Performance Simulations of the HTRS on IXO

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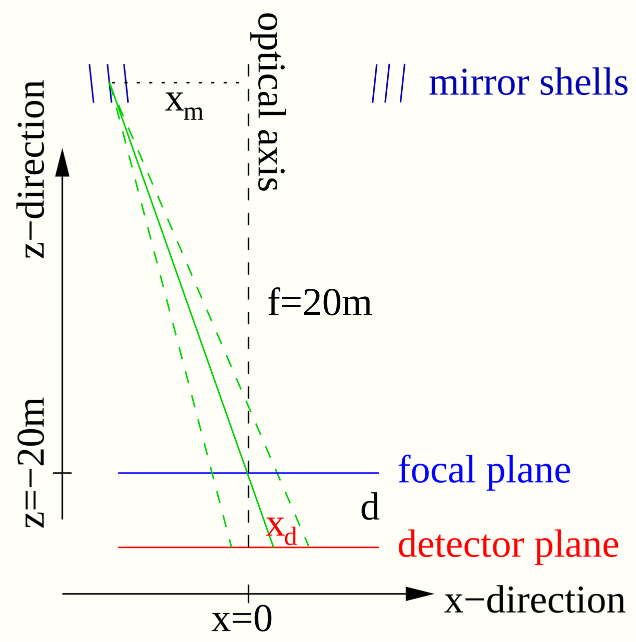
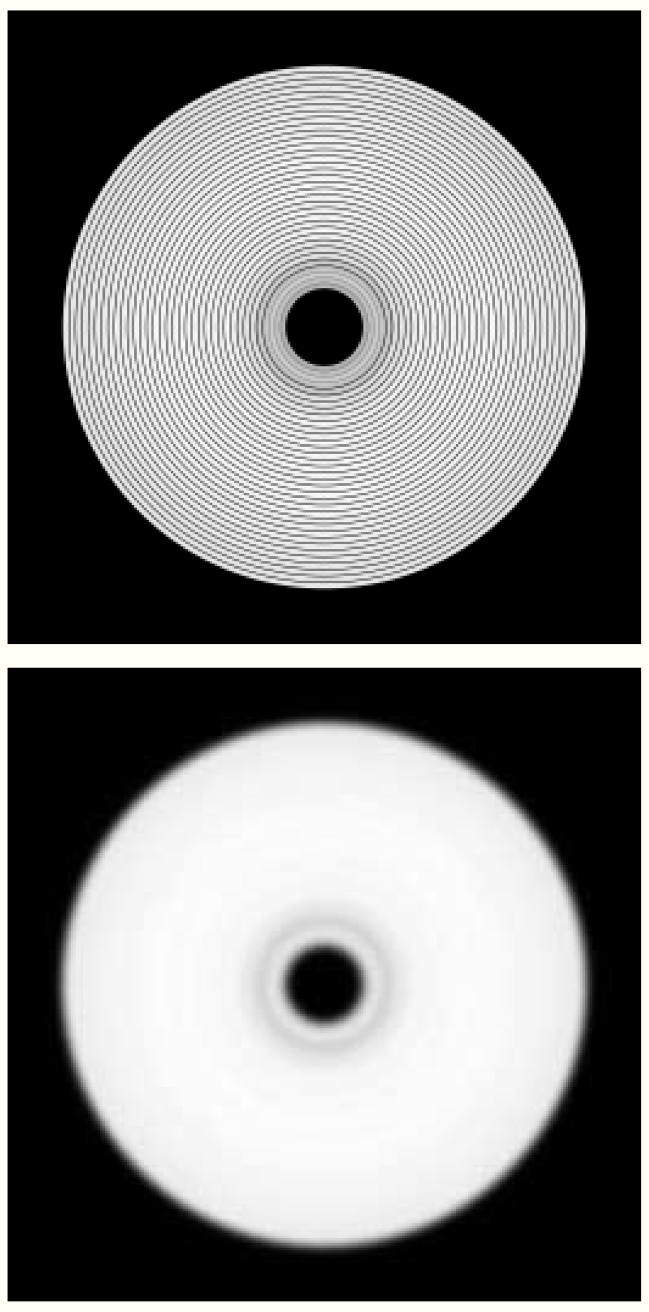
Abstract

We present the results of our analysis of the HTRS performance studied with a Monte-Carlo simulation of the photon imaging and detection processes. The simulation of the X-ray optics is based on the effective area distribution among the individual mirror shells of the IXO silicon pore optics design. The detector model was simulated with analog and with digital readout electronics. We have analysed the photon distribution on the HTRS detector at its particular out-of-focus position taking into account misalignment effects according to the instrument alignment requirements. We have studied different pixel geometries and analysed the bright source performance with respect to pile-up.

Geometrical Setup

In order to determine the photon distribution on the HTRS we have used a Monte-Carlo simulation based on the simplified geometrical setup presented in the right-hand figure (according to an idea of Tim Oosterbroek). After the reflection by the mirrors incident photons are moving on a straight line from their position on the mirror shell $(x_\mathrm{m}, y_\mathrm{m})$ through the focal spot. Due to the out-of-focus position of the HTRS at a distance $d = 12.6$ cm behind the focal plane the intersection of the photons path with the detector plane at $(x_\mathrm{d}, y_\mathrm{d})$ is slightly off-axis depending on the respective mirror shell.





For this simplified geometry the impact position for a particular photon is:

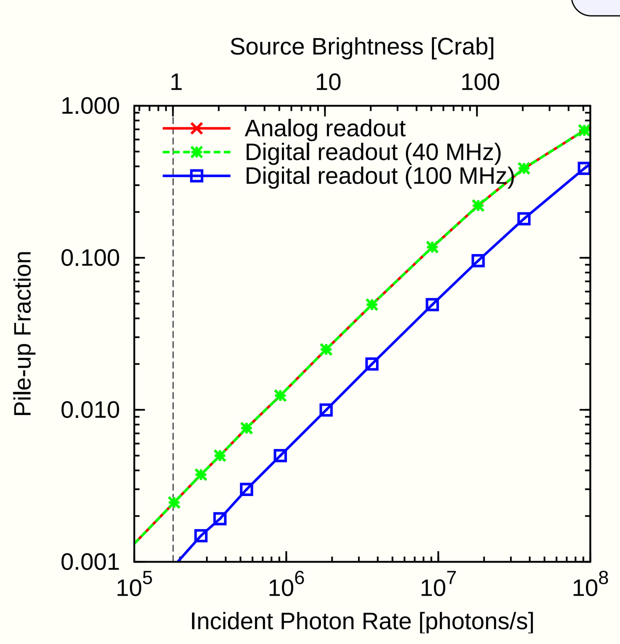
$$\begin{pmatrix} x_\mathrm{d} \\ y_\mathrm{d} \end{pmatrix} = \frac{d}{f} \cdot \begin{pmatrix} x_\mathrm{m} \\ y_\mathrm{m} \end{pmatrix} \tag{1}$$

In the simulation a large sample of photons is distributed among the mirror shells according to their relative effective area. Without blurring effects the image of the photons on the detector would resemble the effective area distribution, as shown in the figure on the upper left-hand side (for 1 keV photons).

However, in reality the shape and alignment of the mirror shells is not perfect giving rise to some blurring. In the simulation these effects are implemented by smearing the photon impact positions with a 2-dimensional Gaussian distribution with a Half Energy Width (HEW) of 5 arcsec, such that the shell structure of the photon spot vanishes as displayed in the lower figure.

Note: The simulations have been performed with $6 \cdot 10^8$ photons per m^2 effective area. The mirror model takes into account the energy-dependent radial distribution of the effective area, which results in the presented shell structure. In reality azimuthal effects due to the modular assembly of the SPO mirrors have to be considered.

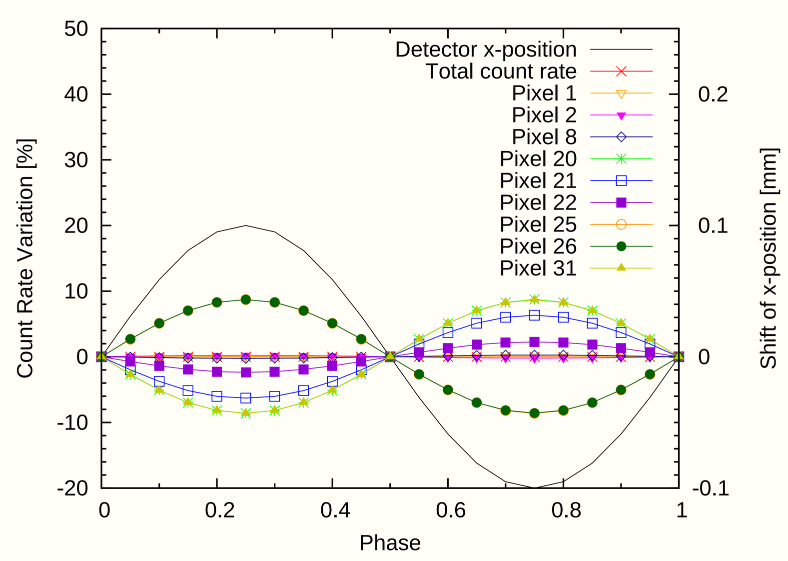
Pile-up



The HTRS readout electronics consist of a slow and a fast filter both for the analog as well as for the digital setup. The slow filter is used for accurate energy determination of detected photons, whereas the fast filter can distinguish close-by photon events in order to prevent wrong detections due to pile-up.

However there are still some pile-up events that cannot be identified even with the fast filter. The left-hand figure displays the fraction of them among the total events as a function of the source brightness. Both setups fulfill the requirement of less than 2 % pile-up at 1 Crab.

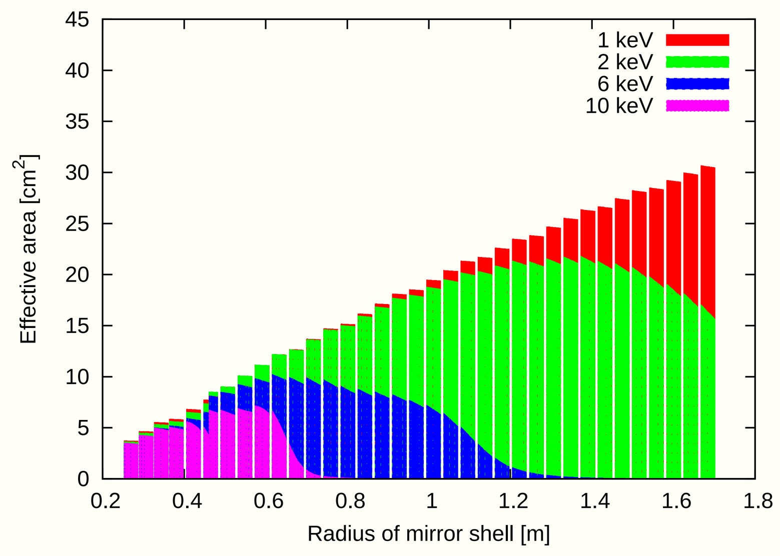
Jitter



The HTRS might be affected by vibrations caused by other instruments on the Movable Instrument Platform of IXO. The graph on the left-hand side displays the impact of vibrations with an amplitude of $100\,\mu$m in the horizontal plane and a frequency of 100 Hz on the simulated HTRS count rate (for 1 keV photons). In the outer pixel ring the count rate variation might be significant due to the motion of the outer edge of the photon spot. However, the impact on the total count rate is negligible.

Note: Due to the modular structure of the SPO mirrors in reality vibrations might have a stronger impact than in this simplified approach.

Effective Area

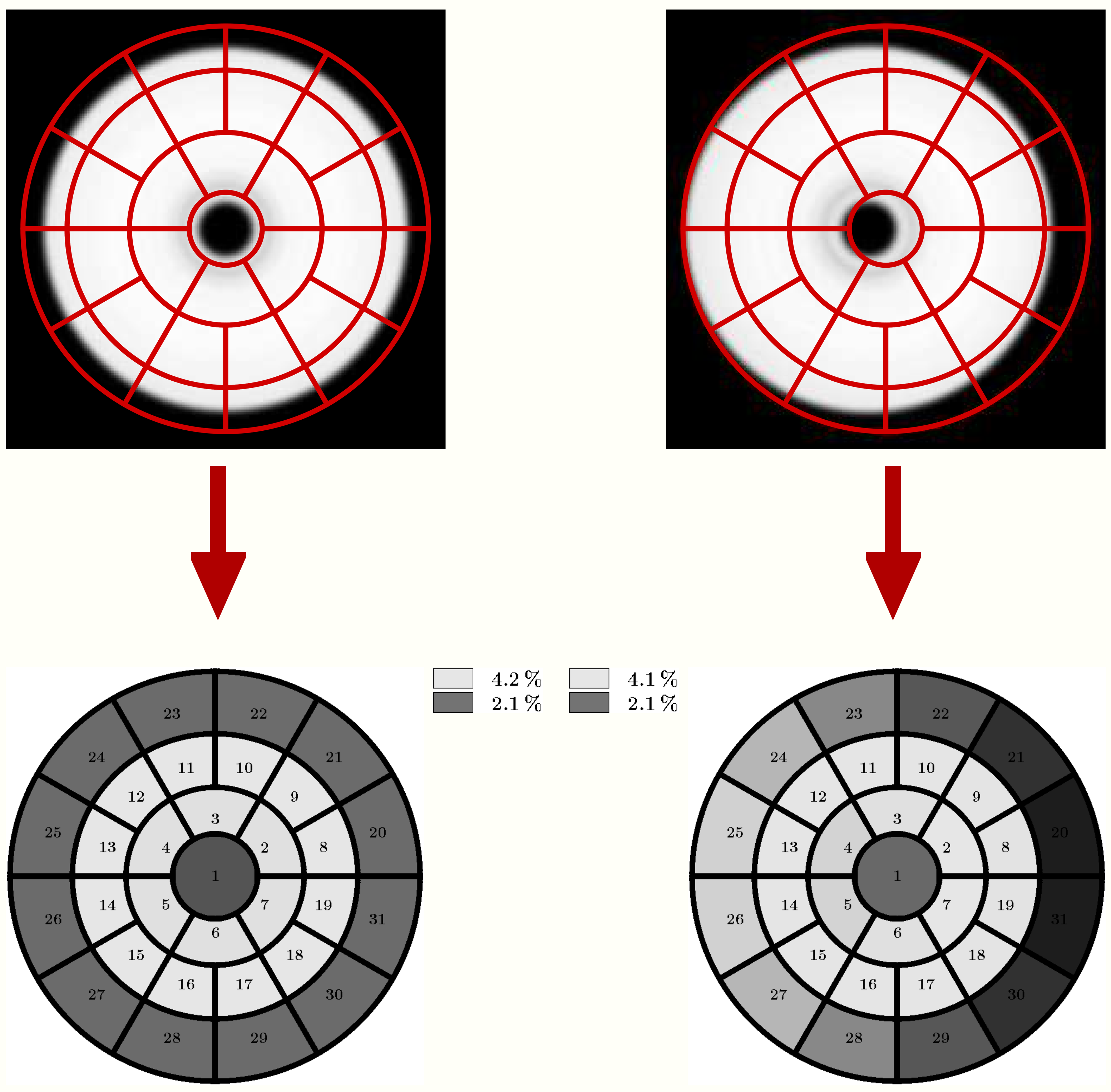


The relative effective area distribution among the individual modules of the SPO mirrors is a crucial part of the simulation. We assume a simplified model for the energy-dependent radial profile neglecting any azimuthal dependence. For the particular assembly of the SPO modules this profile exhibits a shell-like structure, as displayed in the figure on the left hand side for photon energies of 1, 2, 6, and 10 keV. According to Eq. (1) the photon spot on the detector is widest for 1 keV and gets narrower for higher photon energies.

The data shown on this poster are obtained for monochromatic 1 keV photons, as this is the most relevant case due to the large extension of the photon spot on the detector. (Most typical sources also have a maximum around 1 keV in their spectrum).

Photon Distribution & Misalignment

The simulated distribution of monochromatic 1 keV photons on the surface of the HTRS is quite homogeneous, as shown in the figure below. The spot does not completely fill the detector circle, providing some margin in case of misalignment.



The radii in the presented geometry ($r_1 = 2.16$ mm, $r_2 = 5.70$ mm, $r_3 = 9.39$ mm, and $r_4 = 12.0$ mm) have been adapted to the simulated photon distribution. On top of the pixel edges there is a mask with a spoke width of $200\,\mu$m in order to avoid split events. The brightness scale of the images reflects the fraction of photons, whereas the numbers are used to identify the pixels.

By shifting and tilting the detector with respect to its nominal position one can study the impact of misalignment effects. The left-hand side displays the nominal alignment, the right-hand side displays the photon distribution in case of misalignment. Therefore we have assumed the worst case scenario, which is possible according to the HTRS / Platform Interface Requirement Document (HTRS-SP-21-009-CESR):

- horizontal position with respect to the telescope axis: ± 1 mm
- vertical out-of-focus position ± 1 mm
- tilt of the detector plane: $\pm 2°$

Even for worst case misalignment the photon spot is still located within the detector boundaries.

References & Acknowledgements

Barret D. et al., 2010, Proc. of SPIE 7732, 1M-1–1M-12 Lechner P. et al., 2010, Proc. of SPIE 7742, 0W-1–0W-10 HTRS-SP-21-009-CESR

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