III-2-9. A Search of Photons with the Energy of 10^{13} ev from Discrete Sources of Cosmic Radiation*

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In order to test the hypothesis of a high concentration of cosmic rays in certain discrete radio sources, we made an attempt to detect high energy photons coming to the earth from these objects. In this connection during August-September of 1960, the discrete radio sources Cygni A, Cassiopeiae A, and Tauri A were studied for the purpose to observe photons with the energy $E \cong 10^{13}$ ev from these sources. The investigation was carried out in the Crimea, at the sea-level.

The experimental technique was based on recording extensive air showers by the Cerenkov radiation produced by them in the earth atmosphere, and it allowed to determine direction of the primary particle which produced the shower with the accuracy of $\sim 1°$. The installation consisted of four telescopes being four parabolical mirrors 150 cm in diameter. The photomultiplier 6 cm in diameter was placed in a focus of each paraboloid. All the telescopes were arranged at the area of 3×20 m and one could orient them in the given direction. The counting of Cerenkov pulses was carried out by the method of four fold coincidences. The effective area of recording was $\sim 10^5$ m^2 for showers with the energy of 10^{13} ev. Separation of showers from primary photons was based only on the expected angular anisotropy of primary photons (angular distribution of charged primary particles assumed to be isotropic). For a search of showers from the discrete radio sources, the telescopes were oriented to the point of the celestial sphere through which the given source should pass after 0.5 hour. Then a continuous recording of the counting intensity was carried out during an hour.

If the radio source is at the same time a source of photons with $\sim 10^{13}$ ev, then we had to observe increase of the counting rate during the passage of the source through the optical axis of the telescopes. The moment of the source passage through the system optical axis was determined with the accuracy ± 1 min.

The summarized data of many observations are presented in Fig. 1.

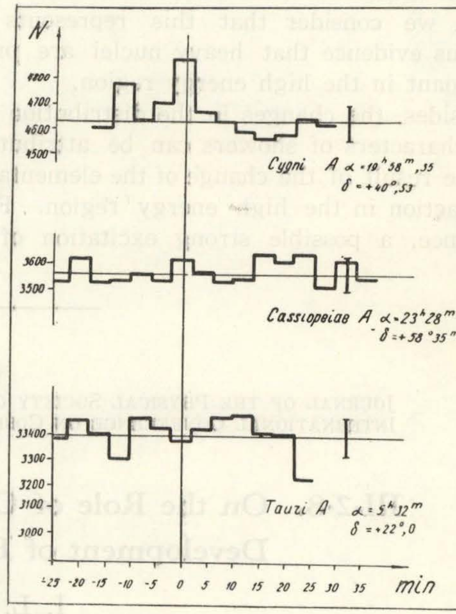

Fig. 1.

On the abscissa axis is given time relatively the moment of the source passage through the telescope optical axis. On the ordinate axis is given the total number of pulses N counted in the 4-min time intervals. A statistical error of that value is given on the right hand. Thin horizontal lines show the average value of N.

In histograms given in Fig. 1 following numbers of separate observations are included: Cygni A–15 observations, Cassiopeiae A–16, Tauri A–15. The zenith angles at which the observations were carried out were different but did not exceed 30°.

* No manuscript has been received and the prepint is reprinted.

One can see from Fig. 1 that in the case of the Cassiopeiae and Tauri any increase of the counting rate at the moment of the source passage is not observable within the statististical accuracy. In the case of the Cygni A such increase is noticeable.

An analysis of the experimental data shows that if one considers the maximum rise as an error, then the only reason of it could be statistical fluctuations.

Probability of such fluctuations in the Cygni case (see Fig. 1, increase of the counting rate averaged in the interval of ± 6 min is $2.7\pm 1.0\%$) is equal to $3\cdot 10^{-3}$. However, the histogram does not comprise four observations for which the zenith angle was greater than 30°. If one adds these four observations, then the effect falls to $1.7\pm 1.1\%$; in this case, when all statistical data are used, the probability of fluctuation is 0.06.

Thus, it is impossible yet to consider the obtained results as an evidence of the photon flux with 10^{13} ev from the object Cygni A.

In the summer of 1961 we hope to carry out measurements which must either disprove or confirm presented data.

Discussion

Greisen, K.: Experimentally, the quantities I_{Cer}/N_e, E_{core}/N_e and N_μ/N_e show less fluctuation in larger shower; on this there is agreement. But are these facts necessarily due to the primaries being heavy nuclei? Should not the fluctuations in these observed properties decrease with increasing shower size, even if all sizes of showers have protons as primaries?

Zatsepin, G. T.: Yes, fluctuations should decrease with increasing shower size. But the role of fluctuations on the other side should increase when exponent γ increases. Experimentally it is evident that decrease of fluctuations occurs in the same energy region, where γ increases.

Kraushaar, W. L.: The assumption which led to your estimate of a photon flux from the Crab equal to 10% of the cosmic ray flux in $\Omega=10^{-3}$ steradian are not clear to me.

Zatsepin: Assumptions are:

1. All the energy emitted by cyclotron radiation is equal to energy of $\pi^\pm\rightarrow\mu^\pm\rightarrow e^\pm$ decays in the same time.
2. The energy of electrons producing cyclotron radiation is about 10^{12} ev.
3. The energy transferred from $\pi^0\rightarrow 2\gamma$ decay to photons is the same as the energy transferred to electrons from $\pi^\pm\rightarrow\mu^\pm\rightarrow e^\pm$ decay.

Kasha, H.: Does the Chudakov *et al.* group select vertical showers, or rely on the telescope angle to do it? In the latter case, a large fraction of non-vertical showers may be also detected, masking the effect.

Zatsepin: The selection of a given direction in these observations was made by coincidences of pulses from four telescope with parallel axes. A control experiment showed that if the axes of telescopes are not parallel (more than 2°~3°), no coincidences are observed.

Greisen: The total energy of all photons from the Crab nebula is accurately calculable from the amount of cyclotron radiation received, under the assumptions that were mentioned. But is it not true that the energy spectrum of these photons is more doubtful, and they may almost all have energies below 10^{12} ev, instead of near 10^{13} ev?

Zatsepin: I agree that the spectrum of electrons generated in Crab is not known very well, because we de not know precise magnetic field. Therefore the intensity of high energy photons can be overestimated, if we calculate it from the intensity of cyclotron radiation. But I wish to mention that the calculated intensity of photon based on cyclotron radiation is about 10^6 times greater than the photon intensity calculated from data about the mass of dispersed matter in Crab and possible intensity of cosmic rays in it. Such discrepancy shows, that the source of energy of cyclotron radiation are not cosmic rays.

Greisen: The angles of scattering of the electrons that emit Cerenkov radiation are 10°, on the average. How is it that you expect the Cerenkov detectors to have an angular resolution as small as 1°?

Zatsepin: If we use the detection with a given threshold, the contributions of different distances will be presented by the function:

$$\rho^{\chi}(r)\cdot r\cdot dr$$

were $\rho(r)$—lateral distribution of light, χ—the exponent of the spectrum of total light emission ($\chi\simeq1.7$). Because of this average distance from the core for detected showers should be much less than for average distance of light spread. This will lead to selection of photons emitted on small angles.

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III-2-10. Cerenkov Radiation Associated with Extensive Air Showers*

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The Cerenkov light flashes accompanying the passage of EAS through the atmosphere were studied at 200 m above sea level by means of telescopes with 4.9° half-opening angle, used in conjunction with an eight-tray hodoscope. Preliminary results show that the spectrum of events accompanied by a light signal is flatter than that of all showers in the range of $\sim10^5-5\times10^6$ particles. The light intensity per shower electron is found to decrease with increasing shower size, while the fluctuations in this quantity increase with the size. The lateral light distribution between 5–80 m, rather flat ($\sim r^{-0.7}$) for showers of $<2\times10^5$ particles, increases steeply with increasing shower size. It was possible to obtain information on the angular distribution of the Cerenkov light in EAS with respect to the shower axis as viewed from a given distance from the center of the shower. It was found that the light intensity falls off by half at 10°.

First results are presented of the Technion EAS experiment being carried out in Haifa at 200 m altitude to study the Cerenkov radiation emitted in the passage of charged EAS particles through the atmosphere.

Experimental method

An eight-tray hodoscope serves as the basic shower-detection system. Each tray contains sixteen Geiger counters of 207 cm² area each. The tray positions are shown in Fig. 1: the

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