

# High Energy X-ray Imaging Telescope : HEXIT

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We have developed a new balloon borne payload for hard X-ray observations in the energy region 20 to 800 keV. The X-ray detector is 1200 sq cm area phoswich crystal, viewed by 13 phototubes with 3" dia, in an 'Anger' mode. The first engineering flight of the payload was made on March 28, 2005. This paper describes the details of the instrument and the detector behaviour at the ceiling altitude during the experiment.

## 1. Introduction

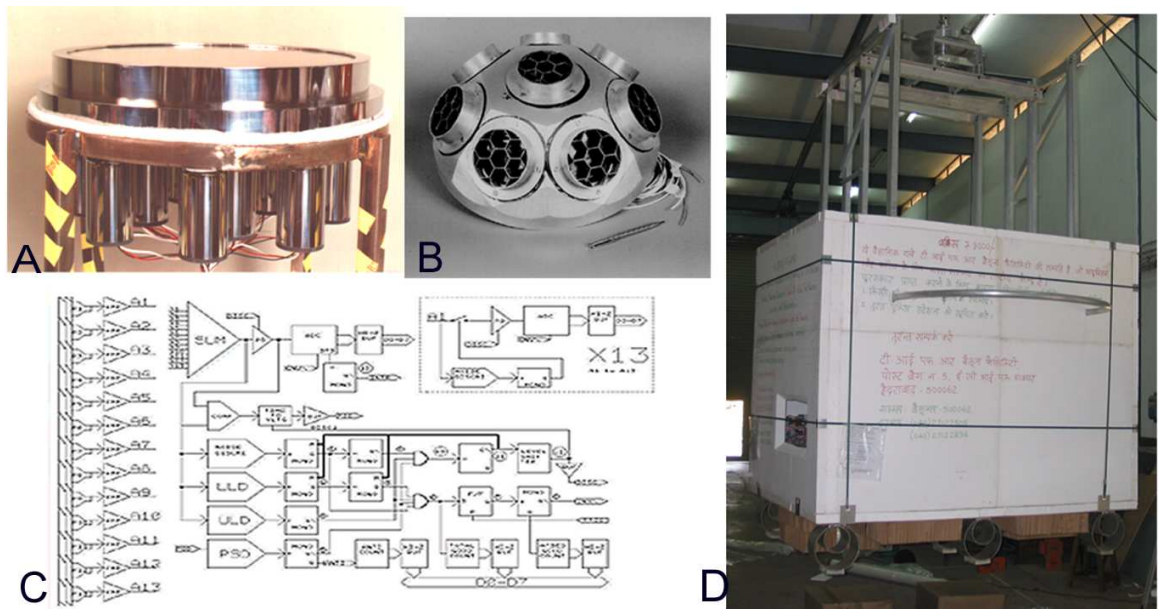
The development of imaging instruments using focusing by grazing incidence below 8 keV, have revolutionized our understanding the X-ray universe at low energies. However, high resolution spatial and spectral mapping in the hard X-ray and low energy gamma ray region has been lacking mainly due to fundamental limitation of the sensitivity of the detector systems and imaging capability of the instruments. Imaging capability with good angular resolution is essential for localizing the hard X-ray sources. An imager also allows the simultaneous measurement of background and the source, which is crucial at low flux levels. The best imaging technique currently in use in the hard X-ray and gamma ray region is the use of coded aperture mask along with a position sensitive detector.

At energies above 30 keV, the only available detector system with high detection efficiency is the scintillation counters. The detection efficiency even in xenon filled proportional counters is extremely small for energies above 30 keV and second, the observed energy loss spectra does not directly map into incident photon spectrum due to large K-escape probability (85% in xenon). Monte-Carlo method used to de-convolve the incoming spectrum, critically depends on the knowledge of systematic effects. In contrast, scintillation detectors do have high detection efficiency. but no spatial sensitivity. A light division technique can be however, used to determine the point of interaction [1]. Satellite and balloon-borne imaging payloads employing single crystal scintillators are currently in use [2] [3] [4]. Imaging payloads using Large area pixilated CdTe and CdZnTe array detectors are currently in the development stages [5].

The inherent background produced in a scintillator due to cosmic ray interaction and the Compton scattering of the high energy photons dominates the aperture flux and therefore, the flux sensitivity does not directly scale with the geometric area. The most favoured arrangement for reducing the detector background is the use of phoswich techniques using NaI(Tl) and CsI(Na), which provides a shielding factor of about 4-6 in cosmic environment.

## 2. Instrument

HEXIT is a new balloon-borne hard X-ray imaging telescope, which combines a large area phoswich anger camera with a coded aperture URA mask. A passive slat collimator made from lead (.5 mm) laminated with tin (.25 mm) and copper (.15mm) on both sides is placed above the detector to limit the field of view to  $7.5^\circ \times 7.5^\circ$ . In addition, to the main detector, a wide angle monitor payload, designed for real-time observations of the X-ray transients is also mounted on the payload



**Figure 1.** The Phoswich Anger Camera (1A), Wide Angle monitor assembly (1B), Schematic for the PAC on-board electronics (1C) and the 1D in the figure shows complete gondola assembly prior to launch

## 2.1 Phoswich Anger Camera

The HEXIT uses a new type of detector which we have been developing for the past few years [6] [7], in order to build a high sensitivity imaging telescope in the hard X-ray range of 20-500 keV. The detector is a large area phoswich assembly having 40 cm dia and made of NaI(Tl) and CsI(Na) scintillator crystals. Since the optimum thickness of the two scintillators in a phoswich detector depends on the targeted energy range, HEXIT assembly consists of 12 mm NaI(Tl) as the prime detector coupled to a 40 mm thick CsI(Na) crystal. The combination is vacuum sealed with a 0.127 mm aluminum entrance window and a 10 mm thick Pyrex back plate. Thirteen 76 mm phototubes are directly coupled to the optical window in a quadrant symmetric fashion. The large area detector and the arrangement of the photomultiplier tubes is shown in the figure 1A. Since the signal separation from the prime and rear detector primarily depends on the pulse shape discrimination and the expected event rate in the shield detector is much larger both due to large area and the higher detection efficiency, an ultra-fast RTD system is essential for a very low dead time and which can handle up to  $10^5$  counts/sec. The observed energy resolution for an un-collimated source is 16% for the 60 keV line emission from Am<sup>241</sup>. Even though the phototubes are relatively widely spaced in our geometry, the summed light output is uniform within 5% over the entire area of the detector. The coordinates determination in the case PAC is computed from the variation of the signal between different tubes. A linearized radial response was measured during the laboratory tests. To obtain the location of the photon interaction over the surface, all signals from 13 phototubes are individually pulse height analyzed and digitized data is transmitted to ground along with pulse height information and time-tag for each photon. To create a look-up table for quick computation of the event co-ordinates, the detector was calibrated using 25 and 60 keV lines from Am-241, at 5000 points. The energy resolution and the peak position was measured for all the 13 tubes for each location of the source on the surface. The estimated position resolution is be about 7mm even at 30 keV.

## 2.2 Wide Angle Monitor

Wide Angle monitor has been designed as a light weight add-on instrument on a conventional balloon-borne payload with narrow field of view, to provide a wide angle coverage for transient events during the flight. However, the monitor can be used as a stand-alone all sky monitor both for the detection of transient events in hard X-rays and for long term monitoring of known X-ray sources.

The detector assembly consists of 8 CsI(Tl) detectors with  $45 \text{ cm}^2$  area arranged on a geodesic frame and is shown in Fig. 1B. Such a geometry provides a large coverage of the sky. The detectors are viewed by miniature 2" Hamamatsu photomultipliers. The field of view of each detector is restricted to  $\sim 55^\circ$  FWHM by using a honeycomb lead collimator. The collimators are so designed, as to give an overlapping view of the same object in at-least two detectors, both in the elevation and azimuthal axis. The simulations show that ratio of the counting rates for bright events recorded by different detectors can give source location to few degrees.

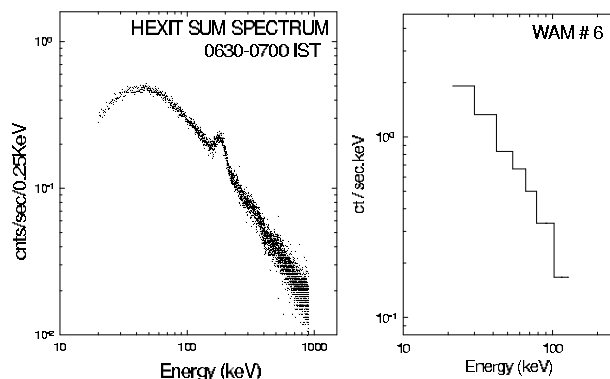
## 2.3 Gondola

The basic design of the balloon gondola is similar to proposed by [8]. Both detectors (WAM and HEXIT) are mounted on a frame, which is stabilized in azimuth using a servo, controlled Reaction wheel, using a magnetometer. The phoswich Anger Camera is mounted on bearings and can be rotated in zenith using DC motor and a 12 bit optical shaft encoder in servo loop. The true North axis of the frame is calibrated on ground using the pole star. The payload gondola is fully automatic and is controlled by an on-board microprocessor based star tracker for payload orientation and source tracking. A GPS system is built into the unit to provide instantaneous value of the balloon coordinates (lat, long) for the computation of the look angles.

The front-end electronics for the two instruments is quite different. In the case of WAM the raw counting rates are transmitted for each of the 8 detectors after pulse height analysis into 16 channels along with the detector identification code. The energy range for each of the 8 detectors was set at 20 to 200 keV. For the HEXIT payload the electronics is much more complex. The block diagram for the HEXIT on-board electronics is shown in Figure 1C. The main requirement are a large dynamic range since the energy band of operation for PAC was set at 20 to 1000 keV. The data from all the 13 tubes are digitized separately and transmitted to ground to compute the position of the incoming photons on the detector surface. In addition, a pulse rise time analysis is done to differentiate between the two types of pulses arising from two different detectors. A digitized sum signal with an absolute time tag accuracy of 5 microseconds is also telemetered to the ground. An Am241 radioactive source is mounted on the FOV collimator of the PAC to calibrated and check the detector gain during the flight. The radioactive source is operated by ground command. The data is transmitted on a 100 kbit PCM link. The real-time analysis of the housekeeping and quick-look analysis of the PAC data are performed on ground. Similarly, the data from the WAM detectors is analyzed in real time to generate the alerts for any transient phenomenon. All parameters of the instrument can also be commanded from ground if required, using manual-mode override. A complete assembly of the balloon payload in launch readiness is shown in Fig 1D.

## 3. Balloon flight and the payload performance

The HEXIT payload was launched on March 25th, 2005 at 0305 IST using a 590,000 cubic-meter balloon. The 650 kg. payload carrying an additional ballast of 200 kg. reached the ceiling altitude of 3.8 mbars. A total of 6 hrs data was obtained on the float altitude before termination of the flight using a ground command. Being the first flight for this new payload, a large majority of the observations were devoted to the study of various



**Figure 2.** (a) Detector counts at ceiling altitude for the PAC and (b) detector 3 in the WAM assembly

engineering, control, stabilization, electronic and the event-selection parameters along with two source targets. Preliminary spectral data from the Phoswich Anger Camera and one of the WAM detector is shown in Figure 2. The figure represents the raw counting rates averaged over 30 minutes time bin and no corrections for detection efficiency, atmospheric absorption or the Compton scattered contribution to the data have been applied to the data. The data shown in the left panel represents the total counting rate observed in the phoswich anger camera. The observed counting rate at the ceiling altitude is  $\sim 2000$  in the energy band 20 to 1000 keV. A strong line feature seen at around 200 keV corresponds to the Iodine spallation line observed in the case of NaI detectors due to atmospheric neutrons [9]. In the right panel in figure 2, we have plotted the typical spectrum of one of the detector in WAM assembly. The data corresponds to 20 to 200 keV. Once again no correction have been applied to the data. The data show that the observed background spectrum is consistent with the observed for the atmospheric gamma rays as seen in our earlier experiments. The analysis of the housekeeping data shows that target acquisition and the orientation stability was within 0.1 degree. All commands worked as expected. The detailed analysis of the flight data is in progress.

#### 4. Acknowledgements

It is a pleasure to thank P.P. Madhwani, T.K. Manojkumar, J.P. Kayande, B.G. Bagade and Mrs. N. Kamble for fabrication of the gondola, electronics subsystems and the Ground support software.

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