Abstract. The paraconic pendulum is described as a dynamic system to detect the gravity effects during the solar eclipses. The author presents the sophisticated device used for the observations during total solar eclipses in Mexico-C.-1991 (Mexico) and Pato-Branco-1994 (Brazil) in purpose to detect so-called effect Allais (gravity shielding). I found that the rotation velocity of oscillation plane of paraconic pendulum is increased during eclipse in the direction of the action of Foucault effect on a value of local Foucault effect in Pato-Branco and 3 times more than local Foucault effect in Mexico.

Key words: Allais effect, azimuth of plane of pendulum oscillations, Foucault effect, solar eclipse.

I. INTRODUCTION

French scientist M.Allais (the laureate of Nobel-1988 in economics worked also as a physicist) was the pioneer to use a paraconic pendulum for detection of gravity effects during the solar eclipse in 1954 [1]. It was an asymmetrical one, consisting of a vertical bronze disc weighing 7.5 kg, attached to a bronze rod hung from a bronze stirrup resting on a steel ball 6.5 mm in diameter, free to roll in any direction on a horizontal plane surface (Fig.1). The latter was itself on a hollowed-out circular support made of aluminum allowed it possible for the pendulum to rotate while in motion over a total angle of 210 degrees. The rod with its stirrup weighed 4.5 kg so the total weight of the pendulum was 12 kg, and the length was 83 cm.

The pendulum was released from a resting position every 20 min using an initial amplitude of about 0.11 radian by burning of a thread. After 14 min the pendulum was stopped, and the azimuth of its oscillation plane was measured with a precision of about 0.1 degree by an aiming system placed on a graduated circle. After 6 min of rest the pendulum was released again in the plane of the last observed azimuth. Thus the successive series of observations were connected with release every 20 min, day and night, so that each 24-hour period was made up of 72 series of connected azimuth observations.

Fig.1: Copy of Allais pendulum used by SAI scientists for the observations during the solar eclipse in Rostov 1961.
Allais claimed in [1] that the monthly series of observations contain the periodic abnormality (of a period 24 hours 50 min and a value of about twice the Foucault effect) in the graphs of the azimuth as function of time received after a harmonic analysis. He claimed also (Fig. 2) that a remarkable disturbance of the azimuth has been observed at the time of the total solar eclipse in June 30, 1954, and it gave the impression of a screen effect (the plane of oscillation of the pendulum shifted briskly the 5 degrees at the beginning of eclipse, and then the 15 degrees during the time of eclipse; the value of effect was the same order as the value of Foucault effect). Allais assumed that the observed effects must be considered as produced by the direct action of a new field.

His results and the device itself were strongly criticized by the opponents especially after the results of the observations of Sternberg Astronomical Institute scientists during the solar eclipse in Rostov 1961 [2]. They used (among other instruments) a constructive copy of Allais pendulum. The change of oscillation plane of that copy had a really random character, and there was not any correlation with the eclipse. The opponents pointed that the Allais device had a lot of defects: the pendulum was not isolated from the atmosphere and environment so one needed to restart it each 14 min because of damping, the deformation of suspension system was too big, the direction of oscillation plane was measured visually with precision 0.1° only, and so on.

II. MY DEVICE

I took part in the expedition of SAI in Rostov-1961, and tried to detect the gravity effects during the solar eclipse by paraconic pendulum of my own construction [3]. My first pendulum, like all my next pendula, has two principal differences in comparison with Allais pendulum: it was much shorter and lighter, and it was symmetrical to avoid a co-swinging which was in my opinion the main defect of Allais pendulum. I understood also even then that the pendulum must be placed inside of a vacuum chamber to avoid the influence of environment.
It is very difficult to construct a special device that will fix the pendulum in the azimuth of stop position, restart it automatically again in the same azimuth and continue such process permanently, especially inside of a vacuum chamber. That’s why I decided not to check out the periodic part of Allais effect by the repeating of successive series of connected observations. My pendulum was started always in the same azimuth with the same initial conditions so the series before, during, and after eclipse will be compared.

I tried many prototypes and had a lot of laboratory experiments. The results of these investigations were verified by the observation during the total solar eclipse - July 22, 1990 in region of Bielomorsk (USSR, North Karelia). They were reported in the 13th International Gravity Commission (Toulouse, September 11-14, 1990), and published [4]. One can see the different kind of my devices in [5]. After several years of experiences I could formulate the main purpose: to create an high-precision transportable automatic device with automatic system of registration and computing system of data collecting, placed inside of thermostatic vacuum chamber.

Such device was finally made. I used it for the observations when my international scientific team arrived to investigate the physical effects during total solar eclipse in Mexico July 11, 1991. It is a nonmagnetic symmetrical pendulum weighing 1320 g, and with the length 31 cm. The rectangular stirrup (the laboratory experiments shown that it’s the best form of stirrup) and the lens body are made of alloy of tungsten, nickel and copper; the rod is made of quartz. The suspension is a steel ball 6.8 mm in diameter. The damping of Allais pendulum was 11.5% within 14 min after the start. My pendulum started with the same initial amplitude was damping on a same value after 4 hours. The pendulum is shown in Fig. 3.

![Fig. 3: Paraconic pendulum used for experiments in Mexico 1991 and Brazil 1994.](image)

The design of support, which is a massy metallic base plate, allows the pendulum to rotate while in motion over a total angle ± 15 degrees. The starting and stopping of pendulum with the constant amplitude of 1° are making automatically by the high-precise electromechanical remote control system. This system together with pendulum and hanging device is shown in Fig. 4.

The pendulum itself, the starting mechanism, the optical bridge, and sensor are inside of the thermostatic vacuum chamber. The automatic work of the device is secured by the specially constructed power source, which is linked to device by a cable. Switching on and off is doing by a single button. The chamber is shown in Fig. 5.
The scheme of device is shown in Fig. 6. The beam of light from the halogen electrical lamp projects on mirror attached to the stirrup. The amplitude and change of azimuth of the oscillation plane are imaging after reflection from the mirror by a system of lenses and prisms on the surface of photoelectrical sensor which is capable to feel 1 micron of the change of spotlight position. The sensor is linked by special translator to PC.
Fig. 6: Scheme of device

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Fig. 7: Scheme of Brazilian experiment (above); azimuth (degrees) of oscillation plane versus time (s) for 1st pendulum (below right) and 2nd pendulum (below left).
The results of observations are very interesting. I will consider them together with the results of observations during the next eclipse in Brazil November 3, 1994. That time two identical devices were used, one of which was served in Mexico. Instead of steel ball the both pendula were suspended by the agate-stone conic needles with the spherical surfaces at the end. The diameters of spheres are 3 and 4 mm respectively. The support plates are made of the agate too because the laboratorial testing shown that the best system of suspension is agate-agate. The starting and stopping mechanisms, data acquisition systems, remote control systems were the same as in Mexico expedition. Both devices were placed inside of thermostatic vacuum chambers. The scheme of experiment with the graphs of the change of azimuths of oscillation planes as function of time for both pendula is shown in Fig. 7.

III. RESULTS OF OBSERVATIONS IN MEXICO AND BRAZIL

The motion of a paraconic pendulum differs generally from the motion of Foucault pendulum. The pendulum has the tendency to generate ellipse due to the anisotropy of the support. At the moment of start the trajectory of pendulum is a straight line. After a few seconds the line becomes to transform in an ellipse with increasing ellipticity, the azimuth of the major axis of which changes in direction of Foucault effect. After some time the ellipticity reaches a maximum and begins to decrease. Then the ellipse becomes the line again, and the deviation of azimuth is a maximum at this moment. After that the trajectory becomes the ellipse again, and the change of azimuth of axis occurs in the opposite direction against Foucault effect. This “return” effect repeats periodically because the plane of oscillation of pendulum tends to locate itself parallel to the plane of greatest elasticity of the support. The number of such “periods” is own for each device, it depends of construction. In Fig. 7 one can see the change of oscillation planes of two pendula during eclipse in Brazil. The photoelectric sensor gives a permanent image of a pendulum motion. The coordinates of points of trajectory memorize in PC: 64 points with coordinates X, Y correspond to each ellipse of a single oscillation. The program of PC permits to see on display the analog of pendulum motion. In Fig. 8 there is an example: the figures below are the azimuth of major axis calculated for this ellipse, coordinates of centre of ellipse $X_0, Y_0$, and values of major and minor axes (in conditional units).

![Analog of pendulum motion on display](image)

A = $-89^\circ, 65199^\prime$; $X_0 = 12^\circ, 17936^\prime$; $Y_0 = 10^\circ, 14693^\prime$

$a = 60, 37078; \delta = 7, 731717$

Fig. 8: Analog of pendulum motion on display

The data were sent in PC each 15 seconds so there were 186504 files of information stored in its memory. The azimuth of big axis of ellipse of oscillation of pendulum as function of time was calculated by standard least square method. The graphs of change of azimuth during eclipse in Mexico (below) and Brazil (above) are shown in Fig. 9. In Mexico, at the beginning of eclipse the azimuth shifted briskly the 12 degrees like it was during Allais experiment in 1954. The calculations show that the deviation was outside of $\pm 3\sigma$ (right graph below). Nothing like that happened in Brazil (graphs above).
The change of azimuth as function of time for a series of observation during total phase, the end of eclipse (Mexico), and for the series covering all time of eclipse (Brazil) in comparison with series before and after eclipse are shown in Fig. 10. In Mexico the periodic change of direction of azimuth occurred three times; in Brazil it occurred 49 times for 1st pendulum and varied from 23 to 28 for 2nd pendulum. The graphs show no abnormalities of azimuth during the total phase and at the end of both eclipses.

The most interesting result of Mexico and Brazil experiments is the increase of rotation velocity of pendulum oscillation plane in direction of Foucault effect during eclipse. In Fig. 11 there are the character trends of rotation velocities of three series for 1st pendulum (Brazil observations), the same series as in Fig. 10 (above left). It’s clear that the trends of velocities before and after eclipse are parallel to each other while the trend during eclipse differs from them rather significantly. The same result is for other 33 series (for 1st pendulum there are altogether 36 successive series of observations during 5 days and nights of experiment). The value of this effect (0.1 ’/sec) is practically equal to the value of local Foucault effect. In Mexico this effect was even
bigger: its value (0.3 °/sec) is 3 times more than local Foucault effect. If one wants to see detailed calculation I address him to publications [6] – [12].

As for the sudden jump of the azimuth in 12° at the moment of the beginning of eclipse in Mexico, it seems this abnormality was due to the atmospheric shock waves which were predicted [13] and observed [14] during solar eclipses. The Mexican graphs differ completely from all laboratory and Brazilian graphs. In Mexico the graphs have “noisy” saw-edged character. The underground laboratory of Mexican Institute of Geophysics is cut down in big lava block, so it’s some kind of resonator of microseisms which is trembling all the time. This “trembling” was registered by accelerometer of our French colleagues. So the pendulum felt a “ringing” of lava bell due to the atmospheric shock waves at the beginning of eclipses.

Fig. 10: Azimuth of oscillation plane of pendula versus time in Brazilian (above) and Mexican (below) experiments.
Fig. 11: Rotation velocity of pendulum oscillation plane; abscissa – number of “period” (see first paragraph of this section).

IV. CONCLUSION

I have to state that neither in Mexican experiment nor in Brazilian experiment was there a step-by-step change of the azimuth of the pendulum oscillation plane during the eclipse or the period of its total phase.

But last 20 years there were many experiments with numerous devices during the solar eclipses accomplished in different places of our planet; one can see for example in [15] the articles of T.J. Goodey (p. 231), A.F. Pugach (p. 257), J. Li, D. Olenici, C.Y. Yang, B. Zhang (p. 227), D. Ionescu (p. 223), I. Mihaila, N. Marcov, V. Pambuccian (p. 191), Q.-S. Wang, X.-S. Yang, W. Wen, Y.-C. Liu, C.-Z. Wu (p. 165), and others.

The results of such experiments are different and controversial, but it is clear that some anomalous events happen during solar eclipses. We need also some theoretical models to reveal their origin. In my opinion it seems rather clear that gravitational screening can be ruled out as theorectical explanation [16].

Every solar eclipse is unique phenomenon. That is why we will receive in each case a variant result. The best way is to collect all different kind of device (gravity meters, pendula, torsion disks and so on) in one place where a solar eclipse will happen, and to carry out these experiments synchronously.

REFERENCES


AUTHOR BIOGRAPHY

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