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TECHNOLOGY STIFNESS IMPACTS ON THE TRUSS LUNAR GRAVITY OSCILLATOR

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Abstract

The manner into which the mechanical design affects the stiffness of a gravitational oscillator in the Moon-Earth-Sun gravitational field is investigated. A model of the oscillator is presented. It is shown that gravitation effects are very tinny and the scalar, inverse square-low model of the gravity does not explain the eclipse effect. Innovative improvements in the theory are required, based on much refined experiments, both on Earth and the Moon.

INTRODUCTION

Trying to demonstrate a physical connection between the gravitational and electromagnetic fields, Maurice Allais (1988 Nobel Prize winner in economics) had discovered, during measurements in 1952-1953, significant discrepancies between the expected Foucault behavior and the pendulum motion during Solar eclipses [3]. These observations were reconfirmed on observational sessions with a "*paraconic*", 6mm steel ball-hook, non-isotropic support pendulum during the Sun eclipses in 30 June 1954 and 2 October 1959 [8]. These deviations were accompanied by optical anomalies, recorded with twin-theodolites.

Independent reports came also from Romania during the solar eclipse of 15 Feb. 1961 (Jeverdan et al [4], [6]). Anomalies were constantly recorded thereafter (1991 in Mexico [7], 1999 in Romania). The theories could not explain these facts [1], [2] and the phenomenon itself is often doubted. In 2003 for example, Prof. Ulrich Walter from T. U. München, also an experienced German astronaut, expressed these specific doubts: "*As a physicist, I don't believe in a new physics due to the Allais effect. ...as far as I know, the eclipse in 1999 didn't lend support to the Allais effect. So I think it would be too much effort to verify such an unclear effect*".

In fact it's in 1999 however that NASA began its own investigations of the half-century old dispute, but no published results are still available. The entire experimental part of eclipse study hardly depends on the level of accuracy of the oscillator itself and of the measuring system. Half of the researchers failed in revealing any gravitation effect during past eclipses, while the other half did this. It is our opinion that neither the photographic method of NASA is accurate enough.

The oscillator in a rotating, steady gravitational field is being acceptably modeled as long as the amplitude and speed develop rather small, the device is isotropic and the duration is fairly limited. A new type of mechanical oscillator is proposed here, aimed at extending the accurate investigation of eclipse anomalies to the lunar surface -a major advance- as first shown at IAC-54 in 2003 [10].

THE ADDA GRAVITATION OSCILLATOR

The reference oscillator is a wire suspended corpuscle M of mass *m*, rotating in *constant gravity* g_e. Similar constructions vary in size from 1-*m* to 70-*m* wire length. To make the devise compatible with a space flight mission to the Moon, the ADDA had selected the 1-*m* size from above, into the basic truss architecture drawn below.

Figure 1- ADDA gravitational oscillator.

The first design is based on a four lending gear support structure, with retractable legs under a convenient inclination to assure the stability under acceptable positioning errors (Fig. 1). For the sake of simplicity the fixing latches were not represented in the draft. As the device must anchor automatically itself in the soil, a gasdynamic reaction motor device is provided on the hood of the set and is fired after the landing and deployment of the mechanism.

The main concern is related to the stiffness of the whole device. Even with stationary Earth-based constructions, the topic of overall stiffness is carefully approached and special measures are taken regarding the foundation of the pendulum. The fixed Earth installations are built with utmost care regarding the stiffness as far as failures in resolving the eclipse effect is often related to imperfect experimental conditions. The problem of creating a transportable Foucault pendulum installation is related to solving in a most confident manner the problem of the structure stiffness. Next to this the problem of hard anchoring of the structure into the soil is another major challenge of the proposal. Here we deal with the first difficulty only. In this regard the required accuracy of the device is the first item to be accessed.

REFERENCE MODEL FOR ISOLATED EARTH

The reference oscillator is a wire suspended corpuscle M of mass m, rotating in *constant gravity* g_e. In local derivatives its basic equation and constraint are

$$\frac{\mathrm{d}^2\mathbf{r}_*}{\mathrm{d}t^2} = -g_e\,\mathbf{e}^3 - 2\boldsymbol{\omega}\wedge\frac{\mathrm{d}\mathbf{r}_*}{\mathrm{d}t} - \frac{S}{ml}\mathbf{r}_*, \qquad (1) \qquad\qquad \frac{1}{2}\frac{\mathrm{d}\mathbf{r}_*^2}{\mathrm{d}t} \equiv \mathbf{r}_*\cdot\frac{\mathrm{d}\mathbf{r}_*}{\mathrm{d}t} = 0\,. \quad (2)$$

where S is the wire tension and the local Earth latitude is φ. This non-inertial description [10] is also a consequence of the classical simplifying assumptions (the angular velocity $\boldsymbol{\omega}$ and the intensity of gravity $g\mathbf{e}^3$ are constant, the centrifugal force induced by $\boldsymbol{\omega}$ is negligible, the Moon-Sun interactions are ignored). These usual assumptions are acceptable when the *Foucault* effect remains well the planet's *Coriolis term* (right-hand, middle term in (1)). The angular velocity of the Earth is

$$\boldsymbol{\omega} = -\omega\cos\varphi\,\mathbf{e}^1 + 0\,\mathbf{e}^2 + \omega\sin\varphi\,\mathbf{e}^3, \qquad (3)$$

and the azimuth angle α_* directed South-East, and z_* axis along the local astrocentric vertical. In a horizontal referential $\{\rho_*\alpha_*z_*\}$ equations (1) and (2) gradually transform into

$$\begin{cases} \dfrac{\mathrm{d}}{\mathrm{d}t}\left[r_*^2\left(\dot{\alpha}_* + \omega\sin\varphi\right)\right] = -2\,\omega\cos\varphi\,\dfrac{r_*^2\dot{r}_*}{\sqrt{1-r_*^2}}\cos\alpha_*, \\[2ex] \dfrac{1}{1-r_*^2}\dot{r}_*^2 + (r_*\dot{\alpha}_*)^2 = 2\,g\sqrt{1-r_*^2} + h. \end{cases} \qquad (4)$$

A linearized solution is provided [1], [2] when setting

$$\psi_*(t) \equiv \alpha_*(t) + \omega\sin\varphi\cdot t\,, \qquad (5)$$

and with the constants K, C the motion reads

$$\begin{cases} \dfrac{\mathrm{d}}{\mathrm{d}t}\left(r_*^2\,\dot{\psi}_*\right) = 2\,\omega r_*^2\,\dot{r}_*\cos\varphi\cos\alpha_*\left(\dfrac{r_*^2}{2} + K\right) \approx 0, \\[2ex] \dot{r}_*^2 + r_*^2\dot{\psi}_*^2 + \left(\dfrac{g}{l} + \omega^2\sin^2\varphi\right)r_*^2 = C. \end{cases} \qquad (6)$$

As the variable r_* is small ($r_* = \rho_*/l$), its powers >2 are negligible and a constant areal velocity in coordinates $\{r_*, \psi_*\}$ results

$$r_*^2\,\frac{\mathrm{d}\psi_*}{\mathrm{d}t} = C_2, \qquad (7)$$

while the constants are connected by $C = C_1 + C_2\,\omega\sin\varphi$.

A motion acted by an elastic central force of intensity f_0 is thus recognized,

$$f_0 = r_* \left(\frac{g}{l} + \omega^2 \sin^2 \varphi \right) \equiv r_* \left(\omega_0^2 + \Omega_0^2 \right), \tag{8}$$

with a centered ellipse as the trajectory, possessing retrograde rotating axes (east-south-west-north-east) by the angular velocity and the periodic time

$$\Omega_0 = \omega \sin \varphi , \quad (9) \qquad\qquad T = 2\pi \sqrt{l / g} . \quad (10)$$

When the pendulum is suddenly released from rest position ρ_0, its initial velocity is $\rho_{*0} \psi_{*0} = \rho_{*0} \omega \sin \varphi$. With the ellipse major semi-axis ρ_{*0}, the minor is

$$b = \rho_{*0} \frac{\Omega_0}{\sqrt{\omega_0^2 + \Omega_0^2}} . \tag{11}$$

The ratio of the semi-axes and of the periodic time of the apsides are the same,

$$\frac{a}{b} \equiv \frac{\Theta}{T} = \sqrt{\frac{g}{l}} \frac{1}{\omega \sin \varphi}, \quad (12) \qquad\qquad \Theta = \frac{2\pi}{\omega \sin \varphi} . \quad (13)$$

At the location of the "Politehnica" University in Bucharest for example, (north latitude of $\varphi = 44.427°$) for the Earth's angular velocity a periodic time results

$$\omega_\oplus = 7.292116065\text{e-}5\ [rad/s], \ (14) \quad \Theta \equiv \frac{2\pi}{\omega \sin \varphi} = 34^h 3^m 50^s \tag{15}$$

for a 360° rotation of Foucault plane. The periodic time (10) for 1-*m* and 20-*m* oscillators and the ellipse apsides ratios (12) are:

$$T_1 = 2.0064\, s \quad T_{20} = 8.9729\, s, \quad (16) \qquad \left.\frac{a}{b}\right|_1 = 60732585 \quad \left.\frac{a}{b}\right|_{20} = 13580.21 \tag{17}$$

For the 20-*m* long oscillator the major semi-axis of 2-*m* is accompanied by a negligible minor semi-axis of 0.14 *mm*. Precession goes fairly slower than the planet rotation.

ENHANCED ELASTIC AND SUN-EARTH-MOON MODEL

The oscillator is now considered as behaving in interaction with the astronomical multiple bodies Sun-Earth-Moon system (SEM). Confining to anomalies with astronomical periodicity only, perturbations introduced by friction, anisotropy and elasticity of the oscillator should be ignored. An *absolute solar referential* H($\mathbf{e}_{\mathrm{H}}^{1,2,3}$) proves convenient to record the momentary absolute position $\mathbf{r}_{\mathrm{HP}}(t)$ at time t [1], [6]. The absolute referential H($\mathbf{e}_{\mathrm{H}}^{1,2,3}$) translates with the mass center of the S-E-M system, but its axes remain in fixed directions to the far stars.

The observation from Earth requires a *mobile, local referential* T($\mathbf{e}_{\mathrm{T}}^{1,2,3}$), moving with the velocity $\mathbf{v}_{\mathrm{T}}(t)$ of its origin about {H} and rotating with the absolute angular velocity $\boldsymbol{\omega}(t)$. In the inertial frame {H}, the following improvements allow the previously neglected effects to be *accounted* [10]. The extended equation becomes

$$\frac{d^2\mathbf{r}}{dt^2} = \mathbf{g}_{\oplus} - \boldsymbol{\omega}_{\oplus} \wedge \boldsymbol{\omega}_{\oplus} \wedge \mathbf{r}_{\mathrm{OT}} + K_L\left(\frac{\mathbf{u}_{\mathrm{TM}}}{r_{\mathrm{TM}}^2} - \frac{\mathbf{u}_{\mathrm{OM}}}{D^2}\right) + K_{\mathrm{S}}\left(\frac{\mathbf{u}_{\mathrm{TS}}}{r_{\mathrm{TS}}^2} - \frac{\mathbf{u}_{\mathrm{OS}}}{E^2}\right) - \boldsymbol{\omega}_{\oplus} \wedge \boldsymbol{\omega}_{\oplus} \wedge \mathbf{r} - 2\boldsymbol{\omega}_{\oplus} \wedge \frac{d\mathbf{r}}{dt} + \frac{\mathbf{S}}{m} \quad (18)$$

Besides the reference terms in (1), small extra interactions appear. In the first row of (18) the deviated gravity $\mathbf{g}_{\oplus} - \boldsymbol{\omega}_{\oplus} \wedge \boldsymbol{\omega}_{\oplus} \wedge \mathbf{r}_{\mathrm{OT}}$ appears. The lunar interaction term $K_L\left(\mathbf{u}_{\mathrm{TM}}/r_{\mathrm{TM}}^2 - \mathbf{u}_{\mathrm{OM}}/D^2\right)$ and the solar counterpart term $K_{\mathrm{S}}\left(\mathbf{u}_{\mathrm{TS}}/r_{\mathrm{TS}}^2 - \mathbf{u}_{\mathrm{OS}}/E^2\right)$, neglected in the usual computations, appear in the second row, while the local centrifugal force of planet's diurnal rotation $-\boldsymbol{\omega}_{\oplus} \wedge \boldsymbol{\omega}_{\oplus} \wedge \mathbf{r}$ enters the first term of the last row.

Earth gravity inclination

With ω from (14) and $|\mathbf{r}_{\mathrm{OT}}| \equiv R_e = 6{,}371{,}221\,m$, the centrifugal acceleration at 45˚ is

$$a_c \equiv \omega_{\oplus}{}^2 R_e \cos\varphi = 23.95602827251\ mm/s^2 . \quad (19)$$

With standard $g_e = |\mathbf{g}_{\oplus} - \boldsymbol{\omega} \wedge \boldsymbol{\omega} \wedge \mathbf{r}_{\mathrm{OT}}| = 9.80665$ [m/s^2], the terrestrial gravity at 45˚ is

$$\mathbf{g}_{\oplus} \equiv g_e(\sin\chi + \cos\chi) = 9.82356021 m/s^2 \quad (20)$$

and $\quad \sin\chi \equiv \dfrac{\omega^2 R_e}{2\,g_e} = 0.0017273452241, \quad \chi = 5'.938176 \quad \Delta s \equiv R_e \sin\chi = 11005.3\ m$

Consistent Earth parameters $K_{\oplus}$, $m_{\oplus}$ are

$$K_{\oplus} \equiv f\,m_{\oplus} = g_{\oplus} R_e^2 = 3.98762 \cdot 10^5\ km^3/s^2, \quad m_{\oplus} = 5.9802 \cdot 10^{24}\,kg. \quad (21)$$

The ratio $\mu \equiv m_{\oplus}/m_L = 81.3007$ gives

$$K_L \equiv K_{\oplus}/\mu = 4.9047848 \cdot 10^3\ km^3/s^2, \quad m_L = 7.355656 \cdot 10^{22}\,kg. \quad (22)$$

The differences to the catalogue values are accepted for computational consistency.

Lunar interaction on Earth

The field $K_L\left(\mathbf{u}_{\mathrm{TM}}/r_{\mathrm{TM}}^2 - \mathbf{u}_{\mathrm{OM}}/D^2\right)$ of the Moon shows two facts. First, the vector differences only of the lunar attraction in T over its Earth center value manifests. Secondly, this small lunar effect *never* ceases, as the two terms of the difference are never aligned and equal. Direction cosines of the unit vector $\mathbf{u}_{\mathrm{OM}}{}^T \equiv [\cos\alpha_L, \cos\beta_L, \cos\gamma_L]$ are

$$\begin{pmatrix} [\sin\varphi\cos i\sin\omega(t-t_{\Omega}) - \cos\varphi\sin i]\sin\Omega(t-T_{\Omega}) + \sin\varphi\cos\omega(t-t_{\Omega})\cos\Omega(t-T_{\Omega}) \\ \cos i\cos\omega(t-t_{\Omega})\sin\Omega(t-T_{\Omega}) - \sin\omega(t-t_{\Omega})\cos\Omega(t-T_{\Omega}) \\ [\cos\varphi\cos i\sin\omega(t-t_{\Omega}) + \sin\varphi\sin i]\sin\Omega(t-T_{\Omega}) + \cos\varphi\cos\omega(t-t_{\Omega})\cos\Omega(t-T_{\Omega}) \end{pmatrix} \quad (23)$$

the connection $\mathbf{r}_{\mathrm{TM}} = \mathbf{r}_{\mathrm{OM}} - \mathbf{r}_{\mathrm{OT}}$, or $L\mathbf{u}_{\mathrm{TM}} = D\mathbf{u}_{\mathrm{OM}} - R_e\mathbf{u}_{\mathrm{OT}}$ gives $\mathbf{u}_{\mathrm{TM}}(t)$ in the form

$$\mathbf{u}_{\mathrm{TM}} \equiv \frac{\mathbf{r}_{\mathrm{TM}}}{L} = \frac{D}{L}\begin{pmatrix} \cos\alpha_L \\ \cos\beta_L \\ \cos\gamma_L - \varepsilon_{\oplus} \end{pmatrix}, \quad (24)$$

where $\varepsilon_{\oplus} = R_e / D = 0.016559262612$ and

$$L/D = \sqrt{1 - 2\varepsilon_{\oplus}\cos\gamma_L + \varepsilon_{\oplus}^2}\,. \quad (25)$$

Lunar action upon a terrestrial particle is compared to the mean lunar gravity $\gamma_L{}^0 = 0.0330696401\ldots mm/s^2$ on Earth (D=384,752,700 m at mean, assumed). When OT is orthogonal to the Site-Moon line (moonset or moonrise), the lunar interaction

$$\boldsymbol{\gamma}_L{}^{\mathrm{I}} \equiv \frac{K_m}{D^2}(\mathbf{u}_{\mathrm{TM}} - \mathbf{u}_{\mathrm{OM}}) = \frac{K_m}{D^2}\varepsilon_{\oplus}\mathbf{u}_{\mathrm{TO}}, \quad (26)$$

manifests the low intensity of $\gamma_L{}^{\mathrm{I}} = 0.00054865\ mm/s^2$, directed towards the *Earth center* O, like an extra gravity.

When the particle is on the Earth-Moon line with the Moon at local zenith, the lunar interaction becomes

$$\boldsymbol{\gamma}_L^{\mathrm{II}} \equiv K_L\mathbf{u}_{\mathrm{OM}}\left(\frac{1}{r_{\mathrm{TM}}^2} - \frac{1}{D^2}\right) \approx 2\varepsilon_{\oplus}(1 + 2\varepsilon_{\oplus})K_L\mathbf{u}_{\mathrm{OM}} \quad (27)$$

where $r_{\mathrm{TM}}{}^{\mathrm{II}} = D - R_e$. The lunar action is a doubled attraction of intensity $\gamma_L{}^{\mathrm{II}} = 0{,}001133646\ldots mm/s^2$ directed *towards the Moon and off the Earth*, like a reduction in Earth gravity. When the particle is oppositely positioned on the Earth-Moon line (Moon at Nadir), the lunar action should be

$$\boldsymbol{\gamma}_L{}^{\mathrm{III}} = -2\varepsilon_{\oplus}(1 - 2\varepsilon_{\oplus})\ K_L\mathbf{u}_{\mathrm{OM}}, \quad (28)$$

while $r_{\mathrm{TM}}{}^{\mathrm{III}} = D - R_e$. Its intensity is again almost double in respect to the first case, manifesting now a value of $\gamma_L{}^{\mathrm{III}} = 0.001060964\ldots mm/s^2$ that acts like repulsion, directed *off the Moon and off the Earth*. For intermediate positions, the Moon acts with similar amplitudes in different directions.

Solar interaction on Earth

The solar field in T is given by the term $K_{\mathrm{S}}\left(\mathbf{u}_{\mathrm{TS}}/r_{\mathrm{TS}}^2 - \mathbf{u}_{\mathrm{OS}}/E^2\right)$ in formula (18), where the parameters of the Sun are $E = 149.6\cdot 10^6 km$, $\varepsilon_s \equiv R_e / E = 4.2588\cdot 10^5$ and

$K_S \equiv f\, m_S = 1.32712\cdot 10^{11}\ km^3/s^2$. At its turn the Site-to-Sun direction $\mathbf{u}_{\mathrm{OS}}{}^T \equiv [\cos\alpha_s, \cos\beta_s, \cos\gamma_s]$ is given by the vector

$$\begin{pmatrix} [\sin\varphi\cos\varepsilon\sin\omega(t-t_\gamma) - \cos\varphi\sin\varepsilon]\sin\Omega_s(t-T_\gamma) + \sin\varphi\cos\omega(t-t_\gamma)\cos\Omega_s(t-T_\gamma); \\ \cos\varepsilon\cos\omega(t-t_\gamma)\sin\Omega_s(t-T_\gamma) - \sin\omega(t-t_\gamma)\cos\Omega_s(t-T_\gamma); \\ [\cos\varphi\cos\varepsilon\sin\omega(t-t_\gamma) + \sin\varphi\sin\varepsilon]\sin\Omega_s(t-T_\gamma) + \cos\varphi\cos\omega(t-t_\gamma)\cos\Omega_s(t-T_\gamma). \end{pmatrix} \quad (29)$$

where the angle ε accounts for the inclination of the ecliptic to the equator. From $\mathbf{r}_{\mathrm{TS}} = \mathbf{r}_{\mathrm{OS}} - \mathbf{r}_{\mathrm{OT}}$, or $S\mathbf{u}_{\mathrm{TS}} = E\mathbf{u}_{\mathrm{OS}} - R_e\mathbf{u}_{\mathrm{OT}}$ and $\mathbf{u}_{\mathrm{OT}}{}^T \equiv [0,0,1]$, the direction $\mathbf{u}_{\mathrm{TS}}(t)$ reads

$$\mathbf{u}_{\mathrm{TS}} \equiv \frac{\mathbf{r}_{\mathrm{TS}}}{S} = \frac{E}{S}\begin{pmatrix} \cos\alpha_s \\ \cos\beta_s \\ \cos\gamma_s - \varepsilon_s \end{pmatrix}. \quad (30)$$

The solar and the lunar influence upon an Earth corpuscle possess thus near magnitudes, with a ratio $\gamma_S/\gamma_m = 0.46049$. This value produces similar attraction and repulsion of the Sun upon a particle in T, with a maximum for the Sun at zenith

$$\gamma_s^{\mathrm{II}} \cong \frac{K_s}{E^2} 2\,\varepsilon_s(1+2\,\varepsilon_s) = 0.00050513\ ...mm/s^2 .$$

The magnitude of different influences about an Earth particle in the SEM system are collected in *Table 1*, with the Coriolis force, the lunar and solar static attractions in T as reference terms.

Maximal interactions on Earth *Table 1.*

Acceleration category	Abr.	Maximal value at 45˚ Earth latitude [mm/s^2]
Maximal Coriolis	a_{Cor}	≤0.00015
Lunar static	γ_m^0	0.0330696401
Solar static	γ_s^0	5.9298950499
Earth centrifugal	a_c	≤23.95602827251
Lunar.................	γ_m^{II}	≤0.00113366455
Solar..................	γ_s^{II}	≤0.00050513222
Centrifugal local	a_l	≤0.00000376004

The local-centrifugal effect, although 100,000-times higher then the Coriolis force has a constant action and does not alter the Foucault motion. The Moon sensible effect on Earth is actually 30 times smaller then its static gravity, while for the Sun the rotational effect is 10000 times smaller.

Elastic effects

The elastic effects are coming from the outer, support configuration and was considered as an increment in the equivalent length of the suspending string. The suspension becomes a moving point animated by the elastic reactions. The effect proves opposite to the astronomical influences and of the same order for the case.

Numerical results

An algorithm was used, based on a separate steps method with optimal time increment (*Fig. 2*). With the optimal h=0.0005s no periodic alteration of the Foucault azimuth motion was recorded, that depends on the stiffness of the device, mainly through the small, constant drift in the angular velocity of the azimuth. It gives slightly different periods of complete rotation of the plane of oscillation. These numerical results are given in *Table 3*. Not directly apparent in the previous computations, the elastic effects prove to have reduced perturbing magnitudes.

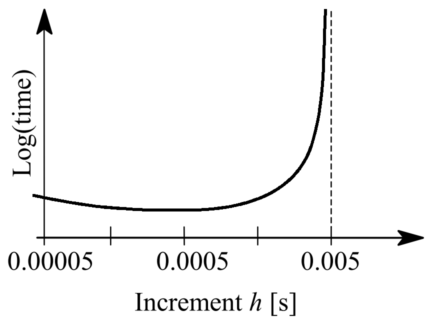

Figure 2- Sensitivity to the increment

Table 3. Foucault period on Earth

Computational condition	Abr.	Time of complete rotation [*h,m,s*]
Theoretical, linear	Θ_T	$31^h54^m45^s.45$
Numerical value, no perturbations	Θ_N	$32^h04^m03^s.90$
Elastic, Lunar and Solar effects	Θ	$32^h03^m11^s.90$

The actual rotation lasts 9 minutes longer then the linear theory states, while the astronomical influences reduce this elongation with 1 minute to some 8 minutes.

CONCLUSIONS

A constant drift in the angular velocity of the azimuth is induced by both elasticity and astronomical perturbations of the Moon and Sun over the motion of the gravitational oscillator. The elastic effects prove to have reduced magnitudes

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