Experimental verification of electromagnetic-gravity effect: Weighing light and heat

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Abstract: Gravity, the distant force interaction of mass, is an elementary part of physics. Current physics does not have any proof of gravitylike interaction between electromagnetic radiation and mass based on controlled experiments. The results presented here could be interpreted as proof of the existence of gravitylike interaction between electromagnetic radiation and mass. They suggest a notion of the indicative value of the "electromagnetic-gravity" constant. The effect manifests itself over a wide spectrum of electromagnetic radiation wavelengths, from infrared to visible. The constant has a surprisingly large value. The "gravity" effect of 1 W of electromagnetic radiation is comparable to the gravity effect of 15 kg of mass. The dependence of the interaction presented here on the wavelength of electromagnetic radiation was not observed. © *2017 Physics Essays Publication*. [http://dx.doi.org/10.4006/0836-1398-30.2.138]

Résumé: La gravité, qui est la force d'interaction à distance entre les masses, représente une partie élémentaire de la physique. La physique actuelle ne possède aucune preuve d'une interaction de type gravitationnel entre le rayonnement électromagnétique et la masse sur la base d'expériences contrôlées. Les résultats présentés ici pourraient être interprétés comme la preuve de l'existence d'une interaction de type gravitationnel entre le rayonnement électromagnétique et la masse. Ils suggèrent une notion de valeur indicative de la constante "électromagnétique-gravitationnelle". Cet effet se manifeste sur un spectre étendu de longueurs d'ondes de rayonnement électromagnétique allant de l'infrarouge au visible. Cette constante a une valeur étonnamment élevée. L'effet "gravitationnel" d'un rayonnement électromagnétique de 1 W est comparable à l'effet gravitationnel d'une masse de 15 kg. La dépendance présentée ici entre l'interaction et le rayonnement électromagnétique n'a pas été observée.

Key words: Gravity Interaction; Experimental Verification; Weighing Light; Weighing Heat; Cavendish Experiment; Electromagnetic Interaction; Controlled Experiment.

I. INTRODUCTION

Coupling between gravity and electromagnetism has been an open question of physics for centuries. The idea of the gravity influence on light was formulated by John Michell in 1783.[b)] Einstein's Mass-Energy equivalence[c)] enables one to calculate the effective mass of a photon, and the gravity interaction between a body with mass and a photon. The calculation shows that the effect is too small to be easily observed. Deflection of light by the Sun[d)] is supposed to be one of very basic proofs of the general theory of relativity.

However, current physics does not have any proof of coupling between gravity and electromagnetism based on a controlled experiment. Experimental work described in this paper is not based on physical thoughts or hypothesis. The work has been motivated by the effort to identify unexpected measurement anomalies.

The anomalies have been recognized during static pendulum measurements in various locations on the earth's surface.[1,2] These measurements have been executed for many years. The apparatus measures the relatively slow change of the local gravity field, together with deformation of its environment. Attempts to explain the anomalies by well-known physical effects have failed. The measured anomalies can be described by the following features:

- Horizontal displacement of the static pendulum weight is greater than 40 μrad (i.e., about 400 μm s^{-2}, or 40 mGal). This is more than 300 times greater than that can be caused by a theoretical tide acceleration in the horizontal plane.
- The basic observed time period is 24.00 h. Spectral analysis shows significant features at 12.00, 8.00, and 6.00 h. No significant Moon-related spectral lines have been observed.
- The measured displacements have annual periodicity, with maximal displacements measured close to the summer solstice and minimal ones close to the winter solstice (apparatus position 50°N, 15°E).
- The measured displacement amplitude is not stable. There is significant correlation between sunshine in the pendulum

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b)Wikipedia, 2016, "John Michell," 2016, available at: https://en.wikipedia.org/wiki/John_Michell
c)Wikipedia, 2016, "Mass–energy equivalence," 2016, available at: https://en.wikipedia.org/wiki/Mass%E2%80%93energy_equivalence
d)Wikipedia, 2016, "Deflection of light by the Sun," 2016, available at: https://en.wikipedia.org/wiki/Tests_of_general_relativity#Deflection_of_light_by_the_Sun

environment and the measured displacement amplitude. (The pendulum is placed in a closed dark space.)

- Simultaneously measured displacements of several pendulums placed in the same building, but on different floors above each other, or on the same floor but in different places, are significantly different.
- The pendulum reaction time to the change in sunshine outside the building is fast (several minutes). It does not show any correspondence with thermo-mechanical features of the building where the pendulum was placed.
- The average displacement amplitude was decreased by a factor of two after weatherproofing of the building where measurements had been executed for more than 15 years. A change in reaction time to the change in sunshine was not observed (7–10 cm thick thermal isolation was used for weatherproofing).
- The effect was not observed using static pendulums placed deep underground.

More details can be found in Refs. 1 and 2. Several attempts to design controlled experiments related to the measured anomaly have failed, although the idea to use a modified classical Cavendish experiment[e)] was successful. After several improvements and modifications of the apparatus, very surprising results have been observed.

II. MEASUREMENT APPARATUS

The measurement apparatus is a modification of the well-known Cavendish experiment, referred to as "weighing the earth." The test masses (fixed, large balls) were replaced with chambers containing electromagnetic radiation sources. The positioning of the large balls in the Cavendish experiment was replicated by switching the sources on and off—see Fig. 1.

A torsion balance is made from electromagnetically neutral materials to decrease disruptive electromagnetic effects like electrostatic, magnetic effects, and electromagnetic induction. The weights are concrete bricks (dimensions 240 × 115 × 71 mm, weight 3.75 kg). The balance rod is made from wood, and brass screws are used to connect the weights to it. The distance between the weight axes is 1 m. The balance wire is 1.9 m long. The torsion balance weights and rod were placed in an isolating box, which is used to decrease the influence of the surrounding air. Three different hang wires were used, see Table I for details.

The torsion balance position was observed using a scanning web camera focused on the contrast pattern on the weight. The evaluating program calculated the weight position by parametric transformation of the pattern image movement in two axes (x and y). The results in pixels were converted to distance, with conversion coefficients determined by geometrical calibration. The scanning camera sensitivity was 0.071–0.082 mm/pixel, depending on the distance of the camera from the weight. All experiments were performed in a closed room without windows, and without the presence of any person during the experiment.

[e)]Wikipedia, 2016, "Cavendish experiment," 2016, available at: https://en.wikipedia.org/wiki/Cavendish_experiment

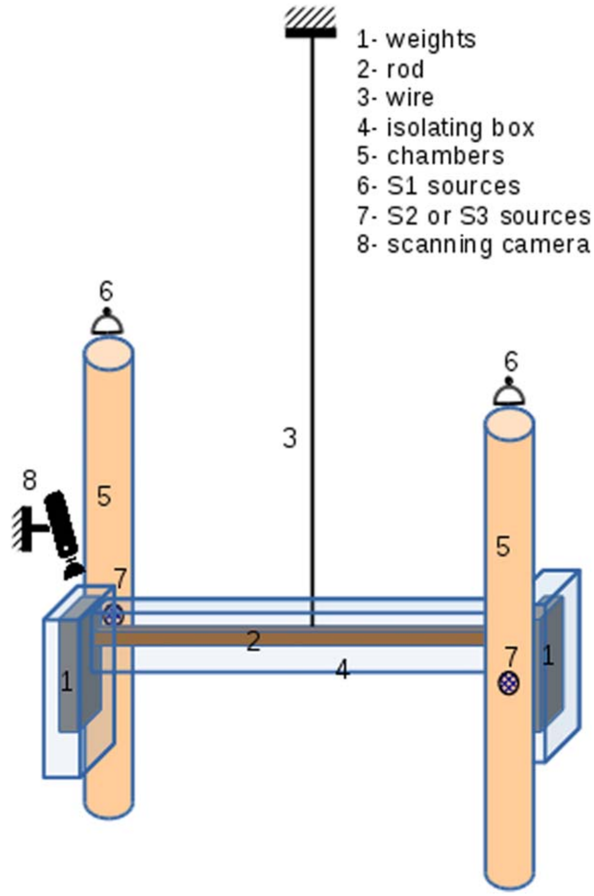

FIG. 1. (Color online) Measurement apparatus schematic apparatus.

Three different electromagnetic radiation sources were used, and three different chambers, in all combinations. All sources were powered by controlled stabilized direct current (DC) power sources.

- Source S1 is the light source. It uses a power LED [15 W—CREE MK-R H4 6000 K (Ref. 3)] with optical lens focusing of the beam into the chamber.
- Source S2 is an approximation of a hot blackbody source. It uses a halogen bulb (12 V, 20 W) placed in the center of the chamber.
- Source S3 is an approximation of a cool or half-heated blackbody. It uses a power resistor placed on a cooler with small thermal resistance. It is placed in the center of the chamber.

Verification measurements, using an alternating current (AC) power source (classical 230 V bulbs), were also taken.

The chamber is cylindrical with diameter 13 or 10 cm, and length 1 m.

- The surface of chamber one, CH1, is made from polyvinyl chloride (PVC) with internal sides and both ends covered with a mirror transparency. The upper end contains the hole enabling light to be input from S1 source lens, or S2 or S3 sources when hanging.
- The surface of chamber two, CH2, is made from PVC, with internal sides covered by triple thermal isolating bubble foil with reflective film.
- Chamber three, CH3, is made from zinc coated iron plate.

TABLE I. Parameters of the torsion balances used.

Torsion balance	TB1	TB2	TB3
Wire material/diameter (mm)	Iron binding wire/0.6	Stainless wire/0.5	Steel string/0.3
Natural oscillation period (s)	327	552	1384
Sensitivity (N/mm)	346×10^{-9}	122×10^{-9}	19.3×10^{-9}
Resolution (N)	24.6×10^{-9}	8.65×10^{-9}	1.37×10^{-9}

A. Experiment implementation

The experimental implementation is similar to the classical Cavendish experiment. The arm position was recorded every 10 or 6 s. Recording was started an adequate time before the first switching on, and finished an adequate time after the last switch off, of the source, in each experiment run. The experiment run took several hours, usually a whole day. Two computers were used for experiment control and for recording of measured quantities. The control computer switched the sources on and off at planned times, and the events were recorded in a log. The measurement computer captured the images of the contrast pattern placed on the weight. The images were transformed online by parametric transformation into position changes and written to another log. The same computer recorded the measured temperature to a third log. The experiment logs were used for results evaluation.

The power supply of the electromagnetic radiation sources was switched on and off according to different time patterns.

- T1—long source activity (two or four hours). Direct analogy with the Cavendish experiment.
- T2—one isolated synchronous impulse T/2 (one half of the balance natural oscillation period)
- T3—synchronous excitation. Repeated periodic switching on and off with frequency equal to the balance natural oscillation period (with total time period two or four hours). A digital phase-locked loop with constant phase was used in some experiments.

The relative position of chambers and weights were changed according to the following scheme:

- P1—chamber position equal to the position of the bigger ball in the Cavendish experiment. The evaluation algorithm calibration gives positive results if the weight is moved in the direction of the chamber.
- P2—chamber moved in the balance arm direction
- P3—chamber position opposite to P1.

Different values of the power source current were used in different experiment runs. The other experiment parameters were the same. The device enabled six different values of stabilized power supply current.

B. Measurement accuracy

The measurement apparatus is relatively simple. Measurement accuracy is negatively influenced by several disruptive effects (see Sec. V for details).

The distance between the chamber and the weight is reproducible to about 15 mm when the distance between center of the chamber and center of the weight is about 17 cm. It is the main reason why the measurement accuracy cannot be better than about $+/-25\%$. In addition, no attempt was made to account for secondary thermal radiation from surrounding objects.

III. RESULTS

The measured balance position difference was so big in the case of the most sensitive torsion balance TB3 and maximal power of the source S2 ($P = 12.2$ W) that the weight of the balance hit against the isolating box. The change of the weight position was possible to be observed without any device; it was nearly 3 cm. The measured results with snapshots taken by a standard camera are shown in Fig. 2.

The sources were switched on and off by the control computer at planned time points. The measured position difference of the weight was always delayed after switching of the sources. The position difference and the delays were reproducible. The observed delay time is dependent on several factors: the natural oscillation period of the balance, the power supplied as a function of time, the chamber used, the source, and the supply power value. The switch on and off time delays were not equal, and lay in the range 5–55 min. The experiments were executed in 10 months, with more than 270 experiment runs and over 500 experiments. An example of the measured time dependence of the position difference of the weight, together with the source power supply time dependence, is shown in Fig. 3.

The result is dependent on the phase difference between the source power supply and the measured weight position if a synchronous phase-locked loop power source is used, see Fig. 4.

A. Spatial dependence

The dependence of the torsion balance displacement on the position of the chamber containing the source was measured by placing the chambers in three different positions (P1–P3).

- P1 position: positive displacements were recorded in all cases when the source was switched on, and negative displacements when the source was switched off.
- P3 position: negative displacements were recorded in all cases when the source was switched on, and positive displacements when the source was switched off.
- P2 position: positive and negative displacements were recorded, with magnitude less than 20% of the absolute

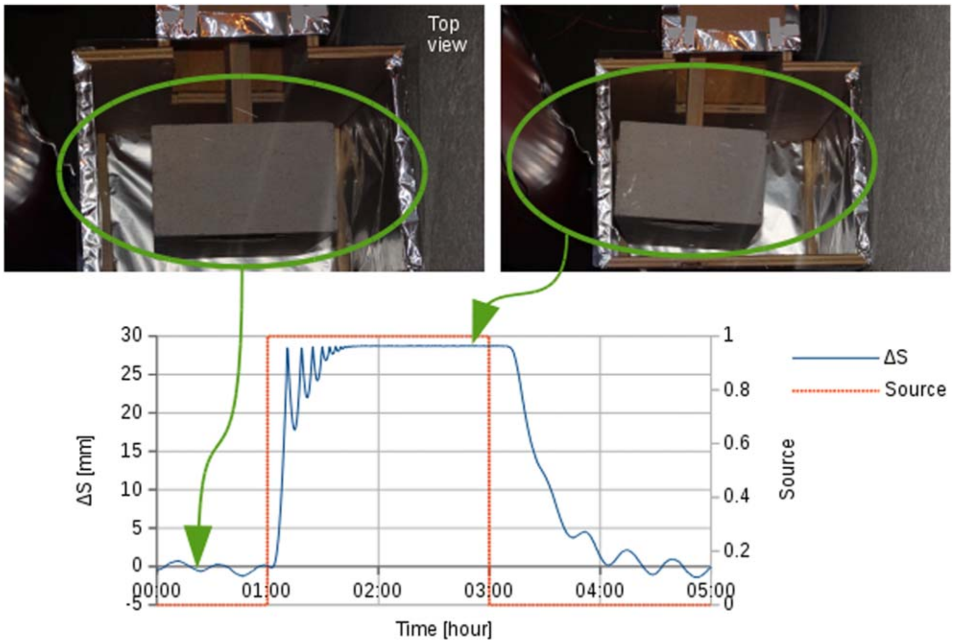

FIG. 2. (Color online) Top: snapshots of the weight positions; Bottom: large measured balance position difference record. ΔS is the measured torsion balance weight displacement.

value measured in the cases of P1 and P3 under the same experimental conditions.

The dependence of the displacement of the balance on the distance between the chamber and the weight was not measured (except for experiments described in Sec. III F).

B. Power dependence

The dependence of the balance displacement on the power of electromagnetic radiation was verified in all combinations of the chambers and sources. More detailed measurements, with more values of input power (five or six input currents values), were executed with all sources and all chambers in various combinations with one source and one chamber. Figure 5 displays the measured results.

The radiation power, P, in Fig. 5 is equal to the input electrical power in the cases of source S2 and S3. P was estimated as the total emitted light power using the LED manufacturer's data sheet (Ref. 3) for source S1.

C. Balance sensitivity dependence

The Cavendish balance displacement is proportional to the second power of the natural oscillation period[4]

$$\Delta S = K \times T^2 \times m, \quad (1)$$

where ΔS is the measured balance displacement, T is the natural oscillation period of the balance, constant K includes geometrical parameters of the balance, balance weights, and gravity constant, and m is the test (large) weight mass.

The results recorded for three torsion balances TB1, TB2, and TB3, with three different sensitivities, using source S2 (input power 3.5–12 W) in chamber CH1, together with the approximation of Eq. (1), are displayed in Fig. 6.

D. Mass dependence

Modified torsion balances were used to verify the dependence of the measured displacement on the mass. Brick pairs

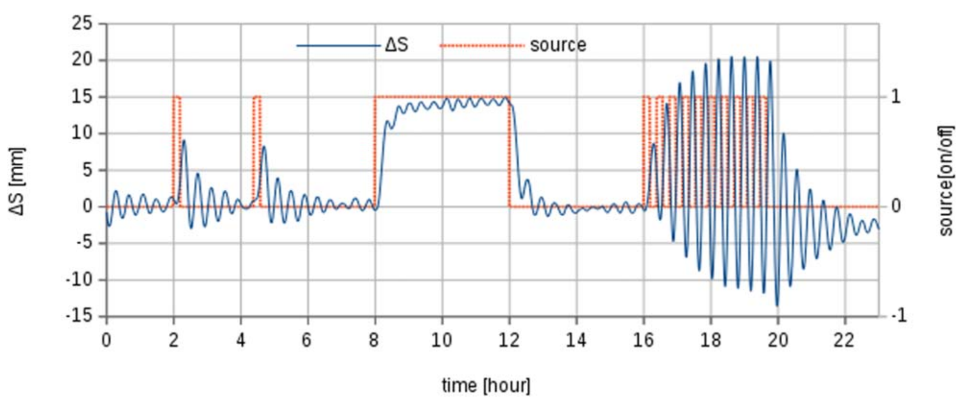

FIG. 3. (Color online) Example of measured time dependence of the weight displacement and the source power supply. Torsion balance TB3 was used. As before, ΔS is the measured torsion balance weight displacement.

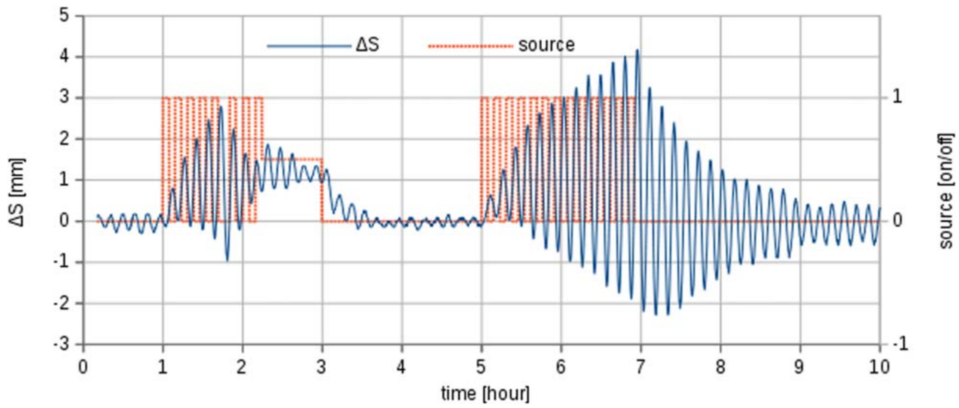

FIG. 4. (Color online) Example of measured time dependence if a synchronous phase locked source is used. Phase difference 180° (time interval on plot 1:45–2:15 h), and 0° (5:45–7:00 h). Torsion balance TB2. ΔS is the measured torsion balance weight displacement.

were placed on both ends of the balance rod, i.e., a doubled mass was used. The additional brick can be removed. The double brick weight is 7.5 kg. Experiment pairs were executed including double and single brick weights, while the other parameters were the same. Other suspensions have to be used instead of the experiments described above due to lack of strength in the rod.

Table II shows the torsion balance parameters when two bricks were used (7.5 kg), and shows those when only one brick was used (3.75 kg).

Measured displacements were 3.3 to six times greater in cases where the double mass was used compared to those obtained with the single mass, all other parameters equal. More than 40 experiments were executed.

E. Source type and chamber type

The measured results show the dependence of the balance displacement time profile on the source and chamber type. They can be interpreted as follows: the thermal isolation of the chamber and the thermal capacity of the source increase the delay of the balance response to the change of the source power supply, and decrease the balance natural oscillation amplitude. Figure 7 shows very different displacement time dependences in experiments using different types of sources and chambers with respect to time-thermal parameters.

F. Negative verification

Negative experiments were executed to verify a causal dependence of the measured balance displacement and the radiation source. In an experiment with source S1, a nontransparent screen was placed directly under the lens. The light beam from the source was blocked at the top of the chamber. In experiments with sources S2 and S3, the sources were placed at the top of the chamber, in the same position as S1 in Fig. 1 (position 6). The distance and direction between the source and the weight were changed in this case. All remaining parameters were unchanged. Using S1, the measured displacement was smaller than 20% of that measured under the same conditions without the screen. With sources S2 and S3, the negative experiment displacement was smaller than 3% of the displacement under the same conditions as when the source was in the center of the chamber (position 7 in Fig. 1).

Experiments without any switched-on source were executed as well. No significant displacements were measured apart from small random movements (less than 3% when compared to sources switched on).

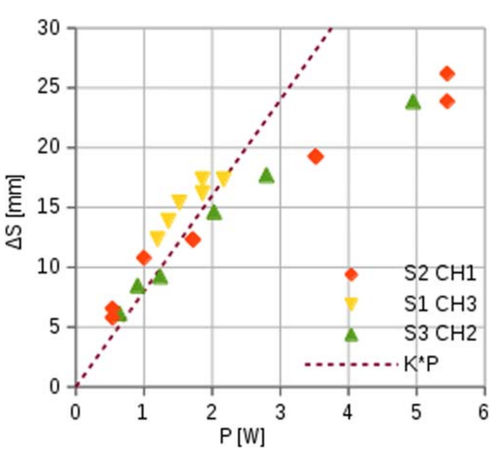

FIG. 5. (Color online) Dependence of the balance displacement on the source power using torsion balance TB3. ΔS: measured torsion balance weight displacement; P: radiation power; K: constant.

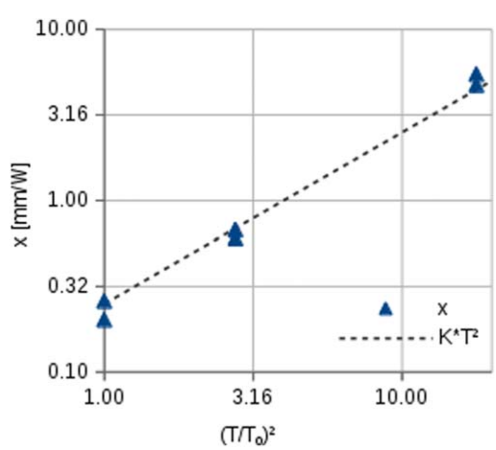

FIG. 6. (Color online) Dependence of measured displacement on the torsion balance sensitivity. x: relative measured torsion balance weight displacement; T: torsion balance natural oscillation period; T_0: reference torsion balance natural oscillation period; K: approximation constant.

TABLE II. Parameters of torsion balances used for double weight mass and parameters of torsion balances used for single weight mass.

Double weight mass torsion balance	TB4	TB5	TB6	TB7
Suspension material /dimension (mm)	PE binding strip /11.5 x 0.75	Iron binding wire /0.8	PVC knitted cord /2.5	Steel string /0.5
Natural oscillation period (s)	371	252	428	763
Sensitivity (N/mm)	540×10^{-9}	1170×10^{-9}	406×10^{-9}	128×10^{-9}
Resolution (N)	38.3×10^{-9}	83.1×10^{-9}	28.8×10^{-9}	9.1×10^{-9}
Single weight mass torsion balance	**TB4**	**TB5**	**TB6**	**TB7**
Suspension material/dimension (mm)	PE binding strip /11.5 x 0.75	Iron binding wire /0.8	PVC knitted cord /2.5	Steel string /0.5
Natural oscillation period (s)	307	165	316	503
Sensitivity (N/mm)	394×10^{-9}	1360×10^{-9}	372×10^{-9}	147×10^{-9}
Resolution (N)	28.0×10^{-9}	96.1×10^{-9}	26.4×10^{-9}	10.4×10^{-9}

G. Reproducibility

The experiments were executed over 10 months, with more than 270 experiment runs including over 500 individual experiments. Except for negative verifications, described above, P2 space dependence experiments, and six apparatus failures, all experiments showed torsion balance displacement with magnitude, direction, and time related to stimulation of the source. It was no situation when the source was on and the weight was not moved. No displacement occurs if no source is on except small periodical displacements with random amplitude and phase (see Sec. V F).

IV. SUPPLEMENTARY EXPERIMENT

Other measurements were executed and can be interpreted as demonstrating the same effect. Some of them are described in Sec. I. They are not controlled experiments, but can have additional value if they are analyzed alongside the controlled experiments described above.

A. Solar eclipse

The static pendulum[1] measurement during a partial solar eclipse with cloudless weather shows anomalies compared with the same situation and no eclipse. The anomaly happened exactly in the time when the shadow of the Moon traversed the place of measurement. The pendulum was placed in a closed room without windows about 20 m above the surrounding terrain (Fig. 8).

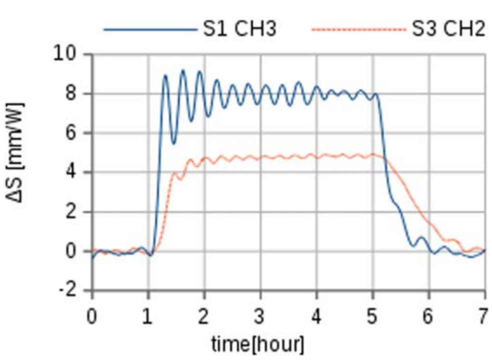

FIG. 7. (Color online) Displacement time dependence comparison of S1 source and CH3 chamber with S3 source and CH2 chamber. ΔS: measured torsion balance weight displacement.

The value of the experiment can be seen because a different measurement apparatus was used, the source change was caused outside the earth, and the observation was made before the controlled experiments were executed.

V. DISCUSSION

The basic question of how to interpret the experimental result is, what is the causal dependence between a controlled input physical phenomenon and the torsion balance response? A large number of experiments were performed including phase locked source control. All experiments, with adequate sensitivity, gave verifiable and controllable results for the time dependence of the torsion balance displacement on the source input power. It is therefore possible to conclude that the torsion balance motion is caused by the source input power.

The second question concerns the physical effect that causes the torsion balance deviation. This issue is discussed in the following text. It is possible to formulate the hypothesis that it is caused by a gravitylike interaction of electromagnetic radiation with the mass. This hypothesis is supported by the following realities:

- It is a remote force interaction with the mass. It arises from the experiment implementation, from measured time dependences, and from balance deviation dependence on the balance sensitivity.
- The interaction is directly proportional to the electromagnetic radiation power. The measured results show that increasing the source power gives greater torsion balance deviation. It is possible to use a linear approximation of the dependence. However, it is not possible to exclude another kind of directly proportional dependence, namely, results of experiments where higher input power was used.
- The interaction is caused by electromagnetic radiation in the infrared and visible part of the spectrum. The measured results show comparable reaction of the torsion balance when thermal radiation was used (S3), when thermal and visible light were used (S2), and when visible light was used (S1). The wavelength ratio was 1:20 over the course of the experiment.
- The measured balance deviation is directly proportional to the weight of the test mass of the torsion balance. The measured results show greater displacement (i.e., force) if greater mass of the test weight is used, and all other

experimental parameters are unchanged. It is not possible to exclude a linear approximation of the dependence, and it is not possible to exclude any other kind of directly proportional dependence.

- The displacement direction corresponds to an attractive force; the radiating source attracts the weight.
- Independent controlled experiment results, see Ref. 5.

The following text discuses known effects that could be the cause of the measured displacement. Direct impacts could be due to mechanical force, or force caused by the air in the isolating box. However, the electromagnetic force could cause a remote force interaction as well.

A. Mechanical force

All torsion balance parts are separated from surrounding objects by air gaps. The only mechanical contact is the wire suspension, which is strongly fixed to the concrete ceiling. The suspension is not connected with any chamber or source and the distance is greater than 0.5 m. Negative experiments and space dependence measurements do not modify the suspension. The screen installation and repositioning of the chamber or source do not modify the suspension, but the measured displacements were changed significantly.

B. Air in the isolating box

The heated air in the gap between the weight and the isolating box can cause the weight displacement as it expands, due to thermal effects and increases in volume. The heating occurs between the chamber and the weight, while the cooling is on the opposite side of the weight. The heated air concentrates at the top of the isolating box. The air expansion is at the heated site, the compression at the cooled site. The air heating effect can cause an opposite displacement to the measured one.

The thermal expandability[f)] of air is 3.7×10^{-3} °C^{-1}. The temperature difference measured between the chamber and the isolating box was 4 °C in the experiment with maximum displacement (Fig. 2). The air temperature difference in the gap cannot be greater. (The indicative measurement of the air temperature change in the isolating box between the chamber and the weight shows about a three times smaller temperature difference.)

The thermal air volume change cannot cause weight displacements greater than 0.45 mm (0.15 mm). The weight displacement caused by thermal expansion of the air cannot be as big as measured and cannot be permanent, because air can move freely and compensate for pressure changes. The measured displacement is opposite and about 80 times (240 times) greater then theoretical maximum of the heated air effect.

The measured dependence of the displacement on the torsion balance sensitivity (Fig. 6) shows that the displacement is related to the torsion coefficient of the wire, i.e., to the second order of the balance natural oscillation period,

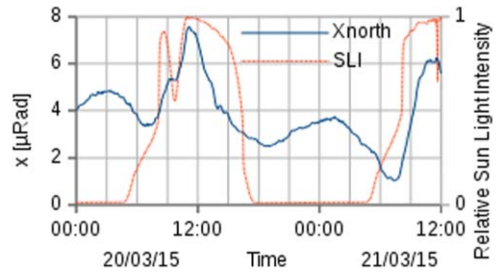

FIG. 8. (Color online) Static pendulum measured results during a partial solar eclipse. Xnorth: the North-South direction of pendulum angular displacement; SLI: Solar Light Intensity.

over a great range of displacements. The force causing the balance displacement is not significantly dependent on the displacement of the weight.

An extreme and stabilized long-term displacement (Fig. 2) exists if the air gap between the weight and the isolating box is very thin. The thin heated air cannot attract the weight for more than one hour. The air behavior in the isolating box could be dynamic. It is a complex task to analyze that dynamic behavior and exclude all different options by calculation.

The wide spectrum of dynamic parameters used in different experiments can answer the question. The natural oscillation period range of the torsion balances used was greater than 4:1. The switch-on time period of the source ranged from less than three minutes to four hours. A synchronous phase-locked source was also used with different phase offsets. No dynamic behavior with constant time parameters was observed in the whole set of experiments.

One can ask if some unknown mechanical force, caused by heated air in the isolating box, can cause the measured displacement. The experiment was not executed in a vacuum, so a Black box analysis[g)] is used to discuss this option. The input and output signal comparison (without knowledge of the physical mechanism) is the key point of the analysis. The measured time dependence of the temperature between the chamber and the isolating box is used as input in the analysis. The measured time dependence of the weight displacement is used as output. The question is, can the output be caused by the input? To simplify reading of the measured quantities relative values are used. The references are measured values in an experiment with long source activity T1.

Figure 9(a) shows the situation at the beginning of the long source activity. The measured time dependence of the weight displacement can be approximated by a time constant $\tau s = 360$ s with no delay. The measured time dependence of the temperature between the chamber and the isolating box can be approximated by a time constant $\tau t = 630$ s, and start delay $d = 240$ s. The indicative measurement of the time dependence of temperature in the isolating box (between the chamber and the weight) gives time constant $\tau t = 750$ s and start delay $d = 240$ s. The conclusion is: the temperature change is significantly delayed from the weight displacement change.

[f)]Wikipedia, 2016, "The air thermal expandability," 2016, available at: http://www.engineeringtoolbox.com/air-properties-d_156.html

[g)]Wikipedia, 2016, "Black box analysis," 2016, available at: https://en.wikipedia.org/wiki/Black_box

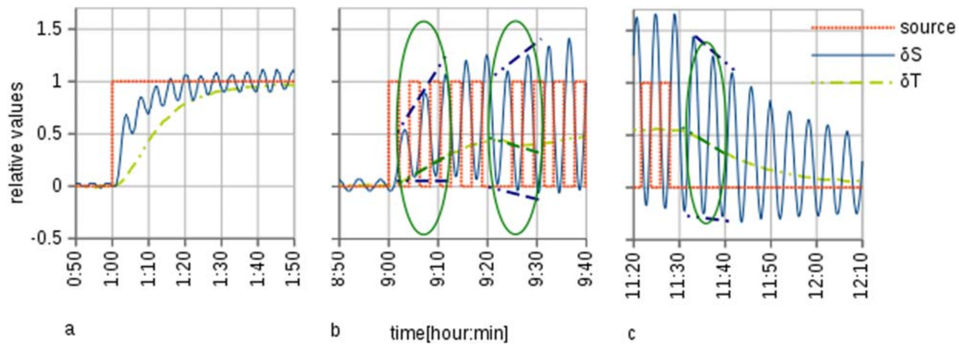

FIG. 9. (Color online) (a) Measured time relationship between balance displacement and temperature change at the beginning of long source activity T1; (b) measured time relationship between balance displacement and temperature change at the beginning of phase-locked stimulation; (c) measured time relationship between balance displacement and temperature change at the end of phase-locked stimulation. δS: relative displacement of the balance; δT: relative change of temperature measured between the chamber and isolating box.

The experiment with a phase-locked source misses nearly one impulse when the phase-lock is started [Fig. 9(b)]. The measured results show two situations (ellipses) where dependency of the balance displacements are similar, but the temperature change is in opposite directions.

The end of periodic stimulation [Fig. 9(c)] shows another situation, where the time dependence of the temperature is similar to the situation when the pulse is missing [Fig. 9(b)] but the weight displacement is in the opposite direction.

These situations exclude the possibility that the air temperature change between the chamber and the weight can cause the measured weight displacement. However, a causal dependence between the source radiation and the weight displacement is not excluded. Note: the influence of the heated air on the measured results was not excluded. For example, the decrease in measured displacement caused by heated air in the isolating box should be taken into account for more accurate measurements.

C. Electrostatic force

The isolating box implementation, aluminium foil placed on both sides and on the bottom of the isolating box, guarantees the same electric potential on both isolating box sides. Together with medium weight resistance (no isolator, no conductor) it ensures the impossibility of any displacement caused by Coulomb forces.[h)] The Coulomb force in a capacitor is proportional to the voltage between the electrodes. The power supply voltage is nearly constant in the case of S1 source (LED) usage due to p-n junction diode nonlinearity.[i)] The measured torsion balance displacements for different supply currents were different, approximately proportional to the source current, i.e., the light power in this case, see Sec. III B.

D. Magnetic force

A magnetic (static) force exists only between magnetized materials, which can be excluded in this work, see Sec. II. The measured displacement is time dependent showing a reliable dependence on the source stimulation (electric power supply), see Sec. III G. Magnetic force is directly proportional to the source current (Ampere's force law[j)]). However, the measured dependence of the balance displacement on the power supply current for source S2 (the bulb) shows an approximate quadratic dependence. When the resistor in source S3 was replaced by another of different value, the torsion balance measured displacement changed approximately in proportion to the resistance ratio when the same supply current was used. An additional experiment using bulbs supplied by an alternative current source (50 Hz) was executed. The measured weight displacement corresponded well with source switching on and off in this case as well.

E. Electromagnetic induction

Most experiments used a DC supply, and took place for several hours. The weight material is not a conductor. The supply cable circuit area is small and oriented in different directions. The cable position was also changed over the course of the experiments. The induced voltage is directly proportional to the time derivative profile of the source current (Faraday law of induction[k)]). The time dependence of the measured displacement does not correspond to the supply current time derivative (e.g., see Fig. 2). The measured delays of torsion balance response, its variance, and dependence on heat features of the source and chamber, are not compatible with any of the hypotheses of electromagnetic interaction described above. We conclude that all kinds of remote electromagnetic interaction can be excluded.

F. Disruptive effects

The experiment implementation was simple, and the hypothesis was not known at the experiment design time. With respect to the formulated hypothesis, the measured results were influenced by secondary electromagnetic emission of heated surrounding objects. This includes the

h)Wikipedia, 2016, "Coulomb's law," 2016, available at: https://en.wikipedia.org/wiki/Coulomb%27s_law

i)Wikipedia, 2016, "V-I characteristics of p-n junction diode," 2016, available at: http://www.physics-and-radio-electronics.com/electronic-devices-and-circuits/semiconductor-diodes/vicharacteristicsofdiode.html

j)Wikipedia, 2016, "Ampere's force law," 2016, available at: https://en.wikipedia.org/wiki/Amp%C3%A8re%27s_force_law

k)Wikipedia, 2016, "Faraday law of induction," 2016, available at: https://en.wikipedia.org/wiki/Faraday%27s_law_of_induction chambers, the isolating box, and the walls close to the balance. The secondary emission was caused by thermal conductivity, thermal absorption, and thermal radiation of the primary and secondary sources, and their combination.

The interaction of the torsion balance with the surrounding air was another disruptive effect. It causes random swings of the rod, especially for the high sensitivity balance. The swing exists even if all sources are switched off, or if no source is close to the balance. This disruptive swing was significantly decreased by placing the balance inside the isolating box and by closing any holes in it.

The isolating box also has an influence on the measured displacement of the weight. It is not limited to knocking of the weight against the isolating box alone. The significant influence was recognized in experiments with synchronous source stimulation and higher movement amplitude. It could be explained by physical features of the air inside the isolating box. This influence was decreased by opening the holes in the isolating box. However, that increases random swings of the balance.

Measured displacements do not correspond exactly with the hypothesis that the displacement has a linear dependence on the power of electromagnetic radiation. The measured displacement is probably negatively influenced by measurement errors, namely, limited space inside the isolating box, the influence of air, secondary radiation, and nonlinear features of the balance. These nonlinear features were experimentally verified in the case of the TB2 balance. The measured decrease in the natural oscillation period of the balance for large periodic displacements was about 15% (i.e., about 80 s).

g. Weight mass dependency

Measurement results show that the force depends on the body mass, and grows with increasing mass. Measured results give a dependence which is greater than linear, but it is too early to make a more exact conclusion.

h. Photon wavelength dependency

Photon energy is directly proportional to photon frequency.[l)] The photon spectrum of sources used in this work ranges in energy by a factor of 20 (measured by frequency of the black-body spectrum maximum[m)]). S3 source temperature was 27 °C, i.e., 300 K for minimum input power used in the experiments. The manufacturer's data sheet[3] gives the equivalent temperature of S1 source as 6000 K. The measured results do not show any significant dependence of the weight displacement on the photon wavelength.

i. The difficulty of recognition

One can ask why the effect was not recognized, measured, and documented if the force interaction is comparable to the Newton gravity interaction. Recognition of an effect and separation from other effects in real nature is not a simple task. For example, building deformation as a result of heating by the Sun is well known, and the 24 h period is a well-known "disruptive" effect in underground tide measurements. To distinguish the deformation of mass caused by thermal expansion from that caused by an electromagnetic-gravity effect, in the real environment with complex geometry and heterogeneous materials, is a very complex task. This is especially so if the existence and features of the electromagnetic-gravity effect are not known. The time-correlated anomalies measured by static pendulums[1] were observed more than 10 years ago. The existence and time correlation with the Sun's radiation were identified from measured results many times in different locations, including measured gravity field inhomogeneities. However, reliably distinguishing between the physical effect with unknown features, and known deformation effects, in a complex environment, has failed many times. Backward reconstruction of the unknown hypothetical cause is a difficult task.

Independent controlled experiments were executed showing the interaction between light and mass.[5] However, a quantitative estimation of the effect was not made and the thermal effect was not recognized.

A volcano eruption is still a physically unpredictable event. One can formulate a hypothesis that the eruption can be significantly influenced by the effect described in this paper (electromagnetic-gravity interaction). The magma, with increasing temperature, should increase the force attracting the surrounding mass in to the magma chamber. The increased pressure will increase the magma temperature, etc. What distinguishes Newton's gravity from the electromagnetic-gravity effect of large masses (Earth, the Sun) remains an open question.

j. Relativistic mass

The force interaction between mass and light based on Newton's corpuscular theory of light was formulated by John Michell.[n)] The opposite effect (force interaction of light on mass) can be calculated from the mass-energy equivalence equation.[o)] This section deals with a quantitative evaluation of this idea and comparison with the experiment results.

The relativistic effective mass of a photon can be calculated by the well-known mass-energy equivalence

$$E = m \times c^2. \quad (2)$$

If a simplified situation is considered, where that effective photon mass interacts with weight only in an area of diameter r, we can give an approximate equation for the total interacting effective mass of all photons emitted by the source

$$m = P \times r/c^3, \quad (3)$$

where m is the total effective mass of all photons in a sphere of diameter r, P is the source emitting power, and c is the speed of light. The calculation for $r = 1\text{m}$ gives $m = 3 \times 10^{-26}\text{kgW}^{-1}$. The value is not comparable with

l)Wikipedia, 2016, "Photon energy," 2016, available at: https://en.wikipedia.org/wiki/Photon_energy

m)Wikipedia, 2016, "Black-body radiation," 2016, available at: https://en.wikipedia.org/wiki/Black-body_radiation

n)Wikipedia, 2016, "John Michell," 2016, available at: https://en.wikipedia.org/wiki/John_Michell

o)Wikipedia, 2016, "Mass–energy equivalence," 2016, available at: https://en.wikipedia.org/wiki/Mass%E2%80%93energy_equivalence measured results. It is possible to argue that secondary emission caused by the emitted photons should also be taken into account. This secondary emission cannot be described exactly by a universal equation. The total mass of all emitted photons during the whole experiment duration T can be used as a maximum value estimate for the photon effective mass gravity effect

$$m_{\max} = P \times T/c^2. \tag{4}$$

Here, $m_{\max}$ is the total effective photon mass emitted during the whole experiment duration, P is the source power, T is the total emission time interval, and c is the speed of light. The calculation for $T = 4\mathrm{h}$ gives $m_{\max} = 1.6 \times 10^{-13}\mathrm{kgW}^{-1}$. Again, this number is not comparable with measured results. It can be concluded that the measured effect cannot be caused by the relativistic effective mass of photons.

k. Terminology notes

Gravity is the term used to name the local or distant force interaction between two or more mass bodies. Weighing is the term used for measurement of the gravity force between a mass and the earth. Electromagnetism deals with distant electrostatic and magnetic forces and with electromagnetic waves. The photon is the elementary unit of electromagnetic wave energy. Light is the term usually used to describe the visible part of the electromagnetic spectrum. This paper deals with the distant force interaction between electromagnetic energy and a mass body. How are we to name the described effect? How can we explain the subject of the paper in a more popular way?

The title uses the term electromagnetic-gravity effect to describe the topic of the paper; the distant interaction between electromagnetic energy and mass bodies. The second part of the title tries to metaphorically describe the subject of the paper, and also to show which part of the electromagnetic spectrum the paper discusses. Other options exist to name the subject of the paper such as semigravity effect, thermo-gravity effect, and photo-gravity effect.

VI. CONCLUSION

The main conclusion of this work is that the controlled experiment produces positive reproducible results of the force interaction between an electromagnetic radiation source and a torsion balance weight. Sources with different wavelengths, output powers, constructions, and time profiles have been used. Seven different torsion balances with different parameters were used. The experimental results obtained could be interpreted as proof of an unknown effect, the distant force interaction between electromagnetic radiation and a mass.

Using the inspiration of Newton's gravity law, it is possible to formulate a hypothesis that this force is given by

$$F = G_{em} \times P \times m/r^2, \tag{5}$$

where F is the force, G_{em} is the electromagnetic-gravity constant, P is the electromagnetic radiation power, m is mass, and r is the distance between the source of radiation and the mass. The measured results give an average value for the electromagnetic-gravity constant of $G_{em} = 1.0 \times 10^{-9} \pm 2.5 \times 10^{-10}\mathrm{m}^3\mathrm{W}^{-1}\mathrm{s}^{-2}$ using Eq. (5).

Comparing the measured electromagnetic-gravity constant with the Newton gravity constant gives the following result: the interaction of 1 W of electromagnetic radiation with the test mass body is nearly equal to the gravity interaction of 15 kg of mass. It is a significantly stronger interaction than Newton's gravity effect when considering the effective mass of emitted photons (about 10^{14} greater value than the total effective mass of photons emitted during the experiment).

Another, perhaps surprising, result is the gravity interaction of a thermal source. It can be explained by the well-known blackbody radiation law.[p)] The thermal radiation is an integral part of the described effect and cannot be eliminated from experiments. A dependence of the gravity interaction on electromagnetic wavelength was not observed. It should be noted that the quantitative values given here are preliminary or indicative due to the simplified experimental implementation and limited suppression of disruptive effects.

Several important questions remain open. Increased accuracy of the measurement apparatus should probe the dependence of the force on the source power, mass value, and distance. There are also open questions relating to how the time dependence of force is changed by materials used and their locations in space, mass material dependence, and other material dependences like absorption and reflection. It is not known if the effect is dependent on position on the earth's surface or not. Future independent experiments should answer these questions.

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[1]L. Neumann, Phys. Essays **20**, 535 (2007).
[2]L. Neumann and P. Kalenda, *Proceeding of 5th International Symposium on In-Situ Rock Stress, Beijing, China*, 25–27 August 2010 (CRC Press/Balkema, Leiden, The Netherlands, 2010), p. 255.
[3]Cree Inc., "Cree® XLamp® MK-R LEDs," Data Sheet CLD-DS60 Rev 8B (Cree Inc., Durham, NC, 2017).
[4]Pasco, "Gravitational Torsion Balance AP-8215A," Instruction Manual with Experiment Guide and Teachers' Notes 012-11032C (Pasco Scientific, Roseville, CA, 2005).
[5]L. Rancourt, Phys. Essays **24**, 557 (2011).

[p)]Wikipedia, 2016, "Black-body radiation," 2016, available at: https://en.wikipedia.org/wiki/Black-body_radiation