SIMBOL–X, a new generation X–ray telescope for the 0.5–70 keV range

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Abstract. SIMBOL–X is a high energy “mini” satellite class mission that is proposed by a French-Italian-English collaboration for a launch in 2009. SIMBOL–X is making use of a classical X–ray mirror, of ∼ 600 cm² maximum effective area, with a 30 m focal length in order to cover energies up to several tens of keV. This focal length will be achieved through the use of two spacecrafts in a formation flying configuration. This will give to SIMBOL–X unprecedented spatial resolution (20″ HEW) and sensitivity in the hard X–ray range. By its coverage, from 0.5 to 70 keV, and sensitivity, SIMBOL–X will be an excellent instrument for the study of high energy processes in a large number of sources, as in particular accreting black-holes, extragalactic jets and AGNs.

1. Scientific case

The study of the non thermal component in high energy astrophysics sources is presently hampered by the large gap in spatial resolution and sensitivity between the X–ray and γ–ray domains. Below ∼ 10 keV, astrophysics missions like XMM–Newton and Chandra are using X–ray mirrors based on grazing incidence reflection properties. This allows to have an extremely good spatial resolution, down to 0.5″ for Chandra, and a good signal to noise thanks to the focussing of the X–rays onto a small detector surface. This technique has however an energy limitation at ∼ 10 keV due to the maximum focal length that can fit in a single spacecraft. Hard X–ray and γ–ray imaging instruments, such as those on INTEGRAL to be launched in Oct. 2002 are thus using a different technique, that of coded masks. This non focussing technique has intrinsically a much lower signal to noise ratio than that of a focussing instrument, and does not allow to reach spatial resolutions better than ∼ 10 arc minutes. This results for example in roughly 2 orders of magnitude of difference in point source sensitivity between X–ray and γ–ray telescopes.

This transition of techniques unfortunately happens roughly at the energy above which the identification of a non thermal component is unambiguous with respect to thermal emission. This obviously strongly limits the interpretation of the high quality X–ray measurements, and particularly that related to the acceleration of particles. Considered from the high energy side, this renders impossible the identification of the γ–ray emitters counterparts. As a single example of this fact, in relation with this workshop, one can cite the case of the SS 433/W50 system. The Eastern lobe is known to emit above 10 keV thanks to RXTE observations (Safi-Harb & Petre, 1999), but the interpretation of this emission is strongly dependent on the assumptions made on the size of the emitting region.
which is completely unknown because of the very poor angular resolution of RXTE (≈ 1°, similar to the lobe size).

The SIMBOL-X mission is basically designed to extend the X-ray focussing technique to much higher energies, up to ≈ 70 keV, i.e. well beyond the transition between thermal and non thermal emissions. Offering a constant spatial resolution and a “soft X-ray type” sensitivity over the full energy range from 0.5 to 70 keV, SIMBOL-X will be an excellent instrument to elucidate the origin of the non thermal emission in accretion / acceleration astrophysical sites, both compact and extended.

2. Mission concept

SIMBOL-X is built on the classical design of a Wolter I optics focussing X-rays onto a focal plane detector system. The gain in maximum energy is achieved by having a long focal length, of 30 metres i.e. 4 times that of XMM-Newton mirrors. Since this cannot fit in a single spacecraft, the mirror and the detectors will be flown on two separate spacecrafts, in a formation flying configuration, as sketched on Fig. 1. We shortly detail below each part of this system.

![Figure 1. SIMBOL-X two spacecrafts configuration.](image1.png)

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![Figure 2. Mirror effective area for different configurations. The baseline for SIMBOL-X is the top curve.](image2.png)

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2.1. Mirror

The focussing optics will be a nested shells Wolter I configuration mirror. Building on the experience acquired on Beppo-SAX, Jet-X, SWIFT, ABRIXAS and XMM-Newton mirrors, it will be made following the Nickel electroforming replication method (e.g. Citterio et al. 2001). The current design is to have a 108 shells mirror, with an outer diameter of 70 cm (like one XMM-Newton module), and an angular resolution of 20 arcseconds of Half-Energy-Width. The coating will be Pt, in order to increase the high energy response w.r.t. a more classical Au coating. The focal length will be 30 metres.

Figure 2 shows the effective area as a function of energy, for the baseline design. It has roughly a constant value of 600 cm² up to about 35 keV, before starting to decrease and fall below one cm² above more than 70 keV. The field of view (FOV) will be of 6 arcminutes at 50 % vignetting.

2.2. Focal plane detectors

The focal plane detector system has obviously to be a spectro-imager covering the full FOV and sensitive to the full energy range provided by the mirror, with
a “reasonable” spectral resolution below 10 keV for measuring lines, particularly that of Iron. Given the above mirror characteristics, the focal plane detector must be of 6 cm diameter with 500 µm of maximum pixel size (to provide an oversampling of the Point Spread Function).

The baseline focal plane responding to these constraints is made of an array of CCD detectors directly on top of a CdZnTe pixelated detectors array. This is completed by an optical blocking filter, and an active anticoincidence shield. Photons of energy less than $\sim 15$ keV will stop in the CCDs, whereas higher energy photons will go through the CCDs to be detected in the CdZnTe array. CCDs with 250 µm depletion depth and 2 mm thick CdZnTe, currently under tests in Leicester and CEA/SAp resp., are perfectly fitting the SIMBOL–X requirements.

2.3. Formation flying constraints and orbit

Both mirror and detector spacecrafts will be of the “mini-satellite” class (500 kg max). To keep a constant image quality requires the following constraints on the spacecraft relative positioning: i) their distance must be kept constant within 1 cm, ii) their positioning perpendicular to the optical axis must be kept within 1 cm, and monitored with a 0.5 mm accuracy, and iii) the angular stability must be better than 1 arcmin, and monitored to 3 arcsec. In order to minimize the differential forces between the 2 spacecrafts, as well as to allow uninterrupted observations of variable sources, SIMBOL–X will be put in orbit around L2.

3. Sensitivity

In order to calculate the signal to background ratio for astrophysical sources, we have used the radiation background spectrum calculation of Ramsey (2001) for the HXT CdZnTe detector, with veto, envisioned for Constellation X (also at the L2 orbit), a configuration very similar to that of SIMBOL–X. We have also modelled the astrophysical diffuse background. With these, we have derived the sensitivity of SIMBOL–X to point sources, or equivalently to diffuse emission in a 1 arcmin diameter region. This is presented in Fig. 3 with respect to other instruments. As expected for an X-ray focussing telescope, the SIMBOL–X sensitivity curve has roughly the shape of the XMM–Newton and Chandra curves (which have no diffuse component here), but is displaced by about a decade in energy. SIMBOL–X is about $\sim 100$ times better than existing instruments in the 10 to 35 keV range, and has a sensitivity equivalent to INTEGRAL/IBIS at $\sim 70$ keV.

We have also used this background model in order to simulate a number of observations that cannot be detailed here. We simply mention two examples to illustrate the SIMBOL–X sensitivity. On the supernovae remnant side, a detailed map of Cas A above 20 keV can be done in 100 ksec, and the spectrum of its brightest 1 arcmin$^2$ part is significant up to 50 keV. On the AGN jet side, the spectrum of the Pictor A hot spot at 4 arcmin from the nucleus (well isolated with SIMBOL–X optics) can be significantly measured up to 40 keV in 50 ks of observation.

4. Collaboration and schedule

The SIMBOL–X mission is a collaboration involving France (CEA/Saclay, PI Institute, and the Grenoble and Meudon observatories), Italy with Brera Observatory, and United Kingdom with Leicester University. At this early stage, the
Figure 3. SIMBOL-X sensitivity to point sources, compared to past and present X and γ-ray telescopes.

The participation of each country which has still to be secured is envisioned to be the following. France will build the detector spacecraft, the high energy part of the focal plane detector, and will take care of the formation flying aspects. Italy is in charge of building the mirror and the mirror spacecraft. United Kingdom is in charge of the CCD part of the focal plane.

Finally, as SIMBOL-X does not involve new difficult technological development neither on the detector side nor on the mirror side, and as the formation flying constraints are rather well within current investigations in this domain, a relatively short development time can be envisioned. Launching SIMBOL-X before the end of the decade would provide an excellent scientific preparation to the much larger observatories Constellation X and XEUS that are scheduled later.

SIMBOL-X has been presented to the Astrophysics group of CNES, the French space agency, with a proposed launch date of early 2009. It has been selected in June 2002 for beginning a phase A study.

References
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