

InFOCuS Hard X-ray Imaging Telescope

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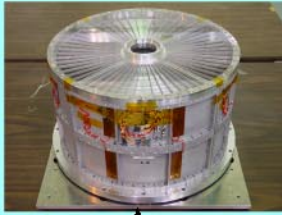
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Summary

InFOCuS is a new generation balloon-borne hard X-ray telescope with focusing optics and spectroscopy. We had a successful 22.5-hour flight from Fort Sumner, NM on September 16-17, 2004. In this paper, we present the performance of the hard X-ray telescope, which consists of a depth-graded platinum-carbon multilayer mirror (called a supermirror) and a CdZnTe detector. The telescope has an effective area of 49 cm² at 30 keV, an angular resolution of 2.6 arcmin (HPD), and a field of view of 11 arcmin (FWHM) depending on energies. The CdZnTe detector is configured with a 12x12 segmented array of detector pixels. The pixels are 2 mm square, and are placed on 2.1 mm centers. An averaged energy resolution is 4.4 keV at 60 keV and its standard deviation is 0.36 keV over 128 pixels. The detector is surrounded by a 3-cm thick CsI anti coincidence shield to reduce background from particles and photons not incident along the mirror focal direction. The inflight background is 2.9×10^{-4} cts sec⁻¹ cm⁻² keV⁻¹ in the 20 - 40 keV band.

Pt/C depth-graded multilayer mirror (supermirror)

Energy band	< 40 keV
Diameter/Focal length	40 cm / 8 m
Optics	Conical appr. of Wolter I
Incident Angle	0.105 - 0.356 deg.
Number of nesting	255
Number of reflectors	2040
Reflector	Al-backed epoxy replica
Reflector radius	59 - 200 mm
Reflector length	100 mm x 2
Reflector Thickness	175 μm
Reflector Surface	Pt/C multilayer supermirror
Periodic thickness	29 - 130 Å
Number of bi-layers	25 - 65



Reflection by multilayer mirror

Hard X-rays are reflected by Bragg Reflection $2d \sin\theta = n\lambda$ (instead of total reflection)

Effective area

Ground calibration was performed at ISAS, Japan. Effective area was obtained with NaI+PMT detector

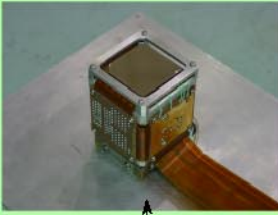
Energy [keV]	Area [cm ²]
20	58
30	49
40	23
50	11

Field of View (FWHM)

Energy [keV]	FOV [arcmin]
20	12
30	11.5
40	11

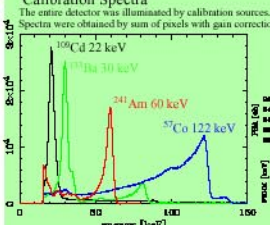
Pixellated CdZnTe detector with Cs-I active shield

Detector Size	1x1 inch (11x11 arcmin)
Pixel Array	12 x 12 (128 pixels)
Pixel Spacing	2.1 mm
Pixel Size/thickness	2x2 mm/2 mm
Operating Temperature	20 deg. C
Detection efficiency	100% (<40keV)
Active Shield	3-cm thick Cs-I with PMTs
Collimator FOV	10 deg. (FWHM)
Onboard Calibration source	²⁴¹ Am (tagged by anti-coincidence)



Calibration Spectra

The entire detector was illuminated by calibration sources. Spectra were obtained by sum of pixels with gain correction.

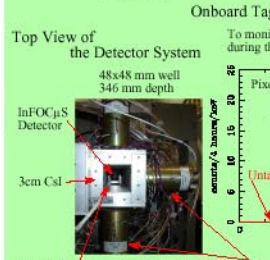


Energy Resolution

Energy [keV]	Res. [keV]
22	3.9 (17.7%)
30	3.8 (12.6%)
60	4.4 (7.3%)

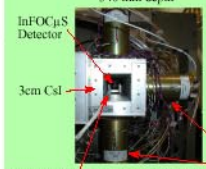
Onboard Tag Source Spectrum (²⁴¹Am)

To monitor the detector gain for each pixel during the balloon flight.



Top View of the Detector System

48x48 mm well
346 mm depth

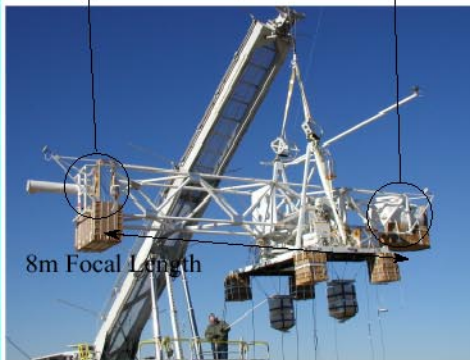


InFOCuS Gondola

Attitude Control System
 - Momentum wheel (Az)
 - Elevation drive (El)
 - Strap adjuster (Cross-El)
 Attitude Monitor
 - Star camera
 - 3-axis gyro
 - Magnetometer
 - Inclinator

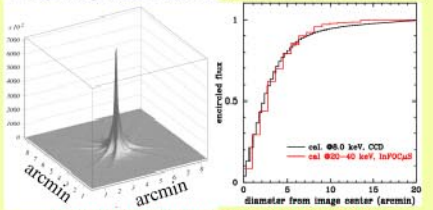
Optical Bench (carbon fiber tube)
 Maintain 8 m focal length
 Two lasers to monitor the mirror-detector alignment
 Weight 1600 kg

8m Focal Length

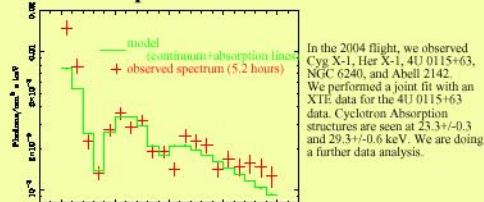


Angular Resolution of the Hard X-ray Telescope

Ground Calibration at ISAS, Japan and Ft. Sumner, NM
 X-ray image at 8keV (CCD) EEF at 8 and 20-40 keV



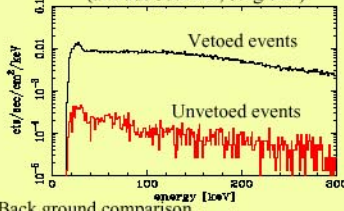
Observed Spectrum of 4U 0115+63



Inflight Background

Low background was achieved during the flight owing to the anti-coincidence active shield (3-cm CsI). The background rate is 2.9×10^{-4} cts sec⁻¹ cm⁻² keV⁻¹ (20-50 keV).

Back ground spectrum (altitude 35.2 km, 5.4g/cm²)



InFOCuS Sensitivity

Owing to the low background and large effective area in the hard X-ray band, InFOCuS achieves sensitivity as great as 500 μCrab in 20-50 keV for the 2004 flight (an 8 hours observation, $\Delta E/E=2$). We plan to improve the angular resolution and the mirror effective area (two mirrors) as well as make CZT thinner for the future flights. We would expect the sensitivity of 100 μCrab level.

