OBSERVATIONS ON DIFFUSE COSMIC X-RAYS IN THE ENERGY RANGE 20–120 keV

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In this paper we present observations of the diffuse background X-rays in the energy range 20–120 keV, based on two balloon experiments carried out from Hyderabad (latitude 17.6°N, longitude 78.5°E), India. The flights were made on April 28, 1968 and December 22, 1968. The detector used was a NaI(Tl) crystal of effective area 97.3 cm^2 and thickness 4 mm. The crystal was surrounded both by active and passive collimators. The passive collimator was a cylindrical graded shield of lead, tin, and copper, and the active collimator was a plastic scintillator surrounding the shield. The FWHM of the telescope was 18.6° and the geometrical factor for isotropic radiation 13.2 cm^2 sr. The pulses from the NaI crystal were sorted into ten contiguous channels extending from 17 to 124 keV. An Am^{241} source came into the field of view of the telescope periodically and provided in-flight calibration of the detector. All the information was recorded on photographic film.

The X-ray telescope was mounted on a oriented platform which was programmed to look in specified directions in the sky. The axis of the telescope was inclined at an angle of 25° with respect to the zenith in the first flight and at an angle of 32° in the second flight. In the 28th April flight, the plan was to look alternately in the North and South directions for about 10 min. However the orientor did not function quite the way it was planned. While it did point for considerable time in the prescribed directions, it suffered oscillations and also got locked in directions in which it was not programmed to look. Since a pair of orthogonal flux gate magnetometers provided information on the aspect continuously, it was possible to retrieve the data unambiguously and obtain results on both the background X-rays and discrete sources.

In the flight on 22nd December, the orientor worked perfectly. The telescope was programmed to point in four specific directions i.e. N$(\phi=0)$, S$(\phi=180°)$, SW$(\phi=110°)$, and NE$(\phi=310°)$. In this flight, the telescope picked up Sco X-1 in the South direction, and Cygnus X-1 in NE$(\phi=310°)$. and a new source in the direction SW $(\phi=110°)$. In the North $(\phi=0)$, there was no source during the period of observation and therefore information on background X-rays, was obtained from this direction.

Table I summarises the experimental results from the two flights. The atmospheric background counts were obtained by plotting the counting rate vs. altitude between 50 g/cm^2 and 10 g/cm^2 and fitting a least square line through the experimental points, and extrapolating to the floating altitude. The attenuation factors given in the table include the attenuation due to the intervening atmosphere in the direction of the axis of the telescope and also the attenuation in the aluminum wall of the

L. Gratton (ed.), Non-Solar X- and Gamma-Ray Astronomy, 289–296.

TABLE I

Data on the diffuse X-ray background from flights on 28.4.68 and 22.12.68

Date of flight	Energy interval keV	Mean energy keV	Total counts per sec	Atmospheric background counts per sec	Cosmic X-ray counts per sec	Attenuation factor (Air + Al)	Flux Photons/keV cm² sec sr.	Flux keV/keV cm² sec sr.
28th April, 1968	23.4 – 31.50	27.5	1.97 ± 0.05	1.12 ± 0.10	0.85 ± 0.11	12.00	$(9.55 \pm 1.24) \times 10^{-2}$	2.70 ± 0.34
Ceiling alt.	31.50– 47.7	39.6	3.43 ± 0.07	2.17 ± 0.13	1.26 ± 0.15	4.70	$(2.76 \pm 0.33) \times 10^{-2}$	1.09 ± 0.13
5.3 g/cm²	47.70– 72.0	59.8	6.96 ± 0.09	5.18 ± 0.08	1.76 ± 0.12	3.00	$(1.66 \pm 0.12) \times 10^{-2}$	$(9.92 \pm 0.71) \times 10^{-1}$
	72.0 – 97.4	84.6	6.74 ± 0.08	5.70 ± 0.07	1.04 ± 0.11	2.66	$(8.10 \pm 0.85) \times 10^{-3}$	$(6.85 \pm 0.68) \times 10^{-1}$
	97.4 –123.7	110.5	5.21 ± 0.05	4.93 ± 0.07	0.28 ± 0.08	2.42	$(1.92 \pm 0.54) \times 10^{-3}$	$(2.12 \pm 0.59) \times 10^{-1}$
22nd December, 1968	29.9 – 52.30	40.1	5.22 ± 0.10	4.28 ± 0.11	0.94 ± 0.14	8.30	$(2.62 \pm 0.50) \times 10^{-2}$	1.05 ± 0.20
Ceiling alt.	52.30– 74.70	63.5	5.63 ± 0.10	5.23 ± 0.15	0.40 ± 0.17	4.92	$(6.59 \pm 2.83) \times 10^{-3}$	$(4.18 \pm 1.79) \times 10^{-1}$
7.5 g/cm²	74.70–118.70	96.7	11.6 ± 0.15	11.30 ± 0.20	0.30 ± 0.25	3.97	$(2.07 \pm 1.68) \times 10^{-3}$	$(2.00 \pm 1.62) \times 10^{-1}$

Geometrical factor of the telescope for isotropic radiation: 13.2 cm² sr.

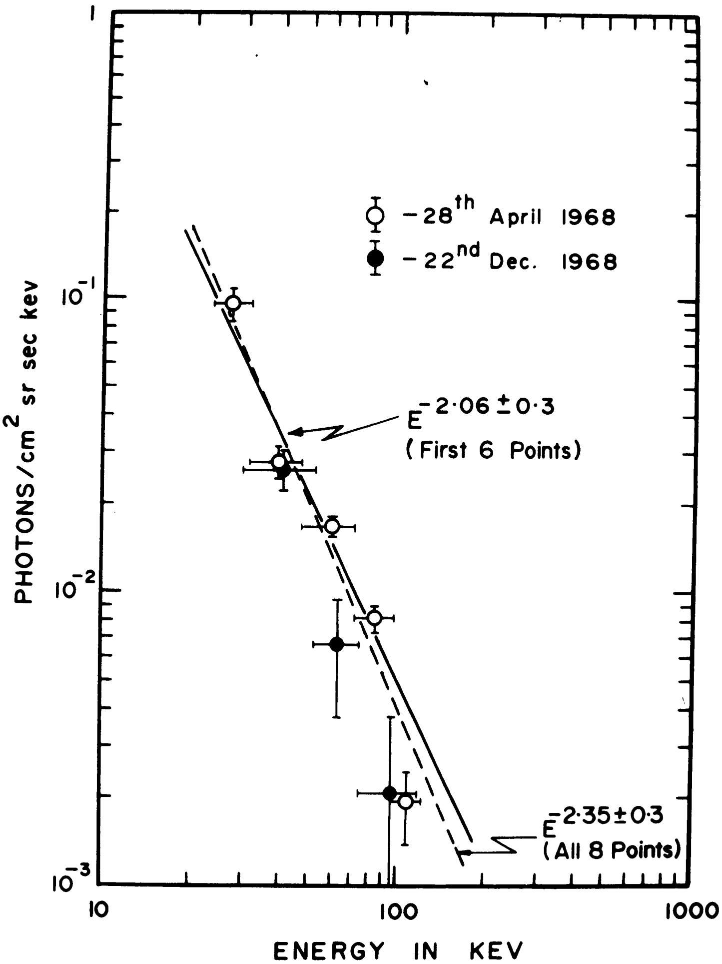

Fig. 1. Spectrum of diffuse X-ray background measured on April 28, 1968 and December 22, 1968.

pressurised gondola in which the entire instrument including the oriented telescope was housed.

In Figure 1, we have plotted the spectral data obtained in the two flights in the energy range 23 to 124 keV, and in Figure 2, a comparison is made with other experimental results [1–3] obtained at balloon altitudes. In Figure 3, we have superimposed our data on the composite spectral curve given by Gorenstein *et al* [4] which covers the range from 0.1 keV to 10 MeV.

Our own data (Figure 1) may be fitted with a power law spectrum $dN/dE = 204\ E^{-2.35 \pm 0.3}$ in the energy range 23.0 to 124 keV. However, it is evident from Figure 1, the two points corresponding to mean energies greater than 90 keV, fall much below the dotted curve, suggesting that a single slope may not fit the entire data very well. The least square line corresponding to the first 6 points has a scope 2.06 ± 0.30,

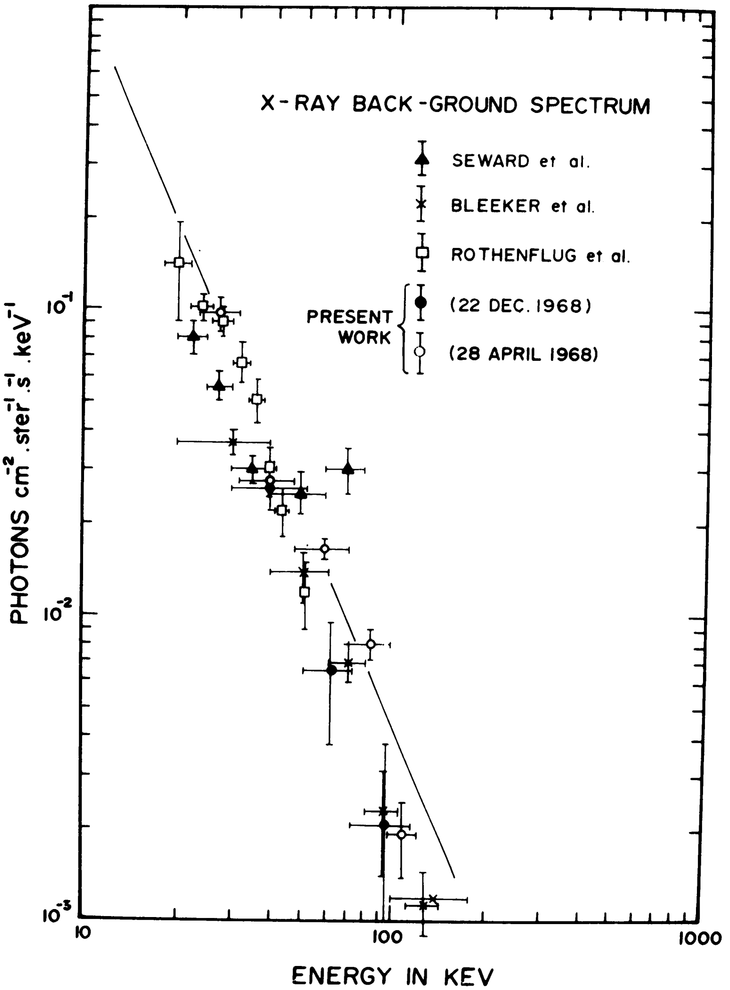

Fig. 2. The photon intensities of diffuse X-rays measured in the present experiments and by other investigators at balloon altitudes. The straight line of slope, −2.35, as in Figure 1, is shown for comparison only.

and the spectrum in the energy range 23 to 80 keV may be represented by $dN/dE = 69.4E^{-2.06 \pm 0.30}$ photons/keV cm^2 sec. sr.

Figure 2 brings out more clearly the existence of a break in the spectrum of the diffuse background X-rays, the slope changing somewhere around 60 to 80 keV.

As already pointed out, in the flight on 28th April, the telescope not only looked at the prescribed directions, but also scanned other directions. This enabled us to obtain information on the variation of the counting rate of the telescope as a function of azimuth. The data have been classified into two time intervals i.e. 2.10–3.00 IST (Indian Standard Time) and 3.00–3.33 IST, and presented in Table II and plotted in Figure 4. During the period 2.10–3.33 IST, the only known strong X-ray source

TABLE II

Date of flight: 28th April, 1968

Counting rates classified according to azimuth (counts/sec)

$\phi =$ 0 North
$\phi =$ 90 West
$\phi =$ 180 South

Time	Energy range (keV)	Azimuth 330–360	0–30	30–60	60–90	90–120	120–150	150–180	180–210	Grand average
2.10–3.00 (IST) 2040–2130 (UT)	17–48	7.67 ±0.14 (360)	7.39 ±0.16 (285)	7.87 ±0.20 (195)	7.77 ±0.25 (120)	8.04 ±0.18 (240)	7.15 ±0.28 (90)	7.19 ±0.18 (210)	8.35 ±0.15 (375)	7.70 ±0.06 (1875)
	48–124	19.04 ±0.23 (360)	18.40 ±0.25 (285)	19.37 ±0.31 (195)	18.10 ±0.39 (120)	18.74 ±0.28 (240)	16.78 ±0.43 (90)	18.63 ±0.29 (210)	18.72 ±0.22 (375)	18.48 ±0.09 (1875)
3.00–3.33 (IST) 2130–2203 (UT)	17–24 + 32–48	6.17 ±0.32 (60)	6.21 ±0.18 (195)	6.26 ±0.17 (225)	5.78 ±0.23 (105)	5.96 ±0.12 (435)	6.06 ±0.16 (225)	6.36 ±0.19 (165)	–	6.11 ±0.06 (1410)
	48–124	19.54 ±0.57 (60)	20.17 ±0.32 (195)	19.25 ±0.29 (225)	18.86 ±0.42 (105)	19.72 ±0.21 (435)	20.02 ±0.30 (225)	20.28 ±0.35 (165)	–	19.69 ±0.16 (1410)

Note: Figures in brackets indicate the observation time in sec.

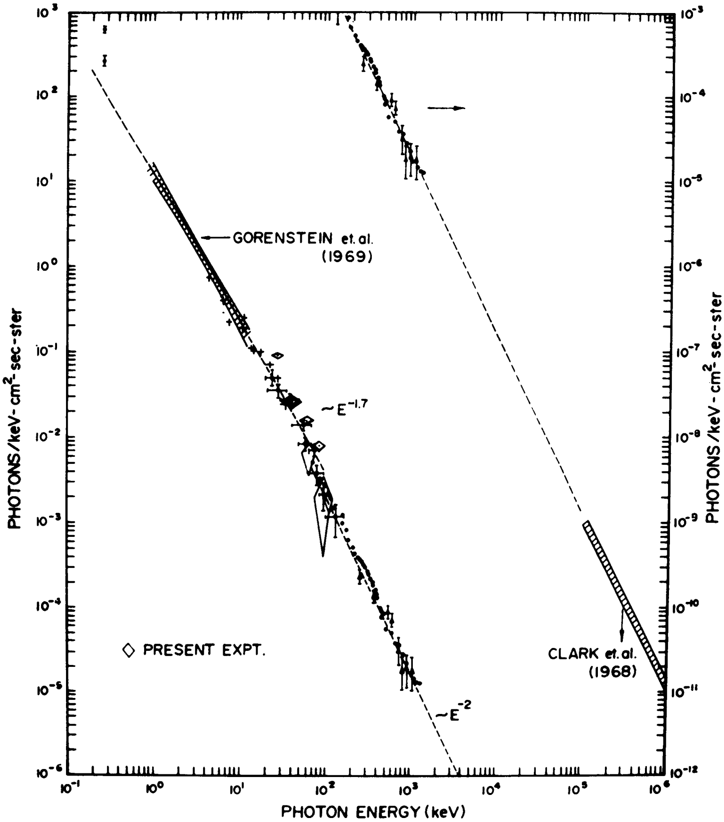

Fig. 3. Our data on diffuse X-ray background super imposed on the composite spectral information as given by Gorenstein *et al.* [4] (1968).

that was expected to be seen was Sco X-1 in the azimuthal range 150–210°. Some of the sources in the Sagittarius region were also in the field of view in the same azimuthal range, but the efficiency of the telescope was very poor for recording any contribution from these sources, since the inclination of the telescope was unfavourable. In the azimuthal range 330–0–150°, there was no known source in the field of view of the telescope. However, the data indicated the possibility of a new source in the azimuthal range 90–120° and the existence of this source has been confirmed in the flight on December 22nd, as discussed in an accompanying paper (Agrawal *et al*, [5]). The telescope did not scan the region 240° to 330°. It is seen from Figure 4, that the total counting rate of the telescope (cosmic X-rays and atmosphere background) as recorded at an altitude of 5.3 g/cm^2 and at an inclination of 25°, did not vary by more than 8% in the entire azimuthal range 330–0–210°. However a puzzling feature of Figure 4, is the large negative peak (4σ) observed in the azimuthal interval 120–150° during the period 2.10 to 3.00 LST in the energy interval 48–124 keV. This observation cannot be simply interpreted as due to a statistical fluctuation since there is a correlated negative peak (2σ) in the lower energy interval 17–48 keV also.

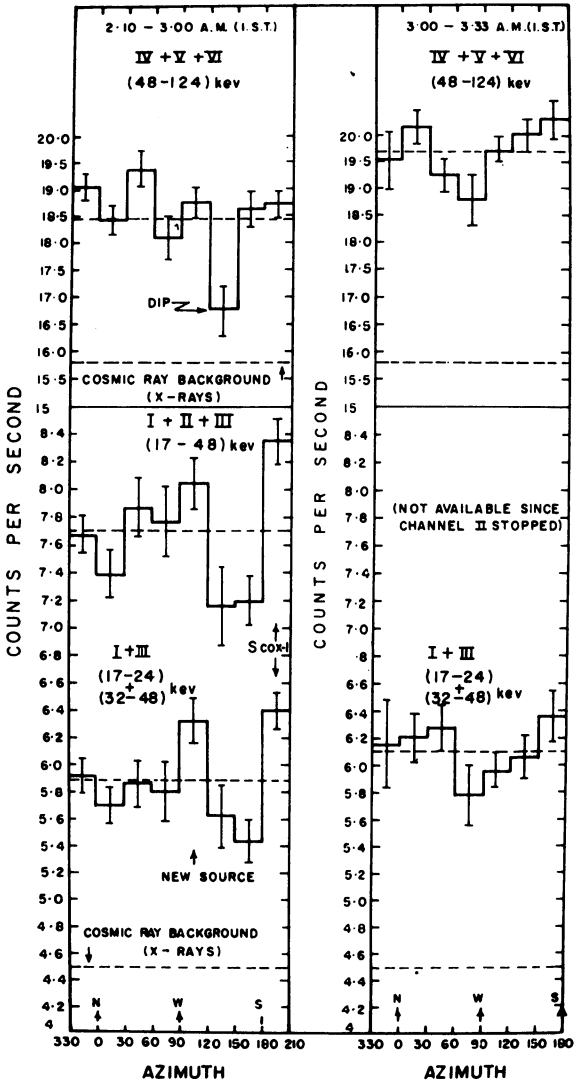

Fig. 4. Variation of the counting rates of the telescope as a function of azimuth on April 28, 1968, for two time intervals, 0210–0300 and 0300–0333 hrs. IST.

If the negative peak is due to physical causes, then we have to find them either in the atmospheric X-rays which are secondary to cosmic rays, or in the diffuse cosmic X-rays themselves. If it is due to cosmic rays, then there is no reason why the peak should be so conspicuously absent in the data corresponding to a later time i.e. 3.00 to 3.33 (Figure 4). Also, if the large variation in the counting rate arises as a result of geomagnetic effect of cosmic rays, then the effect should be more pronounced in the East–West direction, rather than in some odd South-East direction like 120–150°. If the negative peak is to be attributed to the diffuse background X-rays, then the consequences are rather drastic. There would have to be a depletion of the cosmic background X-rays by more than a factor of 2 in a localised celestial region around R.A. = 14 to 16 hrs. and $\delta = -14°$ to $+13°$. The depletion has to be more at higher energies (>48 keV) than at lower energies. As far as we are aware there are no published experimental results that contradict the existence of localised regions of low X-ray intensity, at least at high energies. Clearly further experiments are necessary to establish unambiguously the existence of such regions of depleted X-ray intensity.

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