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78. ON THE POSSIBLE GAMMA-RAY SOURCE IN CYGNUS

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ABSTRACT

A source of gamma rays has been found at right ascension $20^{h}\ 15^{m}$, declination $+35°$, with an uncertainty of 6° in each coordinate. Its flux is $(1{\cdot}5 \pm 0{\cdot}8) \times 10^{-4}$ photons cm^{-2} sec^{-1} at 100 MeV. Possible identifications are reviewed, but no conclusion is reached. The mechanism producing the radiation is also uncertain.

1. OBSERVATIONS AND ANALYSIS

Evidence has been found (Duthie *et al.* 1966) for a source of gamma rays in the constellation Cygnus. The flux received is $(1{\cdot}5 \pm 0{\cdot}8) \times 10^{-4}$ photons cm^{-2} sec^{-1} at 100 MeV. The direction of the source is $\alpha = 20^{h}\ 15^{m}$, $\delta = +\ 35°$, with an uncertainty of 6° in each coordinate.

The detector used to find this source was a spark chamber triggered by a counter telescope. The observational result was obtained by examining photographs of tracks recorded in the spark chamber during exposure of the detector at an altitude of 120 000 feet (36 km), corresponding to a residual atmosphere of 4 g/cm^2. This is small compared to the interaction length in the atmosphere of protons (90 g/cm^2) and gamma rays (37·7 g/cm^2). A lead plate converted the gamma rays into electron-positron pairs.

In the observations there are two anomalies which we interpret as evidence of a source of gamma radiation. First the bisectors of the positron and electron directions were obtained. These bisector directions were then assembled into cells of equal size and exposure. The cells were all 9° wide in right ascension and 30° wide in declination, and were all centered at declination $+31\overset{\circ}{.}5$, the approximate zenith throughout the flight of the detector. The mean number of events per cell was 19·5; at 20^{h} right ascension the number was 31·8. The fractional counts are a result of statistical removal of background fluctuations expected from slight altitude variations throughout the flight. The size of the cells may appear large, but it reflects the crudeness of the directional information as we shall show presently. The count in the cell at 20^{h} right ascension represents an excess of 2·8 standard deviations, an occurrence which should appear once per 300 cells, while we have 16 cells in our sample. The excess count is interesting, but by itself it is not statistically very convincing. What is significant, however, is that a second parameter is anomalous in the same part of the sky.

The opening-angle distribution of detected events over the whole sky has a broad maximum extending over ten degrees. The breadth of this distribution indicated that the present experimental device is not good for the angular resolution of sources. The angular uncertainty in the direction of any photon is of the order $\theta/2$, where θ is the opening angle of the pair.

Examination of our data concerning the rate anomaly in the region of $\alpha = 20^h$ suggested that the anomaly might be centered at about $\delta = +35°$. We selected all events whose bisector fell within a box, 18° by 18° in size, centered at $\delta = +35°$, $\alpha = 20^h$. A statistical analysis of the opening-angle distribution of these events indicated that it was not consistent with the distribution over the whole sky discussed in the previous paragraph. A χ^2 test of the hypothesis that this distribution could have arisen as a result of statistical fluctuations indicated that there was only one chance in 300 of such an occurrence.

From an analysis of scans at fixed declinations, we estimate the location of the source at $\alpha = 20^h 15^m$, $\delta = +35°$. The distribution of events around this location has a halfwidth of 12°.

Other experimenters have exposed detectors to look for primary gamma-rays. In the same region, Kraushaar *et al.* (1965) with the Explorer XI experiment set an upper limit of 5×10^{-4} cm^{-2} sec^{-1} on the flux of Cyg A at 100 MeV, and Frye and Smith (1966) have set upper limits of $1{\cdot}8 \times 10^{-4}$ cm^{-2} sec^{-1} on both Cyg XR–1 and Cyg A. Neither of these results is inconsistent with our own observations of a flux of $1{\cdot}5 \times 10^{-4}$ cm^{-2} sec^{-1}.

2. POSSIBLE IDENTIFICATIONS

For purposes of identification, we consider the region from $19^h 9^m$ to $20^h 54^m$ in right ascension and from +23° to +47° in declination as having a high probability of including the source. The history of attempts to identify radio sources in 1948, when similar directional information was available, warns us against too great optimism.

This region, for example, contains four stars brighter than magnitude 3: δ Cyg, γ Cyg, α Cyg and ϵ Cyg. It further contains the nova of 1670 (CK Vul) as well as the shell star P Cyg. One can choose between six planetary nebulae and twenty-six H II regions out of Sharpless's list of 313. It is unlikely that any of these common objects is uniquely bright in the gamma-ray region.

The revised 3C catalogue lists twelve radio sources in this region, of which Cyg A (3C 405) is a well-known suspected gamma-ray and X-ray source. At 178 MHz, it is approximately twenty times brighter than the brightest parts of Cyg X, which is believed to be a collection of H II regions.

Among the observed X-ray sources reported by Friedman's group at the Naval Research Laboratory, Cyg XR–1 and Cyg A are within this region. To our knowledge, only Tau XR–1 has been definitely identified with an optical object, the Crab Nebula.*

Grader *et al.* (1966), of the Lawrence Radiation Laboratory, report that the spectrum of Cyg XR–1 extends further toward high energies than those of Sco X–1 and Tau XR–1. At energies above 100 keV, it appears to be the brightest X-ray source known. Cyg XR–1 is also unique among X-ray sources in that Byram *et al.* (1966) report a 75% decrease of its intensity in 10 months—cf. Paper 75, Section 2.

3. POSSIBLE EXPLANATIONS

With our present scanty knowledge of this source, it is difficult to be precise in explaining the origin of the radiation. The following statements, however, appear reasonably supported.

* See, however, the report by Rossi (Paper 75).—*Editor.*

(*a*) The radiation is not produced in the same way as the background X-rays (that is, as a decay product of π-meson production from interactions of cosmic rays with local gas). If this were the case, the opening-angle distribution would be much narrower.

(*b*) The radiation could be produced by proton-antiproton annihilation, although we have not quantitatively examined this unlikely possibility yet.

(*c*) The synchrotron mechanism leads to rather fantastic numbers. For a source at 1 kpc distance, with $H = 10^{-5}$ gauss, one needs 10^{39} electrons with energies of 10^{16} eV or higher and a mean life of 2 months. The X-ray flux from Cyg XR–1 is also unlikely to arise from this mechanism, for the same reason.

(*d*) Bremsstrahlung seems the most likely process. It would require electrons of energies comparable to those observed in the local cosmic rays (say above 10^8 eV) in numbers like 3×10^{55} for a source of 1 kpc distance, and density 1 hydrogen atom/cm^3. For condensed matter, say 10^{12} atoms/cm^3, the energy remains the same but only 3×10^{43} electrons would be required. The lifetime of those electrons would be 10^9 years for interstellar densities, and 10 hours for densities of 10^{12} cm^{-3}.

(*e*) The inverse Compton effect could scatter some of the observed X-rays into our measuring band. Because of the small cross-section, bremsstrahlung would exceed the inverse-Compton radiation by the same electrons for densities above 10^{-5} cm^{-3}. The optical photon spectrum is unknown. For 1-eV photons scattered by electrons of 5×10^9 eV to produce the observed flux, about 10^{54} electrons would be required, if one assumes a photon density of 1 cm^{-3}, characteristic of the Galaxy, and a distance of 1 kpc.

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NOTE ADDED TO PROOF

In a paper published after the submission of this report, Frye and Wang (1967) claim that they have found no evidence to support our observation. We have re-evaluated our data and found no evidence of instrumental malfunction. Suggestions of large time variations in the intensities of X-ray sources in this region have been made by Friedman *et al.* (1967). Such effects may also explain the inconsistencies between our own and Frye's data.

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