SPARK-CHAMBER OBSERVATION OF GALACTIC γ-RADIATION

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Abstract. A γ-ray telescope incorporating an acoustic spark chamber is included in the payload of the OGO-5 spacecraft. The performance of the instrument, which is sensitive to photons of energy 25 to 100 MeV, is discussed.

Observations are limited to a portion of the sky near Cygnus, but the first month's data indicate a variation of intensity showing a maximum in the direction of the galactic plane. If this plane contains a line source of radiation, its intensity is found to be $(9 \pm 5) \times 10^{-4}$ photons cm^{-2} sec^{-1} rad^{-1} above an energy of 40 MeV.

1. Introduction

The study of extraterrestrial γ-radiation is inhibited by the low intensity of this radiation compared with that of γ-rays produced in the earth's atmosphere by interactions of cosmic rays and with the much higher intensity of the charged cosmic rays themselves. A γ-ray astronomy experiment should therefore have a large geometrical factor (coupled with a good angular resolution for the observation of anisotropies) and be situated in an environment as free as possible of terrestrial radiation. The combination of wide acceptance solid angle and narrow angle of resolution in a device suitable for a satellite experiment suggests the spark chamber as an ideal instrument. The inclusion of such an experiment in an earth-oriented spacecraft in an eccentric orbit has advantages in the elimination of terrestrial interference, though imposing constraints on the field of view. The present experiment is the first application of the spark-chamber technique to satellite γ-ray astronomy.

2. Experiment Operation

The instrument is shown schematically in Figure 1 and has been described in detail by Dean *et al.* (1968). It includes a six-gap acoustic spark chamber of sensitive area 102 cm^2 surrounded by a scintillation-plastic anticoincidence counter. The chamber is triggered by a counter telescope, of acceptance solid angle 0.2 sr, consisting of a directional Čerenkov counter and a plastic scintillator. The anticoincidence veto may be relaxed on command to allow the recording of cosmic-ray protons for calibration purposes.

The experiment is included in the payload of the spacecraft OGO-5 which was launched on 4 March 1968 into an eccentric earth orbit with an apogee of 24 earth radii. The spacecraft is earth-oriented and the experiment is mounted so that the centre of its acceptance solid angle is directed away from the earth. Experiment operation is limited to the period when the spacecraft is outside the radiation belts because the high flux of charged particles renders the anticoincidence counter inoperative and could permanently change the characteristics of the photomultiplier

L. Gratton (ed.), Non-Solar X- and Gamma-Ray Astronomy, 300–305.

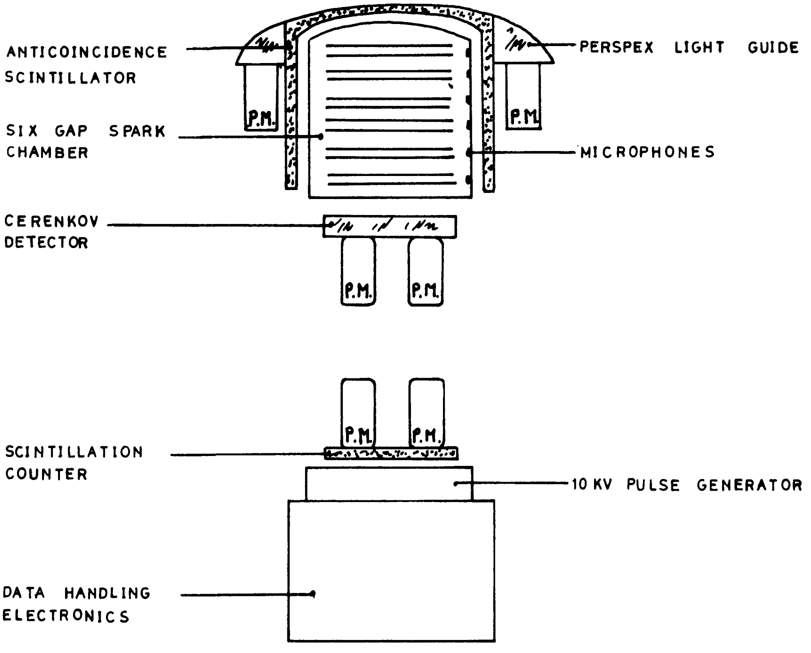

Fig. 1. The experiment configuration.

tubes. Although this represents about 85% of the orbital period the region of sky scanned is restricted to a fairly small area near the direction of apogee. The axis of the telescope scans along the orbital plane from 18^h R.A., $+30°$ decl. to 22^h R.A., $+7°$ decl. but the aperture has a full width at half maximum approaching 30°, in practice restricted to 18° by event-selection criteria (see Section 3).

In orbit it was found that the triggering rate of the experiment was much higher than expected. This was interpreted as an indication that the efficiency of the anticoincidence system was much lower than had been indicated by preflight laboratory tests. This interpretation was confirmed by analysis of spark-chamber data which showed that the majority of events produced sparks along the whole length of their trajectory in the spark chamber and that the directions of incidence of the triggering particles were isotropic as would be expected if they were charged cosmic rays. The distribution of the points of entry of the particles over the surface of the anticoincidence counter was found to be uniform so it is believed that the fault is not in the detector assembly but in the operation of the veto electronics at high counting rates.

This malfunction imposed some restrictions on the operation of the experiment. The high rate of operation appears to have reduced the useful life of the spark chamber to about 5 months, during the last two of which a temporary data anomaly rendered subsequent analysis difficult. In addition the power supply limitations of the spark chamber high-voltage pulse system impose a dead time of 9.2 sec which is long compared with the actual triggering interval so that experiment live time can only be about 10% of real time. As a result of these two effects the total observation time is much less than had been hoped.

3. Data Analysis

In analysing the data genuine γ-rays were selected by using the upper gaps of the spark chamber as additional anticoincidence counters. The efficiency of the six spark gaps were measured from in-flight proton data to be better than 95%, with the exception of the 4th gap which failed 12 hours after the experiment was turned on.

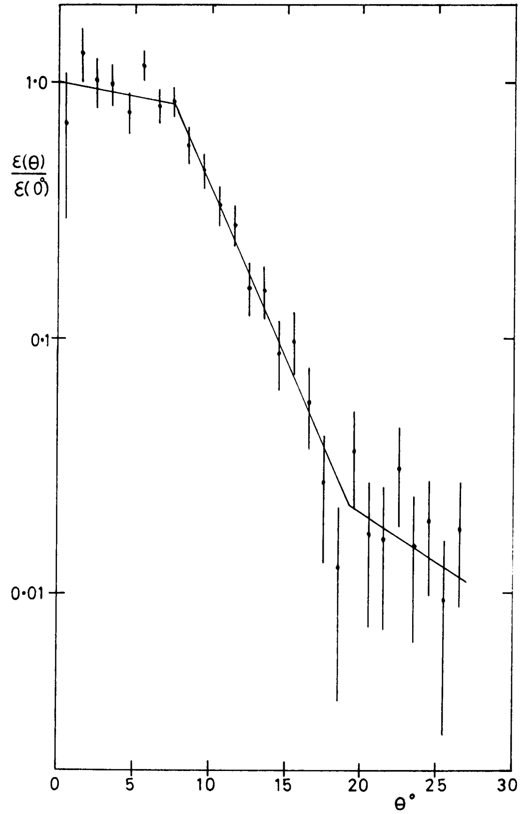

Fig. 2. Variation of detection efficiency, E, with angle of incidence, θ, for particles incident through the top of the spark chamber.

Therefore selection of those events showing sparks in gaps 3, 5 and 6 on a track projecting through the sensitive area of gaps 1 and 2 would include about a 3% contamination of protons (taking the efficiency of the anticoincidence veto to be 75% as indicated by the relative counting rates in the γ- and proton modes). In addition to these requirements confidence in the direction measurement of the γ-rays required the sparks to be collinear within the errors of location, giving an accuracy of about 5°. In the first three months of operation 195 events satisfied these criteria and the present conclusions are derived from an analysis of the first 88 of these.

In order to know the effective viewing time as à function of direction it was necessary to have a measure of the off-axis response of the detector. This was obtained by relaxing the anticoincidence veto for a short period and recording cosmic-ray protons which were assumed to be isotropic. The variation of relative counting rate with

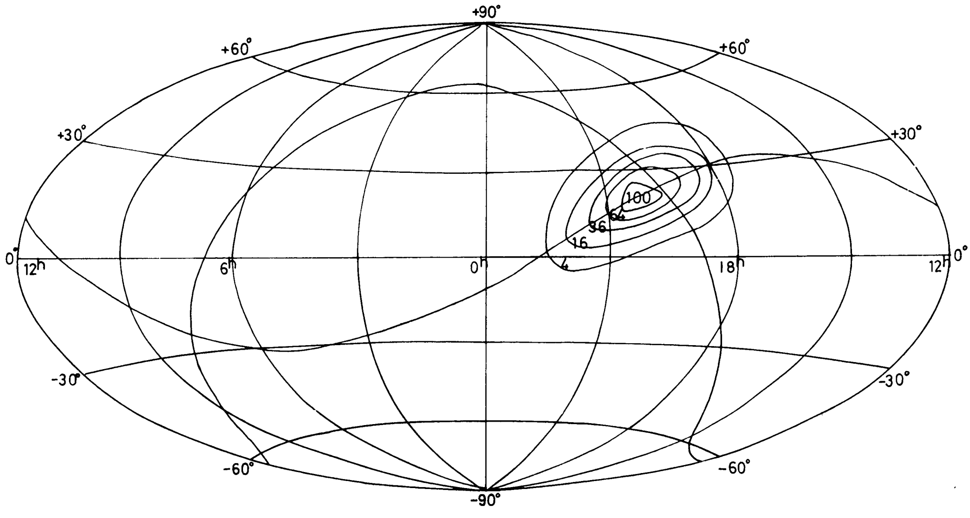

Fig. 3. Contours, in celestial coordinates, of equal effective viewing time, expressed as a percentage of the maximum.

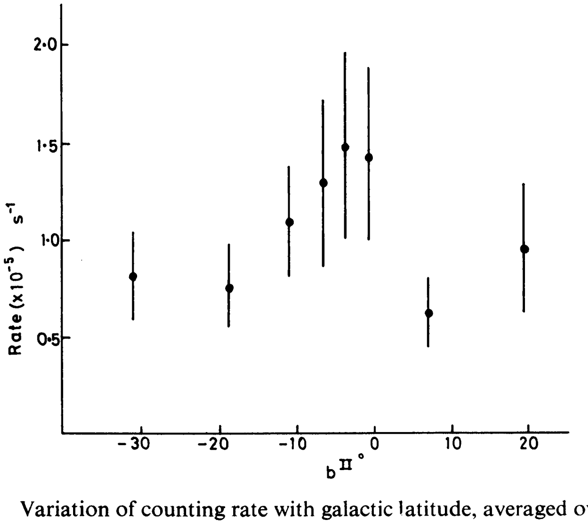

Fig. 4. Variation of counting rate with galactic latitude, averaged over the longitude range $45° < l^{II} < 75°$.

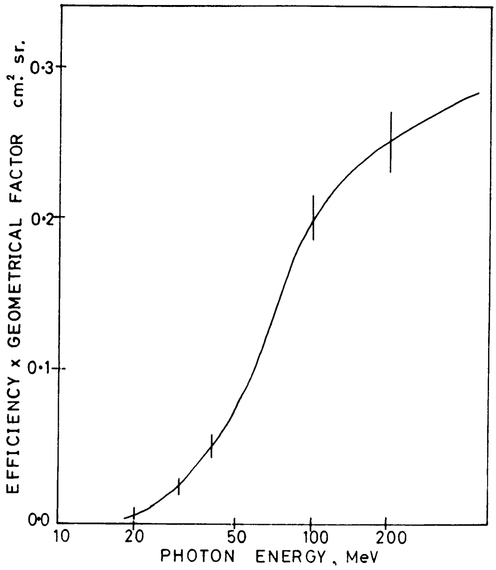

Fig. 5. Variation with energy of the detector response for γ-rays satisfying the selection criteria.

angle to the detector axis, for protons entering the chamber through the sensitive area of the first gap, is shown in Figure 2. For simplicity of analysis three exponential curves were fitted to the experimental points. This result was folded with the distribution of pointing-time for the direction of telescope axis (corrected for the large dead-time effect) to obtain the effective viewing time, defined as the time a particular direction would have to lie on the axis to obtain equivalent observation. Figure 3 shows contours of this parameter in celestial coordinates.

γ-ray events were divided amongst bins 3° square and the number of events in each bin was divided by the effective viewing time for that direction. The results are shown in Figure 4 as a function of galactic latitude, averaged over the range of longitude viewed by the experiment ($45° < l^{II} < 75°$). There is evidence for an excess flux from a direction close to the galactic plane.

4. Line-Source Interpretation

Since the width of the peak in Figure 4 is comparable with the angular resolution of the experiment the suggestion of Clark *et al.* (1968) that an equivalent line-source intensity may be defined can be followed. In order to quote an intensity at a specified energy the energy response of the instrument must be known. This has been estimated by means of a Monte Carlo computer program, the result of which is shown in Figure 5 as the product of conversion efficiency, detection probability (subject to the selection criteria set out in Section 3) and geometrical factor. If the detected γ-rays have a differential spectrum proportional to E^{-2} the relative counting rate varies

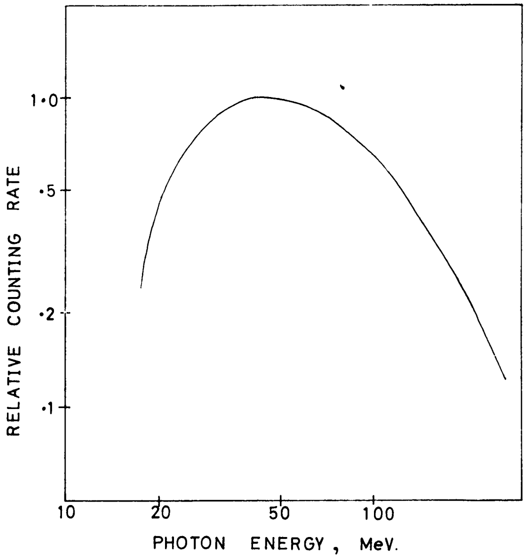

Fig. 6. Relative counting rate of selected γ-rays as a function of energy, assume an energy spectrum of the form $N(E)\,dE \propto E^{-2}\,dE$.

with photon energy as shown in Figure 6. The most probable energy for detection is seen to be about 40 MeV.

The line source intensity for photons of energy greater than 40 MeV is then found to be $(9 \pm 5) \times 10^{-4}$ cm^{-2} sec^{-1} rad^{-1}. This result may be compared with the intensity of γ-rays above 100 MeV from the corresponding longitude measured by the OSO-3 experiment (Clark *et al.*, 1968; Kraushaar, 1970). The comparison supports the assumption, made in the derivation of both results, of an E^{-2} differential spectrum.

Acknowledgements

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References

Clark, G. W., Garmire, G. P., and Kraushaar, W. L.: 1968, *Astrophys. J.* **153**, L203–L207.
Dean, A. J., Hutchinson, G. W., Ramsden, D., Taylor, B. G., and Wills, R. D.: 1968, *Nucl. Instr. Meths.* **65**, 293–300.
Kraushaar, W. L.: 1970, this volume.