

How to Interpret Gravitational Events in the Gravity Probe B Mission? (Gravitational Phonons and Gravitational Deformation Potential)

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Abstract — The Gravity Probe B Mission (GPB) collected valuable experimental data in the years 2004-2005. The geodetic drift in the orbit plane was interpreted as the curvature precession through the space-time curved by the Earth's mass. The frame-dragging effect was interpreted using the Lense-Thirring-Schiff model based on the dragging of the orbit plane of a satellite around the rotating Earth. Both these effects were visible in the CORRECTED data. The gist of this contribution is to describe these gravitational events as the result of the joint effects of the gravitational deformation potential and the gravitational phonons in the gyroscope rotors. The gravitational phonon velocity is "hidden" in the formula discovered by Albert Einstein in his last Prague's paper in 1912. Gravitational phonons and the gravitational deformation potential acting on the gyroscope rotors deform slightly the gyroscope rotor geometry and form both observed longitudinal and transverse precessions. This new interpretation of subtle gravitational precessions was tested on the RAW experimental data published by the GPB Team. The observed gravitational events occur in the classical 3D space in this scenario. We propose to re-analyze all GPB data according to this classical model without additional corrections. The new Gravity Probe C + D missions might deliver more illustrative data comparing this model with the predictions of the general theory of relativity.

Keywords — Gravity Probe B Mission, gravitational deformation potential, gravitational phonon velocity, gravitational phonons, longitudinal and transverse precessions.

I. INTRODUCTION

The Gravity Probe B (GPB) experiment [1]-[10] was very carefully designed, developed, and realized in order to collect valuable experimental data to test two predictions of Albert Einstein's General Theory of Relativity, e.g. [11]-[20]: 1) the space-time curvature in the vicinity of the Earth caused by the Earth's mass (the geodetic effect in the North-South direction), and 2) the dragging of space-time caused by the rotation of the Earth (the frame-dragging effect in the East-West direction). Both these effects were visible in the CORRECTED data.

The gist of this contribution is to newly interpret the RAW data of this GPB experiment based on the model of John Bardeen and William Shockley [21]-[22]: the phonon deformation potential introduced in 1950. Can we find a classical road leading to the interpretation of these "subtle" gravitational effects?

II. THE GRAVITATIONAL DEFORMATION POTENTIAL

In the Gravity Probe B satellite data, three-time scales can be distinguished: the Earth's orbit around the Sun during one sidereal year, the satellite orbital period 97.65 minutes, and the GPB satellite roll 77.5 seconds. During these time scales the gravitational deformation potential acts on the spinning gyroscope rotors as it is shown in Fig.1 and described by Equation 1:

$$\tan \theta \approx \theta \approx \frac{4\pi^2 \omega^2 r^2 R_{sat}}{GM_{\oplus}} \frac{360 \cdot 60 \cdot 60}{2\pi} \frac{1}{2\pi} \quad [\text{marcsec}] \quad (1)$$

where θ is the angle in marcsec (milli arcseconds) deformed by the Earth's gravitational deformation potential, ω is the spinning frequency of the rotor, r is the radius of that rotor, G is the Newtonian gravitational constant, M_{\oplus} is the mass of the Earth, $R_{sat} = 7\,027.400$ km is the distance of the GPB satellite from the Earth's center.

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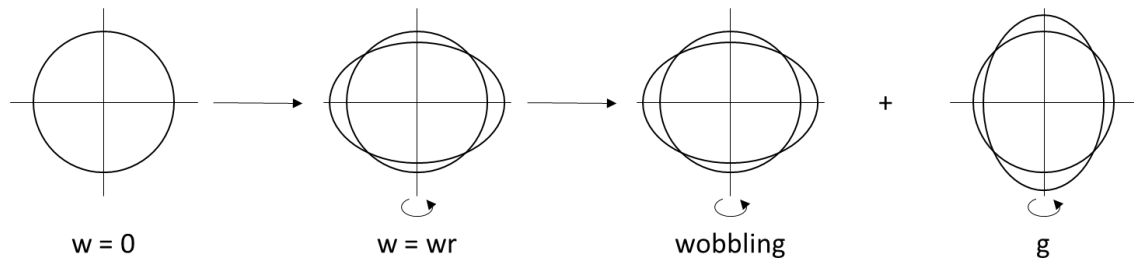


Fig. 1. The spinning gyroscope rotor in the Earth's gravitational deformation potential

The predicted gravitational deformation of the spinning gyroscope rotors is given in Table I based on (1).

TABLE I: THE GRAVITATIONAL DEFORMATION OF THE SPINNIG GYROSCOPE ROTORS

| Gyroscope | Spin of the rotor [Hz] | Radius of the rotor [m] | Rotor deformation θ [marcsec] | Rotor deformation $\theta * e^{-1/6}$ [marcsec] | Rotor deformation $\theta * e^{1/6}$ [marcsec] | Amplitude of the wobbling [marcsec] |
|-----------|------------------------|-------------------------|--------------------------------------|---|--|-------------------------------------|
| 1 | 79.39 | 0.019 | 52.0 | 44.0 | 61.4 | 8.7 |
| 2 | 61.82 | 0.019 | 31.5 | 26.7 | 37.2 | 5.3 |
| 3 | 82.09 | 0.019 | 55.6 | 47.0 | 65.7 | 9.3 |
| 4 | 64.85 | 0.019 | 34.7 | 29.4 | 41.0 | 5.8 |
| Average | | | 43.4 | 36.8 | 51.3 | 7.3 |

The spinning gyroscope rotor is modified by the Earth's gravitational deformation potential and the wobbling is mathematically described using the Shannon shape parameter $\sigma = 1/\sqrt{6}$, that was described in more details earlier in this Journal [23]-[24]. The Einstein-Shannon (ES) log-normal distribution of gravitational phonon velocities was introduced with the Einstein scale parameter μ given in Equation 3 and with the Shannon shape parameter $\exp(\sigma^2) = e^{1/6}$ based on the maximal entropy production during the interaction of the gravitational field with the Maxwell-Boltzmann particles in that spinning gyroscope rotors:

$$f(x) = \frac{1}{x\sigma\sqrt{2\pi}} \exp\left(-\frac{(\ln(x) - \mu)^2}{2\sigma^2}\right) \quad (2)$$

The wobbling amplitudes of individual gyroscope rotors given in Table I are visible in all data of the GPB Mission. E.g., the wobbling amplitudes for the roll of the satellite should be visible twice per orbit frequency. GPB Team documented this wobbling for the gyroscope rotor 2 for the roll +/- twice per orbit with the signal amplitude 5 marcsec [25]. Fig. 2 describes those predicted amplitudes for all four gyroscope rotors in the GPB Mission.

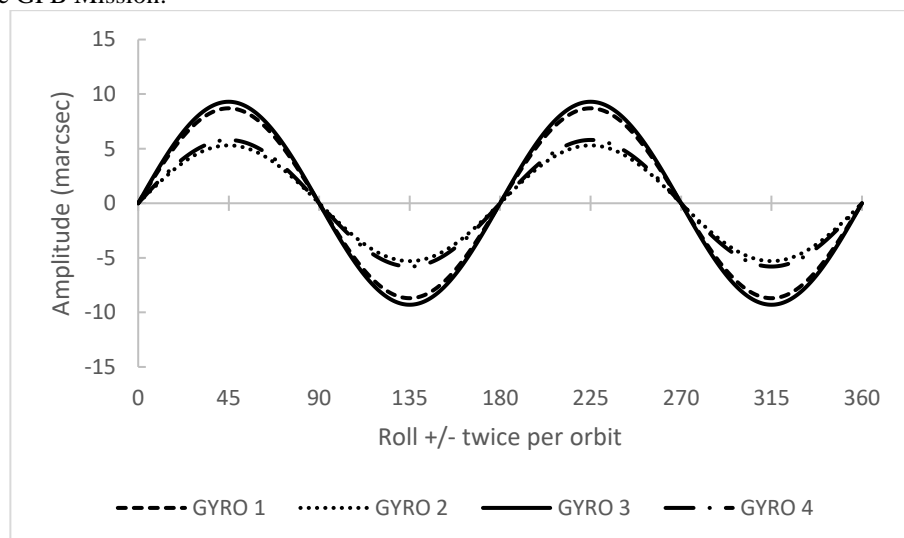


Fig. 2. The amplitudes of spinning gyroscope rotors in the Earth's gravitational deformation potential during their roll orbit.

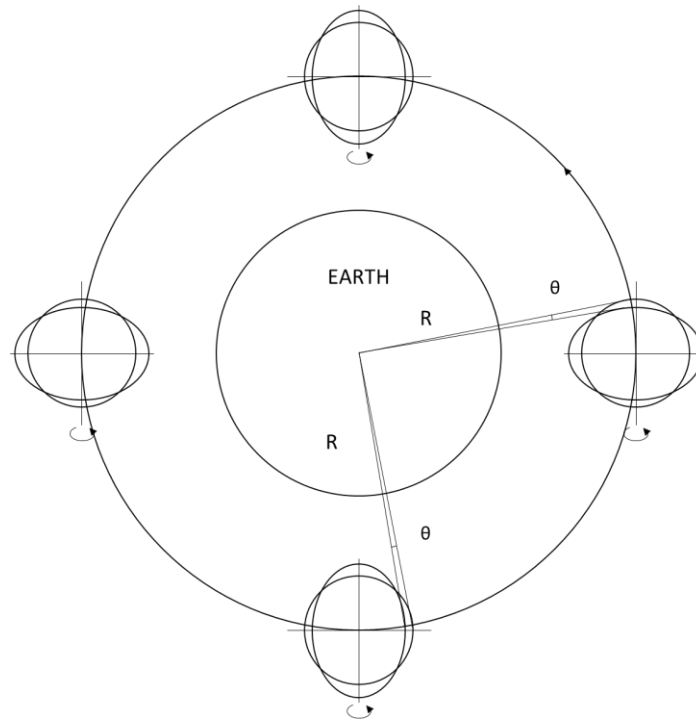


Fig. 3. The deformation of spinning gyroscope rotors by the Earth's gravitational deformation potential during their roll orbit.

III. GYROSCOPE ROTOR DEFORMATION IN THE NORTH-SOUTH DIRECTION AND IN THE EAST-WEST DIRECTION

In our model, gravitational phonons perturb the lattice of the spinning gyroscope rotor in the North-South direction and the East-West direction and thus form those “subtle” observed displacements interpreted in the general theory of relativity as the effects of the curved space-time.

In the previous contribution in this Journal [23]-[24] we have introduced the Earth's gravitational phonon velocity $v_{G\oplus}$ as:

$$v_{G\oplus} = \frac{GM_{\oplus}}{R_{\oplus}c} \approx 208.5 \text{ mm s}^{-1} \quad (3)$$

The Earth's gravitational field creates gravitational phonons in the volume of the spinning gyroscope rotor with its characteristic phonon velocity $v_{G\oplus}$, these gravitational phonons slightly deform the spinning gyroscope rotor characteristic length l_0 as 1:

$$\frac{l}{l_0} = \frac{1}{\sqrt{1 - \frac{\Omega GM_{\oplus}}{R_{sat}c^2}}} \approx 1 + \frac{3}{2} \frac{GM_{\oplus}}{R_{sat}c} \frac{1}{c} = 1 + \frac{3}{2} \frac{v_{G\oplus}}{c} \quad (4)$$

in this formula $\Omega = 3$ equals to 3 active steradians of the Earth's gravitational field [26]. This is a new formulation of the Equation discovered by Albert Einstein in his last Prague's paper in 1912 [11].

The gyroscope rotor is gravitationally deformed in the North – South direction as given in (5):

$$\frac{l_{NS}}{l_0} - 1 \approx 2\pi \frac{3}{2} \frac{GM_{\oplus}}{R_{sat}c} \frac{1}{c} N_{year} \frac{360 \cdot 60 \cdot 60}{2\pi} + \theta = 2\pi \frac{3}{2} \frac{GM_{\oplus}}{R_{sat}c} \frac{1}{c} 5386.27 \frac{360 \cdot 60 \cdot 60}{2\pi} + \theta$$

where N_{year} is the number of satellite orbits per sidereal year. This formula differs from the prediction of the general theory of relativity with the additional angle θ (given in Table I, the fourth column) that represents the gravitationally deformed gyroscope rotor in the Earth's gravitational field.

The gyroscope rotor is gravitationally deformed in the East – West direction as:

$$\frac{l_{EW}}{l_0} - 1 \approx \frac{3}{2} \frac{GM_{\oplus}}{R_{sat}^3} \frac{1}{c} \frac{360 \cdot 60 \cdot 60}{2\pi} 365.256 \quad (6)$$

Table II compares the predictions of the general theory of relativity, the final CORRECTED experimental data of the GPB Mission, and the predictions of this model based on the RAW data of the GPB Mission.

| TABLE II: THE GRAVITY PROBE B PRECESSION DATA: CORRECTED, RAW, GR PREDICTION, THIS MODEL PREDICTION | | | | | | |
|---|--|---|---|--|---|---|
| Gyro | North-South precession corrected final data [marsec/yr] | North-South precession raw data [marsec/yr] | East-West precession corrected final data [marsec/yr] | East-West precession raw data [marsec/yr] | This model North-South precession [marsec/yr] | This model East-West precession [marsec/yr] |
| 1 | -6,588.6±31.7 | -6,623.2±31.7 | -41.3±24.6 | -77.5±24.6 | -6,658.1 | -71.3 |
| 2 | -6,707.0±64.1 | -6,741.6±64.1 | -16.1±29.7 | -52.3±29.7 | -6,637.6 | -71.3 |
| 3 | -6,610.5±43.2 | -6,645.1±43.2 | -25.0±12.1 | -61.2±12.1 | -6,661.7 | -71.3 |
| 4 | -6,588.7±33.2 | -6,623.3±33.2 | -49.3±11.4 | -85.5±11.4 | -6,640.8 | -71.3 |
| Ave rage | -6,601.8±18.3 | -6,658.3±43.0 | -37.2±7.2 | -69.1±19.5 | -6,649.5 | -71.3 |
| GR | -6,606.1 | | -39.2 | | | |

The experimental data taken during the GPB Mission were carefully analyzed in order to extract signals expected by the predictions of the general theory of relativity. Both trends predicted by the GRT were found in the North-South direction and the East-West directions [3]-[10]. However, the RAW data were CORRECTED to be close to the GRT predictions. Fig. 4 and Fig. 5 shows the RAW slopes in data for the North-South and East-West directions.

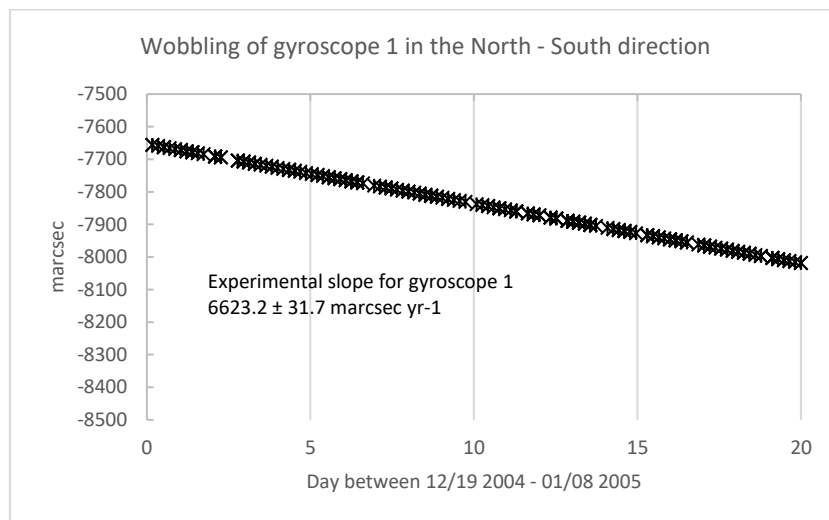


Fig. 4. The wobbling of the gyroscope rotor 1 during December 12, 2004 – January 08, 2005 in the North – South direction [27].

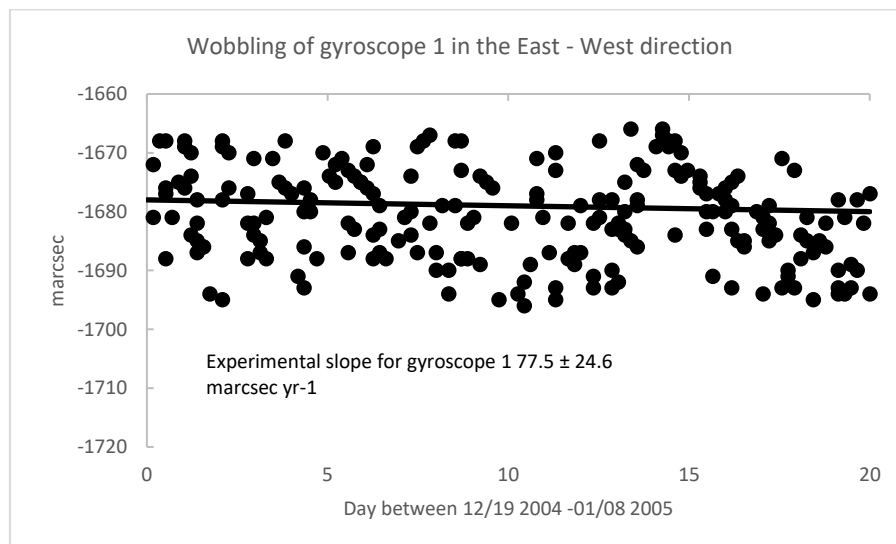


Fig. 5. The wobbling of the gyroscope rotor 1 during December 12, 2004 – January 08, 2005 in the East-West direction [27].

IV. PROPOSAL FOR THE FUTURE GRAVITY PROBE C MISSION

The Gravity Probe B Team made the great scientific contribution with the most precise gravitational data for the “subtle” gravitational effects predicted by the general theory of relativity, e.g., [28]-[30]. The whole procedures of statistical evaluation of the RAW data together with RAW data are available for alternative interpretations.

The model presented in this contribution based on the Earth’s gravitational deformation potential and its interaction with gravitational phonons inside of the spinning gyroscope rotors offers a new interpretation of those two “subtle” gravitational effects within the classical models in the 3D space.

We propose to re-analyze the RAW experimental data of the Gravity Probe B mission based on this model. On the other side, we want to initiate new Gravity Probe C + D Missions based on that excellent GPB technology with four gyroscope rotors spinning with frequencies, e.g., 25, 50, 75, 100 Hz with one satellite at the distance R_1 , and the second satellite at the distance $R_2 = 2 * R_1$. These new experimental data might contribute to the analysis of numerous gravitational models, e.g. [31]-[41], and to select the most realistic gravitational model.

V. CONCLUSION

We might open a new road leading towards the interpretation of gravitational events occurring during the Gravity Probe B Mission. These “subtle” gravitational effects were interpreted as the joint cooperation of the Earth’s gravitational deformation potential and the gravitational phonons inside of the spinning gyroscope rotors orbiting around the Earth. These gravitational deformations of spinning gyroscope rotors could be seen in the longitudinal North-South and transverse East-West directions as extra precessions. These effects “hidden” in the Microworld should be more carefully studied in the new Gravity Probe C + D Missions in order to collect more detailed experimental data and thus compare our gravitational models and to select the most realistic description of gravitational events. The quote of J.M. Overduin [42] is very actual: “It is more actual than ever to push experimental tests of gravitational theory to the limits of existing technology in both range and sensitivity.”

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CONFLICT OF INTEREST

Authors declare that they do not have any conflict of interest.

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