γ-RAY ASTRONOMY BALLOON RESULTS

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1. Introduction

The significance of high energy ($\gtrsim$30 MeV) γ-ray astronomy and its relationship to cosmic rays and many of the high energy processes of the universe has been realized for over a decade. Through the last six to eight years, searches for point sources, mostly from balloon experiments, but also Explorers 11 and OSO-3, have been unsuccessful in clearly establishing the existence of any point source. Recently on OSO-3, Clark *et al.* (1968) have obtained positive evidence for a celestial γ-ray flux which is anisotropic with a higher intensity in the direction of the galactic center region. In this talk, I wish to summarize our balloon results relating to both of these questions and indicate what we hope to accomplish with our new large γ-ray detector over the coming months.

2. 6″ × 6″ Digitized Spark Chamber γ-Ray Telescope

Development of this smaller detector system began in January, 1964, and it has been flown on balloons over the last three years.

A. DETECTOR

The detector system itself is shown in Figure 1 and has been described in detail previously (Ehrmann *et al.*, 1967). The large plastic scintillator anticoincidence dome together with the directional Čerenkov counter is employed to restrict the analysis to downward moving particles and discriminate against charged particles. The spark chamber satisfies the need for a large volume high information content detector to permit selection of the γ-rays and measure the properties of the negatron-positron pair. The central plastic scintillator together with the Čerenkov counter in coincidence and the plastic dome in anticoincidence provides the information to determine whether or not the spark chamber would be triggered. Each of the grid wires in the spark chamber threads a magnetic core, which receives and contains its datum of information when the high voltage is pulsed to the chamber plates. The cores are then read out, and the 'picture' of the e^+, e^- event is telemetered to the ground station.

B. ANALYSIS

A picture of the type shown in Figure 2 can be reconstructed for each event. From an analysis of the coulomb scattering of the electrons in the plates, an estimate of the energy of the electrons and hence the γ-ray can be made. With this information and the direction data resulting from the balloon gondola aspect system, the direction of

L. Gratton (ed.), Non-Solar X- and Gamma-Ray Astronomy, 315–320.

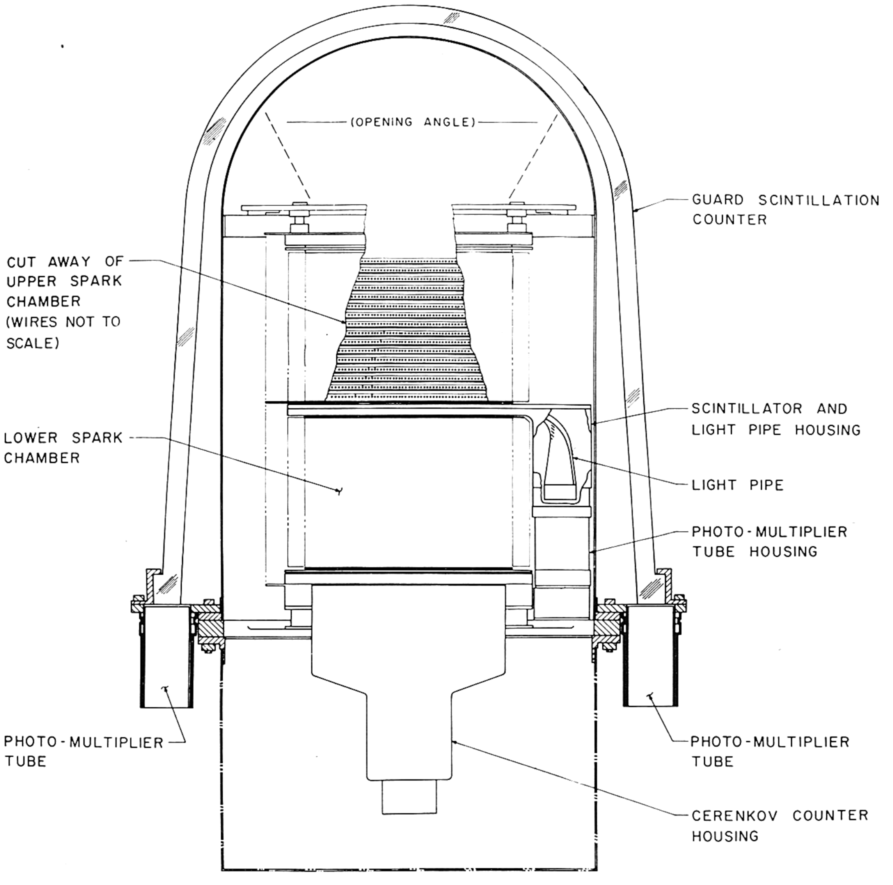

Fig. 1. Schematic diagram of the 6″ × 6″ spark chamber γ-ray telescope flown on balloons over the last three years.

the γ-ray can be determined. This analysis is described in detail in a recent paper (Fichtel *et al.*, 1969) and earlier papers by Pinkau (1966, 1967) and Kniffen (1967).

The uncertainty in the γ-ray energy is determined to be about 30% at 30 MeV and increases to about a factor of 2 at 150 MeV.

C. RESULTS

(a) Point sources: We have now obtained upper limits on a large number of possible point sources, and have no positive evidence for a flux. The limits are generally similar to or above straight line extrapolations of X-ray sources; so negative results are not surprising. The way in which these limits are calculated must be considered carefully. This procedure is described in detail in the paper by Fichtel *et al.* (1969) together with the limits obtained, and will not be reported here.

(b) Galactic Center Region: In the introduction it was mentioned that, with an experiment on OSO-3, Clark *et al.* (1968) detected γ-rays from the galactic plane with a flux which was strongest in the region near the galactic center. In an earlier paper, results of our group were published which set an upper limit for the flux from a point source assumed to be at the galactic center of about $3 \times 10^{-5}/(\text{cm}^2 \text{ sr sec})$ above 100 MeV. The balloon flight data including the galactic center region have now been reanalyzed in terms of a possible line source of finite width centered about the galactic plane.

In the analysis of the balloon flight data obtained in the flight on Dec. 10, 1966, four different spatial intervals were examined; these were contained within the contour for 50% of maximum detection efficiency and $+15°$ to $-15°$ galactic latitude. For each region, the number of observed γ-rays above 100 MeV and above 150 MeV was determined, the flux calculated, and the atmospheric background determined over a region away from the galactic plane subtracted. The resulting flux was then converted to a line intensity and the results are shown in Table I.

The results in Table I by themselves do not justify the claim of a detected flux, but

TABLE I

γ-ray line intensity with one standard deviation errors along the galactic plane from galactic longitude $-10°$ to $+25°$ in γ's/(cm² sec rad)

Energy interval	Galactic latitude interval			
	$-15°$ to $+15°$	$-10°$ to $+10°$	$-5°$ to $+5°$	$-3°$ to $+3°$
30–100 MeV	$0.9^{+2.2}_{-0.9} \times 10^{-4}$	$1.1^{+1.8}_{-1.1} \times 10^{-4}$	$0^{+1.0}_{-0} \times 10^{-4}$	
> 100 MeV	$2.4^{+2.4}_{-2.4} \times 10^{-4}$	$(2.9 \pm 2.0) \times 10^{-4}$	$(2.2 \pm 1.4) \times 10^{-4}$	$(2.2 \pm 1.1) \times 10^{-}$
> 150 MeV	$0^{+2.1}_{-0} \times 10^{-4}$	$0^{+1.7}_{-0} \times 10^{-4}$	$(1.2 \pm 1.2) \times 10^{-4}$	$(1.7 \pm 1.0) \times 10^{-4}$

the line intensity of $(2.3 \pm 1.2) \times 10^{-4}$ γ's/(cm² sec rad) above 100 MeV for the $+3°$ to $-3°$ interval is certainly consistent with a positive flux, and not in disagreement with a line intensity of $(4.1 \pm 0.7) \times 10-^{4}$ γ's/(cm² sec rad) observed in the OSO-3 γ-ray experiment.

An interesting comparison can be made between the balloon results discussed here and the OSO-3 results for the upcoming γ-rays from the earth's atmosphere. The flux of γ-rays coming directly upwards is essentially the same at the balloon altitude of this experiment (~ 3 g/cm²) as it is outside the atmosphere, basically because the interaction mean free path of both the charged cosmic rays and γ-rays is large compared to 3 g/cm². The flux of upward atmospheric γ-rays above 100 MeV measured in this experiment over a solid angle similar to the OSO-3 experiment was $(3.7 \pm 0.8) \times 10^{-3}$ γ-rays/(cm² sr sec).

The fluxes of upcoming γ-rays ($E > 100$ MeV) measured on Explorer 11 (Kraushaar *et al.*, 1965) and on OSO-3 (Clark *et al.*, 1969) at corresponding geometric latitudes

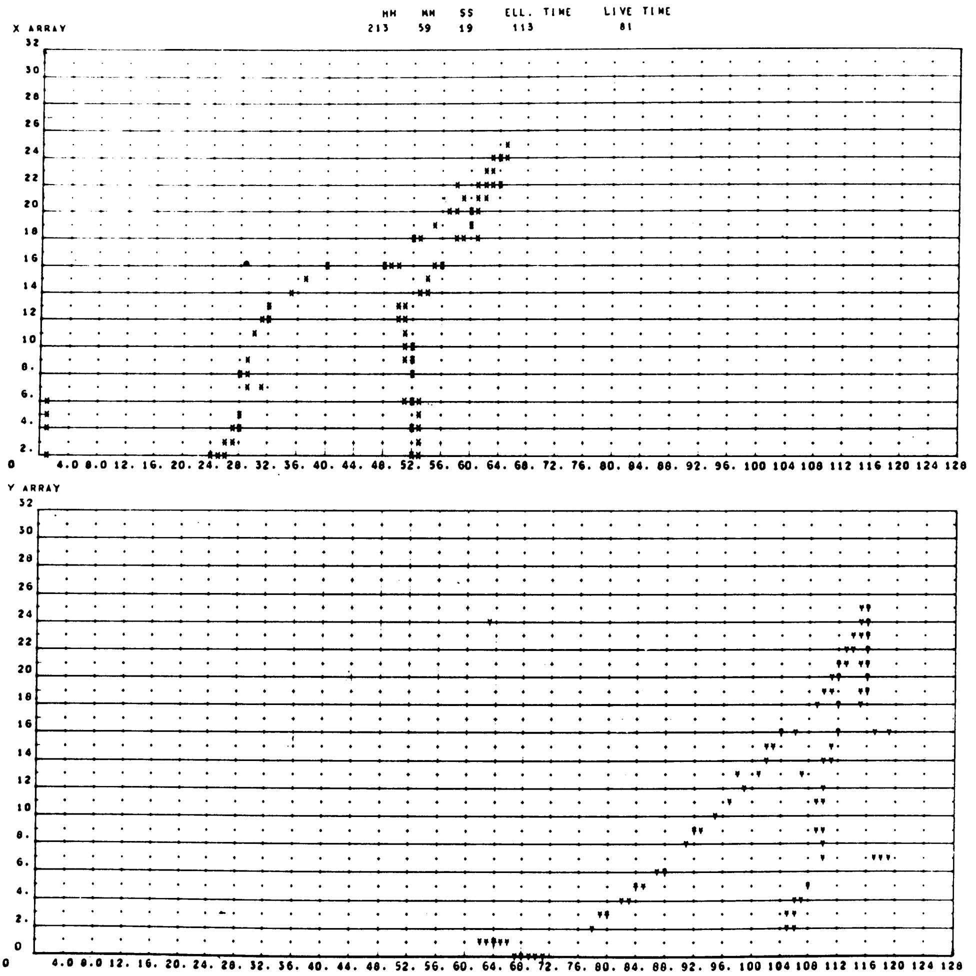

Fig. 2. Computer printout of the magnetic cores showing a γ-ray event in the $6'' \times 6''$ spark chamber. The top view shows the projection from one side view and the bottom from an orthogonal one. The vertical scale is compressed relative to the horizontal one by a factor of about 3. The wires of the 17th and 1st decks are at an angle of 45° with respect to the rest to remove the ambiguity of which track in the x-view is associated with which in the y-view. These decks are not shown in the x-array, but are added for information as the zero and first deck in the y-array.

are $(1.9 \pm 0.5) \times 10^{-3}$ and $(10.5 \pm 1.0) \times 10^{-3}$ γ-rays/(cm^2 sr sec) respectively. Notice that the Explorer 11 results fall below the measurement reported here, but the OSO-3 result is appreciably higher. The differences seem larger than would be expected on the basis of estimated errors, but are small compared to the differences of more than an order of magnitude between the galactic γ-ray flux observed by OSO-III and the predicted one. The differences may in part be due to the steep energy spectrum of the upward γ-rays which makes calibration more difficult.

3. Future Experiments

About two years ago work began on a γ-ray telescope with 10 times the area of the 6″ chamber and having a total of 25200 cores. In order not to lose the advantage of the increased area to dead time resulting from chamber readout, the telemetry data rate was increased by a factor of 8 from 1.5 to 12 kilobits/sec. This instrument is

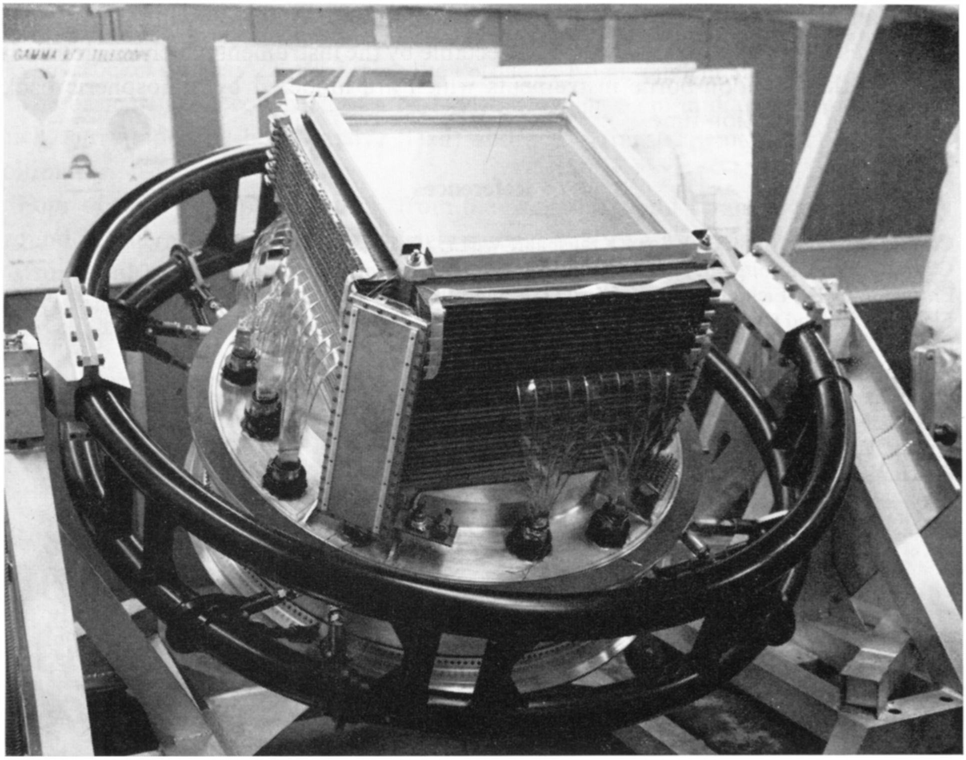

Fig. 3. A picture of the $\frac{1}{2}$ m by $\frac{1}{2}$ m γ-ray spark chamber balloon telescope with the cover and anticoincidence dome removed.

now built, and Figure 3 shows a picture with the cover and anticoincidence dome removed. Unfortunately a balloon burst prevented us from presenting results here, but we hope to have a second balloon flight around the first of July, 1969.

With this detector system, the flux from the galactic plane will be easily detected and will be particularly striking if it is concentrated in a band with a width or the order of 6° or less about the galactic plane. Not only a measure of the flux, but also an estimate of the energy spectrum will be possible. This detector system is equipped to look for supernovae γ-ray bursts resulting from hydromagnetic shock waves reaching the supernovae surface. The experimental method used is described by Fichtel and Ogelman (1968). It will also be possible to search for pulsed radiation even from pulsars with periods as short as that of the Crab, since accurate timing is recorded to the nearest millisecond.

The SAS-B γ-ray satellite experiment has now been approved and work has commenced. Its area will be about three times as large as that of the $6'' \times 6''$ spark chamber telescope, and both the supernovae and the pulsar modes will be included. This experiment will be able to obtain the angular distribution of the γ-radiation measured by OSO-3 to an accuracy of about $1°$ and measure the flux and energy spectrum uncontaminated by atmospheric background. A search will also be made for point sources of γ-rays at the level detectable by the instrument which is significantly lower than balloon-borne instruments which are hindered by atmospheric background and collection time.

References

Clark, G. W., Garmire, G. P., and Kraushaar, W. L.: 1968, *Astrophys. J.* **153**, L203.
Clark, G. W., Garmire, G. P., and Kraushaar, W. L.: 1969, private communication.
Ehrmann, C. H., Fichtel, C. E., Kniffen, D. A., and Ross, R. W.: 1967, *Nucl. Instr. Meth.* **56**, 109.
Fichtel, C. E. and Ogelman, H. B.: 1968, NASA TN D-4732.
Fichtel, C. E., Kniffen, D. A., and Ogelman, H. B.: 1969, *Astrophys. J.* **158**, 193.
Kniffen, D. A.: 1967, Ph. D. Thesis, Catholic University.
Kraushaar, W. L., Clark, G. W., Garmire, G., Helmken, H., Higbie, P., and Agogino, M.: 1965, *Astrophys. J.* **141**, 845.
Pinkau, K.: 1966, *Z. Phys.* **XCCVI**, 163.
Pinkau, K.: 1967, *Nucl. Instr. Meth.* **57**, 173.