ECE2 COVARIANT UNIVERSAL GRAVITATION AND PRECESSION

by

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ABSTRACT

The apsidal method is used to show that for near circular orbits, the ECE2 force equation produces a well defined precession of the perihelion. In the limit of zero spin connection the orbit is a conic section. The vacuum force of ECE2 theory modifies the orbit into an integral which can be worked out numerically, and which can also be approximated in the near circular limit of low eccentricity. The two near circular approximations must produce the same overall result so are equated to give new information. The origin of precession is shown to be isotropically averaged vacuum fluctuations.

Keywords: ECE2 universal gravitation, precession of the planar orbit, apsidal method.

UFT403

1. INTRODUCTION.

In recent papers of this series {1 - 41} the ECE2 covariant theory of universal gravitation has been used to show that the origin of precession is the isotropically averaged vacuum fluctuations that are the origin of the Lamb shift. The spin connection of ECE2 theory has been expressed in terms of these vacuum fluctuations, and the spin connection term of the force equation has been identified as the vacuum term. In Section 2 it is shown that the force equation of ECE2 universal gravitation produces precession in general. The apsidal method is applied in the near circular approximation and the orbit evaluated numerically from the force equation in terms of a well defined integral. In general this integral has no analytical solution, but it can be integrated numerically provided that care is taken near singularities. It can also be approximated analytically in the near circular approximation. Comparison of the two near circular approximations gives a complete solution. As the spin connection goes to zero, the orbit approaches a conic section and Newtonian universal gravitation is retrieved as the spin connection vanishes. So the theory is rigorously self consistent.

This paper is a brief synopsis of extensive calculations and preliminary calculations in the accompanying Notes which should be studied with UFT403 on www.aias.us and www.upitec.org. The ideas and calculations in the Notes gradually crystallize into the finished paper. Note 403(1) describes an approximation to the ECE2 equation of orbits, Note 403(2) develops a method to describe precession, Notes 403(3) and 403(4) develop an analytical approximation to a precessing orbit Note 403(5) gives an approximate solution in the low eccentricity limit. The apsidal method of Section 2 is based on Notes 403(6) and 403(10), the final version of Note 403(6). Notes 403(7) to 403(9) develop solutions for the ECE2 covariant orbit.

Section 3 is a numerical and graphical analysis.

2. THE APSIDAL METHOD AND ANALYTICAL ORBIT

For nearly circular orbits of low eccentricity, the apsidal angle, the angle between two turning points or asides of the orbit, is defined by:

$$\psi = \pi \left(3 + r\frac{F'}{F} \right)^{-1/2} \quad -(1)$$

where $\underline{F}$ is the force between an object of mass m orbiting an object of mass M, and where:

$$F' = \partial F / \partial r. \quad -(2)$$

Eq. (1) gives a simple method for calculating the precession of the perihelion for a given force law, and has been developed in pervious UFT papers. It is described by Fitzgerald in www.farside.ph.utexas.edu/teaching/336k. For example, consider the force law of the obsolete Einsteinian general relativity (EGR) for ease of reference only:

$$F = -\frac{mMG}{r^2} - \frac{3MGL^2}{mc^2r^4} \quad -(3)$$

where G is Newton's constant and L is the constant angular momentum. Here r is the magnitude of the vector $\underline{r}$ joining m and M, and c is the speed of light. Therefore:

$$\frac{\partial F}{\partial r} = \frac{2mMG}{r^3} + \frac{12MGL^2}{mc^2r^5} \quad -(4)$$

and

$$\frac{rF'}{F} = -2\left(1+\frac{6L^2}{m^2c^2r^2}\right) \Big/ \left(1+\frac{3L^2}{m^2c^2r^2}\right). \quad -(5)$$

If:

$$\frac{3L^2}{m^2c^2r^2} \ll 1 \quad -(6)$$

then:

$$\frac{rF'}{F} \sim -2\left(1+\frac{6L^2}{m^2c^2r^2}\right) \quad -(7)$$

and the apsidal angle is:

$$\phi = \pi\left(1-\frac{12L^2}{m^2c^2r^2}\right)^{-1/2} \quad -(8)$$

$$\sim \pi\left(1+\frac{6L^2}{m^2c^2r^2}\right).$$

At the perihelion, the distance of closest approach:

$$r = a(1-\epsilon) \quad -(9)$$

where a is the semi major axis and ϵ is the eccentricity.

For an approximately circular orbit:

$$L^2 = m^2 MG\alpha \sim m^2 MGr \quad -(10)$$

where α is the half right latitude, so the precession at the perihelion is:

$$\Delta\phi = \Delta\phi = \frac{6\pi MG}{c^2 a(1-\epsilon)}. \quad -(11)$$

However, the UFT papers contain numerous refutations of EGR, so the above result is obtained to exemplify the method only. Note carefully that the method of successive approximations given by Marion and Thornton {1 - 41}, produces a different result:

$$\Delta\phi = \frac{6\pi MG}{c^2 a(1-\epsilon^2)} \quad -(12)$$

and that method has been criticised severely in the UFT papers. It is pointless to claim as in the standard model that EGR is precise, because precessions in the solar system are exceedingly small in magnitude and are extracted using Newtonian methods from precessions caused by other planets. EGR is applied inconsistently only to that part of the precession that remains after the "Newtonian filtering" of the effect of other planets has been applied. This has been pointed out on the net by Myles Mathis, and a UFT paper devoted to the subject. The theory of precessions should be applied to systems in which there is no extraneous influence.

Now consider the ECE2 force equation of universal gravitation:

$$\underline{F} = -\underline{\nabla}\phi + \underline{\omega}\phi \quad -(13)$$

where ϕ is the Newtonian gravitational potential energy:

$$\phi = -\frac{mMG}{r} \quad -(14)$$

and where $\underline{\omega}$ is the vector spin connection that transforms the theory from Galilean covariance to ECE2 covariance, a type of general covariance {1 - 42}. In immediately preceding papers it has been shown that the magnitude of the spin connection is:

$$\omega = \frac{2}{3}\frac{\langle \delta\underline{r} \cdot \delta\underline{r} \rangle}{r^3} \quad -(15)$$

and originates in fluctuations of spacetime (synonymous with "aether" or "vacuum"). For example:

$$\delta\underline{r} = \delta\underline{r}(0)\exp(-i\Omega_0 t) \quad -(16)$$

where Ω_0 is a characteristic frequency. The force due to vacuum fluctuations is:

$$\mathbf{F}(\text{vac}) = \boldsymbol{\omega}\,\phi \quad -(17)$$

and a tensorial Taylor series gives the isotropically averaged magnitude of the vacuum force:

$$\langle F(\text{vac})\rangle = \frac{1}{6}\langle \delta\mathbf{r}\cdot\delta\mathbf{r}\rangle \nabla^2 F = \frac{2}{3}\, mMG \frac{\langle \delta\mathbf{r}\cdot\delta\mathbf{r}\rangle}{r^4} \quad -(18)$$

as shown in recent papers.

If a negative spin connection vector is used then:

$$\mathbf{F} = -\boldsymbol{\nabla}\phi - \boldsymbol{\omega}\,\phi \quad -(19)$$

and

$$\langle F(\text{vac})\rangle = -\frac{2}{3}\, mMG \frac{\langle \delta\mathbf{r}\cdot\delta\mathbf{r}\rangle}{r^4} \quad -(20)$$

so:

$$F = -\frac{mMG}{r^2} - \frac{2}{3}\, mMG \frac{\langle \delta\mathbf{r}\cdot\delta\mathbf{r}\rangle}{r^4} \quad -(21)$$

Comparing Eqs. (3) and (21) shows that the Einsteinian general relativity is a special case of the ECE2 covariant Eq. (21). EGR is defined by the choice:

$$\langle \delta\mathbf{r}\cdot\delta\mathbf{r}\rangle = \frac{9L^2}{2m^2c^2} = \frac{9}{2}\alpha\frac{MG}{c^2} \quad -(22)$$

using:

$$L^2 = \alpha m^2 MG. \quad -(23)$$

Using the so called "Schwarzschild radius" of the standard model:

$$r_0 = \frac{2MG}{c^2} \quad -(24)$$

it follows that:

$$\langle \delta \underline{r} \cdot \delta \underline{r} \rangle = \frac{9}{4} \alpha r_0 . \quad -(25)$$

For a nearly circular orbit:

$$\alpha \sim r \quad -(26)$$

where r is the radius of the orbit, so in this approximation:

$$\langle \delta \underline{r} \cdot \delta \underline{r} \rangle = \frac{9}{4} r r_0 . \quad -(27)$$

For the earth's orbit:

$$r = 1.495 \times 10^{10} \, m \quad -(28).$$

$$r_0 = 3 \times 10^{3} \, m \quad -(29)$$

so the isotropically averaged vacuum fluctuation $\langle \delta \underline{r} \cdot \delta \underline{r} \rangle$ is about seven orders of magnitude smaller than the radius of the orbit.

From Eqs. (11) and (22) the precession of the perihelion in EGR is the special case:

$$\Delta \phi = \frac{4}{3} \pi \frac{\langle \delta \underline{r} \cdot \delta \underline{r} \rangle}{a^2 (1-\epsilon)(1-\epsilon^2)} \quad -(30)$$

and the precession of the perihelion is due to the isotropically averaged vacuum fluctuations, which are also the origin of EGR, a major advance in understanding.

EGR is a particular case of: the ECE2 force equation:

$$F = -\frac{mMG}{r^2} + \frac{mMG}{r} \omega \quad -(31)$$

but there are major flaws in EGR because of its omission of torsion. ECE2 correctly considers torsion. So no great importance can be attached to Eq. (22), it is used only for the sake of illustration. The philosophically and mathematically correct perihelion precession due to Eq. (31) used in the low eccentricity approximation is calculated as follows:

$$F' = \frac{\partial F}{\partial r} = \frac{2mMG}{r^3} - \frac{mMG}{r^2}\omega + \frac{mMG}{r}\frac{\partial \omega}{\partial r} \quad -(32)$$

so:

$$\frac{rF'}{F} = \frac{\frac{2}{r^2} + \frac{\omega}{r} - \frac{\partial \omega}{\partial r}}{-\frac{1}{r^2} + \frac{\omega}{r}} . \quad -(33)$$

If it is assumed that:

$$\omega_r = \frac{a}{r} \quad -(34)$$

as in some previous UFT papers, then:

$$\phi = \pi(1+a) \quad -(35)$$

and for

$$a << 1 \quad -(36)$$

it follows that:

$$\phi \sim \pi \quad -(37)$$

which is the apsidal angle for a static ellipse in which the apsides are fixed, one does not precess with respect to the other. This is a useful check on the correctness of the result (33).

For small precessions the spin connection is very small, so:

$$-\frac{1}{r^2}+\frac{\omega}{r}\sim-\frac{1}{r^2} \quad -(38)$$

and:

$$\frac{rF'}{F}\sim-2-r^2\left(\frac{\omega}{r}-\frac{\partial\omega}{\partial r}\right). \quad -(39)$$

The apsidal angle is therefore:

$$\phi=\pi\left(1-r^2\left(\frac{\omega}{r}-\frac{\partial\omega}{\partial r}\right)\right)^{-1/2} \quad -(40)$$

and the precession at the perihelion is

$$\Delta\phi=\Delta\phi=\frac{r^2}{2}\left(\frac{\omega}{r}-\frac{\partial\omega}{\partial r}\right). \quad -(41)$$

Using Eq. (15):

$$\Delta\phi=\frac{4}{3}\frac{\langle\delta\underline{r}\cdot\delta\underline{r}\rangle}{r^2}-\frac{1}{3r}\frac{\partial}{\partial r}\langle\delta\underline{r}\cdot\delta\underline{r}\rangle \quad -(42)$$

so the precession is due to vacuum fluctuations, Q. E. D.

In the limit of an exactly circular orbit:

$$\epsilon=0 \quad -(43)$$

so the perihelion:

$$r=r_{min}=a(1-\epsilon)=\frac{\alpha}{1+\epsilon} \quad -(44)$$

reduces to:

$$r_{min}=a=\alpha. \quad -(45)$$

For an exactly circular orbit:

$$\Delta \phi = 0 \quad -(46)$$

so from Eq. (42):

$$\frac{\partial}{\partial r} \langle \delta \underline{r} \cdot \delta \underline{r} \rangle = \frac{4}{a} \langle \delta \underline{r} \cdot \delta \underline{r} \rangle . \quad -(47)$$

As described in Note 403(2) the ECE2 covariant force equation (13) of universal gravitation can be transformed into two scalar equations:

$$\ddot{r} - r \dot{\phi}^2 = -\frac{mG}{r^2} - \omega_r \frac{mG}{r} \quad -(48)$$

and

$$r \ddot{\phi} + 2 \dot{r} \dot{\phi} = 0 \quad -(49)$$

with the force magnitude:

$$F = -\frac{mMG}{r^2} \left(1 + \omega_r r \right) . \quad -(50)$$

This procedure gives the orbital equation:

$$\frac{d^2}{d\phi^2} \left(\frac{1}{r} \right) + \frac{1}{r} = \frac{1}{\alpha} \left(1 + r \omega_r \right) \quad -(51)$$

in plane polar coordinates, the vacuum corrected Binet equation, together with the equation of conservation of angular momentum:

$$r \ddot{\phi} + 2 \dot{r} \dot{\phi} = 0. \quad -(52)$$

The orbit from Eq. (51) is given by Maxima as:

$$\phi = -\int \left(\frac{\alpha}{2\omega_r \log_e u - \alpha u^2 + 2u - 2C_1} \right)^{1/2} du \quad -(53)$$

in which:

$$u = \frac{1}{r}, \quad \alpha = \frac{L^2}{m^2 M G}. \quad -(54)$$

In the limit of zero spin connection, Eq. (53) becomes the Newtonian:

$$\phi(u) = -L \int \frac{du}{\left(2m\left(H + \frac{mMG}{r} - \frac{L^2}{2m} u^2\right)\right)^{1/2}} \quad -(55)$$

where H, the hamiltonian, and L the angular momentum, are constants of motion. Eq. (55)

then gives the conic section:

$$r = \frac{\alpha}{1 + \epsilon \cos\phi} \quad -(56)$$

with half right latitude:

$$\alpha = \frac{L^2}{m^2 M G} \quad -(57)$$

the eccentricity:

$$\epsilon = \left(1 + \frac{2HL^2}{m^3 M^2 G^2} \right)^{1/2} \quad -(58)$$

and semi major axis:

$$\frac{1}{a} = \frac{2|H|}{mMG}. \quad -(59)$$

Therefore the orbit from Eq. (53) is a small perturbation of a conic section.

The apsidal method shows that the perturbation is a precession of the perihelion. Using a binomial expansion as in Note 403(8), it can be shown that the orbit precesses by:

$$\Delta\phi \sim \frac{2}{3}\alpha^{1/2}\int \langle \delta\underline{r}\cdot\delta\underline{r}\rangle \left(\frac{u^2}{-\alpha u^2+2u-\frac{1}{a}}\right)^{3/2}\log_e u\,du \quad -(60)$$

Comparing Eqs. (42) and (60) gives the equation:

$$\frac{4}{3}\frac{\langle \delta\underline{r}\cdot\delta\underline{r}\rangle}{r^2}-\frac{1}{3r}\frac{\partial}{\partial r}\langle \delta\underline{r}\cdot\delta\underline{r}\rangle = \frac{2}{3}\alpha^{1/2}\int \langle \delta\underline{r}\cdot\delta\underline{r}\rangle \left(\frac{u^2}{-\alpha u^2+2u-\frac{1}{a}}\right)^{3/2}\log_e u\,du \quad -(61)$$

which is an integro differential equation for the isotropically averaged vacuum fluctuation

$$\langle \delta\underline{r}\cdot\delta\underline{r}\rangle = \frac{3}{2}r^3\omega_r \quad -(62)$$

The precession can also be found by integrating Eq. (53) numerically, and measuring the precession graphically.

3. NUMERICAL AND GRAPHICAL DEVELOPMENT

Section by co author Horst Eckardt.

ECE2 covariant universal gravitation and precession

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3 Numerical and graphical development

The orbital precession in near-circular approximation was given by Eq. (60). By the relations (57-59) for circular orbits, only the constants α (half right latitude) and a (semi major axis) are left as input parameters. The integral depends on the quadratic mean fluctuation radius $\langle \delta\mathbf{r} \cdot \delta\mathbf{r} \rangle$. If we assume that this is constant, we can compute the precession angle per quadratic fluctuation:

$$\frac{\Delta\phi}{\langle \delta\mathbf{r} \cdot \delta\mathbf{r} \rangle} \approx \frac{2}{3}\sqrt{\alpha} \int_{u_{min}}^{u_{max}} \frac{u^3 \log(u)}{\left(-\alpha u^2 + 2u - \frac{1}{a}\right)^{\frac{3}{2}}} du \tag{63}$$

where $u = 1/r$ is the inverse radius. The minimum and maximum radius are

$$r_{min} = a(1-\epsilon), \tag{64}$$
$$r_{max} = a(1+\epsilon). \tag{65}$$

The semi major axis is

$$a = \frac{\alpha}{1-\epsilon^2} \tag{66}$$

from which the bounds of integration follow:

$$u_{min} = \frac{1}{r_{max}} = \frac{1-\epsilon^2}{\alpha(\epsilon+1)} = \frac{1-\epsilon}{\alpha}, \tag{67}$$
$$u_{max} = \frac{1}{r_{min}} = \frac{1-\epsilon^2}{\alpha(1-\epsilon)} = \frac{1+\epsilon}{\alpha}. \tag{68}$$

We carried out numerical solutions of the integral (63), using a model system with $\alpha = 1$ and $\epsilon = 0.3$. The integrand has been graphed in dependence of u in Fig. 1. As can be seen, it has infinities (poles) at u_{min} and u_{max}. So a numerical integration is not trivial. The result, the ratio $\Delta\phi/\langle \delta\mathbf{r} \cdot \delta\mathbf{r} \rangle$, obtained

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from Maxima routines, is shown in Fig. 2 in dependence of the eccentricity ϵ. Obviously this function does not approach zero for $\epsilon \to 0$. To obtain $\Delta\phi \to 0$, it is therefore required that $\langle \delta\mathbf{r} \cdot \delta\mathbf{r} \rangle \to 0$ can be seen from Eqs. (60) or (63).

Another interesting point is the behaviour of the orbital function (53) which is an extension of the Newtonian orbital integral (55) for a non-vanishing spin connection. For $\omega_r = 0$, Eq. (53) turns into (55). As can be seen from the graphical representation of the integrand (Fig. 3), the integrand diverges at the integration boundaries. When ω_r is finite, the definition range of the integrand is shifted to higher u values, i.e. smaller radii. It is clear from the apsidal method that the change in the ellipse is a precession, because the apsidal angle is no longer π.

Finally we calculate the isotropically averaged vacuum fluctuation radius for the planet Mercury. The precession angle per orbit is (see UFT 391):

$$\Delta\phi = 5.019 \cdot 10^{-7}\text{rad}. \tag{69}$$

From Eq. (63) follows with $a = 57,909,050\,\text{km}$ and $\epsilon = 0.205630$:

$$\frac{\Delta\phi}{\langle \delta\mathbf{r} \cdot \delta\mathbf{r} \rangle} = 4.88220 \cdot 10^{-20}\,\frac{\text{rad}}{\text{m}^2}. \tag{70}$$

This gives a fluctuation radius of

$$\langle \delta r \rangle = \sqrt{\langle \delta\mathbf{r} \cdot \delta\mathbf{r} \rangle} = 3206\,\text{km} \tag{71}$$

which is much smaller than the orbital radius of Mercury. It is a bit more than twice the diameter of the sun.

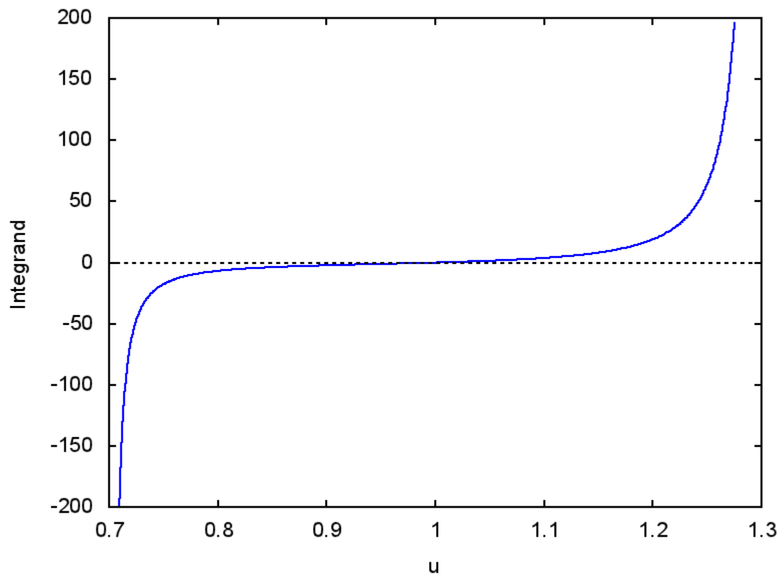

Figure 1: Integrand of Eq. (63) for a model system.

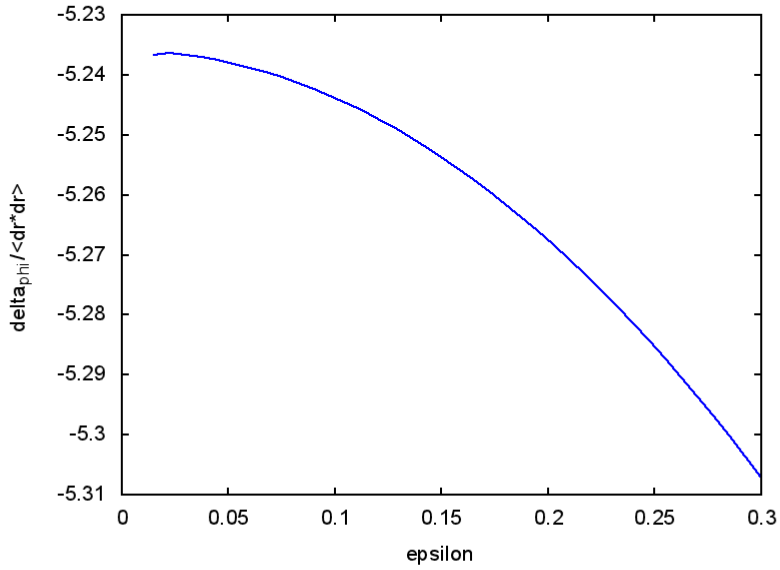

Figure 2: Ratio $\Delta\phi/\langle\delta\mathbf{r}\cdot\delta\mathbf{r}\rangle$ in dependence of orbital parameter ϵ.

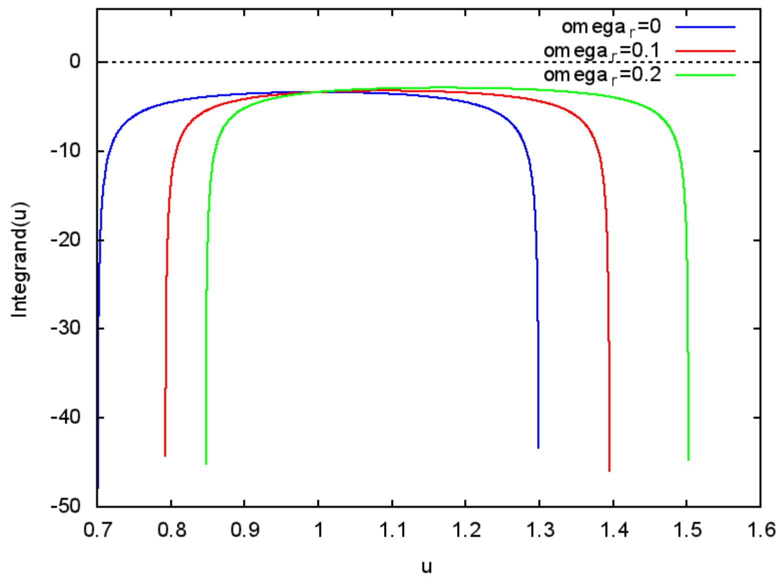

Figure 3: Integrands of Eq. (53) for different ω_r values.

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