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Simbol-X mirror module design scientific optimization

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Abstract. The Simbol-X hard X-ray mission will be based on Wolter I focused telescope with multilayer mirrors. The formation flight concept allows a large flexibility in the focal length (FL) choice, while the use of multilayers makes possible the optimization of the mirror coating aiming at covering a very wide energy band (0.1 - 80 keV). On the other hand, there are other limiting parameters to be considered as e.g. the maximum mirror diameter for the Ni electroforming technology (70 cm) and the maximum size of the focal plane that should not exceed 8 cm. We will discuss the activities carried out to optimize the mirror module design, in order to achieve the best response in terms of effective area and field of view (FOV).

Key words. Telescopes

1. Introduction

The former Simbol-X concept was based on monolayer coated optics. In 2005 the top-level scientific requirements was added to the mission targets. The extension to multilayer optics had been included in the mission design.

The physical and technological constrains to be kept into account for the telescope design are:

- **Mass:** The mass of a shell with a given diameter is determined by its thickness. A linear variation of the shells thickness with shell radius is assumed to keep constant stiffness and HEW for all the shells.
- **Mass to area ratio:** Due to the variation in the incidence angle (the shell slope for focusing), the mass to collecting area ratio is related to the FL according to: $M/A_{coll} \propto f\rho k$, with f focal length and ρ shell density.
- **Shell number and distribution:** The technology for Ni electroforming and replication technique gives a maximum diameter of about 70 cm. In this study a number of 100 shell has been assumed as reliable. Due to the smaller incidence angle, inner shells offer a higher reflectivity for the high energies, but a lower geometrical area.
- **Focal length:** For a given FOV, the image size on the focal plane is proportional to the FL. The maximum detector size (assumed to be 8 cm, minus 1 cm for the DSC dithering) fixes a geometrical limit for the angular image size.

2. Simulation parameters

The impact of the geometrical parameters for monolayer and multilayer coated optics has

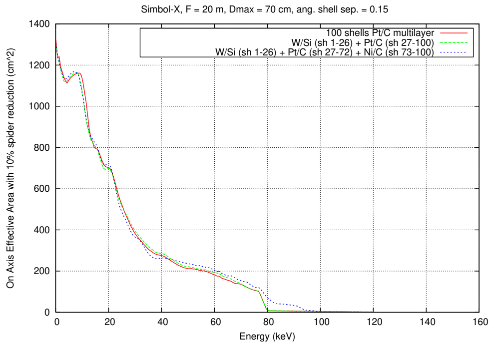

Fig. 1. Effective area assuming different coatings for shells in different angular ranges.

been evaluated by means of ray tracing simulations, in order to determine the behavior of the telescope over the FOV. Double reflected photons on the two surfaces of double cone Wolter-like shells have been counted to evaluate the off axis effective area. The FOV has been evaluated as the off-Axis angle where the effective area is 50% of the on-Axis value. Iridium monolayers, W/Si and Pt/C depth graded multilayers with bilayers number N=250 and a standard power law thickness distribution have been considered as reflecting coatings. FL from 18 to 30 m, shell distributions with angular separation between shells of 0°, 0.07°, 0.15° and maximum diameter values of 60, 65, 70 cm have been considered in the simulations.

3. The new baseline

A new baseline, satisfying the scientific requirements, has been defined with Pt/C multilayer coating, a FL of 20 m, angular shell separation of 0.15° and maximum diameter of 70 cm. The effective area is shown by the solid line in Fig. 1. The effective area is about 400 cmˆ2 at 30 keV, with the response limited at the high energy by the Pt absorption edge at 78.4 keV. The actual FOV is limited to 12 arcsec by the detector size. In this configuration a weight of 460 kg (including an overload of 30%) is estimated to satisfy the image quality requirements.

4. Further improvements

The effective area performances are limited in energy range by the coating materials absorption edges (69.5 keV for W, 78.4 keV for Pt). Higher energy x-rays are reflected only by the most inner shells, which have the smaller incidence angles. Different material for the multilayer coating on different shells, depending on the incidence angle, can be used to maintain some area also at higher energies. A top layer made of a low-density and low-absorption material like carbon over the multilayer coating, can considerably enhance the reflectivity in the soft X-ray spectral region (E<15 keV), being the photoelectric absorption for carbon much lower than for heaviest materials.

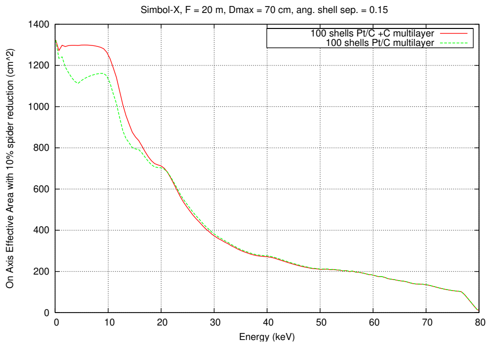

Fig. 2. The effect of the application of a thin (100 Å) C overcoating on the effective area for the baseline configuration.

5. Conclusions

The configuration with 20 m FL, shell separation of 0.15° and maximum diameter of 70 cm appears to be a very appealing one in terms of effective area, energy operative range and FOV, fully satisfying the top-level scientific requirements. Due to the limited detector size, a much longer FL has the effect to reduce the telescope FOV, while a shorter one seems to be not advisable for technical problems related to the formation flight control (in particular to reduce the collision risk). Different materials for the multilayer coating of the optics can be used on different shells (depending on the incidence angles) to achieve a wider energy operative range; a carbon overcoating (especially on the outer shells) enhances the low energy response. Improvements in the optic realization technologies aimed to reduce the shell thickness keeping the same optical quality are highly desirable. A slight reduction of the maximum shell diameter (to about 65 cm) can be considered in a descoping phase. The optimization of the optical coating is required for improving and tuning the effective area response and the FOV over the energy range.

References

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