X-RAY IMAGING TELESCOPES: PREDICTION OF THE EXPECTED IMAGE QUALITY FROM SURFACE ROUGHNESS METROLOGY DATA

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Grazing incidence mirrors optics, coated with wideband multilayer films, are envisaged in the X-ray astronomical instrumentation of the future. For SIMBOL-X[1], the required focal spot size is of the order of 15 arcsec HEW (*Half-Energy-Width*): however, the imaging quality can be severely affected by X-ray Scattering as the photon energy increases, therefore the surface roughness of the mirrors will have to be kept at a few angstroms level. The need of very smooth mirrors and of a sensitive, advanced metrology to assess the compliance of the mirrors to the imaging requirements is an important topic in all the X-ray optic field. Diagnostic methodologies involving surface topography (Atomic Force Microscope, optical profilometers like LTPs…), and X-ray scattering (XRS) techniques can be used to measure the surface roughness PSD (*Power Spectral Density*) in different, complementary spectral windows.

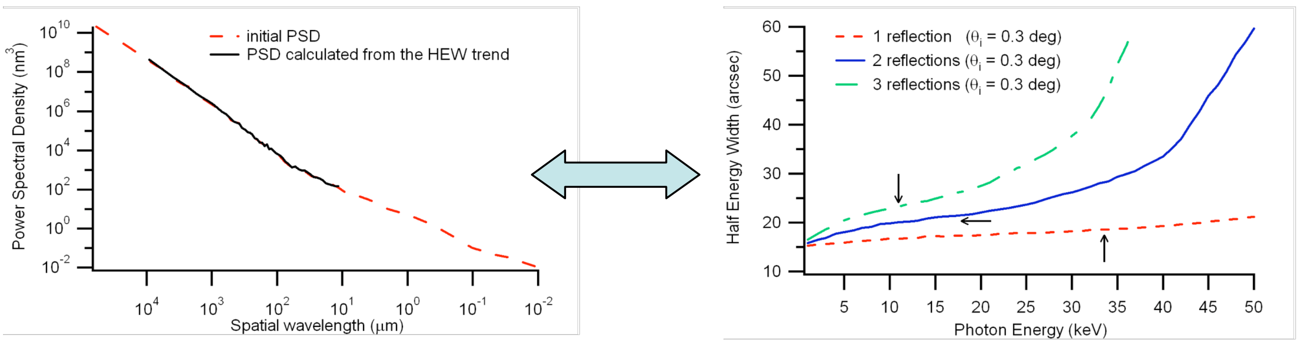

Fig. 1: an example of computation of the HEW scattering term (right panel) from the PSD (left, dashed line) of the surface of an hypothetical X-ray optical system with 1,2,3 reflections at the same grazing incidence angle of 0.3 deg, and vice versa.

However, the prediction of the optical performance from the roughness PSD usually requires a considerable amount of computation, and the calculation cannot be easily reversed (i.e. from the required HEW(λ), as a function of the photon wavelength λ, one cannot derive the needed PSD). In this work (Fig. 1) we expose an analytical approach useful to directly derive the HEW(λ) function from the sample PSD characterization the expected optical performances of the mirrors. More precisely, we assume that the "figure contribution to the HEW, H_0, and the X-ray scattering term of the HEW, $H(\lambda)$, can be combined as follows:

$$HEW^2(\lambda) \approx H_0^2 + H^2(\lambda)$$

to return the measured (or tolerable) HEW, as a function of the photon wavelength. Then, we directly relate the $H(\lambda)$ function to the mirror surface $PSD(f)$, as a function of the surface spatial frequency f, along with simple analytical formulae[2], based on the well-known theory of X-ray scattering from rough surfaces. The results are particularly interesting when applied to the particular case of fractal surfaces, whose roughness PSD fits a power-law model. The method is also applicable to multilayer-coated X-ray mirrors with a slowly-varying reflectance with the photon energy. Furthermore, it can also be reversed in order to translate a HEW(λ) trend requirement into a PSD tolerance (Fig. 1). The exposed formalism can be used to set roughness tolerances for future hard X-ray telescopes from the required angular resolution of the telescope[3], but it can be employed also in other sectors of X-ray optics.

References

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