 + E_0^2 \quad - (62)$$

where

$$E = \gamma mc^2, \quad \underline{p} = \gamma m \underline{v}, \quad E_0 = mc^2 \quad - (63)$$

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In plane polar coordinates the infinitesimal line element (59) is

$$mc^2 = \frac{E^2}{mc^2} - m \left( \frac{dr}{d\tau} \right)^2 - mr^2 \left( \frac{d\phi}{d\tau} \right)^2 \quad - (64)$$

from which it follows as in Note 414(9) that:

$$m \left( \frac{dr}{d\tau} \right)^2 = \frac{E^2}{mc^2} - \frac{L^2}{mr^2} - mc^2 \quad - (65)$$

where E and L are respectively the relativistic total energy and relativistic angular momentum. Both are constants of motion. Using:

$$\frac{dr}{d\tau} = \frac{dr}{d\phi} \frac{d\phi}{d\tau} = \frac{L}{mr^2} \frac{dr}{d\phi} \quad - (66)$$

it follows that:

$$\left( \frac{dr}{d\phi} \right)^2 = r^4 \left( \frac{1}{b^2} - \frac{1}{a^2} - \frac{1}{r^2} \right) \quad - (67)$$

where a and b are constants of motion defined by:

$$a = \frac{L}{mc}, \quad b = \frac{Lc}{E} \quad - (68)$$

Therefore the ECE2 covariant infinitesimal line element (59) gives the orbit equation (67) without any consideration of potential energy. It follows that the orbit equation (67) must be given by the free particle relativistic hamiltonian:

$$H = E = \gamma mc^2, \quad - (69)$$

$$F = \gamma^3 \frac{dv}{dt} = 0. \quad - (70)$$

It follows from Eq. ( 69) that:

$$\gamma = \frac{E}{mc^2} = \left(1 - \frac{v^2}{c^2}\right)^{-1/2} \quad - (71)$$

so

$$\frac{v^2}{c^2} = 1 - \frac{m^2 c^4}{E^2}. \quad - (72)$$

The Newtonian velocity is:

$$v^2 = \dot{r}^2 + r^2 \dot{\phi}^2 \quad - (73)$$

Using:

$$\frac{dr}{dt} = \frac{dr}{d\phi} \frac{d\phi}{dt} = \dot{\phi} \frac{dr}{d\phi} \quad - (74)$$

the Newtonian velocity can be expressed as:

$$v^2 = \left( r^2 + \left( \frac{dr}{d\phi} \right)^2 \right) \dot{\phi}^2 \quad - (75)$$

In Newtonian dynamics the constant angular momentum is:

$$L_0 = m r^2 \dot{\phi} \quad - (76)$$

so

$$v^2 = \frac{L_0^2}{m^2} \left( \frac{1}{r^2} + \frac{1}{r^4} \left( \frac{dr}{d\phi} \right)^2 \right) \quad - (77)$$

From Eqs. ( 71) and ( 77)

$$\left(\frac{dr}{d\phi}\right)^2 = r^4 \left( \frac{1}{b^2} - \frac{m^2 c^4}{E^2} \cdot \frac{m^2 c^2}{L_0^2} \right) - r^2 \quad - (78)$$

In this equation:

$$\frac{m^2 c^4}{E^2} = \frac{1}{\gamma^2}, \quad - (79)$$

$$L_0^2 = \frac{L^2}{\gamma^2} \quad - (80)$$

so:

$$\left(\frac{dr}{d\phi}\right)^2 = r^4 \left( \frac{1}{b^2} - \frac{1}{a^2} \right) - r^2 \quad - (81)$$

which is Eq. ( 57 ), Q. E. D.

Therefore the infinitesimal line element ( 59 ) and the Einstein energy equation and orbit ( 81 ) are those of a relativistic free particle.

Eq. ( 81 ) can be integrated using:

$$\phi = \int \frac{1}{r^2} \left( A - \frac{1}{r^2} \right)^{-1/2} dr \quad - (82)$$

where:

$$A := \frac{1}{b^2} - \frac{1}{a^2} \quad - (83)$$

The Wolfram online integrator gives:

$$\phi = -\tan^{-1} \left( (Ar^2 - 1)^{-1/2} \right) \quad - (84)$$

so it follows as in Note 414(8) that:

$$r^2 = \frac{L^2}{m^2 c^2 (\gamma^2 - 1)} \left( \frac{1}{\tan^2 \phi} - 1 \right) \quad - (85)$$

This the relativistic trajectory of a free particle and is graphed in Section 3. In the non

relativistic limit:

$$v = r \dot{\phi} \left( \frac{1}{\tan^2 \phi} - 1 \right)^{1/2} \quad (86)$$

as in Note 414(9).

In order to describe the relativistic orbit of  $m$  about  $M$  the infinitesimal line

element is needed of the most general spherically symmetric spacetime:

$$ds^2 = c^2 d\tau^2 = m(r) c^2 dt^2 - \frac{dr^2}{m(r)} - r^2 d\phi^2 \quad (87)$$

where  $m$  is a function of  $r$ . In order to introduce the potential energy into the infinitesimal line element the infinitesimal line element (87) must be used together with the rotating frame theory. This will be the subject of UFT415.

### 3. NUMERICAL ANALYSIS AN DISCUSSION

Section by Dr. Horst Eckardt

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