MEMO

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To IXO Study team	**Copy**

Subject: IXO response matrices: assumptions

In this short memo the various input parameters for the generation of the IXO response matrices are documented. The response matrices have been generated to reflect the latest system design and performance prediction, as from the completion of the assessment study activities (May 2010).

It is important to note that the matrices have been computed assuming conservative estimates of the telescope effective area, i.e. a reduced outer radius, as described in [RD1] and corresponding to 35 Mirror Module rows, for a total effective area of about 2.9 m^2 at 1.25 keV.. This approach is in line with that of the ESA industrial assessment study activities. It is not excluded that, pending further optimisation and the finalisation of the optics technology, the goal of 3.0 m^2 mirror effective area at 1.25 keV may be achieved.

Please notice that this report version (2.0) contains a description of the assumptions for the set of matrices derived from the baseline telescope design, and a description for matrices derived from very conservative estimates of mirror effective area, leading to a minimum mirror effective area of 2.5 m^2 at 1.25 keV.

The response matrices also include the latest information on the instruments efficiency as received from the instrument consortia in April - May 2010.

1 MIRROR EFFECTIVE AREA- REFERENCE DESIGN

For the generation of the response matrices a mirror effective area based on the current telescope reference design has been used [RD1]. It should be noted that the effective area calculated in [RD1] takes into account a 10% loss factor, as detailed in SRE-PA/2010-010/NR.

The impact of the grating has been incorporated, assuming a design for the gratings, corresponding to 2 ~30 deg sectors from row 14 to row 35; the loss due to the CATXGS gratings, based on data files of energy-dependent transmission of the level I supports and the zeroth order efficiency is modelled and taken into account.

The curve obtained in this way is presented in Figure 1. This curve is used for the generation of the IXO response matrices. Effective area at 1.25 keV is 2.55 m², while the peak area is 2.66 m². In summary it is derived from the mirror area for the baseline design with loss factors for end-of-life and accounting for the obscuration of the grating.

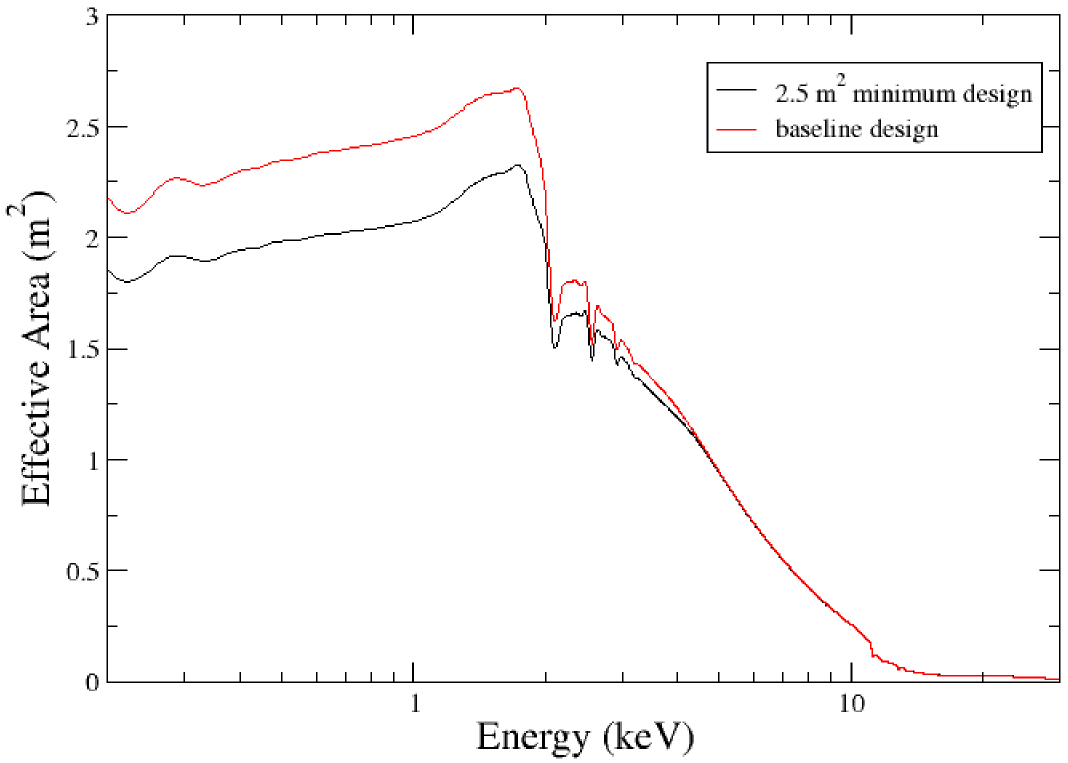

Figure 1 Mirror effective area, including obscuration by the gratings and loss factors, as function of energy for the baseline design and the 2.5 m^2 mirror effective area (see text).

Another set of matrices was calculated based on a design with very conservative assumptions leading to an effective area of 2.5 m² (after losses) at 1.25 keV. While such an effective area can be obtained in various ways by relaxing some assumptions (e.g. packing densities) the following approach was taken: first the outer radius was reduced such that an effective are as close as possible to 2.5 m² was obtained. This was obtained for an outer radius of 1.60 m (and 32 rows). However, due to the fact that only a discrete number of rows is considered, the area thus obtained turned out to be 2.47 m^2. In order to reach 2.5 m^2 exactly all areas were corrected by 1%. The mirror area including obscuration and transmission of the grating was then calculated. However, since the outer radius is smaller than in the baseline design, the inner radius of the gratings was reduced accordingly in such a way that the geometric area of the CATXGS grating stays the same. This will ensure that the effective area will be maintained approximately. The effective area curve is displayed in Figure 1.

2 DETECTOR EFFICIENCIES

The detector efficiencies as provided by the instrument teams are used (delivered at the end of April/beginning of May 2010). Details of the technical notes and filenames are provided in Table 1. For XPOL the detector efficiency was given in graphical form in note IXO-XPOL-TN-005-01. The data in this plot was converted into a digital format and compared with a data file which was already available. It was verified that both were consistent and the data file was used throughout.

Table 1 Technical notes and filenames used for the response matrix generation

Instrument	Technical Note reference	File
WFI	IXO-WFI-MPE-TN-02_1	WFI-eff_w_filter.dat/WFI-eff_wo_filter.dat
HTRS	HTRS-SN-211-013-CESR	HTRS_open_position.dat/HTRS_thin_filter.dat/ HTRS_thick_filter.dat
XMS	SRON-XMS-TN-2010-014 (Issue 1.2)	xms-qe_v1-2.out
XPOL	IXO-XPOL-TN-005-01	See text
CAT-XGS	in spreadsheet	CATXGS_effective_area_2010_04_21-1.xls
OP-XGS	‘OP-XGS Effective Area Technical Note’	OPXGSEffectArea6mods05172010.dat

For the gratings the instrument effective area was not derived from the combination of mirror effective area and instrument efficiency, but the effective area estimates of the grating provided by the instrument teams were used. For OP-XGS the design with 6 modules was used for the effective area.

3 RESOLUTION

The effective area of the instruments is determined by the mirror effective area and the detector efficiency (including filter efficiencies). However, for some simulations also the assumed energy resolution (expressed as Full Width at Half Maximum, FWHM) can be of importance. In Table 2 the calculation of the FWHM as function of energy for the generation of the response matrices is detailed. It is noted here that a consolidation of the resolutions used in the generation of the response matrices will be the next step in the improvement of the response matrices.

Table 2 Details for the calculation of the resolution, FWHM, expressed in eV

XMS	E<7 keV: FWHM = 2.5 eV. E> 7 keV. FWHM = E(eV)/2800
WFI	FWHM = sqrt(2.3159*E(eV)+657.714)
HTRS	Fit to curve in HTRS-SN-211-013-CESR: FWHM = 84.3111-0.025018*E(eV)+0.06986*E(eV)$^{0.92342}$ †
XPOL	FWHM = 0.2*E(eV)*sqrt(6/E(keV))
HXI	FWHM = 350 (eV)+sqrt(2*E(eV))
CATXGS	Constant R=3000, FWHM = E(eV)/3000
OPXGS	Constant R=3000, FWHM = E(eV)/3000

†Correction in constant (0.025018 vs. 0.25018) with respect to version 1.0

Since the version generated on 2010-05-19 had insufficient channels (N_CHAN in the matrix) to properly sample a narrow line, matrices for the in-focus instruments were reissued. This only significantly affects the instruments with poorer resolution (HXI, XPO, HTRS) and only in the case when narrow features are simulated.

4 EFFECTIVE AREAS

In Figure 2 , Figure 3, and Figure 4 an overview is given of all effective areas for both the telescope reference design and the 2.5m² minimal design. The HXI effective area is plotted in a separate figure, because of the different energy range covered.

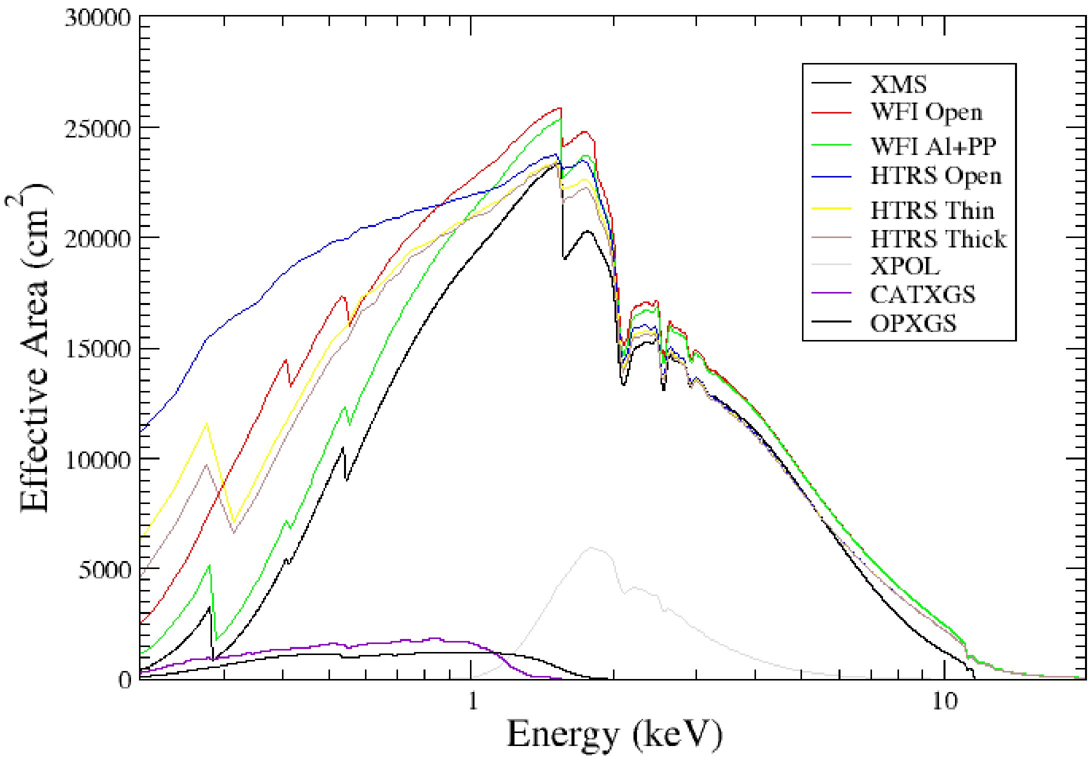

Figure 2 Effective areas for all instruments (except HXI).

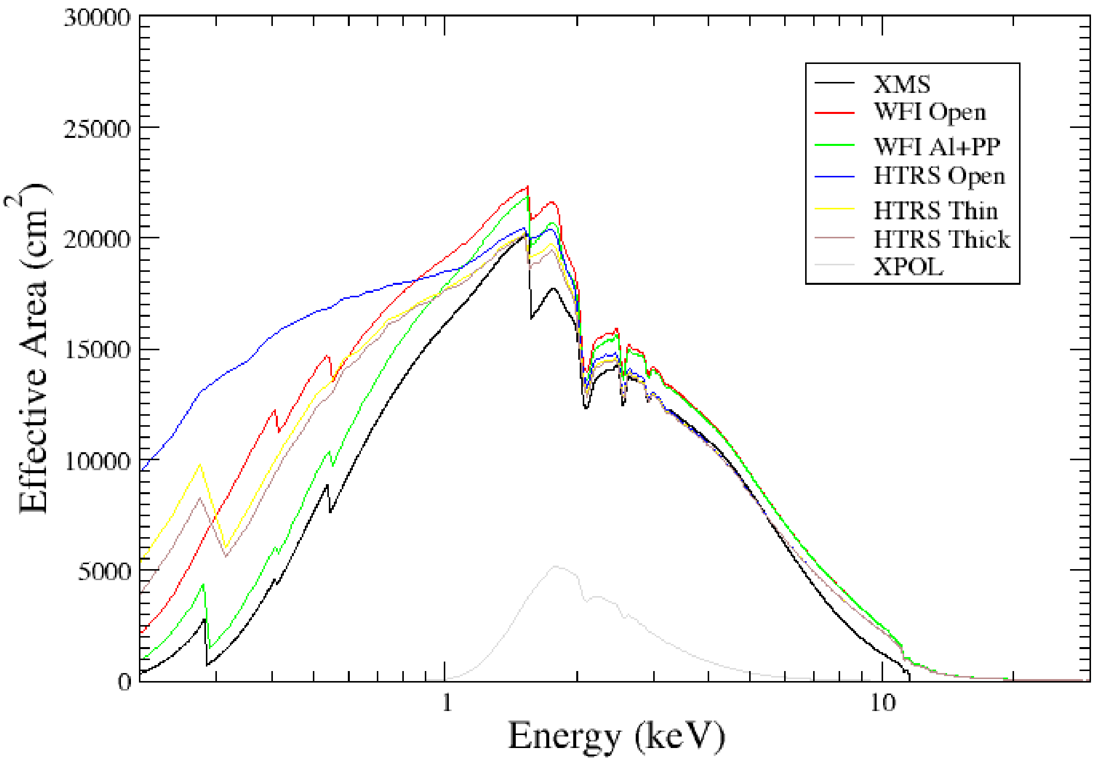

Figure 3 Instrumental effective areas for the 2.5m² minimum design

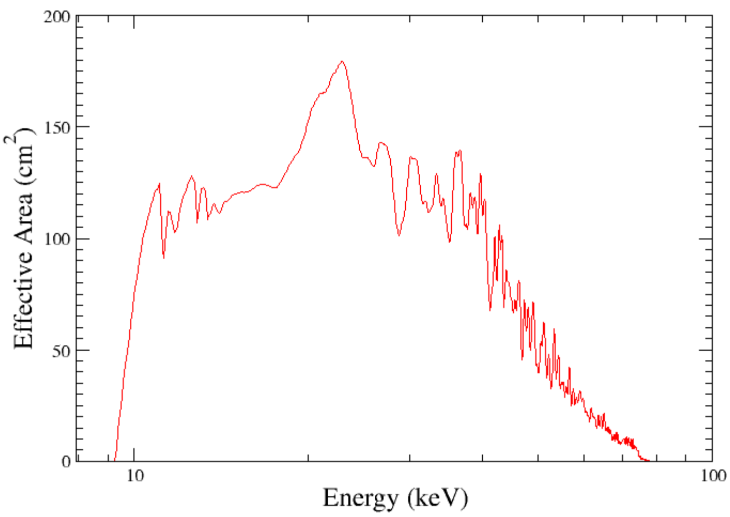

Figure 4 Effective area for HXI. No significant difference is present for the two mirror area curves used for the response generation.

5 VIGNETTING

All the matrices are provided for on-axis sources. In order to obtain the response for an off-axis source a "vignetting" correction has to be applied. Vignetting is an intrinsic property of a Wolter I design (or the double-cone approximation to it), see e.g. Spiga et al. (2009, A&A, 505, 373), and to a lesser extent a result from the ribs in the Silicon Pore Optics. At the same time ribs reduce straylight (due to single reflections). Especially the pores at small radii, and hence the smallest grazing incidence angles, have a limited field of view. For a design with a smaller outer radius the relative contribution of the innermost mirror modules will be larger and therefore a stronger vignetting is expected for a smaller outer radius. However, this only applies to energies for which the whole mirror contributes to the effective area. At higher energies the outside of the mirror does not contribute to the effective area and hence a reduction of the outer radius will affect neither the effective area, nor the vignetting. The change in vignetting, due to the smaller outer radius, is therefore only expected to be present at low energies.

In order to obtain the vignetting curves (i.e. effective area as function of source off-axis angle) one has to do a raytracing of the optical design. Previous estimates have been provided by Industry. I provide below estimates of the vignetting based on some raytracing code which has been written by me. I stress that the results for the vignetting can differ by up to about 15-20% from the results previously provided by Industry. This is probably related to different, or possibly incorrect, assumptions, in the codes. Therefore only the relative change in vignetting when the outer radius is reduced can be used. This relative measure should be more reliable than absolute values.

Since a change to the outer radius does not significantly affect anything at higher energies (e.g. at 6 keV almost all the effective area from the telescope is originating from within a radius of ~1m), it is instructive to present the relative change in vignetting for various energies. In Figure 5 the curves are displayed for 1, 2, and 4 keV. It should be noted that the curve at 1 keV is virtually identical to the curve at 1.25 keV. This figure shows that the difference at 1 keV is about 4% at 8.5 arc minute off-axis position, while at 4 keV for any relevant off-axis angle the difference is less than 1%. Given the small differences the older vignetting curves should be used.

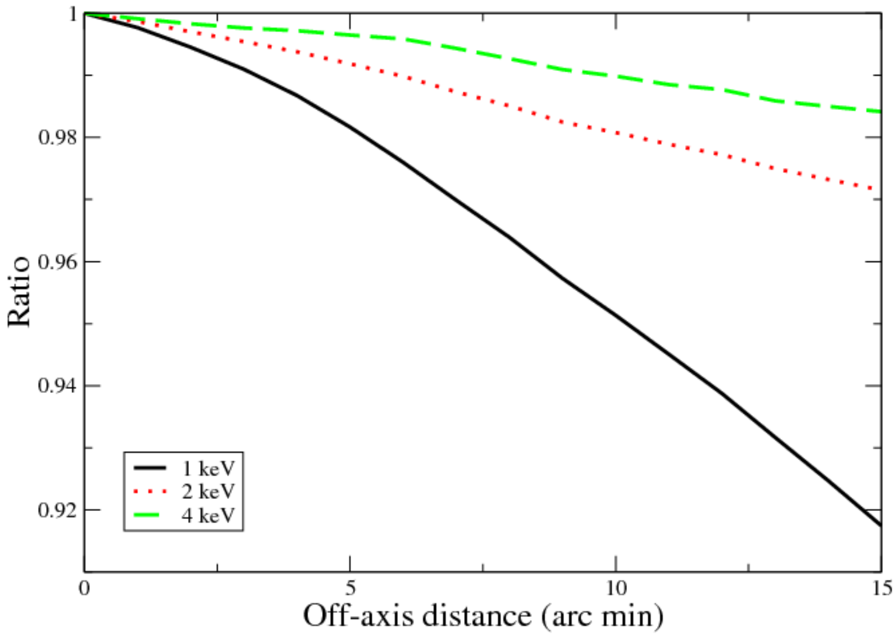

Figure 5 The ratio of vignetting for a reduced outer radius compared to the radius for which the vignetting curves were calculated at 1, 2, and 4 keV

[RD1]: ***Reference IXO telescope geometric design and effective area estimates for a reduced outer radius,*** SRE-PA/2010.021/TO, 31 March 2010.