Example telescope simulations with the AstroX telescope toolbox for McXtrace


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ABSTRACT

We present a number of example studies of telescope optics using the latest version of the AstroX add on toolbox for McXtrace. Among which are first, a benchmark study of effective area and vignetting for the Chandra X-ray Observatory. Second, a convenient way of building a telescope model (in this case NuSTAR) with many similar optical elements scripted using a python module. This lends itself well to be included in online notebooks and/or for teaching. Third, we show a new AstroX module for lobster eye optics, and fourth, a study of the proposed solar axion telescope BabyIAXO.

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Component Contents of the AstroX toolbox are move towards release 1.0. The most basic module that could make up a Wolter telescope is the Pore from which the other elements may be derived. The MCP is the basic block of a lobster eye optic.

CHANDRA

Left: Effective area for the Chandra optic as modeled by AstroX (blue) and extracted from the plots Chandra Proposers’ Guide (POG). For AstroX the coatings of the mirrors were modeled using IMD.

Bottom: Normalized effective area as a function of off-axis angle, i.e. vignetting function for a set of X-ray energies, matching those reported in the POG.

In both cases, we measure the curves using monitors before and after the optic and compute the effective area as:

\[ A_{\text{eff}} = \frac{A_i}{I_i} \]

Where:

- \( A_i \): Illuminated area before the optic
- \( I_i \): Independent parameter, e.g. Energy
- \( I_j \): Impinging intensity
- \( I_{\text{rec}} \): Recorded intensity

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Components:

- Shell (pb/hb/st)
- Ring (pb/hb/st)
- Stellar Object Source
- Mirror Module (pb/hb/st)
- Detector (e.g. Q-eff)
- MCP (Lobster eye)

Example Instruments:

- Wolter I Shell
- Wolter I Ring
- NuSTAR
- Wolter I Pore
- Wolter I Mirror Module
- BabyIAXO (experimental)

NuSTAR Simulations

We can (easily), through a new python package, script the creation of AstroX/McXtrace simulations. As you would normally do in python scripts, we can create loops etc. to ease building very large and repetitive geometries, and easily inject them into AstroX/McXtrace.

This way integrates well with jupyter notebooks for teaching

Code generator

With the upcoming next generation code-generator (nicknamed cogen 3) of McXtrace we have succeeded in cutting code-size significantly – in particular for geometries that have many components of the same type. As is often the case for Wolter optics.

MCP/Lobster eye optic

A lobster eye module, or micro-channel plate (MCP) is now included in AstroX. Below we show a 3D rendering of the structure showing the square channels with reflecting surfaces (top left), the computed effective area for such an optic separated into focused and incomplete/over-focused signals (top right), and heatmaps of signals transmitted to the focal plane by the optic (bottom). The bottom plots clearly indicates where the spurious signals may be found (and thus gives a handle on shielding them).

REFERENCES

1. Wolter, A. d. Physik (1952)