XMM-Newton EPIC-pn single reflections from Sco X-1

WHY ??

flux discrepancies → effective area discrepancies

If you can't beat them, join them !

After presentation: take-away message ...

Send more single reflections !

M. Freyberg + P. Friedrich (MPE), D. Lumb (OU), XMM-SOC (ESAC)

Wolter Type I optics (1:P + 2:H): Mori & Friedrich (2023)

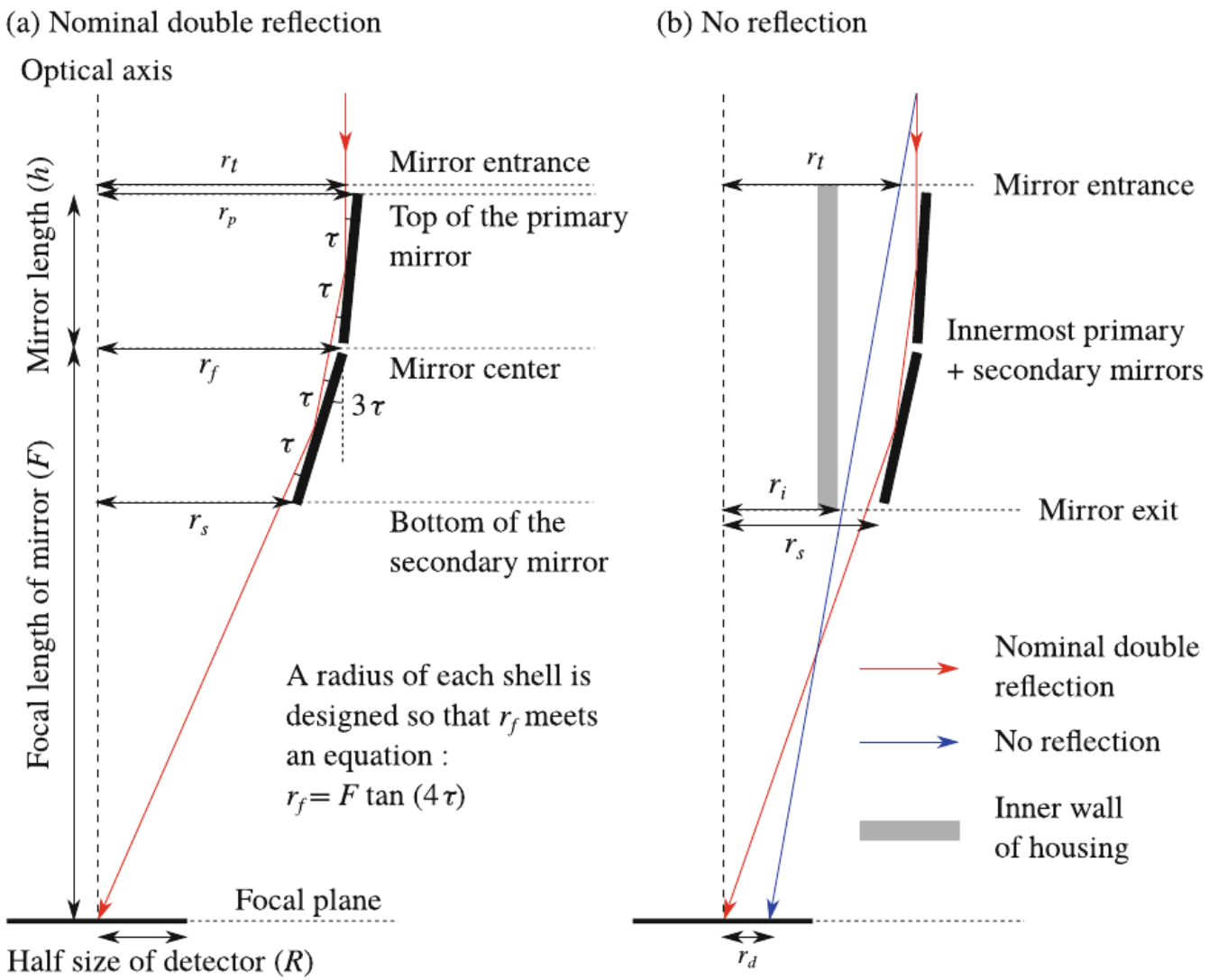


Fig. 3 X-ray paths inside the X-ray mirror for the (**a**) nominal double reflection and (**b**) no reflection. The terms and parameters are also indicated

Wolter Type I optics (1:P or 2:H): Mori & Friedrich (2023)

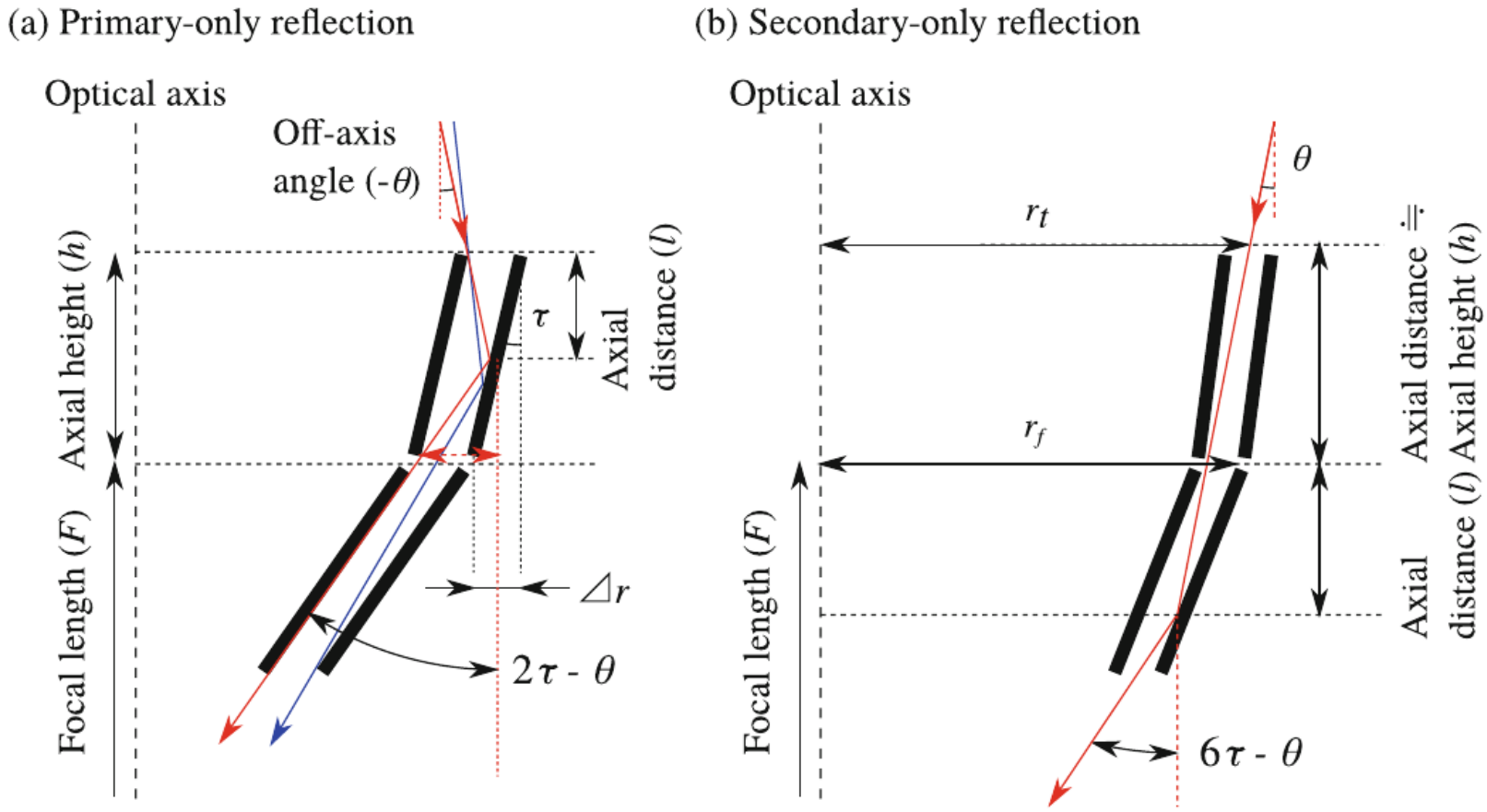


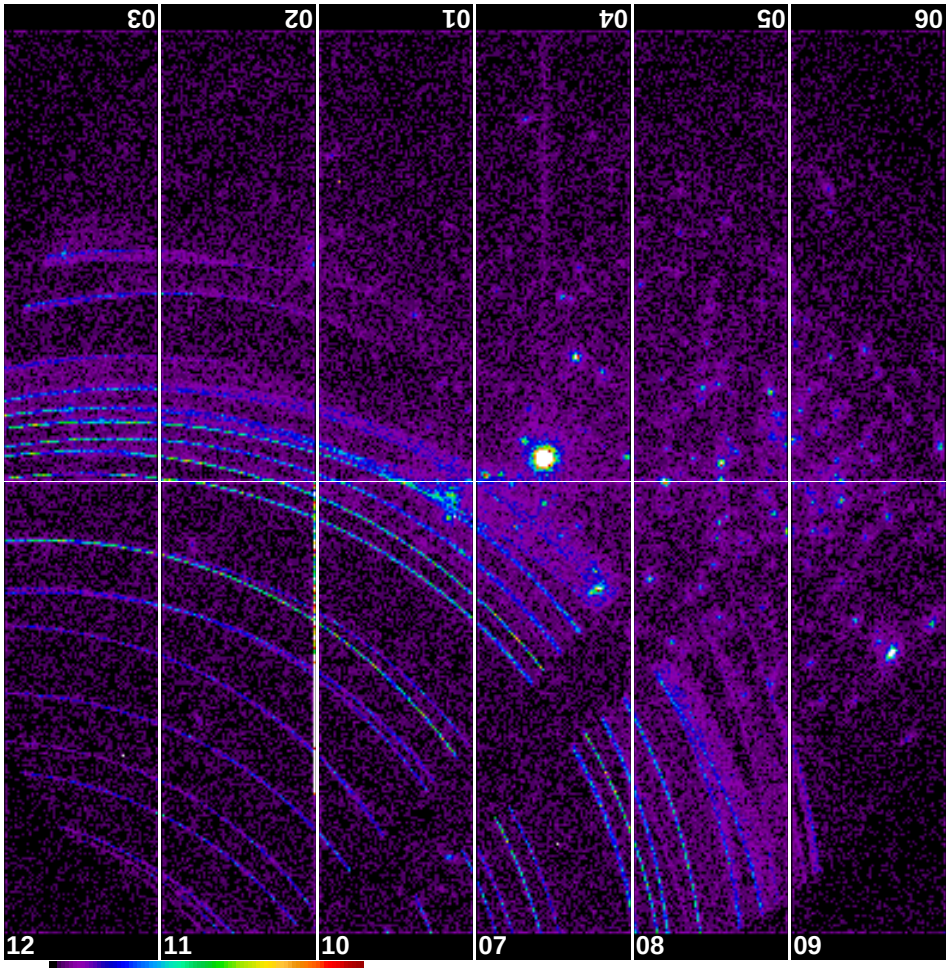
Fig. 5 (**a**) Supplemental drawing of the primary-only reflection in a tightly nested mirror. An off-axis X-ray is hit at the middle of a primary shell. Then, the reflected X-ray passes just behind the inner secondary shell. A blue line shows the case of the primary-only reflection with $\theta > -\tau$. (**b**) Same as (**a**), except for the secondary-only reflection

EPIC-pn: single reflections: GX 5-1 and Crab

HD164794
0228_0008820101_PNU002
Singles, no MIPs, $40 - 1600$ **adu**

Mode = PrimeFullWindow Filter = Thick
$\alpha_{2000} = 18\,03\,48.0$ $\delta_{2000} = -24\,20\,9.9$ PA $= 91.135°$
$l = 6.023°$ $b = -1.178°$ $N_{\rm H,gal} = 86.26 \times 10^{20}\,{\rm cm}^{-2}$

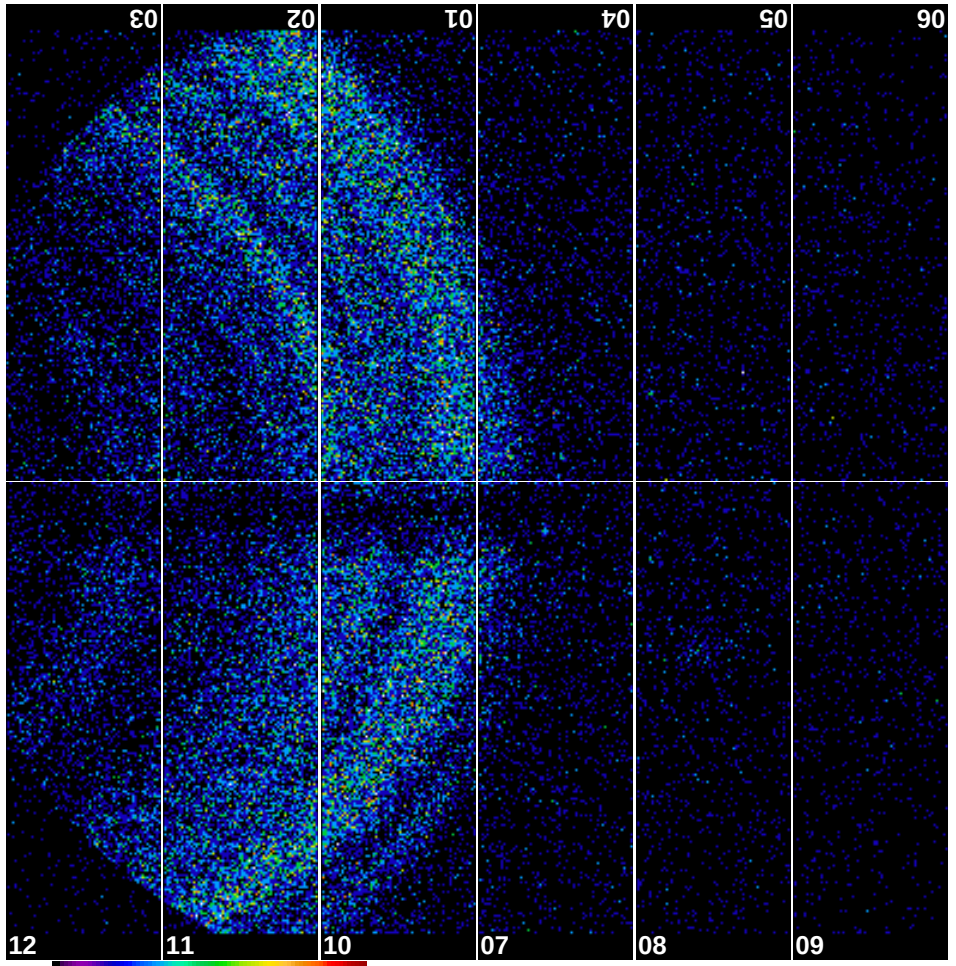
2001-03-08T12:17:05
2001-03-08T17:41:59
19494 s



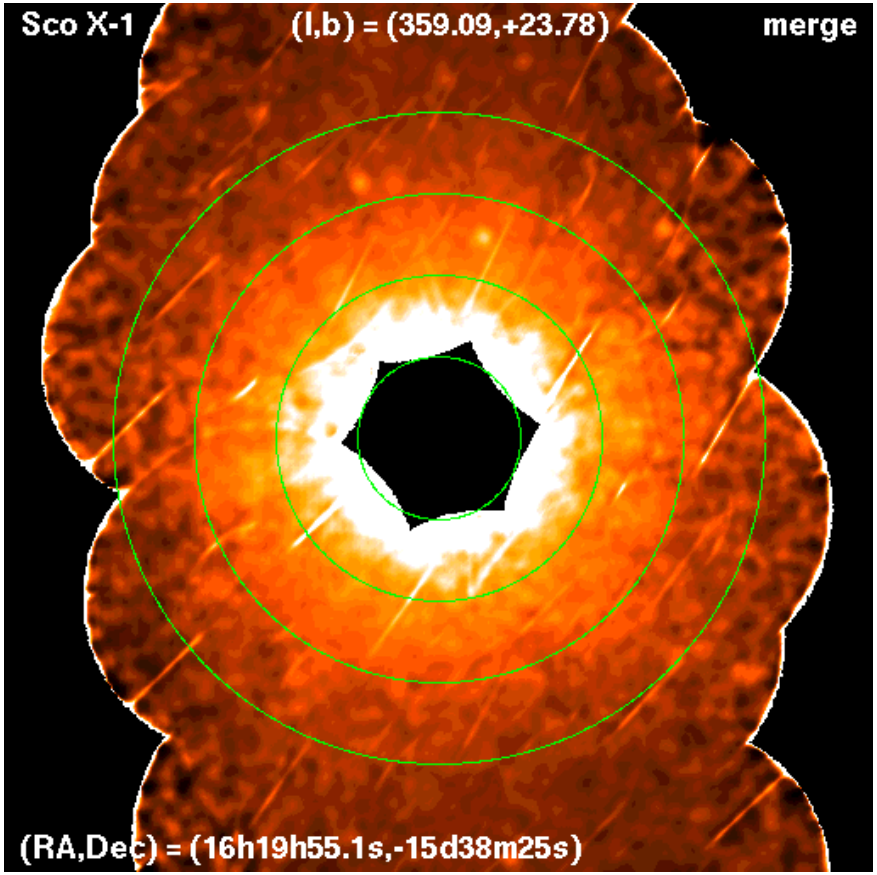
Crab (off-axis 3)
0056_0122330301_PNS003
Singles, $0.50 - 2.00$ **keV**

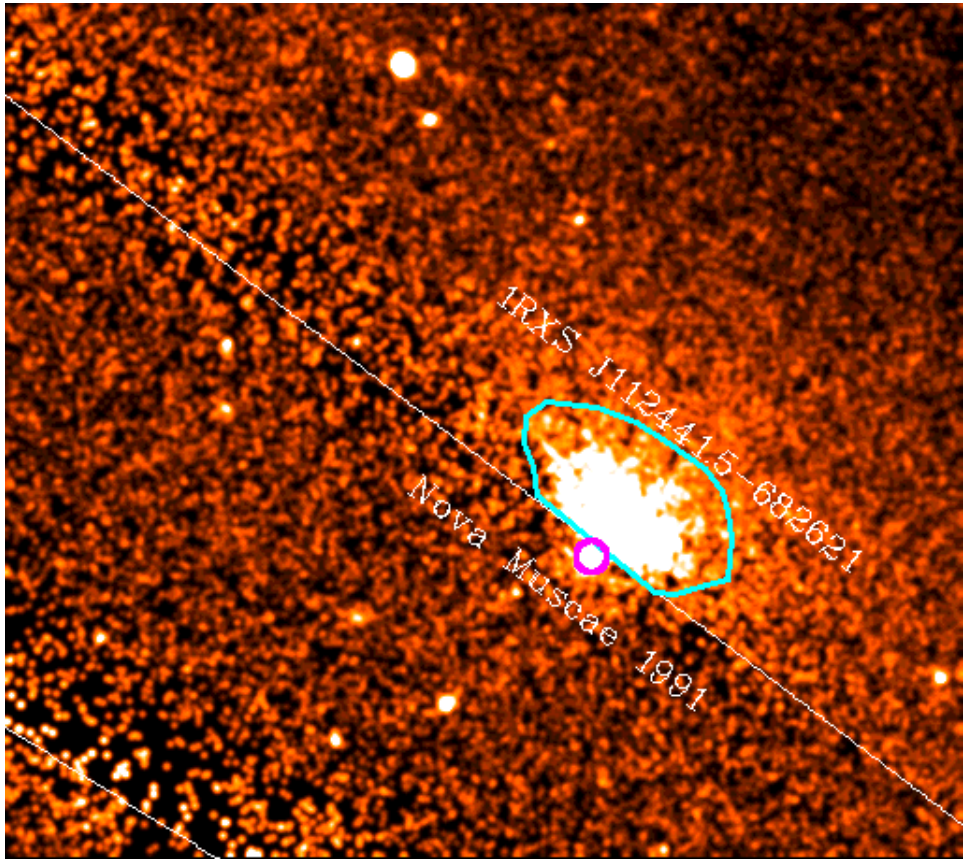
Mode = PrimeFullWindow Filter = Medium
$\alpha_{2000} = 05\,31\,22.2$ $\delta_{2000} = +21\,57\,33.1$ PA $= 269.281°$
$l = 184.209°$ $b = -6.432°$ $N_{\rm H,gal} = 36.5 \times 10^{20}\,{\rm cm}^{-2}$

2000-03-30T09:33:20
2000-03-30T10:26:49
3209 s



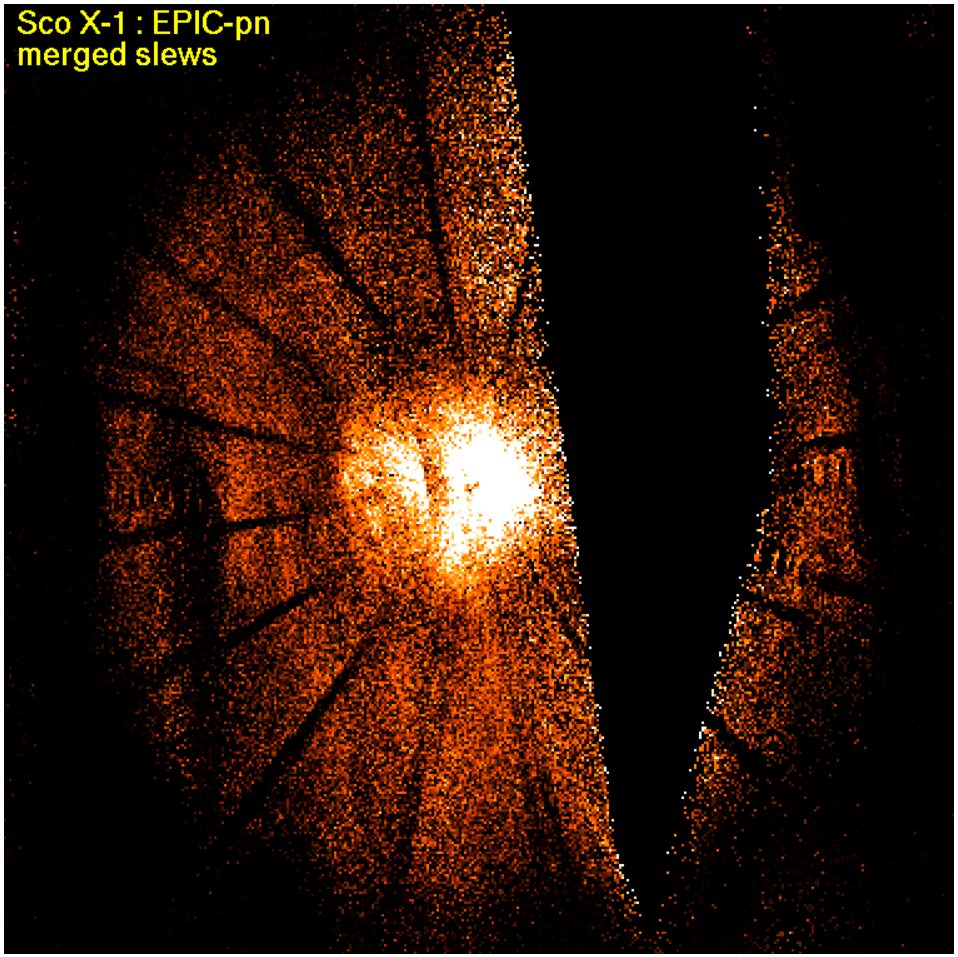
ROSAT PSPC All-Sky Survey: Sco X-1 and Nova Muscae

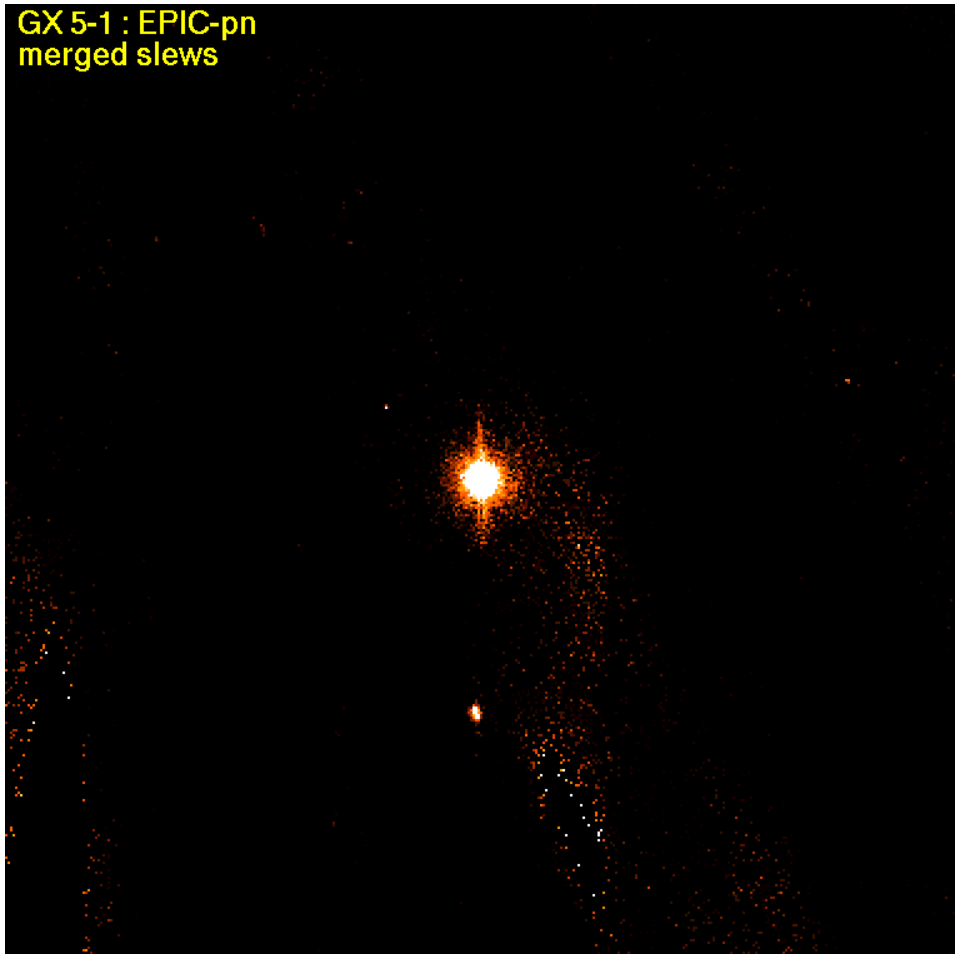




ROSAT survey completion (1997), Freyberg+24

EPIC-pn: merged slews of Sco X-1 and GX 5-1



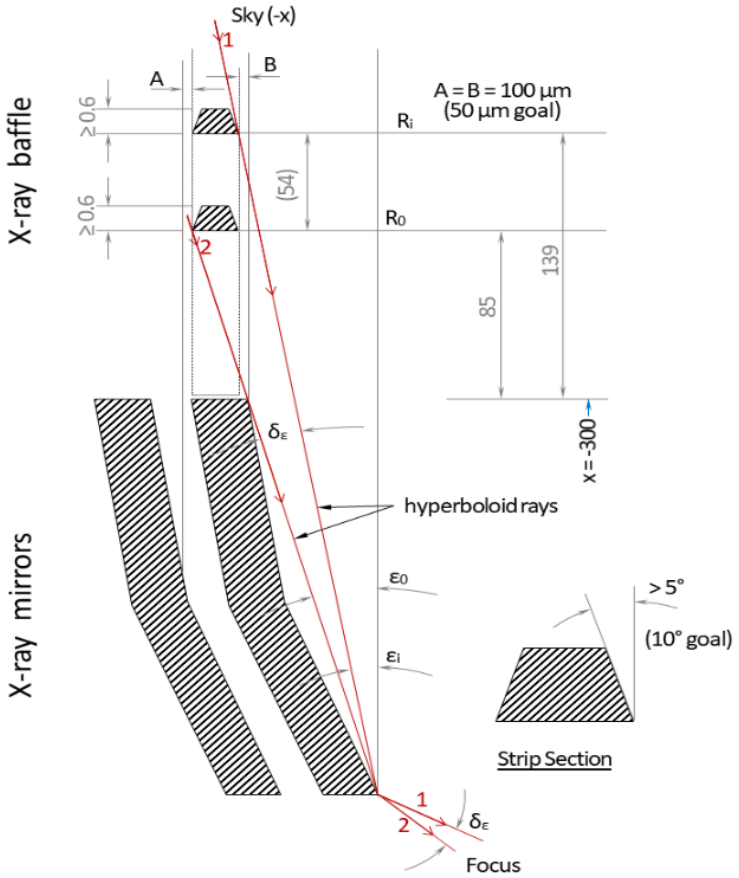


GX 5-1 is about 10-15 times fainter than Sco X-1, and thus slew exposures are not sufficient to show any significant single reflections.
Half image size: 81 arcmin, Energy range: 0.5 - 12 keV

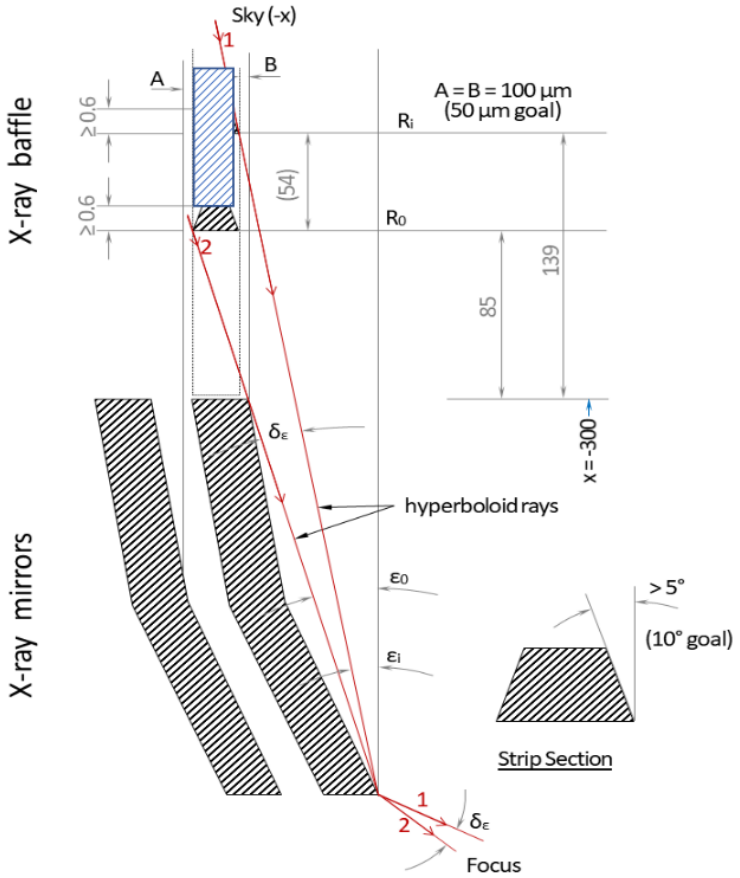
XMM-Newton: simulations of ideal mirror module (P. Friedrich)

Ray-Tracing Simulations: Modelling the X-Ray Baffle (simplified)

„Official“ Design

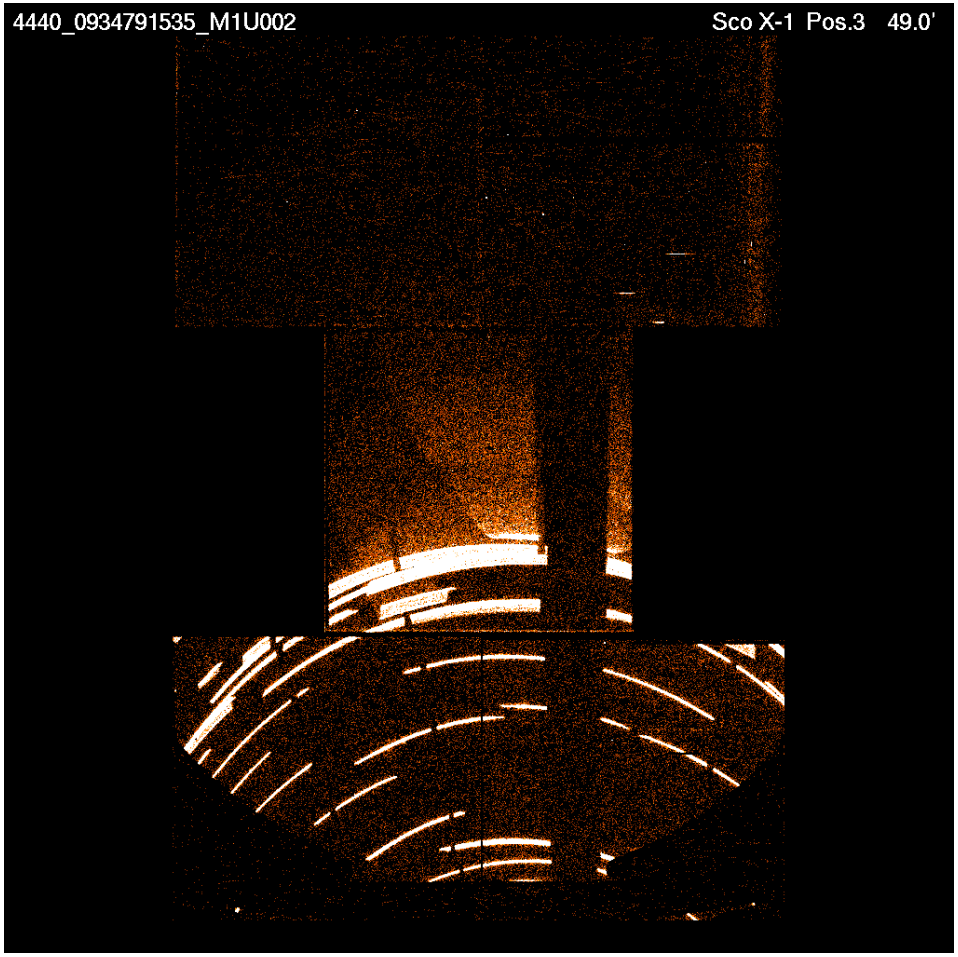


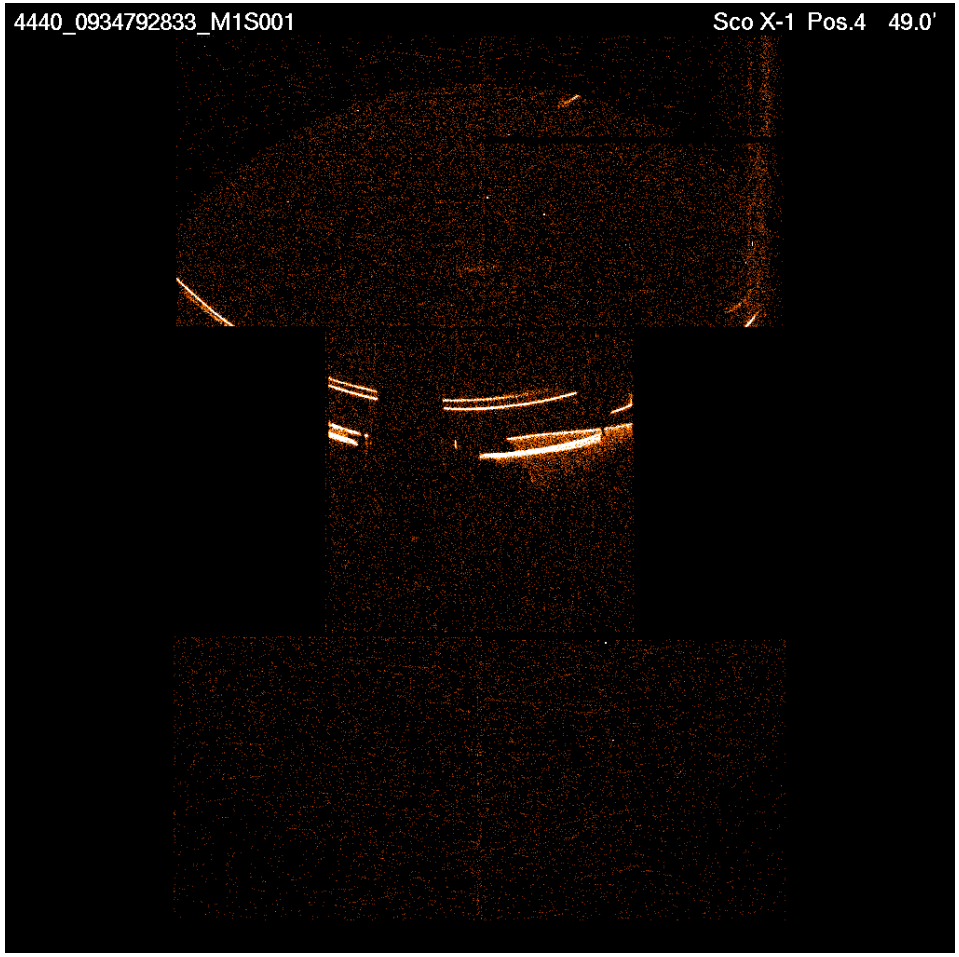
Simplified Model



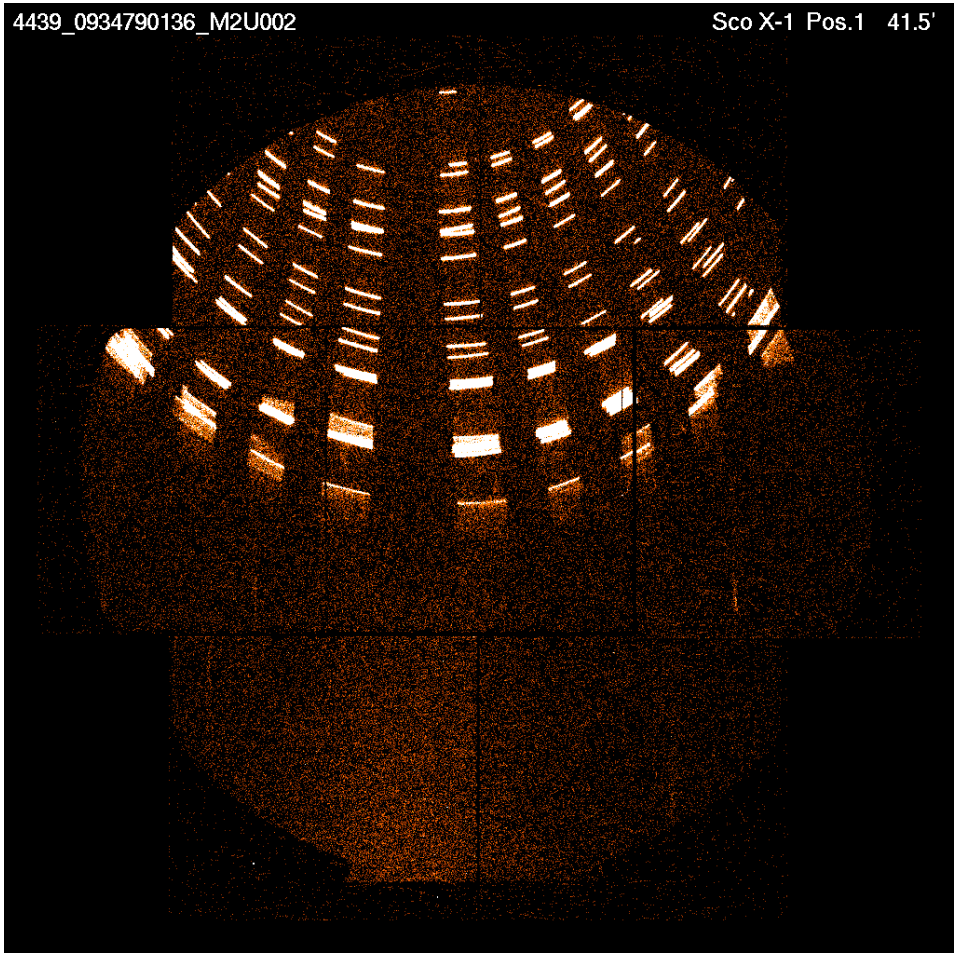
EPIC-MOS1: Pos.1 + Pos.2: 49.0'

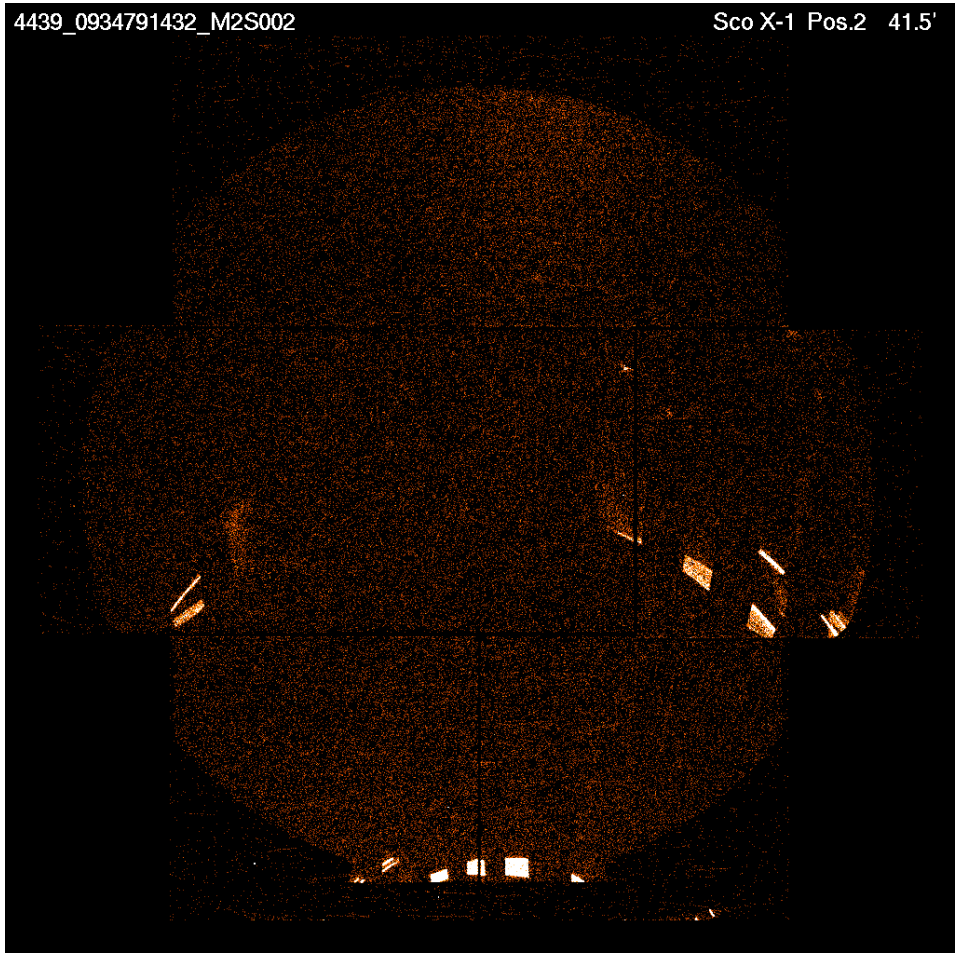
EPIC-MOS1: Pos.3 + Pos.4: 49.0'



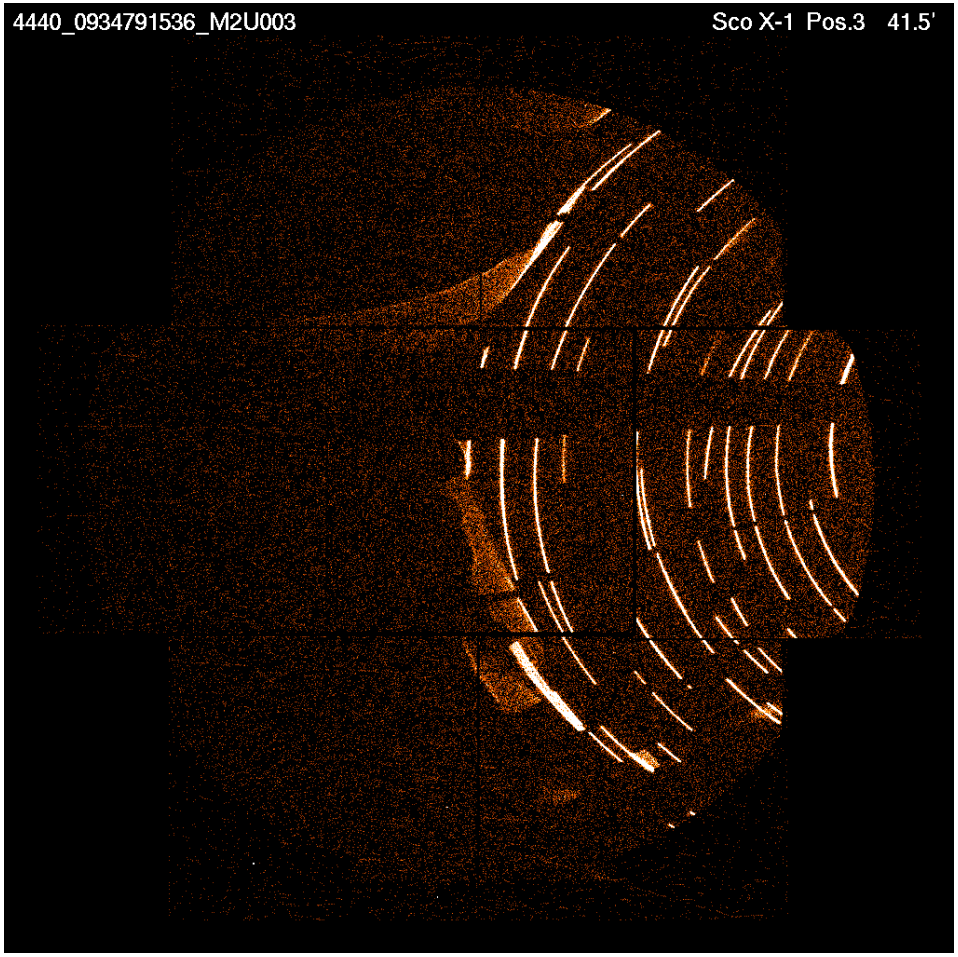


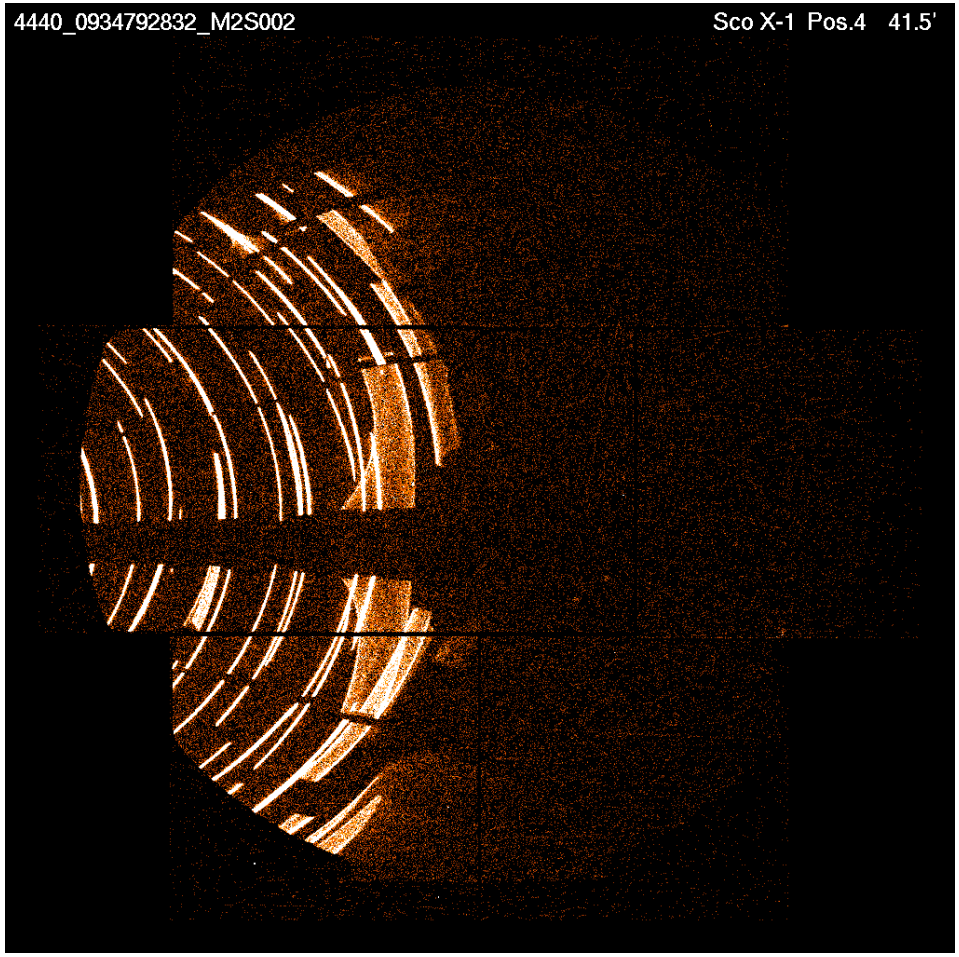
EPIC-MOS2: Pos.1 + Pos.2: 41.5'





EPIC-MOS2: Pos.3 + Pos.4: 41.5'





EPIC-pn: quick-look summary

- strong asymmetry in arc images between mosaics #3 and #4
- light curves of individual CCDs (as summary plots) show variablity within sub-pointings in the quadrants of the single reflection arcs but not in the other quadrants (on timescales of order half an hour), which suggests intrinsic source variability rather than background variation. These variations can be detected and accounted for.
- MAXI data indicate some long-term variability of Sco X-1, which can be corrected for
- counting mode only in mosaic #3 for later sub-pointing positions
- check for pile-up in arcs (ratio of images in singles and in doubles)
- check for other livetime effects (buffer overflows etc.)
- exposure maps (counting mode, background "subtraction")
- large-scale image "centered" on Sco X-1, i.e. $180' \times 180'$ size ...
- ... add (re-normalized) archival single reflection images of GX 5-1 (has to be done semester-wise: PA !)

EPIC-pn: first simulation results (D. Lumb): 5% eff.area loss

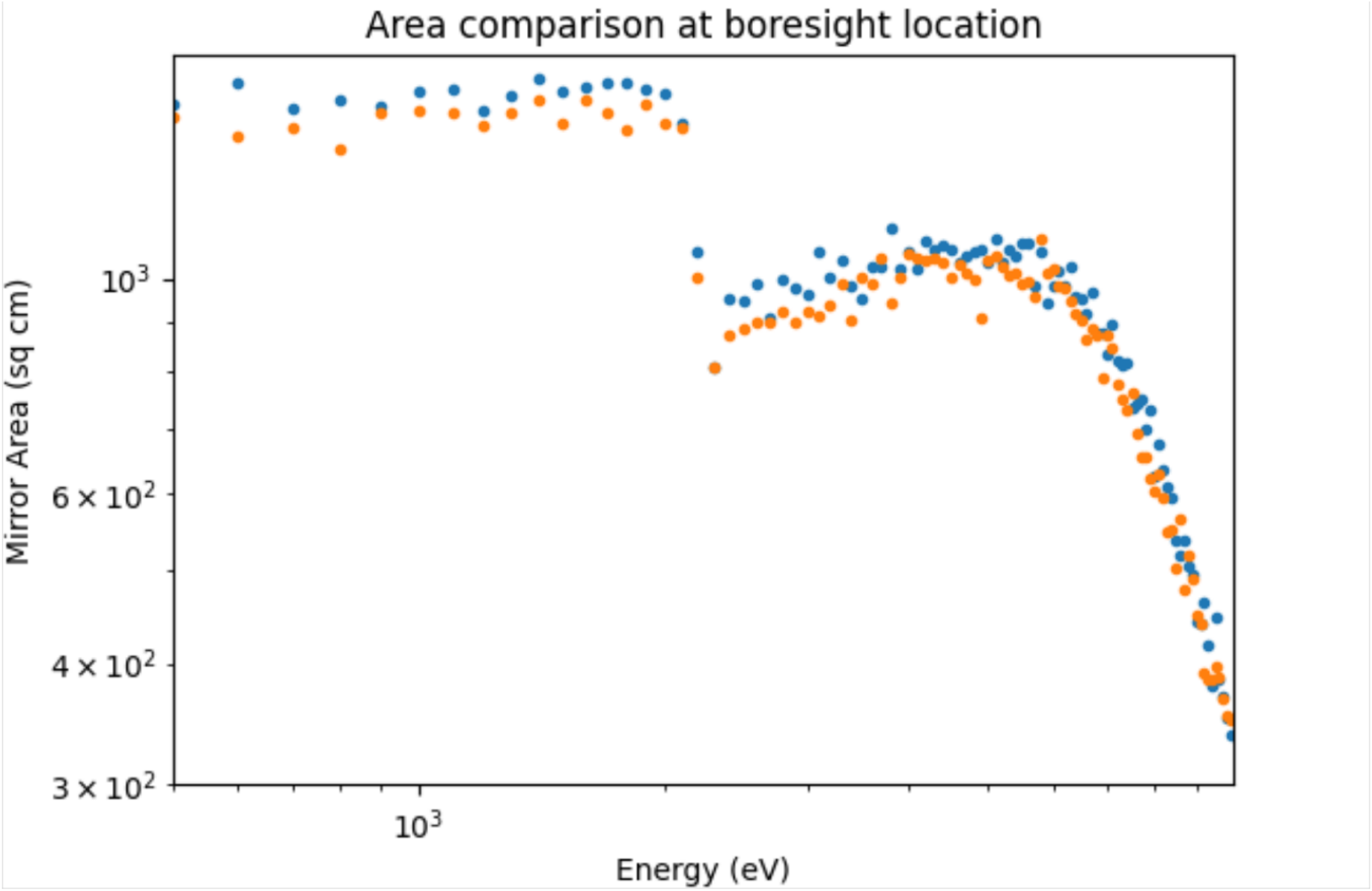


Fig 7 Effective area at the PN Boresight location. ***Blue*** – nominal SCISIM configuration. ***Orange*** – SCISIM with 0.025 degrees baffle tilt

EPIC-pn: conclusions

- NRCO-138 successful – well planned and time well spent !
- qualitative analysis points towards global tilt of "EPIC-pn" X-ray baffle with respect to mirror module by about 1.5 arcmin
- this could account for $\sim 5\%$ effective area loss at the target position
- this method turns out to be very promising for cross-calibration (pn/MOS, Chandra, NuSTAR) corrections
- this analysis does not yet account for additional individual mirror shell imperfections, so reduction could be higher
- add more details to simulation programs (D. Lumb + P. Friedrich)
- then create updated effective area tables
  (for various "imperfection parameters"),
  and perform spectral fits, and analyse systematic residuals
- after completion of this analysis maybe repeat NRCO-138
  in diagonals of previous set-up $\rightarrow$ Send more single reflections !