IMPACT OF A 30% WEIGHT REDUCTION ON THE GEOMETRIC AREA AND SCIENTIFIC OBJECTIVES OF THE SAX/PDS EXPERIMENT

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FOREWORD

This report has been prepared for the SAX - Consortium as a response to a request for a substantial weight reduction (30 kg) of the SAX-PDS hard X-ray experiment.

The implications of such a weight reduction are described in general and high-lighted by some examples of possible X-ray source observations.

1. INTRODUCTION

The SAX satellite is a multi-purpose broad band astronomical mission. It was proposed in 1981 with the aim to have a powerful tool to exploit broad band spectroscopy (1-200 keV) and temporal studies of cosmic X-ray sources (SAX Proposal to PSN, June 1981). This has required a multi-detector observatory, in which the high energy instrument (PDS) is designed to give an essential input to the answers of the following open scientific questions:

a) accurate measurements of hard X-ray spectra of galactic sources (mainly compact objects: white dwarfs, neutron stars, black hole candidates).

b) Temporal and spectral variability of compact galactic sources:
   - b1) X-ray pulsars: accurate pulse-phase resolved spectroscopy in hard X-rays; study of cyclotron lines and of their dependence on pulse phase; pulse timing and pulse noise (also on time-scales of thousands of seconds);chaotic variability in the intensity of the emission and its correlation with softer X-ray bands (from C/S and HP GSPC); flux variability on millisecond timescales;
   - b2) B.H.candidates: study of metastable states; clarification of the nature of ultra-soft emitters with the study of possible hard tails (e.g. LMC X-1; LMC X-3); flux variability on millisecond time scales (Cyg X-1; GX 339-4; Cir X-1 etc.)
   - b3) Accreting white dwarfs: study of hard X-ray spectra with the phase of pulses/orbits; study in hard X-rays of the multi-periodic binary systems (e.g. EX Hydrae); broad band time variability correlations;

c) Accurate measurements of hard X-ray spectra of AGN and study of their variability; broad band correlations either spectral or temporal (with C/S and HP GSPC)

d) Estimate of the contribution of AGN to the diffuse hard X-ray background by means of the observation of a complete sample of AGN down to a limiting flux of 1/20 3C 273.

The trade-off between low weight,small dimensions and high sensitivity resulted in the design of an instrument able to detect limiting fluxes as low as 1/20 3C 273 in the 80-180 keV energy band.

2. THE IMPACT OF A 30 kg WEIGHT REDUCTION ON THE PDS GEOMETRIC AREA

a) The impact of a 30 kg (29% of the total weight in present configuration) cannot be achieved by a simple optimization of the present configuration. It requires a reduction of the detector geometric area.

b) Using the same prescriptions on which the present configuration has been designed, a detector of 400 cm^2 weighs about 74 kg, or 33.5 kg less than the present configuration.

3. FALL-OUT OF A REDUCED PDS CONFIGURATION ON THE SCIENTIFIC OBJECTIVES OF SAX

A 400 cm^2 detector has a geometric area of 340 cm^2. We evaluated the consequences of a 50% reduction in geometric area on the scientific objectives of SAX as described by Perola, Proc. Rome Workshop, Dec. 1983, pag. 175. Here we summarize the most outstanding ones.

a) Reduced sensitivity to flux variations.

Halving the surface area implies doubling the time required to detect a given fractional flux variation from a source. In other words we have a time resolving power that is one half of the previous one. We illustrate the consequences of this loss of information, discussing two remarkable examples. We stress, that these examples are only representative of sources which have shown or are expected to show temporal flux variations.

a1) NGC 6814

This AGN was observed with HEAO 1 A2 to have flux variations on time scales down to hundreds of seconds. Orbit to orbit variations ($\sim$ 4000 s) by a factor 2.5 were also seen between a "high" and a "low" flux state (see fig.1).

In the present configuration (800 cm^2) the SAX/PDS will detect (5 σ) this source in the 15-30 keV energy band in 150 s in the high state,and in $\sim$ 900 s in the low state. C/S will need approximately the same exposure time ($\sim$ 250 s) to detect a flux variation of a factor 2.5. In this, as in all cases where we are hunting for time variability from hard sources C/S and PDS are well matched (with a better sensitivity for PDS on very short timescales).

Moreover in the present configuration the PDS can give a detailed spectrum of the source in high state during one orbit, and a 5 σ hardness ratio I (30-80)/I (15-30) on time scales of 3000 s, when the source is in low state.

By halving the geometric area of PDS, we shall not able to study the short time variations ($\sim$ 100 s) and the hardness ratio from orbit to orbit. The hardness ratio is very important to put constraints on both thermal and non thermal models.

Unfortunately the HP-GSPC cannot compensate the loss of sensitivity of PDS, as it requires about 7000 s to detect the source in the 10-30 keV energy band.

a2) NGC 4151

A 10% flux variation from this source is detected in 3000 s with the PDS in 15-30 keV and in 4000 s with C/S in 1-10 keV. This last time scale is moreover comparable to the time needed by PDS to detect a 10% variation in the 30-80 keV band (5600 s). The extremely extended energy band (1-80 keV) and the overall matching in sensitivity is very promising in order to obtain spectral/temporal correlations needed to clarify the physics of this source. On the contrary a reduction to a half of the PDS area does introduce a mismatching between the PDS and the C/S.

b) Reduced sensitivity to source detection.

The same general conclusions shown in the case a, hold also in this case: half area requires a double integration time to reach the same flux sensitivity. But we stress that doubling the integration time needs a control of long term back ground effects on time scales twice those needed with the standard configuration.

The consequence of the reduced sensitivity on the observation schedule is a double time needed to reach the scientific objectives of SAX, and this could be in conflict with the finite life time of SAX.

We illustrate the impact of a reduced sensitivity of the PDS with the following examples.

b1) Study of AGNs and their contribution to X-ray BKG.

A sample of 20 Seyferts and 10 QSOs with X-ray fluxes $\geq \frac{1}{20}$ 3C 273 can be observed in $\leq$ 30 weeks of live time.

The doubling of this time could be prohibitive considering the nominal life time of SAX of 2 years.

b2) Alternative pointings and serendipitous sources.

When one is observing sources with a very soft spectrum, it is still possible to exploit the observation capabilities of the PDS, as the probability of an AGNs within the field of view is not negligible:

i) We can point the rocking collimator axis in a direction different from that of C/S and in this way "pick-up" other sources. The log N/log S curve for AGNs (Piccinotti et al. (1982)) tells us that the number of AGNs, that are detectable with the PDS as described above, will be reduced to a half, if the PDS detection area is halved.

ii) If we discover a serendipitous source with the C/S, then by reducing the PDS area we halve the chance of obtaining a spectrum at higher energies.

b3) Hard tails in the spectra of clusters of galaxies.
The presence of a hard tail like that discovered in Perseus Cluster of galaxies can be detected with the PDS in other clusters.
We estimate that the PDS spends, for detecting the existence of a hard tail at 50 keV, an observation time which is a factor 5 longer than that needed by C/S to detect a Coma-like spectrum from an annulus 2.5-3.5 core radii.
This mismatching will be doubled with the reduced configuration.

b4) Pulse phase spectroscopy of X-ray pulsars.
We considered the weakest X-ray pulsar with steady emission: X Persei. Assuming an intensity of 10 mCrab (Worrall et al. 1981) with the current configuration we will detect the source in the 80-200 keV band in 10^4 s. So, with an observing time of 10^5 s, we can obtain a pulse phase spectrum with 10 phase bins up to 200 keV. With the same observing time, in the reduced configuration we halve the number of phase bins. As Becker et al. (1979) showed, the dip in the pulse profile ($\sim$ 0.1 times the pulsar period) corresponds to a sudden increase in the temperature. In this particular case with only 5 phase bins we lose the time resolution needed to study the temperature behaviour with the pulse phase (see fig.2).
As we do not know a priori what features we can expect from pulse phase spectroscopy of X-ray pulsars,we halve our chance to detect them with the reduced configuration.

4. CONCLUSIONS

A 30% reduction in weight causes a 50% reduction in geometric area. This has a relevant impact on the capacity of SAX/PDS for discovering new features in hard X-ray emitters, and on the possibility of improving the present knowledge about X-ray sources.

REFERENCES

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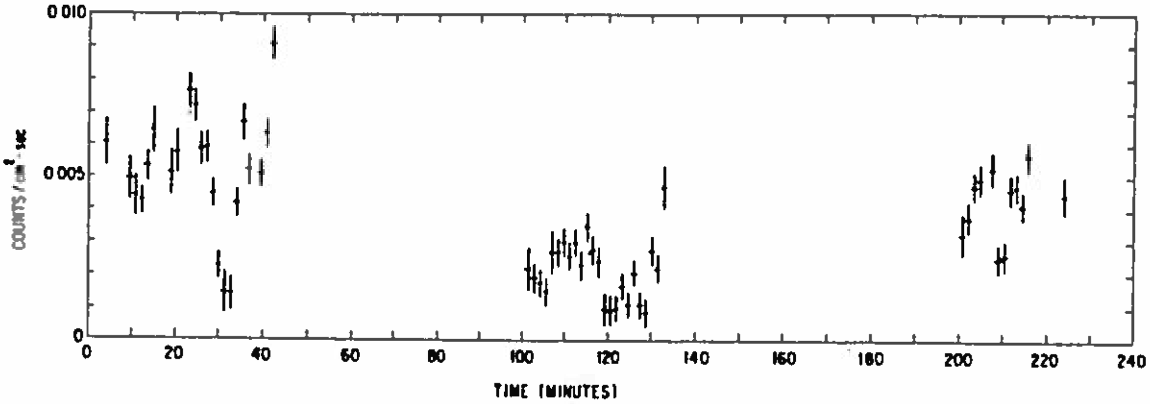

FIG. 1.—The X-ray flux from NGC 6814 as a function of time for the first three spacecraft orbits. Data from both MED and HED 3 were added together to construct this curve, giving an effective bandwidth of 3–20 keV. The bin size is 83 s. Zero corresponds to 1978 April 28, 0000 UT.

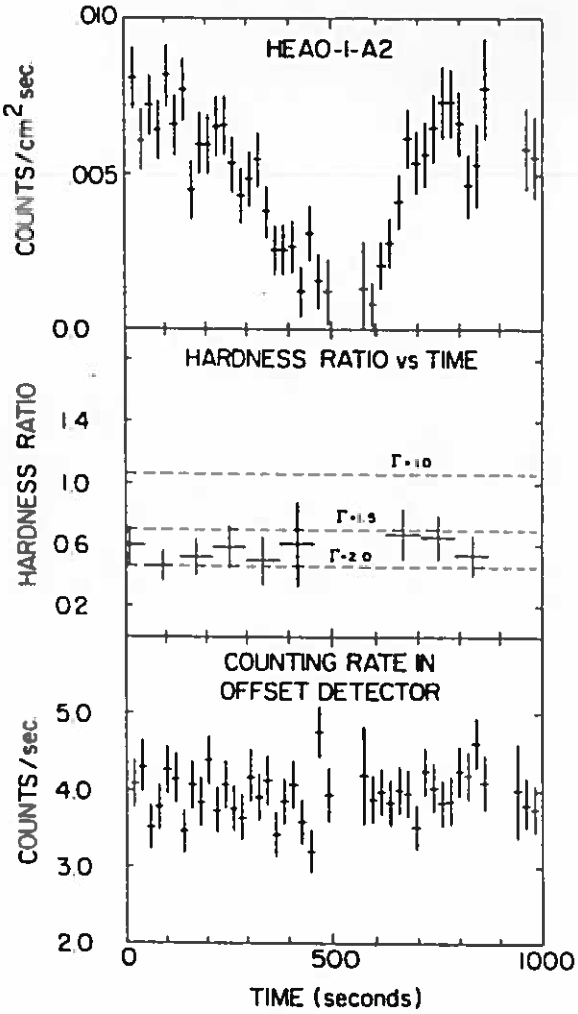

FIG. 2.—(*Top*): Enlarged section of the NGC 6814 X-ray light curve plotted in Fig. 1. Time of zero seconds corresponds to 24 minutes in Fig. 1. For this figure, the bin size was 20.48 s. The data point at $t = 500$ s occurred during a data drop and so does not exist. (*Middle*): The hardness ratios defined as > 6 keV flux divided by the < 6 keV flux in HED 3 during the event shown in Fig. 2 (*top*). The hardness ratio was computed every 82 s. The values of Γ for a given hardness ratio are indicated as straight lines labeled by the value of Γ. (*Bottom*): The counting rate for HED I during the event shown in Fig. 2 (*top*). The HED I field was offset by 6° from MED and HED 3 and so was monitoring the background. For the data shown χ^2 was 42.06 for 42 degrees of freedom.

X-ray light curves of NGC 6814 (Tennant et al.,1981)

Fig. 1

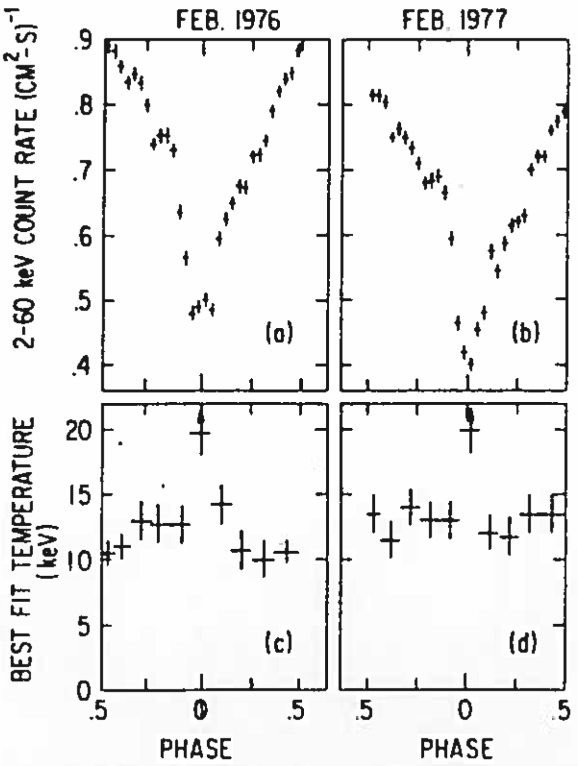

FIG. 2.—(*a*) (*b*) The pulsed light curves of X Per in 1976 February and 1977 February. (*c*) (*d*) The best-fit temperature for thermal bremsstrahlung continua for X Per spectra as a function of the pulse phase. The errors are 1 σ limits.

The pulsed light curves and the best-fit temperatures of X Per (Becker et al.,1979)

Fig. 2