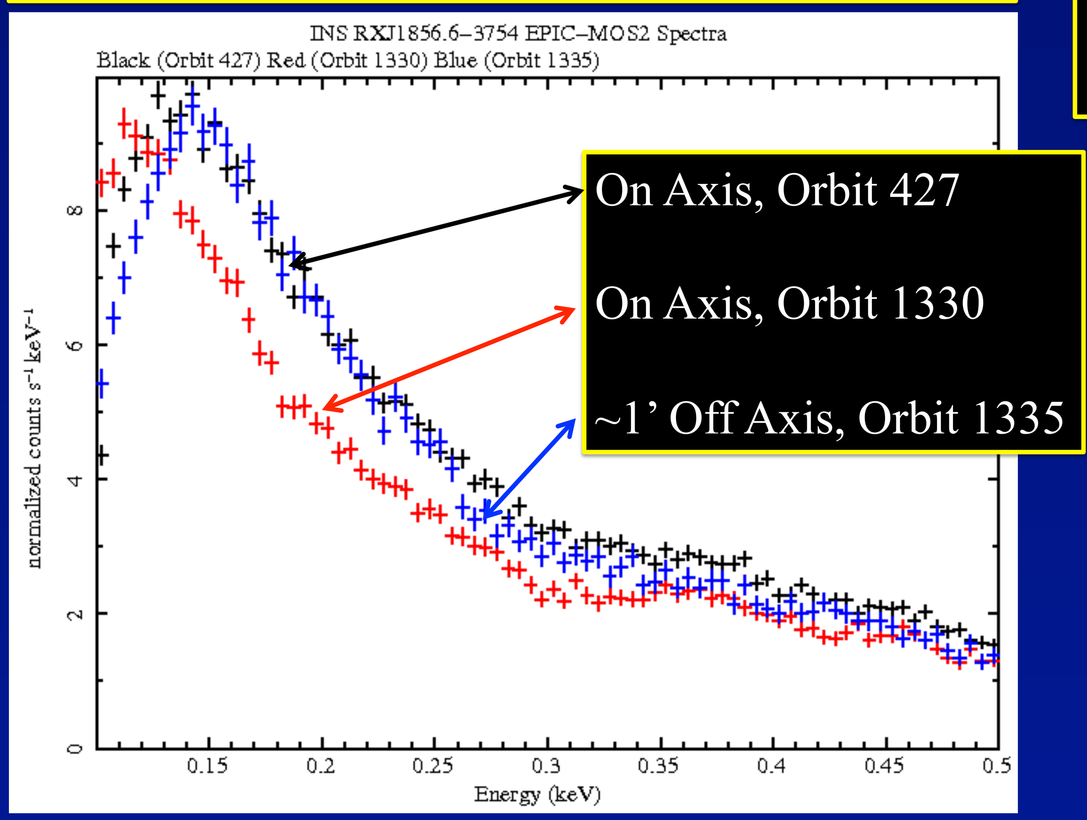
# A phenomenological approach to calibrating the EPIC-MOS detector response


Steve Sembay[1], Richard Saxton[2] & Matteo Guainazzi[2]

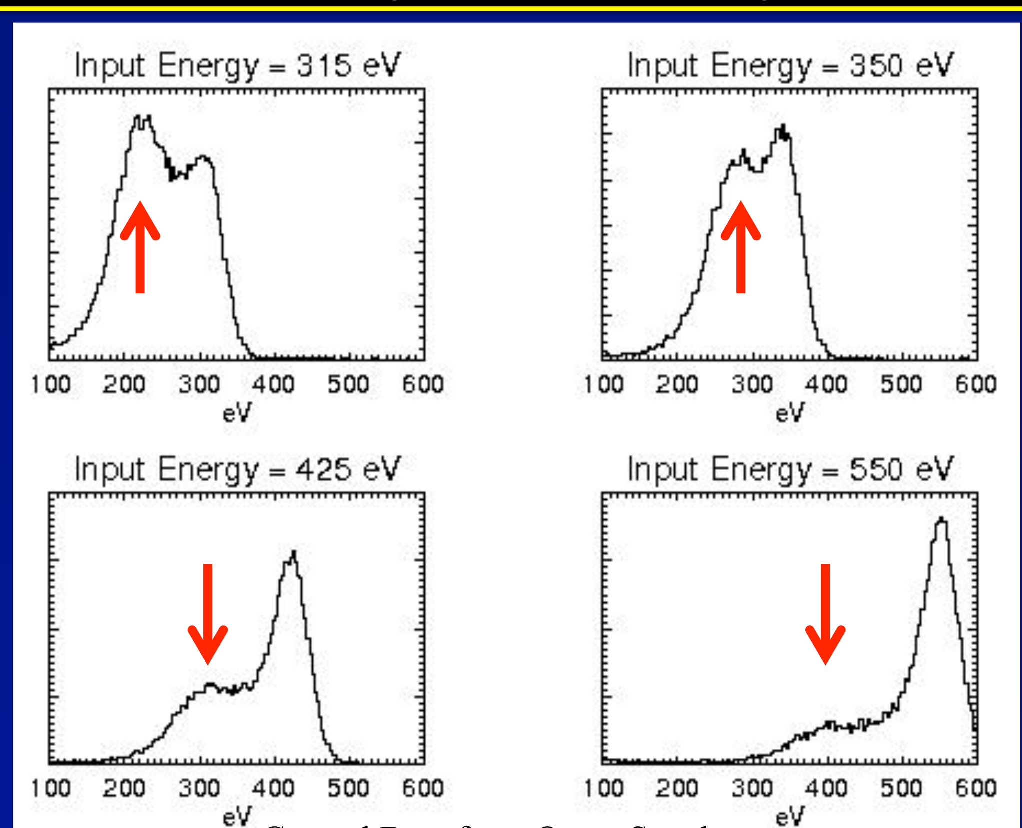
1. Department of Physics and Astronomy, University of Leicester, LE1 7RH, UK
2. XMM-Newton SOC, European Space Astronomy Centre, 28691 Madrid, Spain


**The Problem:** Significant evolution in the on-axis detector response near the boresight. Example shown is MOS2 observations of the relatively stable Isolated Neutron Star, RXJ1856.6-3754



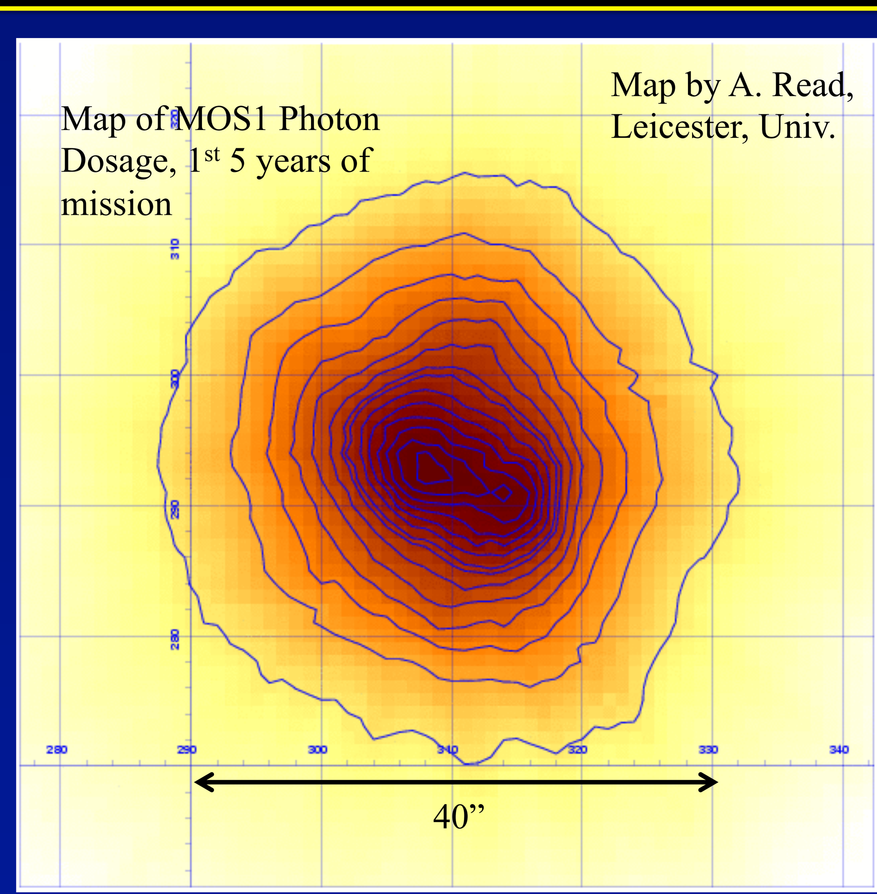

**The later** off-axis observation is similar to the earlier on-axis, observation, but the on-axis observation from orbit 1330 is significantly different. What we observe is an increased REDISTRIBUTION of photons to lower energy, not a suppression of low energy flux due to absorption.

**What is changing?:** The response profile of the MOS CCDs show a large secondary shoulder (red arrow). This is due to incomplete charge collection near the CCD surface caused by a voltage inversion dragging charge away from the collection channels. The observations in orbit are consistent with this shoulder evolving; getting stronger and peaking at lower energies near the boresight.




Ground Data from Orsay Synchrotron

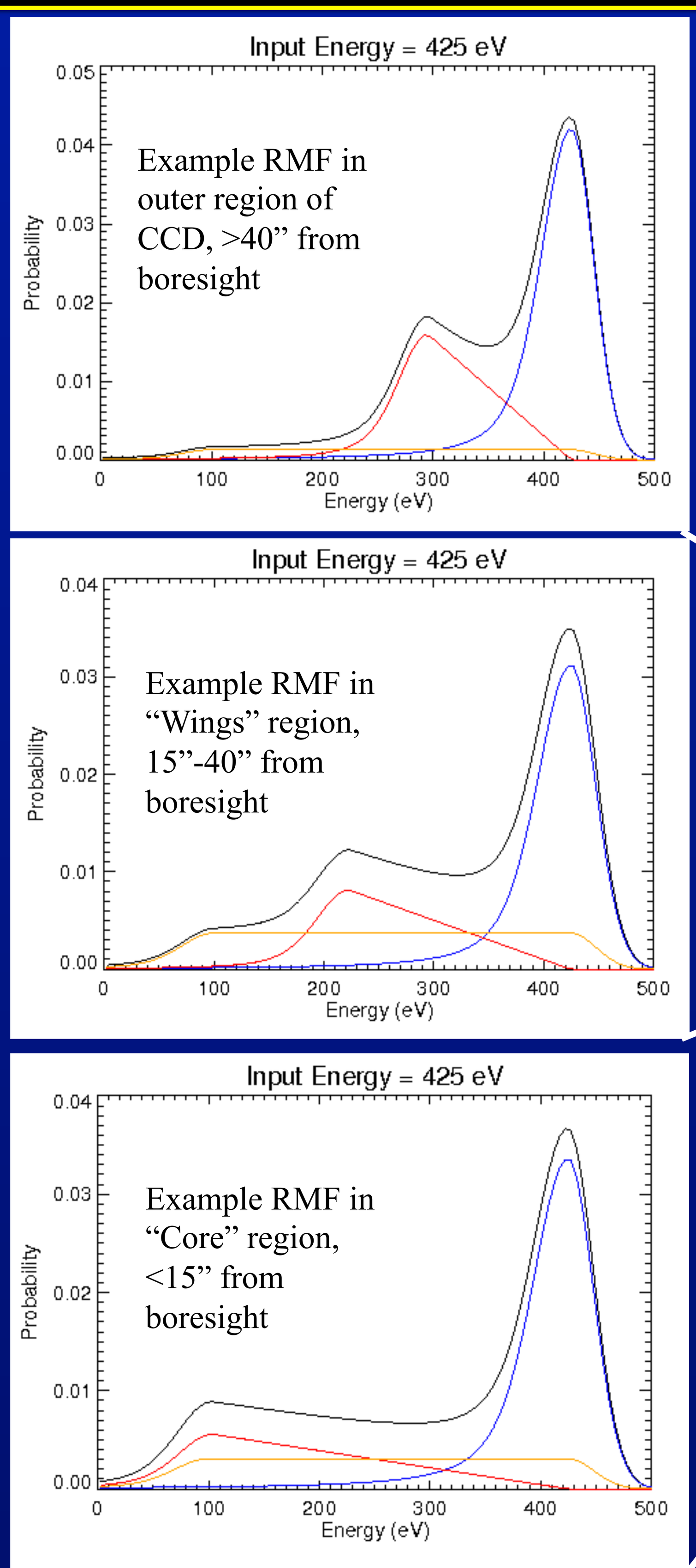
**What is the cause?:** The size of the affected region is correlated with the total photon dosage throughout the mission so it is likely the accumulated X-ray absorption has changed the voltage structure near the CCD surface.



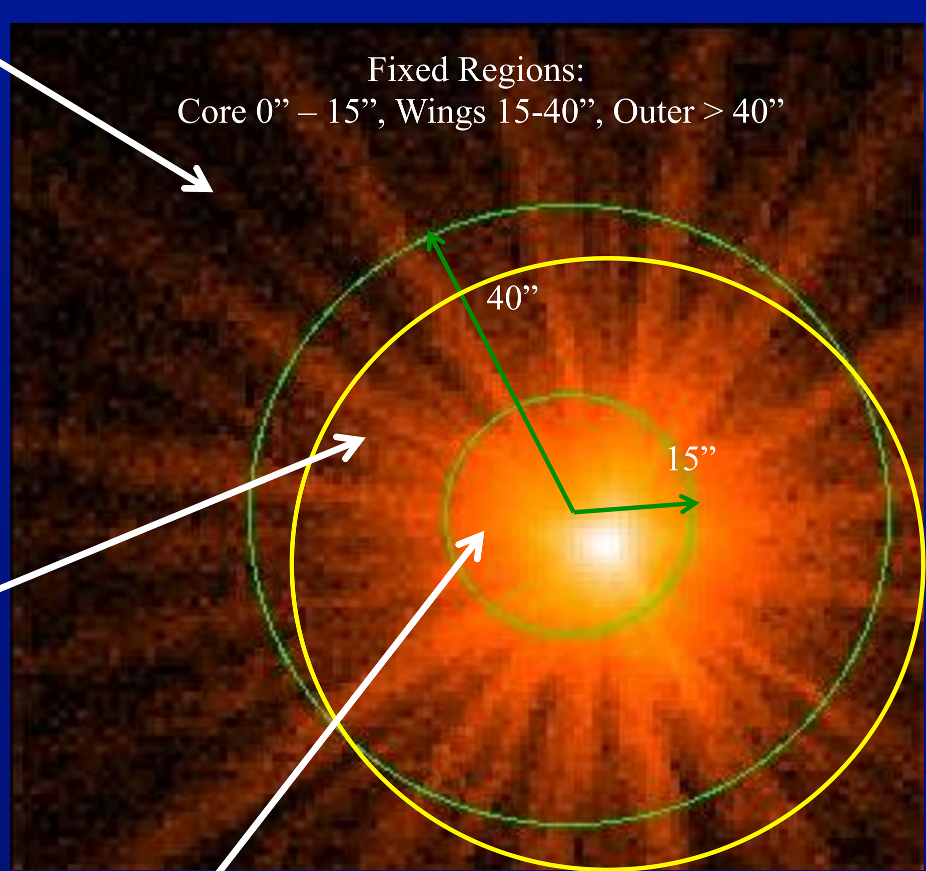

**How do we calibrate this?:** We do not have a physical model of the EPIC-MOS detector response accurate enough to describe the rather complex energy, spatial and epoch dependent shape of the redistribution function (RMF) so we have used a "phenomenological" approach as described here. For more details see reference [1].

**Step One:** We derive a mathematical description of the RMF based on our ground calibration data. This uses simple functions to describe the main photopeak and the charge-loss shoulder. The strength and shape of the charge-loss components are assumed to vary with energy, getting stronger at lower energies. 27 Parameters are required to describe all components of the RMF.

**Step Two:** We define a number of epochs (13 to date, each around 200 orbits in length) to describe the temporal evolution of the RMF and 3 fixed spatial regions on each central CCD (see below) to describe the spatial variation. We derive an RMF solution for each epoch, region, two X-ray pattern classes (0 and 0-12) and camera giving a total of 156 RMF Solutions!




**Step Four:** For a given extraction region specified by the user, the SAS task rmfgen then derives as the ouput RMF a weighted average of the RMF solutions from each of the fixed spatial regions for that epoch. The weighting is based on the fraction of the PSF within each region.




User Selected Region

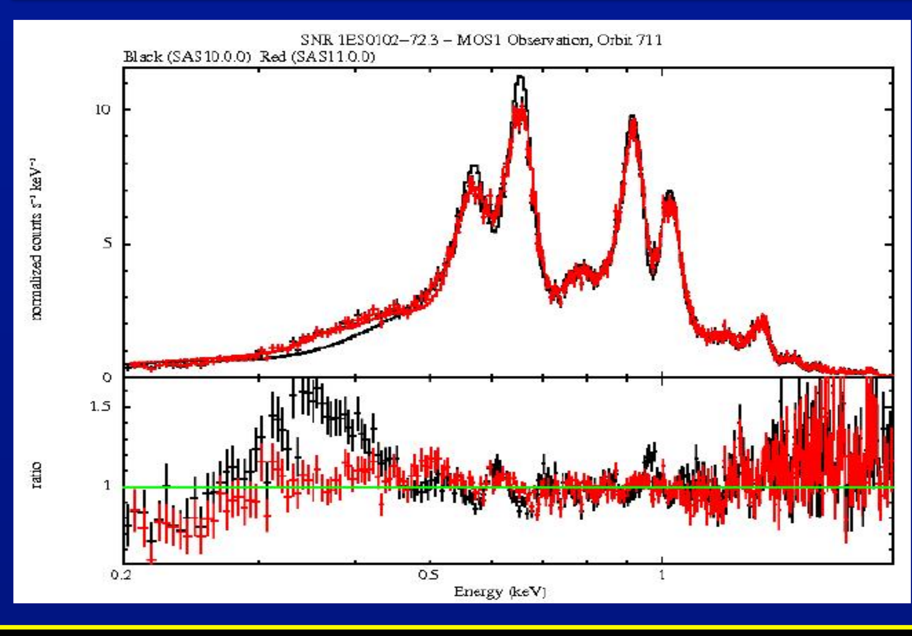
**Step Three:** The RMF solutions are derived using an iterative method.

A) For each case (epoch, region etc) we extract spectra from appropriate astrophysical sources; line rich sources (The SNR 1ES0102-72.3[2] and the O star Zeta Puppis) and, for example, soft sources like RXJ1856.5-3174. We also extract spectra from the onboard MOS Fe55 calibration source giving the spectrum of the lines around Mn $K_\alpha$ (~ 6 keV).

B) We use models derived from fitting EPIC-pn and RGS data to the astrophysical sources and a model of the Fe55 emission. The MOS RMF is therefore tied to the calibration of these instruments.

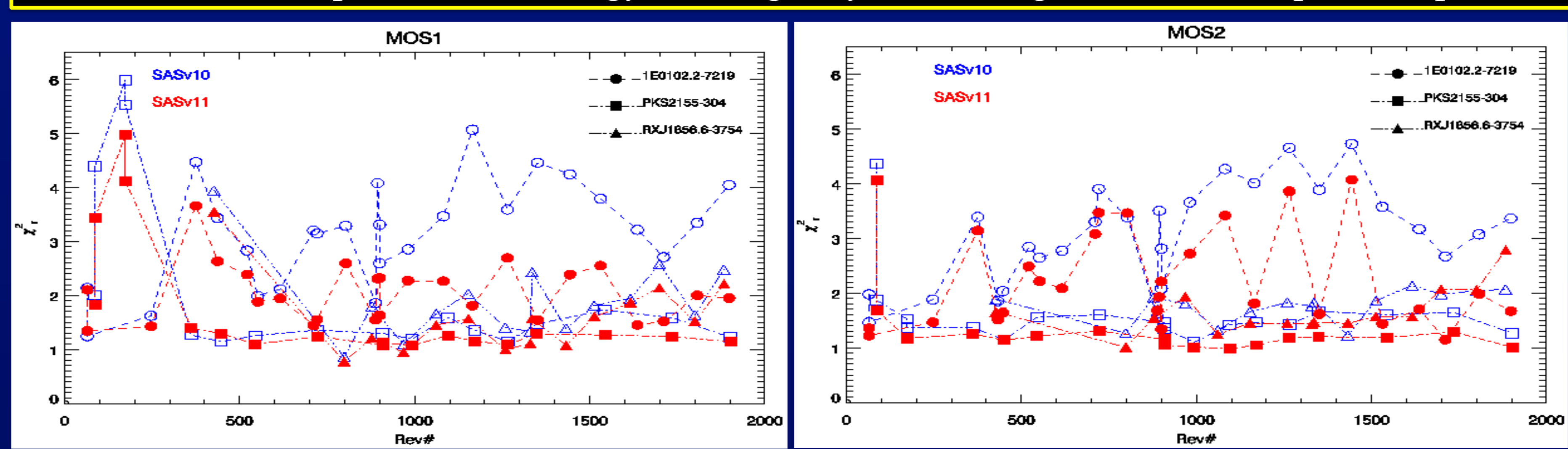
C) We then SIMULTANEOUSLY fold these models through the MOS response and derive a goodness of fit statistic for the TOTAL fit. The RGS derived models (from the line dominated sources) tends to drive the solution from 0.5 to 2.0 keV. The pn derived models (soft sources) drives the solution below 0.5 keV.

D) We use a minimisation algorithm (the IDL routine TNMIN[3]) to find the RMF model parameters which minimises the goodnes-of-fit statistic.




**Comparison** of fit to a MOS1 observation of the SNR 1E0102-72.3 from Orbit 711. The model[2] is derived primarily from fits to RGS data. Here we only allow the global normalisation of the model to vary and show a comparison between the responses generated by SAS10.0.0 (Cstat = 1226.5/318 dof) and SAS11.0.0 (Cstat = 610.0/318 dof). The new RMF model shows an improved agreement.

**General Results:** The plots below show the goodness of fit (Chi-squared) for spectral fits to many observations of RXJ1856, 1ES0102 and the Blazar PKS2155-304, comparing SAS10.0.0 against SAS11.0.0. In the first two cases fixed models derived from RGS and pn data are used. The overall trend is an improvement of the fit against the chosen model in almost all cases. That many fits are not formally acceptable suggests the RMF model parameters can be further refined and the spatial methodology of using only 3 fixed regions can be improved upon.




**References:**


1) http://xmm2.esac.esa.int/docs/documents/CAL-SRN-0272-1-2.ps.gz
2) Plucinsky et al. 2008, SPIE, 7011, 68
3) http://www.physics.wisc.edu/~craigm/idl


University of Leicester

XMM-Newton

esa