PLANETARY PRECESSION AS A GRAVITOMAGNETIC LARMOR PRECESSION OF ECE2 RELATIVITY.

by

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ABSTRACT

Planetary precession is explained straightforwardly in ECE2 relativity as being the Larmor precession produced by the torque between the gravitomagnetic field of the sun and the gravitomagnetic dipole moment of the Earth or any planet. In general any astronomical precession can be explained with the ECE2 gravitational field equations. These are precisely correct and precisely analogous to the ECE2 theory of electromagnetism.

Keywords: ECE relativity, planetary precession, gravitomagnetic planetary precession.

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1. INTRODUCTION

In UFT318 of this series {1 - 12}, the gravitational field equations of ECE2 relativity were derived in a Lorentz covariant theory developed in a space with finite torsion and curvature. They were subsequently incorporated in the ECE Engineering Model (UFT303 on www.aias.us). The gravitomagnetic Ampère Law of the earlier ECE theory has been used in UFT117 and UFT119 to describe the earth's gravitomagnetic precession and the equinoctial precession. In this paper the precession of the orbit of any object of mass m around an object of mass M is described in terms of a gravitomagnetic torque. For example the earth's orbital precession is described through the torque set up between the gravitomagnetic field of the sun and the gravitomagnetic dipole moment of the earth. This produces Larmor precession of the orbit. In general this theory can be developed with two or three dimensional orbits.

This paper is a concise synopsis of the accompanying background notes to UFT344 on www.aias.us. Note 344(1) gives full details of the ECE2 gravitational field equations and writes them out in analogy with the ECE2 electromagnetic field equations. The Lense Thirring effect is calculated precisely with the ECE2 field equations. The effect is observed precisely in the fast spinning pulsar PSR J1748-2446ad, which has a gravitomagnetic field of 1043 radians per second (A. I. Arbab, Astrophys. Space Sci. 330, 61 - 88 (2010), online via Google keywords gravitomagnetic field and precession). The earth's gravitomagnetic field is 1.011×10^{-14} radians per second and in consequence is much more difficult to observe in an experiment such as Gravity Probe B. ECE2 is the first precisely correct theory of the Lense Thirring effect, which is due to orbit of a mass m around a spinning mass M. The de Sitter or geodedic precession is due to the orbit of a mass m around a static mass M and is much larger than the Lense Thirring effect. The original theory of Lense and Thirring was based on a linear approximation of the incorrect Einstein field equation, and cannot be accepted as a valid theory.

Note 344(2) is a summary of some of the concepts given by Arbab, cited above, however Arbab's paper contains some invalidating self inconsistencies. It is derived from hydrodynamics and happens to produce a structure which is the same as the ECE2 field equations. The latter are based on a rigorously correct geometry (1 - 12} within a generally covariant unified field theory fully accepted internationally (UFT307, the scientometrics). Note 344(3) defines the gravitomagnetic dipole moment in precise analogy with the magnetic dipole moment and defines the gravitomagnetic Larmor precession frequency in terms of a gravitomagnetic Landé factor characteristic of every observed orbital precession in the universe. Note 344(4) calculates the precession of the Earth using the torque between the gravitomagnetic field of the sun and the earth's gravitomagnetic dipole moment. Finally Note 344(5) applies the theory to the Thomas precession to illustrate that it can describe any precession and so is a general theory.

Section 2 is based on Notes 344(3) and 344(4) and calculates the earth's precession as a gravitomagnetic Larmor precession. Section 3 illustrates the precession graphically and makes some developments of the theory.

2. THE EARTH'S ORBITAL PRECESSION

Consider the magnetic dipole moment of electromagnetism, defined by:

$$\underline{m} = -\frac{e}{2m}\underline{L} \quad -(1)$$

where -e is the charge on the electron, m its mass, and $\underline{L}$ its orbital angular momentum. The dipole can interact with a magnetic flux density $\underline{B}$ to produce the torque:

$$\underline{Tq} = \underline{m} \times \underline{B}. \quad -(2)$$

The effect of such a torque is animated by Evans and Pelkie on www.aias.us and youtube for 108 molecules in a molecular dynamics simulation. The Larmor precession frequency due to this torque is:

$$\omega_L = \frac{eg}{2m} B \quad -(3)$$

where g is the Landé factor {1 - 12}.

This well known theory can be adopted directly for planetary precession by calculating the gravitomagnetic dipole moment. The orbital angular momentum becomes a macroscopic property. The charge -e on the electron is replaced by the orbiting mass m, so the gravitomagnetic dipole moment is:

$$\underline{m}_g = \frac{m}{2m} \underline{L} = \frac{1}{2} \underline{L} \quad -(4)$$

and is a constant of motion. The orbital angular momentum is defined by:

$$\underline{L} = \underline{r} \times \underline{p} = m \underline{r} \times \underline{v} \quad -(5)$$

where $\underline{v}$ is the orbital velocity of m, and where $\underline{r}$ is the distance between m and M. Therefore:

$$\underline{m}_g = \frac{m}{2} \underline{r} \times \underline{v}. \quad -(6)$$

For a planar orbit $\underline{L}$ is perpendicular to the plane, but in general this theory can be used for the three dimensional orbital theory of previous UFT papers. Therefore for a planar orbit:

$$\underline{L} = m r v \underline{k} \quad -(7)$$

which is a constant of motion of ECE2 relativity. Note carefully that these gravitomagnetic concepts are concepts of ECE2 relativity.

A torque is formed between the gravitomagnetic dipole moment $\underline{m}_g$ and the gravitomagnetic field $\underline{\Omega}$ of ECE2 relativity (1-12 and UFT303):

$$\underline{T}_g = \underline{m}_g \times \underline{\Omega} \quad (8)$$

resulting in the gravitomagnetic Larmor precession frequency:

$$\omega_g = \frac{1}{2} g_r \Omega \quad (9)$$

where g_r is the gravitomagnetic Landé factor. The precession of a planet in this theory is the gravitomagnetic Larmor frequency.

Consider the sun to be a rotating sphere. The sun rotates once every 27 days or so around an axis tilted to the axis of rotation of the earth. So $\underline{L}_{earth}$ is not parallel to $\underline{L}_{sun}$ as required for a non-zero torque. In precise analogy with Lense Thirring theory, the gravitomagnetic field of this rotating sphere in the dipole approximation is:

$$\underline{\Omega}_{sun} = \frac{2G}{c^2 r^3}\left(\underline{L}_{sun} - 3\left(\underline{L}_{sun} \cdot \frac{\underline{r}}{r}\right)\frac{\underline{r}}{r}\right) \quad (10)$$

where G is Newton's constant and where M is the mass of the sun. Here $\underline{r}$ is the distance from the sun to an object of mass m, such as the earth, orbiting the sun. The rotation axis of the sun is tilted by 7.25° to the axis of the earth's orbit (solarscience.msfc.nasa.gov/sunturn.shtml) so to a good approximation:

$$\underline{L}_{sun} \cdot \underline{r} = 0 \quad (11)$$

so the gravitomagnetic field of the sun is:

$$\underline{\Omega}_{sun} = \frac{2G}{c^2 r^3} \underline{L}_{sun} \quad -(12)$$

to a good approximation. A more accurate calculation can be carried out with computer algebra. The torque is therefore:

$$\underline{Tq} = \frac{G}{c^2 r^3} \underline{L}_{earth} \times \underline{L}_{sun} \quad -(13)$$

so it can be non-zero if and only $\underline{L}_e$ and $\underline{L}_s$ are not parallel, where $\underline{L}_e$ is the angular momentum of the earth's spin and $\underline{L}_s$ is that of the sun. The angle subtdended by $\underline{L}_e$ and $\underline{L}_s$ is 7.25° experimentally.

The magnitude of the angular momentum of the sun, modelled by a spinning sphere, is:

$$L = \omega I = \frac{2}{5} MR^2 \quad -(14)$$

where I is its moment of inertia, where $\underline{R}$ is the radius of the sun. Therefore the magnitude of the gravitomagnetic field of the sun is:

$$\Omega_{sun} = \frac{MG\omega}{5c^2 R} \quad -(15)$$

where ω is its angular velocity. After a rotation of 2π radians:

$$\omega = \frac{2\pi}{T} \quad -(16)$$

where T is about 27 days. Therefore:

$$\Omega_{sun} = \frac{\pi}{5} \frac{r_0}{R} \frac{1}{T} \quad -(17)$$

where:

$$r_0 = \frac{2MG}{c^2} = 2.95 \times 10^{3}\ \text{m} \quad -(18)$$

and where the radius of the sun is:

$$R = 6.957 \times 10^{9}\ \text{m}. \quad -(19)$$

In one earth year (365.25 days):

$$\Omega_{sun} = 365.25 \times 24 \times 3600\ \frac{\pi}{5}\ \frac{r_0}{R}\ \frac{1}{T} \quad -(20)$$

in radians per year.

The Larmor precession frequency at the distance R is:

$$\omega_L = 1.802\, g_{eff} \times 10^{-6}\ \text{radians per year.} \quad -(21)$$

where g_{eff} is the gravitomagnetic Landé factor. The observed perihelion precession of the earth at the earth sun distance is:

$$\omega(\text{perihelion}) = 0.05\ \text{per year} = 5.741 \times 10^{-21}\ \text{radians per second} \quad -(22)$$

Therefore the earth's gravitomagnetic Landé factor is:

$$g_{eff}(\text{Earth}) = 2\omega_q / \Omega \quad -(23)$$

Each planet has its characteristic g_{eff}, and in general every object m in orbit around an object M has its own g_{eff}. This theory is rigorously correct and is much simpler than the Einstein theory. In general perihelion precession is a Larmor precession at a frequency

$$\omega_L = g_{eff}\,\frac{\pi}{10}\left(\frac{r_0}{R}\right)\frac{1}{T}. \quad -(24)$$

In one earth year, or 2π revolution, the precession at the point R is:

$$\omega_L = 365.25 \times 3600 \times 24\, g_{eff} \frac{\pi}{10} \left(\frac{r_0}{R} \right) \frac{1}{T} \quad \text{radians per year} \qquad (25)$$

It is known experimentally that the precession of the perihelion is in general:

$$\omega_L = \frac{6\pi G M}{a c^2 (1 - \epsilon^2)} \quad \text{radians per year} \qquad (26)$$

where a is the semi major axis of an elliptical orbit and where ϵ is its eccentricity.

3. NUMERICAL ANALYSIS AND MORE ACCURATE THEORY

(Section by Dr. Horst Eckardt)

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3 Numerical analysis and more accurate theory

The gravitomagnetic field given by Eq. (10) depends on space coordinates, X, Y, Z in a cartesian frame. In order to get an impression on its behaviour in a spherical symmetry we transform it to spherical coordinates (r, θ, ϕ), according to the transformation equations

$$X = r \sin\theta \cos\phi \tag{27}$$

$$Y = r \sin\theta \sin\phi \tag{28}$$

$$Z = r \cos\theta \tag{29}$$

with radius r, polar angle θ and azimutal angle ϕ. Applying an analogous transformation for the angular momentum, we obtain an expression for $\Omega(r, \theta, \phi)$. Using the choice

$$\mathbf{L} = \begin{bmatrix} 0 \\ 0 \\ 1 \end{bmatrix} \tag{30}$$

(in arbitrary units) and restricting Ω to the XZ plane ($\phi = 0$), we obtain (with constants and radius set to unity):

$$\boldsymbol{\Omega} = 2 \begin{bmatrix} -3\cos\theta \sin\theta \\ 0 \\ 1 - 3\cos\theta^2 \end{bmatrix}. \tag{31}$$

The components of this vector have been graphed as a function of θ in Fig. 1. The Y component vanishes as expected, the X and Z components are phase shifted. At the equator ($\theta = \pi/2$) and at the poles there is only a Z component.

The structure of the gravitomagnetic field in dipole approximation (10) can further be demonstrated by computing two-dimensional hypersurfaces. These

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will be shown for the cartesian components $\Omega_{X,Y,Z}$. First we have to evaluate the full angular dependence in Eq. (31) which gives quite complicated expressions. Then we define a constant value $\Omega_{X,Y,Z} = \Omega_0$ for each of the components. This gives equations which can be resolved for the radial coordinate r, defining a hypersurface in 3D. We choose $\mathbf{L}$ again to lie in the Z axis as in Eq. (30). Then the equations for the hypersurfaces take the form

$$r = A_1(\cos\phi\cos\theta\sin\theta)^{1/3} \tag{32}$$

$$r = A_1(\sin\phi\cos\theta\sin\theta)^{1/3} \tag{33}$$

$$r = A_2(2 - 3(\sin\theta)^2)^{1/3} \tag{34}$$

with constants A_1 and A_2. The first hypersurface (for the X component of $\boldsymbol{\Omega}$) has been graphed in Fig. 2. The surface for the Y component looks the same but is rotated by 90° around the Z axis. These have a shape of atomic p orbitals. The Z component (Fig. 3) has a different form, being reminiscent of an atomic d orbital. If the axis of angular momentum is rotated, the hypersurfaces change to a form similar as (but not identical to) a rotated Ω_Z. As an example we have plotted Ω_Z for an angular momentum

$$\mathbf{L} = \begin{bmatrix} 1 \\ 0 \\ 1 \end{bmatrix} \tag{35}$$

in Fig. 4. This effect will occur qualitatively in the solar system where the sun's rotation axis is tilted by about 7.25° from the axis of the earth's orbit.

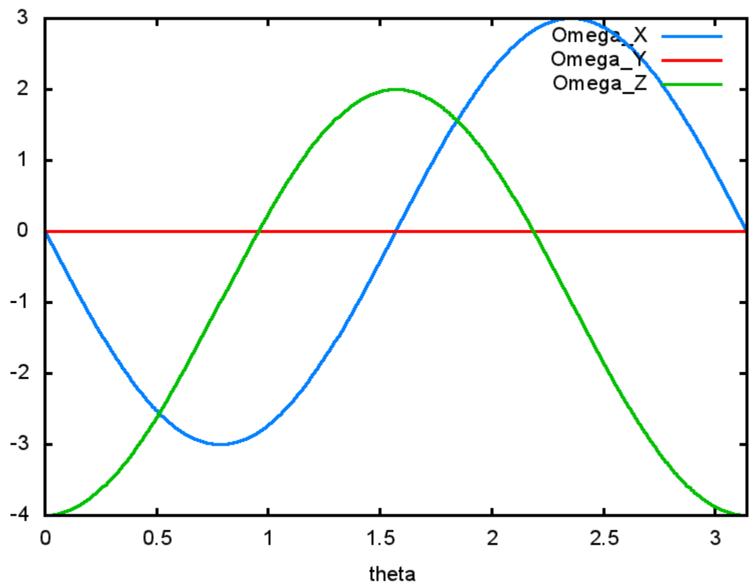

Figure 1: Components of $\boldsymbol{\Omega}$ according to Eq. (31).

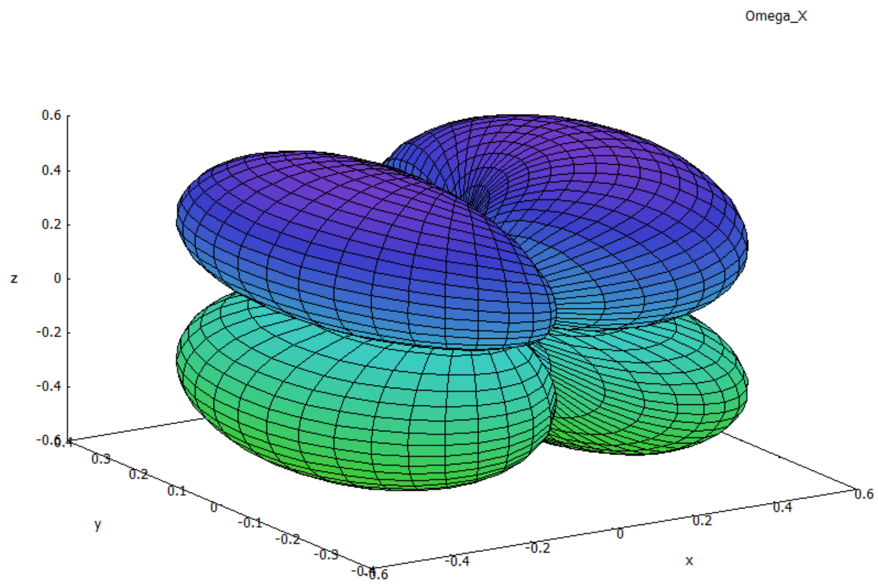

Figure 2: Hypersurface of Ω_X, identical to that of Ω_Y except a 90° rotation.

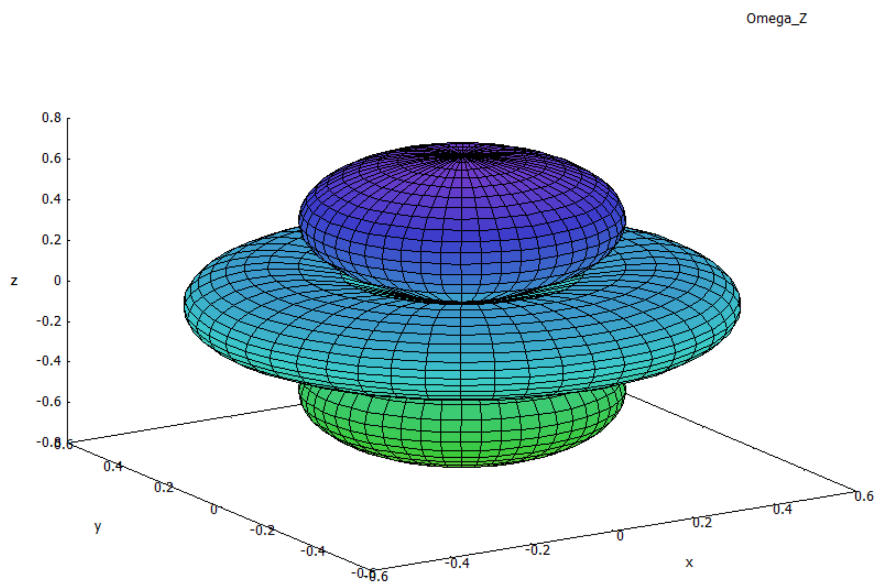

Figure 3: Hypersurface of Ω_Z.

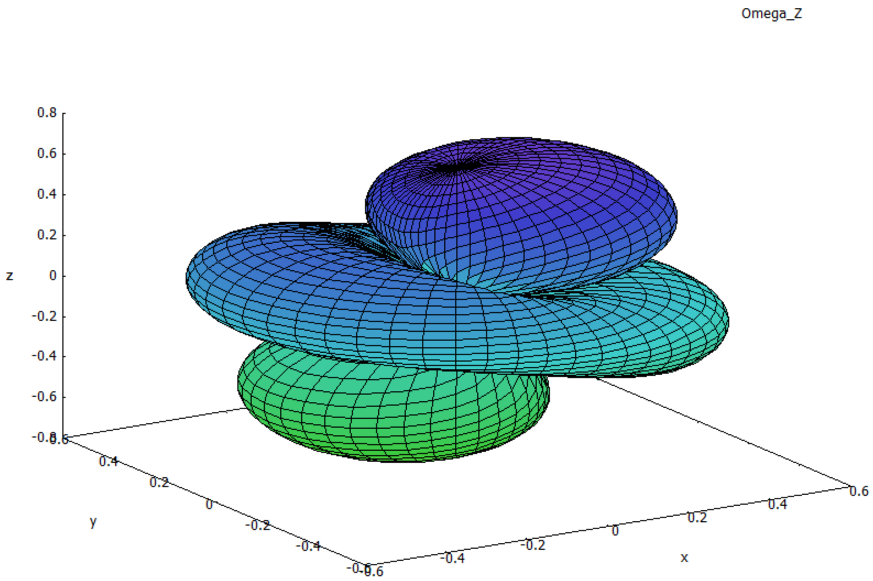

Figure 4: Hypersurface of Ω_Z for a tilted angular momentum $\mathbf{L} = [1, 0, 1]$.

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