Cross-calibration investigations – straylight (and others)

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Motivation

- Following the last EPIC calibration meeting continued investigations into off-axis stray light
- Aim is to understand reported gross discrepancies, and examine if a physical model also contributes to understanding on-axis cross calibration uncertainties

Method

- Looked into archive for observations with obvious single reflection arcs
- Dominated by LMCX-1, Cyg X-3 and Galactic Bulge binaries
- As the arcs are very extended across the focal plane have reanalysed all using the ESAS scripts
- Made a comparison with SCISIM ray trace that replicates each observation

Main Analysis Steps

- Select regions for each camera and run *esas*
- Extract spectra and background
- Made an .arf that is a "guess" for typical off axis angle (fn(E) knowing only a single reflection occurs)
- Assume source spectrum of a LMXRB e.g. const*phabs*(diskbb+comptt) ***probably the detailed spectrum doesn't matter to 1st order***
- Also require an in field background of gauss+gauss+apec+phabs*apec that has a different normalisation per camera

Source flux

- Depending on epoch - find nearest RXTE ASM or MAXI observation (2-10keV flux or sometimes for latter even a spectrum)
- With MAXI data joint spectral fit with a constant multiplier between instruments
- Or do EPIC spectral fit alone and just make a flux estimate comparison
- Difference gives the straylight rejection factor
- ***If there is a gross problem in any source, should at least be able to renormalise the 3 cameras to allow azimuthal trends to be tracked***

Ray Tracing Tasks

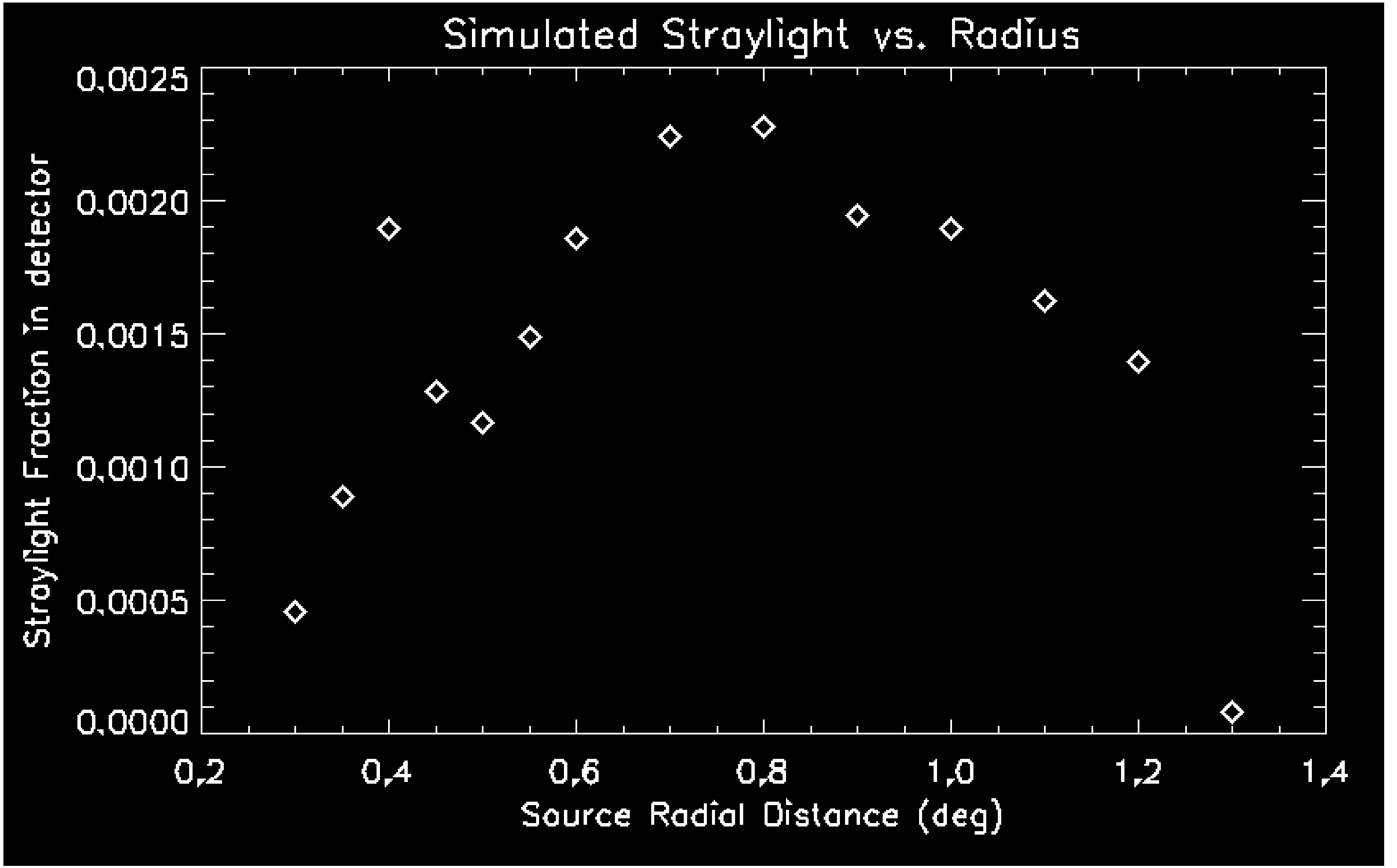
- Assume catalogued source position and the RA,DEC, PA PNT keywords to define a source input to SCISIM
- Ray trace for all 3 telescopes
- Especially for smaller off-axis angles, realised need a good estimate of focal plane offsets and geometries to determine fraction of single reflected arcs contained within observation selected regions (not in plain vanilla *SCISIM*)
- Now realise that to get enough sources will need to use full range off-axis radii, where the "guess ARF" is ***NOT*** good enough (more work )

Factors also considered

- By far biggest uncertainty is the source flux (RXTE 5% systematic on its Crab calibration, but sometimes are no simultaneous data)
- Statistical errors on flux ~5-30% typically
- Unknown effect of spectral model and the use of assumed .arf – but probably a common factor
- Compared average of observation with average of simulation to flag gross source flux problem
- ~50 observations continued for final analysis

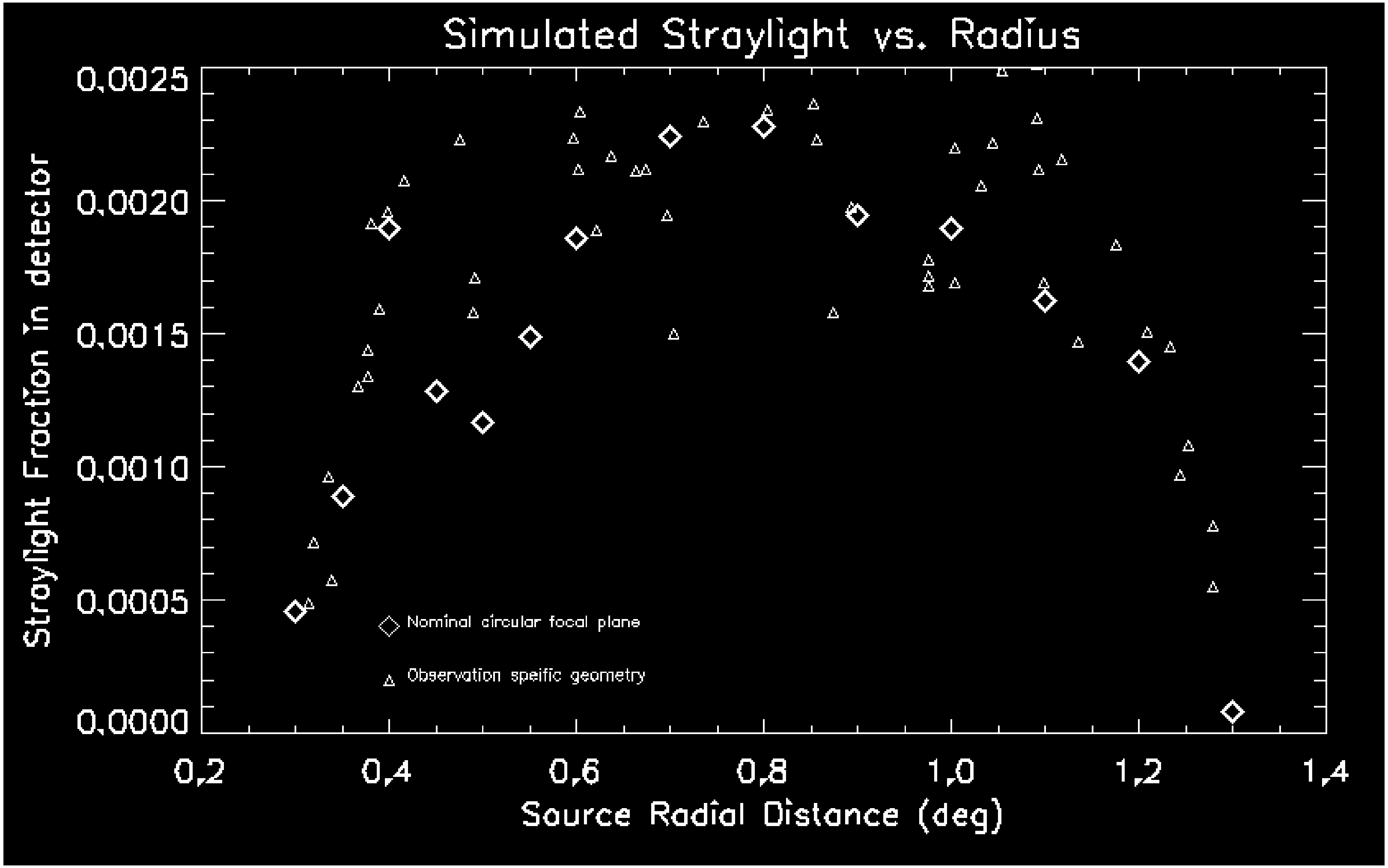
Radial Variation

- Nominal radial variation from SCISIM (circular focal plane FOV)



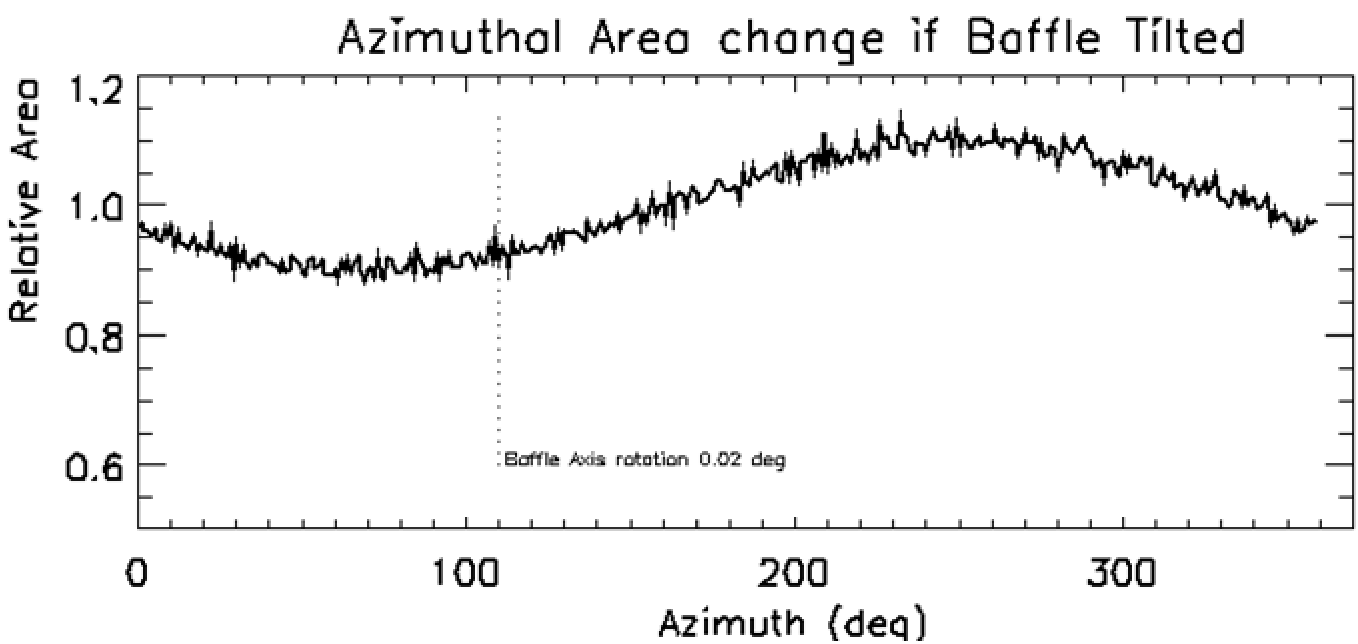
Radial Variation

- Radial variation for the pathology of observations –*i.e. when you add in the focal plane geometry*

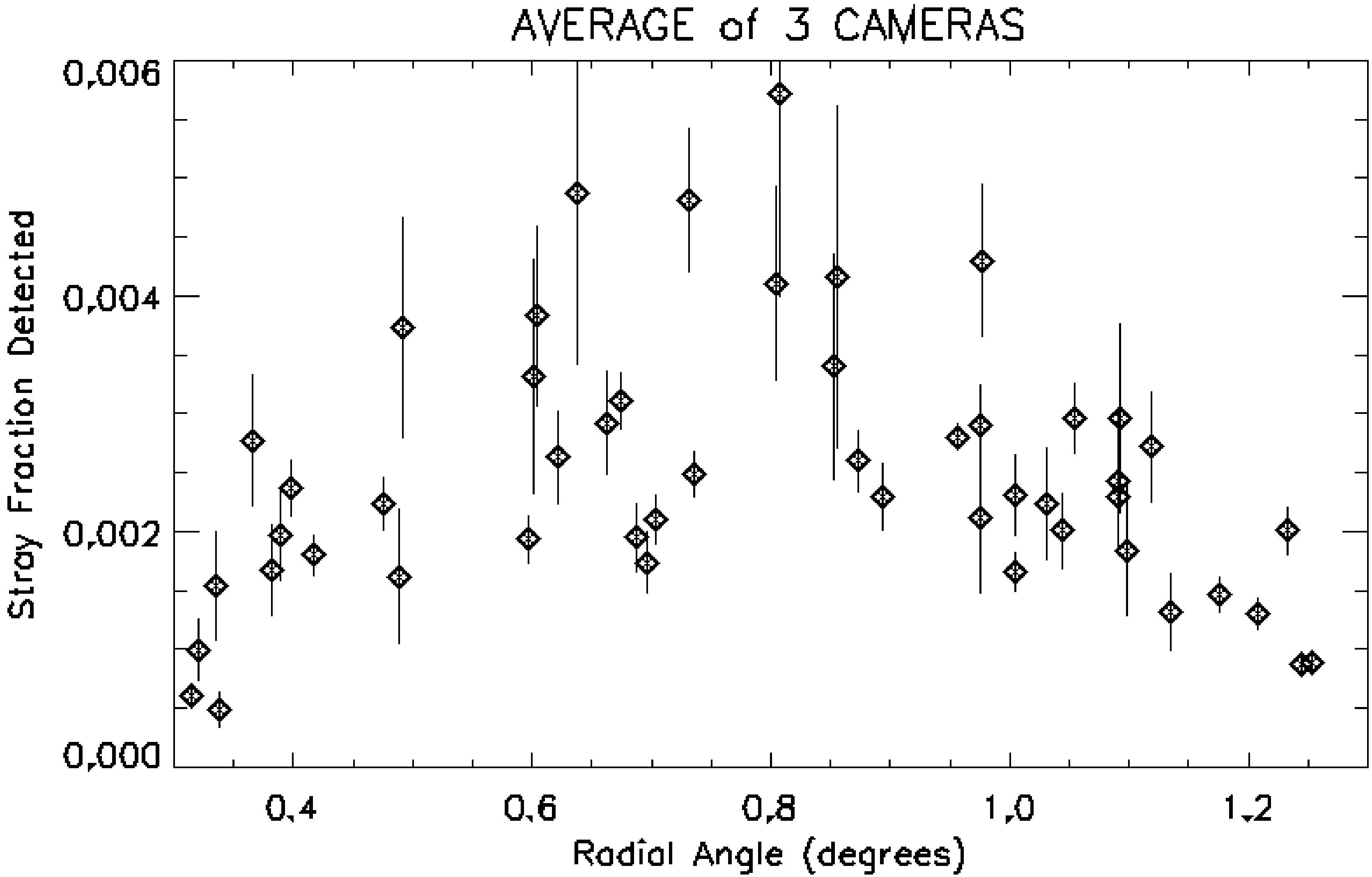


Azimuthal Variation

- Ray trace for a "typical" 0.8 degree off-axis source and uniform azimuthal distribution
- Compared for both a 100 micron baffle shift or a 0.02° Rotation, onto a circular aperture in detector plane
- Typical change +/- ~cosine like variation

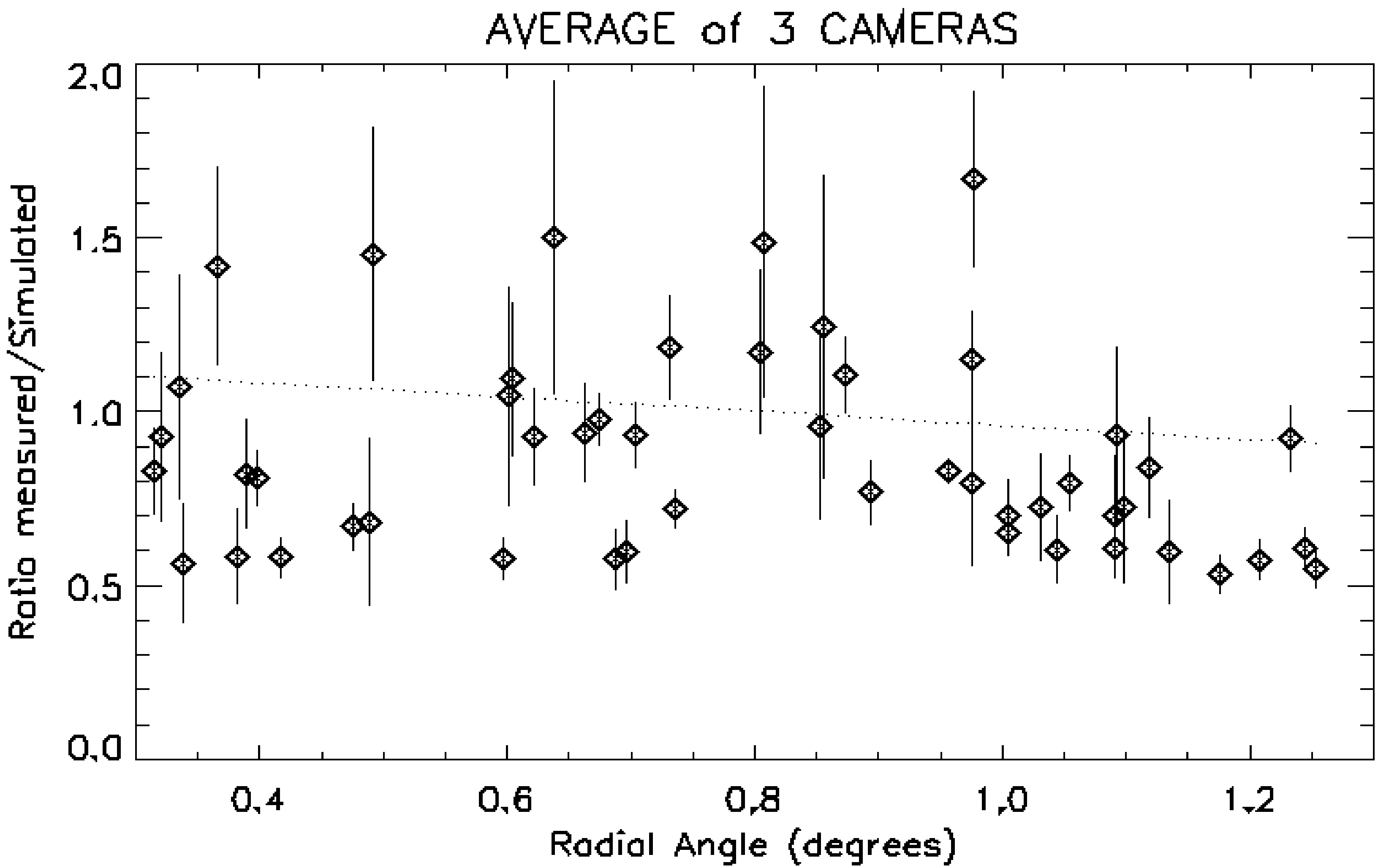


Camera results - radial

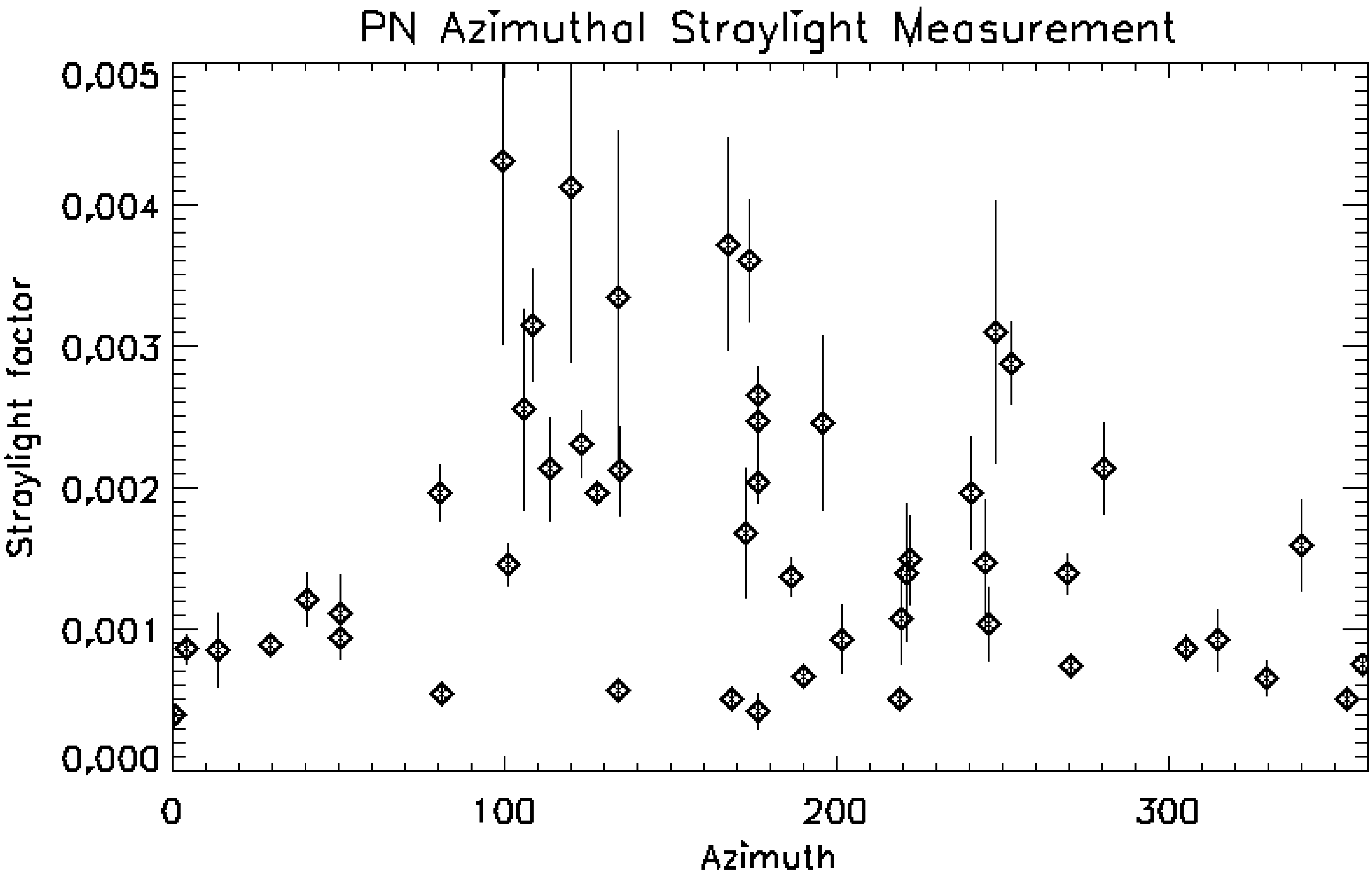


Scaling for source flux error?

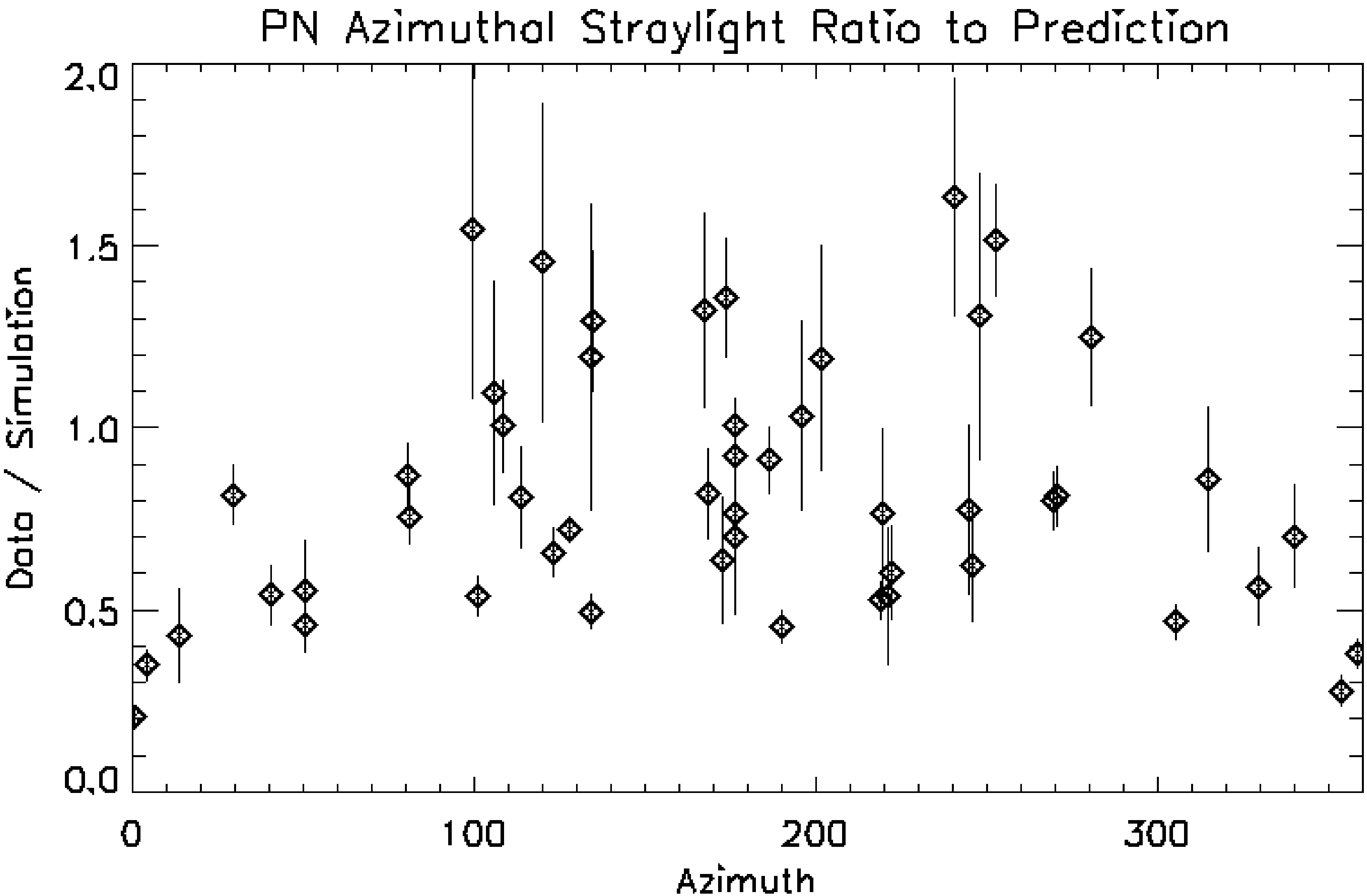
Average 3 cameras difference between measured and simulated



PN Camera results - azimuthal

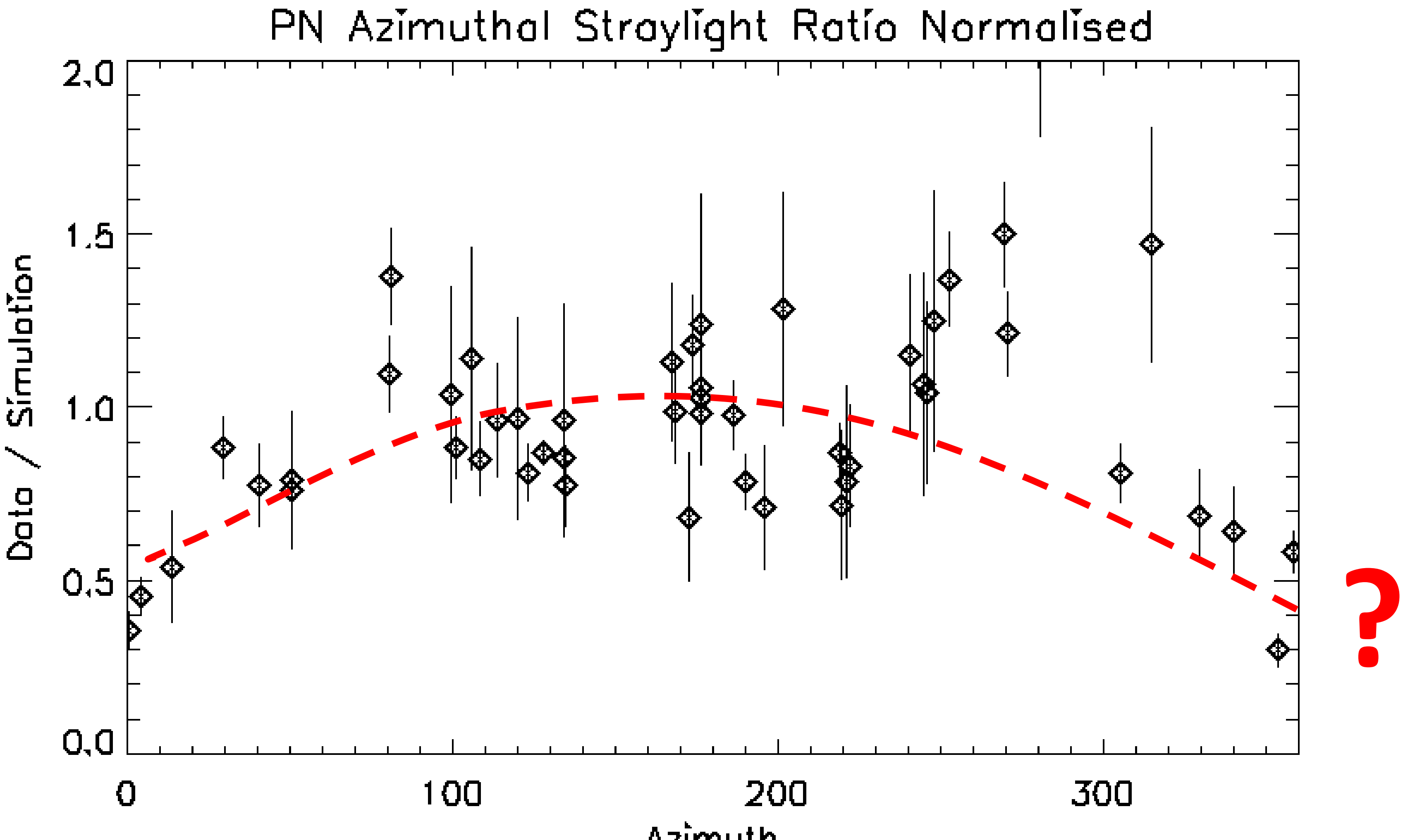


PN Camera results – ratio to simulation

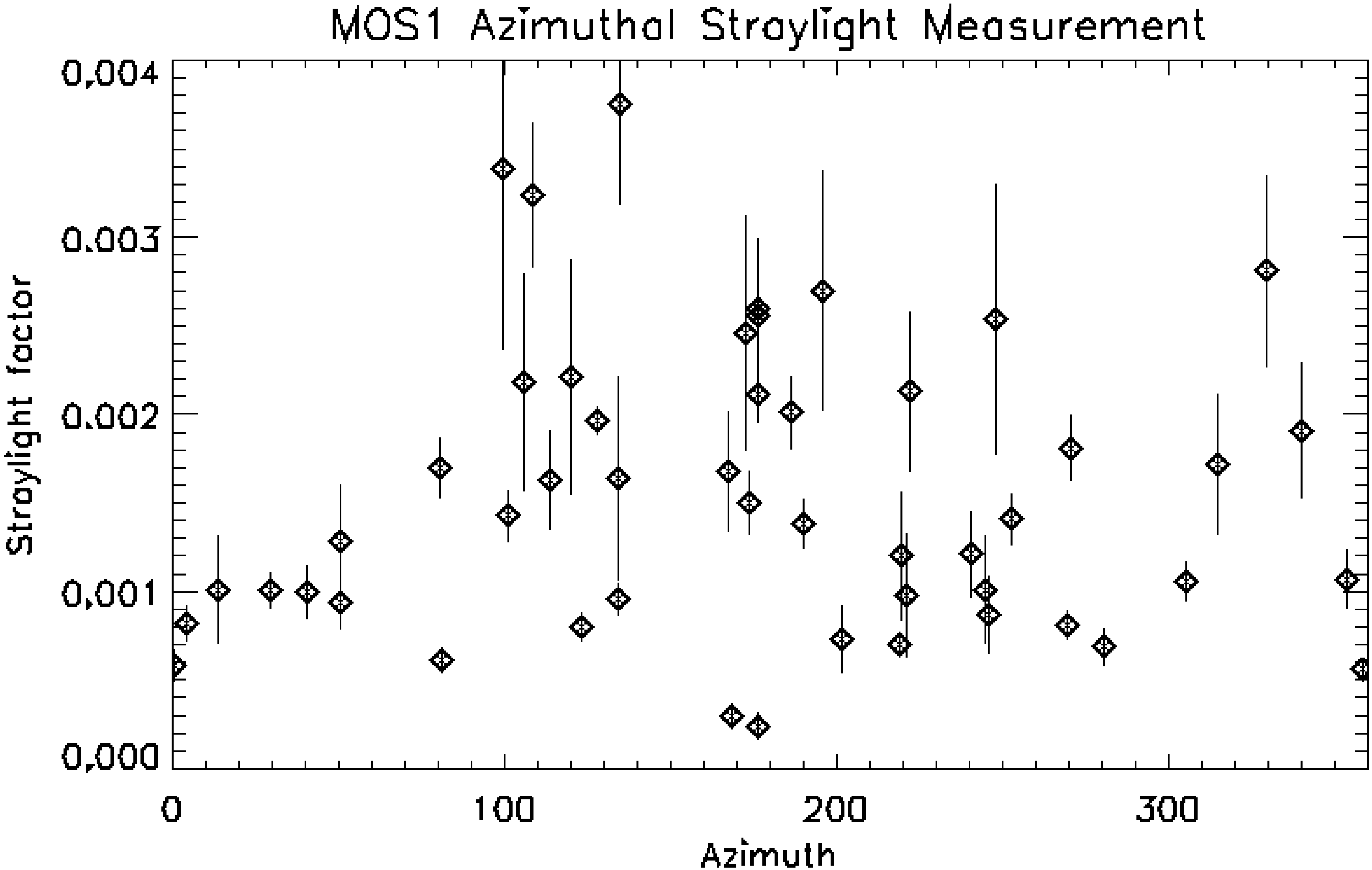


PN Camera results - azimuthal

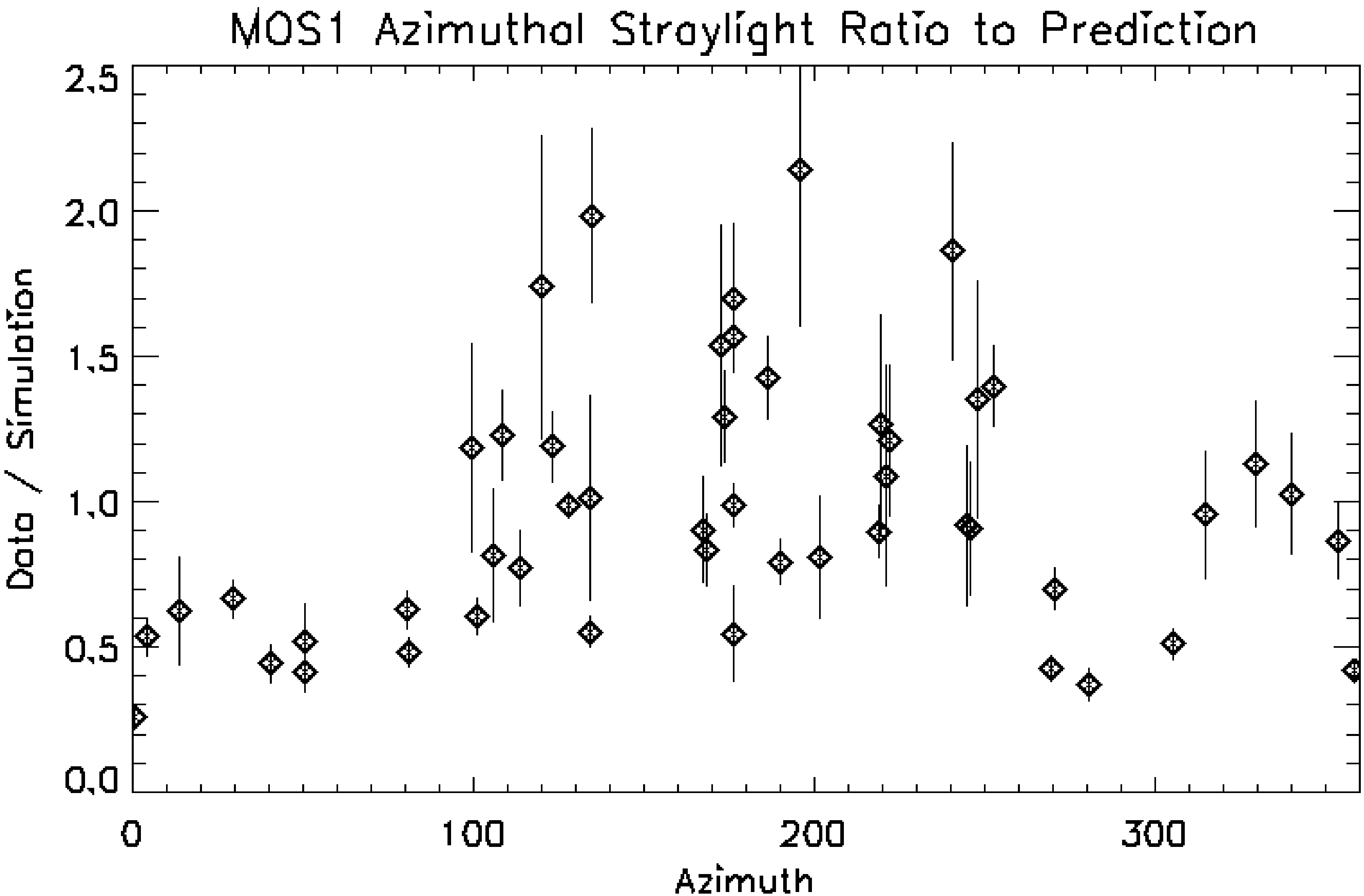
Scale for flux errors and divide by simulation



MOS1 Camera results - azimuthal

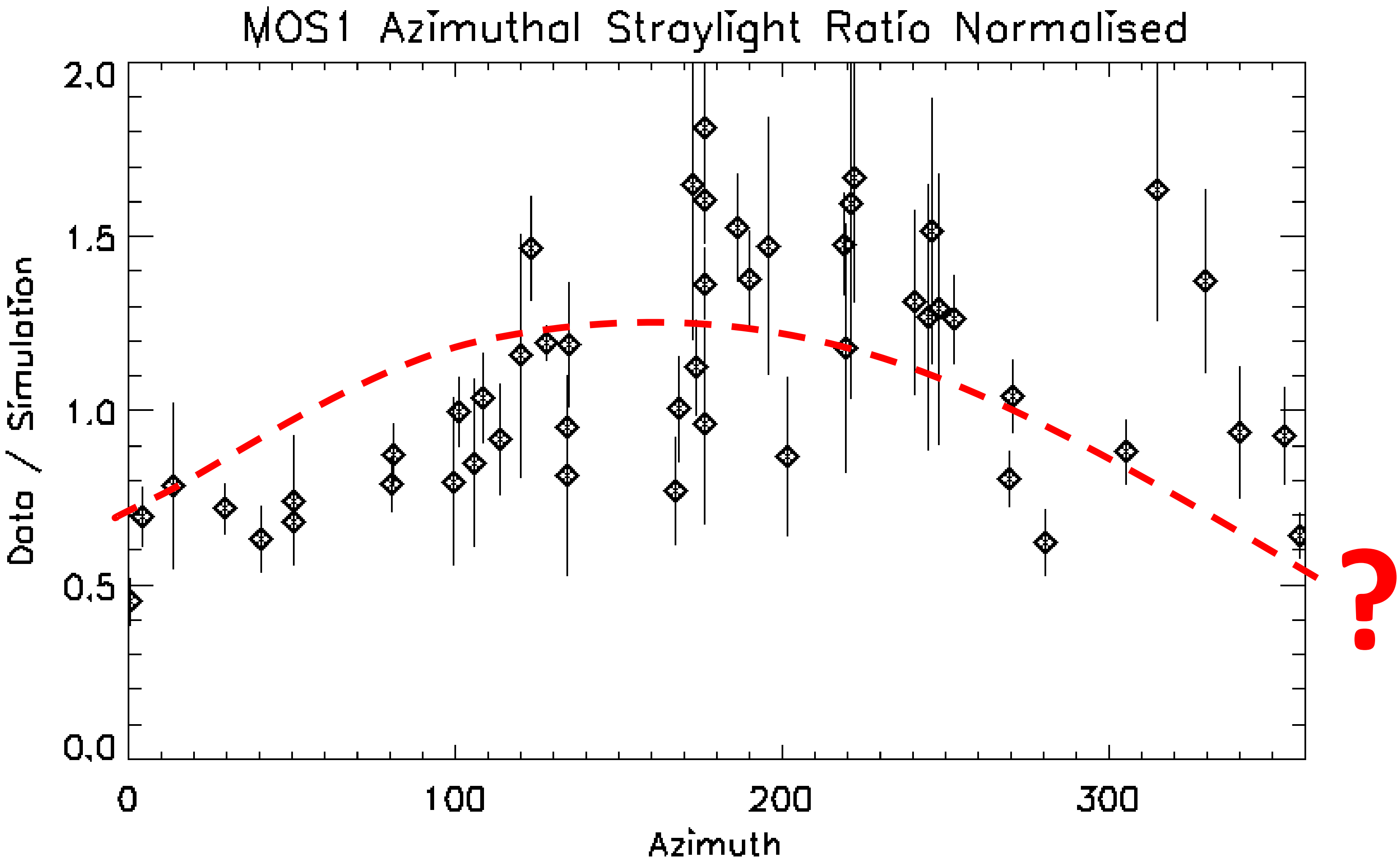


MOS1 Camera results – ratio to simulation

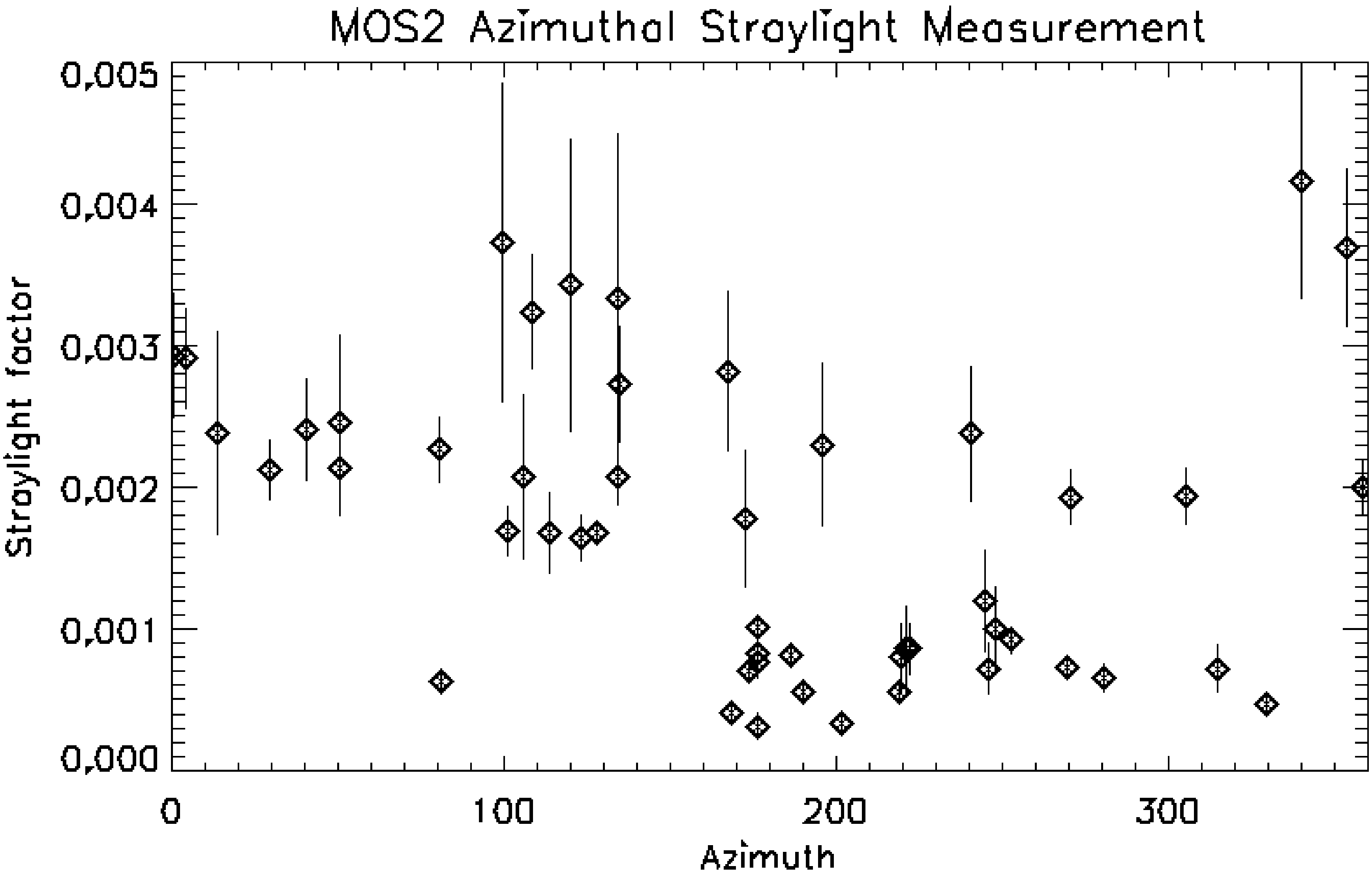


MOS1 Camera results - azimuthal

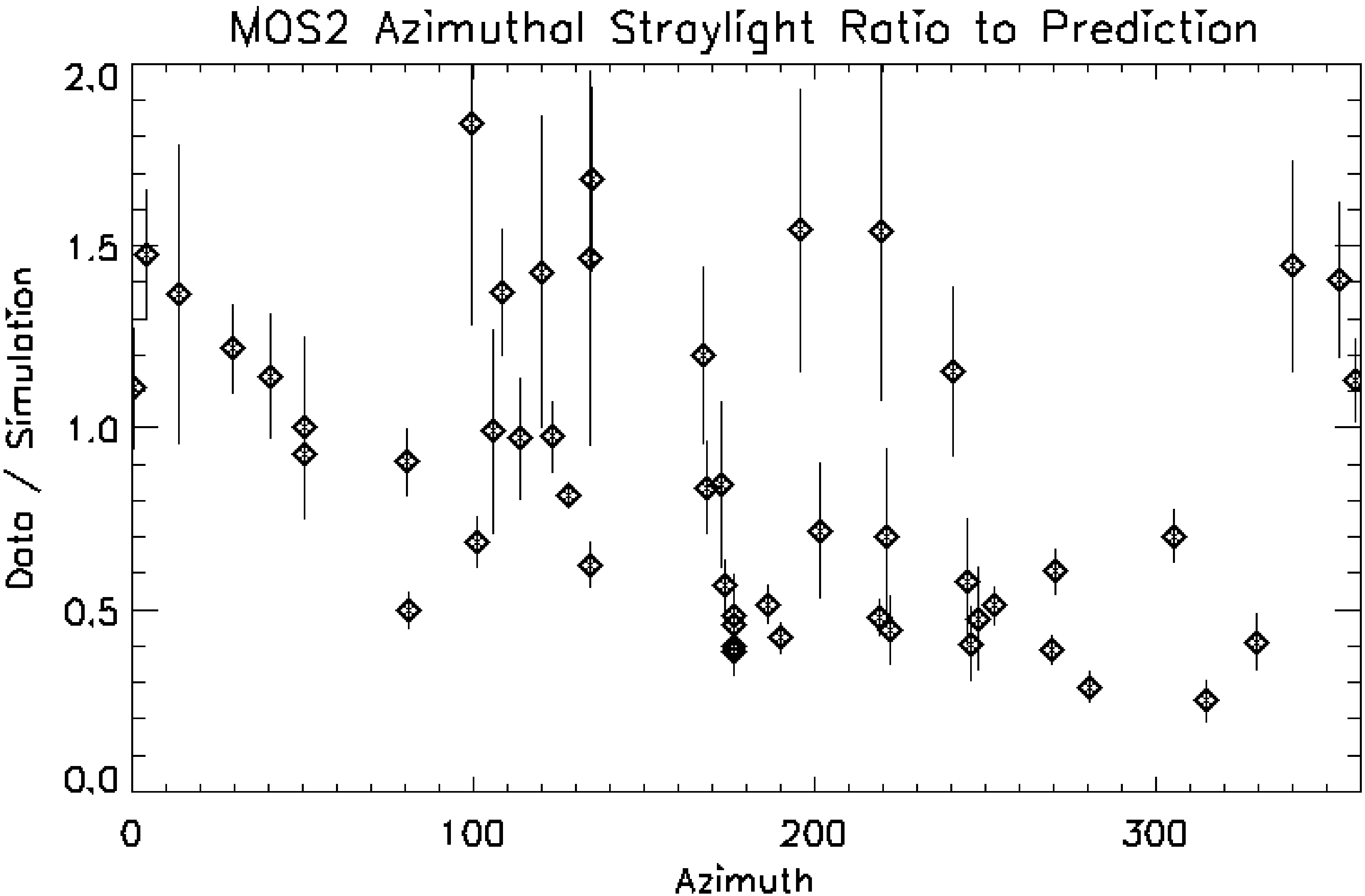
Scale for flux errors and divide by simulation



MOS2 Camera results - azimuthal

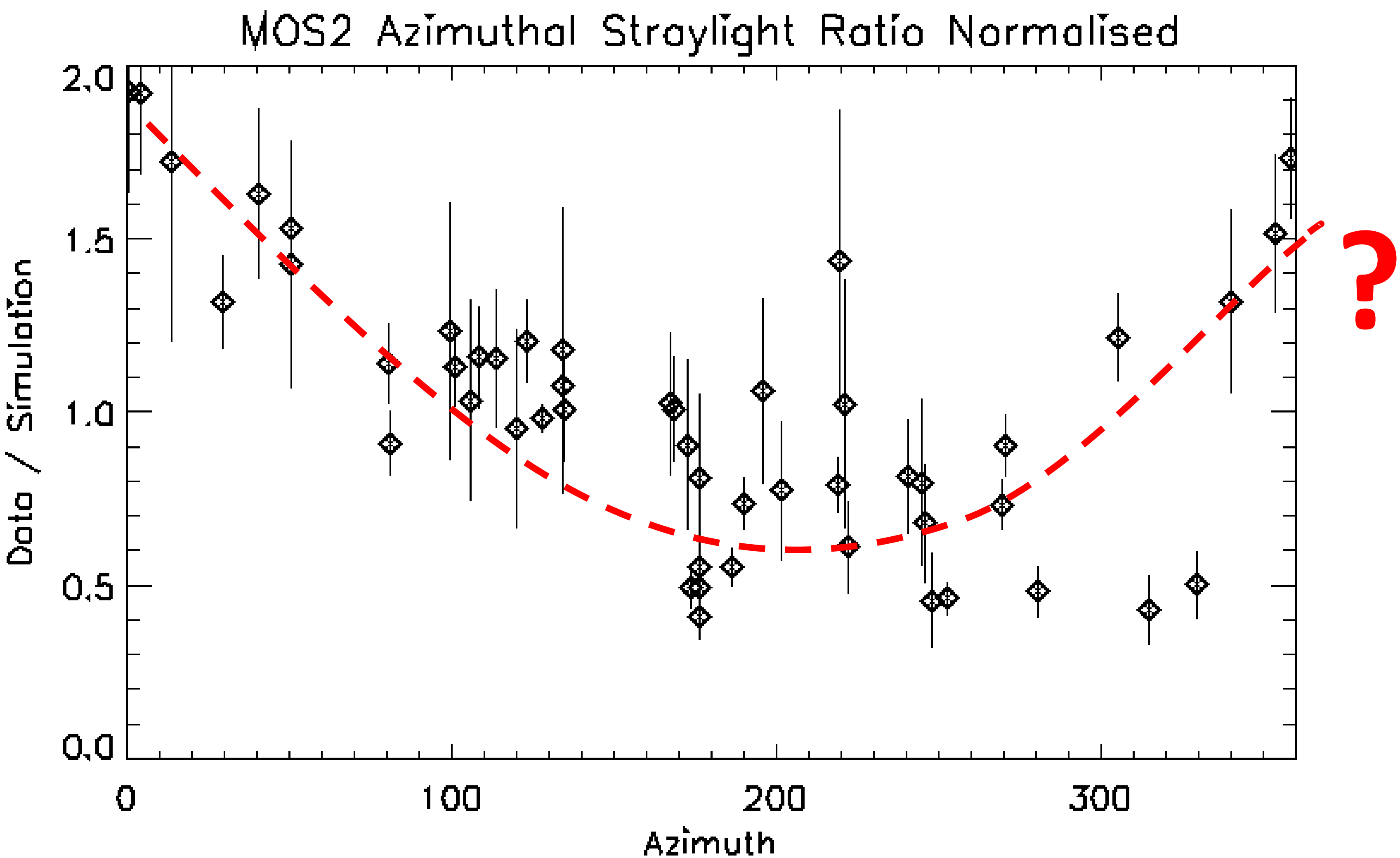


MOS2 Camera results – ratio to simulation



MOS2 Camera results - azimuthal

Scale for flux errors and divide by simulation



Conclusions – still in progress

- Average straylight vs radius not grossly discrepant
- After source flux adjustment, different azimuthal variation per camera
- Not possible to say if due to baffle rotation or shift
- Possible impact on Effective Area on axis (Fn of Energy) was ray traced – only ~1% effect
- Azimuthal variation – like the ***Matteos effect***
- But also has similar effect to the telescope axis modification made XMM-CCF-REL-156 in 2004 ?
- Is that a combination of two effects??????

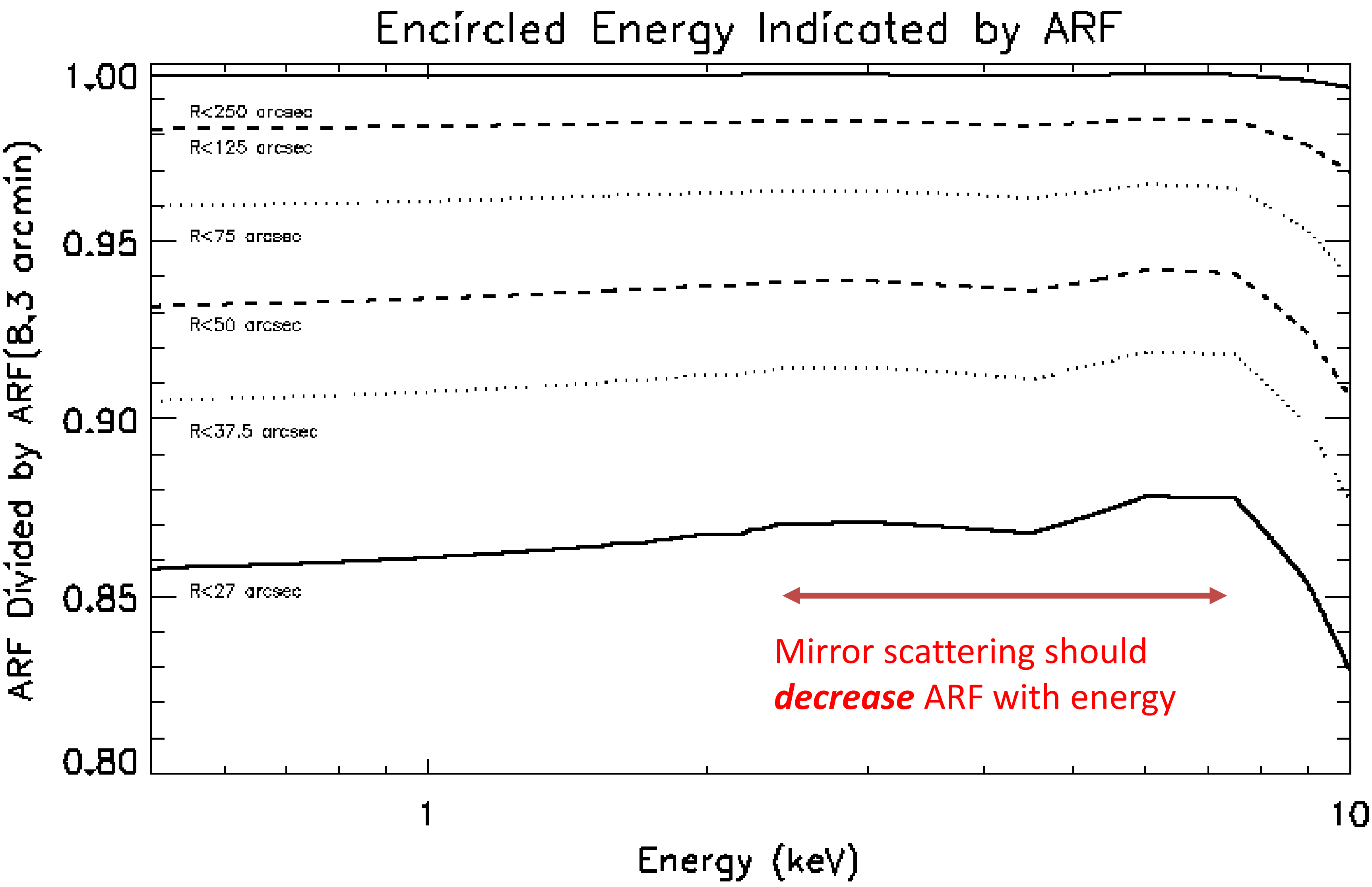
Questions about ARF

- Work on clusters cross-calibrations and the XMM Catalogue point source comparisons show the similar effects
- XMM gives lower temperature than ACIS, PN effective area returns progressively lower flux than MOS
- Few % effect – MG wondered if in the end we just use an ***aphysical*** fudge factor

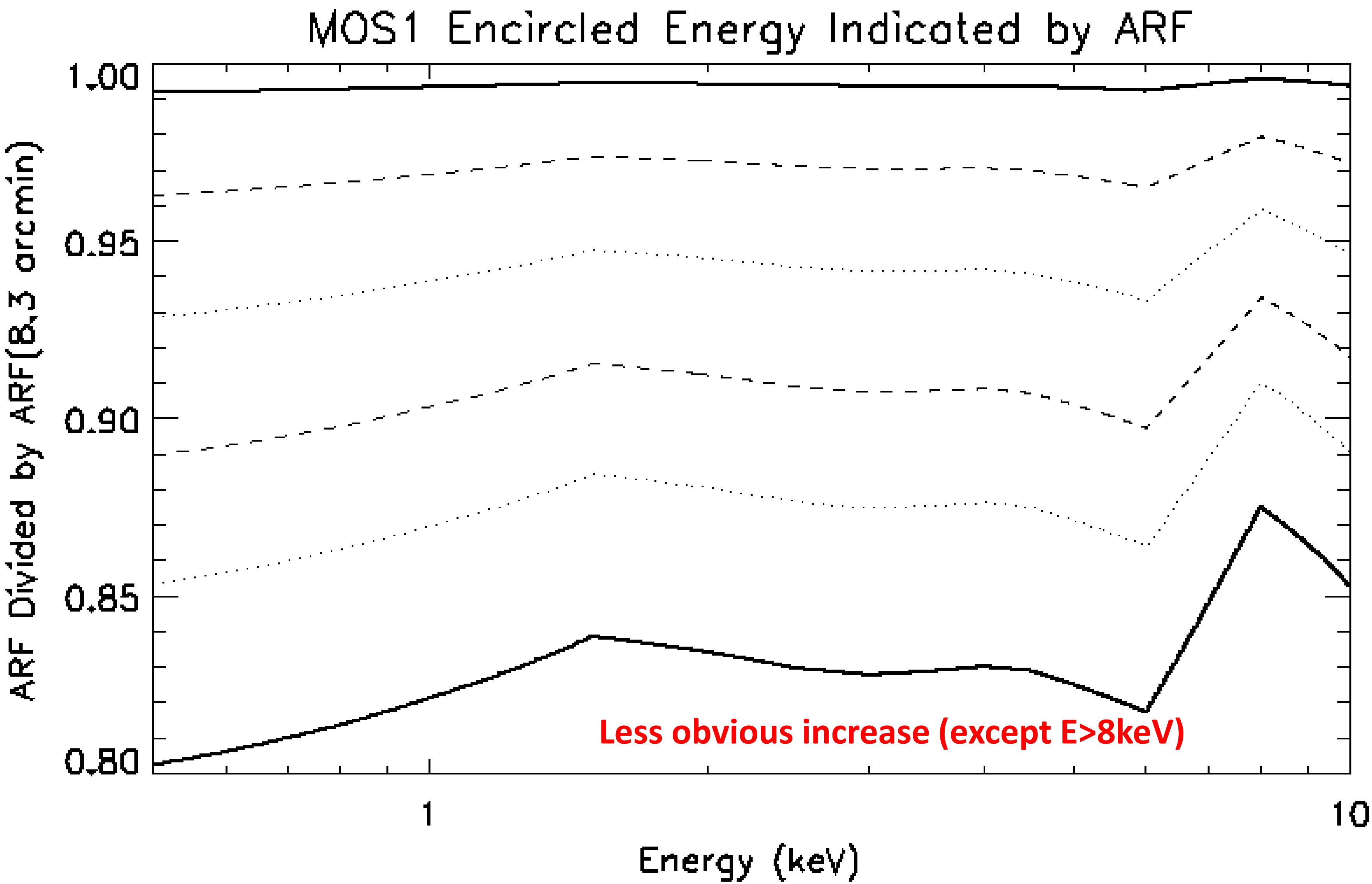
ARF vs extraction radius

- Using SAS 13.0 (as likely was done for pre 2014 IACHEC cross calibration exercises)
- Generate an ARF for different spectral extraction radii up to ~10 arcmin
- As expected compares quite well with the Encircled Energy output of *calview* when using ELLBETA accuracy
- But seems very aphysical – why doesn't mirror scattering get worse with increasing energy?

PN ARF


Encircled Energy Indicated by ARF
ARF Divided by ARF(8.3 arcmin)
Energy (keV)
1.00
0.95
0.90
0.85
0.80
1
10
R<250 arcsec
R<125 arcsec
R<75 arcsec
R<50 arcsec
R<37.5 arcsec
R<27 arcsec
Mirror scattering should
decrease ARF with energy

MOS ARF



MOS1 Encircled Energy Indicated by ARF
ARF Divided by ARF(8.3 arcmin)
1.00
0.95
0.90
0.85
0.80
1
10
Energy (keV)
Less obvious increase (except E>8keV)

Encircled energy differences

- 0.5 – 2 keV band and “typical” enclosed diameters 54 arcsec & 1.67 arcmin

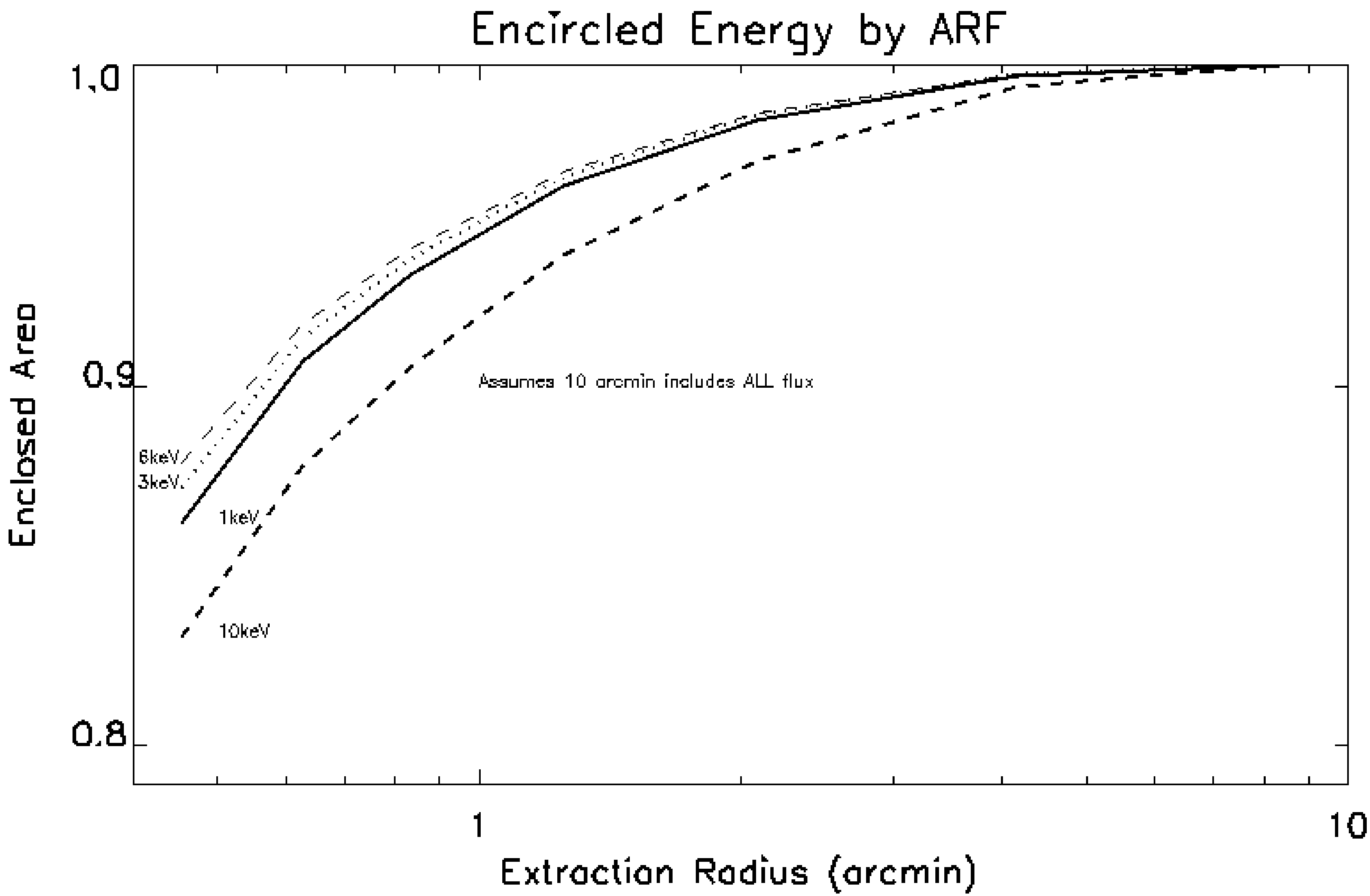
  PN 86.3 / 93.5% **MOS1 83.0 / 90.9%**

- 2 – 7 keV band and “typical” enclosed diameter 54 arcsec & 1.67 arcmin

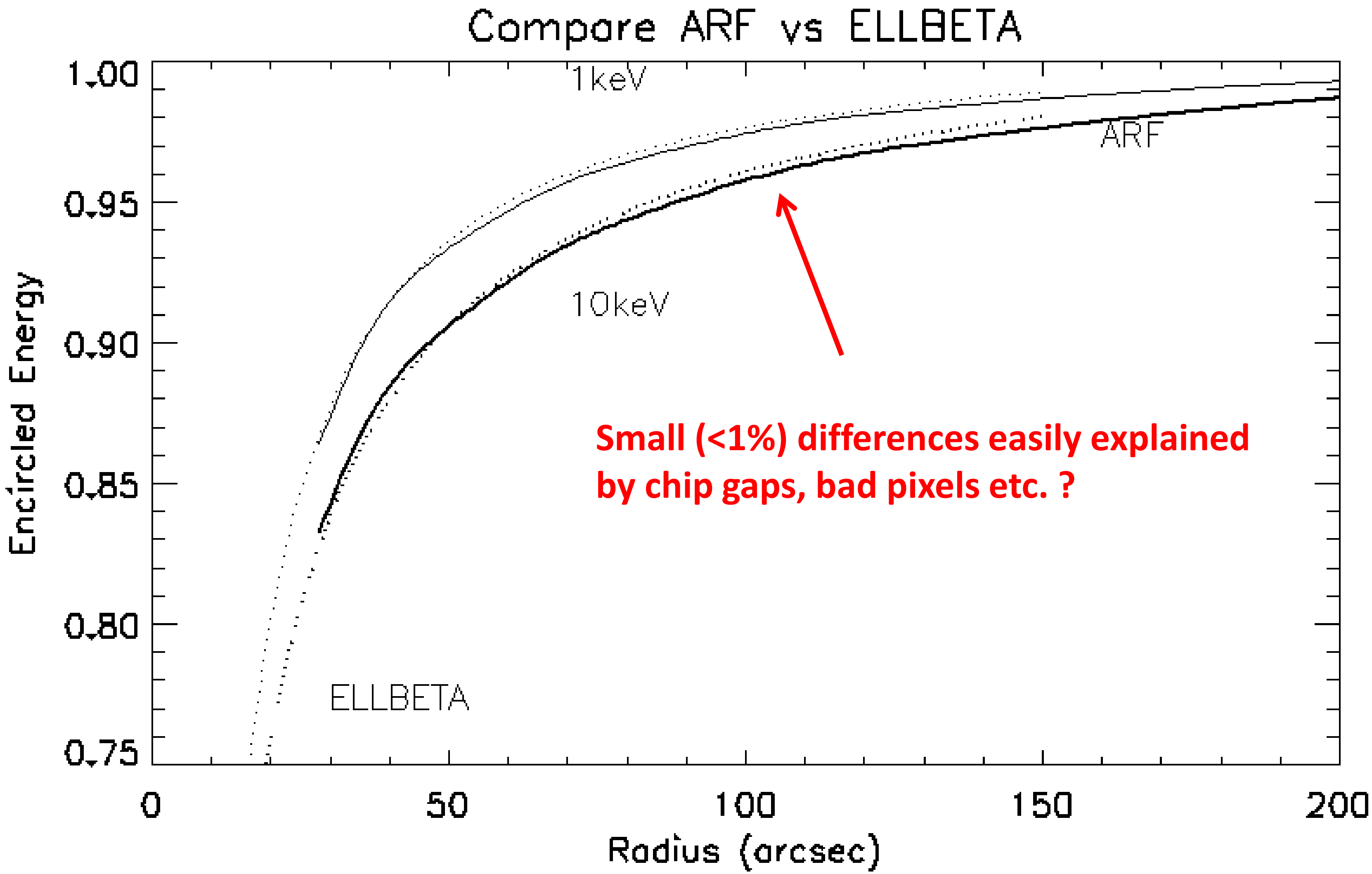
  PN 87.1 / 93.8% **MOS1 82.8 / 90.6%**

- PN would report 3- 5% lower flux yet actually its PSF is worse than MOS1 (admittedly core)

PN Encircled Energy Normalised to ~10 arcmin radius



PN ARF matches the ELLBETA description



OOT Correction

- Seems to do nothing for the *withootcorrection* flag in arfgen ?
- Exposure is supposed to be corrected for ~6% OOT effect, but comparison with GTIs and LIVETIMEs shows much larger reduction?
- In any case with extended sources how do you book-keep for increasing recovery of OOT events INTO spectral extraction?
- PN has more complex time accounting – any small errors potentially affect normalisation
- And for clusters the cross-arf problem will surely blow up any incomplete ARF accounting as fn(E) !!

Example:

	PN	MOS1
Observation Duration	69719	76317
On Time	64122	68914
Live Time	56489	68012
Total GTI		
Image Exposure	64124	68921
Spectrum Exposure	56359	68002
Spectrum/Image Exposure	0.88	0.987

Flux and Spectral Differences?

- We are looking for few % differences in normalisation and also some trend with energy
- Normalisation could be hostage to small errors in the LIVETIME/GTI calculations and OOT correction
- Encircled energy function calculated by ELLBETA seems to go in wrong direction in energy AND between PN and MOS