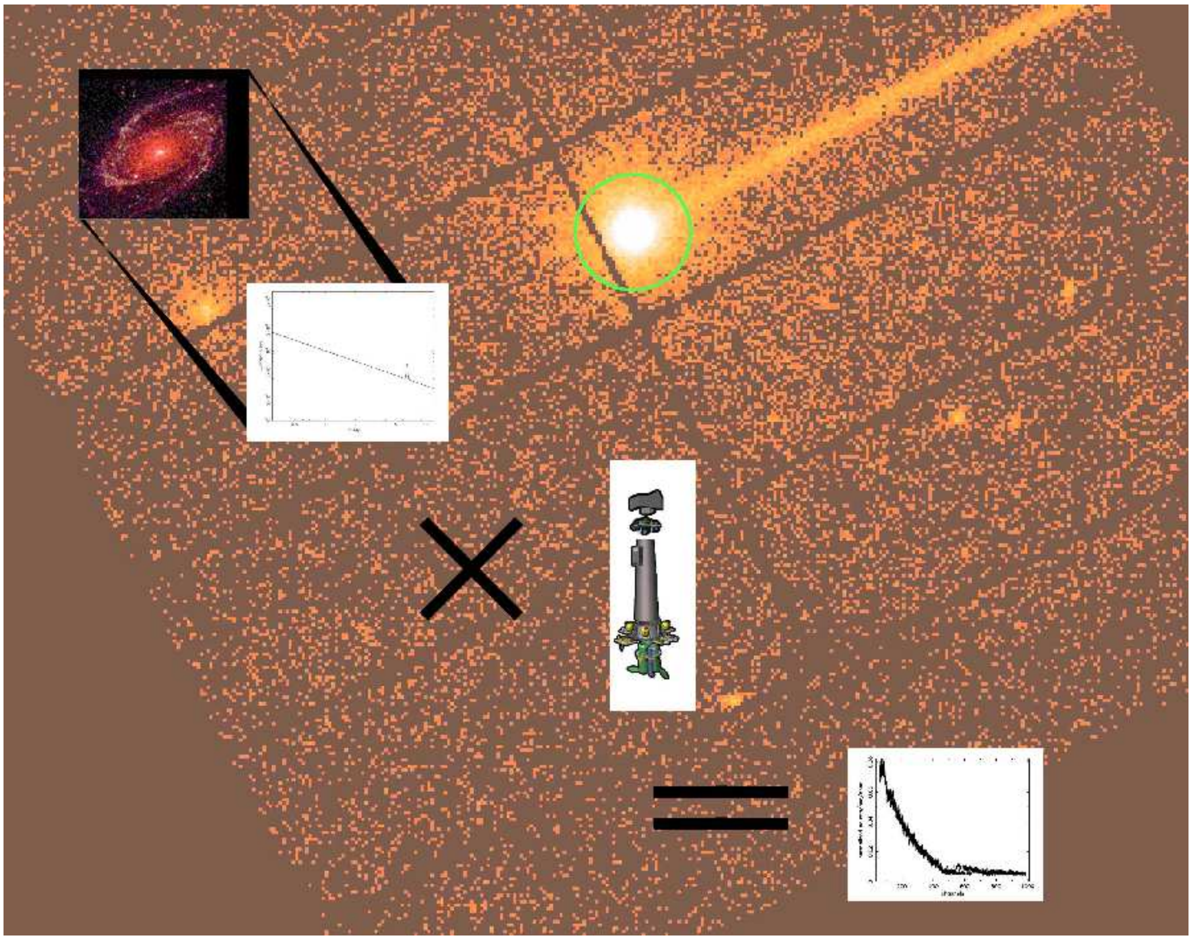
The status of the SAS spectral response generation tasks for XMM-EPIC



XMM-SOC-PS-TN-43
Version 3.0

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Contents

1 Changelog

Version 1.0 – SAS 5.0
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Version 3.0 – SAS 5.3

2 Introduction

This report details the status of the SAS spectral response generation software , arfgen and rmfgen, at the time of the SAS Version 5.3 release. Comparisons have been made between the SAS generated response files and the following matrices, supplied by the hardware teams:

```
m1_r6_all_15.rmf              - MOS 1, patterns 0-12, redistribution matrix
m1_r6_p0_15.rmf               - MOS 1, pattern 0, redistribution matrix
m2_r6_all_15.rmf              - MOS 2, patterns 0-12, redistribution matrix
m2_r6_p0_15.rmf               - MOS 2, pattern 0, redistribution matrix
m1_medv9q20t5r6_all_15.rsp    - MOS 1, patt 0-12, on-axis medium filter
                                         response matrix
m1_thin1v9q20t5r6_p0_15.rsp   - MOS 1, patt 0, on-axis thin filter
                                         response matrix
m2_thin1v9q20t5r6_all_15.rsp  - MOS 2, patt 0-12, on-axis thin filter
                                         response matrix
epn_ff20_sY9.rmf              - PN, pattern 0 only, Full frame on-axis
                                         redistribution matrix (07/01/2002)
epn_ff20_sY9_thin.rmf         - PN, pattern 0 only, on-axis thin filter
                                         response matrix (07/01/2002)
epn_ef20_sdY9_FH.rmf          - PN, pattern 0-4, extended full frame,
                                         redistribution matrix (07/01/2002)
epn_sw20_sY9_thin.rsp         - PN, pattern 0, small window mode, thin filter
                                         response matrix (07/01/2002)
```

These will be referred to as the "canned" matrices and are assumed to be the most accurate description of the instrument responses for the purposes of this document. For a description of how well they represent a perfect calibration of the instrumentation see [1,2] and section 9.

All errors quoted are 90% confidence.

Table 1: **Feature support**

Feature	*arfgen*	*rmfgen*
On-axis	Y	Y
Off-axis	Y	Y
Window mode	Y	Y
Pattern 0	Y	Y
All Patterns	Y	Y
PSF	Y	-
Vignetting	Y	-
Pile-up	N	N
Extended source	Y	N
Time dep. CTI	-	N

2.1 Summary of changes

The following major changes have been introduced in SAS V5.3.

- Response matrices can be made for all event grades
- Observing mode dependencies are calculated
- All allowed box shapes are handled by arfgen
- PN chip gaps are handled correctly
- PN out of time events exposure time correction
- Accurate PSF correction for annular source box
- `rmfgen` uses variable format to save space
- CAL changes produce faster processing

Table 1 gives an at-a-glance summary of the features supported by the software release SAS V5.3.

The SAS tasks reflect the current status of the instrument calibration (as of the date of this document) but lack support for pile-up, line broadening due to evolution of the CTI and RMF averaging over an extended source area.

3 Data Analysis

3.1 The analysis procedure

The general procedure has been to compare the spectral parameters yielded from model fits in `XSPEC` using the SAS-generated response files, against those produced by spectral fits using the canned matrices.

The SAS response consists of a redistribution matrix file (RMF), generated by the SAS task `rmfgen` , which describes the probability distribution in channel space for incident photons at a range of energies, and an ancilliary response file (ARF), generated by the SAS task `arfgen` , which describes the instrumental effects such as telescope effective area, quantum efficiency, and filter transmission. The canned matrix collection comprises both the pure RMF files (terminating in .rmf) and the RMF $\times$ effective area files (teminating in .rsp). These latter files are termed response files.

The canned matrix collection may be downloaded from:

`http://xmm.vilspa.esa.es/ccf/epic`

NB: With this release only canned RMF files will be made available. The effective areas file (ARF) produced by `arfgen` is deemed to be sufficiently accurate and quick that canned .rsp files are no longer needed.

3.2 Selecting the appropriate RMF

The redistribution matrices generated by `rmfgen` duplicate almost exactly the canned, instrument team, RMFs. The user has the option of using a canned RMF or generating a new one. In the current release of the SAS there is actually nothing to be gained by generating a new RMF, however, in the next release it is expected that extra functionality, such as spatial averaging, will be introduced to make `rmfgen` genuinely useful.

MOS:

The release includes four EPIC-MOS RMFs:

```
m1_r6_all_15.rmf         MOS-1, patterns 0-12
m1_r6_p0_15.rmf          MOS-1, pattern 0
m2_r6_all_15.rmf         MOS-2, patterns 0-12
m2_r6_p0_15.rmf          MOS-2, pattern 0
```

Strictly speaking these matrices are only valid on-axis. It is expected, however, that the response function will not vary greatly across CCDs or across pixels within a single CCD.

For most observations either `m1_r6_all_15.rmf` or `m2_r6_all_15.rmf` should be chosen, depending on which camera was being used. In certain cases, for instance when it is suspected that an observation suffers from pile-up, a spectrum may be created from pattern=0 events only. These spectra should be represented with the "p0" matrices.

PN:

The release includes ten single-pixel EPIC-PN canned RMFs, listed in Table 1, ten equivalent matrices for double pixels, e.g. epn_ff20_dY0.rmf and ten more for single **and** double

Table 2: **PN RMFs and corresponding pixel values**

File	RAW-Y	DET-Y			
		From	To	From	To
epn_ff20_sY0.rmf	0-19	+13400	+15000	-15400	-17000
epn_ff20_sY1.rmf	20-39	+11800	+13400	-13800	-15400
epn_ff20_sY2.rmf	40-59	+10200	+11800	-12200	-13800
epn_ff20_sY3.rmf	60-79	+8600	+10200	-10600	-12200
epn_ff20_sY4.rmf	80-99	+7000	+8600	-9000	-10600
epn_ff20_sY5.rmf	100-119	+5400	+7000	-7400	-9000
epn_ff20_sY6.rmf	120-139	+3800	+5400	-5800	-7400
epn_ff20_sY7.rmf	140-159	+2200	+3800	-4200	-5800
epn_ff20_sY8.rmf	160-179	+600	+2200	-2600	-4200
epn_ff20_sY9.rmf	180-199	-1000	+600	-1000	-2600

pixels, e.g. epn_ff20_sdY0.rmf. These matrices are valid for fullFrame mode. Similar matrices are available for extended full frame (e.g. epn_ef20_sdY9.rmf) and small window (e.g. epn_sw20_sY9.rmf) modes.

The correct RMF to use depends on the position of the source on the image. The position of the centre of the source area should be found in RAW or Detector coordinates and then the appropriate RMF selected from Table 2 depending on the value of RAW-Y or DET-Y. In general, on-axis sources use the epn_ * _*Y9.rmf matrices. For extended sources the best rmf can be chosen by finding the average RAW-Y or DET-Y from an event list using the FTOOL `fstatistic`. For large source areas it may be more accurate to divide the spatial region into several areas and fit these spectra simultaneously with their appropriate matrices. `rmfgen` calculates the correct RMF for the input spectrum by reading the observation mode, source position and pattern selection from the file header.

3.3 Features tested

This work has tested:

- Mirror effective areas
- Vignetting
- Thin and Medium filter transmission
- Detector quantum efficiency
- Energy redistribution functions
- PSF or encircled energy correction
- Event pattern selection

It has not tested:

Table 3: **Observations table**

Source	Revolution(s)
G21.5-09	60,61,62,64,65
MKN205	75

- Thick filter transmissions.
- Pile-up effects

3.4 Observations used

The calibration observations used within this work are listed in Table 3.

3.5 CCF elements used

The following CCF files were used in the generation of ARFs and RMFs.

```
EMOS1_PATTERNLIB_0005.CCF
EMOS2_PATTERNLIB_0005.CCF
EPN_PATTERNLIB_0001.CCF
EMOS1_QUANTUMEF_0010.CCF
EMOS2_QUANTUMEF_0010.CCF
EPN_QUANTUMEF_0010.CCF
EMOS1_REDIST_0012.CCF
EMOS2_REDIST_0012.CCF
EPN_REDIST_0007.CCF
XMM_ABSCOEFS_0004.CCF
XMM_MISCDATA_0014.CCF
XRT1_XAREAEF_0008.CCF
XRT2_XAREAEF_0009.CCF
XRT3_XAREAEF_0008.CCF
XRT1_XPSF_0005.CCF
XRT2_XPSF_0005.CCF
XRT3_XPSF_0003.CCF
```

Please see the CCF release notes, particularly XMM-CCF-REL-100, XMM-CCF-REL-112 and XMM-CCF-REL-113 for more details. These are available from *http://xmm.vilspa.esa.es/ccf/releasenotes*

3.6 Preparation of spectra

Spectra used within `arfgen` and `rmfgen` **MUST** be created using the default PI channels and binning.

MOS: spectralbinsize=15, specchannelmin=0, specchannelmax=11999
PN: spectralbinsize=5, specchannelmin=0, specchannelmax=20479

The software will usually complete successfully if different size spectra are created but the response matrices will not be correct.

To improve statistics, spectra may be rebinned after the response matrices have been made using commands such as `grppha`.

4 Detailed comparisons

4.1 MOS

4.1.1 Response at all energies

The `fakeit` function in XSPEC was used to produce a spectrum over all channels of an unabsorbed power-law of photon index 1.5, using the canned response. This was then compared with the SAS generated response to the same spectrum, using the same spectral parameters (Figures 1 and 2). The ratio plot for both MOS cameras shows that the SAS response is within 1% of the canned matrices except below 0.3 keV.

4.1.2 Off-axis response

A set of observations of the supernova remnant, G21.5-09, were used to test the SAS off-axis response. The observations have been made on-axis and at four different positions off-axis and are described in an earlier analysis of the XMM vignetting function [3]. The off-axis measurements have all been made at an off-axis angle of about 10 arcminutes but on different CCDs. This latter point is important as it allows a consistency check on the response of each chip and also tests the understanding of the azimuthal dependance of the vignetting function, introduced on the MOS cameras by the transmission through the Reflection Grating Array (RGA) [5].

The spectra were extracted from a circular source region of radius 67 arcseconds to minimise any correction needed for the point spread function (PSF). Response matrices were generated with the PSF correction turned off. The spectra were fitted over the energy range 1.0–10 keV and were reasonably well described by an absorbed power-law of photon index ~ 1.86 and galactic absorption $N_h \sim 2.3 \times 10^{22}$ cm^{-2}.

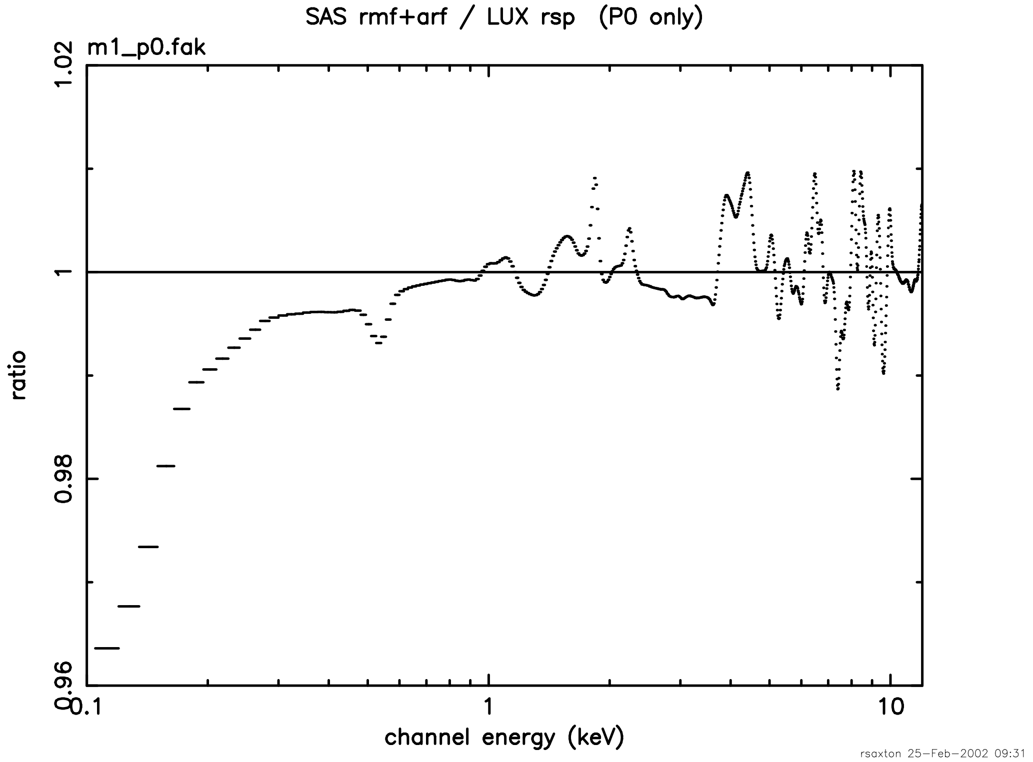

Figure 1: Comparison of MOS-1, single-pixel event, thin filter response to a slope=1.5 power-law spectrum

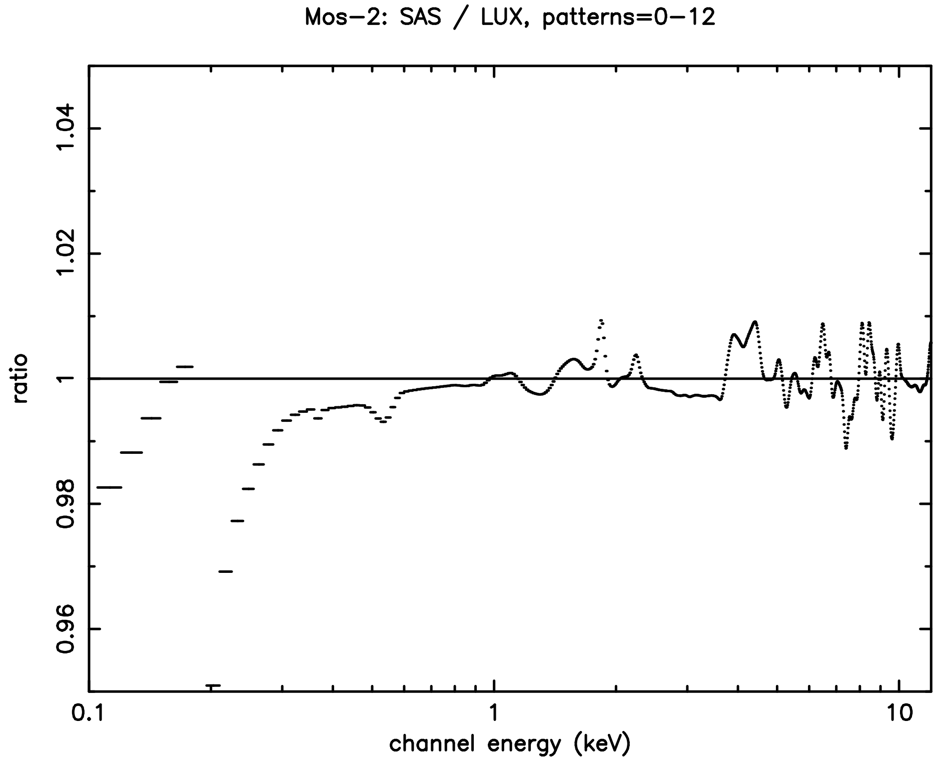

Figure 2: Comparison of MOS-2, pattern 0–12, thin filter response to a slope=1.5 power-law spectrum

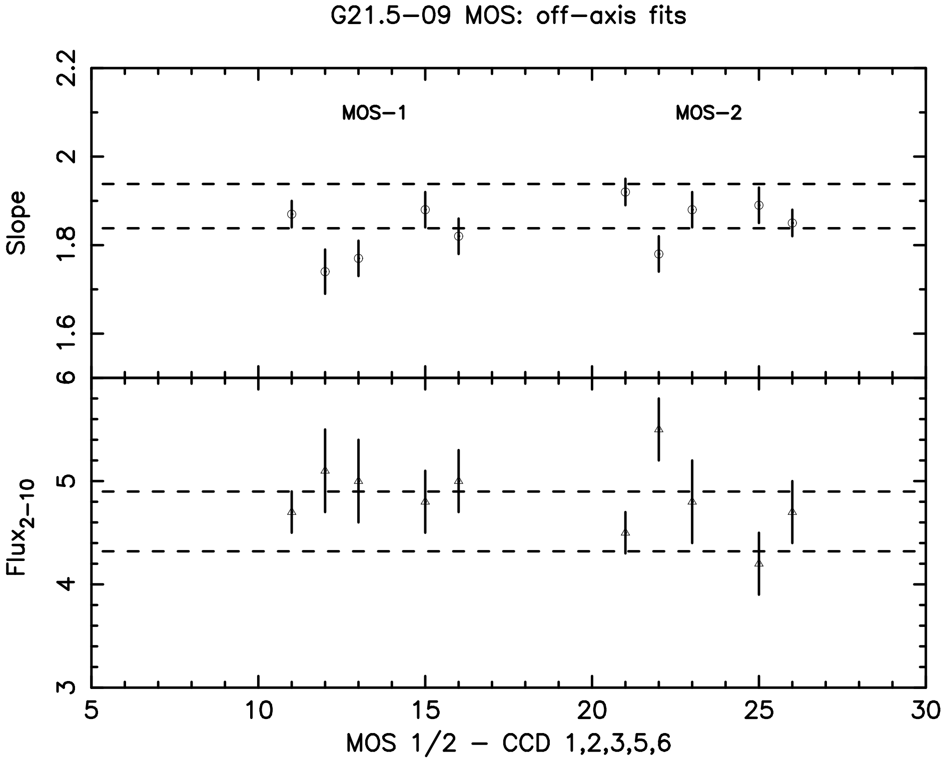

Figure 3: Comparisons of MOS SAS generated and standard matrix spectral fits

Both the index of the best-fit power-law and the 2–10 keV flux were compared for each observation and are displayed in Figure 3. The dashed lines represent the 90% error limits of the averaged best-fit parameters for the spectral fits of the two on-axis observations using the standard responses. The data points are the best-fit parameters of all the observations using the SAS generated matrices. The X-axis codes the camera number and CCD number of the observation, e.g. X=11 is [MOS1, CCD1], X=23 is [MOS2, CCD3], where the CCD1 observation is on-axis and the others are about 10 arcminutes off-axis. It can be seen that the fits aren't quite consistent. This implies a problem with the vignetting calibration which is being actively investigated (see http://...... for the latest information).

4.1.3 Check for pattern consistency

A MOS2 spectrum of G21.5-09, observed on-axis with the Medium filter, was extracted using the standard selection of event patterns 0–12. As a check that the SAS can support spectra chosen with different patterns, a spectrum containing only pattern 0 events was also created. This was fit with the SAS generated RMF and effective area files. The spectra were fit between 1.0 and 10 keV with an absorbed power-law and gave consistent spectral parameters (Table 4).

Table 4: **Spectral fits using different pattern selection**

Camera	Spectrum	Photon index (2-10 keV)	Flux
Mos-1	Patts 0-12	1.87 ± 0.03	4.7 ± 0.2
Mos-1	Pattern 0	1.88 ± 0.04	4.8 ± 0.3
PN	Patts 0-4	1.87 ± 0.02	4.0 ± 0.1
PN	Pattern 0	1.90 ± 0.03	4.0 ± 0.1

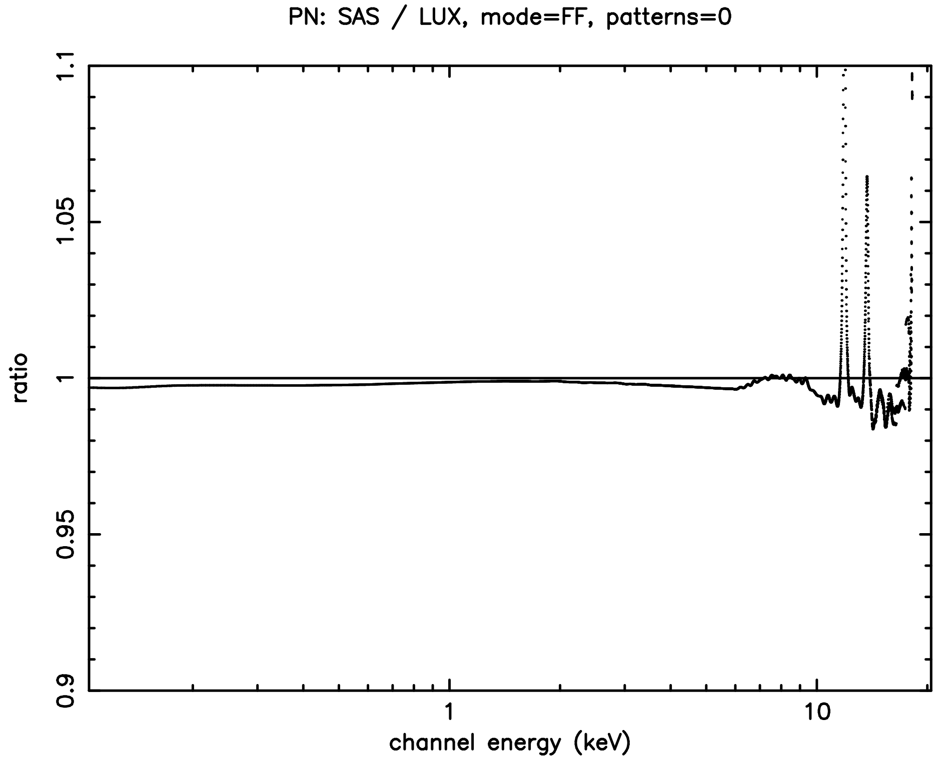

Figure 4: Comparison of PN, single-pixel event, full frame mode response to a slope=1.5 power-law spectrum.

4.2 PN

4.2.1 Response at all energies

The `fakeit` function in XSPEC was used to produce a PN spectrum, over all channels, of an unabsorbed power-law of photon index 1.5, using the on-axis standard response. This was compared with the SAS generated response to the same spectrum (Figure 4). The ratio plot shows that the responses are comparable from $\sim$ 0.1 to 14 keV. There are some sharp differences above 11 keV which are probably caused by different extrapolation techniques.

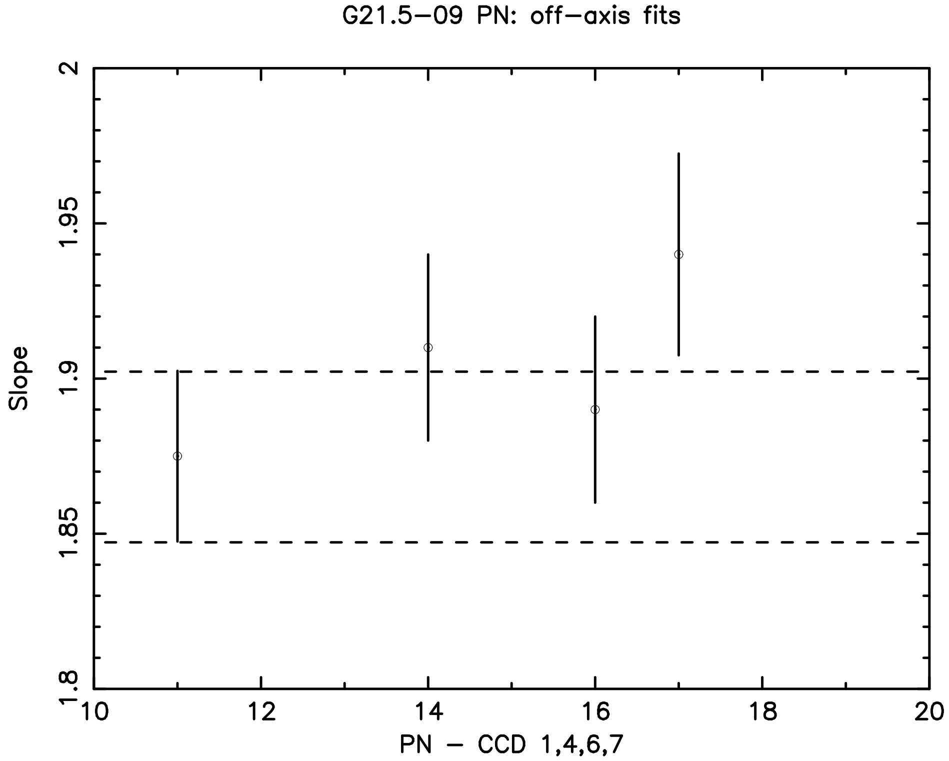

Figure 5: Comparison of PN SAS generated and standard matrix spectral fits

4.2.2 Off-axis response

The same set of G21.5-09 observations were used to calibrate the off-axis response of the EPIC-PN although only the on-axis (CCD 1) and three off-axis observations (CCDs 4, 6 and 7) were useable. The spectra were fit over an energy range of 1 to 10 keV where a good fit was obtained to an absorbed power-law. The spectral indices calculated using the SAS generated matrices are shown as data points in Figure 5. The observations show slightly inconsistent slopes which again may point to a vignetting calibration problem.

5 Point Spread Function correction

A new encircled energy correction was introduced in SAS v5.1, which is energy dependent, varies with off-axis angle and is relevant for sources extracted from within a single circular source box. The values are based on a parameterisation of the PSF as a King profile [8] and on-axis show a slight increase of the encircled energy with photon energy for source areas of radius 1 arcminute or less.

The SAS encircled energy correction is applied by default if the spectrum has been extracted from within a circular source box. If the source region is non-circular then a different PSF correction is applied which is known to have normalisation problems. In

Table 5: **Spectral fits using different extraction radii**

Radius	Mos-1		PN	
(arcsec)	Slope	Flux[a]	Slope	Flux
20	$1.80^{+0.04}_{-0.02}$	$5.31^{+0.18}_{-0.08}$	1.83 ± 0.02	5.12 ± 0.10
40	$1.79^{+0.03}_{-0.02}$	$5.31^{+0.16}_{-0.07}$	1.83 ± 0.02	5.04 ± 0.09
60	$1.79^{+0.03}_{-0.02}$	$5.36^{+0.16}_{-0.06}$	1.84 ± 0.02	5.00 ± 0.11
120	$1.80^{+0.04}_{-0.02}$	$5.47^{+0.10}_{-0.10}$	1.83 ± 0.03	5.18 ± 0.12
5–40	$1.76^{+0.04}_{-0.03}$	$5.44^{+0.25}_{-0.09}$	1.82 ± 0.03	4.91 ± 0.23
15–60	$1.72^{+0.06}_{-0.06}$	$5.57^{+0.30}_{-0.20}$	1.84 ± 0.05	4.48 ± 0.30

[a] 2–10 keV flux in units of 10^{-12} ergs cm^{-2} s^{-1}

either case the encircled energy correction may be turned off by setting *modelee=no* on the `arfgen` command line.

To test the validity of the PSF, spectra of MKN 205 have been extracted from circles of radius 20", 40", 60" and 120" and annuli of 5–40" and 15–60" and the corresponding ARF generated. The resultant fits show an good agreement of the spectral parameters for the MOS-1 and PN telescopes (Table 5) except for the PN 15–60" annulus.

The encircled energy for all three telescopes has been calculated for off-axis angles of upto 10 arcminutes and the correction in the SAS is valid out to this distance.

6 CCD gaps and bad pixels

Sources which lie close to chip gaps or close to the edge of the field are difficult to analyse because of the uncertain loss of flux within the source box. An option to correct the ARF for this missing flux is switched on by default within `arfgen` . For extended sources it reduces the ARF by the ratio of the dead area (chip gaps and bad pixels/columns) to the live on-chip area. For point sources it folds the bad pixels and chip gaps with the point spread function to give an energy-dependent estimate of the reduction in the encircled energy fraction due to the dead area. The PSF used is the same as described in section 5. In theory this feature allows a reasonably accurate measure of the flux and spectrum of a source even when its centre lies within a CCD gap.

The bad pixels, which include ones specific to the instrument and also specific to the particular observation, are contained in extensions within the event dataset. To include a correction for these pixels the parameter *badpixlocation* should be set to the event file on the `arfgen` command line (see section 8.1).

PN events falling in pixels adjacent to chip gaps are not reliable and should be excluded by creating the spectrum with the option *FLAG=0*. It is assumed that these events have been excluded within *arfgen* and the effective areas are corrected accordingly. For the MOS cameras, pixels which lie next to chip gaps are generally included in the analysis and not corrected for in `arfgen` .

7 Processing time estimates

Calculated from a lightly-loaded SUN enterprise 450, with 4 processors and 2GB of memory.

```
Camera          Time(mins)
            arfgen      rmfgen
mos           2           23
pn            2           43
```

The quoted time for `arfgen` is for all effects switched on and a 10 x 10 pixel detector map.

8 Examples and recommendations

This section gives advice on how the SAS could be used to analyse XMM spectral data.

8.1 An on-axis point source

The PSF correction is reliable for circular source boxes of radius > 10 arcseconds and so, if possible, spectra should be extracted from a circular source region.

It is recommended to create a spectrum of PI channels with `xmmselect` or `evselect`, specifying the spatial area in terms of DETECTOR coordinates (DETX, DETY) or image coordinates (X,Y). The standard selections are given by:

Camera	Flags	Patterns	Spec binning	Channel Range
MOS	#XMMEA_EM	0-12	15	0-11999
PN	0	0, 1-4	5	0-20479

NB: These PI channels and this binning **MUST** be used when creating a spectrum which is going to be used within `arfgen` and `rmfgen` .

The XMMEA_E(M/P) keywords represent an ensemble of event selection flags which can be applied to the event lists. They may be applied in `xmmselect` by including them within the selection expression, e.g.

```
#XMMEA_EM&&((DETX,DETY) IN circle(103,-217,1340))&&(PATTERN<=12)
```

The 'writedss' and 'updateexposure' options must be selected in the `general` pane of `evselect`. The former creates a data subspace description in the SPECTRUM extension of the spectral file while the latter updates the EXPOSURE keyword in the same extension. Patterns 0–12 should be used for MOS spectra unless the source is piled-up (see section 8.4). The recommended processing for PN spectra is to produce a pattern 0 only (single-pixel event) spectrum and a pattern 1–4 (double-pixel event) spectrum; process them separately but fit them simultaneously. If the source is weak, however, it is better to extract a single spectrum containing patterns 0–4 to improve the statistics.

The RMF file(s) may be generated by `rmfgen` , e.g.

```
> rmfgen spectrumset=<myspec.ds> rmfset=<myrmf.ds>
```

or may be retrieved from the standard set of matrices using the information in section 3.2. An ARF file can be created by the command:

```
> arfgen spectrumset=<myspec.ds> arfset=<myarf.ds> badpixlocation=<event file>
         detmaptype=psf
```

This will produce a file, myarf.ds, appropriate for the position of the source on the detector, with the default energy binning, with a PSF correction applied and corrected for any bad pixels, columns or chip gaps which lie within the source region. **NB:** Do not run the FTOOL `grppha` on the spectrum file prior to running `arfgen` , as the former adds keywords to the spectrum file that are not compatible with any SAS task.

If a canned rmf file is going to be used then the ARF should be created with a command of the form:

```
> arfgen spectrumset=<myspec.ds> arfset=<myarf.ds> badpixlocation=<event file>
         withrmfset=yes rmfset=<rmffile> detmaptype=psf
```

where rmffile is the name of the standard matrix, e.g. m1_r6_all_15.rmf.

The quantum efficiency of the detectors is spatially dependent and this is averaged correctly for a point source if a PSF detector map is used.

8.2 Preparing a background spectrum

A simple background file may be generated, using `xmmselect` or `evselect`, over the same channel range and having roughly the same off-axis angle. In `xmmselect` this may be done by either:

(i) Dragging the source extraction region to a neighbouring source-free region, preferably at a similar off-axis angle.

(ii) Creating an annulus around the source with the expression:

```
!(detx,dety in CIRCLE(x,y,radius))&&(detx,dety in CIRCLE(x,y,2*radius))
```

where x,y, radius defines the circular source box.

The relative sizes of the source and background regions are specified in the spectra by the BACKSCAL keyword which is created by the `backscale` routine (run automatically within xmmselect if selected within the *Products* menu option). This value is then used to normalise the background before subtraction by programs such as `xspec`.

If the background is taken from a region at a different off-axis angle to the source then it ought to be corrected for the telescope vignetting. This can be performed by the routine `backcorr` although there are many issues here, such as the different spatial distribution of particles and photons, which haven't yet been addressed in the SAS and for which no corrections may currently be applied.

As an example the resultant files may be used in XSPEC by:

```
> xspec
  XSPEC> data myspec.ds
  XSPEC> back myback.ds
  XSPEC> resp epn_ff20_sY9.rmf
  XSPEC> arf myarf.ds
```

8.3 An off-axis point source

The procedure is essentially the same as for an on-axis source except that for large off-axis angles the source extraction radius should be made a little larger to account for the extended PSF.

8.4 A source suffering from Pile-up

This problem can be alleviated to an extent by extracting spectra with pattern=0 only. The pattern zero response matrix should then be used when spectral fitting.

Another option is to exclude the centre of the PSF from the analysis. A spectra may be extracted from an annulus about the source of inner radius 20 arcsecs and outer radius 60 arcsecs. This will contain $\sim 17\%$ of the counts at 1.5 keV. The fraction of counts contained in the annulus will be calculated by `arfgen` . A little care needs to be excercised here;

the absolute error on the PSF calculation is $\sim 1\%$, this is small compared to the encircled energy in a circular source box but actually equates to an error of $\sim 6\%$ for the above annulus. The ARF does not contain errors and so spectral fits of annular source regions contain a substantial implicit systematic calibration error which is not taken into account by the fitting software.

8.5 An extended source

If the source has considerable spatial variation then a flux weighted ARF needs to be generated. This requires the generation of a detector map (an image of the source in DETX/DETY) coordinates, which should be passed to `arfgen` by setting the parameter *detmaptype* to `dataset` and setting the parameter *detmaparray* to the name of the image file. The detector image should be created in detector pixel coordinates by xmmselect or evselect and should be coarsely sampled, an image of 20 x 20 pixels would be normal. It needs to more than cover the region over which the spectrum was taken.

The parameter *extendedsource* must be set to `true` to turn off point source effects such as the PSF correction.

```
> arfgen spectrumset=<myspec.ds> detmaptype=dataset detmaparray=<detmap.ds>
extendedsource=true badpixlocation=<event.ds> withrmfset=yes
rmfset=<epn_ff20_sY6.rmf> arfset=<myarf.ds>
```

For extended sources which have little spatial variation the default *flat* detector map can be used.

```
> arfgen spectrumset=<myspec.ds> detmaptype=flat extendedsource=true
badpixlocation=<event.ds> withrmfset=yes rmfset=<m1_r6_all_15.rmf>
arfset=<myarf.ds>
```

8.5.1 Preparation of a detector image

A detector image produced by *evselect* or *xmmselect*, as described above, will of course have the vignetting folded in. Ideally, flux weighting the ARF should be performed with a de-vignetted image. This can be achieved by dividing through with the exposure map, using the following procdeure.

Create the exposure map in detector coordinates by e.g.

```
> eexpmap attitudeset=P0051590201OBX000ATTTSR0000.FIT usedss=true attrebin=2
expimageset=detexpmap.ds pimin='200'
eventset=P0051590201PNS002PIEVLI0000.FIT pimax='12000'
imageset=detmap.ds withdetcoords=yes
```

Then divide the source image with the exposure map by:

```
> farith detmap.ds detexpmap.ds devigimage.ds "/"
```

8.5.2 Surface Brightness

If the output required from the data analysis is the surface brightness of the source, rather than the flux, then a different approach is needed. The live area of the detector used to extract the source counts is calculated by `backscale` and stored in the BACKSCAL keyword in the spectrum header. Surface brightness would then be calculated by dividing the flux by this value. It is important that the flux calculated by spectral fitting does not also take into account dead areas such as chip gaps, otherwise these corrections will be applied twice. To avoid this, create the ARF by:

```
> arfgen spectrumset=<myspec.ds> detmaptype=dataset detmaparray=<detmap.ds>
extendedsource=true withbadpixcorr=no arfset=<myarf.ds>
```

8.6 Spectral fitting advice

As mentioned earlier an ungrouped spectrum should be used as the input file for `arfgen` when an ARF is being created. However, grouping spectral channels to give a minimum number of counts per bin, using for example the `GRPPHA` routine, before performing spectral fits is recommended. This tool may also be used to set the BACKFILE, RESPFILE and ANCRFILE keywords in the spectrum.

8.6.1 Selecting an energy range

From the point of view of the SAS, spectral fits can be safely made down to 300 eV. There are known calibration issues which mean that care should be excercised when fitting at the low-energy end of the spectrum. With the calibration status, as of SAS V5.3, it would be wise to consult the instrument teams if spectral fitting below 600 eV is required.

There are no known major problems at the high-energy end.

8.6.2 Gain calibration effects

The spectral information of each event is originally extracted from the CCD as a PHA channel. A gain calibration is applied to this PHA channel to convert it into a PI channel which can then be interpreted in terms of photon energy. It is clear that the interpretation of the resultant source spectrum is dependent on the gain calibration being right.

There are currently some concerns about this calibration including:

- Significant gain changes have been observed in both the MOS and PN instrumentation as a result of platform temperature variations. Preliminary corrections for these are currently being applied to the data, but discrepancies of order 10eV might occasionally be experienced.
- There are some mode-dependent effects in the EPIC-PN detector which have been incorporated in the system since SASv5.3. Validation on a wide range of GO data sets has still to be completed.

The practical effect of this is that an apparent shift may be visible in the energy of line features. For example the gain can vary by up to $\sim$ 10eV at the Mn K (5.89 keV) calibration line. Some self-calibration may be done by taking a spectrum of a large area of background sky and finding the energy of the strong Al K (1.487 keV), Si K (1.740keV) and Cu K (8.048 keV) lines to check that the nominal gain calibration is correct before doing any fitting.

9 Calibration status

This document and the SAS tasks `arfgen` and `rmfgen` were consistent with the best known calibration at the time of the SAS 5.3 release. However, the calibration is continuously evolving and a snapshot of current knowledge is maintained on http://.......

The spectral calibration of the EPIC detectors is rather good in general. However, a number of problems have been identified and are being addressed by the instrument calibration groups. Solutions for these problems will become available in the SAS through updates to the CCF and new releases of the canned RMFs. The CCF release notes, available from *http://xmm.vilspa.esa.es/ccf/releasenotes*, may be monitored by the user wishing to keep in touch with advances.

- Canned RMFs for the PN camera modes LW, TI and BU will be made available from *http://xmm.vilspa.esa.es/ccf/epic/* . These modes are not supported by `rmfgen` currently.
- The MOS CTI has degraded to the point where spectral line resolution is now measurably worse than at the beginning of the mission. It is proposed to issue a small series of canned RMFs to cover different observing epochs.
- There are questions surrounding the vignetting which suggest that the optical axis may not be correctly set. This could lead to flux errors of a few percent
- The MOS and PN cameras show small differences in their spectral fits with the PN tending to exhibit steeper spectral slopes with a deficit of flux at the higher energies [9].

- There are systematic residuals of $\sim 5\%$ seen in both MOS and PN spectral fits around the Oxygen edge (~ 0.6 keV) and less significantly at the Gold edge (2.2 keV).

10 Future plans

- Support all observing modes
- Support time-dependent MOS RMFs within `rmfgen`
- Allow spatial-averaging of RMFs for extended sources
- Include a full treatment of event selection flags within `arfgen`

Please mail rds@star.le.ac.uk to discuss any extra functionality which may be required or alternatively raise an SPR/SCR via the SOC web-site,
http://xmm.vilspa.esa.es/sas/db/

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