Investigations of the XMM-Newton X-ray baffle alignment

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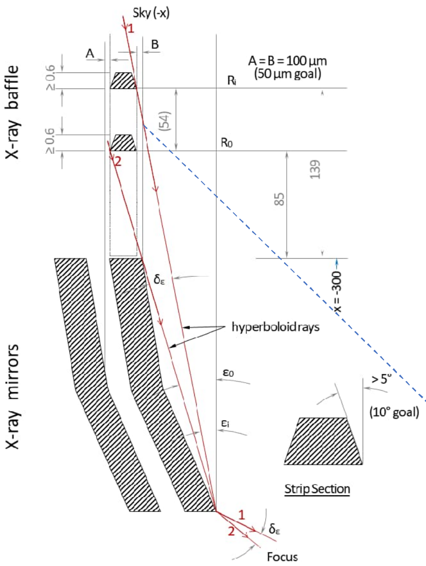
What is the X-ray baffle good for?

An unwanted side effect of nested Wolter telescopes is the occurrence of so-called single reflections in the image field. These are caused by beam paths with only one reflection either at the parabolic or hyperbolic part of the mirror. Some of these beam paths, especially with reflection at the hyperbolic part, reach the camera field of view. As the rays in question come from a certain off-axis angle range, they can be suppressed – at least in part – by shielding in front of the Wolter mirror module.

XMM-Newton X-ray baffle design

With XMM-Newton, this shielding, also known as an X-ray baffle, is realised in the form of two sieve plates, which are aligned with the 58 mirror shells of the mirror modules. The figure shows exemplary its nominal design.



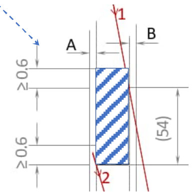
Schematic view (cross section) of the XMM-Newton X-ray baffle design. using the example of a single one of the 58 nested mirror shells

Remaining Single Reflections

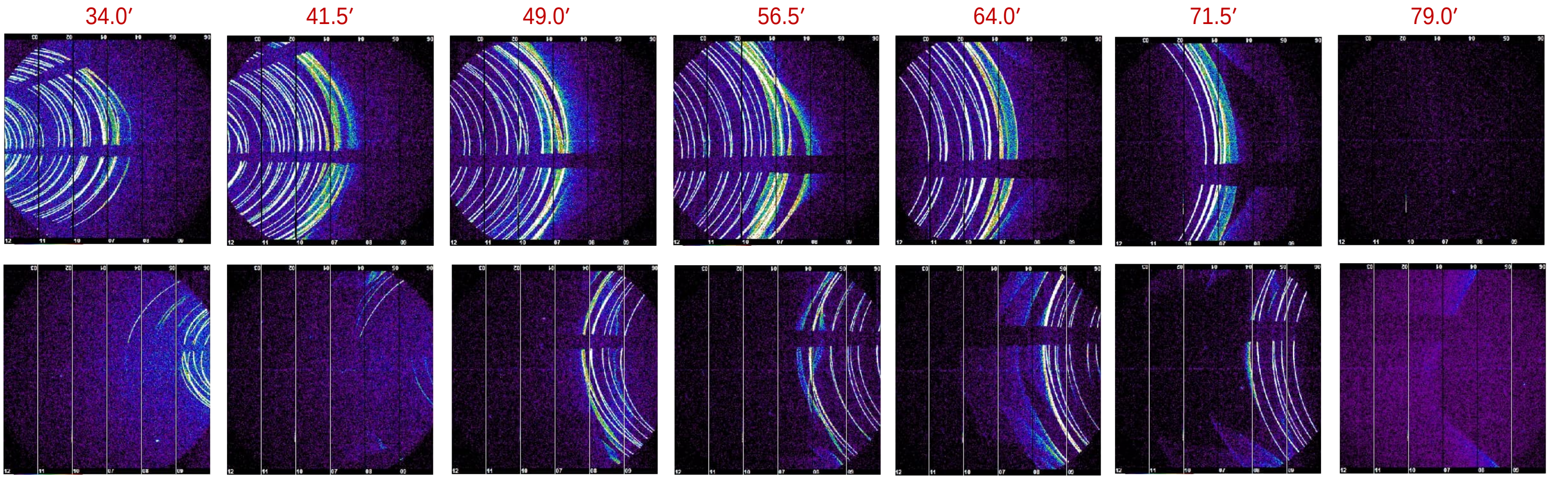
Detailed studies of the remaining single reflections in the observations, which manifest themselves in arcuate patterns near real X-ray sources, reveal an asymmetry of these arcs. They are particularly pronounced in one direction, while they are considerably weaker on the opposite side. It is likely that this effect is due to a slight misalignment of the X-ray baffle with respect to the mirror module.

Ray-tracing analyses

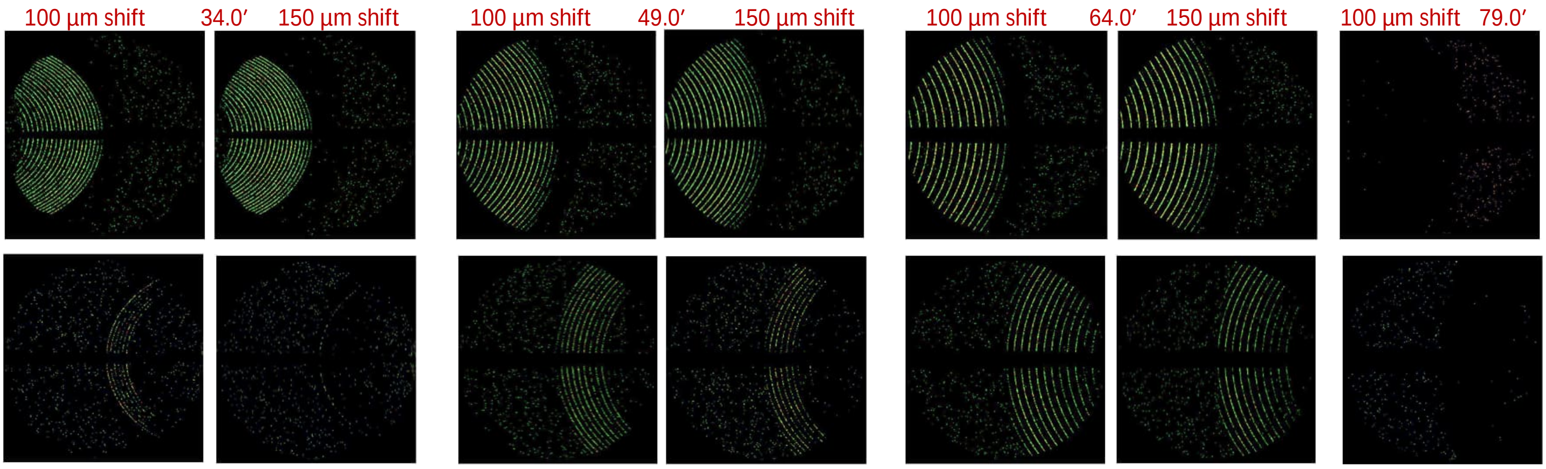
Ray-tracing simulations were able to confirm this assumption and show that a lateral shift of the baffle in the order of 100 micrometres can in principle explain the observations.



Preliminary approximation of the sieve plate design in the ray-tracing tool



XMM-Newton observations of single reflections of Sco X-1, the brightest X-ray source in the sky, at different off-axis angles; the source itself is out of the view.



Ray-tracing simulations of single reflections of (selected) corresponding off-axis angles; results are shown for shifts of 100 µm and 150 µm.

Results

The simulations – performed for potential misalignments of 25 to 150 µm shift – suggest that a shift of about 100 -150 µm can in principle reproduce the asymmetry observed. In particular, the decreasing asymmetry with increasing off-axis angles, seen in the observations, is well reproduced.

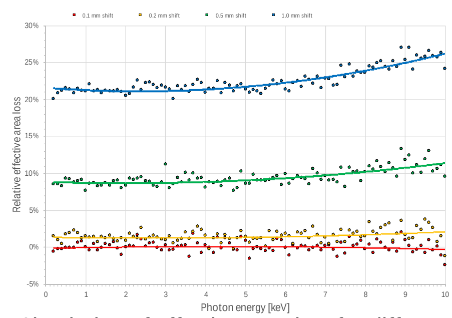
In contrast to the observations, the simulations assume perfect mirror shells, while in reality mirror shells are statistically slightly tilted towards each other, which doesn't harm the imaging performance but displaces the single reflection patterns that can easily cross each other.

Literature: „Collimators for X-ray Astronomical Optics" by Hideyuki Mori and Peter Friedrich in Handbook of X-ray and Gamma-ray Astrophysics, ed. Cosimo Bambi and Andrea Santangelo, Springer 2024

Effective area affected?

A mismatch between X-ray baffle and mirror shells should be also associated with a slight reduction in the effective collection area.

However, a shift of only 100-150 µm will not result in a measurable reduction as the simulations show.



Simulation of effective area loss for different amounts of shifting the baffle w.r.t. mirrors