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The relation between the weight and the quality image in a X-ray telescope, with a particular regard to Simbol-X

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Abstract. In a X-ray telescope the main problem is that the small incident angles constrain to use many concentric shells and this is true especially for a long focal length as SIMBOL-X. In this paper it is presented the approach followed to estimate a reliable trend for the thickness-to-diameter ratio to reach a given angular resolution. The solution is based on the extrapolation from two representative optics realized in past experiments, that were characterized by different geometrical parameters (e.g. focal length, radius, thickness, filling factor), but produced using the same manufacturing technology foreseen for Simbol-X (the Nickel electroforming replication).

Key words. X-rays: Wolter-I, shell thickness, mass

1. Introduction

SIMBOL-X is a hard X-ray mission based on a formation flight architecture being jointly carried out by CNES and ASI and operating in a wide energy range (0.5 – 80 keV) with a long (20 m) focal length multilayer-coated X-ray mirrors in Wolter-I configuration (Pareschi & Ferrando (2006)). The SIMBOL-X angular resolution goal is $\sim$ 15 arcsec HEW at 1 keV and < 20 arcsec HEW at 30 keV.

2. Mass of a X-ray telescope

If the Wolter-I (or a double cone) X-ray telescope is a multishell optics, with the shells made with the same material, length, and the same filling factor, in addition to a constant ratio between thickness (t) and radius (r), the mass can be described by a simply formula obtained integrating the volume of a continuous revolution solid with the section shown in Fig. 1. The useful formula expresses the ratio between mass and collecting area as a function of the other parameters (focal length, material density, . . .)

$$M/A_{\rm col} = 8 f \rho k c \qquad (1)$$

The symbols are:
f: focal length
ρ: material density (for Ni: $\rho = 8.8 \mathrm{g/cm^3}$
k: $k = r/t$
c: coefficient that considers the weight of mechanical structure, ($c = 1.3$)

As can be noted, the formula does not depend on the filling factor and the maximum/minimum radius. $M/A_{\rm col}$ is just proportional to the focal length. This is important: it is not allowed to compare the mass efficiency

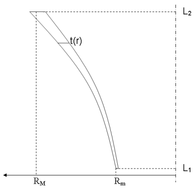
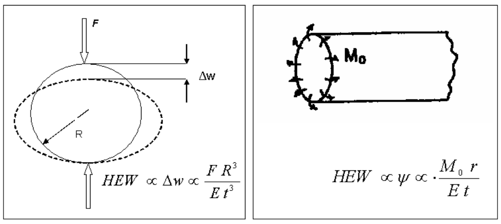


Fig. 1. Continuous solid of revolution that simplifies a multi-shell optic.



$$HEW \propto \Delta w \propto \frac{F R^3}{E t^3} \qquad HEW \propto \psi \propto \cdot \frac{M_0 r}{E t}$$

Fig. 2. Left: Radial force for a thin shell. $z = 3$. Right: Edge moment for a thin shell. $z = 1$

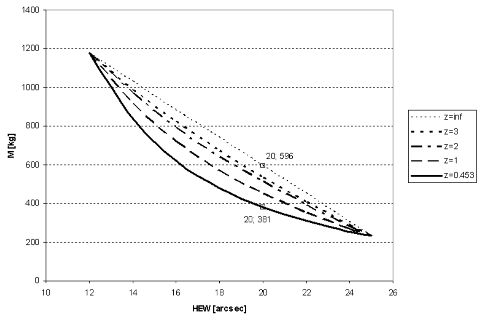


Fig. 3. Estimate of the total (optics and mechanic structure) mass of the Simbol-X telescope as function of the optical resolution, with A_{col} =1500 cm^2. The continuous line describes the best interpolation.

(M/A_{col}) of X-ray telescopes with different focal lengths without re-scaling with the focal length of the telescope to be evaluated.

3. Interpolating function

At the state of the art, the two past cases that could effectively be used to extrapolate the mass needed for Simbol-X are the Flight Module n4 of the XMM project and a thin mirror shell that has been replicated by a Jet-X mandrel in 2003 (Pareschi et al. (2003)). The latter was used because it is the best and represented case of a very thin Ni mirror shell. The mass-to-collecting-area-ratio for the two input telescopes used in this study changes in the following way, re-scaling with the focal length:

XMM: 0.294 kg/cm^2 → 0.785 kg/cm^2

Jet-X 1sh: 0.027 kg/cm^2 → 0.155kg/cm^2

In order to determine the function that interpolates the two points, a link between the HEW and a parameter connected to the mass has to be found. The link is given by:

$$\mathrm{HEW} = H(1/k)^z \tag{2}$$

where H and z are two constants to be found extrapolating from the parameters of the two well-known input telescopes. It should be noted that this equation is strictly true only if the length of the shells of the three telescope is the same, but this is the case (600 mm for all of them). It is also possible to fix the value of z if a distribution of the load is overriding (Fig. 2)

A strong hypothesis regards the value of HEW of the recent thin shell made with Jet-X mandrel: in fact the value assumed (25 arcsec) does not consider the degradation due to the integration of a large number of shells. A more realistic value of HEW could be 30 arcsec. In this last assumption the masses increase moreover (see table).

z	M/A_{col} [kg/cm^2]	k	M [kg] A_{col} = 1500cm^2
0.566	0.3180	0.00174	**477**
1	0.3650	0.00199	548
2	0.4221	0.00231	633
3	0.4466	0.00244	670
∞	0.5048	0.00276	757

4. Conclusions

The final consideration is a general plot of the mass of Simbol-X as function of the HEW (see Fig. 3).

References

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