Correlated anomalous effects observed during the August 1st 2008 solar eclipse

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***Abstract* — During the solar eclipse of 1 August 2008 three programs of physics observations were independently conducted by teams in Kiev, Ukraine, and Suceava, Romania, separated by about 440 km. The Ukraine team operated five independent miniature torsion balances, one Romania team operated two independent short ball-borne pendulums, and the other Romania team operated a long Foucault-type pendulum. All three teams detected unexplained disturbances, and these disturbances were mutually correlated. The overall pattern of the observations exhibits certain perplexing features.**

***Keywords* — solar, eclipse, physics, anomaly, pendulum, torsion, Allais, effect, gravity**

I. INTRODUCTION

There is a long history of experiments and observations aimed at investigating possible previously unknown physical effects during solar eclipses. The outstanding such investigation is undoubtedly the famous Eddington expedition of 1919 which confirmed the prediction by the new theory of general relativity of the double deviation past the Sun of light-rays.

Types of apparatus that have been used in more recent eclipse experiments include pendulums of various types such as long Foucault-type pendulums, ball-borne pendulums, stationary pendulums, horizontal pendulums and torsion pendulums, vertically and horizontally operating gravimeters, tilt-meters and long water levels, gyroscopes, and atomic clocks. Many clear negative results and a number of disputed positive results have been obtained, but no clear picture has emerged. The subject is an outstandingly difficult one for application of proper scientific methodology, in particular because the circumstances of every eclipse are different and thus no experiment can be effectively repeated.

A solar eclipse on 1 August 2008 passed across northern regions of Canada, Greenland, Russia, Mongolia, and China. On this occasion a group in Kiev, Ukraine (including the second author of this paper) and a group in Suceava, northern Romania (including the first and third authors) performed observations of various types. It is considered significant that, at the time, neither group had any knowledge whatever of the existence or the activities of the other. The general observational locations (at both of which the eclipse was shallow partial) were about 440 km apart. The group in Ukraine operated five miniature torsion balances, while the group in Romania operated two short ball-borne pendulums and one long Foucault-type pendulum.

We describe the three experiments individually, and then compare their results. All times are referred to UT, unless otherwise stated.

II. OBSERVATIONS IN KIEV, UKRAINE

A. Historical Review

The idea of using a torsion balance for observation of astronomical phenomena was suggested by Nikolai Kozyrev, the famous Russian astrophysicist [1]. In this reference he claimed that a torsion pendulum would respond to an eclipse, but did not cite any actual experimental work. Subsequently torsion pendulums of various types have been used in investigations during eclipses by Saxl and Allen [2], Luo Jun [3], and Kuusela [4, 5], with mixed but interesting results.

B. Structure of the Kiev Apparatus

Starting in 2006, the second author's team has conducted observations during solar and lunar eclipses using multiple asymmetrical torsion balances at the Main Astronomical Observatory of the Ukrainian Academy of Sciences in Kiev [6, 7].

The suspended unit of each of the torsion balances used in these experiments consists of a light wooden beam (referred to hereafter as the "pointer"), a small lead counterbalance, and a very thin suspension fiber (usually a natural silk thread about 30 μm in diameter). The total weight of this suspended unit is 0.5 g or less. The housing is made from glass plates 2 mm thick in the shape of a 24 x 24 x 18 cm box. The edges of this glass box are sealed from the inside with silicon sealant, and are covered from the outside with adhesive tape. In order to exclude electrostatic influences, this housing is completely surrounded by a reliably grounded (sometimes double) metal net of cell size 1~2 cm. The upper end of the suspension fiber is attached by adhesive to the center of the upper inner surface of the box,

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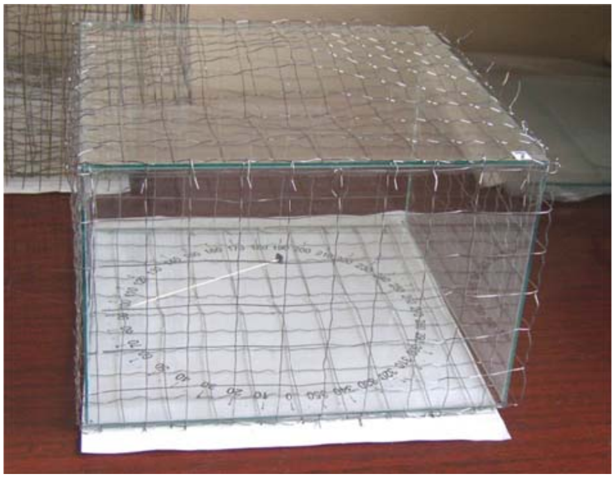

Fig. 1: One of the Kiev torsion balances

and a circular scale with 5° divisions is fixed to the bottom surface of the box. The device is oriented so that the scale zero is coincident with zero astronomical azimuth.

Fig. 1 shows one of our torsion balances. The balance beam asymmetry index (the ratio of the arm lengths L, x) is 1:26~29. When balanced, with m and M being the respective masses of the long and short arms, the condition m * L = M * x is satisfied.

The design of such a balance makes it insensitive to variations in gravitational potential and ensures that it is unaffected by gravitational (tidal) influences from any direction. This is particularly important at times of syzygy, when the combined gravitational effect from the Sun and Moon is maximal. The sealing of the housings rules out any possibility of interference due to air currents or humidity variations, and improves the thermal stabilization. The diamagnetic properties of the materials reduce significantly the influence of magnetic fields, although they do not eliminate them completely, while the small-cell grounded steel wire cages in which the housings are contained protect the balances from the action of static electricity. These grounded cages also serve as barriers against electromagnetic radiation with wavelength longer than 1 cm. The possibility of reaction to shorter-wavelength electromagnetic radiation is not considered.

C. Operation

Observations are performed with all the devices thermally stabilized. In particular, the balances are set up at the observational site at least one day before the beginning of measurements, in rooms with closed doors and windows. These precautions are taken in order to standardize the conditions of observation and minimize noise.

In the absence of any automatic registration system, the reading process is visual. In order to take readings, every 5 minutes, an observer enters the room where the devices are installed and approaches them for about 15-20 seconds, while he remains in a neighboring room at other times. The reading error does not exceed 3°. Other people, computers, electromechanical devices, metallic furniture, air conditioners, unnecessary illuminating lamps, and so on are rigorously excluded from the experimental chamber.

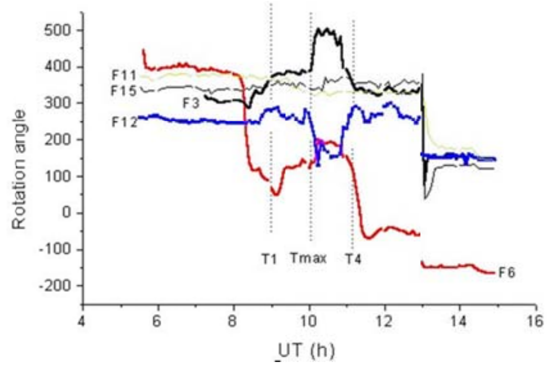

Fig. 2: Behavior during the solar eclipse

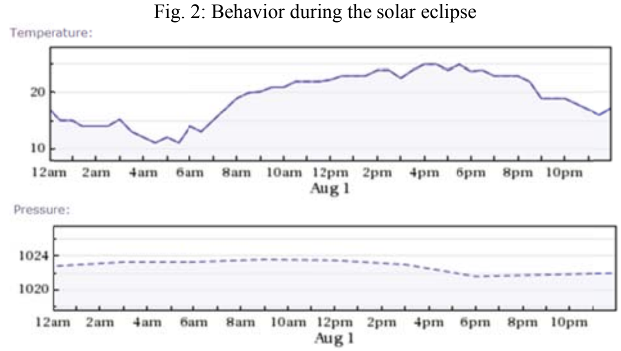

Fig. 3: Local meteorological conditions on eclipse day

D. Results

On 1 August 2008, the day of the solar eclipse which was partial at Kiev, observations began 4 hours prior to first contact and continued until 4 hours after fourth contact. Five independent torsion balances were operated. The experimental location was at 50°21'50.29" N, 30°29'48.02" E. Here (at the Main Astronomical Observatory in Kiev) the magnitude at the partial eclipse maximum was 0.38, the first contact T1 occurred at 09h 05m 14s, and the fourth contact T4 occurred at 11h 07m 03s.

Fig. 2 is a time chart of the recorded variations of the azimuths of the torsion balance pointers. F3, F6, F11, F12, and F15 are our device serial numbers.

Fig. 3 shows the temperature and pressure recorded in Kiev on the day of the eclipse in terms of local time (UT+3).

E. Analysis

During the first three hours of observations there were no variations that we interpret as meaningful, and all five devices behaved relatively quietly. But significant movements of the pointers of three of the devices (F3, F6, and F12) occurred between the first contact T1 and the fourth contact T4. Exactly, deviations began somewhat before T1 and ended a little after T4, and F6 was generally disturbed in the opposite direction to F3 and F12. For all these three devices, the disturbance pattern after Tmax (the moment of maximum eclipse) was significantly stronger than before Tmax. Approximately half an hour after T4 the behavior of all five devices became generally stable. However somewhat later, at 13.00±2.5 min (the resolution of the 5 minute observational cycle), the pointers of all the five devices all rotated abruptly in the same direction. These movements occurred simultaneously in terms of the temporal resolution of observation. It is clear from the calmness of the environmental data that variation of meteorological conditions was not responsible for this phenomenon.

F. Comments

This sharp disturbance suggests some abrupt new signal. It does not seem to have been provoked by any local factor, because the experimental environment remained exactly what it had been during the previous 8 hours of observations, and the observational procedure was exactly the same. We consider that this sudden jump was related to the solar eclipse, even though it occurred about 2 hours after fourth contact, because such drastic variations were quite absent during observations on other days, including times of New Moons when the angular distance between the Sun and Moon was only a few degrees. See, for example, [2]. At no other time have we ever observed such an abrupt deviation correlated over multiple devices. The fact that device F6 generally moved in the opposite direction to devices F3 and F12 appears strange, but over the period that we have been working with these miniature torsion balances we have often observed similar phenomena, for which we currently have no explanation.

III. Observations in Suceava, Romania

A. Historical Review

The "paraconical" or ball-borne pendulum is a solid or physical pendulum suspended upon a small ball which rolls upon a plane, and thus has three degrees of freedom: two orthogonal directions of oscillation, and rotation about the vertical axis. The behavior is very sensitive and rather complex. This type of pendulum was invented and built by Maurice Allais around 1950, and during the subsequent decade he used his apparatus to perform a number of marathon non-stop observational runs. On 30 June 1954 a solar eclipse took place which was partial at Paris, the experimental location. Prof. Allais reported an abrupt and unexplained deviation of the oscillation plane of his pendulum [8], occurring somewhat after the midpoint of the eclipse. And on 2 October 1959, the occasion of another solar eclipse partial at Paris (and of lower obscuration), he reported a similar but less pronounced deviation [9], [10].

Anomalies in the behavior of long Foucault-type pendulums during solar eclipses have been reported by Jeverdan [11], Popescu and Olenici [12], Mihaila [13-15], and Wuchterl [16] (but apparently later repudiated).

B. The Experiments

The first and third authors conducted coordinated pendulum experiments in Suceava, northern Romania on the occasion of the 1 August 2008 eclipse. The first author operated two short ball-borne pendulums of length about 1 m in two rooms separated by about 15 m, while the third author operated one conventional Foucault-type long pendulum of about 17 m at another location about 1.5 km away.

C. The Two Short Pendulums

Structure. The two short pendulums were almost identical in structure. A 1 meter solid rod extended down from an upper ring to a 12 kg horizontally oriented lenticular bob.

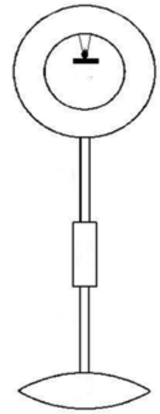

Fig. 4: Schematic pendulum structure

The ring was supported upon a very accurate spherical sintered tungsten carbide ball rolling upon a highly accurate hard steel flat. Fig. 4 shows this structure schematically.

For the pendulum of the automatic system, the three moments of inertia about the suspension point were calculated as $1184\ \mathrm{kg{\cdot}dm^2}$, $1182\ \mathrm{kg{\cdot}dm^2}$, and $8.13\ \mathrm{kg{\cdot}dm^2}$, while, for the pendulum of the manual system, the moments of inertia were approximately but not exactly the same, due to an angular adjustment device (termed a pendulo-torquator, see below) partway along the rod being somewhat different. However the in both cases the ratio between the horizontal oscillation moments (a crucial parameter for the pendulum behavior) was almost exactly the same, as also discussed below. One pendulum was mounted upon a very rigid aluminium tripod structure and was operated by an automatic system and observed automatically with laser rangefinders, while the other was mounted upon brick piers and was operated manually and observed manually. The automatic system was protected against air currents by a plastic shroud and also by being housed in a dedicated small room specially built within the Planetarium, while the manual system was housed in a very small windowless storage room having no ventilation, about 15 meters away from the automatic system. The two systems are shown in Figs. 5 and 6.

Fig. 5: The automatic system

Fig. 6: The manual system

Operation. Once every 12 minutes, each pendulum was released from a specific starting azimuth and was allowed to swing for 10 minutes, during which interval the initially rectilinear motion of the bob gradually became an elongated oval (as is normal) and precessed, while also the azimuth of the plane of the ring changed somewhat. Then the pendulum was stopped, and was released again after 2 minutes in the same starting azimuth. Thus each 10 minute swinging episode was independent, and their starting conditions were identical. For the automatic pendulum, the ring plane azimuth, the oval minor axis magnitude, and the oval major axis azimuth (precession angle) were recorded every 30 seconds; while, for the manual pendulum, at the end of the 10 minutes of swinging, only the precession angle was recorded (since the other parameters cannot effectively be determined by eye). An effort was made to set both the release azimuths to be the same at 135°-315°, but due to the labyrinthine nature of the Suceava Planetarium building, this attempt may regrettably not have been completely successful. We later determined that each of these initial azimuths may have been inaccurate by as much as ±10°, so that they may have differed by up to 20°. The periods of the pendulums were both about 1.84 seconds.

Results. The automatic pendulum was operated continuously for 114 hours spanning the eclipse. The experimental location (Suceava Planetarium) was at 47°38.51' N, 26°14.73' E. Here the magnitude at the partial eclipse maximum was 0.27, the first contact T1 occurred at 09h 12m 0s, and the fourth contact T4 occurred at 10h 58m 30s. Fig. 7 is a time chart showing the amounts of precession of the automatic pendulum after each swinging episode of 10 minutes, during this entire run. As usually is the case, the other recorded parameters (minor axis and ring angle) followed similar trends quite closely, and so they will not be discussed. This type of chart is quite typical of those we obtain when operating our pendulum. It is clear that the variations in behavior are not due to random noise, because the precession amounts in the supposedly independent swing episodes are clearly auto-correlated: the value obtained for each episode is very close to the one obtained for the apparently independent previous episode. The generally uniform trend of the chart must therefore be due to some

Fig. 7: Behavior of automatic pendulum over 5 days

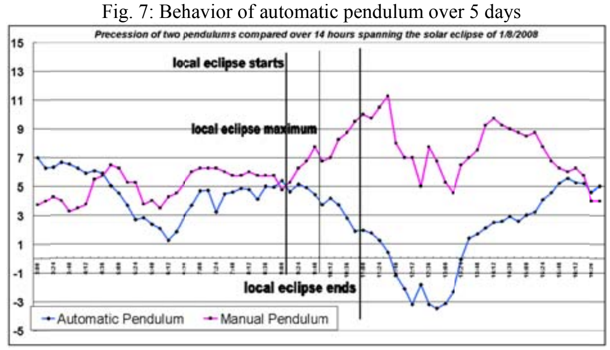

Fig. 8: Behavior of automatic and manual ball-borne pendulums during the eclipse compared

non-aleatory influence that varies on the time scale of hours; the nature of that interesting influence is still under investigation.

The manual pendulum was operated continuously for about 90 hours spanning the eclipse, but effects associated with operator changeover impel us only to consider the data for the 14 hours spanning the eclipse, which was recorded continuously by a single operator. Fig. 8 shows the behavior of both the manual pendulum and the automatic pendulum over this period. In this figure, for convenience of comparison, the precession readings of the manual pendulum have been adjusted by a scaling factor and an origin shift (see below). For the automatic pendulum, one unit on the vertical scale corresponds to 0.011 radians of precession, i.e. to 0.64°.

Fig. 9 shows the temperature and pressure recorded in Suceava on the day of the eclipse in terms of local time (UT+3).

Analysis. From Fig. 7 we see that about 24 hours before the eclipse the motion of the automatic pendulum became generally disturbed, and that this continued until well after the eclipse, when the pendulum again calmed down.

The detailed behavior of both pendulums over the eclipse period shown in Fig. 8 was remarkable. During the period before the eclipse no particular disturbance was detected, and the 10-minute precession amounts of both pendulums generally exhibited the same behavior. After the local eclipse maximum the precession amount of the automatic pendulum started to increase steadily, while that of the manual pendulum started to decrease steadily. This trend continued unabated until about forty minutes after fourth contact, when the sense of change of the precession of the manual pendulum changed to be the same as that of the automatic pendulum. After this both pendulum precession amounts marched together in almost perfect lockstep, decreasing until about 12:15, then executing an abrupt spike upwards and back downwards which ended at about 13:15, and then increasing until about 14:20, at which point the manual pendulum precession again reversed its trend. It is clear from the calmness of the environmental data that these phenomena were not linked to any variation of meteorological conditions.

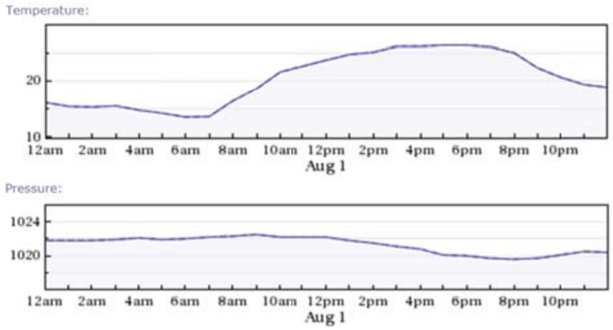

Fig. 9: Local meteorological conditions on eclipse day

Comments - the behavior after the eclipse. With the qualification of the above reversals in sign, the similarity between the post-eclipse disturbances of the two pendulums from about 11:30 to about 14:30 is very salient. In particular the sharp spikes at around 12:45 are identical, bearing in mind the low temporal resolution of the experimental method. It is difficult to believe that these coordinated deviations were coincidental.

Remarks upon non-identity of the pendulums. The fact that the two pendulums did not do the same thing at the same time must be faced. We had aimed at the ideal of constructing two identical pendulums, but did not completely succeed. The following factors are considered to have been involved:

(1) The masses and moments of inertia of the two pendulums were not the same, although they were close. (It is very difficult to build two pendulums that are absolutely identical.)

(2) The pendulum angular adjustments were almost certainly different.

(3) The initial release azimuths may have been somewhat different.

We do not think that (1) was an important factor. Although the masses and dimensions of the various components of the two pendulums were slightly different, these differences did not exceed 1% (except in the case of the pendulo-torquators) and were probably less. In particular a very important parameter for the movement of the ball-borne pendulum is the proportional difference between the moments of inertia around the two orthogonal horizontal axes through the suspension point, i.e. Allais's value $\beta = 2(M1-M2)/(M1+M2)$. In our design this value β is entirely determined by the shape and the mass of the ring, and was virtually the same for the two pendulums, since the rings were very accurately machined and weighed. (In the case of our pendulums, β=0.001828 almost exactly.)

(2) is a fundamental factor that has previously been overlooked in work with the ball-borne pendulum. Before release, the pendulum is held by a latch that engages with a small pin projecting from the rim of the lenticular bob. The exact angular position of this pin around the central axis of the pendulum rod, with respect to the angular position of the trihedral of inertia, therefore determines the "twist angle" of the initial swinging plane with respect to that trihedral: ideally this twist angle would be zero. The way in which the motion evolves from the moment of initial release is very sensitive to the twist angle. In our pendulum we accordingly provide an accurate rotational adjustment device at the approximate longitudinal center of the rod: the pendulo-torquator. By experiment we have found that adjustment of the pendulo-torquator by as little as 10' is sufficient to produce a noticeable difference in the time evolution of the pendulum motion as recorded by our high precision sensors. Since it is impossible in practice to set the twist angle to zero in the workshop to this level of accuracy, the only possible procedure is to perform repeated releases while adjusting the pendulo-torquator systematically, and to infer when the twist angle is zero by analysis of the motion. This was done for our automatic pendulum, but the pendulo-torquator we provided on the manual pendulum was improvised and was difficult to adjust accurately when the pendulum was mounted, so that we were compelled to set it beforehand on a jig. Therefore it cannot be guaranteed that both pendulums were identically adjusted in twist. We are fairly certain that this fact was responsible for the requirement to include the scaling factor and the origin shift in order to make the precession angles roughly comparable as in Fig. 8; but that crude linear compensation is purely ad hoc. Moreover, although the analysis is not complete, we consider that this matter may have been at the root of the reversals in the trend of the precession value for the manual pendulum, which may have represented one precession tendency overcoming an opposite tendency at a certain stage.

(3) Whether it is considered that an (undetermined) difference in the release azimuths could have been important must depend upon the model adopted for how a ball-borne pendulum might respond to an eclipse. As yet we have no such model, and therefore the importance of this factor must remain moot; but this introduces a further element of uncertainty, and provides another possible reason for why the two pendulums did not behave in the same way.

D. The Long Pendulum

Structure. A long pendulum of the Foucault type (the bob and alidade are shown in Fig. 10) was set up by the third author in a disused church tower having very solid walls more than 1.5 m thick, in Suceava town center at 47°38.77' N, 26°15.72' E. The suspension was a simple hook engaged in a cup. The length of the pendulum wire was about 17 meters, and the bob was a lenticular mass of about 8 kg, made of lead.


Fig. 10 - Foucault pendulum bob

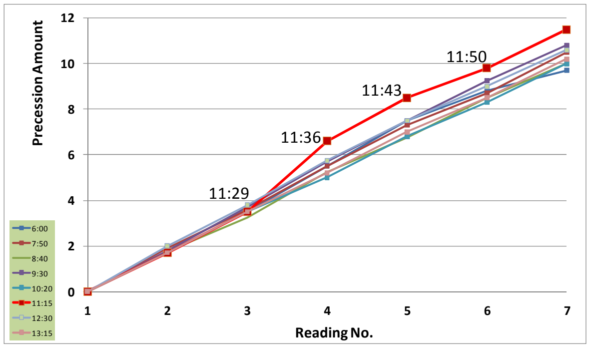

Fig. 11 - The Foucault pendulum behavior on eclipse day

Operation. The pendulum was released along a swing azimuth of 90° (i.e. E-W) approximately every 50 minutes in the conventional manner by burning a thread, and the azimuth of swing was recorded every 7 minutes, i.e. at release and at 7, 14, 21, 28, 35, and 42 minutes after release. The period was about 8.26 seconds.

Results. The observed changes of azimuth on the day of the solar eclipse are plotted in Fig. 11.

Analysis. This long Foucault-type pendulum behaved in a very stable manner, which is quite typical for long pendulums. However well after the end of the locally visible eclipse, at around 11:33 (to the recording resolution, i.e. between the readings at 11:29 and 11:36), some influence clearly acted for a short period to increase the precession rate. This influence no longer acted during the next interval between readings (from 11:36 to 11:43), and then reversed itself to some extent during the next interval (from 11:43 to 11:50).

Comments. This striking deviation during the episode starting at 11:15 is unexplained. Structurally it closely resembles Allais's 1954 observation (Refs. 8, 9, and 10): first an increase of the precession rate, then a plateau, and then a decrease back to the original trend. However it occurred after the end of the visible eclipse, whereas the deviation observed by Allais occurred during the eclipse.

IV. Comparison and Conclusions

Timings. First the details of the effect timings are considered with the temporal resolutions of the different types of apparatus borne in mind. The resolution for the Kiev balances was 5 minutes, due to the frequency of observation; the resolution for the Suceava short ball-borne pendulums was 12 minutes, due to the frequency of release; and the resolution for the Suceava long pendulum was 7 minutes, due to the frequency of observation.

Within the bounds of accuracy set by these resolutions, the moment when the five torsion balances in Kiev executed their abrupt movement was 13:00. The time span of the coordinated sharp spikes in the precessions of the Suceava short pendulums (where the fourth contact occurred 8.5 minutes earlier than in Kiev) was 12:15 to 13:15, mid-point 12:45. And the time span of the disturbance (to and fro) of the Suceava long pendulum was 11:29 to 11:50, mid-point 11:39. So all three devices cannot be said to have reacted simultaneously. It is noted that the largest-scale device (the long pendulum) was disturbed first, the medium-scale devices (the short pendulums) were disturbed substantially later, and the smallest-scale devices (the torsion balances) were disturbed a little later than that. When the relative temporal resolutions of all the devices are considered, the time between the disturbances of the Kiev torsion balances and the local fourth contact may have been substantially the same as the time between the spike disturbances of the Suceava short pendulums and the local fourth contact. However the same cannot be said for the Suceava long Foucault pendulum; it was definitely affected earlier than the short ball-borne pendulums were, if that is taken as being at approximately the mid-points of the build-ups of their hump-shaped deviations.

General. The outstanding feature of the results is that, although the types of apparatus used by our three independent teams were quite different, in all three cases, for each apparatus, the most outstanding peculiar effect was seen after the visible eclipse had ended. This was not the pattern that might be expected beforehand: a priori one might well suppose that, if any anomalous effect were to be observed, it would occur during the visible eclipse, when (from the point of view of the experimental apparatus) the body of the Moon partly covers the Sun and might conceivably intercept any influence progressing linearly from the body of the Sun. Of course, a third possibility is that an anomalous effect might be observed before the visible eclipse starts, and actually that feature was part of the patterns seen during independent and mutually 'blind' gravimeter experiments performed by Wang, Mishra, and Duval, [17] - [20].

Even if the five devices in Kiev are considered as not having been operating independently and the two short ball-borne pendulums in Suceava Planetarium are considered as not having been operating independently, still, three completely independent experiments were conducted in three separated locations, and the result of each was that the most significant deviation occurred substantially after the visible eclipse. If the observed deviations of all three sets of equipment were random events due to faulty equipment or poor operation and thus were not attributable to any common external factor, then the chances of such a coordinated outcome are rather low. This conclusion holds irrespective of the acknowledged deficiencies of our experimental apparatus. Moreover, it is our opinion that the contention that the two short pendulums in the Planetarium were both responding to a common local environmental influence is not really tenable, and in this case the number of independent experiments becomes four, so the conclusion becomes much stronger. If the existence of a common local disturbing environmental influence to the five devices in Kiev is also excluded - and no such influence is apparent - then the chance against the overall outcome having been accidental becomes enormous.

Given the above, the authors consider that it is an inescapable conclusion from our experiments that after the end of the visible eclipse, as the Moon departed the angular vicinity of the Sun, some influence exerted itself upon the Eastern European region containing our three sets of equipment, extending over a field at least hundreds of kilometers in width.

The nature of this common influence is unknown, but plainly it cannot be considered as gravitational in the usually accepted sense of Newtonian or Einsteinian gravitation. The basic reason is that in those models the gravitational influences of several bodies are combined by addition, at least to the accuracy detectable by molar equipment. However all three of our experiments exhibited rather brusque variations (the abrupt jumps of the Kiev balances, the humps and particularly the sharp spikes in the Suceava short pendulum charts, and the deviation of the Suceava long pendulum) which cannot have resulted from linear combination of the gravitational/tidal influences of the Sun and the Moon, the magnitudes and angles of which vary only gently over the time scales of the effects seen. We therefore are compelled to the opinion that some currently unknown physical influence was at work.

V. NOTE UPON ERRORS

The possibility of systematic error in the results should be considered.

It is the opinion of the authors that errors due to meteorological conditions such as temperature and pressure may be conclusively excluded. Variation of the Earth's magnetic field was not monitored, but seem unlikely to have affected the results.

We think that the torsion balance results are the most likely to have been affected by aleatory local conditions, although stringent precautions were taken to exclude such a possibility.

The readings of the two short pendulums over time usually exhibit auto-correlated deviations of which the origin is not clear. Clearing up this question is a major objective of future research. However the disturbances around the time of the eclipse were significantly larger than these wanderings.

The data from the long Foucault-type pendulum appears to us to be the most reliable. Several control experiments were made with the same apparatus on other days, but nothing like the variation on eclipse day as shown by the red line in Fig. 11 was ever seen. In general it is thought that the stability and repeatability of the motion of a pendulum is proportional to the square of its length, and many thousands of observations of long Foucault pendulums by hundreds of experimenters have verified the predictability and stability of their motion. For this reason we have no hesitation in asserting that the deviation shown in Fig. 11 is a genuine external disturbance of unknown origin, and absolutely cannot be ascribed to experimental error.

The authors will be happy to make their raw data available to interested parties.

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