Physics-based ray tracing of X-ray telescopes

Neo Reinmann

and the SIXTE Team

Bamberg, 28 July 2025

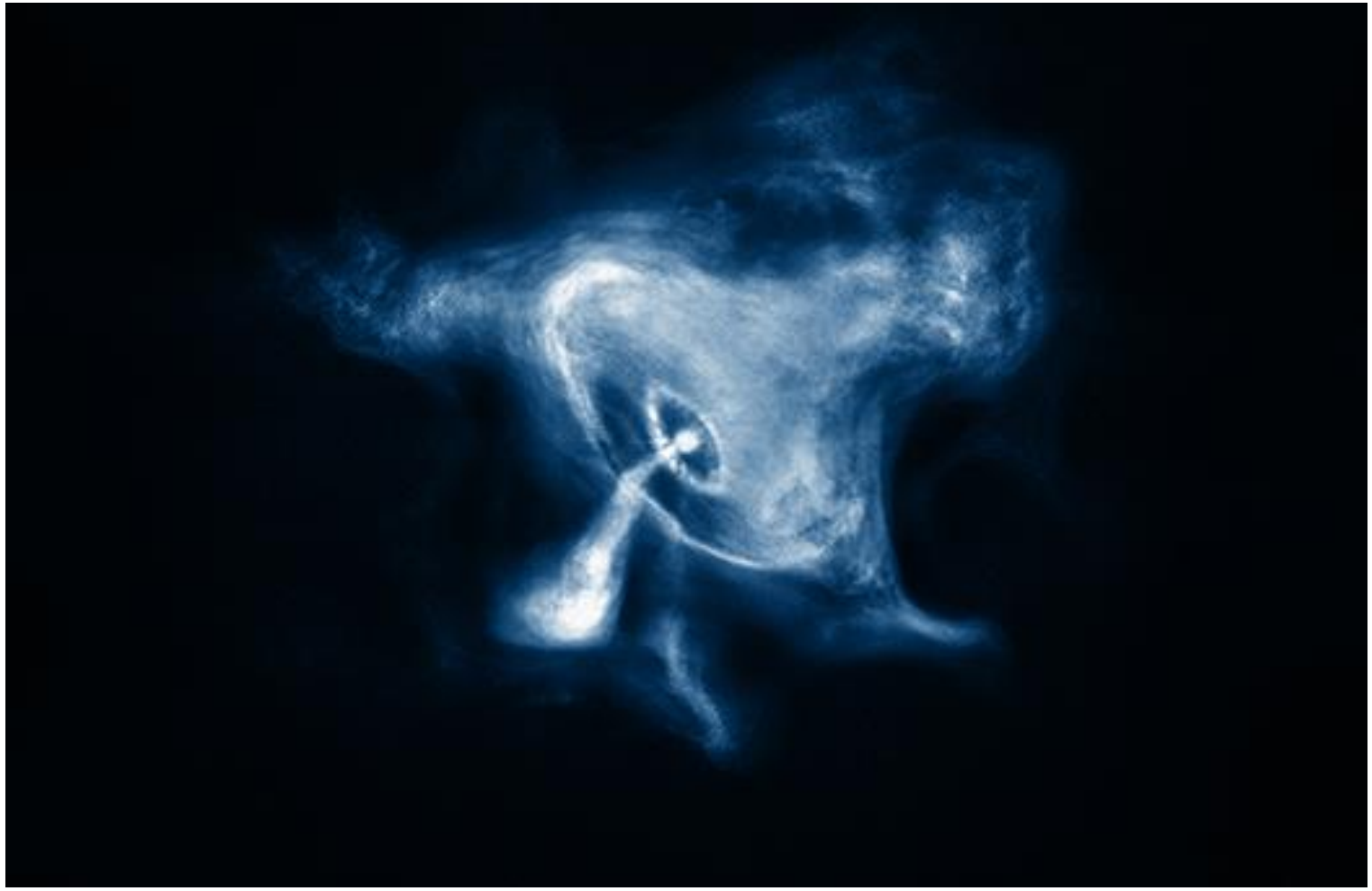
X-ray astronomy

And how to observe it

Crab Nebula in the visual light

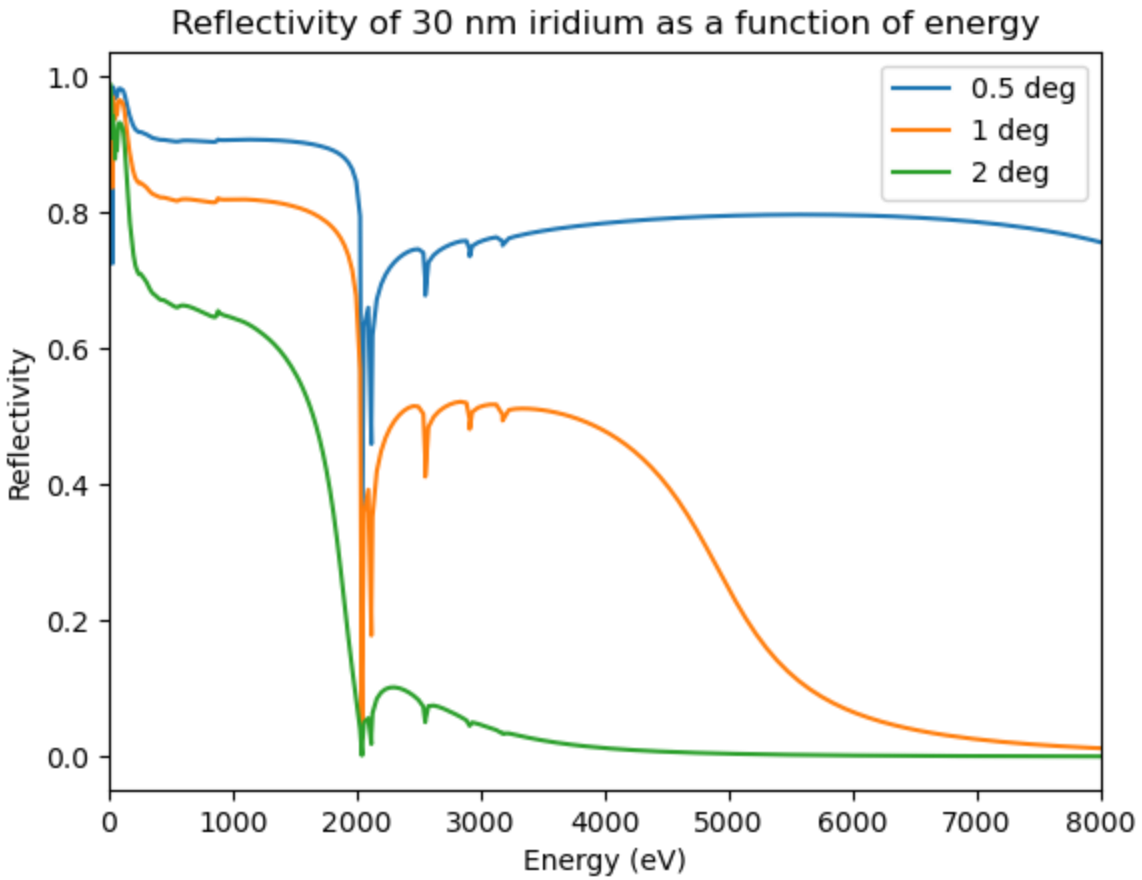
(NASA/STScI)

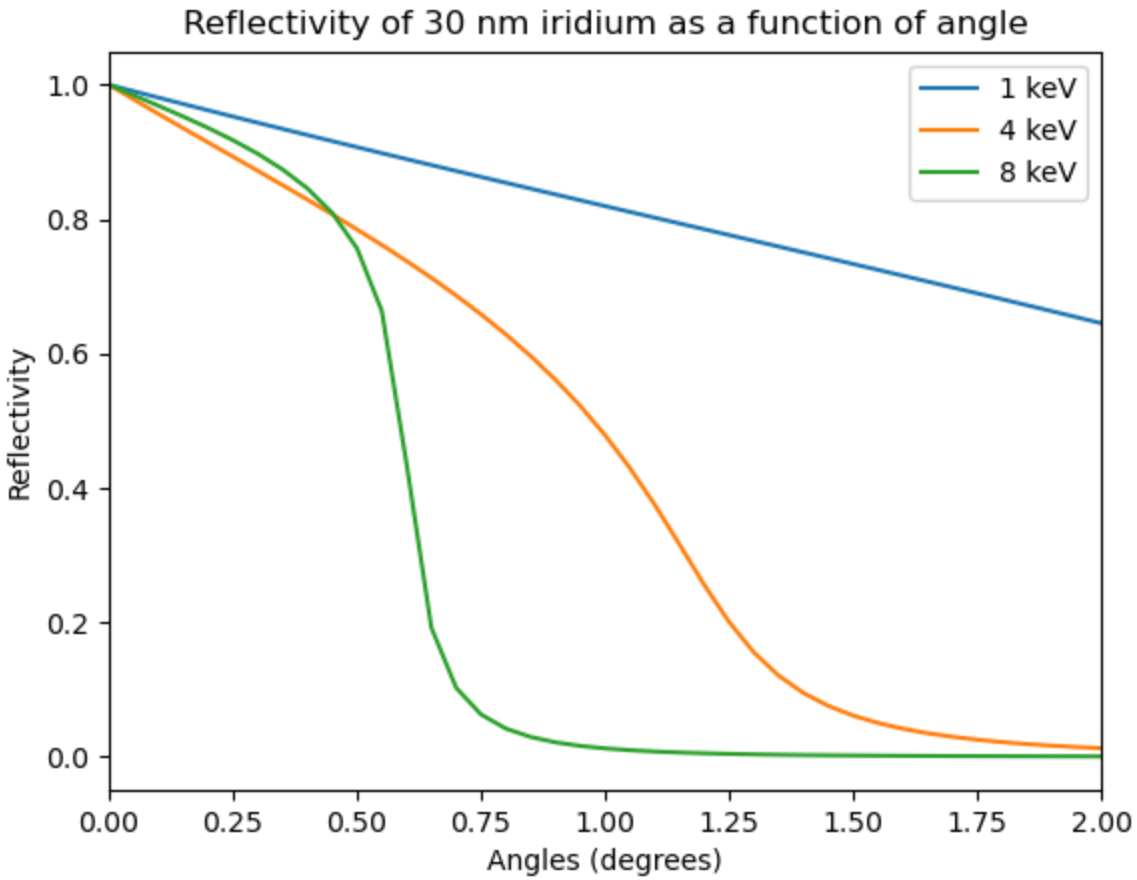
Crab nebula in the X-rays



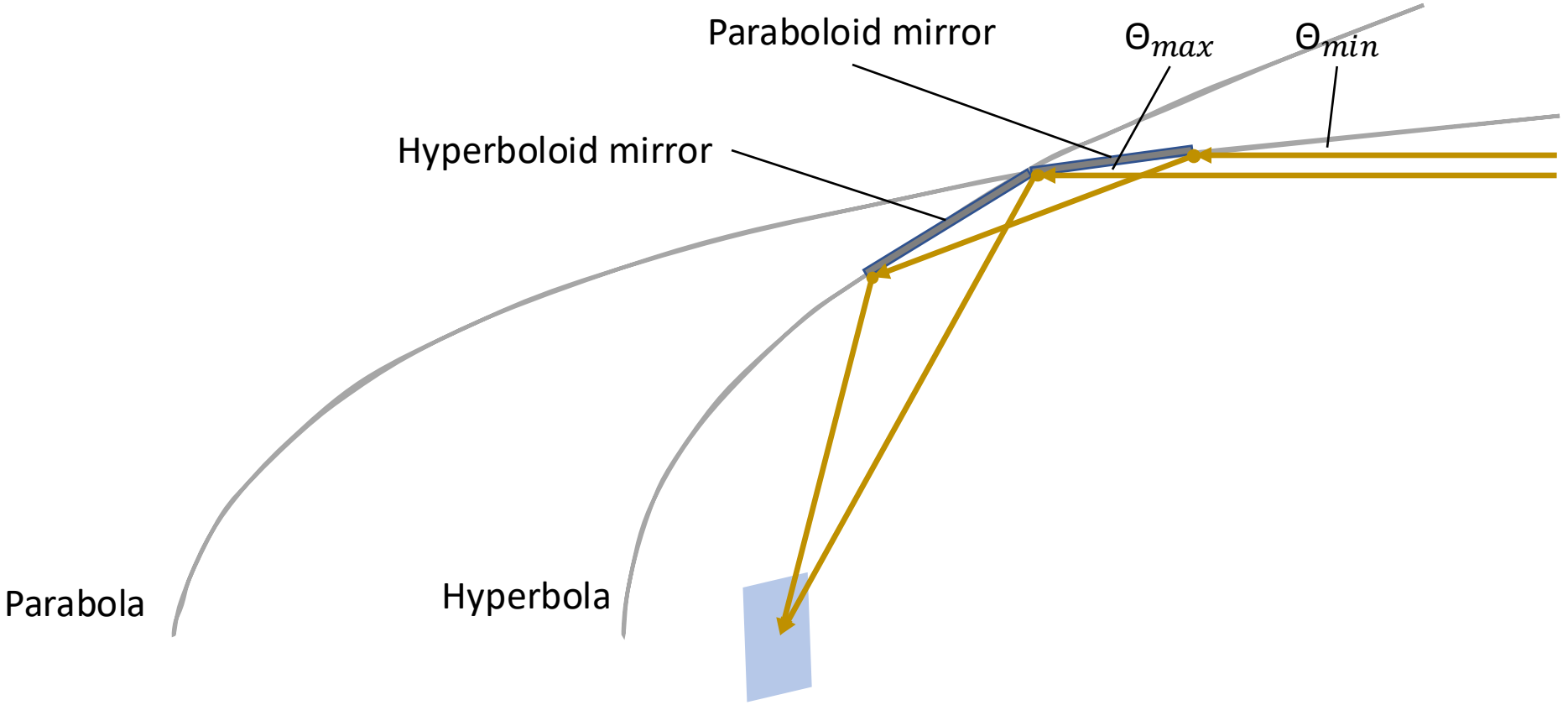
(NASA/CXC/SAO)

Reflectivity of X-rays

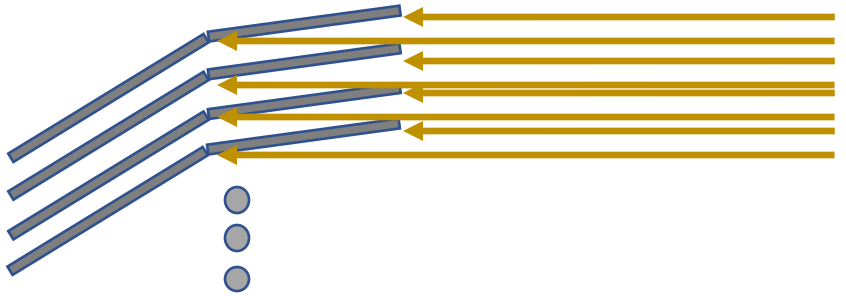




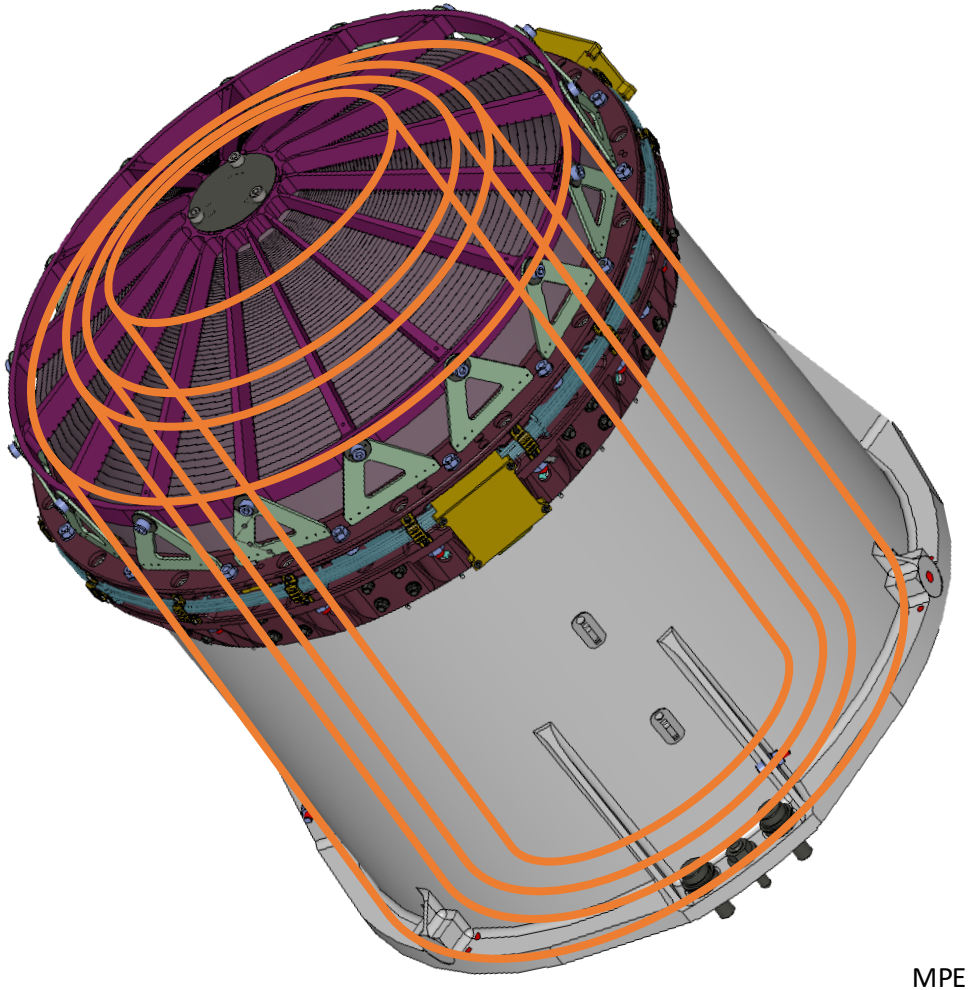
Wolter Type 1 Telescope



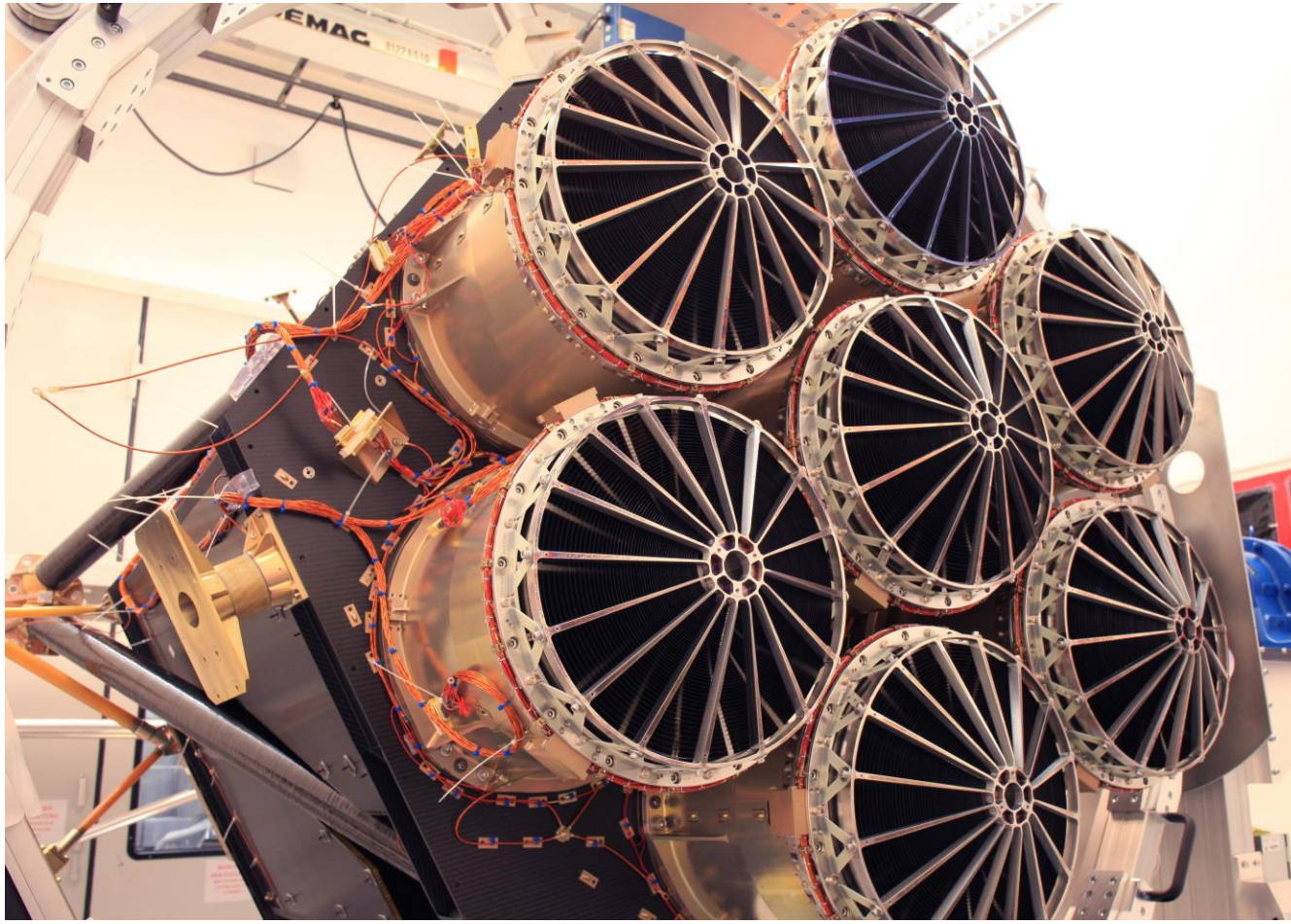
Wolter Type 1 Telescope



eRosita as one Wolter 1 implementation



MPE

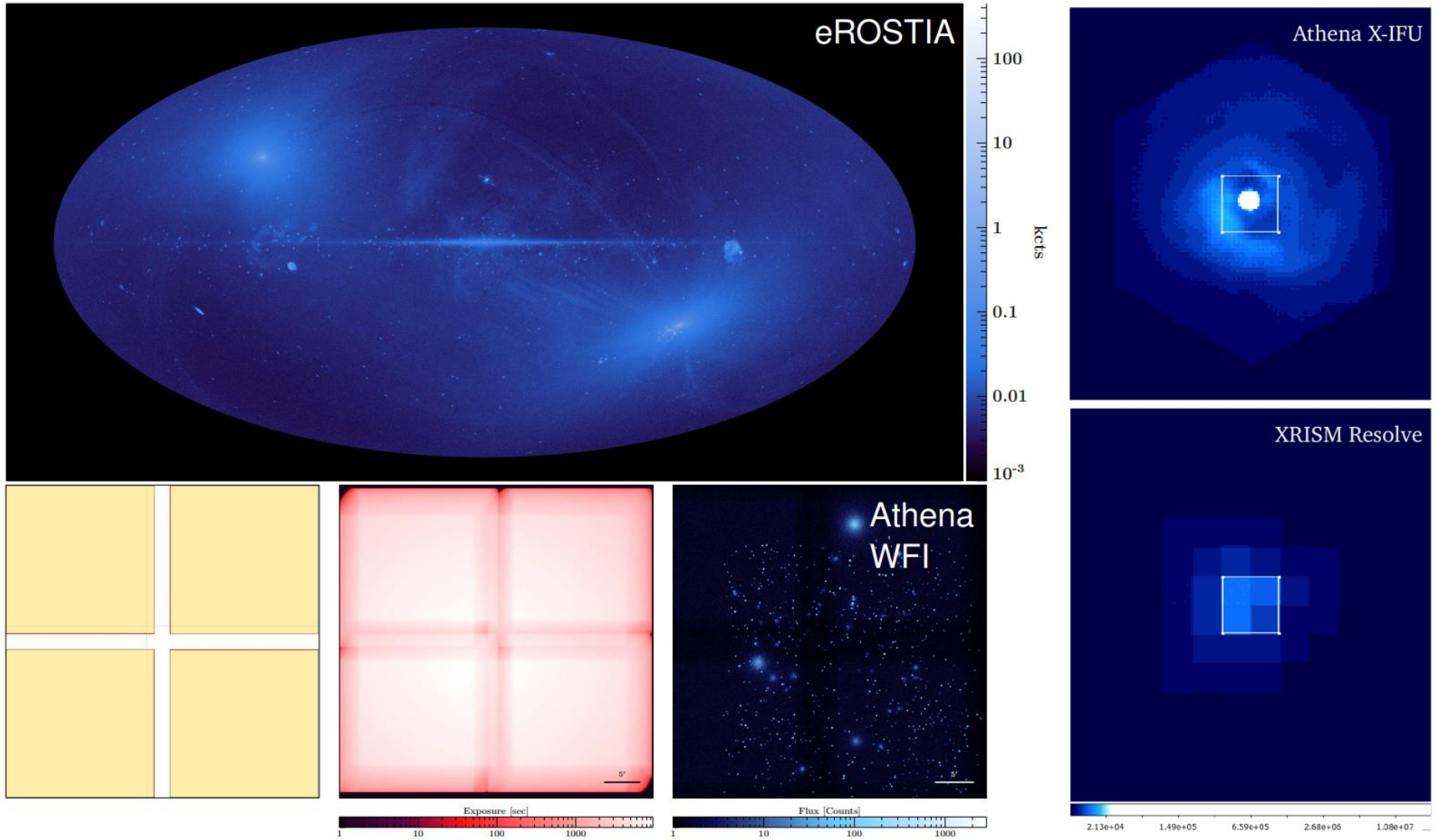


MPE

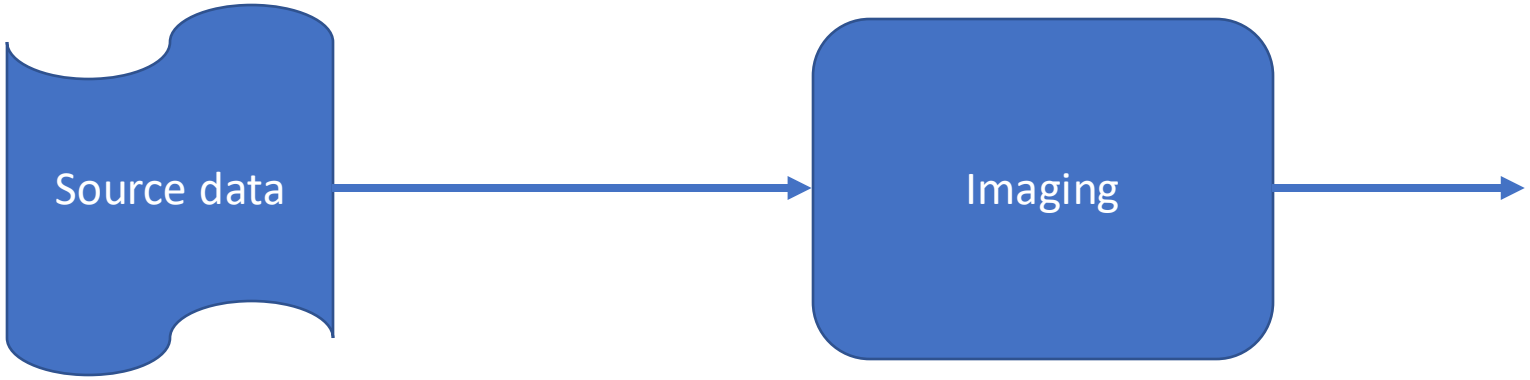
Simulation of X-ray telescopes

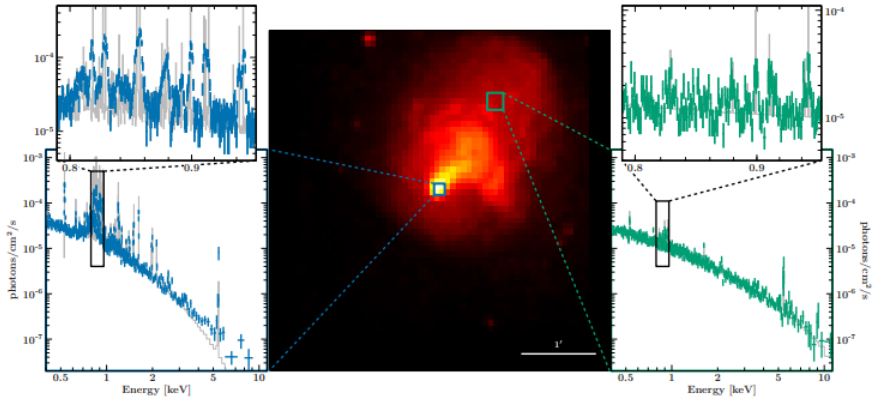
Or in short: SIXTE

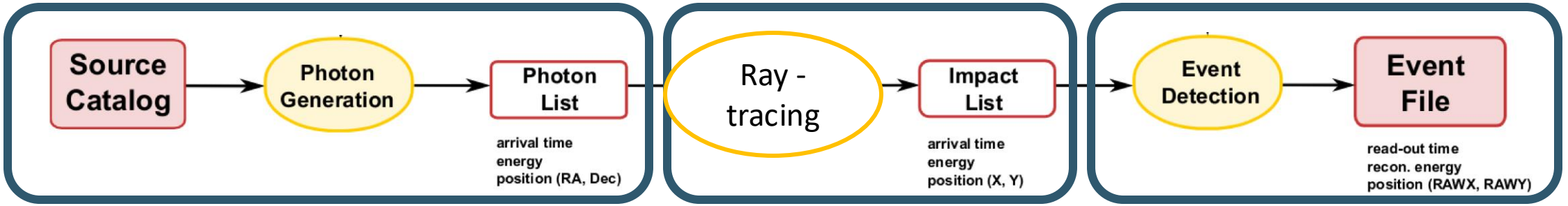
Modular end-to-end simulation software for X-ray detectors



SIXTE Architecture

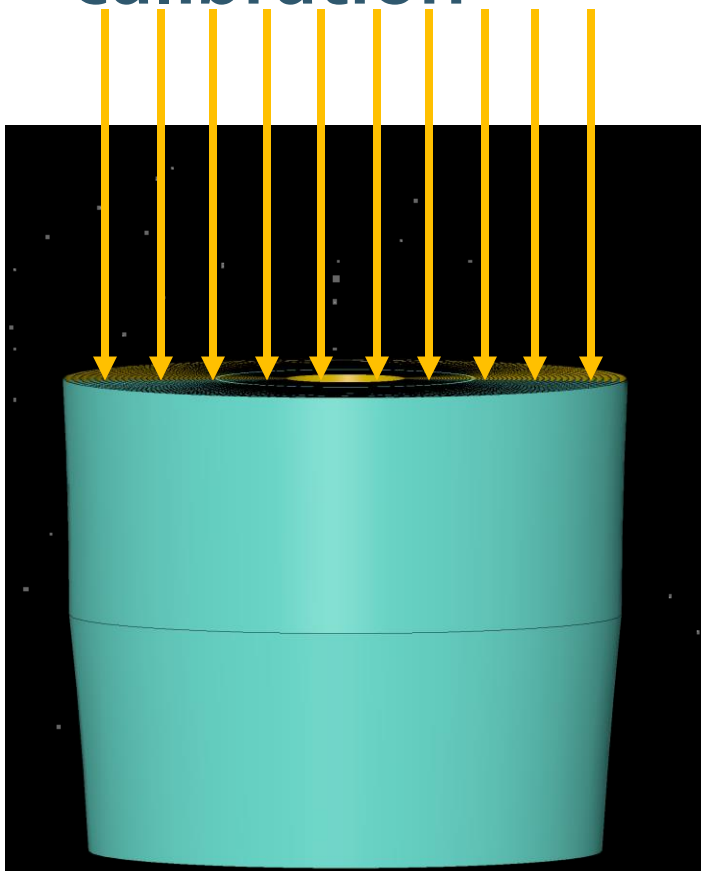




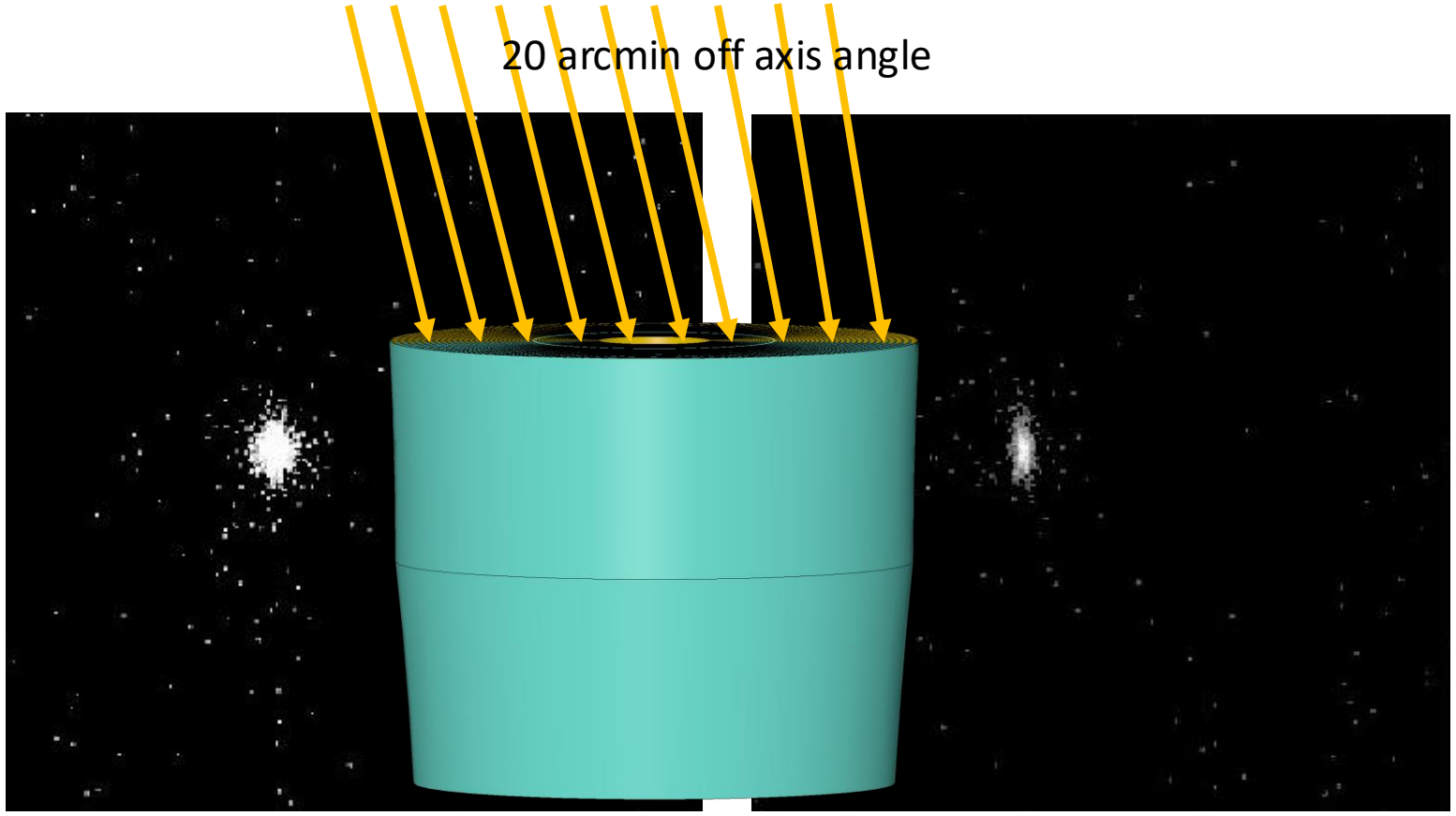


T. Dauser

Measured PSFs (point spread functions) from telesope calibration



On-Axis



0.3 keV

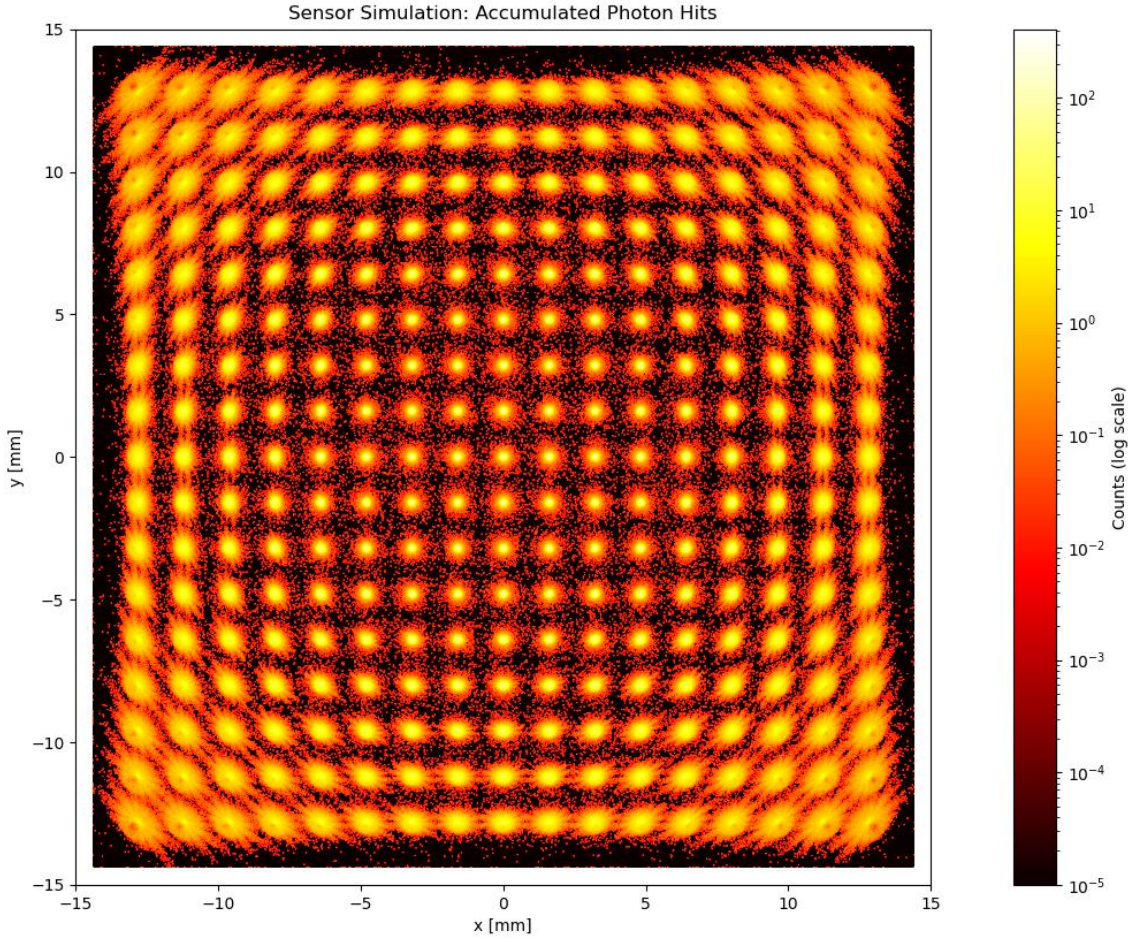
3.0 keV

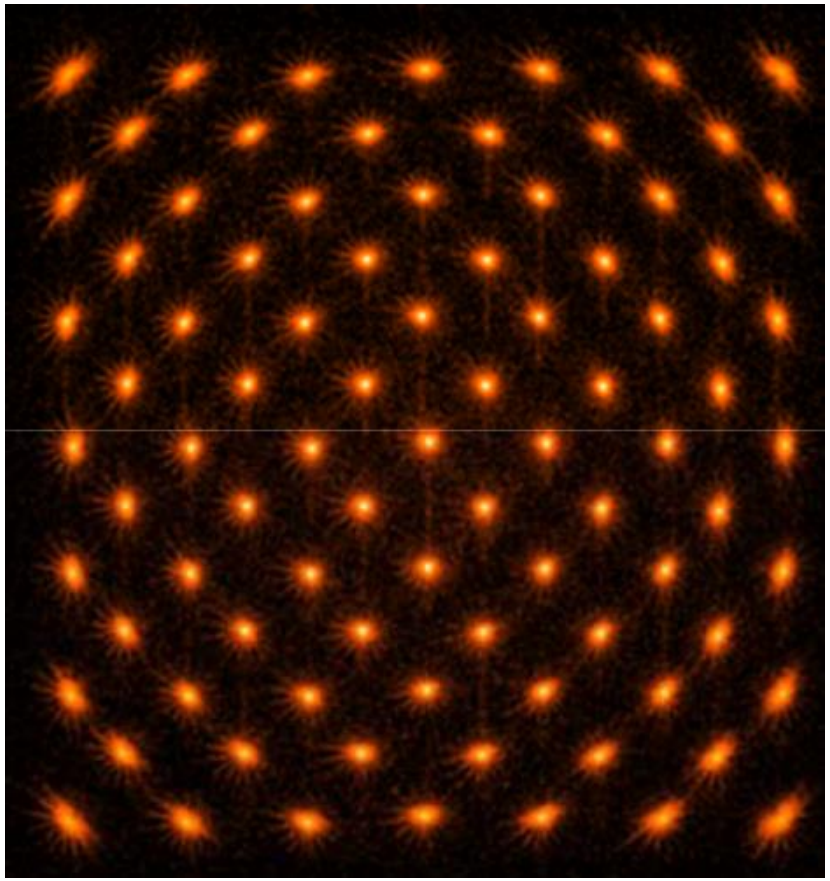
Off-Axis

Results

So far...

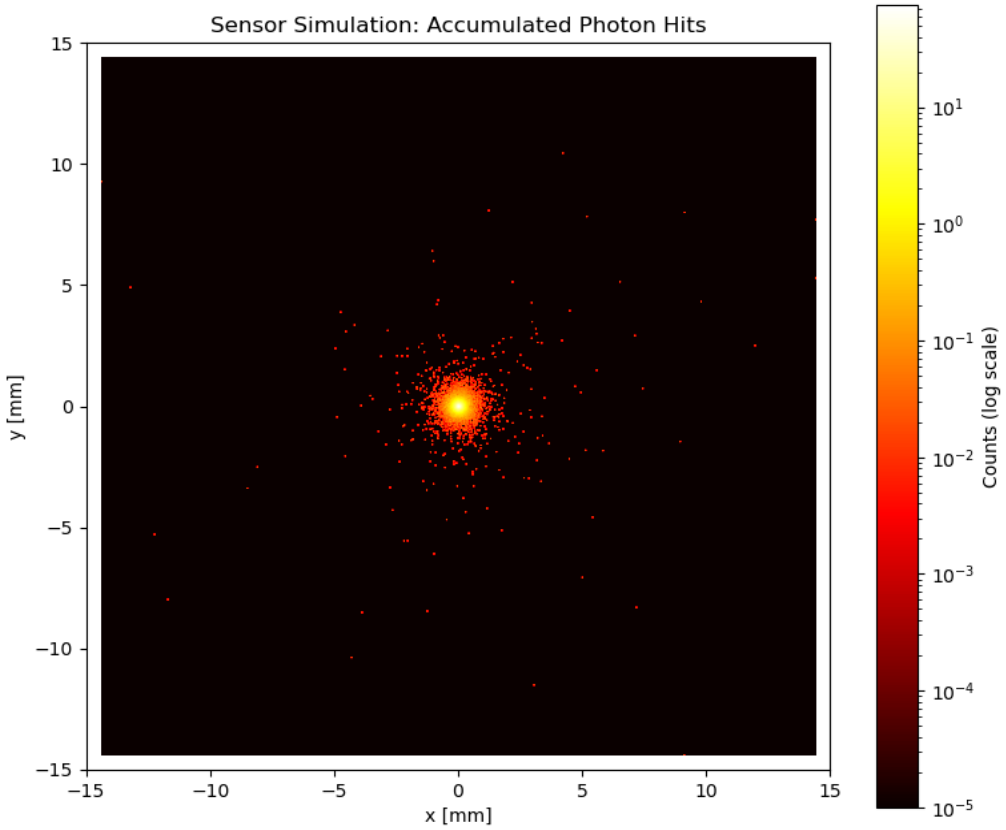
PSF - Evaluation

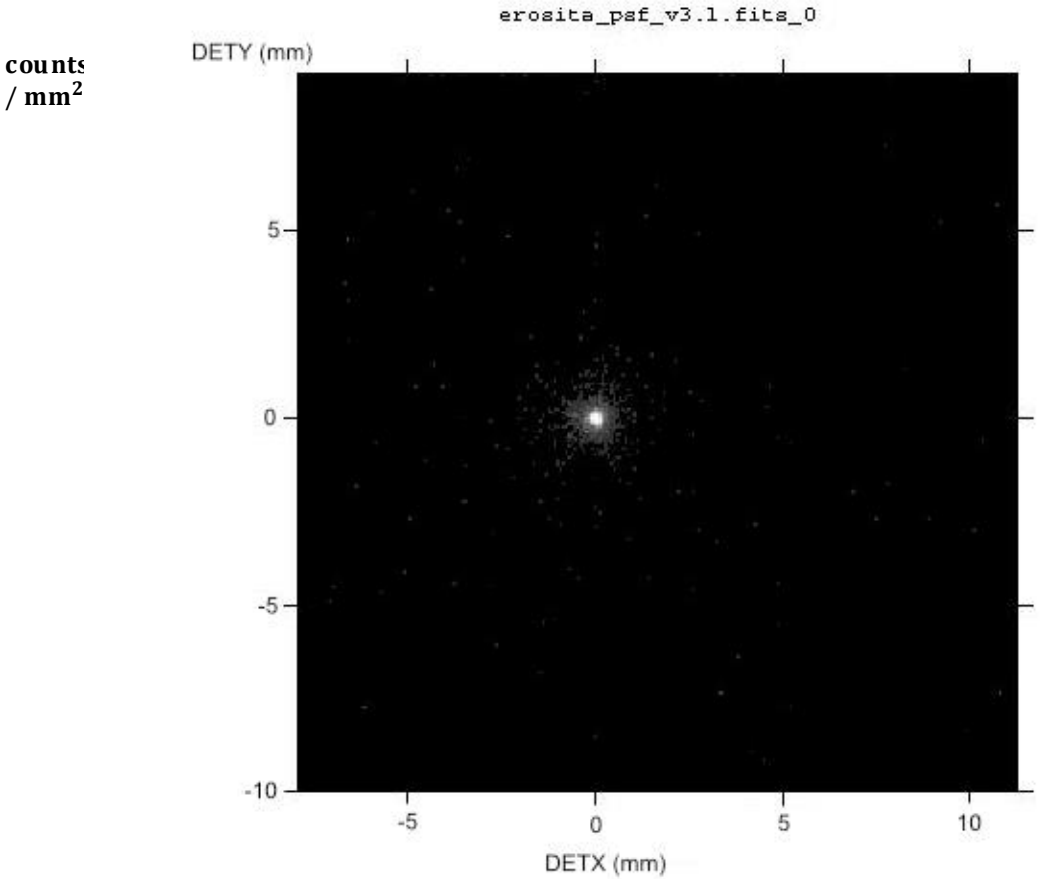




(IACHEC Dennerl)

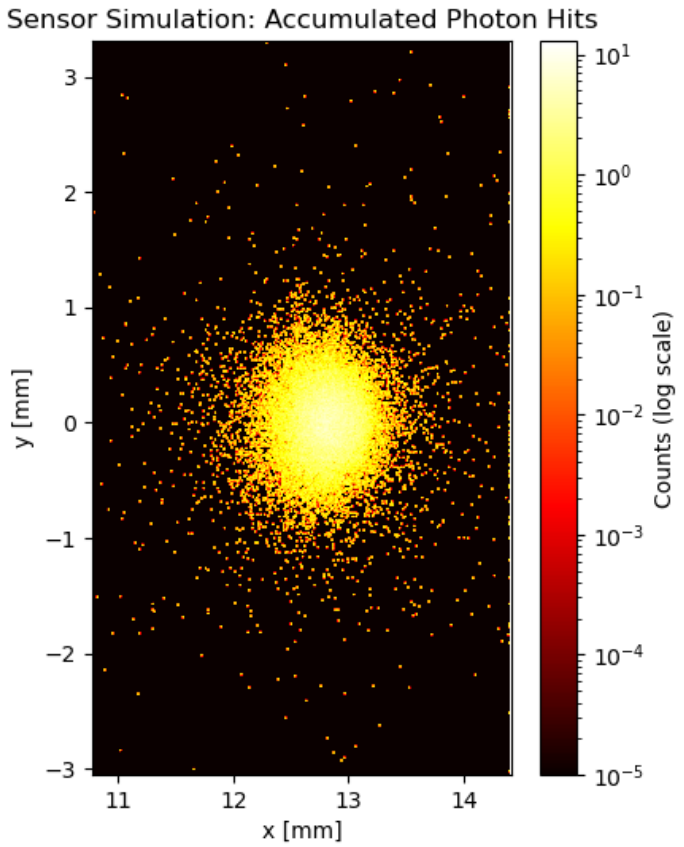
Radial distribution histogram



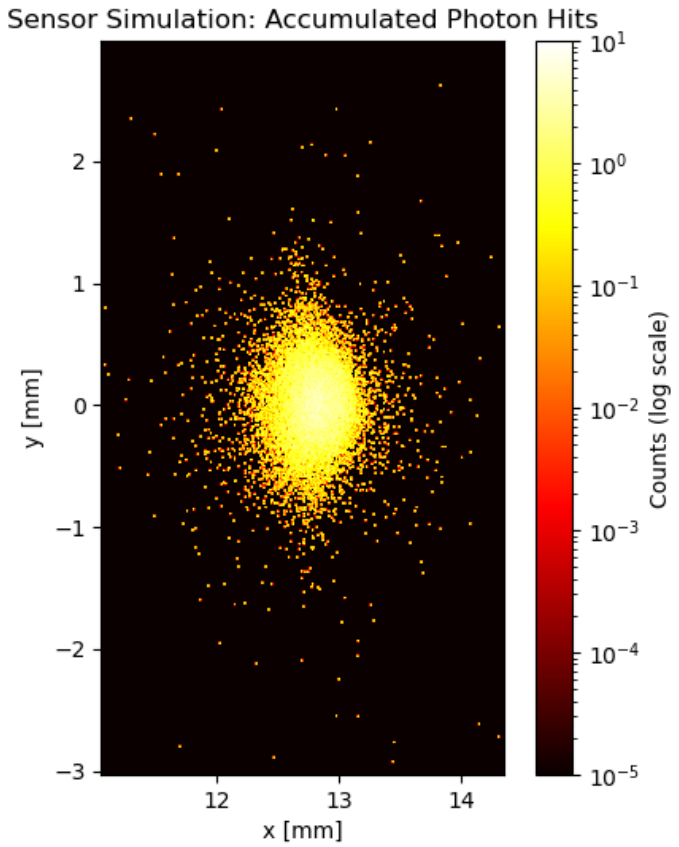


Simulated GGX distribution with α = 0.0012

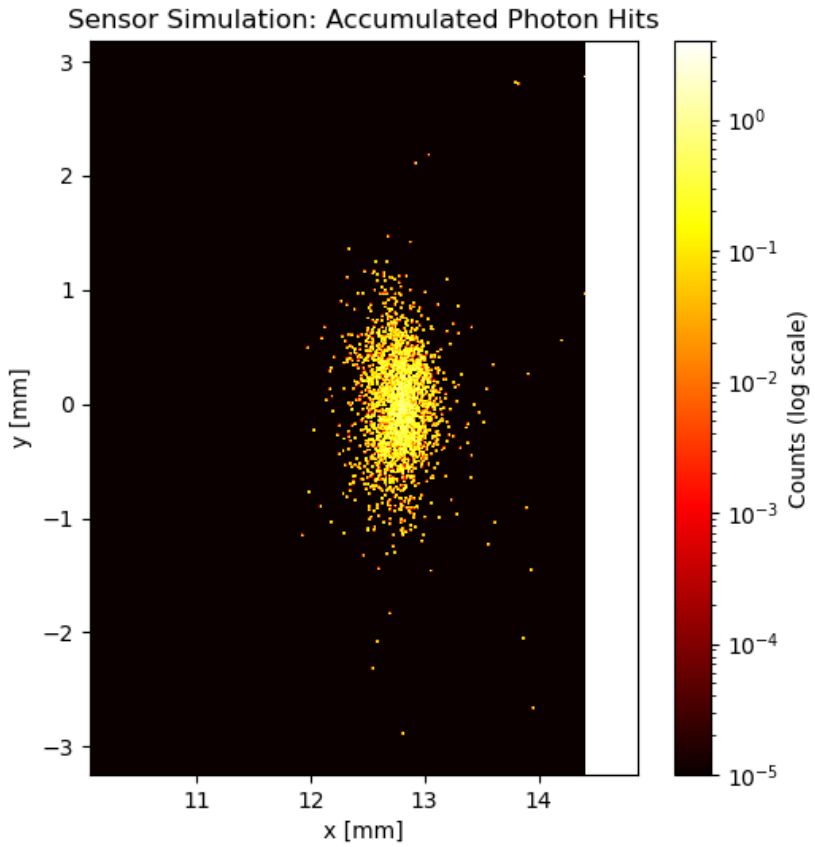
Energy-dependent reflections



Energy independent

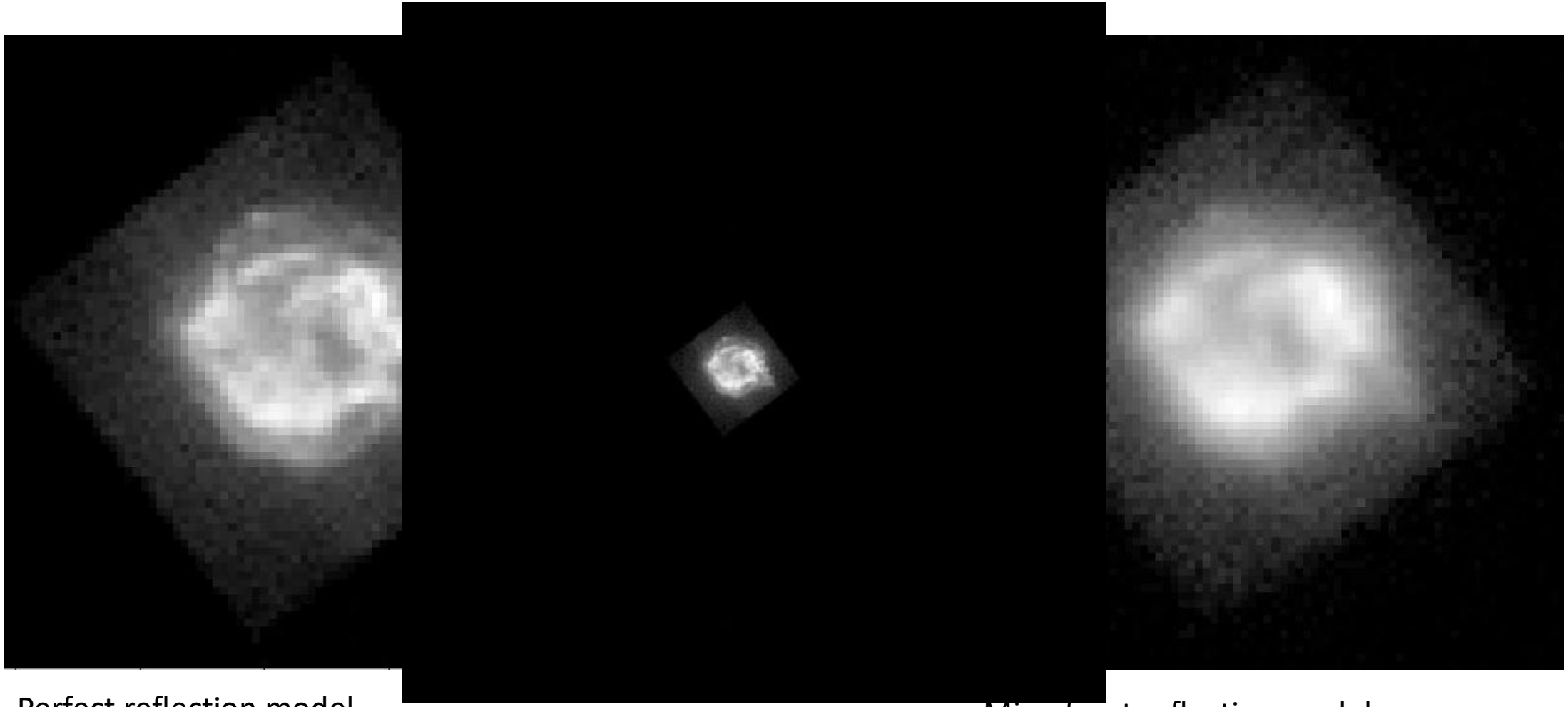


0.3 keV



3.0 keV

Cassiopeia A (Cas A)



Perfect reflection model

Microfacet reflection model

Thank you!

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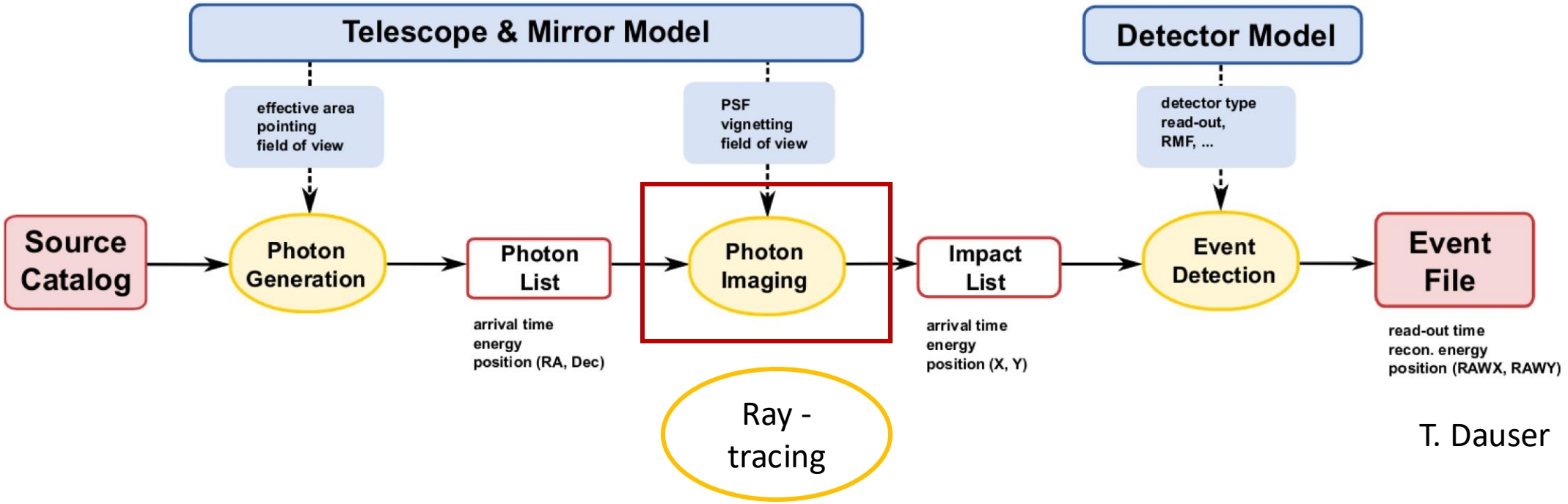
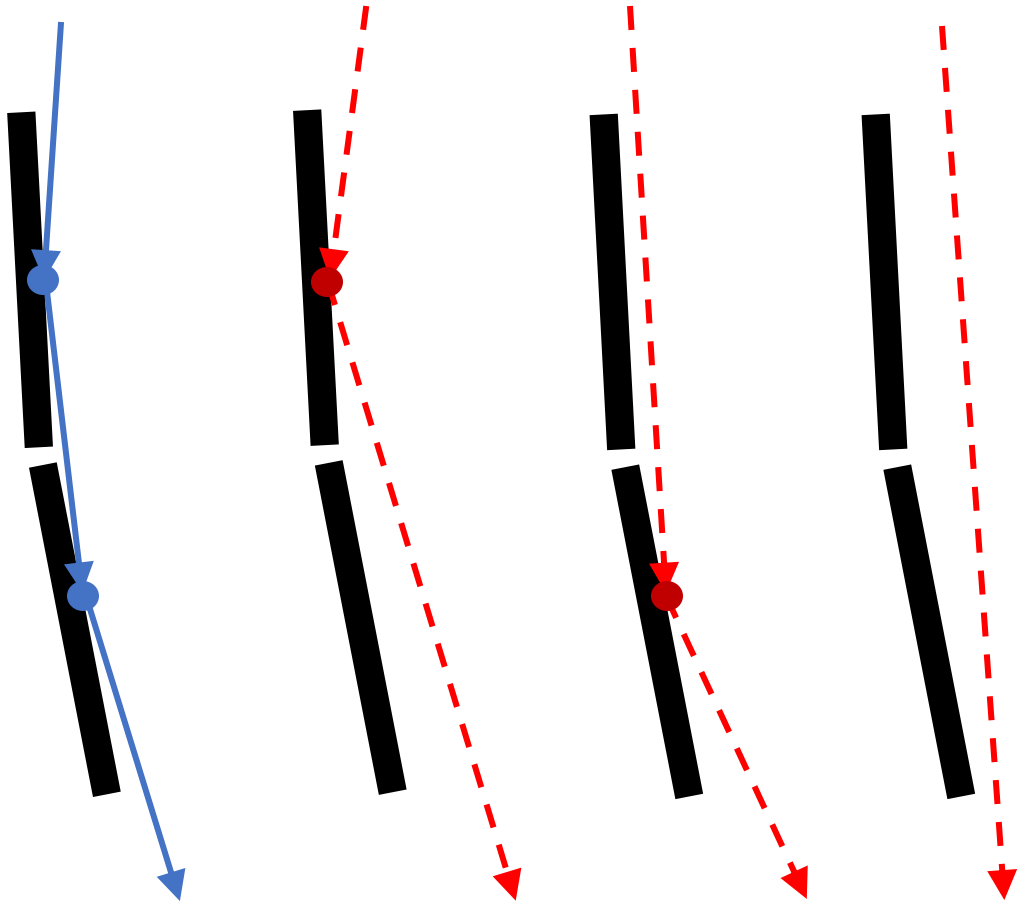
Neo Reinmann

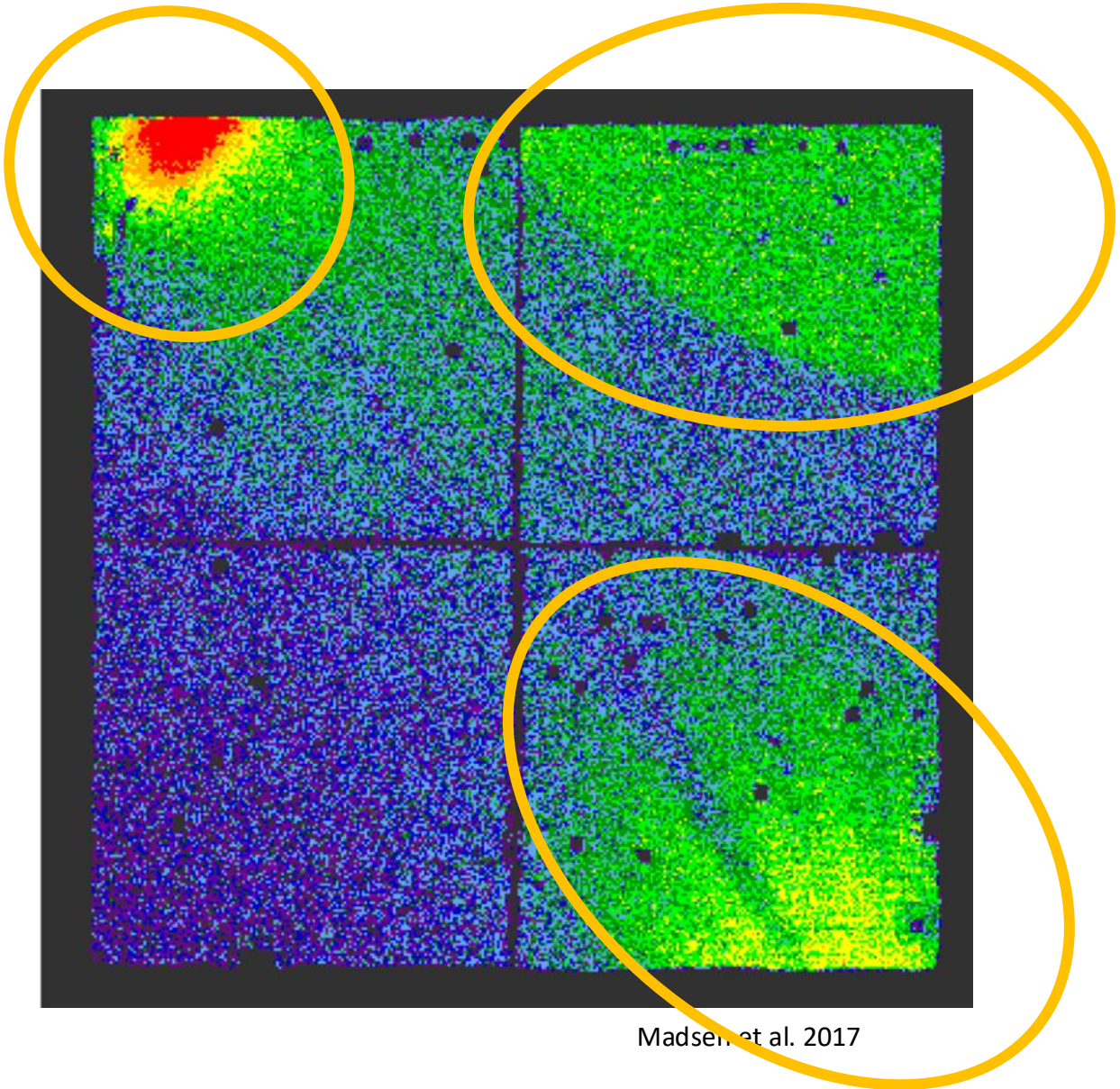
SIXTE Architecture - revised



T. Dauser

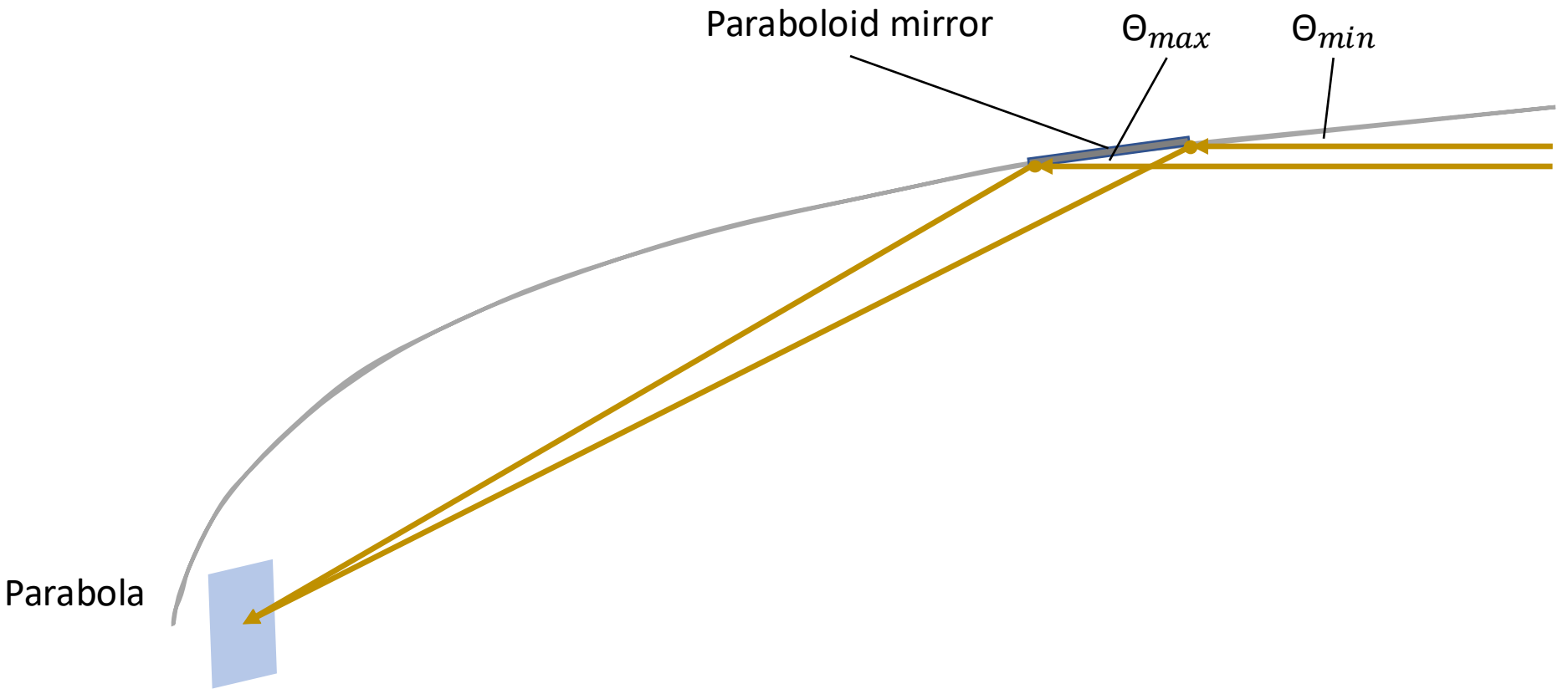
Ghost rays and stray light





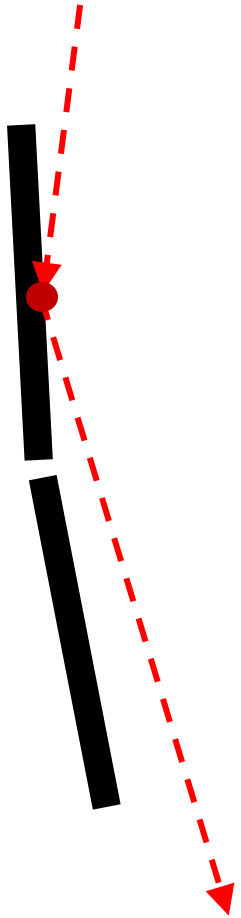
Madsen et al. 2017

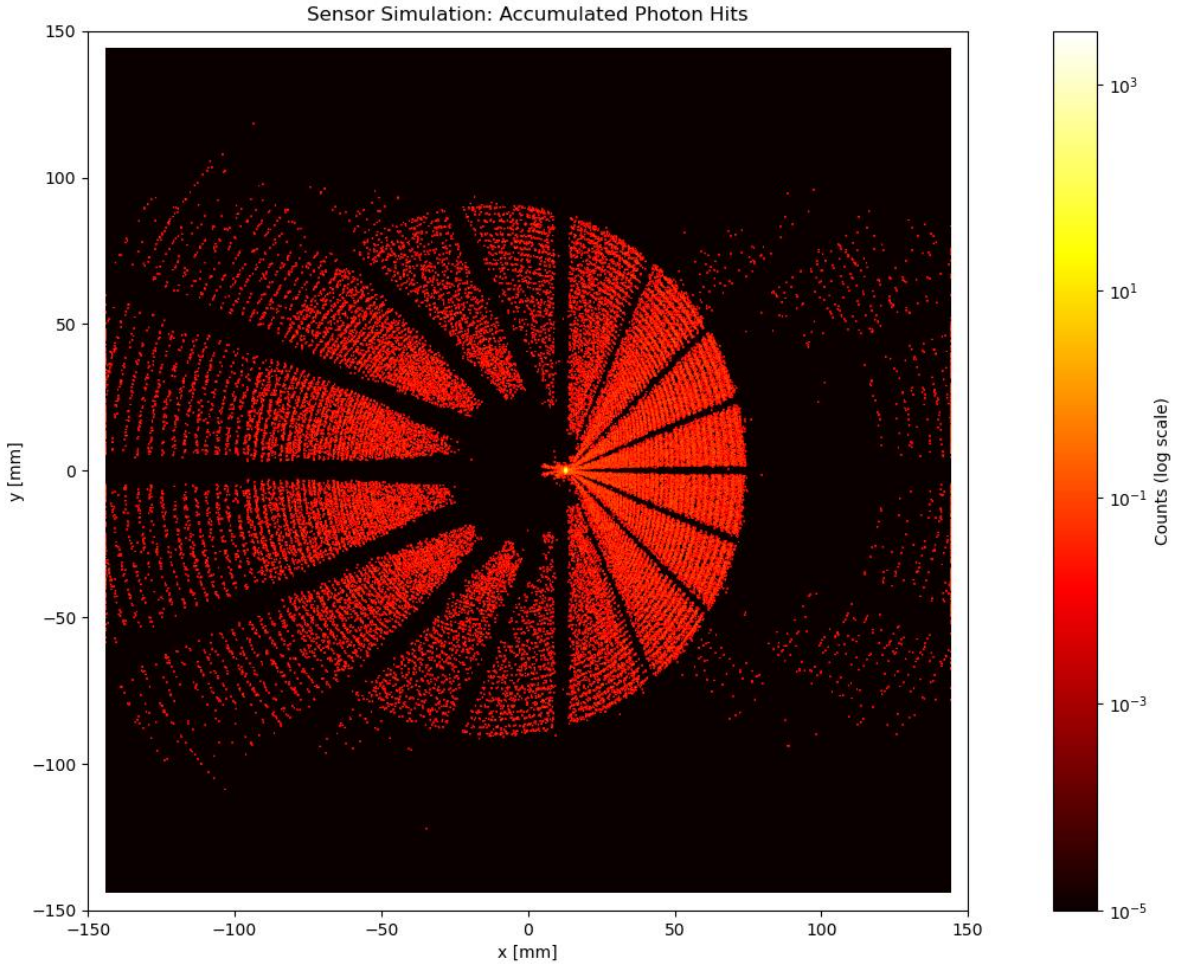
Wolter Type 1 Telescope



(Based on M. J. Pivovaroff and T. Okajima 2023)

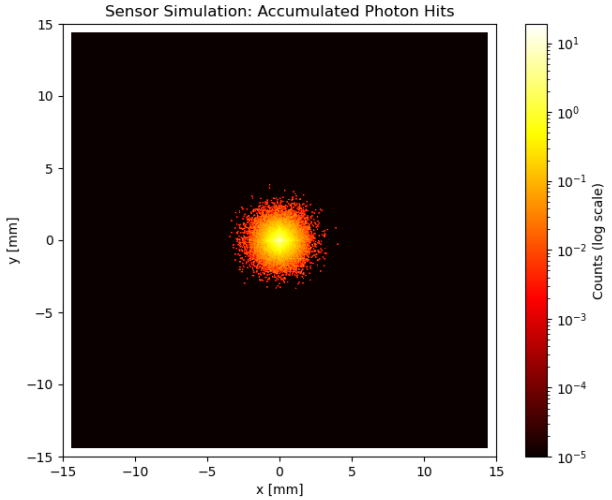
Single Reflection Patterns

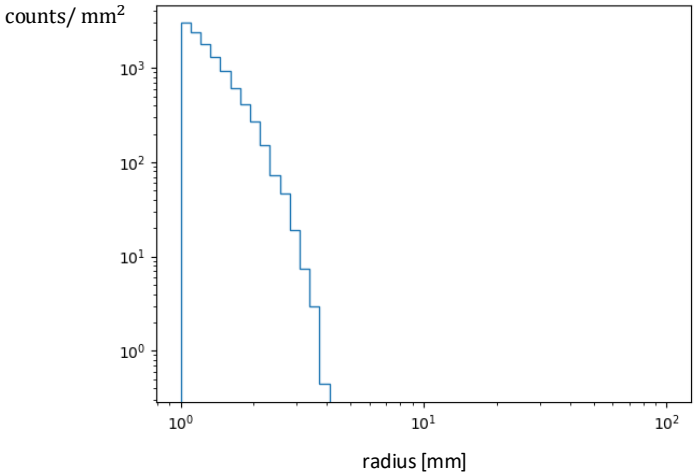




Other surface simulation models

Gauss
a = 0.004





Beckmann
α = 0.008