Short-period pulsations of the flux of atmospheric gamma rays

A. M. Gal'per, V. G. Kirillov-Ugryumov, A. V. Kurochkin,
N. G. Leĭkov, B. I. Luchkov, and Yu. T. Yurkin

Moscow Engineering Physics Institute

(Submitted August 13, 1976)
Pis'ma Zh. Eksp. Teor. Fiz. **24**, No. 7, 426–430 (5 October 1976)

An analysis of the temporal variations of the gamma-ray flux with energy higher than 40 MeV in the upper layers of the atmosphere has revealed the existence of periodic pulsations with periods 11.7 ±0.1, 12.7±0.1, 15.8±0.2, 23.2±0.2, and 33±1 min, which agree well with the periods of the solar-surface oscillations discovered recently by Hill *et al*. The pulsations of the γ rays are characterized by large relative amplitudes (up to 80%).

PACS numbers: 91.87.Nw, 92.50.+a

Long-period pulsations of cosmic rays are well known, ranging from 11-year pulsations connected with the cyclic solar activity to diurnal pulsations due to the reclosing of the magnetic force lines as a result of the earth's rotation. The existence of shorter periods, other than higher harmonics of the diurnal oscillations, has not yet been reliably established.[1–3] A hint of a quasiperiodic pulsation of the electrons and γ rays, with a period 25—30 min, was observed in[4,5].

We describe in this article the results of a search for short-period pulsations (with periods from 10 to 40 min) of the flux of γ rays of energy $E > 40$ MeV in the upper layers of the atmosphere. Gamma rays with such energies are genetically connected both with the proton-nuclear components of the cosmic rays—via production and decay of neutral pions—and with the electrons that produce bremsstrahlung in the atmosphere. The pulsations of the flux of atmospheric γ rays can result from periodic variations of the primary cosmic rays, and also from periodic changes in the earth's magnetosphere.

The measurements were performed with a large-aperture γ telescope with spark chambers[6] on a high-altitude balloon starting with 18:30 world time on 10 May (start of the drift at the maximum height) and ending with 4:30 WT on 11 July 1974. The height of the balloon was determined with a barograph

TABLE I.

№	Period, min	Steps of the period, min	Value of χ^2	Region of the periods for which $\chi^2 > 10$, min
1	11.7	0.03	24.5	11.6 - 11.8
2	12.7	0.04	21.6	12.6 - 12.8
3	15.8	0.05	21.3	15.6 - 16.0
4	23.2	0.11	21.4	23.0 - 23.4
5	33	0.22	25.2	32 - 34

and varied smoothly during the time of the drift in the range 7—9 g/cm^2 of the residual atmosphere (the relative error in the height did not exceed 2.5%). The instrument registered cases of conversion of the γ rays in steel plates—the electrodes of the upper spark chamber. The energy of the γ rays was estimated from the aperture angle of the conversion pair and from the electron shower produced in the lower spark chamber. The picture of the event, together with the readings of the clock, the intensity meters, and the navigational instruments, were photographed with a special camera. After 10 hours of measurements we registered ~7600 events, of which 90% were γ rays.

The search for the periodic pulsations was carried out first with the entire count of the instrument, using the method of linear selective conversion.[7] To ascertain whether the deviations from the mean over the period are statistically meaningful, we used the χ^2 criterion. The calculations were made with a computer for successive values of the period τ in the interval 11—35 min. The steps of variation of the period increased with increasing τ. The obtained

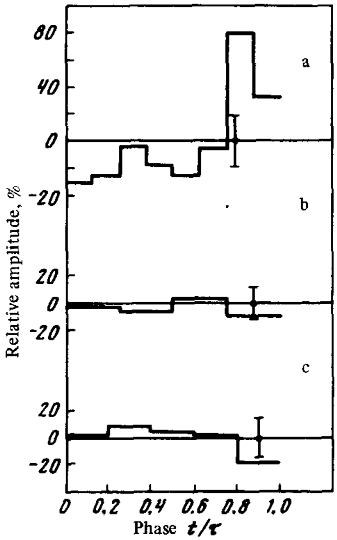

FIG. 1. Averaged count of the instrument over a period τ 24 min for events of various types: a—low-energy γ rays (E=40—150 MeV); b—high-energy γ rays ($E \gtrsim 800$ MeV); c—background events.

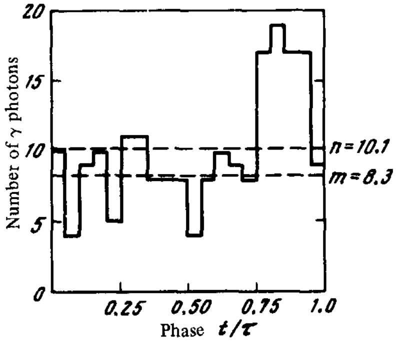

FIG. 2. Pulse shape averaged over nine periods ($\tau \approx 24$ min); average over all channels $n = 10.1$; average over 16 channels (without peaks) $m = 8.3$.

periodogram $\chi^2(\tau)$ has five statistically significant peaks for which $\chi^2 > 20$ (at seven degrees of freedom), whereas the expected number is $\lesssim 1$. The values of the periods are listed in Table I.

The relative amplitudes amount to ~10% and greatly exceed those that could be expected as a result of uncontrollable fluctuations of the height of the balloon ($\lesssim 2.5\%$). The results point to the existence of prolonged periodic pulsations in the flux of atmospheric γ rays with periods 11.7 ± 0.1, 12.7 ± 0.1, 15.8 ± 0.2, 23.2 ± 0.2, and 33 ± 1 min.

The subsequent analysis was carried out for one of the obtained periods (No. 4 in Table I) and for different types of events registered in the spark chambers:

1. Low-energy γ rays—effective energy range 40—150 MeV—form conversion pairs with large (>4°) aperture angle.

2. High-energy γ rays—effective energy region $\gtrsim 800$ MeV; they form showers with a large number of particles in the lower spark chamber.

3. Background events—without tracks in the spark chambers.

Figure 1 shows the results of the analysis. Whereas there is no effect for high-energy γ rays and for the background events, for the low-energy γ rays it is very strongly pronounced—the amplitudes of the deviation from the mean level reaches 80%! The largest effect was observed ~3 hours near local midnight. The shape of the pulse averaged over this time is shown in Fig. 2. The best period of the pulsations, determined from the low-energy events, is 23.7 ± 0.9 min. The values of χ^2 corresponding to this event and the probabilities of the random deviation are $\chi \approx 35$ and $p \approx 10^{-5}$. The analysis points definitely to a *physical* and not a methodological origin of the observed periodic pulsations. It is perfectly clear, however, that the pulsations of the atmospheric γ rays are merely the consequence of periodic pulsations of the parent components, either the proton-nuclear or the electronic component. An analysis of data obtained by a number of supermonitors has revealed pulsations with periods of dozens of minutes, but with small relative amplitudes.[8] As to the pulsations of the electron components, preliminary data of balloon work by the group of our Institute have observed them in the flux of electrons in the upper

TABLE II.

Periods of oscillations on the sun, min (Hill *et al.*, 1975)		Period of pulsations of the flux of atmospheric γ rays (1974), min
1973	1975	
52	47.9	—
33	30.3	33 ± 1
23.8	21.0	23.2 ± 0.2
16.7	17.1	15.8 ± 0.2
13.3	14.6	12.7 ± 0.1
11.9	11.8	11.7 ± 0.1
10.4	10.5	—
9.2	8.8	—
7.6	7.9	—
7.0	7.2	—

layer of the atmosphere, and their relative amplitude reached several dozen percent.

Additional research is necessary to ascertain the nature of the effect and the conditions under which it is produced. It is already appropriate to note, however, the surprising agreement between the measured period and those of the oscillations of the solar surface.[9,10] Table II shows a comparison of our data, obtained in 1974, with data[9] obtained 1973 and 1975. The periods of the pulsations of the atmospheric γ rays and the periods of the solar oscillations of 1973 are in full agreement (the relative error in the measurement of the period was ~ 5%). Periods longer than 35 minutes and shorter than 11 minutes were not verified by our experiments.

It is natural to assume that the oscillations are transferred from the sum to the earth by the solar wind. Indeed, periodic oscillations of the magnetic field with close periods ($\lesssim$ 10 min) have been observed in interplanetary space.[11] It is necessary to search for similar oscillations in the earth's magnetosphere.

Observation of periodic pulsations of particle streams in the earth's atmosphere with "solar" periods is undoubtedly of interest for the purpose of revealing sun-earth relations, and possible also for the purpose of solving problems of solar seismology.

[1] M. S. Dhanju and V. A. Sarabhai, Phys. Rev. Lett. **19**, 252 (1967).
[2] Z. Fujii, S. Mori, S. Yasue, and K. Nagashima, Thirteenth Intern. Cosmic Ray Conf. 2, 783 (1973).
[3] M. Komada, T. Sakai, E. Tamai, S. Kogami, and M. Kato, Fourteenth Intern. Cosmic Ray Conf., München 3, 1120 (1975).
[4] I. M. Martin, D. B. Ray, J. M. daCosta, R. Palmaira, and N. B. Trivedi, Nature Phys. Sci. **240**, 84 (1972).

[5] I. M. Martin, D. B. Ray, R. Palmaira, N. Trivedi, M. Abdu, and J. M. daCosta, Nature **252**, 25 (1974).

[6] A. M. Gal'per, A. V. Kurochkin, N. G. Leĭkov, B. I. Luchkov, and Yu. T. Yurkin, Prib. Tekh. Eksp. No. 1, 50 (1974).

[7] M. G. Serebryannikov and A. A. Pervozvanskiĭ, Vyyavlenie skrytykh periodichnosteĭ (Detection of Latent Periodicities), Moscow, 1965.

[8] N. P. Chirkov and V. I. Ipat'ev, Kosmicheskie luchi **15**, 100 (1975).

[9] H. A. Hill, R. T. Stebbins, and T. M. Brown, Preprint SCLERA, University of Arizona; Science News **108**, 5 (1975).

[10] J. Christensen-Dalgaard and D. O. Gough, Nature **259**, 89 (1976).

[11] N. F. Ness, C. S. Scearce, and S. Cantarano, J. Geophys. Res. **71**, 3305 (1966).