THE JET-X EXPERIMENT ON-BOARD SPECTRUM-XΓ MISSION

T. Mineo and G. Cusumano

Istituto di Fisica Cosmica ed Applicazioni dell'Informatica, CNR
Via M.Stabile 172
90139 Palermo, Italy

ABSTRACT

The Joint European X-ray Telescope JET-X is one of the experiment on-board SPECTRUM-XΓ. It consists of two identical co-aligned X-rays imaging telescopes, with a cooled CCD detector on the focal plane, and an optical monitor. A description of the experiment with some informations about the satellite and the ground segment are given.

INTRODUCTION

JET-X (Joint European X-ray Telescope) is designed for detailed studies of the X-ray emission from sources and cosmic background in the energy band 0.2-10 KeV. The experiment is being developed by a consortium of Italian groups from Istituto di Fisica Cosmica ed Applicazioni della Informatica del CNR in Palermo, Istituto di Fisica Cosmica e Tecnologie Relative del CNR in Milano, Istituto dell'Osservatorio Astronomico dell'Università "La Sapienza" di Roma, Dipartimento di Fisica dell' Università di Milano, Osservatorio Astronomico di Brera-Merate; British groups from University of Birmingham, University of Leicester, Rutherford Appleton Laboratory, Mullard Space Science Laboratory; a German group from Max Plank Institut fuer Extraterrestrische Physik, Garching bei Munchen; and the Space Science Department of ESTEC, ESA.

JET-X consists of two identical co-aligned X-rays imaging telescopes with a cooled CCD detector on the focal plane. This will provide an high spatial resolution combined with a good energy resolution, in particular, around the 7 KeV Fe-line complex $E/\Delta E$ is less than 50. An optical monitor is co-aligned with the X-ray telescopes for simultaneous observations of the optical counterparts of the X-ray target sources.

JET-X is one of the components of the overall payload of the USSR's SPECTRUM-XΓ, an international mission whose combined response extends from 20 eV to 100 KeV. The satellite will be placed in orbit by PROTON launch vehicle. The SPECTRUM-XΓ scientific payload includes two groups of instruments:

1)Narrow field instruments employed for detailed investigations of quasistationary sources.

2)Burst and Survey instruments with large field of view intended for locating X and Γ rays burst sources.

JET-X, a stand alone instrument of the first group, is chosen as reference experiment for the alignment, and all the other instruments of the payload are aligned relative to this. In fact, it has the best spatial resolution, and is equipped with an optical sensor with an angular reso-lution up to 5 arcsec.

Data Analysis in Astronomy IV, Edited by V. Di Gesù *et al.*
Plenum Press, New York, 1992

AXAF and XMM. In comparison with contemporary ... spectral and imaging resolution than SODART ... throughput, but a better limiting sensitivity, spectral and imaging resolution than SODARI ... comparable throughput, but better spatial resolution than ASTRO-D the Japanese mission ... a larger throughput and a higher resolution than the imaging spectrometer on SAX.

INSTRUMENT DESCRIPTION

Telescope

Each of the two X-ray telescope is composed by a nested array of twelve Wolter I ... rors (paraboloid+hyperboloid). The focal length is 3.5 meters and the field of view 20 ... min. The instrument effective collecting area is 360 cm^2 at 1.5 KeV and 140 cm^2 at 8 K... Fig. 1 shows the effective area as function of energy at different incident angles.

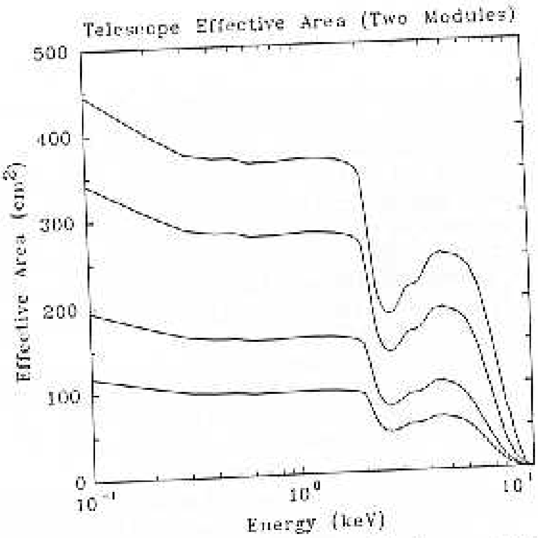

Figure 1. Total collecting area of one JET-X telescope on axis and at off-axis angles of 7.5, 15.0, 22.0 arcmin.

The angular resolution is strongly dependent on the microroughness of the mir... face and on the manufacturing tolerances (Aschenbach et al. 1980). Using the same ... ction technique as the Italian satellite SAX, based on the electroforming replica, it wil... ter than 30 arcsec. A mandrel is machined to the required figure, and then superpol... such a way to have a surface microroughness less than 5 A at 8 KeV. On each m... gold layer is evaporated and a nickel layer is electroformed on top of this. The go... gives the reflecting surface for X-rays, while the nickel, a few millimeters thic... supporting the gold (Citterio et al. 1987).

The CCDs on the focal plane provide a spatial resolution compatible with the optics together with a broad band spectroscopy, covering the energy range 0.2-10 KeV. The type of CCD chosen for JET-X is based on an enhanced version of the P88200 CCD, with a lower noise amplifier included. It is a deep depletion CCD, 65 μm thick, with a 40 μm depletion depth and 25 μm undepleted silicon underneath (Lumb and Holland 1989). The device is fabricated on high resistivity silicon to obtain good quantum detection efficiency at energies above 3 KeV (see fig. 2). It is front illuminated with a substantially reduced electrode thickness to improve the sub-KeV response, compared with the standard CCD.

The field of view is covered by a set of two CCDs closely butted; each of them is fabricated in two identical sections: one collects the images and the other is shielded and used to read out the signals. The coverage of the total focal plane, considering both telescopes, is 98% (Wells and Lumb 1989). The CCDs are cooled at temperature around 170-180 K in order to reduce the dark current. The FWMH energy resolution is 150 eV at 8 KeV and is determined by the equation:

$$\delta E = 8.58 \sqrt{(n^2 + f*E/3.65)}$$

where n is the electronic noise, E the energy of the incident photon, and f the Fano factor. Fig. 3 shows the energy resolution versus the energy.

There will be two operating modes:

framestore: the image data are collected in one half of the array and with a rapid shift, the stored signal changes to the shielded store section. Data are readout whilst the next image accumulates in the image section. The time necessary to complete the readout operation is almost 2.5 sec.

timing mode: the readout mode comprises a row shift followed by a pixel shift and read, repeated indefinitely. The time resolution increases to 0.3 msec, that is the time for a single pixel to across the photon impact area.

The high thickness of the device will improve the charge particle background rejection. In fact, the mean energy deposited from each particle in such thick device will be almost 25 KeV, well out the working range. By a pixel-to-pixel anti-coincidence discrimination a 99.95% rejection efficiency is reached.

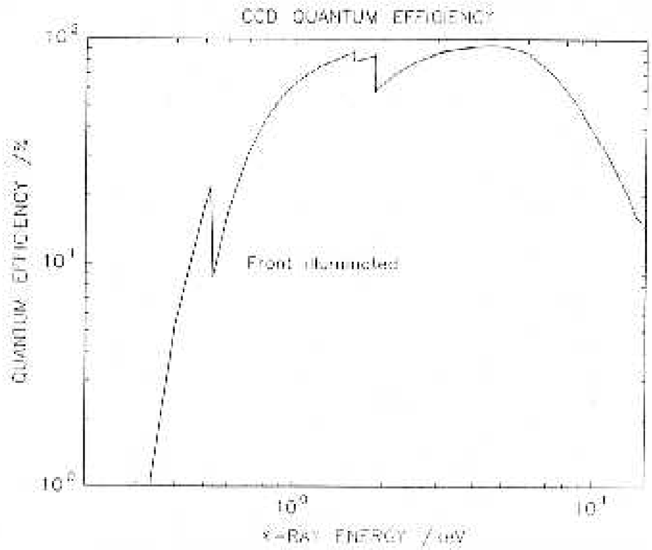

Figure 2. JET-X CCD quantum efficiency versus energy.

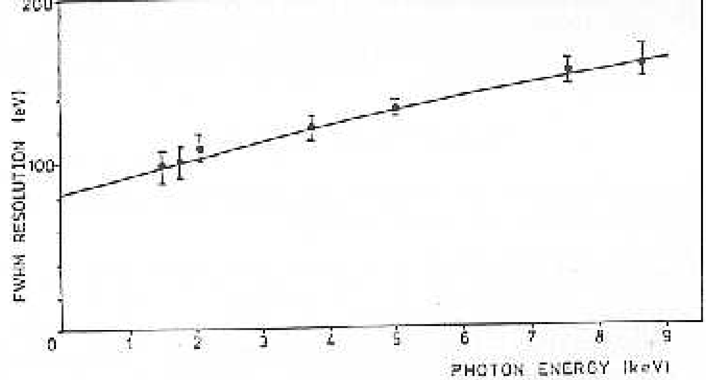

Figure 3: Predicted CCD energy resolution versus energy. The points represent the measured values.

SCIENTIFIC CAPABILITY

The two characteristics that determine the scientific strength of JET-X are the high s tial resolution that gives a potential high point source sensitivity, and the spectral per mance. The sensitivity to X-ray sources depends on the flux level of the source and on source spectrum. Fig. 4 compares the source sensitivity in three different energy bands. source is assumed to have a power law spectrum with photon index 1.7 and absorb column density of $3*10^{20}$ cm^{-2}. The detection limits is 5σ over the background. The kin background considered is represented by three components: the cosmic X-ray backgrou the galactique diffuse X-ray background and the charge particle background, for altit greater than 40000 Km, after rejection. The sensitivity does not depend strongly on

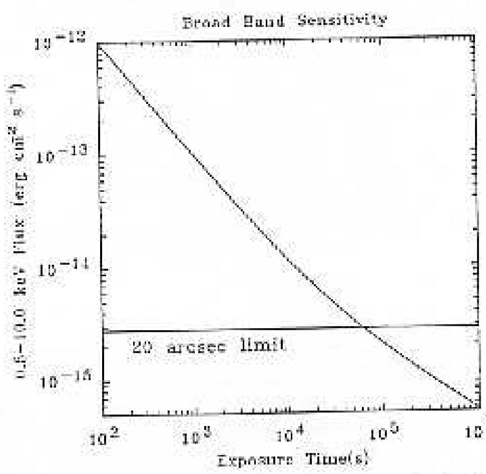

Figure 4. Time required for a 5σ detection of a point source for JET X. Also shown is the confusion limit assuming a Euclidean extrapolation of the EINSTEIN logN-logS.

rate by less than 25%, while increasing the assumed column density to 10^{21} cm^{-2}, would decreases the count rate by 30%.

The limiting sensitivity, computed using one source per 30 beamwidth criterion, for a detector with 20 arcsec beamwidth is almost $3*10^{-15}$ erg/cm^2/sec in the range 0.5 - 10 KeV. The confusion limit has been extrapolated considering the EINSTEIN logN-logS population of sources. The time necessary to reach this limit is of the order of 10^5 sec. Fig. 5 shows the minimum flux detected with a 5σ level for a line at 7 KeV with an equivalent width of 2 KeV, 1 KeV, 100 eV over a power law continuum with photon index 1.7.

GROUND SEGMENT

The SPECTRUM-XΓ spacecraft will be commanded to dump stored memory data to ground, nominally once per day for about 1 and 1/2 hours. A low speed telemetry channel (65 kbit/sec) will be used for commanding and housekeeping. Normal science data will be telemetered using 1 Mbit/sec link. The prime ground station is at Eupatoria in Crimea. All data from SPECTRUM-XΓ will be transmitted when possible by 1 Mbit/sec analogue data link from the Ground Station to Moscow (IKI).

As back-up to this link, data may be sent by magnetic tapes with small sub-sets being transmitted by 4.8 kbit/sec public data link. The back-up ground station for SPECTRUM-XΓ is at Ussuriysk near Vladivostok. At IKI, the data will be filtered in order to pass to West-European share of JET-X data, together with the necessary spacecraft housekeeping data, to the JET-X Quick Look Facility (QLF) in IKI, where a brief analysis on the data, before the transmission to the United Kingdom, will be performed. The nominal volume of data for JET-X is 40 Mbyte per day, when spacecraft housekeeping, parity and the other administrative data are added the total volume will be 60 Mbyte /day.

From the QLF at IKI data will be transmitted by dedicated commercial data link to Rutherford Appleton Laboratory in UK, where all data will be checked for completeness, in order to inform the QLF that they have arrived safely. At Leicester University there will be a Instrument Analysis Centre responsible for the off-line functions of the instrument calibration and detailed science analysis. JET-X data will be distributed to the consortium groups in data sets corresponding to the observations requested.

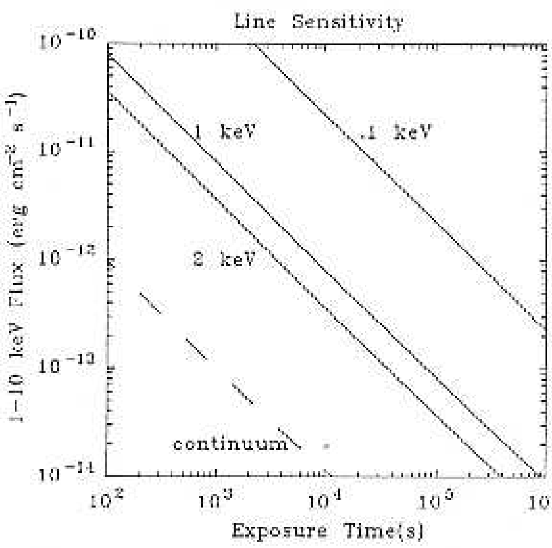

Figure 5: Time required by JET-X for a 5σ detection of lines of varying equivalent widths as a function of the continuum intensity.

Aschenbach, B., Brauninger, B., Hasinger, G., Trumper, J., 1980, Proc. SPIE **257**, 223.
Citterio, O., Bonelli, G., Conti, G., Mattaini, E., Santambrogio, E., Sacco, B., Lanzara, E., Brauninger, H., Burkert, W., 1987, Proc. SPIE **830**, 139.
Lumb, D.H., Holland, A.D., 1989, Proc. SPIE **830**, 116.
Wells, A., Lumb, D.H., 1989, Proc. SPIE **1159**, 372.
Antonello, E., Citterio, O., Mazzoleni, F., Mariani, A., Pili, P., Lombardi, P., 1990, Proc. SPIE on 'Astronomical Telescopes & Instrumentation for the 21st Century', Tucson, Arizona.