Should the Laws of Gravitation Be Reconsidered?

Part I—Abnormalities in the Motion of a Paraconical Pendulum on an Anisotropic Support

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Whenever a physical theory is revised or transformed, it is revealed that, nearly always, the observation of one or several facts which could not fit within the framework of the theory in its then current form is at the base of the changes. The facts always remain the keystone on which the stability of any theory is dependent, no matter how important it may be.

For a theoretician really worthy of the name, it may be said in passing that nothing could be more interesting than a fact which runs counter to a theory until then held to be sound; for him, the real work begins at that point.

Max Planck[1]

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THE MOTIONS of a pendulum, suspended on a ball and resting on an anisotropic support, have statistically significant amplitude and periodic components of periods approaching 24 and 25 hours.

The installation and the experimental technique are briefly described. The observed motions result from four conjugate effects: the Foucault effect, an effect of the suspension release, the aleatory influence of balls, and, finally, a periodic influence.

The observed periodic structure cannot be considered as due to the disturbances of an aleatory order. Neither can it be considered as produced by an indirect influence of known factors (temperature, pressure, magnetism, etc.). Finally, it cannot be identified with periodic lunisolar effects resulting from the actual theory of gravitation.

A remarkable disturbance has also been observed at the time of the total solar eclipse—June 30, 1954.

At this stage of the discussion, the observed effects must be considered as produced by the direct action of a new field.

Findings

From 1953 to 1957, I carried out various experimental research projects on the motion of a pendulum resting *on an anisotropic support* S″ through a steel ball, this anisotropic support being characterized by very small differences in its elasticity as measured in two rectangular planes.[2]

Even though various types of pendulum were used in succession, I shall limit myself to a brief description of the arrangements used and the results obtained during the series of continuous observations which were run for 30 days in June and July of 1955.

Description of the Pendulum

The paraconical pendulum used was an asymmetrical one, consisting of a vertical bronze disc weighing 7.5 kg., attached to a bronze rod hung from a bronze stirrup E resting on a steel ball 6.5 mm. in diameter, free to roll in any direction on a horizontal plane surface S.

The latter was itself on a hollowed-out circular support S′, made of aluminum, with an extension A, 4.5 cm. thick. This design (hollowed-out part) made it possible for the pendulum to rotate while in motion, over a total angle of 210 centesimal deg. This circular support S′ finally rested on three micrometric screws V. The pendulum rod and its stirrup weighed 4.5 kg. so that the total weight of the pendulum was 12 kg. and the length of the equivalent elementary pendulum approximately 83 cm.

The steel balls in use were high-precision SKF balls, with bearing surfaces of tungsten carbide and cobalt.

The experiments were conducted in a basement, and the center of gravity of the pendulum was moving at a level of approximately 1.50 m. below the surface of the natural ground. Support S″ was bolted to a beam, pressed against the ceiling by a set of beams.

The pendulum and hanging device are shown in Figs. 1 to 4.

[1] *Initiation to Physics*, French transl., page 40; Flammarion, Paris.

[2] My findings and the investigations to which they gave rise are dealt with in six notes of the Academy of Sciences: C.R.A.S., 245, 1697; C.R.A.S., 245, 1875; C.R.A.S., 245, 2001; C.R.A.S., 244, 2469; C.R.A.S., 245, 2467; C.R.A.S., 245, 2170. The reader may refer to these for useful data which cannot be quoted here for lack of space. The object of the present paper is to reveal only the general philosophy of the results achieved. It is but an abstract of a general report which will be published shortly.

In Part I we propose to review, in an extremely cursory manner

(a) the abnormalities observed in the motion of a paraconical pendulum (pendulum hanging from a steel ball) on an anisotropic support.

(b) the manner in which they should be interpreted, according to the present status of our information and discussions.

In Part II (to be published in the October issue), we shall point out the relationship that these abnormalities appear to have with the irregularities or abnormalities noted when investigating a number of phenomena in the realms of mechanics, optics, and electromagnetism.

Experimental Process

The pendulum was released from a resting position every 20 min., using an initial amplitude of about 0.11 radian, by the burning of a thread. Its motion was then observed for about 14 min. by aiming at a needle attached to its lower extremity.

Generally speaking, the point so observed generated a curve comparable to a flattened ellipse, the plane of the major axis of which was observed with an aiming system placed on a circle C centered on the axis of the pendulum as defined at rest, and equipped with a scale graduated in centesimal degrees and a vernier. This system made it possible to determine the azimuth of the plane of oscillation with a precision of about 0.1 centesimal deg.

After 14 min., the pendulum was stopped, and it was again released in the plane of the last observed azimuth. Thus the successive series of observations were *connected*, with releases every 20 min., day and night, so that each 24-hour period was made up of 72 series of connected azimuth observations.

In order to rule out any systematic effect, the steel ball which carried the pendulum was changed after *each experiment*, every 20 min., and surface S was changed at the beginning of each week of observations.

A curve showing the azimuths observed from June 7 to 12, 1955, is given in Fig. 5. Each point represents the release azimuth corresponding to each series of 14-min. observations, equal to the azimuth of the plane of oscillation established after 14 min. in the above experiment.

Anisotropy of the Support

Since support S″ was characterized by a very *small* difference in its elasticity values in two rectangular planes, the mean position of the plane of oscillation tended, under this influence, to locate itself parallel to the plane of greatest elasticity of the support indicated by vector $\overrightarrow{PQ}$ in Figs. 1 and 3, the azimuth of which was approximately 171 centesimal deg., measuring azimuths from the south in the direct sense. Here again, *the overall tendency was to generate ellipses* when the pendulum was released in a plane other than $\overrightarrow{PQ}$. These influences were determined more accurately by releasing experiments in various azimuths, in eliminating the influence of the epoch with a random choice of the release azimuths.

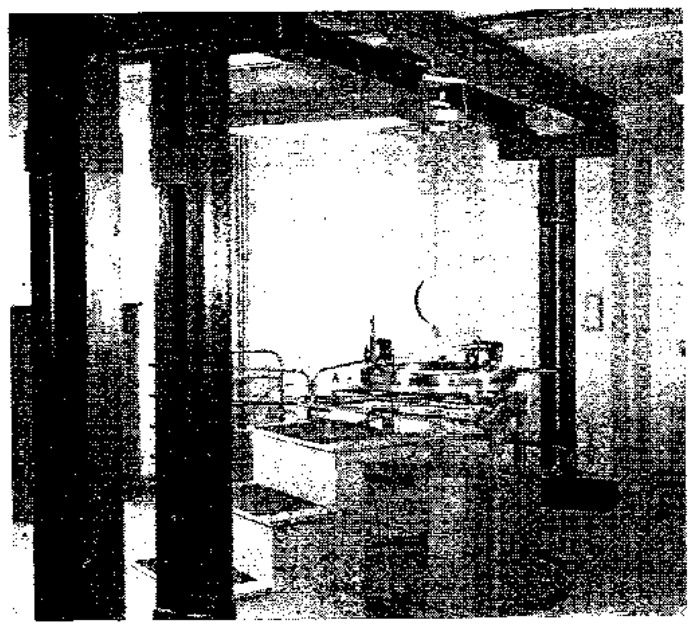

Fig. 1. General view.

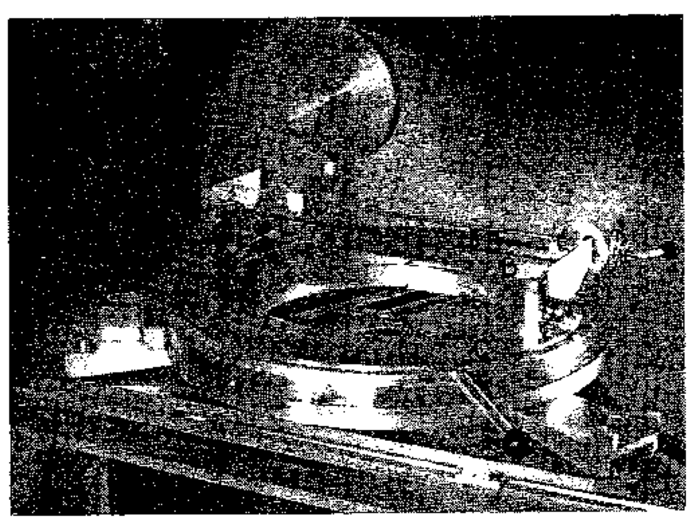

Fig. 2. Measuring circle.

Observed Phenomena

During a continuous series of observations, however, the oscillating plane had not evinced any tendency to settle in the vicinity of direction PQ, as might have been expected—allowing for the Foucault effect—and the variation of the azimuth as a function of time was found to be an oscillation which appeared to be very irregular, at least at first glance, about the mean direction PQ′. The deviations observed over a given 24-hour period were very large; azimuth variations occasionally reached and exceeded 100 centesimal deg. The mean observed azimuth P′Q′, as a matter of fact, was 150 centesimal deg. on June-July, 1955, less than the azimuth of PQ by 22 centesimal deg.

It is noteworthy that the tangent to the start of the mean of the various curves that correspond to the 2160 series of 14-min. elementary observations making up the monthly series for June–July, 1955, is an accurate representation of the Foucault effect.

Factors Influencing the Motion

In the *present* condition of my information, it may be assumed that the observed azimuth movements are the result of four conjugated effects: the Foucault effect, a "return" effect due to the suspension, the random influence of the spherical ball, and, finally, a periodic effect.

This periodic effect, which constitutes the very striking aspect of the phenomenon reviewed, was revealed, in the time series made up of the azimuths observed over a given period, by a number of techniques of harmonic analysis, the results of which were in remarkable agreement: Buys-Ballot filter, adjustment to a given group of waves by the Darwin or the least square method, periodogram, and correlogram.

Fig. 6 shows the adjustment graph obtained by the application of the Buys-Ballot method to the June–July, 1955, series for the 25-hour wave.

Defining Σ as the typical deviation of the time series made up of the values of the azimuths observed and R as the radius of the wave which corresponds to the analysis made with a Buys-Ballot filter, we give (in Table 1) the results obtained for the series of observations of June–July, 1955:

Order of Magnitude of Effects Noted

The azimuth rates which correspond to the amplitudes of the two major periodic components revealed in the June–July, 1955, series—the periods of which are close, respectively, to 24 and 25 hours—are each of an order of magnitude equal to one-tenth of the Foucault effect. However, the disturbing influences noted are, on an average and as a whole, about twice the Foucault effect.

Table 1.

Σ	$2R$ 24^H	$2R$ 25^H	R_{25H}/R_{24H}	R/Σ 24^H	R/Σ 25^H
19.99	11.66	14.01	1.20	0.29	0.35

The values are given in centesimal degrees.

Abnormality Noted During Total Solar Eclipse

Let us point out, finally, that an abnormal lunar and solar influence also became apparent in the form of a remarkable disturbance of the motions of the paraconical pendulum (which gave the very definite impression of a screen effect) during the total solar eclipse of June 30, 1954. The plane of oscillation of the paraconical pendulum shifted approximately 15 centesimal deg. during the eclipse (see Fig. 7).[3] The forces involved were of the same order of magnitude as those which correspond to the Foucault effect.

Here, reduced to essentials, are the facts noted to date.

Four Basic Questions

The interpretation of the experimental results leads to the following four basic questions, to be raised in the order given.

First Question

Do the monthly series of observations contain statistically significant periodic terms, with periods in the vicinity of 24 and 25 hours?

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[3] Fig. 7 shows an azimuth curve tracing for the period extending from June 28, 1954 (8 p.m.), to July 1, 1954 (4 p.m.), as well as a curve symmetrical to the left part of the curve, which represents the azimuth referred to, about the vertical straight line for June 30 (midnight). Just at the beginning of the eclipse, the azimuth of the plane of oscillation suddenly was raised 5 centesimal deg. above the trend which first characterized its motion. Twenty minutes before the maximum of the eclipse, which was recorded at 12:40, this deviation reached a maximum of 15 centesimal deg. and then decreased progressively—but more suddenly than it had increased. The deviation was no more than 1.20 centesimal deg. prior to the end of the eclipse.

It will be noted that, to such an extent as may be ascertained, the shift of the plane of oscillation resumed, after the eclipse, the appearance of a motion CD, analogous to AB, which had been noted prior to the said eclipse (Fig. 7b).

Fig. 7a reveals an approximate symmetry of the azimuth curve with respect to the vertical for June 30, at 12 midnight. This symmetry, which can be ascribed to the periodic structure of the motion, is noted for approximately 28 hours. If we assume, as is likely, that this symmetry corresponds to a physical reality independent of the disturbances created by the contact between the steel ball and the surface, it is notable that nothing in the branch of the azimuth curve which precedes the time corresponding to the center of symmetry is in any way comparable to the very strong deviation noted during the eclipse.

It must be further underscored that, during all continuous observation periods, no variation of the azimuth curve similar to branch BC, corresponding to the solar eclipse of June 30, 1954, was ever observed.

It should be noted that the maximum deviation due to the eclipse took place 20 min. prior to the maximum of the eclipse. Thus there is a measure of dissymmetry in the effect noted. A similar dissymmetry has been observed for terrestrial magnetism, but in the opposite direction, the maximum of the effect having been observed after the maximum of the eclipse. (Lion, C.R.A.S., 1851, T. 33, p. 202; Lion, C.R.A.S., 1852, T. 34, p. 207; Lion and Muller, C.R.A.S., 1874, T. 74, p. 199. For the terrestrial electric field: Nordmann, C.R.A.S., January, 1906, p. 40; Chevrier, C.R.A.S., 1933, T. 197, p. 1143; Rouch, C.R.A.S., 1954, T. 239, p. 465.)

Second Question

If so, can the periodic effects so noted be identified with those due to the current theory of gravitation (as derived from the double principle of inertia and universal gravitation, which is assumed to apply with respect to the whole set of Galilean frames of reference) as complemented (possibly) by corrections derived from the theory of relativity, and such as this current theory of gravitation is applied within the framework of the current theory of relative motions?

Third Question

If not, can the existence of periodic terms which are of significance in the series so obtained be ascribed to an indirect influence of a known periodic phenomenon, specifically, to one of the following phenomena:

(1) Deviation of the vertical (terrestrial tides).
(2) Variation in the intensity of gravity.
(3) Thermal effect:
  (a) General (temperature at Le Bourget).[4]
  (b) Local (laboratory temperature).

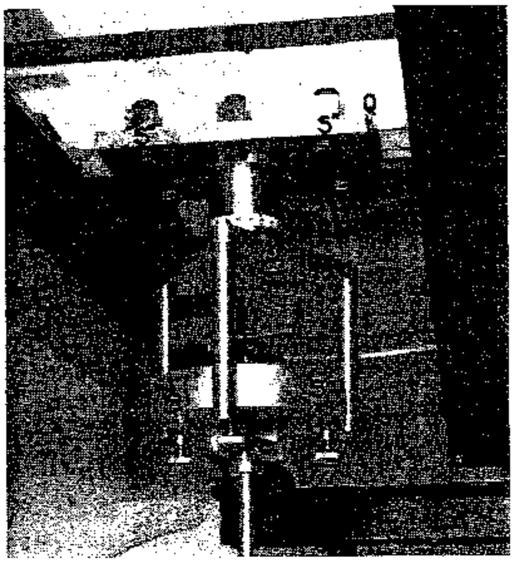


Fig. 3. Suspension.

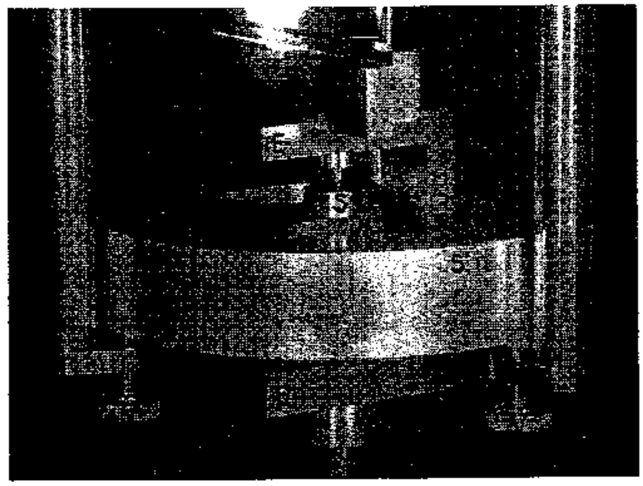


Fig. 4. Detail of suspension.

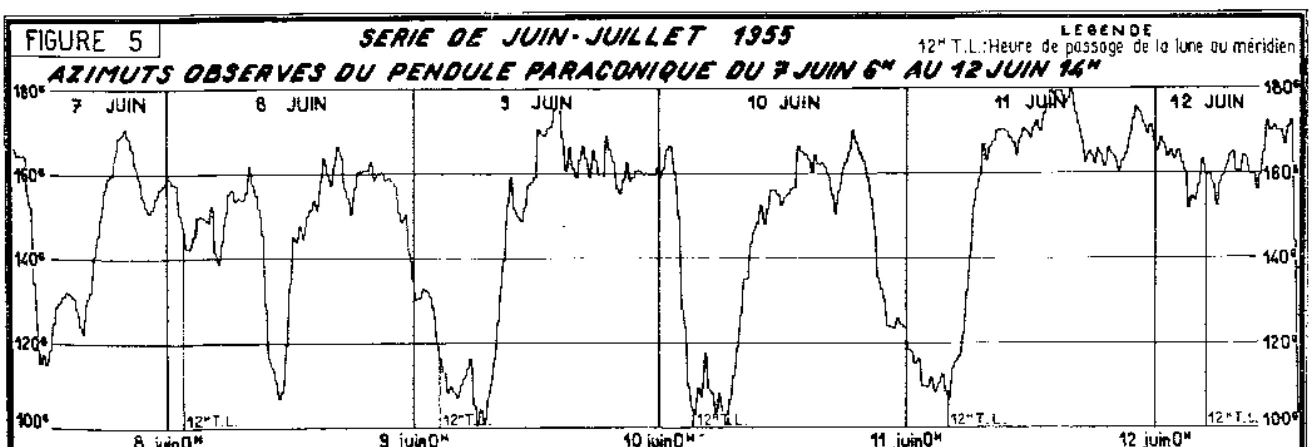
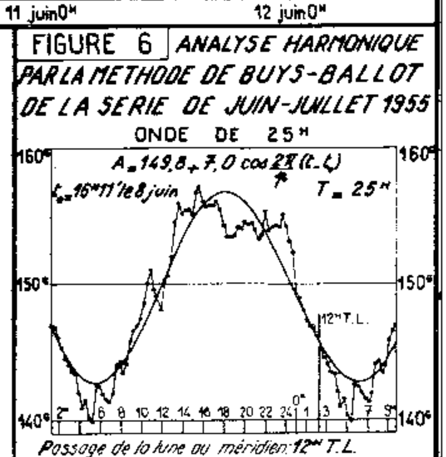


Fig. 5 (above). Series for June–July, 1955. Azimuths of the paraconical pendulum observed from June 7, 6:00 a.m., to June 12, 2:00 p.m.

Fig. 6 (*right*). Harmonic analysis of the June–July, 1955, series, using the Buys-Ballot method.



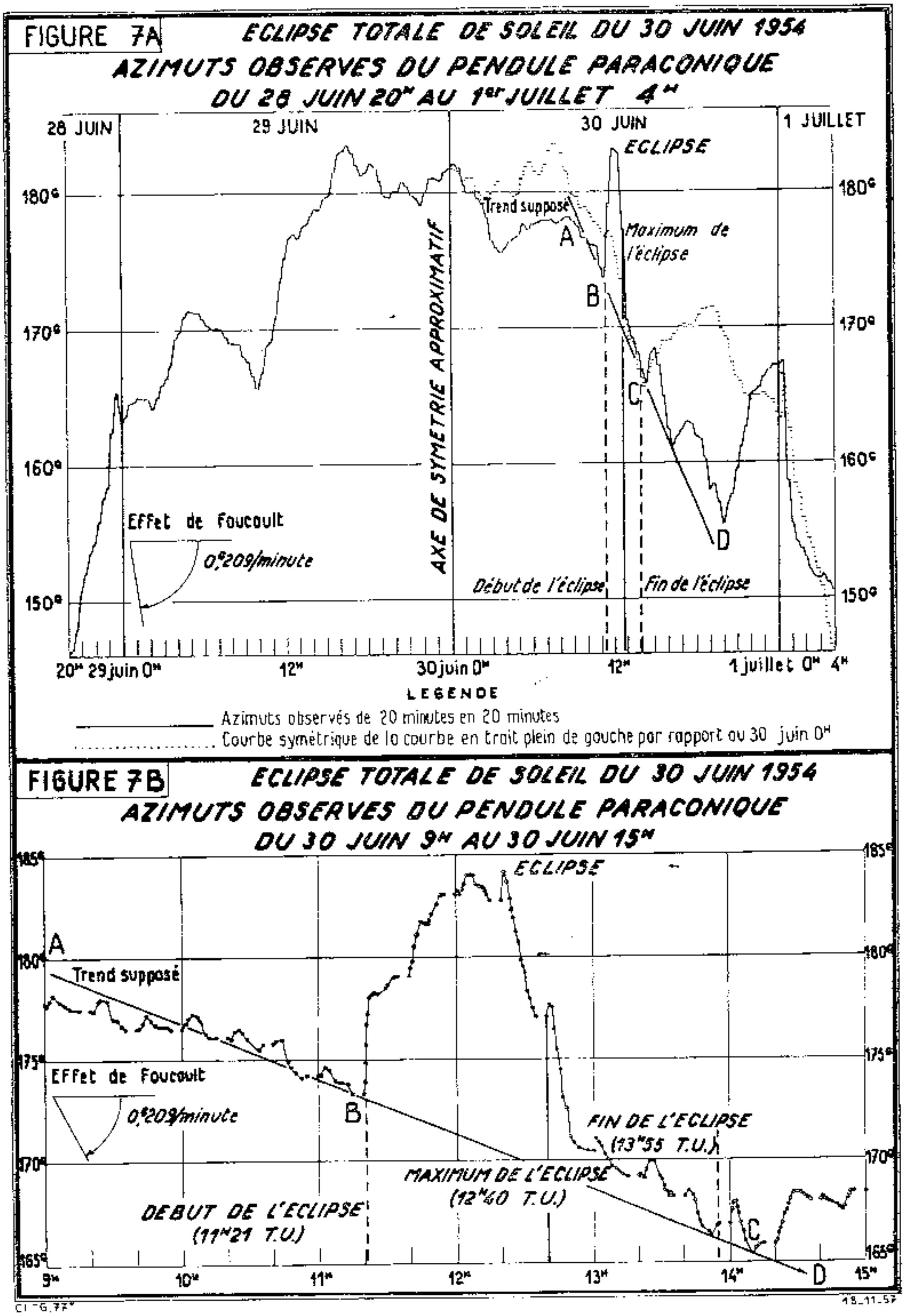


Fig. 7a (top). Total solar eclipse, June 30, 1954. Azimuths of the paraconical pendulum observed from June 28, 8:00 p.m., to July 1, 4:00 a.m. Fig. 7b (bottom). Total solar eclipse, June 30, 1954. Azimuths of the paraconical pendulum observed from June 30, 9:00 a.m., to June 30, 3:00 p.m.

(4) Barometric effect:

(a) General (pressure at Le Bourget).

(b) Local (pressure in the laboratory).

(5) Magnetic effect:

(a) Normal effect (terrestrial magnetic field as recorded at Chambon la Foret).[4]

(b) Magnetic agitation (K numbers of Bartels).

(6) Microseismic agitation:

(a) Industrial microseisms.

(b) Wind effects.

(c) General microseismic agitation.

(7) Cosmic rays.

(8) Periodic character of human activity.

(9) Periodic modification of the structure of the device.

Fourth Question

If a negative answer to the third question is in order—namely, if we must conclude that the effects noted are due to the direct action of a new field—should the origin of this field be assumed to be solar, lunar, lunar and solar, or spatial?[5]

Answers to the Four Basic Questions

Answer to the First Question

Any discrete series of $2n + 1$ numbers may be represented by the sum of a constant and n sine waves.

The obtaining of a sine wave of a given period by any method of harmonic analysis can therefore be of real significance only if its radius is sufficiently large and if the periodic structure noted is found again in the various elementary periods into which the period of observation under review can be broken down.

(a) The generalization of the Schuster test[6] leads to the conclusion that, for the two monthly series of November-December, 1954, and June-July, 1955, the amplitudes of the waves (or groups of waves) which have periods close to 24 and 25 hours must each be considered to be very significant statistically (the significance level is at least 10^{-4}).

(b) The periodic structure of the monthly series must be considered to hold for the two periods of one fortnight, and even for the periods of one week, into which each one-month series can be broken down, for the following reason:

Simultaneous analysis, by the method of the least squares, for 13 waves of the tide series, gives 13 sine curves, the sum of which can be found with the help of Lord Kelvin's tide predictor. The calculated series so obtained, *which is the sum of the 13-sine curve*, can be analyzed, for 24 and 25 hours, by the same method of the Buys-Ballot filter.

Table 2.

Series	Values H-H′ June-July, 1955	
	24^H	25^H
1 + 2 + 3 + 4	0^H06^{mn}	0^H02^{mn}
1 + 2	-1^H09^{m}	0^H02^{m}
3 + 4	$+0^H43^{mn}$	$+0^H15^{mn}$
1	-1^H08^{m}	-0^H33^{m}
2	$+0^H59^{mn}$	$+2^H20^{mn}$
3	-1^H23^{mn}	-0^H56^{mn}
4	$+0^H59^{mn}$	$+0^H57^{mn}$

If the sine curves obtained *really* exist in the raw series, the Buys-Ballot method must give, for each elementary period, a sine curve having phases that are comparable for both the crude and the computed series. Table 2 shows the results obtained for the value H-H' representing the difference between those two phases in hours and minutes, for the series of June-July, 1955.

Notation 1 represents the first week; notation 1 + 2 represents the first 2 weeks, and 1 + 2 + 3 + 4 represents the whole of the month.

Allowing for the fact that each week can be considered an independent experiment, such agreement between the phases must be deemed to reveal the existence of true periodicity. This leads us to the conclusion that the monthly series of June-July, 1955, *actually* contains periodic elements with periods close to 24 and 25 hours.

Thus the answer to the first question must be "yes" in all certainty.[7]

Answer to the Second Question

The current theory of gravitation (being the result of the application, within the framework of the current theory of relative motions, of the principles of inertia and universal gravitation to any one of the Galilean spaces), complemented or not by the corrections suggested by the theory of relativity, leads to orders of magnitude for lunar and solar action (which are strictly not to be perceived experimentally) of some 100 millions of times less than the effects noted.[8]

These effects are so small that none of the nineteenth-century authors who worked on the theory of the pendulum, some of whom were excellent mathematicians, ever had a desire to compute them.

The extreme smallness of the effects computed can readily be accounted for if we allow for the fact that, in order to obtain the true gradient $\vec{f}$ of the moon and sun attraction at a point, on the surface of the ground, with respect to the earth, we must take the difference between the attractions at this point and at the center

[4] Observatory nearest my Saint-Germain laboratory.

[5] By this, I mean a field which could not be related to the sun or to the moon. This could be, for instance, a field resulting from a dissymmetry of the inertial sidereal space. A possible period would then be 24 sidereal hours.

[6] See footnote 2.

[7] Much store has been set in the defects of the equipment used—imperfect steel balls, imperfect horizontal positioning of the support, etc. I cannot stress enough that the only possible effect of imperfections in the equipment are effects of a systematic or random type and that, under no circumstances, could they entail, whatever they be, the existence of any real periodicity.

[8] On the order of 10^{-13} instead of the periodic effects noted of some 10^{-5} rad. per sec.

Table 3.

	2R			
	25^H	24^H	12^H30	12^H
June-July, 1955	14.01	11.66	3.71	2.69

of the earth, respectively. Gradient $\vec{f}$ is of the order of 10^{-8}.

Furthermore, the plane of oscillation of the pendulum can rotate, under the influence of the solar and lunar attraction, only because of the variations of the gradient about the point considered. Therefore, the difference $\Delta\vec{f}$ between the value of $\vec{f}$ at the mean position of the pendulum and its magnitude at a nearby point must be considered. It[9] is of some 10^{-13}.

Furthermore, nothing in the current theory of gravitation can be considered likely to account for the screen phenomenon observed during 1954.

Therefore, the answer to the second question must be *no, and this in all certainty*.

Answer to the Third Question

The very peculiar periodic structure of the series observed (amplitude of the 25-hour wave of the same order of magnitude as that of the 24-hour wave and very much larger than the amplitude of the 12- and 12.5-hour wave) leads to the elimination, as possible causes of the observed abnormalities, of all the phenomena noted above under the order numbers 1 to 9. (Table 3 shows the results obtained for the series of June-July, 1955, the periodicity of which is significant.)

Indeed, for all these phenomena, the total of the amplitudes of the waves having periods close to 25 hours is small as compared to the total of the amplitudes of the diurnal solar wave group, the semidiurnal solar wave group, or the semidiurnal lunar wave group.[10, 11]

The answer to the third question therefore must be, for elements 1 to 9 as limitatively listed above, that the effects observed cannot be assumed to arise indirectly out of the action of any of these elements. This statement can be made *categorically*.

As long as a phenomenon other than those listed above has not been proposed as a possible explanation, it will be necessary to assume that the phenomena observed are due to the direct action of a new field.

Thus the answer given to the third question is a qualified one.[12]

Answer to the Fourth Question

If, in the present condition of the discussion, we must answer the third question with a hypothesis of the direct action of a new field, there will arise the question of determining whether this field is derived from the action of the moon, from that of the sun, from their conjugated action, or, again, from a spatial influence.

Two remarks are in order:

(a) In reviewing monthly series, there is no way of specifying, when a wave with a period of 24 hours is revealed, whether one is dealing with a solar or sidereal 24-hour period.

(b) Similarly, when dealing with a period close to 24 hours, 50 min., nothing justifies the claim that one is dealing with a lunar—rather than a solar—effect. The mean synodic rotation of the sun about its own axis is 27.275 mean days, whereas the sidereal revolution of the moon is 27.321 days. As for the mean solar day, it is very close in value to the mean sidereal day.

In order to reach a definite decision, it would be necessary to use far longer periods of observation.

Thus it appears to me that it is impossible to conclude with definite certainty that the periods revealed, of an order of magnitude equal to 24 and 25 hours, are derived respectively from a solar and a lunar action. *In the current status of available information*, such an action only appears to me as *very likely*.[13]

The answer given to the fourth question, therefore, has to be of the qualified type.

(This article will be concluded in the October issue. Part II will discuss experiments in connection with the abnormalities described in Part I.)

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[9] See the accurate expression of the effect in my paper to the Academy of Sciences (December 16, 1957).

[10] Thus, for instance, for the lunar and solar gravitational potential, the total of the amplitudes of the waves having periods of close to 24 hours is approximately 18 times greater than the total of the amplitudes of the waves with periods of close to 25 hours.

[11] Aside from the general argument of the specific periodic structure of the results obtained, which, of itself, is enough to rule out causes 1 to 9, a certain number of additional arguments may be presented, some of which are of considerable value and lead to the same conclusion but, for lack of space, are not presented here.

[12] I believe I should point out that nothing else can be the case. I can give my answer only with regard to the phenomena which I considered or which were suggested to me as being such as to account for the effect noted. It is quite possible that an explanatory phenomenon be propounded very soon which would definitely prove decisive when investigated. However, in the present condition of the discussion and allowing for all the factors already reviewed, the existence of such a phenomenon seems at least to be unlikely.

[13] The only known phenomenon related to the rotation of the sun is that of the spots. It really seems quite unlikely that the variations in the radiation due to the spots can have effects of an order of magnitude similar to that of the suppression of radiation during the night. As a matter of fact, there is no connection at all between the observed azimuths and the Wolf numbers, which are characteristic of lunar activity (for which, unfortunately, we have only one value per diem).

However, it cannot be claimed that there are no other effects related to solar rotation. This is enough to rule out a fully certain and unequivocal conclusion.

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