A 3.1a. EFFICIENCY RESOLUTION AND ESCAPE X-RAYS OF THE DETECTOR:

The efficiencies of the detectors for the detection of X-ray in the present experiments are shown in figure A 3.1 and A 3.2. The detector efficiency at any given energy (E) is given by the product of the window transmission and the absorption of the incident radiation in the detection media. In case of proportional counter the window was 100 micron thick beryllium and detection media was 25 mm thick xenon gas at 1 atmospheric pressure. For the balloon experiments these were 0.8 mm Aluminium and 4 mm thick NaI (Tl) crystal respectively.

The efficiency of the detector thus will be given by the equation,

\[ f(E) = \exp\left[-\mu_w(E) \cdot \rho_w \cdot X_w \right] \left[1 - \exp\left(-\mu_g(E) \cdot \rho_o \cdot X_o \right)\right] \]

where \( \rho_w \) and \( \rho_o \) are the densities of the window material and detector material respectively, \( \mu_w(E) \) and \( \mu_g(E) \), represent the mass absorption coefficient of the window material and of the detection media at energy E(keV). The efficiency curves shown in figures A 3.1 and A 3.2 have been derived using the mass absorption coefficients given by Allen (1963), Victoreen (1947) and Henke et al (1957).

The resolution of the proportional counter detector as a function of its geometry was also experimentally determined by placing radioactive sources at different portions on the window. The result of this test showed that the counter had an overall resolution of 20%. The resolution of the detector was approximated by \( \sigma(E) = \sqrt{E} \).
A 3.1b. ESCAPE X-RAYS CORRECTION:

In addition, it is necessary to correct the calculated efficiency using the above equation for decrease in efficiency due to the escape radiation. No such calculations were necessary for Xenon counter since K-escape peak (34 keV) did not fall in the region of interest and at L-escape peak (∼4 keV) the yield was very small. But for balloon experiment, since the detector used was NaI (Tl) crystal in which case the escape K-radiation (∼32 keV) for iodine fell in the region of interest, photons whose energy exceeded the above limit may appear as photons of energy ∼32 keV due to the above effect. The necessity for correcting for this effect has been shown by Staein and Lewin (1967), and detailed calculations of the escape probability $K_{\alpha}$ and $K_{\beta}$ have been done by Liden and Starfelt (1954). Assuming $P_{\alpha}$ and $P_{\beta}$ to be the probabilities that an incident photon will give rise to a $K_{\alpha}$ or $K_{\beta}$ photon which escape from the detector with energies of $E_{K_{\alpha}}$ and $E_{K_{\beta}}$, we have calculated the escape probability using the equation (Overback 1959)

$$P_{\alpha}(E) = \int_{0}^{X_{0}} C \frac{d^{2}N_{x}}{dx} \frac{1}{2} \delta \omega f_{\alpha}(E \alpha) \left[ \frac{-M_{x}X - M_{x}(X_{o} - X)}{M_{x}X - M_{x}X_{o}} - M_{x}(X_{o} - X) \right]$$

and similarly,

$$P_{\beta}(E) = \int_{0}^{X_{0}} C \frac{d^{2}N_{x}}{dx} \frac{1}{2} \delta \omega f_{\beta}(E \beta) \left[ \frac{-M_{x}X - M_{x}(X_{o} - X)}{M_{x}X - M_{x}X_{o}} - M_{x}(X_{o} - X) \right]$$

where $X_{0} =$ thickness of the crystal = 1.468 gm.cm$^{-2}$

$E_{K_{\alpha}} = 32.5$ keV, $E_{K_{\beta}} = 28.6$ keV
FIG. 3

THE CALCULATED EFFICIENCY OF THE PROPORTIONAL COUNTER (UPPER). LOWER CURVE SHOWS VARIATION OF COUNT RATE WITH HIGH VOLTAGE.
FIG: A32. THE FIGURE SHOWS THE DETECTION EFFICIENCY OF THE NaI(Tl) CRYSTAL FOR 4 MM AND 1 MM THICKNESS. THE ESCAPE PROBABILITY IS ALSO SHOWN.
\( \mu = \text{mass absorption coefficient of NaI (Tl)} \)
\( \mu = (E \lambda) = 6.62 \text{ cm}^2/\text{gms} \)
\( \mu = (E \beta) = 4.66 \text{ cm}^2/\text{gms} \)

\( \delta \) is the fraction of photoelectric photons that originate in the K-shell = 0.875, \( \omega \) is the K-fluorescence yield of iodine = 0.84. \( f_\lambda \) and \( f_\beta \) are the fraction of K X-rays which are \( K_\lambda \) and \( K_\beta \) X-rays respectively and are given by,
\( f_\lambda = 0.7937, f_\beta = 0.2063 \)

The calculated values of \( P_\lambda \) and \( P_\beta \) are plotted in A 3.2 which shows that at \( \approx 33 \text{ keV} \), the escape probability of incident photons was \( \approx 18\% \), which was a significant fraction and hence was considered in deriving the true spectrum of the incident radiation.

The resolution of the detector \( f(E) \) is usually, in terms of its standard deviation, given by,
\[ f(E) = aE + bE^{\frac{1}{2}} \]
the values of the constants \( a \) and \( b \) were determined experimentally by using the full width at half maximum resolution when the detector was irradiated by \( \text{Cs}^{109} \) (22 and 88 keV) and \( \text{Am}^{241} \) (59.5 keV).

**A 3.2. EXPOSURE EFFICIENCY OF THE DETECTOR:**

Collimator used in the present balloon flights was of cylindrical shape whose theoretical response is shown in figure A 3.3. To calculate the exposure efficiency for a source displaced at an angle \( \theta \) with respect to the telescope
ANGLE OF SOURCE FROM TELESCOPE AXIS (DEG)
axis, the following formulae were used,

\[
\cos Z = \frac{\sin \delta - \sin \phi \sin h}{\cos \phi \cdot \cos h}
\]

\[
\sin h = \sin \phi \sin \delta + \cos \phi \cos \delta \cdot \cos t
\]

where,

- \( h \) = elevation of the star,
- \( \delta \) = declination of the star,
- \( \phi \) = latitude of the place of observation
- \( Z \) = azimuth of the star and \( t \) is the hour angle of the star given by,

\[
t = \text{local sidereal time (L.S.T.)} - \text{R.A. of the star.}
\]

After performing these calculations the angle between the telescope axis and source (\( \theta \)) was calculated by

\[
\cos \theta = \cos h_1 \cdot \cos h_2 \cdot \cos Z_1 \cdot \cos Z_2 + \cos h_1 \cdot \cos h_2 \cdot \\
\sin Z_1 \cdot \sin Z_2
\]

The effective transmission factor was then given by,

\[
T_r (\text{coll}) = \left(1 - \frac{\theta}{\text{FWHM}}\right) \times 100 \ \text{percent}
\]

The elevation angle for the present flight was fixed at 72° for observations on Her X-1 and Cyg X-1.

A 3.3. SEPARATION OF SOURCE FROM BACKGROUND:

Observations of discrete X-ray sources at balloon altitudes are always carried out in the presence of secondary cosmic ray background as well as the cosmic diffuse X-ray background. It is, therefore, necessary to separate the background from the observed count rate to obtain the source flux.
To separate the effects of the background for evaluation of the true intensity of the source, the detector was made to alternately view in the direction of the source and $180^\circ$ away for nearly equal time. Let $B$ and $N$ be the counts due to the background and the source respectively. Then the detector while looking towards the source registered $(N + B)$ counts and when looking away from it registered $B$ counts. The corresponding fluctuations are given by their standard deviations viz.,

$$\sqrt{(N + B)} = \sqrt{(N + B)}$$
$$\sqrt{(B)} = \sqrt{B}$$

and by the law of propagation of errors,

$$\sqrt{(N)} = \sqrt{(N + B)^2 + (B)^2}$$

i.e. $\sqrt{(N)} = (N + 2B)^{1/2}$

For the more general case of fluctuating background the average value $\bar{B}$ of the background was used and then the signal level was defined as,

$$n = \frac{(N + B) - \bar{B}}{\sqrt{(N + B) + \bar{B}}}$$

This value of $n$ was used for testing the $\chi^2$ distribution to establish the genuiness of the signal.

A 3.4. SPECTRUM FOLDING:

From the data obtained describing the pulse height distribution of the incoming photons in different energy ranges the spectral information could be derived taking into account the following factors:

1. Detector area and field of view i.e. collimator transmission.
The figure shows the mass attenuation coefficient used in analysis of spectra above 10 keV.
2. Finite resolution of the detector
3. Effect of escape radiation
4. The counter-detector efficiency.

To derive the spectrum of the source following procedure was adopted.

In case of balloon the payload floated at an altitude of \( \approx 5 \text{ gm/cm}^2 \).

At this altitude the incoming X-rays from the source are subjected to attenuation by the residual atmosphere above the detector. The attenuation coefficients of air were calculated taking the attenuation coefficient of nitrogen, oxygen and argon.

Figure A 3.4 shows the absorption coefficient of air above 10 keV. Absorption by detector window and collimator transmission were also taken into account while deriving the final spectrum as already described. In addition, the transmission through air was also taken into account. Let the actual photon spectrum of the source be,

\[
\left[ \frac{dN}{dE} \right] D = AE^x \quad \text{or} \quad A \exp \left( \frac{E}{kT} \right)
\]

then the attenuated spectra by atmosphere will be represented by,

\[
\left[ \frac{dN}{dE} \right]_1 = \left[ \frac{dN}{dE} \right]_D \cdot e^{-\mu(E)g}
\]

where \( \mu(E) \) = attenuation coefficient of air and \( g = g/\text{cm}^2 \) of air along the line of sight. After correction for the efficiency \( \xi(E) \) and escape probabilities \( P_\alpha \) and \( P_\beta \), the primary spectrum