THE X-RAY ASTRONOMY SATELLITE SAX

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ABSTRACT

The SAX satellite is forseen for launch at the end of 1992 to study the X-ray emission from galactic and extra-galactic sources in the energy range 0.1-200 keV. The payload consists of four concentrator/spectrometer systems (3 units 1-10keV, 1 unit 0.1-10keV), a high pressure gas scintillation proportional counter (3-120keV), a phoswich scintillation counter (15-200keV), and two wide field cameras (2-30keV). Together these instruments will perform the following:-

- Broad band spectroscopy (E/ΔE=12) in the energy range 0.1-10 keV with imaging resolution of 1 arcmin
- Continuum and cyclotron line spectroscopy (E/ΔE=5-20) in the wide energy range 3-200 keV
- Variability studies of bright source energy spectra on time scales from milliseconds to days and months
- Systematic long term source variability studies in selected regions of the sky down to a source intensity of 1 mCrab.

THE SAX MISSION

SAX, 'Satellite for Astronomy in X-rays', is a major program of the Italian Space Plan (PSN) involving a collaboration with the Netherlands Agency for Space Programs (NIVR). SAX is currently finishing its Phase B activities with the satellite forseen for launch at the end of 1992. Its scientific objectives are to carry out systematic and comprehensive observations of celestial X-ray sources in the very broad energy band 0.1-200 keV with special emphasis on spectral and timing measurements.

SAX was originally designed for launch by the Shuttle and insertion into a circular orbit at 550 km and 12 deg inclination, but has been redesigned for launch by the Atlas G-Centaur directly into a 600 km circular orbit at 2 deg inclination. The ground station will be situated near the equator (at the San Marco Base, Malindi, Kenya), while the operations control centre, connected by relay satellite will be in Italy. The satellite will achieve better than a 2 arcmin pointing stability over a series of orbits for a total single observation time of typically upto 100,000 seconds, with a postfacto pointing accuracy of 1 arcmin. During each orbit 450 Mbits of information will be stored onboard and transmitted to the ground during station passage. SAX has a design lifetime of just over two years, but will remain in orbit for upto four years.

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THE SAX PAYLOAD INSTRUMENTS AND THEIR CAPABILITIES

The chief characteristics of the SAX payload instruments, described in more detail by Spada (1983) and Perola (1988), are given in Table 1. Fig.1 illustrates the arrangement of the instruments in the payload module, with the concentrator/spectrometer, HPGSPC, and PDS, collectively called the narrow field instruments, all pointing in the same direction, while the WFC point in diametrically opposed directions perpendicularly to them.

	Aperture FWHM	Ang.Res.	Total Eff. Area	Energy Res. FWHM
Concentrator/Spectrometer	30'	1'	200 cm^2 7keV	8% 6keV
(3 units, 1-10 keV, MEC/S)			56 cm^2 0.25keV	39% 0.27keV
(1 unit, 0.1-10 keV, LEC/S)				
High Pressure Gas Scint.	60'	-	280 cm^2 60keV	3% 60keV
Proportional Counter			300 cm^2 6keV	10% 6keV
(3-120 keV,HPGSPC)				
Phoswich Detector System	87'	-	140 cm^2 200keV	17% 60keV
(15-200 keV, PDS)			680 cm^2 20keV	
Wide Field Cameras	20° x 20°	5'	250 cm^2 (/unit	20% 6keV
(2 units, 2-30 keV, WFC)			through mask)	

Table 1. The Chief Characteristics of the SAX Payload Instruments.

Each of the four mirror assemblies in the concentrator/ spectrometers consists of 30 nested gold coated, double cone approximations to the Woltjer 1 configuration with a focal length of 185 cm. (Citterio et al 1987). Thier design maximises the effective area around 7 keV for iron K-line studies, while the position sensitive GSPC's in their focal planes' will have energy resolutions comparable to that of the solid state spectrometer of the Einstein Observatory and more than a factor of two better than previous proportional counters at 7 keV. The concentrator/spectrometers' sensitivity-confusion limit will be a factor of about three better than that of the ROSAT ($E \leqslant 2$ keV) all-sky survey so they will be capable of fully exploiting the survey in their choice of representitive samples of faint objects for detailed study upto 10 keV. Their ability to detect emission lines and determine the spectra of different regions of extended sources is shown in Fig.2.

The very good energy resolution of the HPGSPC will be particulary important in the detailed study of narrow cyclotron emission and absorption line features as illustrated by the simulated Her X-1 cyclotron line in absorption in Fig.3. It will also complement the iron K-line studies of the concentrator/spectrometers and the source continuum studies of the PDS.

The high source flux sensitivity over a broad energy range and the energy resolution of the PDS ideally suit the instrument to detailed studies of the continuum in galactic and extra-galactic sources down to its ultimate 5σ sensitivity limit of 1/20 3C273 in 300,000 seconds. It will also study cyclotron line features in known sources and search for these in other binary pulsars extending the measurements of the HPGSPC particularly for broad line features.

The balance in overall broad band sensitivity of the narrow field instruments from 0.1-200 keV is best illustrated by the simulated results on a typical AGN (1 mCrab at 3 keV, energy spectral index =0.6, N =4.10**20 cm**-2) in Fig.3 from which the spectral index can be obtained with about an order of magnitude smaller uncertainty than with previous experiments (Exosat, HEAO-1). Soft excesses or spectral breaks at higher energies should be clearly visible if present.
The payload is completed by the two WFC. Each contains a position sensitive proportional counter filled with two atmospheres of xenon, with a random mask aperture. Their energy range will complement those of the narrow field instruments.They will perform long term monitoring of both galactic and extra-galactic sources, and the detection/ localisation of transients on timescales from 2 ms upwards.

SAX SCIENTIFIC OBJECTIVES

The SAX payload has been chosen to cover the energy range 0.1-200 keV in a balanced manner to notably extend the spectroscopic and time variability studies performed to date. In the mission life of atleast two years SAX will perform between 2000 and 3000 seperate observations. The majority will be governed by the narrow field instruments while the WFC will perform long term monitoring of selected sources. Periodically the WFC will survey the galactic plane with particular emphasis on transients. The observations will be based on a core program chiefly devoted to systematic studies of various classes of objects, and a guest observer program allocated about 20% of the time. A selection of the areas, discussed in more detail by Perola (1983), inwhich SAX is expected to make its most significant contributions is given below:-

- Compact galactic sources: the shape and variabilty of their continuum and temporal studies of features such as iron flourescence lines, cyclotron lines and absorption effects as a function of orbital phase and rotation, transient detection and light curve studies
- Supernova remnants: spatially resolved spectra of extended ($\gg$1') galactic SNR's, and the spectra of the Magellanic Clouds remnants
- Stars: coronal emission spectra with a sensitivity comparable to that of the Einstein Observatory upto 10 keV
- Active galactic nuclei: spectral and temporal variability studies of their continuum upto 200 keV, the spectra upto 10 keV of very distant sources (z=3.2 for sources equivalent to 3C273) and soft X-ray excess, photoelectric absorption and iron flourescence line studies
- Clusters of galaxies: spatially resolved spectra upto 10 kev of the nearby clusters with iron flourescence line and temperature gradient studies and high energy spectra for $z < 0.1$ and temperature measurements out to $z \sim 1$
- Normal galaxies: spectral studies of their extended emission.

Its launch date at the end of 1992 will give SAX a first opportunity to take advantage in a systematic way of the many new results that should become available from the all-sky imaging survey of ROSAT, and it will preceed the large observatory type missions due for the second half of the 1990's which will concentrate on X-ray astronomy upto 10 keV only.

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REFERENCES

Citterio, O., et al. 1988, Applied Optics, 27, 1470.
Perola, G.C., 1988, Cospar XXVII, Helsinki, in the press.
Perola, G.C., 1983, Proc. of Workshop on Non-thermal and Very High Temperature Phenomena in X-ray Astronomy, eds. Perola, G.C., and Salvati, M., Rome, 19-20 December 1983, p.175.
Spada, G.F., 1983, ibid.

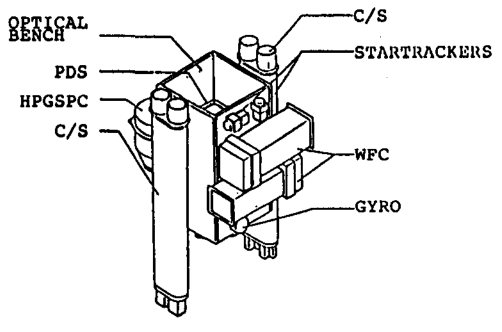

Fig.1 The SAX payload module

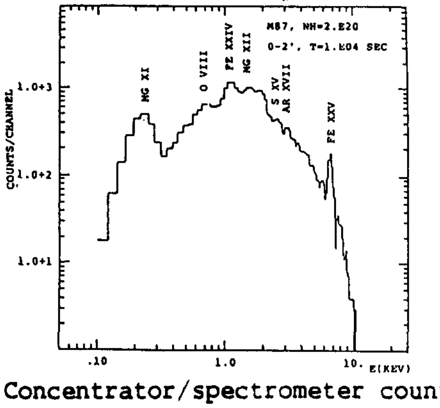

Fig.2 Concentrator/spectrometer counts in 10**4s from the central region of M87

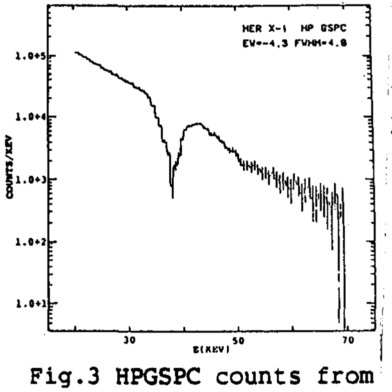

Fig.3 HPGSPC counts from Her X-1 in 10**5s showing the cyclotron line in absorption

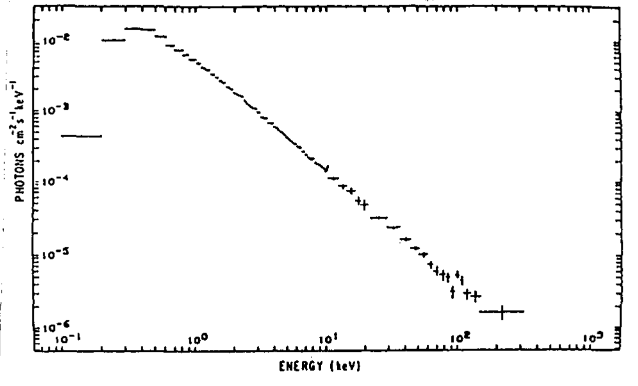

Fig.4 The deconvolved spectrum of a typical AGN observed for 10**5s

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DISCUSSION-R.C. Butler

DISCUSSION

R. Pallavicini: Since the LEGSPC on SAX is sensitive up to 10 keV, what is the reason to have only 1 LEGSPC and 3 MEGSPC, rather than four LEGSPC detectors?

R. Butler: The choice of 3 MEGSPC's and only 1 LEGSPC in the concentrator/ spectrometer comes above all from reliability considerations given that the LEGSPC is now position sensitive and thus capable of very similar results above 1 keV to the MEGSPC's, which was not the case in the original proposal where no imaging capability was foreseen from the LEGSPC. The reliability of a 1.5-2 μm polypropeline window over a mission lifetime of at least two years is very difficult to assess, and so the configuration with 3 MEGSPCs with 25 μ beryllium windows was retained to ensure mission success.

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