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DIFFUSE X-RAY BACKGROUND MEASUREMENTS IN THE ENERGY RANGE 2–18 keV

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Abstract. Rocket measurements, of the diffuse X-ray background in the energy range 2–18 keV, conducted from Thumba Equatorial Rocket Launching Station (TERLS), India, are presented. The estimates of the cosmic background are derived by the method which employs the Earth and its atmosphere as a shutter to intercept the celestial X-rays. The results are shown to be consistent with a power law photon spectrum.

$13.6^{+4.3}_{-3.3}\ E^{-1.73\ \pm 0.15}$ photons/cm²-sec-keV-ster the spectrum being much flatter than that observed at higher energies.

1. Introduction

Precise estimation of the energy spectrum and the anisotropy of the celestial diffuse X-ray background over a large energy range is of vital importance in the understanding of its production mechanism, and its cosmological implications (Setti and Rees, 1969). In this paper, we report the results obtained from the analysis of data over the energy range 2–18 keV from two spin stabilised, Centaure rocket flights, conducted on November 3, 1968 (35.01) and December 7, 1969 (45.03), from the Thumba Equatorial Rocket Launching Station (TERLS), Trivandrum, India. Reliable estimation of cosmic background is rendered difficult due to contamination of secondary X-rays of terrestrial origin. Therefore experiments done at equator have a great special value since the contribution from the secondary X-rays at these latitudes is least due to the high geomagnetic cut-off rigidity. Besides, to derive the cosmic background, we have employed a new powerful method of analysis which uses the Earth and its atmosphere as an effective shutter.

2. Experimental Details

The detector systems used in both the rocket experiments, consisted of proportional counters filled with xenon and methane and having thin beryllium entrance windows. The physical details of the counters are described elsewhere (Rao *et al.*, 1969; Rao *et al.*, 1970). The counters having an effective area of about 60 cm^2, had an energy resolution of about 15% FWHM for 6 keV X-rays from Fe^{55} radioactive source. The detectors, mounted perpendicular to the spin axis of the rocket, scanned in the direction of the rocket horizon during each spin. Slat type collimators with full width half maximum transmission angles of 8.7° × 17.2° and 7° × 15°, defined the geometrical apertures of the detectors in the two flights. The X-ray data were analysed into four contiguous discrete energy channels 2–4, 4–6, 6–12, 12–18 keV in the flight 35.01 and into eight equal energy windows over 2–10 keV in the flight 45.03. The

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calibration of the detectors and the associated electronics were checked during a part of the flight, by using an Fe^{55} radioactive source mounted on the nose cone in front of the counter, the nose cone portion being explosively ejected at about 60 km altitude. The attitudes of the rockets were derived from suitably located Sun sensor and crossed magnetic sensors, using standard techniques, details of which are published elsewhere (Rao *et al.*, 1969; Rao *et al.*, 1970). The regions of celestial sky scanned by the detector in each of these two flights are shown in Figure 1.

3. Method of Analysis

A number of methods have been used in the past for estimating the cosmic X-ray flux, which are summarised by Matsuoka *et al.* (1969). One of these is to use the Earth and its atmosphere as a shutter to intercept the celestial X-rays, when the counter views the Earth during some parts of the spin of the rocket. The detector registers both the secondary background and the diffuse cosmic X-rays, when it views the celestial sky. When the detector faces the Earth completely, the counts it registers are only due to the secondary charged particle background. The difference in count rate, when the counter field of view is intercepted by the Earth and other periods can provide a reliable estimate of the diffuse X-ray background.

The above simple situation exists only for low rocket elevations and small opening angles of the telescope. In practice, when the elevation of the rocket is not very far from 90° and the detectors have a fairly large opening angle, intermediate situations exist, and even in the best case a small portion of the solid angle of the detector will be looking at the celestial sky. The elevation of the two rockets in the present experiment

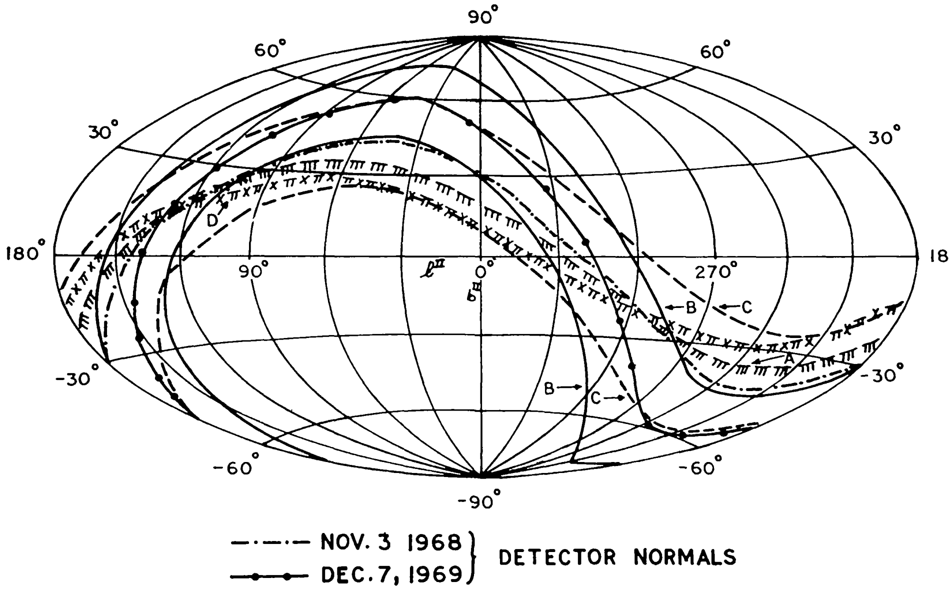

Fig. 1. Regions of celestial sky scanned by the detector during the two rocket flights. A and D are local horizons, CC and BB are belts scanned during November 1968 and December 1969 flights respectively.

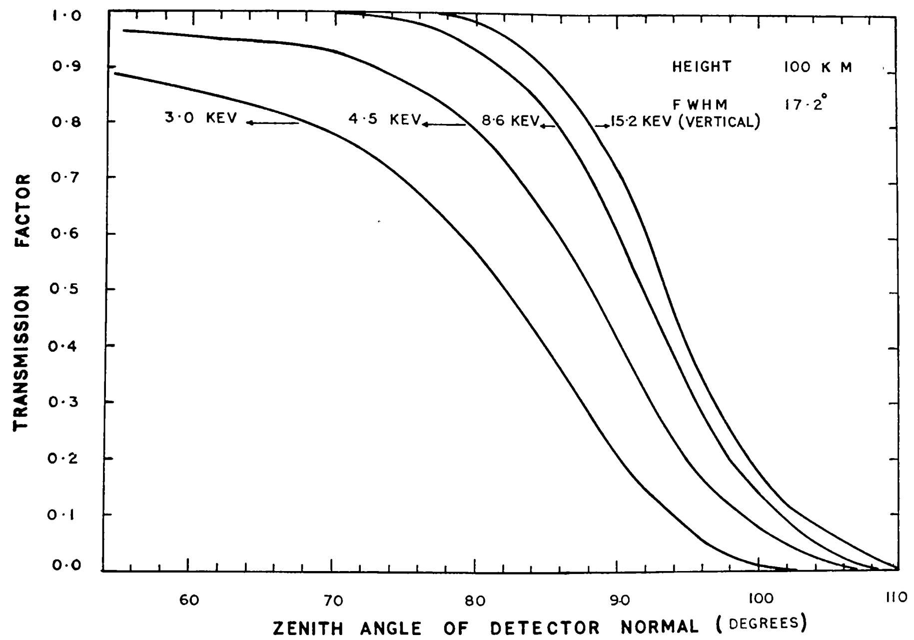

Fig. 2. Effective transmission factor of the detector with a field of view with FWHM of 15° along the spin axis, at four specific energies, for an altitude of 100 km.

being 73° and 64° respectively, effective solid angles have to be evaluated for different portions of the spin azimuths to estimate the background flux.

The geometrical sensitivity (as a fraction of total geometrical aperture) of an element of the detector, between zenith angle θ and $\theta + \mathrm{d}\theta$ is given by

$$G(\theta) = \left(1 - \frac{\tan(|Z - \theta|)}{\tan F}\right) \frac{\mathrm{d}\theta}{F},$$

where Z is the zenith angle of the detector normal and F is the half angle of opening of the collimator along the spin axis of the rocket. The effective transmission factor of the detector at a zenith Z is given by

$$TR(Z, E) = \int_{Z-F}^{Z+F} G(\theta) \exp(-\mu(E)\, m(\theta))\, \mathrm{d}\theta,$$

where $\mu(E)$ is the mass absorption coefficient of air for X-rays of energy E, and $m(\theta)$ is the mass of air in the line of sight along the zenith angle Z. These factors, for four different energies for the detector at 100 km altitude have been calculated and are shown in Figure 2. Weighted means of these transmission factors for different energies have been computed for each flight, taking into account the time spent by the detector at different altitudes.

Figure 3 shows the plot of count rate in the energy range 2–10 keV as a function of spin azimuth for the rocket experiment 45.03. The absolute photon flux in each differential energy channel was derived by deconvoluting the count rate data with the

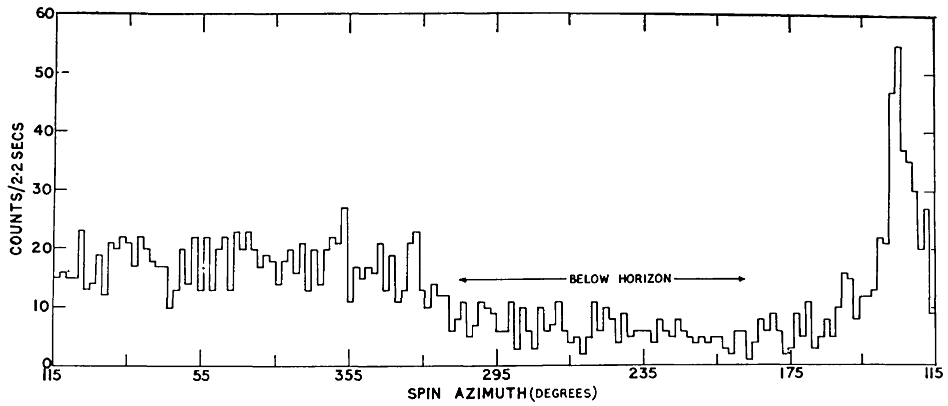

Fig. 3. The count rate in the energy range 2–10 keV, plotted versus spin azimuth of rocket, for the flight 45.03.

detector efficiency $\varepsilon(E)$, and the computed transmission factors $TR(E)$, using the expression

$$C(E_1, E_2) = TBG + \int_{E_1}^{E_2} P(E)\,\varepsilon(E)\,TR(E)\,\mathrm{d}E,$$

where $C(E_1, E_2)$ are the observed counts in an energy interval E_1 to E_2 keV, TBG is the contribution from terrestrial background and $P(E)$ is the true photon flux at energy E.

4. Results

The results of the diffuse X-ray background from the two rocket flights are shown in Figure 4, along with the spectral fits given by Gorenstein *et al.* (1969) and Baxter *et al.* (1969). Since the results obtained in the two rocket flights agree within the experimental errors, data from both the flights have been combined to obtain the best fit power law spectrum given by

$$13.6^{+4.3}_{-3.3}\, E^{-1.73\pm0.15}\ \text{photons/cm}^2\text{-sec-keV-ster}.$$

The spectral behaviour of the cosmic X-ray flux obtained in our experiment is consistent, with the results obtained by other workers (Gorenstein *et al.*, 1969; Baxter *et al.*, 1969) for the low energy cosmic X-ray flux but much flatter than the spectral exponent of 2.45 reported by Bleeker and Deerenberg (1970) for energies greater than 20 keV.

5. Discussion

The results, besides establishing the effectiveness of the method which uses the Earth as a shutter, clearly confirm that the spectrum of diffuse X-ray background in the energy range 2–18 keV is flatter than at higher energies (Rao *et al.*, 1967 and Bleeker and Deerenberg, 1970). The existence of such a break in the spectrum at about

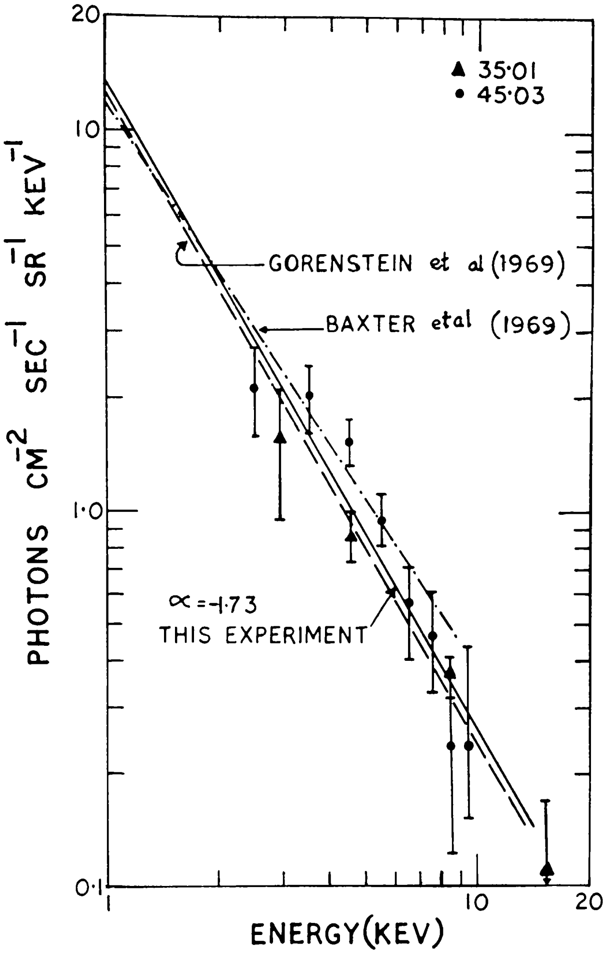

Fig. 4. Energy spectrum of diffuse X-ray background in the energy range 2–18 keV.

20–40 keV has also been reported by other workers and consequently any theoretical model proposed must be able to explain this feature of the spectrum. The models proposed till now can generally be classed under two categories (a) those which interpret X-ray background as the effect of superposition of discrete sources and (b) those which invoke emission mechanisms that operate over extended diffuse regions, possibly throughout the intergalactic space. Both these categories of models fail from the intensity considerations when the cosmological evolutionary effects are not considered. The discrete source model (Silk, 1969) which takes into account cosmological effects, though capable of explaining the observed magnitude of the flux by appropriate choice of evolutionary parameters, fail to satisfactorily explain the change of spectral exponent, as the contribution from the distant galaxies would be integrated even if objects having power law spectra with different exponents are assumed. The model based on inverse Compton scattering of blackbody photons by relativistic electrons from radio sources at large red shifts (Setti and Rees, 1969) seems to give the most satisfactory explanation of the diffuse background. Change in this spectral exponent can be explained (Rees and Setti, 1968) by invoking additional adiabatic energy losses, such that the Compton life time for the relevant electrons is equal to the time required for the radio source to expand to twice its radius. However, for this process to be effective one needs to assume that the X-ray emission is mainly from a region of small window of redshift, so that the break is not smeared out.

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