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# The Allais Effect and an Unsuspected Law of Gravity

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***Abstract*—Anomalies in measurements made with pendulums and torsion balances have led to a suggestion of the reconsideration of the laws of gravitation. This paper discusses the anomalies and postulates that there is a need for an addition to the existing laws of gravitation. Hitherto, gravitation influences of the Sun and Moon result in the well documented rise and fall of sea and ocean tides. Tide tables are calculated from knowledge of the micro changes of Earth's gravity. What does not appear to be documented is an analysis of the rate of change of magnitude and direction of gravitational tilt and its resolved horizontal component (circular anisotropy) at any particular location on the Earth's surface. The purpose of this paper is to show that the horizontal direction of the gravitational tilt rotates in an undulating manner with varying magnitude. It is shown that such rotation results in relatively sharp increases in angular acceleration giving rise to horizontal torque. It is also shown that this torque is the reason why very sensitive instruments such as paraconical pendulums and torsion balances react in the way experimenters have reported. These effects are sensitive to the tilt of Earth's axis and to the tilt of lunar orbit with respect to the ecliptic. Anomalies are, in fact, the most normal physical manifestation that can be expected when this additional previously unknown law of gravity is taken into consideration.**

## I. Glossary of terms

*Vertical* is defined as being coaxial with a radial line of a sphere.

*Horizontal* is defined as being in the plane tangential to the surface of a smooth sphere.

*Azimuthal* is defined as being in the plane tangential to the surface of a smooth sphere.

## II. Introduction

While the use of torsion balances is relatively recent, dating from the 18th century, pendulums have been with us for centuries. For many decades, unexplained disturbances to the expected motion and period of these sensitive devices, when being used as a measurement aid, had been noted. In the mid-20th century Professor Maurice Allais [1] conducted a series of tests using a paraconical pendulum of his own design. Other researchers have also carried out experiments of a similar nature, producing anomalous results. Antonio Iovane designed a static pendulum which exhibited anomalous behaviour during eclipses. Alexander Pugach [2] designed a torsind (a special type of torsion balance) using a disc instead of a bar so that it would not respond to stray horizontal gravity fields. This exhibited unexpected rotational anomalies. Henceforth, the term Pugach Effect will be used for anomalies noted during experiments with a torsind.

There has been much controversy about the origin of such anomalies. A number of sources discuss the possibilities of cause other than gravitational. Duif [3], Múnera [4], Pugach & Olenici [5], Goodey, Pugach & Olenici [6] refer. It is even questioned by Múnera [4] whether the laws of gravitation should be reconsidered. Certainly that is a necessary and reasonable question to pose. This paper argues that there may, in fact, be a hitherto unknown law of gravity.

Whether the Allais Effect really exists or not is still being debated because not all experiments have revealed such anomalies. Hitherto, established scientific thought appears to be that gravitation cannot be responsible for either the Allais Effect or the Pugach Effect.

From the above, it is apparent that there has not yet been any reasonable explanation for this phenomenon. Neither has there been any modelling to substantiate it. There are no published tables or charts which provide details of predicted azimuthal gravitational magnitudes and direction. There are only tables of ocean tides. It is more than half a century since the first known recorded and well documented Allais Effect. Is this perhaps a result of experimenting with the focus being mainly on solar eclipses? After all, Allais made it clear that there are phenomena of which the eclipse is a less significant event than the anisotropy of space. It was Allais [1] who first noted this effect, but he also emphasised that the lunar effect was vastly more important than the eclipse effect [4] (pp. 232/235). Many researchers, however, continue to focus on the less readily observable eclipse effect and recent experimental focus has been centred predominantly on pendulum behaviour during solar eclipses. That there are deviations from the normal precession at times other than during eclipses is borne out by Noever's message to Zepletal [7], as indicated in his summary point 5), where he notes that one report seemed to show deviations outside of the eclipse, which were comparable to those during the eclipse. Thus any proposed theory put forward to explain the Allais Effect must also include non-eclipse events. It is of note that Pugach has recorded numerous, but unpublished, examples of disturbances to torsinds during

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periods without solar eclipses occurring. The author's own experiments have confirmed this.

What follows in the next section is a theorem that there are horizontal accelerating rotating gravitational fields, and that these are linked to the anomalies encountered with pendulums and torsion balances. An appendix at the end of this paper explains the mathematical and geometrical constructs used to determine the theoretical horizontal gravitational components of magnitude and azimuth. Direction and amplitude of lunisolar gravitational interactions are quantified. The derivation of rotational field velocities and accelerations are not discussed in the appendix but in following text. The main body of this paper continues with a presentation of how gravitational tilts at the surface of the Earth result in horizontal components which exhibit synergistic angular accelerations. It is explained how these angular accelerations cause pseudo-torque forces (see Conclusion to Appendix) that can disturb sensitive measuring instruments. The Allais Effect will be explained. It will become clear why a disc exhibits change in angular momentum. It is shown that, when gravitational tilt is resolved into its appropriate orthogonal components, there will be a varying azimuthal component of the gravitational field, and that this field will be subject to substantial angular acceleration transients. These angular accelerations will result in a gravitational pseudo-torque which will consequently cause the rotation of any sensitive device freely supported in that field.

The effect of distant galaxies (i.e. the anisotropic gravitational field) is not considered fully here, although it could form part of future work if found necessary.

Results from experiments are presented and compared with theory. It will be shown that the same mechanism is responsible for both the Allais and Pugach Effects. Finally a conclusion is made proposing an additional law pertaining to angularly accelerating gravitation fields and how this theory could be used to assist in planning future experiments.

By the end of this treatise, it will have been shown that:

a) synergistic effects occur,

b) Allais' eclipse and restricted (or lunar) effects do occur,

c) Allais effect is not always evident during a solar eclipse,

d) torsion balances respond to the horizontal rotating gravitational field,

e) Newtonian gravitational laws, with the addition of one new law, are sufficient to explain anomalous behaviour,

f) the same mechanism is responsible for both types of anomaly.

## III. Theory

Mathematical modelling is based on Newtonian physics and laws of gravitation. Unit mass in calculations is assumed so that numerical acceleration values can be used in lieu of force.

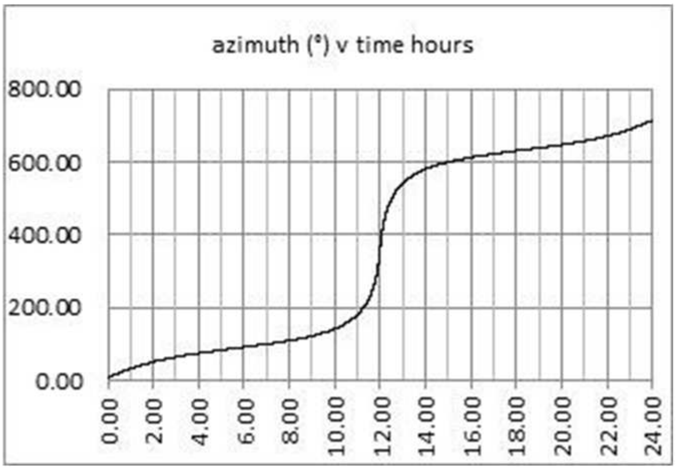


Figure 1. Typical azimuth field direction on day of noon solar eclipse Lat 48.8° Tilt = -23.5° lunar orbital plane -3.9° (N = 90°) .

### A. *Azimuth during a solar eclipse*

Gravitational conditions for the two weeks preceding and following a simulated eclipse are described in the Appendix. It is now appropriate to analyse the horizontal gravitational field at and near the time of a solar eclipse. Consider the Sun (or the moon) at a particular elevation and azimuth in the sky. The direct gravitational pull of the Sun can be calculated and the resultant tidal pull obtained. Resolving this pull into N-S, E-W and vertical directions, gives three orthogonal vectors representing the Sun's pull. Repeat this to obtain the lunar vectors. It is only the azimuthal (N-S, E-W) vectors that are of interest because the vertical component does not contribute to azimuth. From the two N-S vectors and the two E-W vectors, the magnitude and direction of the resultant vector can be calculated for a given instant. By repeating this process for successive time intervals, the progress of the horizontal gravitational vector can be monitored. Fig.1 gives an example of how the horizontal gravitational field changes in azimuth throughout a simulated solar eclipse day.

A static azimuthal component of a gravitational field will not alter the major swing axis of a pendulum. Nor will it cause rotation of a suspended rod (or disc) of a static torsion balance. The application of torque is required. No torque exists in a static azimuthal component of a gravitational field, thus anomalies will not occur. However, the suspension mechanism will exhibit a tilt from the vertical in the direction of the azimuthal field. Tilt will also occur in the case of a static pendulum.

By permission of Iovane, Fig.2 shows one of his typical static pendulum responses [4] recorded during the period of a solar eclipse. Note that the y-axis gives the direction of the horizontal field and thus indicates the direction of vertical tilt.

### B. *Azimuthal angular velocity during a simulated solar eclipse*

The data for Fig.1 give the angular distance through which the horizontal field has rotated against time. Dif-

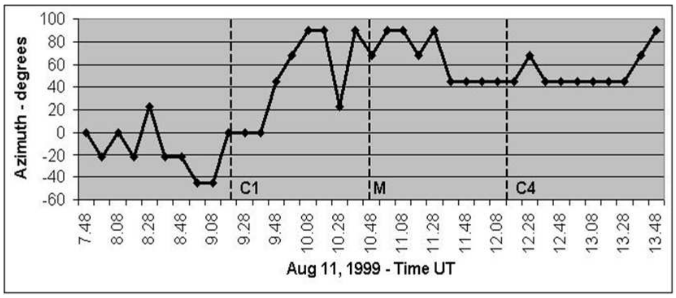


Figure 2. Record of azimuth tilt direction for Aug 11th 1999 solar eclipse (by kind permission of Antonio Iovane).

ferentiating this data with respect to time gives the result shown in Fig.3, where a velocity transient is clearly evident.

The rotation, with constant velocity, of an azimuthal component of a gravitation field will not alter the major swing axis of a pendulum. Nor will it cause rotation of a suspended rod (or disc) of a static torsion balance. The application of torque is required. No torque exists in an azimuthal component of a gravitational field rotating with constant angular velocity, thus anomalies will not occur. However, the suspension mechanism will exhibit a tilt from the vertical in the direction of the azimuthal field. Tilt will also occur in the case of a static pendulum.

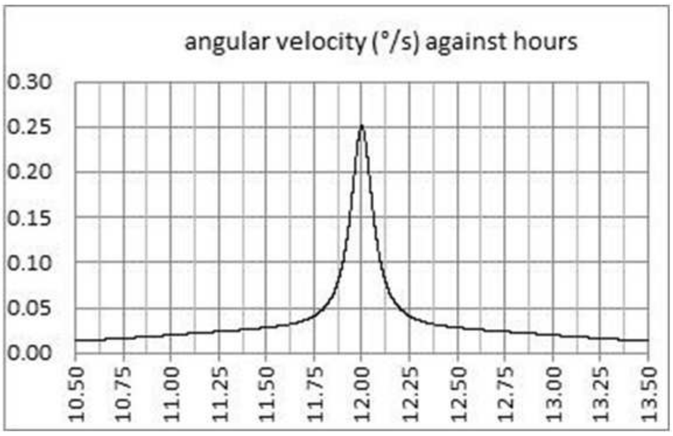


Figure 3. Angular velocity of azimuth gravitational field on day of noon solar eclipse. Lat 48.8° Tilt = -23.5° lunar orbital plane -3.9° (N = 90°).

*C. Azimuthal angular acceleration during a simulated solar eclipse*

Having discussed the null effect of static fields, and fields with constant angular velocity, it is now necessary to consider the effect of fields having angular acceleration. Differentiating the data for Fig.3 gives the angular acceleration of Fig.4, revealing another sharp transient. Note that Duif [3] produced a graphical response, similar to that of Fig.4, by differentiating azimuth plot with respect to time.

Normally, in the mechanical world, torque causes angular acceleration. The question now is whether or not, during acceleration transients, any sensitive device in an

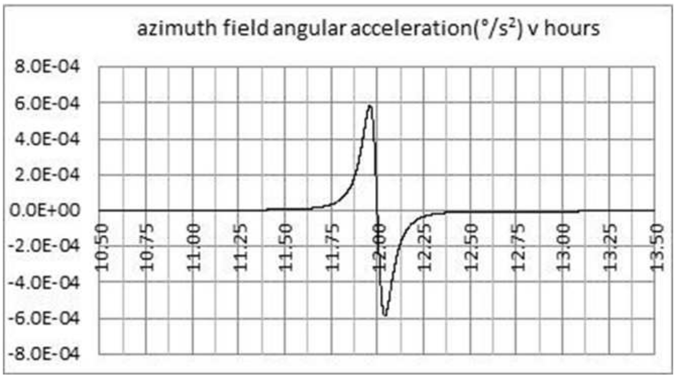


Figure 4. Angular acceleration of azimuth gravitational field on day of noon solar eclipse. Lat 48.8° Tilt = -23.5° lunar orbital plane -3.9° (N = 90°).

accelerating rotational gravitational field would experience transient torque. The implication is that this would be a pseudo-torque in the same way that the Coriolis force is a pseudo-force. This is discussed next.

*D. Tidal field rotating with angular acceleration*

Notwithstanding the fact that gravity is a central force it has been shown above that conditions can exist which would result in angular acceleration of the horizontal tidal component of the Earth's gravitational field.

In classical mechanics, a central force on an object is a force whose magnitude only depends on the distance $r$ of the object from the origin and is directed along the line joining them. But this cannot be true in the case of a field rotating with angular acceleration, because the field is distorted and $r$ is no longer the shortest distance to the origin.

Fig.5 shows the plan view of a horizontal rod suspended in the laboratory's inertial frame of reference. The arc $p_1Op_2$ represents the locus of equipotential gravitational points through the centre of the rod at time $t_1$. The arc $p_1'Op_2'$ represents the locus of equipotential gravitational points through the centre $O$ of the rod $AOB$ at time $t_2$. Four arrows, denoted with the suffix $f$, tangential to the dashed circle at $A$, $A'$, $B$ and $B'$, represent the magnitude $f$ and direction of the acceleration of the horizontal tidal field at times $t_1$ and $t_2$. These are individual geodesics for any free particle located at $A$, $A'$, $B$ and $B'$ constrained to move in the horizontal plane. They do not induce rotation. Let $\alpha$ be the angular acceleration with which the equipontential locii rotate between times $t_1$ and $t_2$ so that the gravitational potential at point $A$ has accelerated to point $B$, and the gravitational potential at point $A'$ has accelerated to point $B'$. A rotating gravitational field with rotational acceleration is a non-inertial frame of reference. The laboratory is in an inertial frame of reference, but the bob is in the non-inertial frame of reference of the horizontal rotating field. Now, it is not known whether any experiment in classical mechanics has ever shown that a rotating gravitational field will cause rotation of a symmetrically distributed mass. And, from the previous discussion

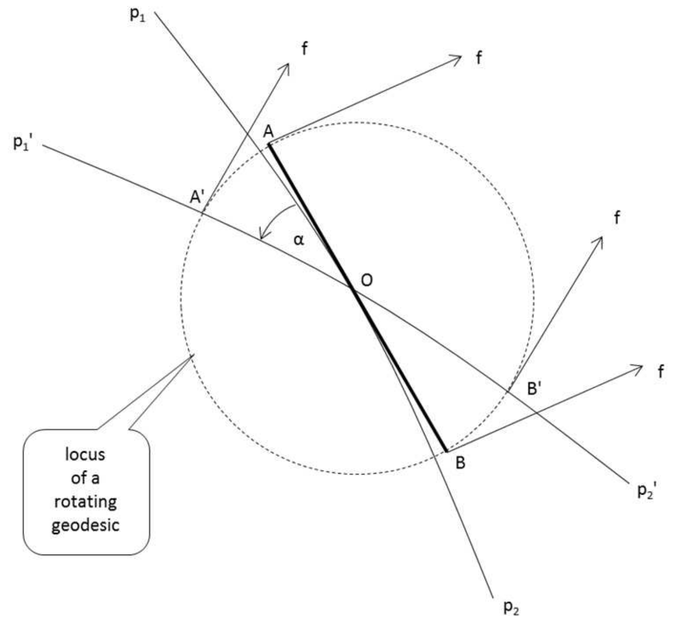


Figure 5. Torsion pendulum rod located in a rotating horizontal component of a gravity field.

there is no reason why it should. But that does not mean that such a field with angular acceleration would not drag a symmetrical mass and give it angular motion. Therefore, it is now postulated that the accelerating rotating field will act upon connected particles freely located in the same plane. Such a postulate is reasonable because, firstly it is intuitive, and secondly the theoretical result, as shown later in the document, is confirmed by experiment. Thus a particle at B will be subject to an acceleration of $f+OB\cdot\alpha$. Similarly a particle at A will be subject to an acceleration of $f–OA\cdot\alpha$. But $OA = OB$ therefore a pseudo-torque $OA\cdot\alpha$ will be applied to the rod $AOB$, and will act about its centre $O$. Consequently the rod $AOB$ will rotate.

If the rod is replaced by a disc, the same argument can be applied if it is assumed the disc is made up of a large number of thin rods. Similarly a disc could be replaced by a ring with the same result that it will rotate. In each case the horizontal acceleration only results in a slight tilt from the vertical of the pendulum suspension filament.

It is expected that the above reasoning also applies to a paraconical pendulum whereby it will experience a large torque causing its line of apsides to rotate. Note that this circular anisotropic torque is in addition to, and can be several orders larger than, the small linear anisotropic forces causing elliptical precession – see Pippard [8]. In general $\alpha$ can be several orders greater than $f$. So, without a formal mathematical treatise, it is not unreasonable to expect the line of apsides to reach a limiting angle following the reduction in magnitude of the angular acceleration. At this point the Airy [9] precession would dominate. Small tidal torques could not be expected to change the orientation of the apsides over the time periods considered (2 to 3 hours). Note that the theory in [8] and [9] does not discuss large uni-directional torques which do not cancel out at each half-cycle.

Close examination of Fig.3, Fig.4 and appendix Fig.A.5 shows that maximum angular field acceleration occurs at or near zero field strength. This difference in parameter phasing has a parallel in other mechanical and electrical disciplines. For example:

- maximum velocity and maximum acceleration of a disturbed spring are in quadrature,
- maximum velocity and maximum acceleration of a disturbed pendulum are in quadrature,
- maximum voltage and maximum current in a tuned circuit are in quadrature.

## IV. Model Assessment

Model comparison will concentrate only on the paraconical pendulum of Allais, the static pendulum of Iovane [4], and the torsion balance of Pugach [2]. These three devices have shown consistent anomalies and they have been very well documented whereas failed experiments have little data to study.

Operation of the paraconical pendulum is by means of setting the pendulum to swing for a given period of time, after which, it is set swinging again along the same path at which it had finished the previous run. Allais' discovery of anomalies in the path direction at the time of a solar eclipse became known as the Allais Effect. Of significance is the fact that he also noted there were greater anomalies not involving an eclipse.

The torsind disc is suspended by a filament of extremely low torsion so that it will not oscillate like a standard torsion balance. Operation of this type of balance is with the disc initially at rest as far as can be ascertained and any rotational angular change noted over time. Pugach noticed that, during a solar eclipse, the disc would rotate first in one direction and then in the other, returning more or less to its initial position after a few hours. Furthermore, on other days the disc could be seen to rotate, sometimes several revolutions, within a period of a few hours.

The static pendulum is not given an initial impetus but is allowed to move without any intervention. Observations show that it also exhibits anomalistic behaviour, particularly at times of eclipse. A typical record can be seen in Fig.2. The deviations are in keeping with the author's theory with respect to linear horizontal anisotropy. Evidence of torque was not predicted, nor was it reported.

### A. *1954 solar eclipse and the Allais Effect*

Professor Allais conducted a multitude of experimental tests using paraconical pendulums of his design. It was following his detailed reports, which included his chart shown in Fig.6, that the term 'The Allais Effect' was introduced.

Essentially, he claimed that the plane of oscillation of a pendulum deviated from its normal precession rate by about 13° at the time of the 1954 solar eclipse, as shown in Fig.6. It then returned to its normal precession

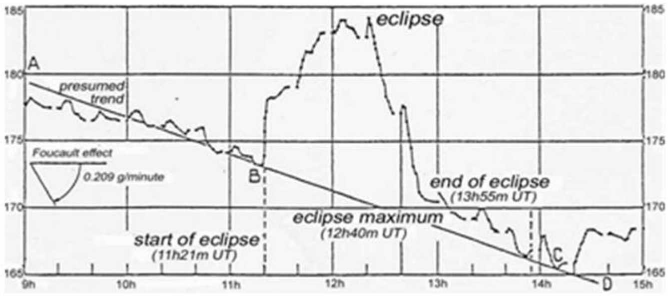


Figure 6. Allais Effect - graphical record of the 1954 solar eclipse (by kind permission of Thomas Goodey).

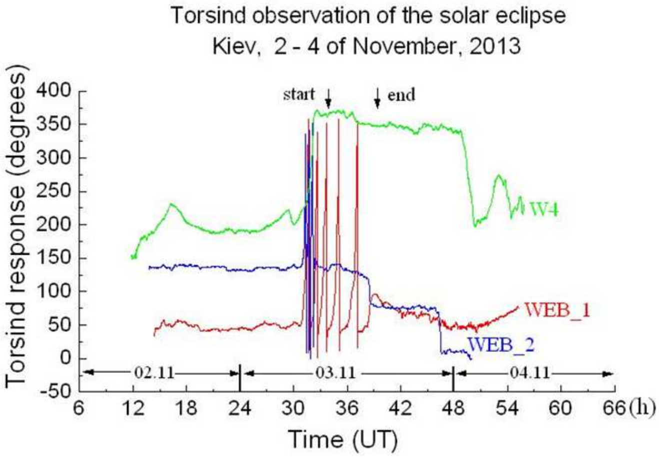


Figure 7. Response of torsinds WEB1, WEB2, W4 at solar eclipse 2 - 4 Nov 2013 (by kind permission of Alexander Pugach).

rate. This figure also shows that the deviation (anomaly) lasted for approximately 100 to 120 minutes. Compare this timing with that of the predicted transient acceleration shown in Fig.1. Notwithstanding that the model azimuth is increasing and Allais' azimuth is decreasing, the duration of the transient is also approximately 120 minutes. Thus the rotation of the line of apsides matches the forcing acceleration. This cannot just be coincidence and provides support for the theory outlined above, that angular acceleration of the horizontal component of the gravitational field is the cause.

*B. 2013 Solar Eclipse*

Pugach [2] designed a novel torsion balance, called a torsind, which uses a thin light disc instead of a beam. He has conducted many experiments and amassed much data, some of which he has made available to this author for research. Of great significance was his release of the chart (Fig.7) and associated data for the 3rd November 2013 solar eclipse. It shows the results, plotted on one chart, of three torsinds, WEB1, WEB2, and W4, simultaneously under test. When expanded to present cumulative rotations, as shown in Fig.8, they exhibited similar onset of perturbations. Thus the stimulus must have been common. This information turned out to be the missing link for the author, confirming his theory presented in this work on gravitational torque.

Data presented in Fig.7 has a saw-tooth effect because the recording equipment is unable to show the accumulation of angles beyond 360°. To resolve this issue the angular data beyond one revolution has been summed manually thus allowing the vertical axis of Fig.8 to display accumulated azimuth revolution of the torsind. Additionally, the start angles of each torsind are not synchronised at zero. Therefore, for ease of presentation in Fig.8, the data for each of the torsinds has been normalised to start close to zero. Presented this way, the classical characteristic response to a sinusoid forcing function can now clearly be seen. At this stage it is possible to 'reverse engineer' the data by differentiating the angular position curve twice - once to obtain angular velocity and second to obtain angular acceleration of the disc.

This second differentiation for each torsind reveals a sinusoid transient in Fig.9 that is very similar to that in Fig.4, as predicted above. Hence the evidence is very strong in support of the above theoretical explanation for the Allais Effect as applied to a torsion balance.

W4 data was used for the presentation of differentiation exercise because it had the 'cleanest' curve and was not subject to the spurious and confusing transients that would have resulted from the forced sinusoids seen for WEB1 and WEB2. Also plainly visible on WEB1's curve (and to a lesser extent on WEB2) is a fundamental harmonic (typical of a sinusoid forcing function) plus a second harmonic just noticeable on WEB1. It is clear that WEB2 did not return to a static state within 80 minutes or so as WEB2 and W4 had done. The most likely reason for this would be that WEB1 was already in a state of wound-up tension.

Note that the W4 acceleration curve is very noisy and has had significant smoothing applied to reveal the transient hence a slight delay is observed. Note also that, in terms of a step forcing function, W4 exhibits signs of very heavy damping while WEB1 exhibits signs of lesser damping. It is suspected that the damping is due to energy being absorbed in the suspension filaments. Whether this energy is absorbed as potential torsional energy or dissipated as heat (or both) is subject to future study. It seems that the suspension filaments do not obey Hooke's law. Either, that, or they display some kind of hysteresis effect. Note Pugach records the coefficient of reaction as only 0.0865. Of further note is that WEB1 did not respond to the reversal of direction caused by the transient, as did the other two, but continued to rotate till slowed down to a stop by damping. It is suspected that stored potential energy assisted the increase in disc angular velocity such that the restoring half of the accelerating transient could not stop the disc in time. Its inertia then carried it on till it was stopped by the effect of damping. This event could be subject to further study, but is believed to be the result of each torsind having different initial conditions at the start of the eclipse. This is similar to the action of, say,

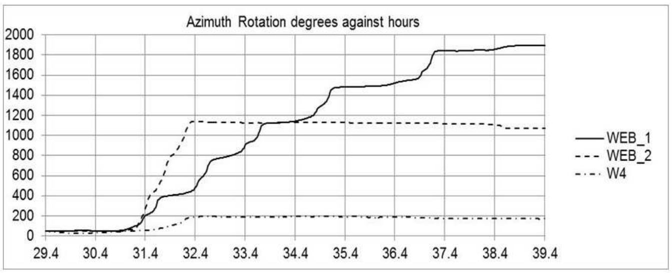


Figure 8. Cumulative normalised rotation of WEB1, WEB2, W4. Solar eclipse 2 - 4 Nov 2013, hours from midnight 1st Nov.

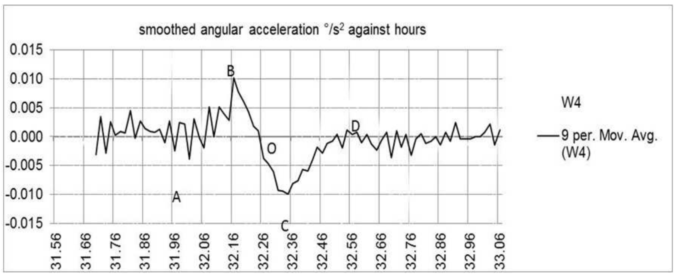


Figure 9. Forcing transient derived from smoothed 2nd derivative of W4 rotation angle. Solar eclipse 2 - 4 Nov 2013, hours from midnight 1st Nov.

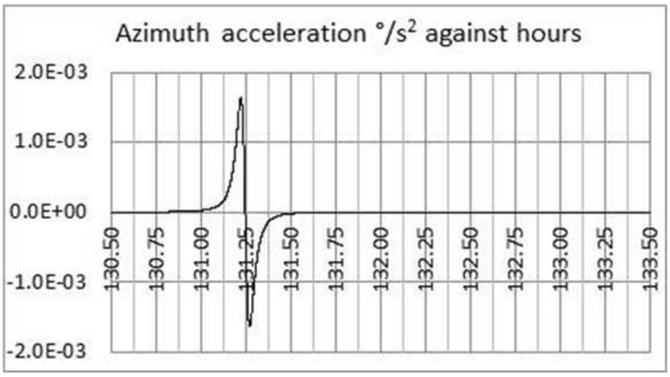


Figure 10. Angular acceleration of azimuth gravitational field five days after solar eclipse. Lat 48.8° Tilt = -23.5° lunar orbital plane -3.9° (N = 90°).

a pendulum which receives a forcing impulse at different times during its swing.

It is worth making the point here that the maximum rate of rotation of any of the torsinds did not exceed 0.55°/min for WEB2, 0.5°/min for WEB1 and 0.1°/min for W4. These values are within the value quoted in [2] for the stated condition of no reverse torque. Why these values are so different, if there is no torque, requires an explanation as follows.

Making the assumption that each torsind has similar physical characteristics, it would have been expected that they display similar time constants. Since they do not, then obviously each must have had different initial conditions when the transient occurred. For example, in the case of WEB1, there must have been energy stored in its filament. This energy, plus the energy from the gravitational transient (in the same sense), would have provided sufficient momentum to have driven the disc past the reverse transient position. In the case of W4, torque energy must have been stored in the filament also. But this energy would have been stored in the reverse sense to the gravitational transient, thus giving the impression of a damped response. This explains why different torsinds appear to react to the same stimulus in different ways. This also explains why any nominated torsind will react differently to similar impulses on other days. The conclusion is that torque energy must have been stored in the torsind filaments.

With reference to Fig.8 and Fig.9, for the initial static conditions of the discs, action of the transient is described thus. Between points A and B acceleration is increasing positively so the discs accelerate. Between B and O acceleration is reducing positively so the discs continue to accelerate but at a reducing rate. Between O and C the transient acceleration is increasing negatively, so WEB2 and W4 discs commence to decelerate while still rotating positively. Between C and D acceleration is again increasing positively, so WEB2 and W4 discs continue to decelerate. Because the energy in the positive and negative halves of the transient are substantially equal but opposite in sign, then momentum gained by the two discs is cancelled and the discs effectively cease to rotate. WEB1 response differs due to the circumstances described in the previous paragraphs. Note that the transients of Fig.9 and Fig.10 are of the same order.

Now, it is time to turn to each of the assertions a) to f) announced earlier. These are considered next.

a) Synergistic effects

There is no doubt that gravitational synergies occur. Several prominent examples can be shown but the one of interest is on eclipse day, Fig.1. Examination of consecutive readings at these synergistic times reveals rapidly changing data thus there is no sudden jump due to, perhaps, an algorithmic error.

b) Allais eclipse and restricted (or lunar) effect

Allais has emphasised that the "restricted" effect is of more importance than the eclipse effect but there is not much publicly available test data on pendulum phenomena at times remote from eclipses. Fig.10 demonstrates Allais' conviction most effectively. It is seen that this particular acceleration transient is two to three times greater than that during an eclipse shown in Fig.4. Thus there is an expectation of seeing similar anomalies at times other than at times of a solar eclipse. Pugach has recorded many such unpublished examples.

c) Allais effect is not always evident during a solar eclipse

Several researchers in this field have reported null or debatable results in their efforts to repeat Allais findings during a solar eclipse. One reason, for an experiment being unable to record the Allais effect, is that the effect may be too weak. Fig.11 shows an example of such a condition, where the rotational transient is very weak, being nearly two orders lower than that shown in Fig.4.

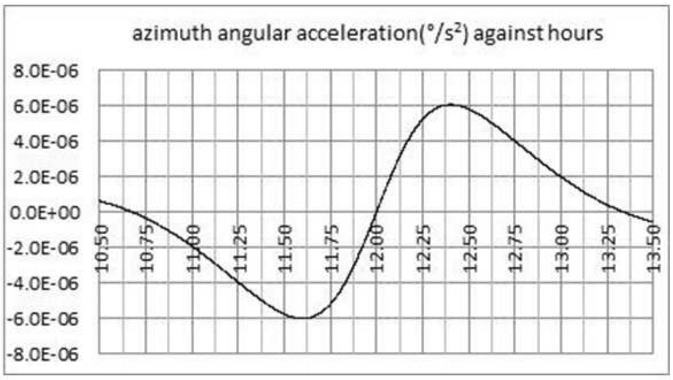


Figure 11. Angular acceleration of azimuth gravitational field on day of noon solar eclipse. Lat 48.8° Tilt = -23.5° lunar orbital plane -5° (N = 90°).

Further theoretical experimentation, by varying the Latitude in the model, indicates that there is an optimum range of Latitude to detect the Allais effect. Initial checks using this model indicates that the range would be approximately 50° to 70° in each hemisphere, dependent on season, but more work is needed in this area.

d) Torsion balance response

It has been shown that the lunisolar gravitational field at the surface of the earth is rotating azimuthally one way or the other in a pseudo sinusoidal manner. This has been shown to lead to angular accelerations which, in turn, produce torque. Thus, although a torsion balance is designed not to respond to vertical or horizontal directional influences, it clearly must react to transient torque forces. Hence, the torsind disturbances recorded by Pugach.

e) Newtonian gravitational laws

From the foregoing discussion, it is evident that characteristics of the model presented match several characteristics of experimental result very well. For example, by comparing Fig.9 with Fig.10, it is seen that the charts have very similar waveforms. Thus the postulate made earlier is reasonable because the theoretical result has been confirmed by experiment.

Note that the model discussed in this paper has been based on standard Newtonian laws of gravitation. What is significant about this observation is that it is extremely likely that the anomalous effects must be purely gravitational in nature with no requirement for a new type of physics. It is only necessary to adopt the hitherto unsuspected relationship that torque is produced by a rotationally accelerating gravitational field. Furthermore, this torque is at a maximum when the magnitude of the field in the plane of rotation is at a minimum.

f) Common cause for Allais & Pugach Effects

Earlier it was shown that gravitational torque will be exerted on a body by the angular acceleration of a gravitational field. It was shown that this affects both a paraconical pendulum and a torsion balance. Hence the anomalies of each type of device are deemed to have the same physical source.

It has been shown that there is a varying horizontal gravitational field at the surface of the Earth, and that this field can exhibit substantial angular velocity and transient angular accelerations (synergistic effects). Furthermore, it has been shown that these angular accelerations will result in a torque being applied to any sensitive device such as a horizontal rod or disc freely suspended in that field and consequently will cause rotational movement of that device. It has also been shown how these angular accelerations produce a torque sufficient to produce anomalies in the rotation of the line of apsides of a paraconical pendulum. It should be noted that it has only been necessary to consider horizontal angular accelerations, derived from North-South and East-West gravitational tilt components, in order to assess the forces causing the Allais effect and the Pugach effect. The vertical tidal variations in gravity can be ignored even though there may be an association with the effect.

The modelled results have been shown to reflect the anomalies noted in the Allais eclipse and Allais restricted effects. Similarly the modelled results reflect the anomalies noted in the WEB torsion balance tests conducted by Pugach. Anomalies have been shown to be dependent on the luni-solar gravitational tides by the motions of Earth and Moon in their orbital paths around the sun.

Thus, the model is a realistic demonstration that Newtonian laws of gravity, when fully interpreted, explain why the anomalies occur and that they are a result of rapid variations in azimuthal gravitational acceleration. It could be stated that the anomalies are not really anomalies at all but are in fact normal reactions to the forces of extraterrestrial gravity.

## V. Magnetospheric storms

It has been proposed by Iovane that the Pugach effect could be the result of magnetospheric effects due to coronal mass ejections, rather than as the result of gravitational forces. Iovane has shown a significant correlation between Torsind fluctuations and the magnetospheric records of the GOES 13 and GOES 15 geostationery satellites. One example of this [10] shows the remarkable change in magnetospheric activity which occurred at the same (corrected) time as Pugach's records (Fig.7) for his torsinds during the November 2013 solar eclipse.

It is perfectly justifiable to claim that strong magnetospheric effects would induce eddy currents in an electrically conductive torsind disc and thus cause rotation. Parallel tests with a conductive torsind and a non-conductive torsind would resolve this issue. Fortunately, while updating this document, the author had been conducting his own experiments with conductive and non-conductive static torsion pendulums. It was found that the conductive pendulum would react significantly to magnetospheric storms, sometimes rotating several thousand degrees, and usually returning to a similar azimuth from whence it started. In comparison, the non-conductive pendulum did not react to magnetospheric storms, and rarely turned by much than 700 degrees. Its response exhibited characteristics predicted by the gravitational theory outlined in this paper.

Whether Iovane's theory could also explain the Allais effect experienced by paraconical pendulums is an issue which does not appear to have been resolved yet, but there is little reason to suspect it wouldn't. Meanwhile the gravitational theory is complete and can explain the Allais effect and those Pugach effects which are not related to magnetospheric storms.

There is no reason to discount Iovane's theory as both, his theory and the theory proposed in this paper, are viable. Each theory proposes forces of a different nature, and each type of force has its own characteristics resulting in different types of disturbance.

## VI. Conclusions

For an explanation of the Allais Effect the simple model presented demonstrates a good case for accepting Newton's laws of gravity without modification other than the acceptance of a previously unsuspected law. It has been shown that rotating gravitational fields exist. It has also been shown that such a field which has also angular acceleration creates a couple. Therefore, an observer will experience a torque due to it. Predicted gravitational circular anisotropic accelerations and the second derivative of experimental rotations have been shown to be of the same order, similar in form, and of similar duration. This is strong circumstantial evidence that gravity plays a part. It is therefore hypothesised that the circular anisotropy (with acceleration) leads to pseudo-torque. It may now be appropriate to propose a new law of gravity as follows:

*A rotating gravitational field will exert upon a body a torque whose magnitude is proportional to the angular acceleration in the plane of rotation of that field.*

Using this model, and accepting the new law, could provide a priori knowledge of expected gravitational influences in advance of possible future work. Thus experiments could be planned to take place during periods of predicted synergistic effects in addition to expected solar eclipses. Continuing experiments could utilise the model to check for correlation with 'anomalies' found in real time. Any such correlation would be corroborative evidence that Newton's laws of gravity are still valid in terms of anomalies. The theory outlined above is consistent with the solar eclipse experimental test results of Allais, and Pugach. Hence it can be stated that the experiments support the model, the theory is valid but it requires one new law of gravitation in addition to Newton's existing laws to explain the Allais Effect and other anomalies. A future study could compare test results against real ephemeris data.

Other disciplines may find an interest in the theory outlined above. For example, it is possible there could be correlation shown between gravitational torque and observations made in the disciplines of meteorology, oceanology, human behaviour, animal behaviour, space research, etc. It is of note that Pugach [11] has raised the implication of a "new energy", possibly sourced by the sun, and worthy of further study. Since Issue 3 of this paper the author has himself carried out tests with a ring pendulum which is more massive than the extremely sensitive torsind. His results show that Pugach's implied energy is available and can be scaled up. Earlier in this paper it was shown that torque can be generated by lunisolar gravitational action which also could lead to harnessing gravitational energy. Perhaps there are implications for experiments involving tests for light deviation such as those of Morin [12]. Could it be gravitational torque that caused unexplained deviations in Morin's experiments?

Although the mathematical model described in the appendix is partly validated by practical experiment, it is not without its shortcomings. The author's own experimental results confirm some reservations held about its accuracy. Further evaluation of the model is planned for future study.

## VII. Acknowledgements

The author wishes to thank Alexander Pugach, Antonio Iovane and Thomas Goodey for their kind permission in allowing use of some of their documentation and experimental results and for their patience and time taken in explaining some of the finer technical and scientific facts and in correcting my misapprehensions. Thanks also go to Andrew McCracken for his critical and helpful reviews of this paper, and to Lockie Cresswell and Michel Auberger for their technical suggestions and mathematical corrections. The professional review of this paper by Professor Verrault was especially appreciated for its re-assuring attention to detail and very clear and helpful physical explanations.

## Appendix A
## Extraterrestrial gravitational influences and the Allais effect

### A. Theory

Newtonian laws of gravity are assumed throughout. The Earth's sinusoidal orbit around the Sun is shown in Fig. A.1. As the Moon circles the Earth the rotating lunar gravitational field interacts with the solar gravitational field. The resultant field is further modified as the Earth's centre of gravity (CG) circles the Earth/Moon subsystem barycentre. It is the addition of these accelerations in the azimuthal plane that will be examined.

For the purpose of this treatise it will be assumed that a test particle P is of unit mass and is freely suspended as the bob of an ideal omni-directional pendulum. Gravitational forces and accelerations under consideration are thus numerically interchangeable and forces can be replaced by accelerations.

First consider the accelerations induced on the bob within the free-falling Earth/Moon subsystem. Each of these influences will be considered in turn.

1) Tidal acceleration due to the moon.
2) Tidal acceleration due to the Sun whose gravitational influence is modified by the Earth's position with respect to the Earth/Moon barycentre.
3) An effect due to Earth's tilt.

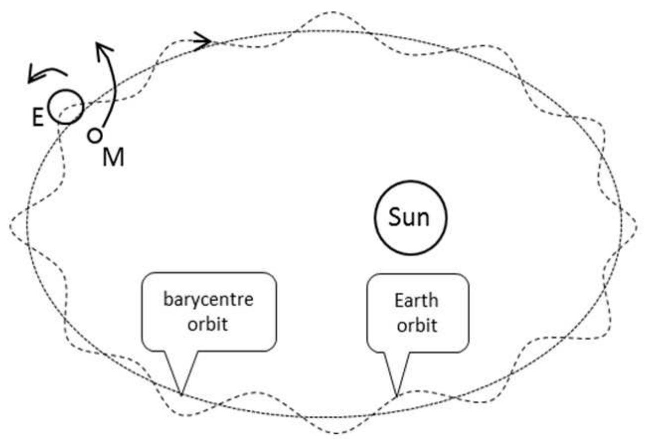


Figure A.1. Earth/Moon sinusoidal elliptic orbit around the sun.

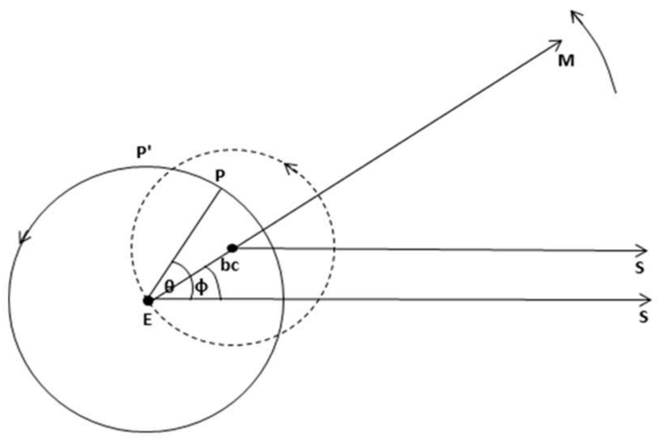


Figure A.2. Earth/Moon subsystem with Moon $\phi$ degrees into lunar cycle.

4) An effect due to the plane of the lunar orbit.
5) Acceleration due to the centrifugal effect of the Earth's rotation.
6) The Coriolis effect.
7) Cosmic anisotropic influence.
8) Centrifugal force due to Earth circling around Earth/Moon barycentre.
9) Centrifugal force due to Earth circling around Earth/Sun barycentre.
10) Tidal force due to land and sea tides changing Earth's spheroid shape.
11) True tidal force generated across geometry of pendulum bob.

Consider the Moon orbiting the Earth. This subsystem has a barycentre located at a distance ($R_{bc}$) of $4.667 \cdot 10^6$ m from the Earth's CG. Earth's centre rotates around the barycentre once every lunar month (assumed 27.5 day mean). Thus it is the barycentre, and not the Earth that follows a smooth elliptical orbit (dashed ellipse Fig. A.1) around the sun. The ellipse is essentially the free-fall path of the Earth/Moon subsystem's barycentre. Instead Earth's orbit around the Sun follows the solid sinusoidal line (Fig. A.1) whose mean is the ellipse while its own CG rotates around the barycentre.

Now determine the amplitude of the angular accelerations acting on the bob due to the gravitational influence in the respective directions of Moon and sun. Each of these attractive influences is considered in the following paragraphs.

*1) Lunar influence:* It is initially assumed there is no tilt of the Earth's axis so that it is perpendicular to the ecliptic. The effect of tilt will be shown later. The lunar influence is demonstrated in (Fig. A.2) which represents an observer's view of Earth from a position vertically above the plane of the ecliptic. Let the Earth's CG be at the point $E$. Let a radius to the point $P$ on the surface of the Earth make angle $\theta$ with the reference radial $ES$ joining Earth's CG and the sun. $ES$ is the distance between Earth's CG and the sun. Let $M_M$ be the mass of the moon, $EM$ the Earth/Moon distance and $R_E$ the radius of the Earth. Earth's rotation is anti-clockwise as is the moon's orbit in the figure. The dotted circle represents the path taken by Earth's CG around the Earth/Moon subsystem barycentre bc.

$\phi$ is the angle subtended at the centre of the Earth by the Sun and Moon in the ecliptic plane in plan view. $PM$ is the distance from point $P$ to the moon. $f_M$ is the tidal acceleration towards the moon. $PS$ is the distance from point $P$ to the sun. $f_S$ is the tidal acceleration towards the sun.

The reference position for the following discourse has point $P$ facing the Moon at 12 noon with maximum solar eclipse and is referenced to the plane of the ecliptic. Let $L$ be the latitude of point $P$. As the Earth and Moon are effectively orbiting each other each is in free fall relative to their barycentre so it is the delta difference between point $P$ and Earth's CG that is of interest. The distance of $P$ from the Moon is a minimum when $\theta$ and $\phi$ are both zero. This distance is given by equation (A.1) and the component of delta acceleration, $f_M$, towards the Moon is given by equation (A.2).

$$PM = EM - R_E \cos(L)\cos(\theta - \phi) \quad [\mathrm{m}] \qquad (\mathrm{A}.1)$$

$$f_M = -GM_M/PM^2 - GM_M/EM^2 \quad [\mathrm{m/s^2}] \qquad (\mathrm{A}.2)$$

Temporal changes in the orbital positions of the Moon are calculated in one second increments.

*2) Solar influence:* As before it is initially assumed there is no tilt of the Earth's axis so that it is perpendicular to the ecliptic. The effect of tilt will be shown later. As the barycentre of the Earth/Moon subsystem is in free fall around the Sun (Fig. A.1) there is no net acceleration at that point. The Earth's orbital distance to the Sun is modulated due to the Earth circling the Earth/Moon subsystem barycentre so this must be considered. It is necessary also to consider the acceleration delta due to the Sun at point $P$ on the surface of the Earth. Let $M_S$ be the mass of the sun, $ES$ the distance of Earth from Sun and $R_{BC}$ the radius of Earth's CG around the barycentre bc. The distance of $P$ from the Sun is given by equation (A.3)

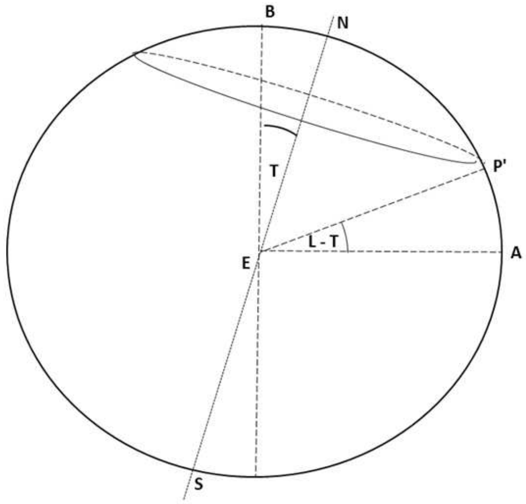


Figure A.3. Earth tilted with North towards the sun.

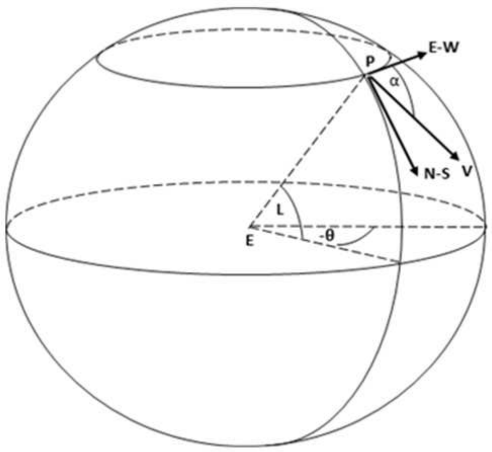


Figure A.4. Azimuth gravitational vectors.

where $bcS$ is the distance from the barycentre to the sun. The tidal delta component of acceleration, $f_S$, towards the Sun due to the sun's gravity is given by equation (A.4). These equations take into account the effect of the Earth/Moon subsystem barycentre.

$$PS = bcS + R_{BC}\cos(\phi) - R_E\cos(L)\cos(\theta) \quad [\text{m}] \quad (\text{A.3})$$

$$f_S = GM_S/PS^2 - GM_S/bcS^2 \quad [\text{m/s}^2] \quad (\text{A.4})$$

Temporal changes of Earth's daily rotation are calculated in one second increments.

*3) Tilt of Earth's axis:* Consider the construction given in Fig.A.3 showing the relative position of bob $P$ on the surface of the Earth as a result of positive tilt angle $T$ measured clockwise from the ecliptic North. The bob $P$ is now at the position $P'$ shown in Fig.A.3 with respect to the plane of the ecliptic. Let $BE$ extended be the original axis position when $T$ is zero.

Then angle $AEP'$ is equal to the angle of Latitude $L$ minus the angle of tilt $T$. The line $EB$ is the new Sun distance reference used to calculate tidal deltas in lieu of Earth's axis. Therefore equations (A.1) and (A.3) for the distance of $P$ to the Moon and Sun respectively become:

$$PM = EM - R_E\cos(L-T)\cos(\theta-\phi) \quad [\text{m}] \quad (\text{A.5})$$

$$PS = bcS + R_{BC}\cos(\phi) - R_E\cos(L-T)\cos(\theta) \quad [\text{m}] \quad (\text{A.6})$$

As the Earth orbits the Sun the effective Earth tilt angle reduces to zero and changes sign as the seasons pass. To accommodate this change of tilt angle it is only necessary to insert the current effective value for $T$ before calculating.

*4) Plane of Lunar Orbit:* The lunar orbit can be effectively inclined by up to $\pm$ 5.1 $^\circ$ to the ecliptic. To compensate for this a term $\beta$ for the lunar plane tilt must be added to the expression including $L$ and $T$ and in the same sense as $T$. The solar equations are not affected. Thus:

$$PM = EM - R_E\cos(L-T-\beta)\cos(\theta-\phi)\cos(\beta) \ [\text{m}] \ (\text{A.7})$$

$$PS = bcS + R_{BC}\cos(\phi)\cos(\beta) - R_E\cos(L-T)\cos(\theta) \ [\text{m}] \ (\text{A.8})$$

The value of $\beta$ can be anywhere from -5° to +5° dependant on the lunar orbital position with respect to the ecliptic. To accommodate this change of orbit inclination it is only necessary to insert the current effective value for $\beta$ before calculating.

*5) Earth's rotation:* The vertical component of the centrifugal acceleration due to Earth's rotation is assumed constant and is balanced by gravity. Thus there is no variable acceleration of the bob and ideally it moves to a position of equilibrium.

*6) Coriolis effect:* The Coriolis force is proportional to velocity. Since the Coriolis force is independent of the position of the Sun or the Moon then it cannot be related to the Allais effect. The Coriolis force is a permanent, cyclic feature, dependent only upon the speed of the pendulum bob. In the case of the static torsion balance there is no velocity therefore there can be no Coriolis force.

*7) Cosmic anisotropy:* Cosmic anisotropy is not simulated in this simple model as neither its magnitude nor direction is known. But its effect could be considered in a future model. Jupiter and Venus produce tidal effects several orders lower than the lunisolar effects, but these are too small to be of any significance.

*8) Earth/Moon barycentre:* Centrifugal force, acting at the centre of the Earth due to the Earth circling the barycentre of the Earth/Moon system, is equal and opposite to the gravitational pull of the Moon. Its effect is therefore cancelled and can be ignored.

*9) Earth/Sun barycentre:* Centrifugal force, acting at the centre of the Earth due to the Earth circling the barycentre of the Earth/Sun system, is equal and opposite to the gravitational pull of the Sun. Its effect is therefore cancelled and can be ignored.

*10) Earth's tidal spheroid shape:* Maximum tidal bulge at Earth's equator is 55cm. This is many orders of magnitude smaller than the radius of the Earth and would therefore be insignificant in terms of tidal effects.

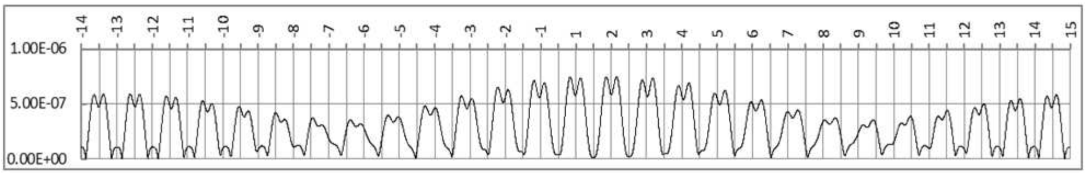


Figure A.5. Typical amplitude of resultant azimuth vector in m/s/s versus days.

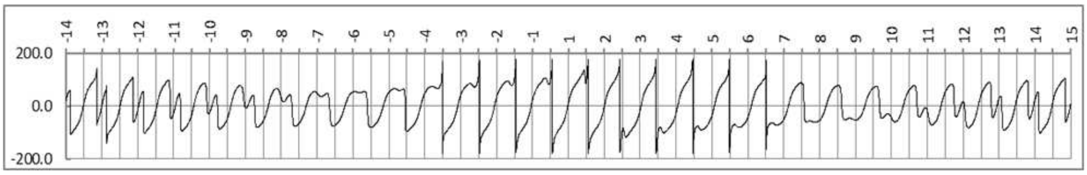


Figure A.6. Typical azimuth vector in degrees versus days.

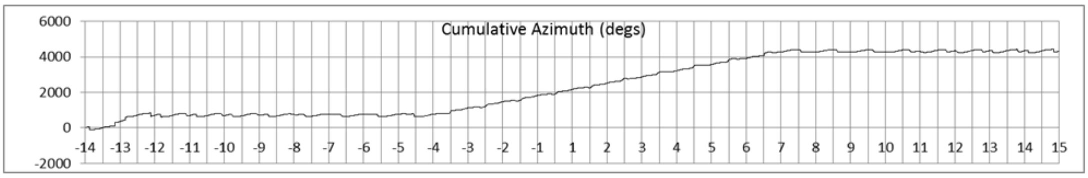


Figure A.7. Typical cumulative azimuth vector in degrees versus days.

*11) Tidal force across geometry of pendulum bob:* As Allais has shown in [1] the micro-tidal force across the extent of the pendulum swing are far too small to be the source of observed anomalies.

*12) Vector sum of component accelerations:* Up to this point it is only the tidal accelerations in the direction of extraterrestrial influencing bodies that have been considered. It is now necessary to determine horizontal and vertical accelerations by converting these tidal accelerations into $NS$ and $EW$ components. Each of the above accelerations are now resolved horizontally along a Parallel and vertically along a Meridian, see Fig. A.4 and equations (A.9) and (A.10).

$$\begin{aligned} V_{EW} = {} & f_M \sin(\theta - \phi)\cos(L)\cos(T+\beta)\cos(\beta) + \\ & + f_S \sin(\theta)\cos(L)\cos(T) \quad [\mathrm{m/s/s}] \qquad \text{(A.9)} \\ V_{NS} = {} & f_M \cos(\theta - \phi)[\sin(L) + \sin(T+\beta)]\cos(\beta) + \\ & + f_S \cos(\theta)[\sin(L) + \sin(T)] \quad [\mathrm{m/s/s}] \qquad \text{(A.10)} \end{aligned}$$

Once the two orthogonal vectors $E - W$ and $N - S$ have been calculated they can be summed by vector addition to determine the resultant amplitude $V$ and direction $\alpha$ of the delta gravitational field at bob $P$ as in equations (A.11) and (A.12).

$$V = \sqrt{V_{EW}^2 + V_{NS}^2} \qquad \text{(A.11)}$$

$$\alpha = \arctan(V_{NS}/V_{EW}) \qquad \text{(A.12)}$$

For the purpose of simplification an ideal situation is created whereby an eclipse of the Sun occurs in the middle of a 27.5 day period in order to illustrate the behaviour of the horizontal gravitational field. With suitable data for lunar and planetary positions extracted from Ephemeris tables the vectors for live situations can be calculated and compared with the results of practical experiments. The use of live parameters is a project for future study.

### B. Results

For the predicted test results Latitude 48.8°N, Earth tilt of -23.5° and lunar orbit inclination of -3.9° are used although these values can be altered. In Fig. A.5 the results are sampled at 3 minute intervals and give a typical example of horizontal gravitation vector amplitude.

In Fig. A.6 the results are sampled at 3 minute intervals and give a typical example of the horizontal gravitation vector azimuth.

In Fig. A.7 the results are sampled at 3 minute intervals and give a typical example of the horizontal gravitation vector cumulative azimuth.

The above model calculates the magnitude of the longitudinal, latitudinal and vertical gravitational fields caused by the influences of Sun and moon. It takes the longitudinal and latitudinal values and calculates the resultant azimuthal gravitational acceleration vector in magnitude and azimuthal angle. Directional changes are shown to be sometimes very rapid thus leading to synergistic effects.

### C. Conclusion to Appendix

From the results presented it is clear that the gravitational interactions produce significant and unexpected angular accelerations in the azimuthal rotation of a horizontal gravitational field. Thus a freely suspended object situated in an angularly accelerating rotating gravitational field must be subjected to angular acceleration as explained in the main body text. In this case the normal causal relationship, (torque producing angular acceleration) appears reversed so that the object experiences a pseudo-torque. This is akin to the way objects can experience centrifugal and Coriolis pseudo-forces.

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