ABSTRACT. The X-ray satellite BeppoSAX, a major programme of the Italian space agency with participation of the Dutch space agency, was successfully launched from Cape Canaveral on April 30, 1996. After a 2 months period devoted to engineering check out that confirmed the nominal functionality of the satellite and the scientific payload, we have performed a series of observations of celestial objects devoted to calibrate the instruments and verify their scientific performances. Here we will present some preliminary results obtained in this phase. They are confirming the expected scientific capabilities of the mission.

1. Introduction

The X-ray satellite SAX, named BeppoSAX after launch in honour of Giuseppe (Beppo) Occhialini, is the first X-ray mission with a scientific payload covering more than three decades of energy - from 0.1 to 300 keV - with a relatively large area, a good energy resolution, and with imaging capabilities (resolution of about 1 arcmin) in the range of 0.1-10 keV. This capability, in conjunction with the presence of wide field instruments primarily aimed at discovering transient phenomena, which could then be observed with the broad band instruments, provides an unprecedented opportunity to study the broad band behaviour of several classes of X-ray sources.

The broad band capability is provided by a set of instruments co-aligned with the Z axis of the satellite, Narrow Field Instruments (hereafter NFI) and composed by:

- MECS (Medium Energy Concentrator Spectrometers): a medium energy (1.3-10 keV) set of three identical grazing incidence telescopes with double cone geometry
(Citterio et al. 1985, Conti et al. 1994), with position sensitive gas scintillation proportional counters in their focal planes (Boella et al., 1996).

- LECS (Low Energy Concentrator Spectrometer): a low energy (0.1-10 keV) telescope, identical to the other three, but with a thin window position sensitive gas scintillation proportional counter in its focal plane (Boella et al., 1996).

- HPGSPC, a collimated High Pressure Gas Scintillation Proportional Counter (4-120 keV, Manzo et al., 1996).

- PDS, a collimated Phoswich Detector System (15-300 keV, Frontera et al., 1996).

Access to large regions of the sky (∼ 3000 degree²) with a resolution of 5’ in the range 2-30 keV is provided by:

- two coded mask proportional counters (Wide Field Cameras, WFC, Jager et al., 1996), perpendicular to the axis of the NFI and pointed in opposite directions.

Finally, the anticoincidence scintillator shields of the PDS (GRBM) will be used as a gamma-ray burst monitor in the range 60-600 keV with a fluence greater than about \(10^{-6}\) erg cm\(^{-2}\) and with a temporal resolution of about 1 ms.

More details on the mission and its instruments can be found in Piro, Scarsi & Butler, 1993, Boella et al., 1996, in the special session devoted to BeppoSAX of the SPIE Vol. 2517 and on line at:

http://www.sdc.asi.it

2. THE SCIENCE VERIFICATION PHASE

The goal of the Science Verification Phase is to verify the expected scientific capabilities of the mission and to calibrate the instruments. To this aim a series of objects with well known properties have been selected and are being observed. Here we present some preliminary results on the X-ray pulsar Vela X-1, the Seyfert galaxy NGC 4151 as examples of the broad band spectroscopy of bright and weak sources, and the simultaneous observation with the WFC and the GRBM of a γ-ray burst to show the capabilities of monitor wide regions of the sky to observe transient phenomena.

2.1. Broad Band Spectroscopy with the NFI

2.1.1. The X-ray pulsar Vela X-1

In fig.1 we show the spectrum of the X-ray pulsar Vela X-1 in the range 3-200 keV obtained in a 30 ksec observation with the MECS, HPGSPC and PDS. The data are fitted with a power law with absorption and an exponential cut off. The residuals show large deviations from the model. The most noticeable are those due to the presence of an iron line and absorption edge in the 6-8 keV region and an absorption feature around 60 kev. Following the results from GINGA (Mihara 1995) we have then fitted the spectrum with a power law with two cyclotron absorption lines, plus an iron line and iron edge. This model provides a satisfactory fit to the data (fig.2). The values of the cyclotron
Fig. 1. The pulse height spectrum of the X-ray pulsar Vela X-1 by the MECS, HPGSPC and PDS fitted with a power law with exponential cut-off. The residuals show the presence of iron line and absorption edge as well as an absorption feature around 60 keV lines are remarkably similar to those obtained by Mihara in a fit employing the same model. The first line is at around 27 keV, with an optical depth of about 0.2, whereas the optical depth of the second harmonic at 54 keV is about 10 times larger. The two lines are rather broad, being respectively about 15 keV and 35 keV. Further analysis is ongoing to study different models and phase-resolved spectra.

2.1.2. The Seyfert 1 galaxy NGC 4151: the spectrum

The X-ray spectrum of NGC 4151 is the most complex observed so far in AGN, being characterized by narrow and broad spectral features from soft to hard X-rays (e.g. (Perola et al., 1986); (Warwick, Done & Smith, 1995); (Zdziarski, Johnson & Magdziarz, 1996)). It is then the best candidate to verify the unique capability of BeppoSAX to disentangle spectral features over the 0.1-200 keV energy range.

In fig. 3 we show the spectrum of the LECS (7 ksec of effective exposure time), MECS (about 55 ksec) and PDS (about 35 ksec) fitted with a complex model of the broad continuum components. The presence of iron line and iron absorption edge is very clear in the residuals of the MECS (fig. 4). In fig. 5 we show the best fit model spectrum required to fit the data and composed by: an intrinsic power law with an exponential cut-off around 70 keV; an absorbing medium with a column density $\sim 10^{23} \text{cm}^{-2}$ which...
Fig. 2. The best fit to the Vela X-1 spectrum obtained with a power law with 2 cyclotron lines at about 30 and 60 keV, iron line and absorption edge (see text) 

is likely producing the observed iron fluorescence line and the iron absorption edge; this medium has a complex structure, well described by a leaky absorber, that allows a fraction (~20%) of the intrinsic power law continuum to be transmitted without strong absorption. However, to be consistent with the spectrum (and lack of variability, see (Perola et al., 1986)) in soft X-rays, this component needs to be absorbed by a further, uniform absorbing screen with $N_H \sim 10^{22} cm^{-2}$. Finally, a soft component, possibly of thermal origin ($kT \sim 0.4$ keV), external to the uniform absorber, is present below 1 keV.

2.1.3. The Seyfert 1 galaxy NGC 4151: spectral variability

The study of spectral variability provides the most powerful tool to identify the origin of the several components - some of which presumably share the same physical origin - located across the whole X-ray band. In the past this approach has been hampered basically by the limited bandwidth of the instruments, that did not allow to disentangle the different contribution of those components to the observed spectral variability.

From this point of view BeppoSAX provides an unique opportunity and the case of NGC 4151 is a very good example of its capability. EXOSAT observations of this object showed a clear evidence of spectral variability in the band 2-10 keV. However its origin was attributed either to a change in the slope of the intrinsic continuum (Perola et al. 1986) or to a variation associated with the absorbing medium (Yaqoob et al. 1989).
Fig. 3. The pulse height spectrum (detector cts/s) of NGC 4151 observed by the LECS, MECS and PDS (from left to right) fitted with a complex model: a power law, a soft X-ray component, a complex absorbing medium, a high energy cut-off.

Fig. 4. The spectrum of NGC 4151 in the MECS around the iron complex region. The best fit model is the same as that in fig.3 to show in the residuals the clear presence of the iron line and absorption edge.
Fig. 5. Best fit model (photon spectrum) of NGC 4151

Fig. 6. Ratio of the high and low state MECS and PDS spectra of NGC 4151. The spectral variability extends above 10 keV, and is therefore most likely produced by a change in the slope of the intrinsic continuum. Note as the region around 6.4 keV remains relatively constant, indicating that the iron line does not follow continuum variations on a scale of a few days.
GINGA observations suggested that, of the two explanations, an intrinsic variation was preferred by the data (Yaqoob and Warwick 1991).

Here we show some of the results we obtained during the observation by BeppoSAX. The object increased its flux by a factor of 2-3 in about 2 days. In fig. 6 we show the ratio of the spectra of the MECS and PDS relative to the second and the first part of the observation, when the source was respectively in a high and low state. The spectral change is evident in the whole range. In particular we note that the spectrum changes its shape also above 20 keV, a region where any effect of absorption by a medium with column densities as observed in this object ($N_H \sim 10^{23} \text{ cm}^{-2}$) is negligible.

Another result that appears from fig. 6 is the smaller variation observed around 6.4 keV (see also Molendi et al. 1997) indicating that the iron line does not follow the continuum variations on a scale of a few days. The medium producing the iron line has thence to be located at greater distances from the central source (Perola et al. 1986).

Fig. 7. Light curves of the γ-ray burst (GB960720) detected simultaneously in the GRBM and WFC detectors
2.2. Transient phenomena: the WFC and the Gamma-ray burst monitor

One of the primary scientific goals of BeppoSAX is the observation of transient phenomena in the sky. Two set of instruments are devoted to this purpose: the two WFC and the GRBM.

An exciting example of the capability of BeppoSAX of observing transient phenomena is the simultaneous observation of the $\gamma$-ray burst GB960720 by the WFC and the GRBM (Piro et al. 1996a). The WFC image allows to localize the event within a few arcmin. This observation has triggered a series of follow up observations in different energy bands (e.g. Frail et al. 1996; Murakami et al. 1996). We have carried out a deep observation of the field with the NFI, that has led to the discovery of a previously unknown X-ray source in the WFC error box (Piro et al. 1996b). It is not yet clear whether this source is actually related with GB960720, since the probability of finding a serendipitous AGN at this flux level in the error box is of about 0.1. Along with the imaging information, the wide band energy range covered simultaneously by the WFC and the GRBM provides important information of the evolution of the burst at different energies. In fig. 7 we show the light curves of the event in different energy ranges of the two instruments. The event duration decreases at higher energies. On the basis of the logN-logS of the $\gamma$-ray bursts and the instruments' sensitivities we expect to detect about 5 $\gamma$-ray burst in a year in both instruments.

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