XMM Mirror Calibrations - Revisited

David Lumb, 26 March 2014

EPIC XCAL Meeting #6, MPE

Scope

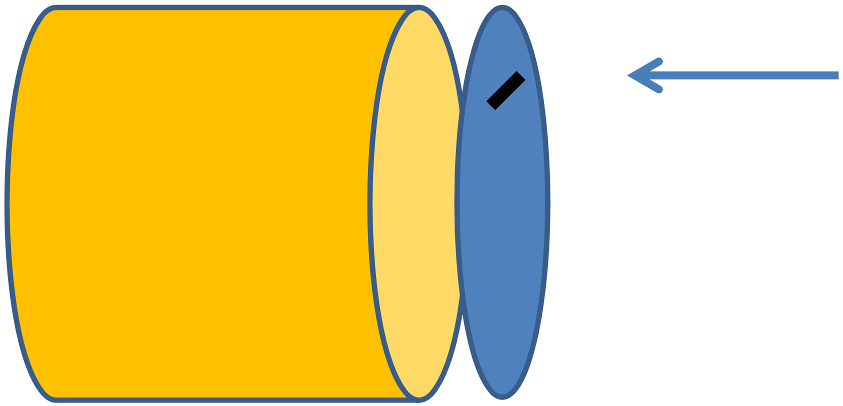
- History lesson
- Mirror Module variable parameters
- Ray trace comparisons
- Latitude for “arbitrary” modifications ?
- Vignetting

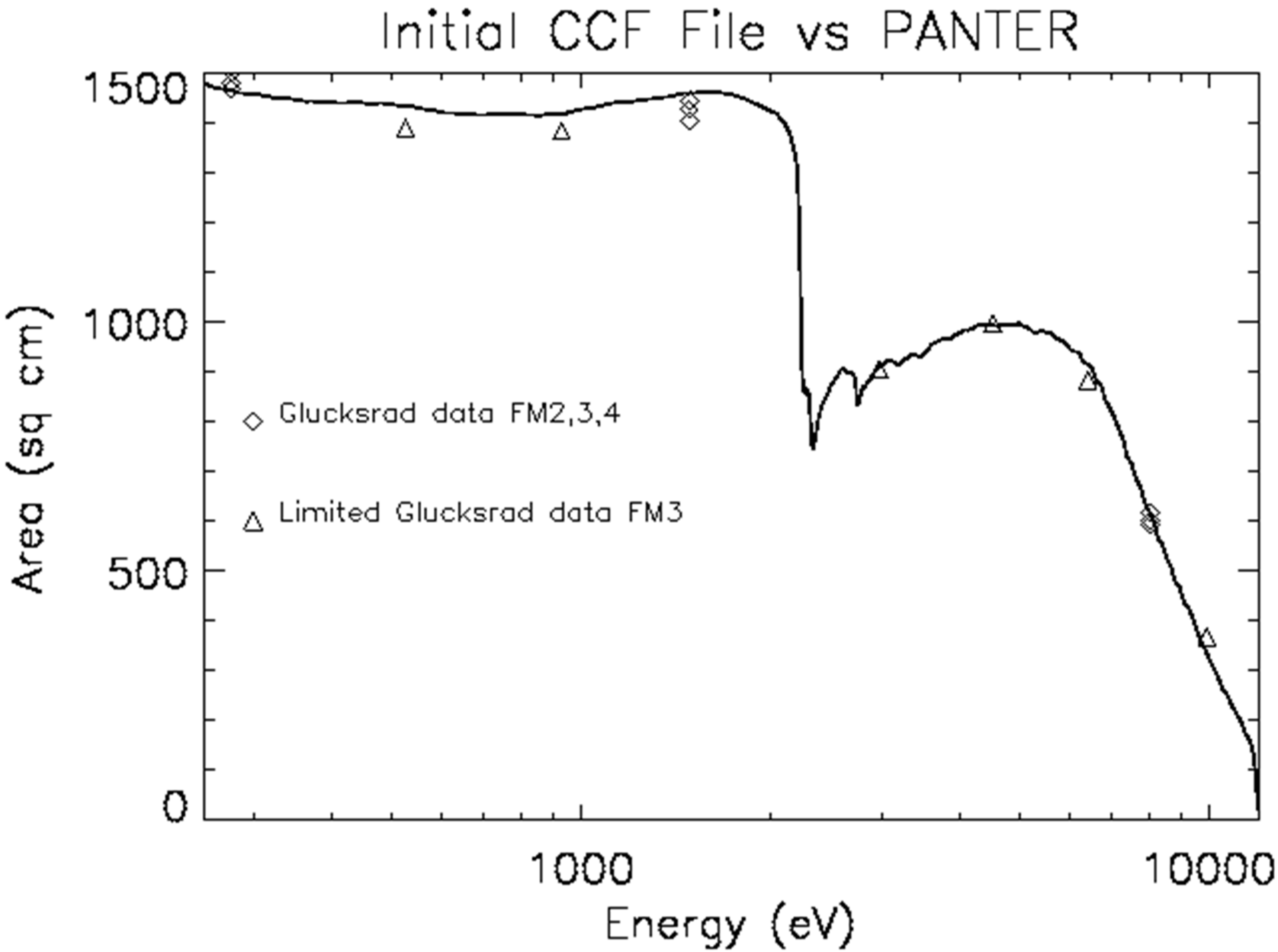
Panter

- ~128m beam – not parallel
- Shell distortions – partial blocking and 30% not illuminated
- Persistent 15 % area deficit – reflectivity or geometry?

Panter

- Glücksrad – sector (16) and radius (4) selector to make illumination much more parallel
- But reduced S:N per unit time and only used on FM3 (= XRT1 = MOS1) for all energies
- Still ~4% total loss, and some azimuthal variations




Initial CCF File vs PANTER
1500
1000
500
0
Area (sq cm)
1000
10000
Energy (eV)
Glucksrad data FM2,3,4
Limited Glucksrad data FM3

CSL

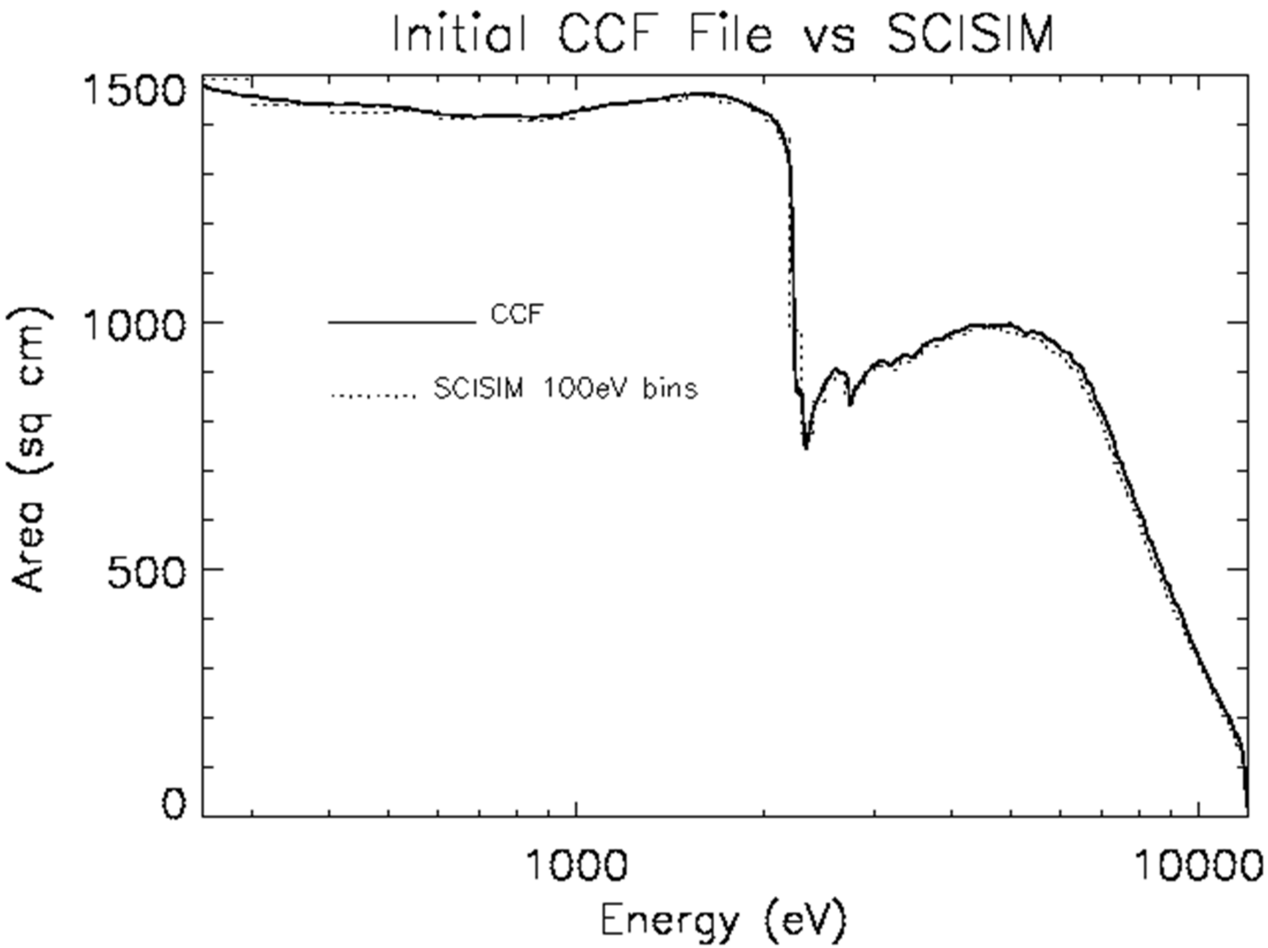
- EUV beam to check geometrical PSF in parallel illumination
- X-ray scans confirmed shell locations correct (+/-100μm) in selected azimuths
- Effective area at 1.5 and 8keV, & reflectivities of individual shells at selected azimuths
- Stability of effective area following environmental tests, RGA installation, stray light baffle installation etc.
- Saw few % loss in effective area compared with nominal model – consistent with Panter

CCF

- Adopted an effective area assuming a gold density, dust contamination and mirror surface roughness consistent with all the calibration data
- No statistically significant trend between mirrors so all three XRT data files set identical
- Subsequently, minor changes resulting from in-orbit calibration programme (spectral residuals not attributed to CCDs)

Ray Trace

- Revisit the MSIM component of SCISIM to verify the original CCF model



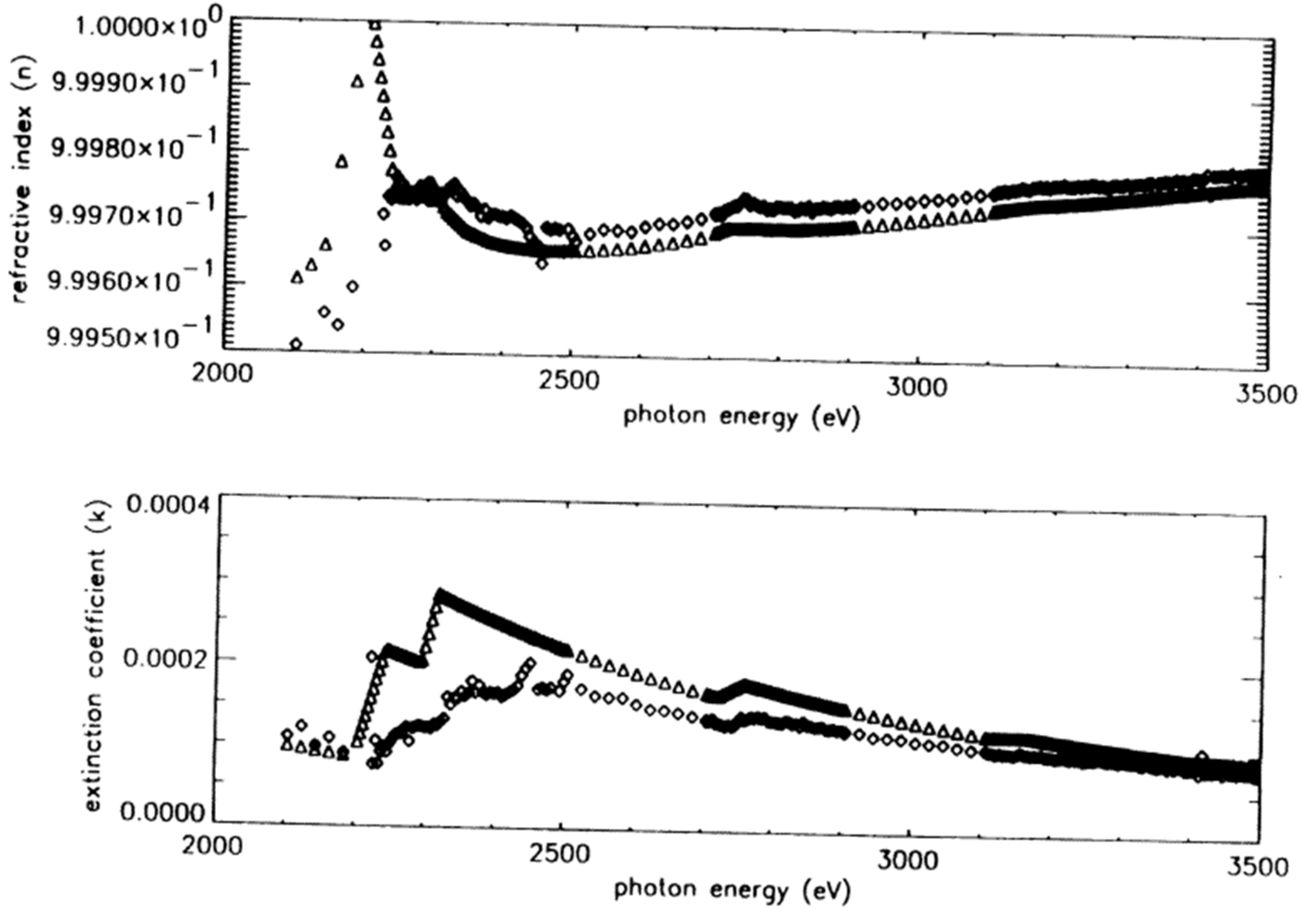
100ppm dust, 97% bulk Au density, 0.45nm roughness

Variables investigated

i) Actual mirror shell metrologies
ii) Range of shell roughness
iii) Range of dust contamination
iv) Range of baffle blocking misalignment
iv) Small axis tilt error
v) Layer of hydrocarbon contamination
vi) Post processing

SCISIM

- Used specific FM metrology
- Revised Au optical constants (AXAF witness)



AXIS Tilt Error

- A tilt in telescope axis leads to energy dependent differential shadowing.
- Alignment cube on mirror assembly ~10 arcsec accuracy for placement (CSL) between measurements and for location on spacecraft (unglued !)
- Verified best throughput at CSL ~10's arcsec from nominal, changes slightly
- Burkert test and maximised throughput for Panter measurements – qualitatively similar misalignment as measured at CSL
- Although changes will have been expected before getting to orbit, to first order should be covered by the vignetting calibration work – although implies small % unknown wrt to ground absolute calibration reference

Gold Density

- Different deposition techniques can lead to wide range of density reduction compared with bulk density
- Deposition on mandrel is reverse process cf. depositing on a glass or Al shell !
- E.g. some Suzaku/ ASCA mirror models had assumed $<90\%$ bulk
- Effects especially the high energy reflectivity
- Best XMM fits to modelling suggests high ρ

Shell Roughness

- Metrology (*AFM, Wyko*) showed range of roughnesses 3.5 – 6 Å.
- Spatial frequencies not necessarily represented in simple X-ray reflectivity model
- Poor reflectivity in individual shells at CSL correlated with measured high microroughness
- Affects the energy dependent reflectivity (*and also via. Encircled Energy correction the wings of PSF as 2nd order*)

Dust Contamination

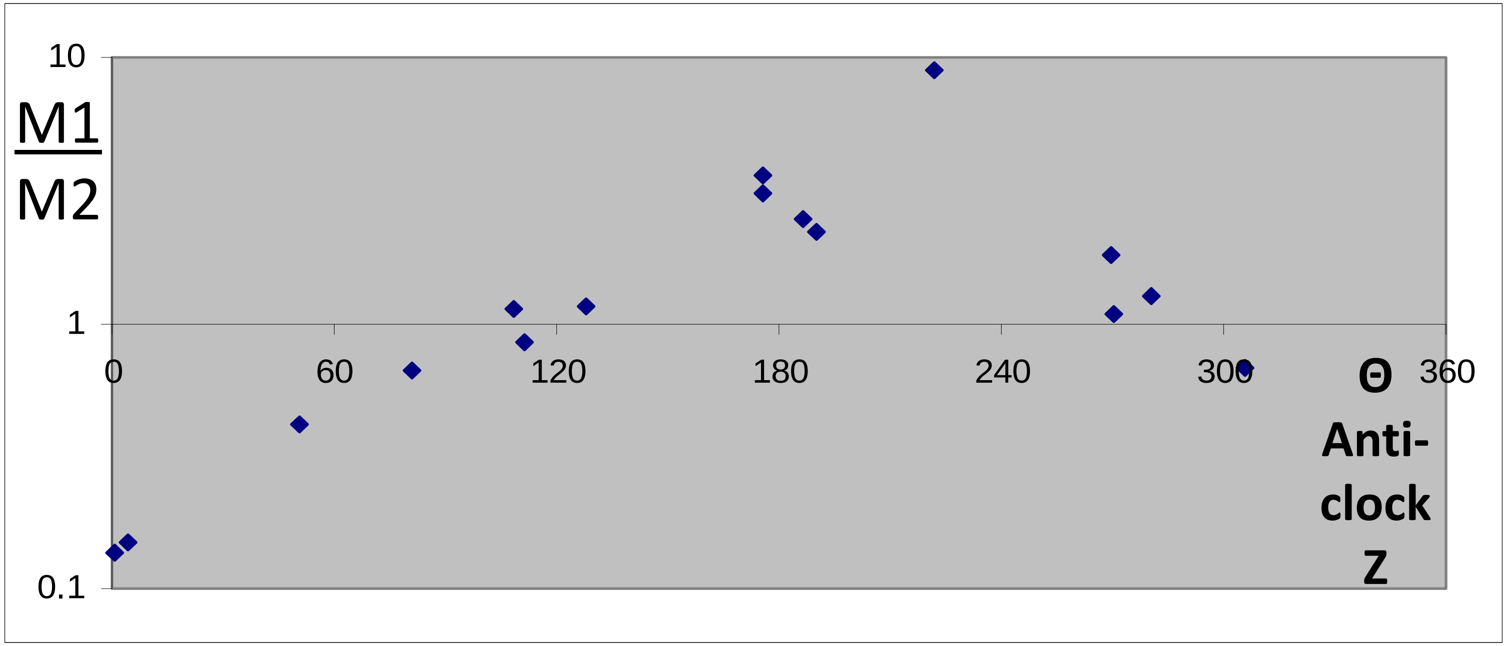
- Simple model assumes blocking by total absorption (no scattering or energy dependence)
- However if a uniform coverage, inner shells preferentially lose more due smaller graze angle interception
- Detailed budget based on anticipated exposure for number of days in different class clean room (~100 ppm)
- The different telescopes had range of AIV durations, potentially location within spacecraft might have led to different (incl. launch) exposures
- *Contamination WG suggested that need to allow up to 140ppm between calibration and operations in orbit*

Hydrocarbon

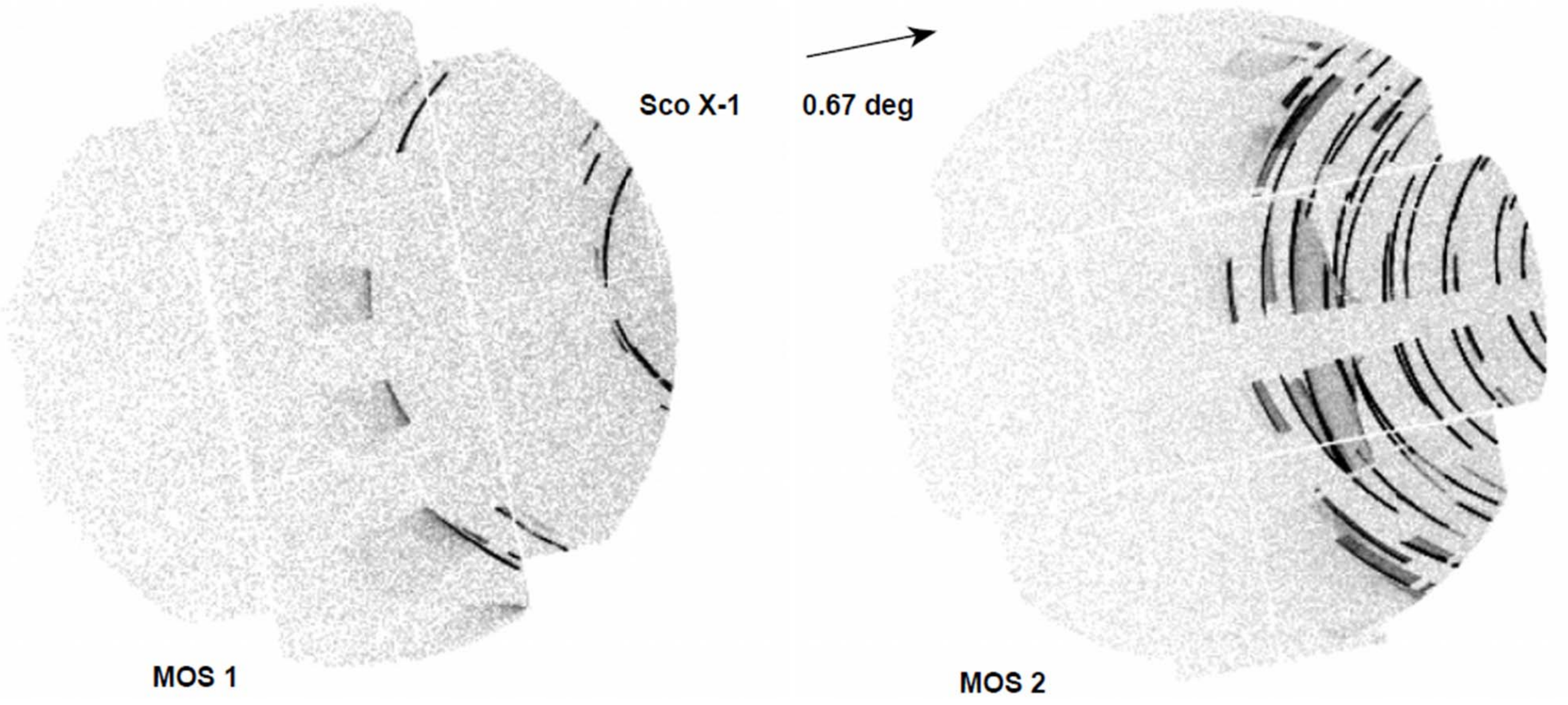
- Contamination Working Group advised project that the science requirement on hydrocarbon contamination unlikely to be achievable
- Between calibration and in-orbit operations revised to 1.510^{-7} g cm^{-3}
- Particularly affects reflectivity around Au edge (bi-layer effect) and ~0.2% / Å below edge
- Ad hoc assumption to be made about thickness, density
- Phthallate plasticiers from cables, esters from Carbon fibre tube ~ (CH_2 CH_2 CH_2 ..) $1gcm^{-3}$
- Do not expect change in-orbit (vapour barrier, cold trap and mirror temperature)

Baffles

- Sieve plates installed in front of mirrors (after calibrations) to minimise off-axis stray light from single reflections
- Budgeted ~50 microns ring-to-ring alignment and 100 microns centring error for fabrication.
- CSL measurements indicated no gross misalignment on installation
- Ray trace can implement selectable randomised misalignments
- However – in orbit data suggest GROSS misalignment problem – probably could act as a “gray “ filter even for on-axis sources …..
- Analogous issue with RGA ?



10
M1
M2
1
0.1
0
60
120
180
240
300
360
Θ
Anti-
clock
Z

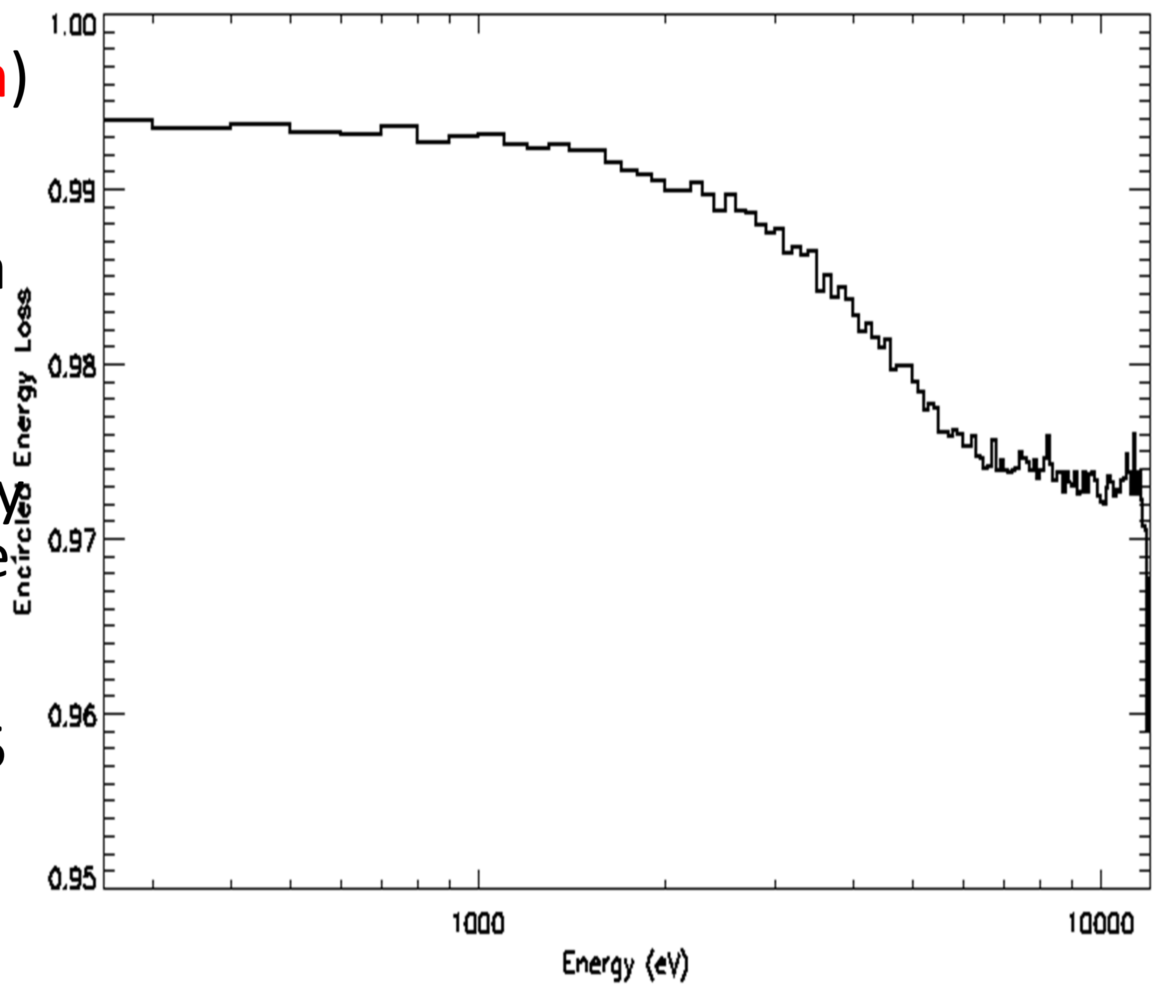


Sco X-1
0.67 deg
MOS 1
MOS 2

Post-processing

- Mimic the Panter configuration by using the same radius (38mm) in focal plane as PSPC measurements for analysing ray trace data

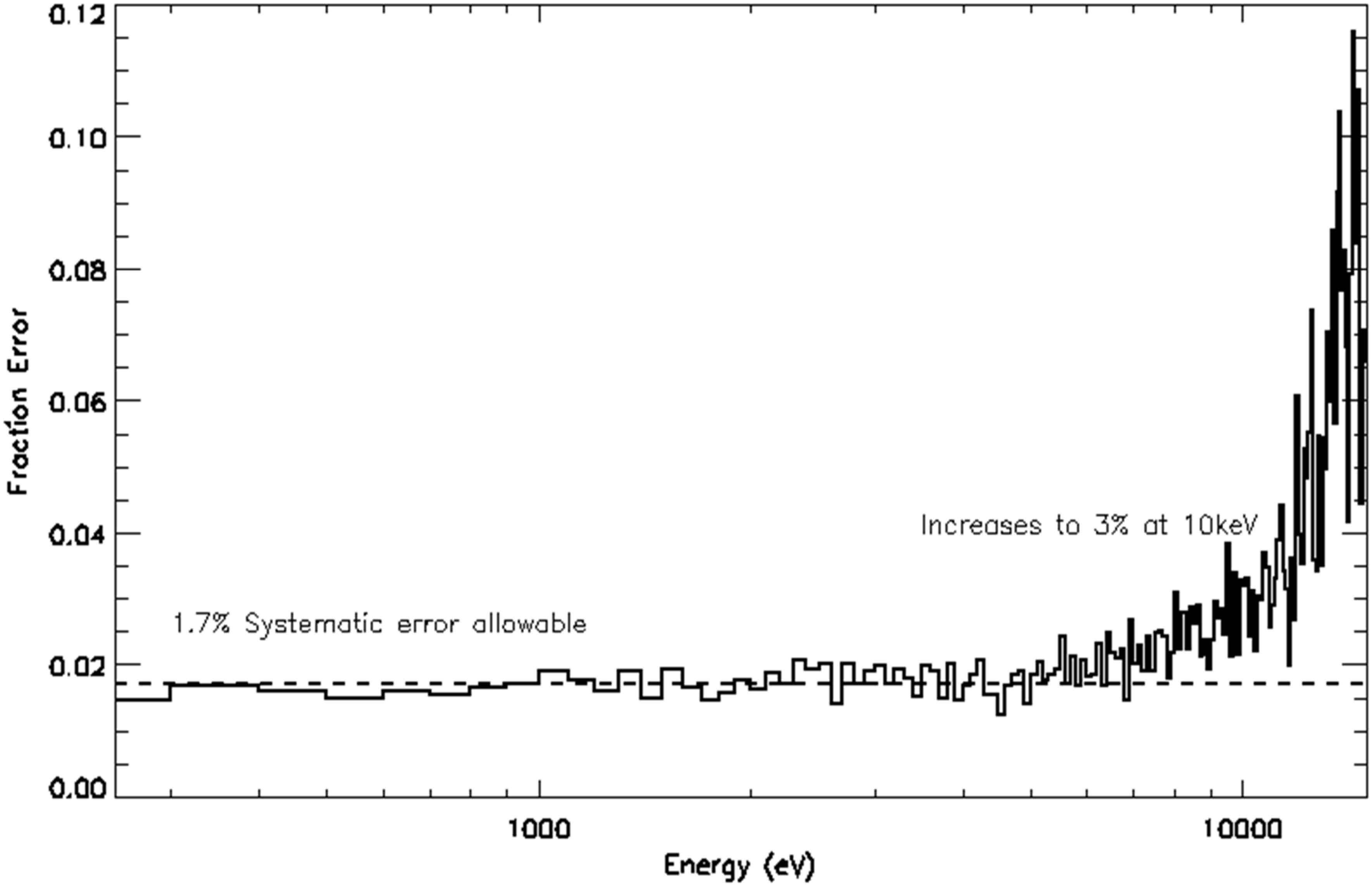
- But then due to PSF wings there is an energy dependent effect at the 1-2 % level if one assumes the existing SAS *arfgen* algorithm (5 arcmin)



What is the allowable error from these parameters?

- Density < 0.5% absolute (*averaging ?*)
- Roughness – 0.05nm rms (*averaging ?*)
- Dust 30% variation – max due to exposures?
- 30 µ rms within the baffle structure and 150 µ centring baffle to telescope
- Axis – 10 arcsec at calibration and 10 arcsec in orbit vignetting calibration method
- Sum the errors r.s.s. as 1 σ?

Systematic Error

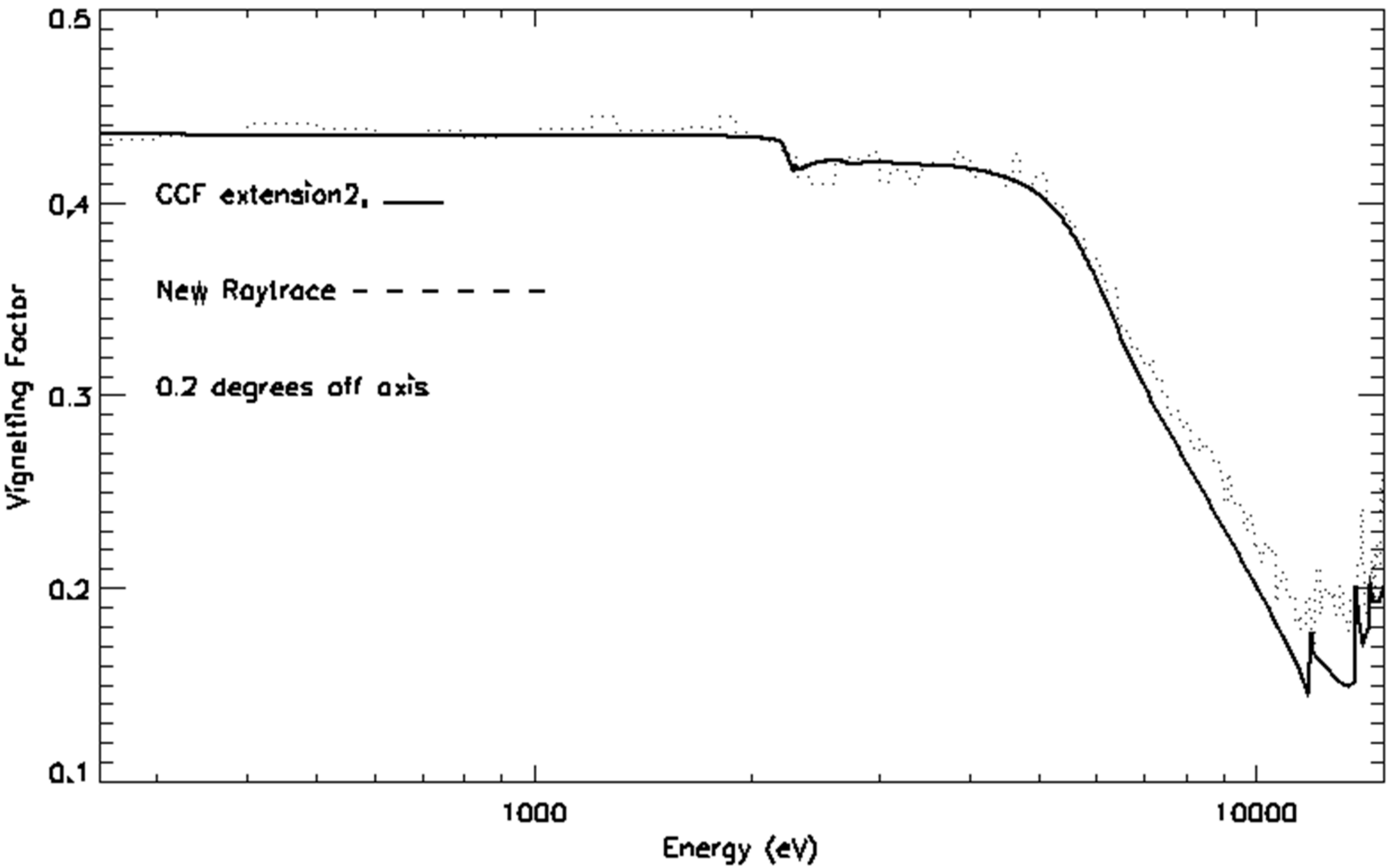


Some Initial Results

- FM2 = XRT3 = PN has effective area 1 – 2 keV that is about 2.5% lower than the CCF, but also the high energy falls faster than the latest CCF
- MOS1=XRT1=FM3 about 1.5% higher area than MOS2=XRT2=FM4
- Average of all common energies Glücksrad data suggests MOS1/MOS2 ~1.02-1.03
- Also need to check the encircled energy effect?

Vignetting as well?

- Large objects – clusters to edge of field



Suggestions

- Following feedback initial changes, revise the ray trace and also use high S:N and spectral resolution
- In-orbit calibration programme to verify the stray-light/baffle problem
- Revisit also the RGA blocking issue via. ray trace and RGS information
- Gold edge data?