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Simbol–X shielding system optimization studies

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Abstract. Simbol–X large focal length (∼ 20 m) implies a correspondingly large plate scale (∼ 6 mm/arcmin) thus emphasizing the need for a low background noise in order to reach the required sensitivity limit. As there is no telescope tube between the mirror and the focal plane unit, the overall shield design and optimization must be done at telescope level, considering both detector spacecraft (DSC) and mirror spacecraft (MSC) at the same time. This is accomplished by means of a tube–like structure on DSC coupled with an annular passive shield placed around the mirror unit. The present work reports the results of analytical simulation studies regarding: (a) mirror spacecraft passive shield geometry, composition and overall mass budget; (b) background spatial disuniformity on the focal plane associated with the expected tolerance in the alignment between detector and mirror spacecraft; (c) background spectral signatures caused by secondary fluorescence emission and their minimization.

Key words. Telescope: Simbol–X – Background: shielding

1. Introduction

The basic concept of the Simbol–X mission (Pareschi & Ferrando 2005) is the extension of the focusing capabilities of X–ray mirror based telescopes (e.g. Chandra and XMM–Newton) up to energies of ∼ 100 keV. This is achieved by means of a large (∼ 20 m) focal length multilayer telescope coupled with a hybrid focal plane, placed on two distinct spacecrafts in a formation flying configuration. The absence of a telescope tube between the mirror and the focal plane unit, combined with a large plate scale (∼ 6 mm/arcmin), emphasizes the need for a low background noise in order to reach the required sensitivity limit ($< 1\ \mu$Crab for deep, $T_{int} \sim 10^6$ s, survey observations).

2. Passive shielding design

The geometry of the shielding system is required, in a first conservative approach, to completely baffle the detector from unwanted aperture flux, caused by the cosmic X–ray background (CXB) that reaches the focal plane without being focussed (see Gehrels 1985, for a review). The overall shield design must be done at the telescope level, by means of a tube–like structure on DSC coupled with an annular passive shield (“skirt”) placed around the mirror unit (Fig. 1). The selected collimator

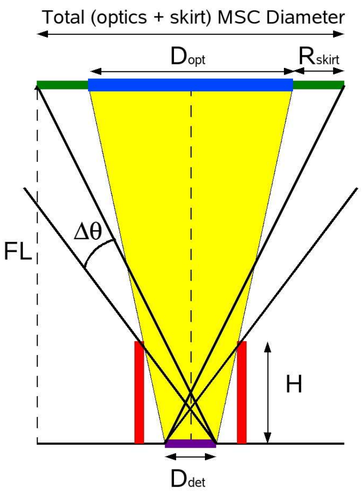

Fig. 1. Passive shielding basic geometry. *Green line*: skirt around the optics; *red line*: collimator walls; *blue line*: X–ray optics; *purple line*: detector.

height of 2.2 m coincides with the need of a skirt length (R_{skirt}) of ~ 65 cm (Malaguti et al. 2005).

3. Skirt composition and mass budget

For the main absorber, materials under analysis are Lead (Pb), Tungsten (W) and Tantalum (Ta). In addition, four layers with decreasing atomic number (Tin, Copper, Aluminum and Carbon graded shield) will ensure the minimization of K_α emission lines falling within detector energy range. For an absorption efficiency of 99% at 40 keV (main absorber) and at K_α energy, a set of Ta plus grading results in the lowest column density, 1.36 g cm^{-2}. This value translates into a skirt mass (for R_{skirt} ~ 65 cm) of 40 kg, widely over the limit imposed by feasibility studies. Several trade–off scenarios have then been investigated (see Rio 2006, for a preliminary optimization study).

4. The imperfect shielding ($\Delta\theta \neq 0$)

Leaving a non–zero opening angle ($\Delta\theta > 0$, see Figure 1) to the unfocused CXB reduces skirt length and mass. At the same time it allows for possible spacecrafts misalignment during observations.

With a R_{skirt} reduction from 65 to 58 cm, the background flux at 30 keV is below the assessed acceptance level of 10^{-4} cts cm^{-2} s^{-1} keV^{-1}, while at 3 keV is too high, with a gain of only 7 kg. Figure 2 shows the resulting background distribution on the detection plane for this configuration at 3 and 30 keV.

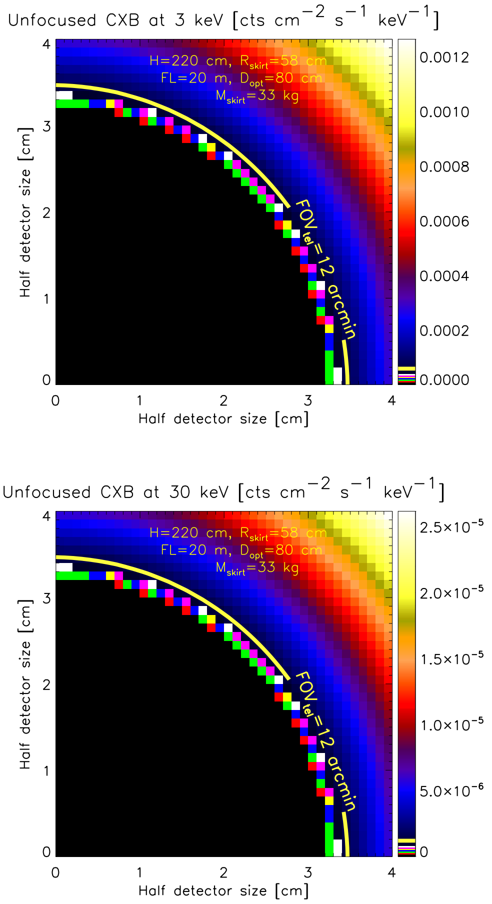

Fig. 2. Unfocused CXB spatial distribution on Simbol–X detector (1° quadrant) at 3 keV (top) and 30 keV (bottom). The superimposed yellow line indicates the telescope FOV border (12′ FWHM) projected at a focal length of 20 m.

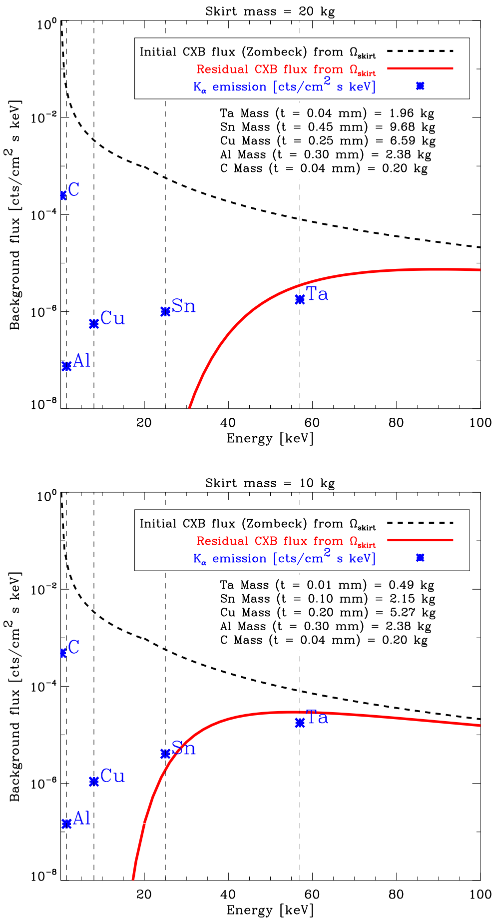

Fig. 3. Detector background level leaking through the skirt for two different mass budgets: 20 kg (top) and 10 kg (bottom). The dotted line indicates the initial CXB flux (Zombeck 1991) coming from the solid angle covered by the skirt.

5. Relaxing skirt absorption efficiency ($\Delta\theta = 0$)

The skirt covers a solid angle $\sim 10^3$ times lower than the one shielded by the collimator and, as a consequence, even the secondary background caused by the skirt is lower. It is therefore possible to relax skirt absorption requirement (keeping $\Delta\theta = 0$) with a significant decrease of thickness and mass budget.
In Figure 3 the red line shows the residual CXB flux, for a mass budget of 20 kg (top) and 10 kg (bottom), that leaks through the skirt without being absorbed and the blue asterisks represent the expected K_α emission caused by Ta and graded shields. Comparing the two panels, a mass reduction translates into an higher background level (both CXB flux and K_α) and it is necessary to set an upper limit to the background caused by the skirt to define the final configuration. This trade–off analysis shows that a mass decrease from 40 to 10 kg is possible, if the related background is under the acceptance level.

6. Conclusions and future work

For an absorption efficiency of 99% at 40 keV (main absorber) and at K_α energy, the skirt mass is too high. A minimum decrease of the skirt dimension causes an aperture flux over the acceptance background level. Since the residual background depends on the skirt absorption efficiency, a thickness decrease is possible only evaluating its contribution to the total detector background level. Preliminary analytical evaluations indicate the possibility of significantly reduce the skirt mass budget down to 10 kg by means of a fine tuning optimization of the main absorber and grading layers thickness. More detailed and complete results will be achieved by implementing a GEANT4 model of Simbol–X to include both the complete geometry of MSC and the tracking of all secondary photons created either by scattering or fluorescence mechanisms.

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