CORRELATION BETWEEN THE "GRAVITATIONAL SIGNALS" IN WEBER'S EXPERIMENT AND SOLAR AND TERRESTRIAL MAGNETIC ACTIVITY

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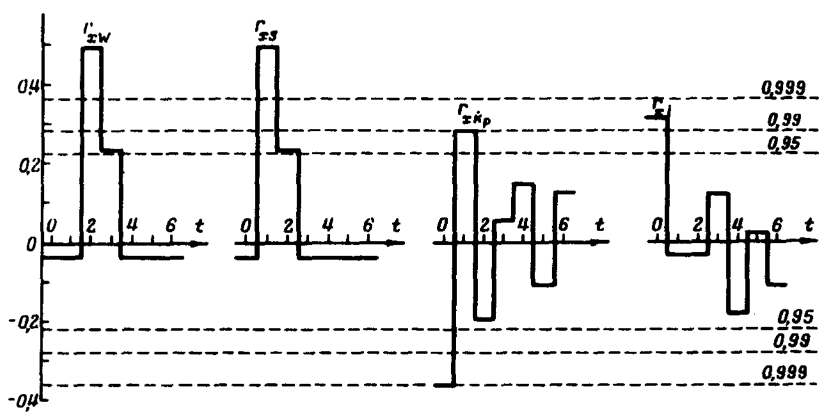
The interpretation of Weber's experiments [1] as being the action of gravitational radiation on the detector encounters serious difficulties. In particular, an estimate of the radiation power leads to an estimated universe lifetime $10^7 - 10^6$ years [2], which is exceedingly small compared with the cosmological and geological times. We have carried out a correlation analysis and observed a significant connection between Weber's data and the solar and geomagnetic activity, and also the cosmic-ray intensity. We analyzed the data during the period from 30 December 1968 through 21 March 1969 [1]. The employed characteristics of the solar activity were the Wolf numbers W and the number S [3], and the characteristics of the geomagnetic activity were the planetary indices K_p [4]. Information on cosmic rays were taken from the data of the Swarthmore cosmic ray laboratory, which is closest (200 km) to the Maryland detector [5]. (The Chicago laboratory [6] closest to the Argonne detector is 30 km away. There is a considerable correlation, r = 0.85, between the intensities of the cosmic rays in both points, thus justifying the use of data for one point only.)

The information on the "gravitational signals" registered by Weber's apparatus consists only of an indication of the time of the event. To be able to carry out a quantitative analysis, this information was coded, namely, an event was valued as unity and the absence of an event as zero. If several events occurred per unit time (24 hours), the units were summed. The characteristics of the phenomena with which the correlation was sought were also coded, viz., a band symmetrical about a mean value was introduced for each characteristic. A characteristic was assigned a value +1 if it fell in the region above the band, -1 below the band, and zero inside the band. In the case of the K_p indices, which were determined for three-hour time intervals, algebraic summation over each 24-hour period was carried out after the coding. The remaining characteristics were mean-diurnal quantities, and no such summation was required for them. The band width 2h was determined in fractions of the standard deviation σ and ranged from 0 to $(4 - 5)\sigma$. The latter was due to the fact that the correlation coefficient depends significantly on the width of the band and, generally speaking, there exists an optimal width at which the correlation is maximal.



The correlation coefficient was determined from the formula

$$r_{xf} = \frac{\frac{1}{n-1}\Sigma X(i)f(i-m) - \bar{x}\bar{f}}{\sigma_x \sigma_f},$$

where X(i) is the Weber series of observations of the gravitational signal, f(i) the coded characteristic of the phenomenon, n is the number of degrees of freedom determined by the length of the Weber series of observations and equal to 82 for the functions f(i) and 81 for the derivatives f'(i), and m is the shift of the observed series of observations. By virtue of the limited duration of the observations, m could not be taken larger than the mean 5.05 interval between the "gravitational" events. In the calculations we assumed n_1 = 0, 1, 2, ..., 6.

The figure shows the results of calculations of the coefficients of correlation between the aforementioned series of observations with Weber's gravitational detectors and, respectively, the Wolf numbers W ($h_{opt} = 3.3\sigma_W$), the numbers S ($h_{opt} = 2.1\sigma_S$), the rate of change of the K_p indices ($h_{opt} = (4/9)\sigma_{cr}$, and the rate of change of the intensity of the cosmic rays I ($h_{opt} = 0$). The dashed lines denote the values of r for three significance levels, obtained in accordance with the usual procedure for verifying the hypothesis that the correlation coefficient is equal to zero [7], namely, r having absolute values larger than the indicated values are significant and the zero hypothesis should be rejected for them with a corresponding fiducial probability (0.95, 0.99, 0.999). The significance determined in this manner should apparently be reduced: one can consider each shift of one series of observations relative to the other as a new independent test, which leads to an increase in the probability of a random appearance of a large correlation coefficient from a significance level p to a value $1 - (1 - p)^m \simeq mp$. The reliability of the conclusions should be decreased by this amount. However, even when this correction is introduced, the maximum correlation coefficients have high significance levels corresponding to a fiducial probability larger than 0.99 (see the figure).

The results enable us to interpret Weber's experiments as a result of action exerted on the detectors by oscillations of the earth's magnetic field, excited by fast corpuscular streams emitted by the sun. Favoring such an interpretation are the following: The high correlation between Weber's results and the solar activity (the numbers W and S), which reaches 0.49. The shift of this correlation towards a delay of the events registered by Weber's detector relative to the solar activity, by a time (1 - 2 days) equal to the travel time of the fast corpuscular particles from the sun to the earth [8], and, finally, the significant (with reliability not lower than 0.99) correlation (r = -0.37) between Weber's results and the geomagnetic activity observed without delay. Weber's results are apparently influenced also by cosmic rays, since the correlation coefficient for this connection, equal to 0.31 (there is no delay) is significant at a reliability level of at least 0.93.

The concrete mechanism whereby the magnetic field influences Weber's detectors may depend on construction features or registration-system features not reported in the general descriptions of the apparatus. We confine ourselves therefore only to an indication of a possible "ordinary" interpretation of Weber's results, although the possibility that Weber's detector has registered bursts of gravitational waves is not fully excluded.

In conclusion, the authors thank Professor V.B. Braginskii and V.M. Morozov for useful discussions and Professor K.P. Stanyukovich for interest in the work.

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CONCERNING THE ATMOSPHERE OF MAGNETIC NEUTRON STARS (PULSARS)

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Of great importance in the theory of neutron stars and pulsars is the conclusion [1] that the star should, generally speaking, be surrounded by an extended "atmosphere," in spite of the action of the force of gravity. The point is that the neutron star, as follows from natural considerations (see, for example, [2]), should be magnetized and rotating, and the angular velocity Ω and the magnetic field B (say dipole field at the magnetic pole) are sufficiently large. As a result, an electric field $E \sim r_0\Omega B/c$ is produced in the vacuum at the surface of a well-conducting star and its action on a particle with charge eZ and mass Am_p greatly exceeds the action of the force of gravity, under the condition

$$\Omega B >> \frac{m_p A}{eZ}\frac{cGM_0}{r_0^3} \sim 10^4 \text{ W/sec} , \tag{1}$$

where M_0 is the mass of the star, r_0 its radius, m_p the proton mass, and G the gravitational constant; the numerical value was obtained for $M_0 \sim M_\odot = 2 \times 10^{33}$ g, $r_0 \sim 10^6$ cm, and $A/Z \sim 1$.

If the field B is determined in the "vacuum approximation," i.e., if it is assumed that the pulsar emits magnetic-dipole radiation as in vacuum [2], then for the known pulsars ΩB ranges from 1.5×10^{12} for PSR 0808 to 5×10^{13} for PSR 0532 (see [3]), and condition (1) is satisfied with a tremendous margin. Therefore, insofar as we know, it has not been doubted that pulsars can be sources of particles that fill their magnetosphere and are responsible for the emission of electromagnetic waves. In fact, however, particles can escape only if a certain gas layer exists at the surface of the star or if extraction of ions from the solid surface of the star is possible. Both conditions may, incidentally, not be satisfied. Concretely, in a strong magnetic field $B >> B_c = 4.6 \times 10^9$ G, the surface of a neutron star is something in the nature of a "polymer" (quasi-one-dimensional) metal [4, 5] with density $\rho \gtrsim 10^4$ g/cm and binding energy in the lattice (per "atom" whose nucleus has a charge eZ)

$$W \approx 13.6 Z^3 \eta^{4/5} \text{ eV}, \quad \eta = (B/B_c Z^3)^{1/2} >> 1$$
$$W \sim 27 Z^3 \eta^{12/5} \text{ eV}, \quad Z^{-3/2} << \eta << 1. \tag{2}$$