A COMPARISON OF CALCULATED AND MEASURED BACKGROUND NOISE RATES IN HARD X-RAY TELESCOPES AT BALLOON ALTITUDE

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ABSTRACT

An actively shielded hard X-ray astronomical telescope has been flown on stratospheric balloons. In this paper we compare the measured spectral distribution of the background noise counting rates over the energy loss range 20-300keV with the contributions estimated from a series of Monte Carlo and other computations. The relative contributions of individual particle interactions aré assessed.

1. Introduction. The sensitivity of hard X-ray telescopes is dependent to a first approximation upon a number of desirable characteristics: a large sensitive area, long observation periods, high photon detection efficiency and a low background noise level. The first two factors are very dependent upon the platform from which the telescope must operate, whilst the effective suppression of background noise requires a detailed analysis of the physical processes involved. We present in this paper the background levels observed in an actively shielded collimated telescope during a balloon flight from Palestine, Texas in 1982. The experimental results are compared with theoretical and computer predictions of the background counting rates.

2. Configuration of the Hard X-ray Telescope. The telescope was composed of 8 NaI(Tl) scintillation crystals (200x200x6mm) shielded over the lower 2π steradians by a 5cm thick NaI(Tl) crystal of the same area. A thin plastic scintillator designed to reject events due to charged particles covered a large fraction of the upper 2π steradians. The aperture of the detectors was restricted to 3 degrees FWHM by a copper collimator. A passive graded shield also surrounded the collimators and the sides of the crystals. A schematic diagram of the telescope is shown in Fig.1. In addition a Sodium Iodide detection crystal, identical to the primary crystal in the telescope, was flown in a completely unshielded configuration in order to determine the efficiency of the

shielding system. The telescope and unshielded crystal were flown on the same stratospheric balloon gondola from Palestine, Texas.

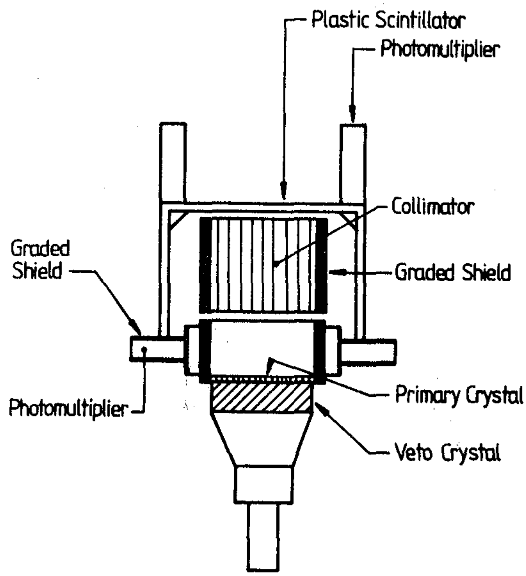

Fig.1. A schematic view of the X-ray telescope detector units

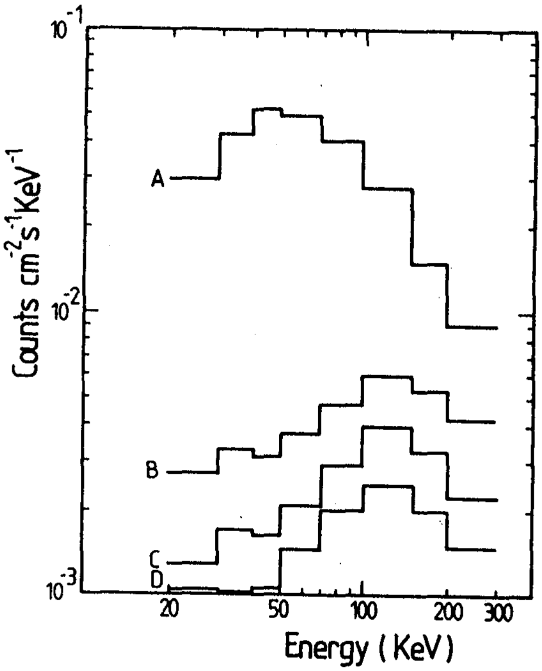

Fig.2. The counting rate in the MIFRASO NaI(Tl) detectors at 4.1mbs residual pressure for four different shielding configurations;
a) counting rate in unshielded det.
b) counting rate in unshielded det. with all active anticoincidence off.
c) counting rate in shielded det. with NaI(Tl) active shield on but with plastic anticoincidence off.
d) counting rate in primary det. with all shielding systems functioning.

Figure 2 demonstrates the effectiveness of each type of shield by showing the counting rates at balloon altitudes for different shielding configurations. It clearly demonstrates that the majority of the reduction in background counting rate is achieved by the passive shield with both sets of active anticoincidence causing roughly similar further reductions in the unwanted background noise.

3. Comparison of measured and calculated background levels. The predicted background counting rate in the detectors of the MIFRASO telescope was computed by a combination of theoretical and Monte Carlo techniques. The photon induced background was determined from the results of an extensive Monte Carlo model of the entire detection system. The program modelled the processes of photoelectric absorption and Compton scattering, but neglected electron transport due to the fact that the path lengths involved for the energy range under consideration are generally small compared to the dimensions of the elements of the telescope. The angular and energy distribution of the gamma-ray fluxes incident over the detector could be varied to suit the particular physical processes under investigation. In each case the energy deposits in all the elements of the telescope were recorded in order to provide an insight into the efficiency of the various shielding systems.

Neutrons arriving at the primary crystal may generate background noise by a variety of mechanisms but the most important are (n,γ) radiative capture and inelastic scattering by the 127_I nuclei. Radiative capture by 127_I leads to a variety of possible prompt gamma-rays by the reaction $127_I,(n,\gamma)\ 128_I$. The various gamma-ray energies are very extensive and extend from 60 keV up to 6.7 MeV. There is also a delayed effect from the decay of 128 which has a half life of 25 min. The two lowest levels to be excited by inelastic scattering at a 127_I nucleus lead to the emission of gamma-rays at energies of 58 and 203 keV.

The neutron flux incident upon the detectors is made up of two components, atmospheric neutrons and those produced within the payload by "boil off" from cosmic ray interactions. The modified neutron flux will depend upon the exact geometry and mass of the payload but may be estimated as described by Charalambous et al (1985) by assuming a uniform distribution of mass and integrating over the volume of the payload. This neutron flux was folded with the cross sections for radiative capture and inelastic scattering to yield an estimate for the background counting rate of neutron induced events. The contribution from charged particles has been estimated from the effect of the plastic scintillator shield. If the shield is assumed to be 100% efficient over the solid angle that it covers, it is possible by considering the effect of switching on and off the shield, to estimate the number of events caused by particles that enter through the solid angle that is not shielded.

High energy cosmic ray protons which are incident upon the material of the detection plane give rise to background events which are derived from the radioactive spallation products produced in the interaction. In general, the veto pulse may be made as long as possible to suppress a number of these types of events. However, since the timescales associated with many of the decay schemes are considerably longer than practicable veto pulse lengths the active shield does not eliminate this type of noise. Calculations of spallation involved background are extremely complex and subject to considerable error so that a reliable estimate of this source of noise is best obtained by experiment. Results of such tests have been reported in the literature (Baker et al 1979) and have been used to yield an estimate for the MIFRASO detectors.

The results of the various calculations are shown in Fig.3. The agreement between calculation and experiment is quite good being within a factor of two and having the same spectral distribution. The similarity in spectral shapes is an encouraging sign that the relative contributions of the various effects as determined by calculation are correct

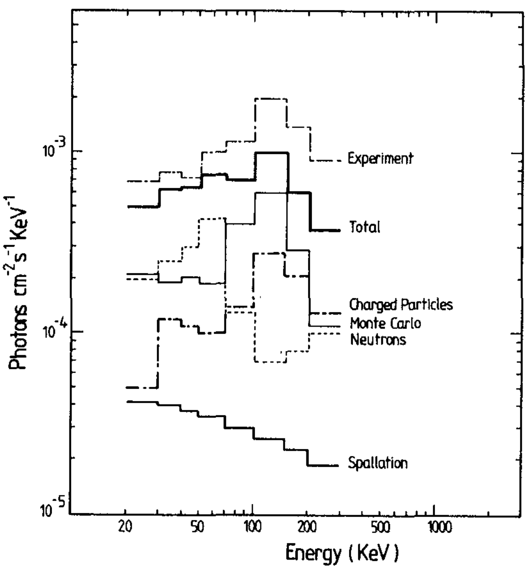

Fig.3. A comparison between observed and calculated background noise events.

References

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