XMM-Newton CCF Release Note

XMM-CCF-REL-280

2-D PSF parameterization

A. M. Read & R. Saxton

March 28, 2012

1 CCF components

Name of CCF	VALDATE	List of Blocks changed	Change in CAL HB
XRT1_XPSF_0014.CCF	2000-01-01	ELLBETA_PARAMS	YES
XRT2_XPSF_0014.CCF	2000-01-01	ELLBETA_PARAMS	YES
XRT3_XPSF_0014.CCF	2000-01-01	ELLBETA_PARAMS	YES

2 Change

The elliptical beta, 2-D PSF model (ELLBETA) consists of an elliptical King function plus a central narrow Gaussian to model the core plus spoke structures (see [1] and CAL-SRN-0263 for a fuller description). This release includes two separate changes: a modification to the strength of the spokes and a tuning of the slopes of the elliptical King function.

2.1 Spokes

A spatial analysis of fits of the 2-D PSF to real sources showed that small problems with the spoke strength still exist [2]. To correct this, the spoke structure has been reworked in this release to vary the intensity along the spokes such that

1. The overall spoke intensity has been modified to CHNGFRAC=0.42 from its previous value of 0.375.
2. The spokes start at a radius, RD1=10". For smaller radii the spoke strength is zero.
3. The spoke strength increases linearly until reaching a peak at RD2=110".

Table 1: Observations used in the determination of optimum King profile slopes

Source name	Obsid
1H0414+009	0161160101
3C 273	0126700301
3C 273	0414190701
H1426+428	0165770201
IRAS0578+1626	0502090501
MCG-6-30-15	0029740101
MCG-6-30-15	0029740701
MCG-6-30-15	0029740801
PG1116+215	0201940101

4. It then decreases linearly until attaining zero intensity at RD3=180". The spoke strength is zero beyond this radius.

These values are stored in the following keywords in the header of the ELLBETA_PARAMS extension:

- CHNGFRAC - (maximum) fraction of image to be filtered (0[none]-1[all]) which defines the strength of the spoke
- RD1 - minimum radius to start spoke filtering (arcsec)
- RD2 - radius at which the spoking peaks (arcsec)
- RD3 - radius at which the spoking tails to zero (arcsec)

Note that the keywords related to the spoke structure currently have the same values for the three cameras.

2.2 King function slope

A detailed spectral investigation of the 2D-PSF fit to several bright on-axis sources has revealed that at some energies the measured flux varies depending on the extraction region. This has been resolved by tuning the slope of the elliptical King function individually for each camera and for 6 energy bands from 0.15–10 keV.

In detail, source spectra have been extracted from annuli of outer radius 40" and inner radius ranging from 0" to 20" from the set of observations of bright on-axis AGN listed in Table 1. Effective area files (ARFs) have been produced by the SAS task *arfgen* and the spectra have been fit using an absorbed power-law model.

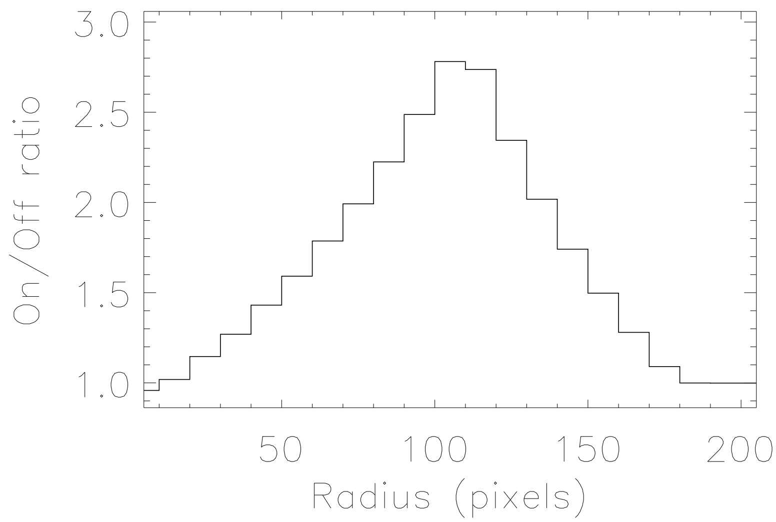

Figure 1: The ratio of the model on-spoke to off-spoke intensity plotted against radius (in 1 arcsecond pixels).

3 Scientific impact of this update

3.1 Spoke structure

The spoke structure, as represented in XRTn_XPSF_0013.CCF, had been tuned using data contaminated with a galactic scattering halo [2]. In this release, the radial structure of the spoke has been reworked to account for this effect. The overall change is a slight increase in the strength of the spokes plus a radial change in their intensity. The new implementation is a better fit to real data and should lead to a reduction in the number of spurious detections which are found in the wings of bright point sources during source detection runs.

3.2 Encircled energy

In the current PSF implementation it was found that at some energies the fitted source flux was quite dependent on the extraction region. In this release the King profile slope has been adjusted for each camera, and at each energy, to make the flux as region-independent as possible. In Fig. 2 we show the relationship between extraction region, flux and power-law slope for the obsid=0126700301 observation of 3C 273 in the energy band 0.54–0.85 keV. The relationship can be seen to be flatter for the new parameterisation. This gives higher confidence in the robustness of the solution and means that fluxes will not be affected when the core of the PSF has to be excluded to counter pile-up effects. Changes have been made to the slope parameterisation at 0 and 3 arcminutes off-axis. The parameters for the PSF at larger off-axis angles have not been changed.

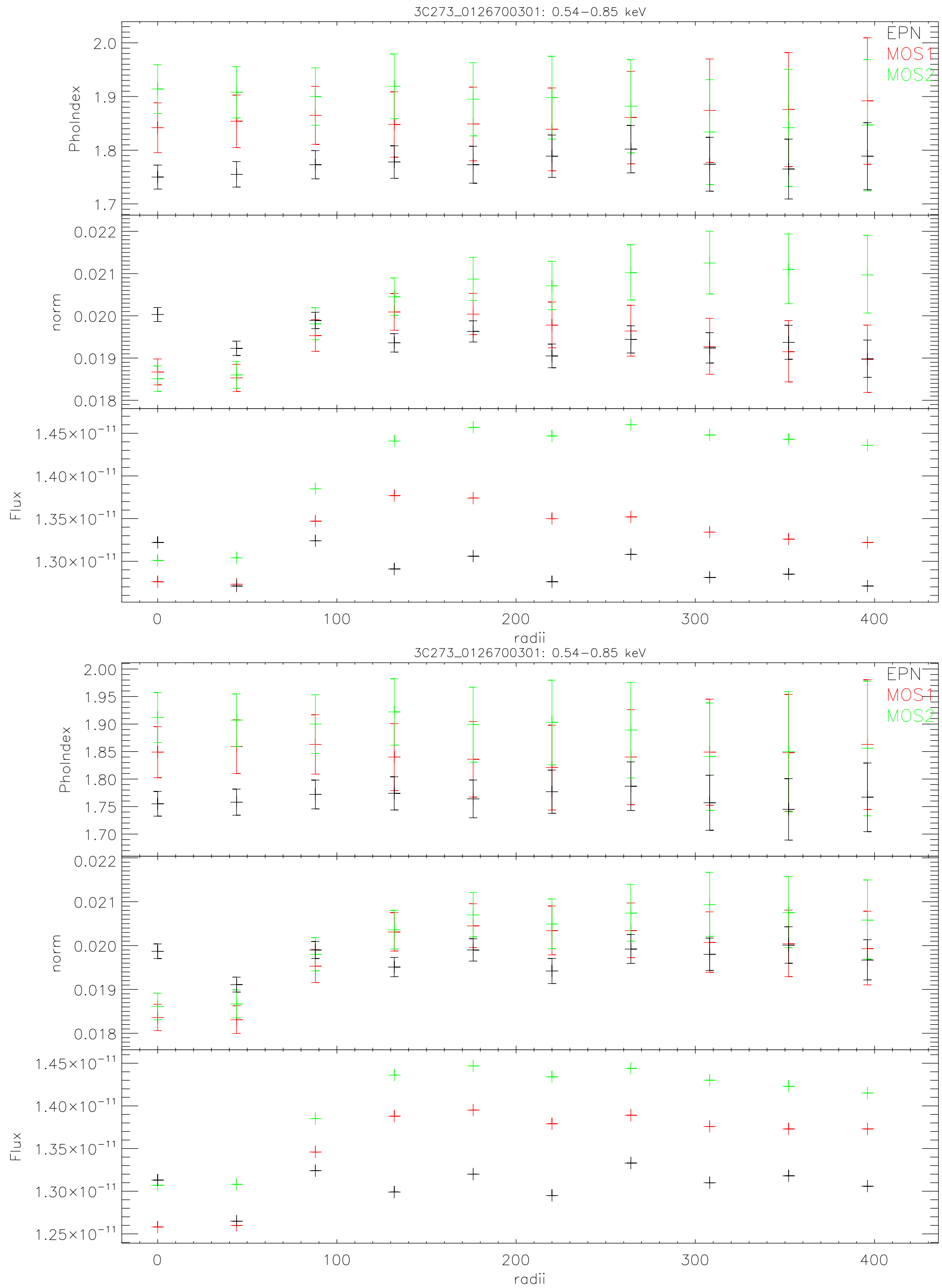

Figure 2: Spectral fit parameters for an observation of 3C 273 (obsid=0126700301) in the energy range 0.54–0.85 keV. Spectra have been extracted from an annulus of outer radius 40" and inner radius ranging from 0 to 400 sky pixels (equivalent to 0 to 20"). Upper panels give the photon index, normalisation and flux for the current 2D-PSF parameterisation (black=EPIC-pn, red=EPIC-MOS1, green=EPIC-MOS2); lower panels give the same information for this new release of the 2D-PSF. This observation suffers from pile-up in the inner 5" (50 sky pixels).

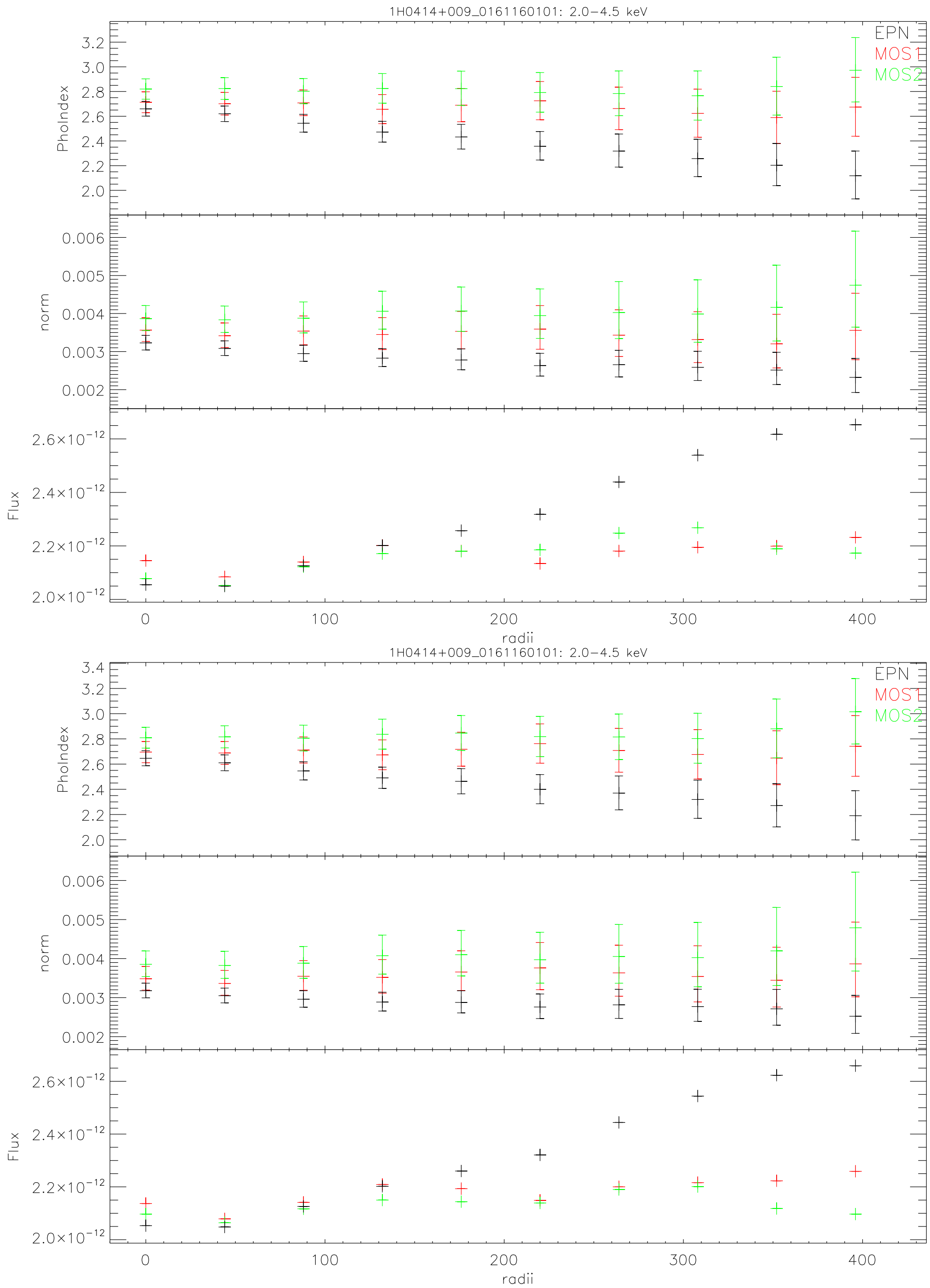

Figure 3: Spectral fit parameters for an observation of 1H 0414+009 (obsid=0161160101), in the energy range 2.0–4.5 keV, using the current 2D-PSF parameterisation (upper panels) and this release (lower panels) .

4 Estimated scientific quality

The spoke model has been designed to fit the data in [2] to an accuracy of a few % in the three EPIC cameras.

For the tested observations of 3C 273 and MCG-6-30-15 the changes introduced in this release lead to fluxes which are consistent to within $\sim 5\%$ for annular extraction regions with outer radius 40" and inner radius ranging from 5-20", for all energies and for the three EPIC cameras (see Fig. 2 for an example at 0.54-0.85 keV). Note that data within the inner 5" are likely affected by a small amount of pile-up in these sources.

Some of the sources in the analysis had trends which went in opposite directions making it impossible to resolve all the problems in all the sources with a single set of PSF parameters. For example, the lower statistic sources, 1H 0414+009 and H 1426+428 show larger deviations in spectral parameters with inner extraction radius for energies above 2.0 keV. This is perhaps related to low statistics and background subtraction issues. An example is shown in Fig.3. Nevertheless, overall the changes introduced here give an improvement in the flux consistency in most sources at most energies. Figure 4 shows the standard deviation about the mean flux for the the old and new CCFs. Points below the dotted line represent improved performance.

5 Test procedure and results

The new CCFs have been used within `calview`, `psfgen` and `eregionanalyse` to test that they produce the correct PSF images and encircled energy values.

The modified SAS code needed to take advantage of the new CCF structure is not yet public. To ensure that these changes do not adversely affect the current public SAS (v11.0) the same three tasks, `calview`, `psfgen` and `eregionanalyse` were executed from the current SAS using the new CCF elements. No problems were seen.

6 Future changes

It is likely that changes to the PSF parameters at off-axis angles greater than 3 arcminutes will be needed in the future.

7 References

[1] Read, A., Rosen, S., Saxton, R. & Ramirez, J. 2011, A&A, 534, 34
[2] Owen, R. & Ballet, J. 2011, SSC-CEA-TN-1001, v2.1. (http://xmm2.esac.esa.int/documents/CAL-SSC-CEA-TN-1001-2.1.pdf)

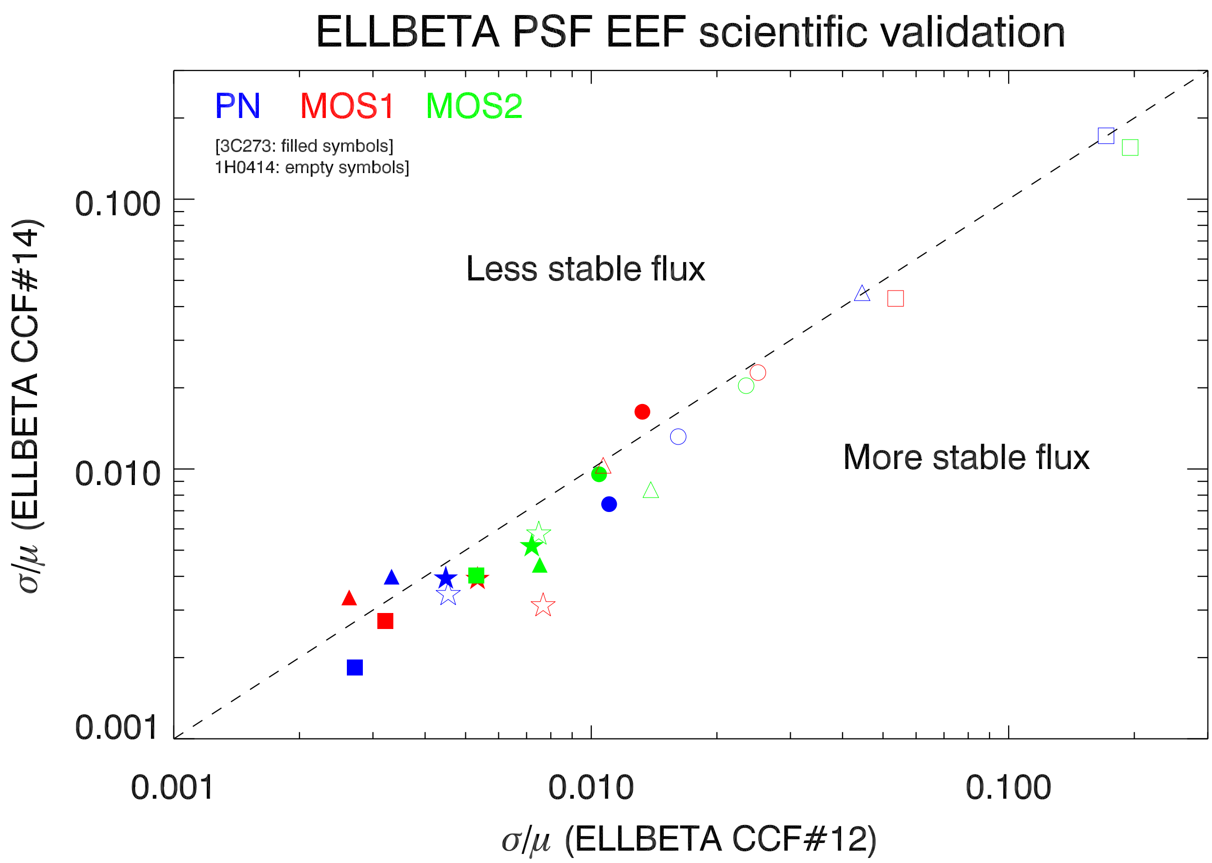

Figure 4: A plot of the consistency of the measured flux with changing extraction region. The axes represent the standard deviation of the flux normalised by the mean flux for the current CCF (version 12) and the new CCF (version 14). Different cameras are represented by different colours while filled and open symbols represent 3C273 and 1H0414 respectively. Energies are represented by the circle (0.54-0.85 keV), star (0.85-2 keV), triangle (2-4.5 keV) and square (4.5-10 keV) shapes.