

XMM-Newton

XMM-Newton Science Analysis System 15.0 scientific validation

XMM-SOC-USR-TN-0026 Issue 1.0

C.Gabriel, I. de la Calle, A.Ibarra, R.González-Riestra,
E.Ojero, J.V.Perea, P.Rodríguez, R.Saxton, M. Smith, M.Stuhlinger, A.Talavera
XMM-Newton Science Operations Centre

July 15, 2016

Revision history

Revision number	Date	Revision author	Comments
0.9	June 15, 2016	C. Gabriel	first issue
1.0	July 15, 2016	C. Gabriel	after revision

Contents

1	Introduction	1
1.1	Methodology	1
1.2	Calibration data to be used	3
2	New and updated in SAS 15.0	3
2.1	Updated in SAS 15.0: attcalc and a number of related tasks affected by the wrong sign of the Euler ψ angle	3
2.2	New in SAS 15.0: ebkgreg , a task for determining optimal background position for a source in the FOV	4
2.3	Updated in SAS 15.0: eimagecombine , a script introduced in SAS 14 for producing (combined) EPIC background subtracted, exposure corrected smoothed images	4
2.4	New in SAS 15.0: Extraction of separated redistribution matrix (RMF) and ancillary response function (ARF) for RGS	4
2.5	New in SAS 15 - use of embadpixfind for RGS bad pixel / column finding	4
2.6	New in SAS 15.0: RGS filtering without flagging FIFO buffer full periods	4
2.7	New in SAS 15.0: Only one 32bits Linux version released	5
3	Validation results	6
3.1	Validation schedule	6
3.2	Processing of standard datasets	7
3.2.1	RGS data - standard dataset	7
3.2.2	SAS OM data processing	7
3.3	Dedicated analysis	7
3.3.1	EPIC data - G21.5-0.9	7
3.3.2	EPIC data - PKS 0558-504	8
3.3.3	Standard tests of esas	9
3.3.4	OM Fast Mode processing	9
3.3.5	Interactive tasks: omsource and omgsource	9
3.3.6	Repeatability of OM filter photometry	9
4	New and updated in SAS15 - Validation	10
4.1	Updated in SAS 15: attcalc and all the tasks affected by the wrong sign of the Euler ψ angle	10
4.2	Updated in SAS15: eimagecombine	12
4.3	New in SAS 15: ebkgreg - determining the optimal background position for a source in the FOV	12
4.4	New in SAS 15: Extraction of separated redistribution matrix (RMF) and ancillary response function (ARF) for RGS	13
4.5	New in SASv15.0: - use of adapted embadpixfind for RGS bad pixel / column finding	13
4.6	New in SASv15.0: RGS filtering without flagging FIFO buffer full periods	15
4.6.1	Validation	16
5	Conclusion	16

1 Introduction

The SAS scientific validation is performed on a standard set of XMM-Newton observations, which cover all commissioned observational modes, and a number of observations, specially chosen for testing new / special aspects of the data reduction corresponding to the version to be validated. Table 1 lists all the datasets used for the validation of SAS version 15.0. Some of these observations are particularly suitable to test calibration-related items, as specified in the rightmost column of Tab. 1. These datasets are partly intended as a standard reference, which has been and will be used to verify the performances of all SAS versions. However, additional datasets may occasionally be used to test version-specific SAS items. This is the case, for instance, for the datasets discussed in Sect. 2 of this report. Datasets discussed in a given report and not listed in Tab. 1 do not belong to the reference datasets, and are therefore not intended to be discussed in later SAS versions validation reports.

1.1 Methodology

The SV for SAS v15.0 consisted of the following steps:

1. all the datasets listed in Tab. 1 were processed through the SAS 15.0 based testing Pipeline System (PPS) running at the SOC, and
2. the same datasets were also processed through the SAS reduction meta-tasks:
`e[mp]proc`, `om[ifg]chain`, `rgsproc`
3. all the SAS threads were ran as documented, for checking the integrity of the software and the validity of the threads
4. products generated by the above steps were used as basis for the *interactive SV analysis*. Standard scientific products (images, light curves, spectra, source lists) were generated and analysed. This allowed us to:
 - test the SAS interactive tasks.
 - verify the calibration accuracy obtained with SAS v15.0, and compare it with the expected accuracy on the basis of the calibration status at the time the SV is performed.
5. in addition the whole cross-calibration database has been reduced by standard analysis scripts based on SAS but including also model fitting through Xspec.

Table 1: SV datasets

Instrument	Mode	Object	Revolution Obs. ID	ID	Calibration item
EPIC MOS	Full Frame "	Lockman Hole G21.5.09	544 0147511601 060 0122700101	1 2	Astrometry + source detection Effective area
	Small Window (W2)	Mkn 421	165 0099280201	3	
	Large Window (W3)	PKS0558-504	153 0129360201	4	Effective area
	Timing Uncompressed	Her X-1	207 0134120101	5	Timing
EPIC-pn	Full Frame Full Frame/Small Window	Lockman Hole PKS0558-504	544 0147511601 153 0129360201	1 4	Astrometry Effective area
	Large Window	AB Dor	185 0133120201	6	
	Small Window	PKS0558-504	084 0125110101	7	Effective area
	Fast Timing	Her X-1 Crab	207 0134120101 698 0160960201	5 8	Timing
	Fast Burst	Crab Crab	411 0153750301 411 0153750501	9 10	Timing Timing
	Extended Full Frame	G21.5-0.9	060 0122700101	2	Effective area
	Slew Data		1388 9138800002	18	Slew data processing
	Slew Data		1450 9145000003	19	Slew data processing
RGS "	SPEC+Q	PKS0558-504	084 0125110101	7	
	"	Mkn 421	165 0099280201	3	Effective area
	"	AB Dor	185 0133120201	6	Wavelength scale
	"	AB Dor	338 0134521301	11	Wavelength scale
	"	AB Dor	462 0134521601	12	Wavelength scale
	"	AB Dor	572 0134522201	13	Wavelength scale
OM	Image Mode	BPM 16274	261 0125320701	14	Photometry
	Fast Mode	X1822-371	228 0111230101	15	
	FF Low Resolution	BPM 16274	261 0125320701	14	Astrometry
	Optical grism	Hz2	503 0125910901	16	Wavelength scale & flux calibration
	UV Grism	HD13499 (offset)	657 0125911301	17	Wavelength scale & flux calibration

1.2 Calibration data to be used

The calibration data to be used for this version was derived from the full public calibration constituents as of 21 December 2015, plus the following components which at this date were not yet public:

- XMM-BORESIGHT_0026.CCF (made public with the SAS 15 release, since it is related to a new ALGOID for the upgraded astrometry),
- RGS1_ADUCONV_0026.CCF, RGS2_ADUCONV_0033.CCF, RGS1_CTL_0014.CCF and RGS2_CTL_0015.CCF (all of them were already approved at mid December, but were waiting for editorial work of the corresponding release note to be made public), and
- XRT3_XPSF_0017.CCF (it was waiting for the release note to be written, affecting only source detection by slew data).

2 New and updated in SAS 15.0

V. 15.0 is a main yearly release of the SAS, containing some new capabilities of the package. The main item of the upgrade, though, was the correction of a problem related to the conversion between image (POS, X/Y) and camera (DET or RAW) coordinates, manifested in several conversions in the SAS infrastructure.

The error introduced very early in the SAS history increased with off-axis angle and could go up to 7-8 arc-seconds. It originated in a wrong sign of the Euler ψ angle, contained within the boresight matrix and also in the task `attcalc`, in which the wrong sign of ψ was introduced. Since the boresight misalignment angles have been calculated using that matrix, whenever this is used by `attcalc` the error cancels out. This is the reason why the source positions in eg. the XMM-Newton source catalogues are not affected. However, the usage of fundamental routines for coordinates transformation using the boresight misalignment angles was affected.

SAS 15 contains also a new task (`ebkgreg`) for optimal background position determination for any source in the FOV. Especially designed for optimising the pipeline processing of specific source products, it can also help the interactive SAS user for obtaining net spectra and light curves of multiple sources after source detection.

Further important upgrades have been performed in the RGS data analysis area. Now it is possible to obtain separated ARF and RMF matrices for RGS. Also a new non-default bad column / pixel determination for RGS has been developed, based on the algorithm used for the same purpose with the MOS data. In addition, filtering out so called FIFO full events can be disabled.

2.1 Updated in SAS 15.0: `attcalc` and a number of related tasks affected by the wrong sign of the Euler ψ angle

A full campaign has taken place for validating all the changes introduced to get the conversion between image and camera coordinates right. The results are shown in a separate technical note (<http://xmm2.esac.esa.int/docs/documents/CAL-SRN-0332-1-0.ps.gz>), but also summarised in this validation document.

2.2 New in SAS 15.0: `ebkgreg`, a task for determining optimal background position for a source in the FOV

This task has so far been implemented only for PN. Interactive use has been tested, including its behaviour by crowded images. A number of observations with many sources in the FoV (i.e. deep observations of the Lockman Hole area) as well as with extended sources (eg. clusters) were used for the validation.

2.3 Updated in SAS 15.0: `eimagecombine`, a script introduced in SAS 14 for producing (combined) EPIC background subtracted, exposure corrected smoothed images

The basic work is performed by another introduced task with SAS 14, `eimageget`, which creates a set of images from one EPIC exposure, which make possible the derivation of combined background-subtracted exposure corrected images. (`eimagecombine` is a perl script around that task for the combination of the images derived from one or several observations).

The script was not running on Mac platforms under certain circumstances and has been upgraded and made more robust.

Validation of the task has been done processing different observations covering certain regions of the sky and creating the corresponding mosaic. In addition the products should be compared to interactive sophisticated background estimation and mosaic creation with `esas`.

2.4 New in SAS 15.0: Extraction of separated redistribution matrix (RMF) and ancillary response function (ARF) for RGS

The task `rgsrmfgen` is capable now of producing RMF and ARF in separate files. This can ease the analysis in many cases, making it much more efficient.

Validation has been performed by comparing spectral results with the (default) combined matrix and with the individual ARF and RMF for the same observations.

2.5 New in SAS 15 - use of `embadpixfind` for RGS bad pixel / column finding

The task `embadpixfind` has been adapted for its use on the RGS data reduction chain. The corresponding (default) task `rgsbadpix` used for flagging bad pixels and columns has been reported to discard in certain circumstances columns belonging to bright emission lines, when actually these columns should be perfectly valid.

A thorough validation has to show the advantages in those cases, but also the results of applying this new bad pixel recognition to data of continuum sources, i.e. in the absence of emission or absorption lines.

Validation has been therefore done comparing the results of tens of observations showing emission lines at different wavelengths (ie. AB Dor, HR1099) using both methods for flagging bad columns, as well as of continuum observations at different signal levels (ie. different observations of Markarian 421).

2.6 New in SAS 15.0: RGS filtering without flagging FIFO buffer full periods

"FIFO buffer full periods" are those reported in the HK data when the number of events getting into the RGS on-board processor reaches a certain limit, which eventually can be followed by not accepting events anymore. The data in those frames going through the processor, however, get processed correctly. So far, the data during those periods, due to bright sources or to

high radiation, with "FIFO Buffer full", were discarded. It has been shown that the data can be perfectly valid in those periods, and that a counter "NLOSTEVT" in the science data is actually more reliable. If a frame shows NLOSTEVT=0 then the frame is perfectly acceptable. Validation was performed processing a large number of observations comparing them with and without this flag been used for filtering. Especially data from bright sources showing periods discarded due to the FIFO Buffer Full flag has been processed in both ways and compared as well as the spectra obtained in the different periods (with and without FIFO Buffer Full).

2.7 New in SAS 15.0: Only one 32bits Linux version released

This SAS version has been released in diverse Linux OS 64 bits versions as well as two MacOS versions, to cover a broad band of kernels. And for the last time probably one 32 bits Linux version has been included. The number of 32bit users of the latest SAS version (in three different Linux flavors) is around 18%, according to the collected download statistics. Releasing just the most downloaded 32 bit version, we would be affecting less than 10% of the SAS users. A validation cross check has been performed testing this version under other 32bit operating systems, by running the testing sequences.

3 Validation results

3.1 Validation schedule

The schedule for the validation had foreseen a total of 6 weeks for performing the different tasks (for the period from going into release track mode to final release). This was the projected schedule with the different milestones:

- SAS into release track mode - 14 December 2015
- SAS builds on different platforms - 18 December
- SAS 15 binaries (at least 1 platform) - 18 December
- Processing of all the standard datasets - finished - 22 December
- Installation of SAS 15 binary in XCal grid - 18 December
- Communication to validators about success and data location - 22 December
- Preparation of a SAS 15 based PPS test version - 8 January
- Processing of standard datasets by testing pipeline - 15 January
- Processing of standard datasets by all binaries - 22 January
- Processing of XCal archive - 15 January
- Processing with single 32bit SAS binary on diverse OS - 15 January
- First I/A analysis of standard data - to be ready by 22 January
- Integrity checks running all the existing SAS threads - to be ready by 29 January
- Evaluation of XCal - to be ready by 29 January
- Screening of PPS processed standard datasets - 29 January
- Dedicated analysis - to be ready by 29 January:
 1. `ebkgreg` tests
 2. `eimageget` and `eimagecombine`
 3. RGS data processed with separate ARF / RMF
 4. RGS new bad pixel finding method
 5. RGS new filtering (no FIFO buffer full)
- Summary reports due on 29 January
- Release notes + SAS 15 web pages contents ready + XMM Newsletter text - 3 February
- SAS 15 distribution tar files ready - 3 February
- Final SV individual reports - 4 March
- SAS 15 release - 4 February
- Final SV Report compilation

With small variations in the order of days, the plan was followed. The release date was respected, so that SAS 15 has been released punctually on February 4.

3.2 Processing of standard datasets

All the data listed in Tab. 1 have been processed with the full data reduction scripts used for validation without any failure, on the 11 building platforms (9 Linux and 2 MacOS). In addition, the 32 bit SAS 15 binaries produced for Ubuntu 14, has been used by the other three 32bit platforms (Fedora 20, RHEL 5.8 and SuSe 13.1) for cross-checking. The processing was fully satisfactory.

A test pipeline version, built on the basis of SAS 15, has also been used for the data reduction of the standard sets. No errors were found, and the output was correctly derived. Screening of the PPS processed data has taken place with fully satisfactory results. The test pipeline version has evolved into the final released PPS based on SAS 15, operational since end of April.

The XCal archive was also populated with all the products from processing with SAS15 all the data in the calibration database. Again, no failures found, the analysis of the data and the comparisons with products from former validation campaigns form the basis for further calibration activities and reports.

3.2.1 RGS data - standard dataset

Output products of the whole processing by `rgsproc` have been compared with the results of processing with previous versions of SAS. No significative differences have been found. Detailed studies are referred further below.

3.2.2 SAS OM data processing

There are no major changes in the OM tasks in this version of SAS.

The changes in the use of the XMM-Newton Boresight CCF in the attitude reconstruction tasks of EPIC do not affect OM. Only an update of the variable component of the boresight has been implemented via the corresponding CCF.

A bug has been corrected: it affected the deadfraction correction of the rates of sources detected in mosaiced or stacked images. In previous versions of SAS, running `ommosaic` assigned to the final image the maximum framerate and deadfraction of the component images. This is contradictory because both parameters are inversely proportional, thus once the framerate is assigned (the maximum one) the corresponding deadfraction is deduced from that framerate. The error of the wrong assignement in the final count rates was very small, less than 2 %. Now this inconsistency has been solved.

In addition to checking the mentioned new implementations, as in previous deliveries, this Science validation has been devoted to check and confirm that the main functionalities already present in previous versions are maintained, in other words, we confirm the overall stability of the system. The reader is thus referred to previous Science Validation Reports for more detailed comments or descriptions.

3.3 Dedicated analysis

3.3.1 EPIC data - G21.5-0.9

The non-thermal SNR G21.5-0.9 has been used as one of the standard targets for the validation of the EPIC effective area calibration. Additionally, this source has proven useful in multi-

mission cross-calibration studies (Tsujiimoto et al. 2011). Its spectrum can be well modelled by a simple power-law combined with a photoelectric absorption.

In observation 0122700101, G21.5-0.9 was observed with MOS in Full Frame mode and PN in Extended Full Frame Mode (all using Medium Filter) for 30 ks. MOS and PN source spectra were extracted from a circular region (~ 2.5 arcmin radius) around the SNR, and spatially filtered through their common exposure mask. MOS background spectra were obtained from annular regions around the source, whereas PN background was obtained from neighbouring source free regions. EPIC data were reduced with SAS 15.0 and spectra were extracted with standard event pattern selection.

The results of the comparison of PN and MOS are summarised in Fig. 1, and are essentially in agreement with the previous SAS science validation study. This is as expected, as no significant changes in energy scale calibration have been introduced in the meantime.

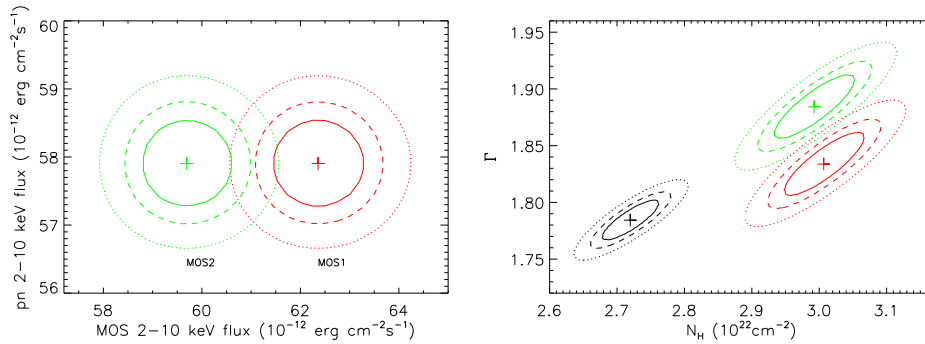


Figure 1: Comparison of PN versus MOS spectral fits of G21.5-0.9. Spectra based on data reduced with SAS 15.0, using standard pattern selection. *Left panel:* the 2-20 keV flux confidence contours for PN versus MOS1 (red) and MOS2 (green). *Right panel:* column density versus photon index confidence contours for PN (black), MOS1 (red), MOS2 (green). Levels shown are at 68%, 90% and 99% confidence.

3.3.2 EPIC data - PKS 0558-504

PKS 0558-504 is a well studied radio loud Narrow Line Seyfert 1 galaxy (e.g. Siebert et al. 1999), and has been observed by *XMM-Newton* as calibration target. Its 2-10 keV spectrum is characterised by a spectral slope $\Gamma \sim 2.2$, and the 0.2-2 keV emission is dominated by a large and featureless soft excess.

EPIC spectra of ObsId 0125110101 are compared as part of this science validation. PN was operated in Small Window Mode, and both MOS instruments in Large Window Mode. Data were reduced with SAS 15.0 (using the respective latest calibration files), and resulting spectra were fit in the 0.3–10 keV band with a model consisting of a power-law and bremsstrahlung component with an ISM absorption model (Papadakis et al. 2010). As the MOS data are subject to pile-up the spectra were extracted from annular regions.

The best fit results are summarised in Table 2. The main differences between instruments are due to the imperfect relative effective area calibration, resulting in fluxes which are formally not consistent across all three instruments.

Table 2: Comparison of MOS and PN spectral fits to PKS 0558-504 (ObsId 0125110101) with a power-law plus bremsstrahlung model.

Instrument	kT keV	Γ	Flux $10^{-11} \text{ erg cm}^{-2} \text{ s}^{-1}$		$\chi^2/\text{d.o.f.}$
			(0.3–2.0 keV)	(2.0–10.0 keV)	
MOS1	$0.24^{+0.10}_{-0.06}$	$2.20^{+0.16}_{-0.20}$	$2.09^{+0.02}_{-0.02}$	$0.91^{+0.05}_{-0.06}$	224.4/226
MOS2	$0.27^{+0.10}_{-0.08}$	$2.22^{+0.15}_{-0.19}$	$2.21^{+0.02}_{-0.02}$	$0.87^{+0.05}_{-0.05}$	252.6/244
PN	$0.28^{+0.03}_{-0.02}$	$2.01^{+0.06}_{-0.06}$	$2.47^{+0.03}_{-0.03}$	$1.06^{+0.07}_{-0.06}$	540.0/524

3.3.3 Standard tests of esas

Due to the special characteristics of **esas**, the package for analysis of extended sources observed with the EPIC cameras, particular validation tests are run with every new SAS version, to ensure its integrity and the validity of their separate calibration files. With this purpose the full thread for **esas** images extraction (<http://www.cosmos.esa.int/web/xmm-newton/sas-thread-esasimage>) has been run on the odf 0097820101 (Abel 1795 cluster), with both PN and MOS data, and the comparison to earlier results showed no discrepancies.

3.3.4 OM Fast Mode processing

The inconsistency reported in the validation of SAS 14 in relation to the contents of the BACKGROUND column in time series files (*TIMESR*) is still present: the values of the BACKGROUND have different scaling depending on the type of measurement. If it is obtained from the fast mode data, the background is given for the extraction area, while if from image data it is scaled to a 12 pixels aperture radius.

3.3.5 Interactive tasks: omsource and omgsource

Here, again the caveats reported in the validation of SAS 14 are still valid:

- **omsource**

After performing the interactive photometry of a given source, the results can be written to a FITS file. The photometric values for the source (rate, magnitude, flux) are correct, while other file columns giving the applied corrections are wrong.

- **omgsource**

During the interactive extraction of grism spectra (in 64 bits installations), a temporary plot is produced. This plot may be wrong. However, the final extracted spectra are correct.

3.3.6 Repeatability of OM filter photometry

Several spectrophotometric standard stars are observed repeatedly with OM in order to establish and monitor the photometric and flux calibrations. These are the white dwarfs GD 153, HZ 2 and BPM 16274.

As we have done in the past all existing data of these stars have been reprocessed using SAS 15. The results are presented in Tab. 3 and in Tab. 4.

The quoted errors are the standard deviation of the mean values given as percentage. We see that after all corrections are applied, the count rates of these stars obtained from all observations taken during the life of OM vary within 3 %.

Table 3: Standard stars processed with SAS 10.0: average count rates of several observations

star	N_obs	UVW2	UVM2	UVW1	U	B	V
GD153	8	82.00	160.72	327.27	418.97	282.95	70.36
error (%)		1.1	1.1	0.8	1.8	1.2	1.5
HZ2	11	23.54	48.09	111.42	168.80	149.01	43.05
error (%)		2.7	3.0	1.9	0.9	1.2	1.2
BPM16274	18	14.60	30.28	72.78	112.85	107.87	32.57
error (%)		2.8	3.3	1.6	1.1	1.5	1.8

Table 4: Standard stars processed with SAS 15.0: average count rates of several observations

star	N_obs	UVW2	UVM2	UVW1	U	B	V
GD153	13	83.51	163.59	331.00	420.92	284.60	71.53
error (%)		1.6	1.6	1.0	1.4	1.0	2.4
HZ2	17	23.90	48.78	112.30	169.29	149.36	43.88
error (%)		2.2	2.2	1.5	0.9	0.9	3.2
BPM16274	31	14.80	30.65	73.25	113.02	108.11	33.05
error (%)		1.8	1.9	1.1	0.7	0.9	2.5

4 New and updated in SAS15 - Validation

4.1 Updated in SAS 15: attcalc and all the tasks affected by the wrong sign of the Euler ψ angle

The CCF release note XMM-CCF-REL-332, related to calibration file XMM-BORESIGHT_0026 (<http://xmm2.esac.esa.int/docs/documents/CAL-SRN-0332-1-0.ps.gz>), derived after correcting the sign of the Euler ψ angle in the `attcalc` task, reports on all the tests performed for validating both the calibration file and the several tasks affected by the error introduced with ψ . They include not only checks that the celestial positions of sources detected by SAS 15 are not significantly altered by all the changes introduced (see Fig. 2 taken from that release note) but also that the RGS and OM data are not affected.

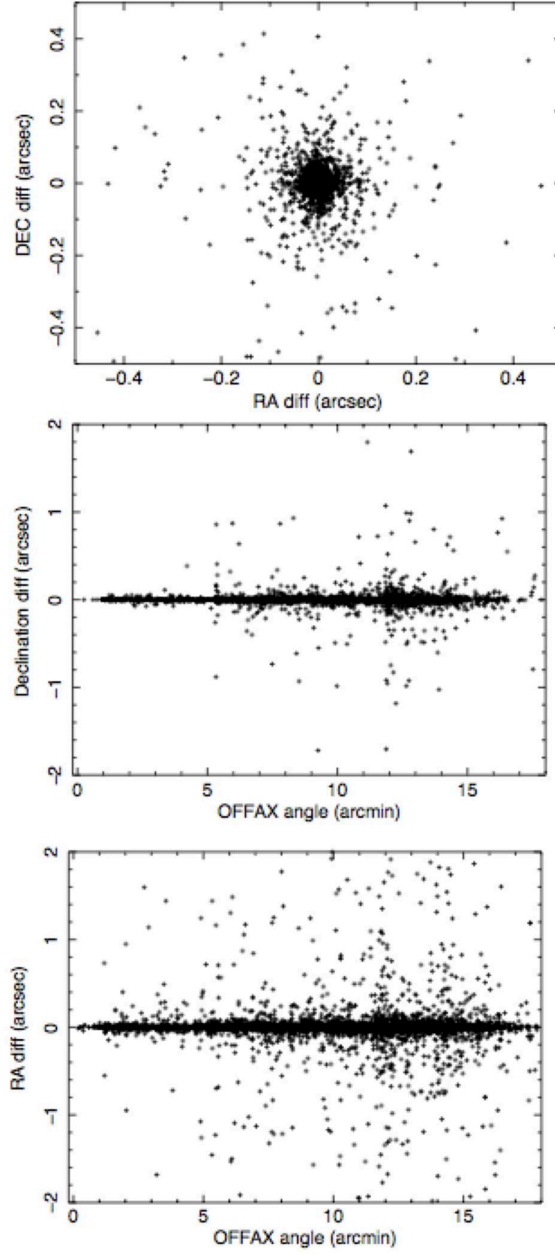


Figure 2: Differences between the celestial positions of EPIC-pn sources returned by SAS v14 with XMM_BORESIGHT_0024.CCF and SAS v15 with XMM_BORESIGHT_0026.CCF from a sample of 28 observations spread evenly in time from 2000 to 2015. Upper: Differences in RA and DEC of sources in the full sample; Middle: Difference in the declination of source positions as a function of the off-axis angle; Bottom: Difference in the right ascension of source positions as a function of the off-axis angle.

4.2 Updated in SAS15: eimagecombine

The upgrade of the task with the aim of increasing its robustness, and particularly to solve the problems for running it on Mac platforms, has been tested with positive results. The functionality is fully OK, the combination of different images as produced by `eimageget` for producing a background-subtracted, vignetting-corrected and smoothed mosaic has been confirmed. While a report comparing its level of reliability against interactive sophisticated background estimation and mosaic creation as performed with `esas` is still missing, `eimageget` and `eimagecombine` offer a fast and easy background corrected mosaic production method. Fig. 3 shows an RGB image obtained with a mosaic production combining three observations with all three EPIC cameras in three spectral bands (red=[200,1000]eV, green=[1000,2000]eV and blue=[2000,4500]eV).

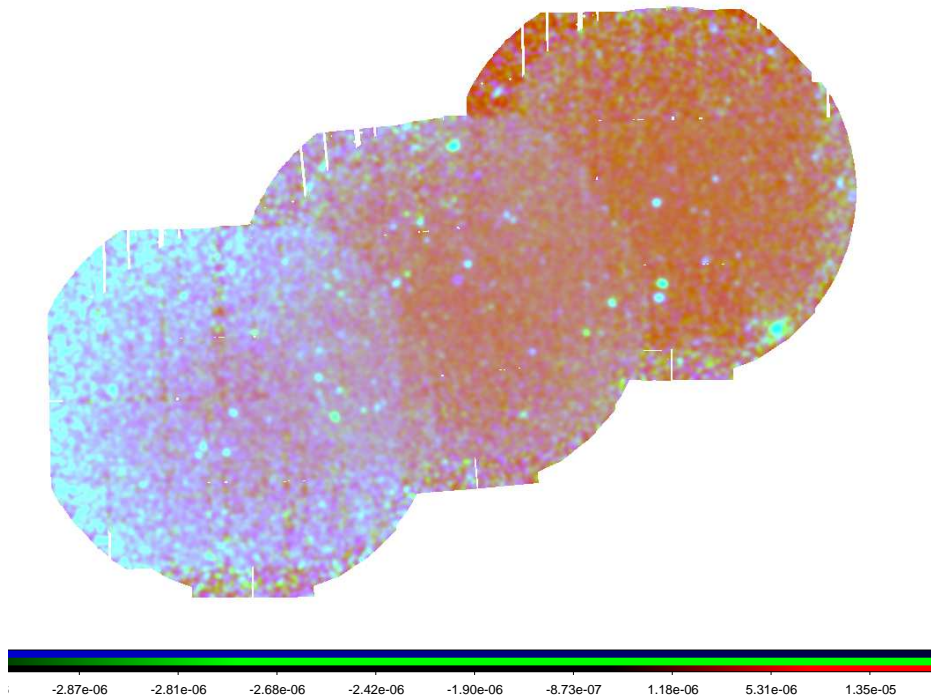


Figure 3: RGB image using three spectral bands (red=[200,1000]eV, green=[1000,2000]eV and blue=[2000,4500]eV) from a mosaic obtained combining the data from three observations with the three EPIC cameras.

4.3 New in SAS 15: ebkgreg - determining the optimal background position for a source in the FOV

The new task has been tested extensively within the pipeline, and it is showing the expected behaviour. In SAS 15 it works only with PN data, but it is planned to be extended to MOS in the next SAS version. Fig. 4 shows the source positions and corresponding background regions obtained with the Lockman Hole data, for those detected sources showing more than 150 counts.

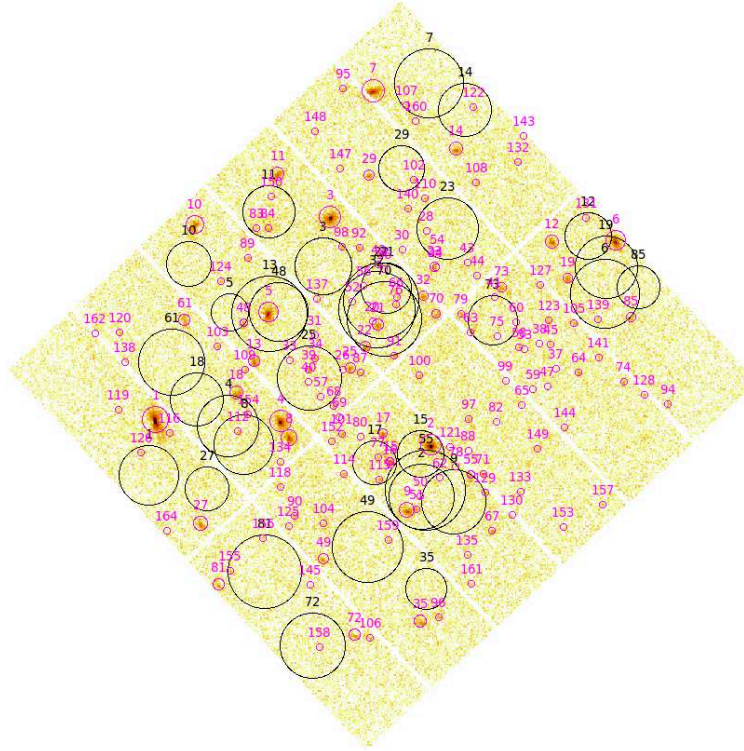


Figure 4: Detected sources, including background positions as derived by `ebkgreg` in a Lockman Hole observation. Background extraction positions are only shown for sources with more than 100 counts (sources in red circles with extraction radius and identification numbers in red, background derived regions in black circles with corresponding numbers in black, as calculated by the task).

4.4 New in SAS 15: Extraction of separated redistribution matrix (RMF) and ancillary response function (ARF) for RGS

The task `rgsrmfgen` can now produce separate RMF and ARF files. Validation has been performed by comparing the result of spectral fits obtained with the default combined matrix and with the individual ARF and RMF for the same observations.

We show in Table 5 the results of the XSPEC spectral fit of the RGS spectra of PKS2155-304 in revolution 1543 (ObsId 04117803) using combined and separate ARF and RMF. The assumed spectral model is an absorbed power-law. The table lists the best fit parameters and the 90% confidence intervals. Same results are obtained with both sets of response matrices.

4.5 New in SASv15.0: - use of adapted `embadpixfind` for RGS bad pixel / column finding

The use of this adaptation of the MOS task for bad pixel and column finding looked very promising to solve the problem, reported time ago, that the `rgsbadpixfind` task is filtering out many emission lines of bright sources, misidentifying them as bad columns. Fig. 5 shows a comparison between fluxed spectra processed using the default and the new method. With `rgsbadpixfind` several columns are missed, especially the Fe XVII triplet emission lines at 15-

Table 5: Fits using combined and separate ARF and RMF files

RGS 1 order1	combined		separate	
H Column Density (10^{22} cm^{-2})	0.0093	(0.0074 - 0.0112)	0.0093	(0.0074 - 0.0113)
Photon Index	2.61	(2.59 - 2.63)	2.61	(2.59 - 2.63)
Normalisation	0.0446	(0.0443 - 0.0450)	0.0446	(0.0443 - 0.0450)
RGS 2 order 1	combined		separate	
H Column Density (10^{22} cm^{-2})	0.0061	(0.0043 - 0.0079)	0.0061	(0.0042 - 0.0079)
Photon Index	2.57	(2.55 - 2.59)	2.57	(2.55 - 2.59)
Normalisation	0.0426	(0.0424 - 0.0429)	0.0426	(0.0423 - 0.0429)
RGS 1 order 2	combined		separate	
H Column Density (10^{22} cm^{-2})	0.060	(0.036 - 0.084)	0.060	(0.036 - 0.083)
Photon Index	3.00	(2.86 - 3.15)	3.00	(2.86 - 3.15)
Normalisation	0.0531	(0.0495 - 0.0568)	0.0530	(0.0495 - 0.0568)
RGS 2 order 2	combined		separate	
H Column Density (10^{22} cm^{-2})	0.056	(0.035 - 0.078)	0.056	(0.035 - 0.078)
Photon Index	2.86	(2.75 - 2.98)	2.85	(2.75 - 2.98)
Normalisation	0.0491	(0.0460 - 0.0625)	0.0491	(0.0460 - 0.0525)

15.5 Angstrom and the OVII emission line at 17 Angstrom are highly disturbed, while most of them are recovered using the new algorithm.

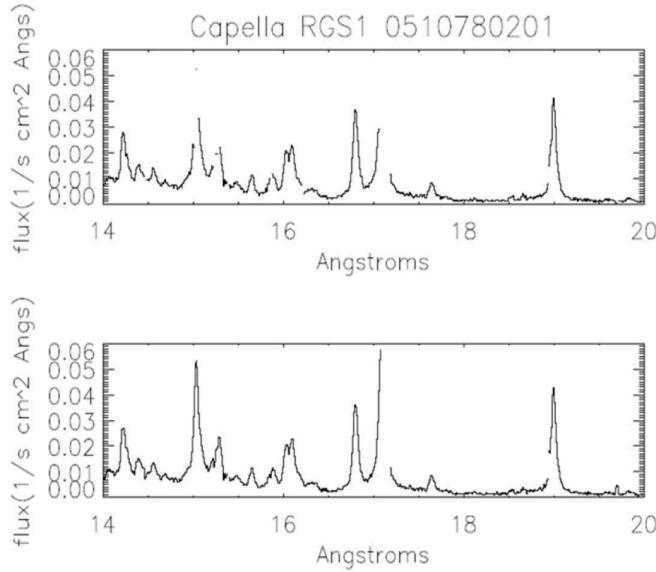


Figure 5: Capella fluxed spectra processed using `rgsbadpixfind` (above) and `rgsembadpixfind` (below).

In order to validate the new task, several tests have been conducted with two aims, to see its efficiency a) in the absence of emission lines, and b) with more or less bright lines of different strengths. To the first purpose, 64 observations of the BL Lac Mrk421 have been processed, showing basically a line-free continuum in this spectral range at different brightness levels, with the one and the other task for bad pixel/column recognition. The results were undistinguishable. For analysing the main cases of emission rich sources, we have chosen three sources, the stars Capella (27 observations), AB Dor (35 observations) and HR1099 (33 observations). All of them have undergone full data reduction using alternatively `rgsbadpixfind` and the modified

embadpixfind. The procedure foresaw simultaneous fitting of the 1st and 2nd order spectra of both RGS1 and RGS2, with a model, capable of catching most emission lines present. After that, a comparison of number of columns discarded and the goodness of fitting in the one and the other case was performed.

We started with the AB Dor observations, using the ISIS spectral fitting package, with an APED model with three temperatures and free abundances, provided to us by the authors of Sanz-Forcada et al., similar to the one used in that publication. We were not interested in the physics, but needed just an approximation fitting most lines, and all prominent ones without exception. This was reached just by adjusting the abundances. The results were very promising favouring the new algorithm, with many few “hot columns” (actually false positives in the **rgsbadpixfind** case), typically 100 less hot columns found per observation with the new algorithm (counting the four spectra together), and in almost all cases, smaller Cash values per degree of freedom, ie. fitting perfectly those non-discarded columns. The problem was the non-detection of eminent hot columns in three observations out of the 35 analysed (see Fig. 6). This deficiency points to the necessity of assessment of the full parameter space of the new task **rgsembadpixfind**, something which goes beyond the scope of this validation exercise, and expected to be performed before the next SAS version release. The task **rgsembadpixfind** has been, therefore, withdrawn from SAS 15.

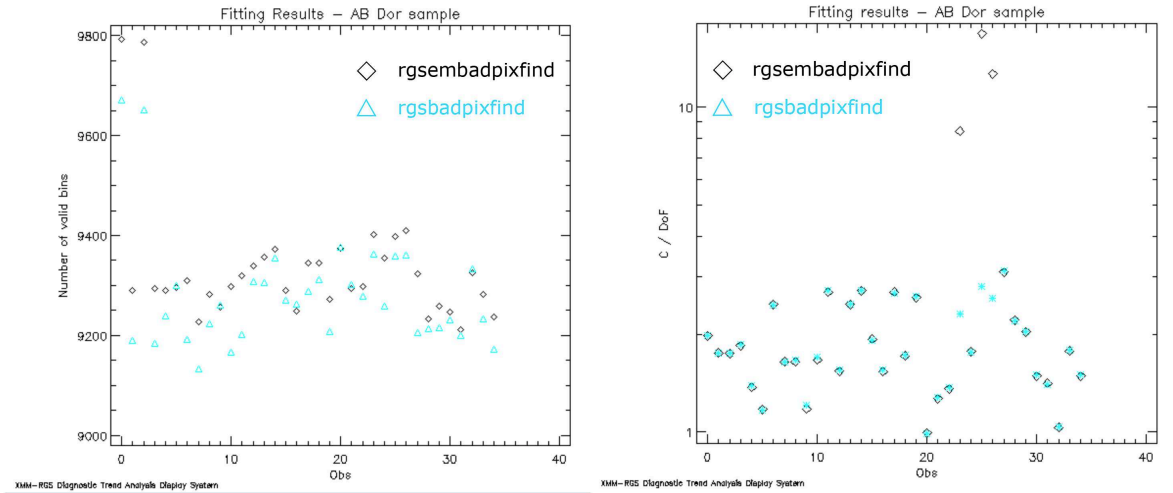


Figure 6: Results comparing **rgsbadpixfind** and **rgsembadpixfind**: left the number of valid columns in the four spectra per observation is plotted, right the Cash value per degree of freedom obtained per observation. The three high values are due to non-recognised isolated hot columns.

4.6 New in SASv15.0: RGS filtering without flagging FIFO buffer full periods

“FIFO Buffer Full” periods are those reported in the housekeeping data when the number of events going into the RGS on-board processor reaches a certain limit, which eventually can be followed by not accepting events anymore. So far, the data during periods with “FIFO Buffer Full” were discarded during the generation of GTIs.

Nevertheless, it has been shown that events in those frames going through the processor get processed correctly and, if the “NLOSTEVT” counter counter is zero, data in those periods are

valid.

SASv15.0 implements in 'rgsproc' a new parameter (`includeinputfifofull`) allowing to enable/disable the inclusion of the periods with "FIFO buffer full" in the housekeeping GTIs. For the time being, the default value of this parameter is `no`, i.e., these periods are discarded.

4.6.1 Validation

The test has been done processing 40 observations of bright targets for which a large loss of exposure time (and events) during the standard processing with `rgsproc` has been previously detected. These observations have been processed with SASv15.0 with default value `includeinputfifofull=no` and with the new option `includeinputfifofull=yes`, and the results have been compared.

Table 6 shows the exposure time (`ONTIME` keyword) obtained with both options, `ONTa` for the default processing, `ONTb` for the new option. In some cases the gain in time is as large as 5 ks. The other columns show the difference in total GTI duration for individual CCDs. In all the studied observations there is a net gain in exposure time; for clarity, we show in the table only the cases in which the difference is larger than 1000s.

The same test has been made in 40 randomly chosen observations: no difference in exposure time has been found for those cases.

Three of the observations in Table 6 have been studied in more detail (see Table 7). ObsId 01375508 (Crab) is the case for which the largest difference in exposure time has been found: 5.5 ks for RGS1 and 6.5 ks for RGS2. ObsId 04101803 (RS Oph) is a peculiar case, since there is a large difference for RGS1 (4.2 ks), but almost no difference for RGS2. Finally, ObsId 01113602 (GX339-4) has a similar countrate than 04101803, but in this case the gain in exposure time for both RGS is of the same order.

Figures 7, 8 and 9 show, for these three cases, the spectra and the light curves obtained with the two filtering options.

5 Conclusion

The SAS scientific validation process concluded that SAS 15 was validated and should be released, as it happened on February 4, 2016. The only caveat with respect to the originally planned contents of this release was the necessity of withdrawing the task `rgsembadpixfind` from it, leaving it for a future release after determination of optimal task parameters.

Table 6: Comparison of the processing of observations of bright sources with includeinputfifofull=no/yes

RGS1											
ObsId	Target	ONTa	ONTb	1	2	3	4	5	6	8	9
01375508 S004	Crab	7592	13102	3943	5281	5529	5703	5455	2270	1434	1558
02024012 S005	Cyg X-1	5584	9937	3167	3396	4026	4191	4352	3074	2183	2146
04101803 S004	RS Oph	9857	14062	3001	2987	3369	3585	3208	4205	3282	3401
02024011 S005	Cyg X-1	4219	8185	2895	3511	3966	3994	3341	2886	1200	1783
01113601 S004	Cyg X-2	15179	17987	1733	1953	1985	2192	2445	2762	2808	2316
01113602 S004	GX 339-4	2592	5129	1521	2496	2477	2496	2537	2564	1765	1177
06111822 S004	Crab	1264	3029	1103	1393	1746	1765	1604	1163	515	952
01537503 S004	Crab	4782	6304	-	-	-	1522	1462	1443	-	-
02027602 S004	Cyg X-1	16631	17996	653	823	933	1048	1273	1365	1287	1066
01537504 S004	Crab	6800	7957	-	-	-	1117	-	-	1157	1007

RGS2											
ObsId	Target	ONTa	ONTb	1	2	3	5	6	7	8	9
01375508 S005	Crab	7008	13484	4817	6135	6475	4628	3539	1765	1425	2725
03115905 S005	XTE J1817	14122	20299	1521	3221	5281	6356	6176	5055	1949	956
02024012 S013	Cyg X-1	5450	10809	3111	4270	5359	5064	4058	2403	988	1448
02024011 S013	Cyg X-1	5303	10575	3111	4513	5271	4256	3732	1135	120	1521
04125926 S007	Crab	7700	12277	4208	4577	4421	3490	2739	2839	2571	3269
01113601 S005	Cyg X-2	11043	14803	2882	3419	3759	2964	2608	3474	2767	2064
02027602 S005	Cyg X-1	13846	17104	1631	1935	2546	2790	3038	3258	2128	1668
01113602 S005	GX 339-4	2307	5423	2289	2523	3116	1811	1723	1480	1218	1443
01609615 S006	Crab	1388	3539	1572	2151	2155	1475	625	322	276	901
01537505 S005	Crab	3081	4981	-	-	-	-	1899	1827	1741	-
01557625 S003	GRO J1655	21985	23832	1622	2077	2091	2022	1825	1457	83	23
01609612 S006	Crab	1062	2868	1351	1806	1714	1287	657	3687	391	988
01609613 S006	Crab	993	2753	1305	1760	1687	1126	515	253	285	823
01609608 U002	Crab	928	2652	1172	1655	1724	1167	501	253	211	781
06111817 S005	Crab	15872	17584	-	-	1591	1594	1713	-	-	-
06111819 S005	Crab	15566	17279	-	-	1628	1587	1713	-	-	-
01609614 S006	Crab	1314	2987	1232	1673	1696	1232	584	230	234	772
01609611 S006	Crab	951	2597	1296	1668	1521	1071	538	317	303	791
01609610 S006	Crab	1140	2771	1246	1604	1641	1255	588	349	331	777
01537503 S005	Crab	2757	4333	-	-	-	1351	1589	1575	-	-
01537504 S005	Crab	4944	6358	-	-	-	-	-	1413	1226	1276
03127901 S047	Crab	933	2151	910	1218	1163	873	404	244	216	538
04125907 S007	Crab	4472	5661	-	-	1189	1115	1091	-	-	-
06111821 S005	Crab	12629	13816	-	-	1112	1092	1187	-	-	-
06111823 S005	Crab	13460	14640	-	-	1106	1109	1180	-	-	-
04125903 S007	Crab	4777	5958	-	-	1181	1153	1015	-	-	-
01539502 S007	Sco X-1	1927	3042	-	-	-	-	1042	1116	-	-
01609609 U003	Crab	620	1650	749	1030	988	754	368	179	175	473

ONTa: ONTIME (s) for includeinputfifofull=no

ONTb: ONTIME (s) for includeinputfifofull=yes

The rest of the columns list the difference (in s) of the GTIs for individual CCDs:

GTI(include...=yes) - GTI(include...=no)

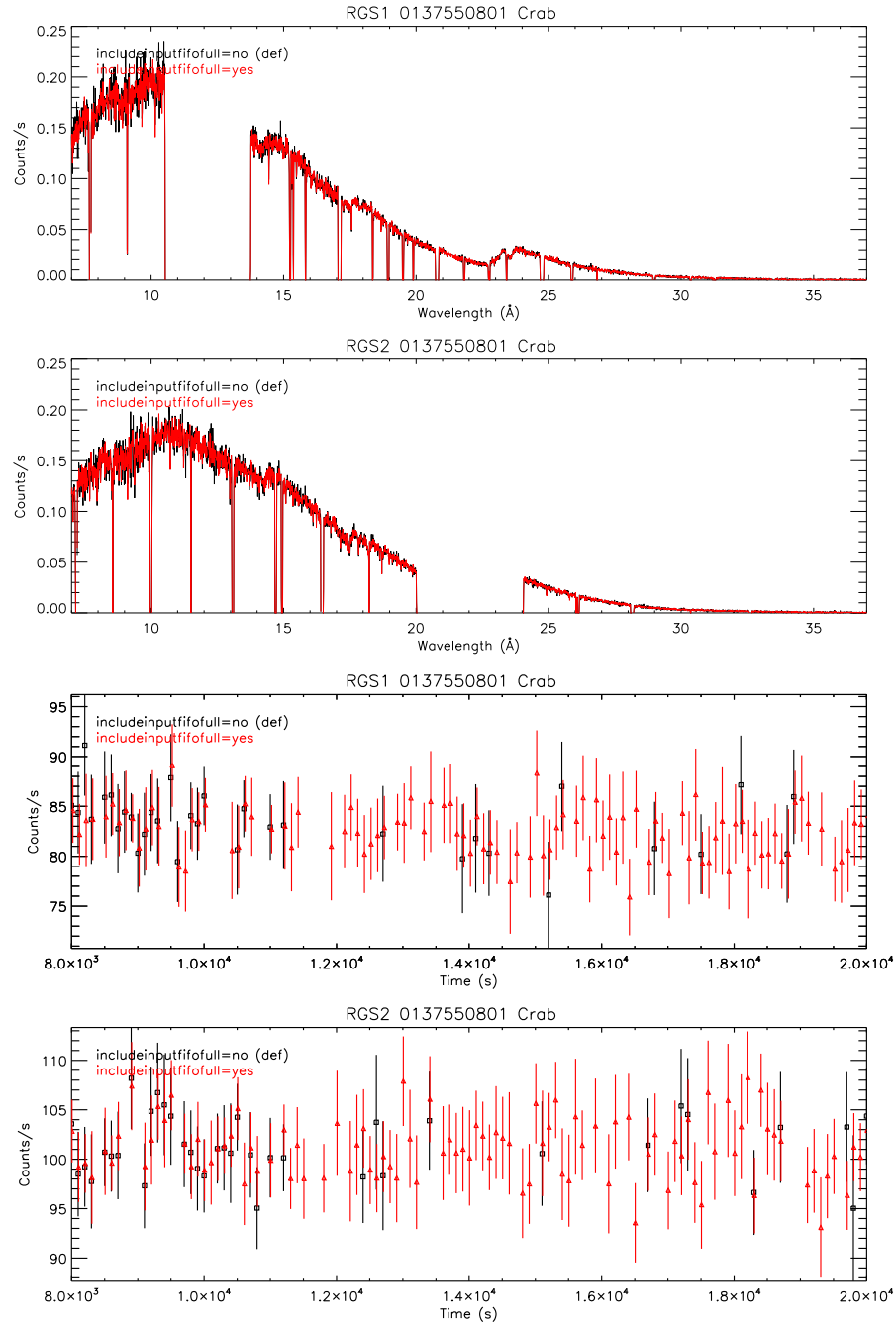


Figure 7: Example of processing with/without “FIFO full” periods for Crab ObsId 01375508, top: spectra, bottom: lightcurves

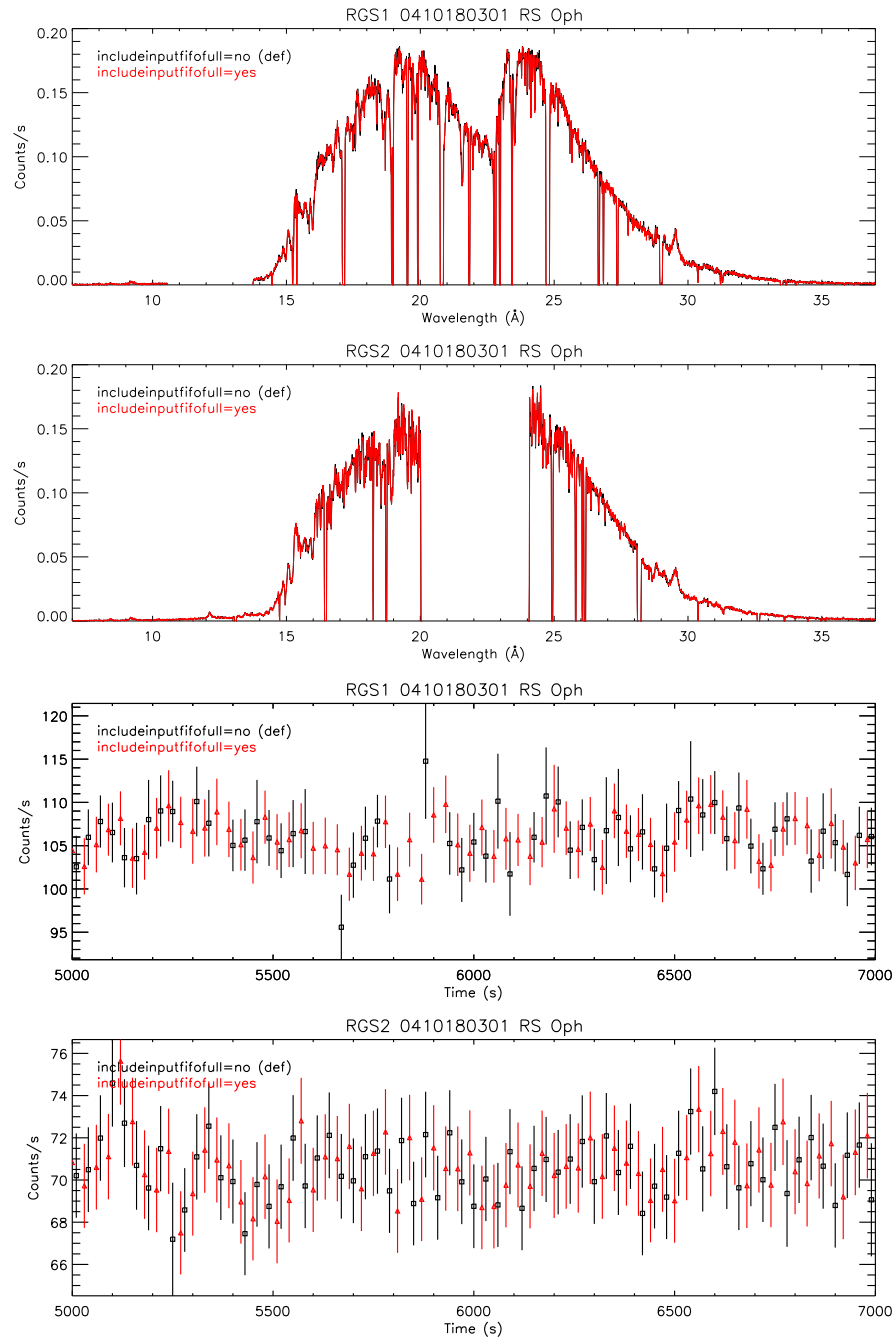


Figure 8: Example of processing with/without “FIFO full” periods for RS Oph ObsId 04101803, top: spectra, bottom: lightcurves

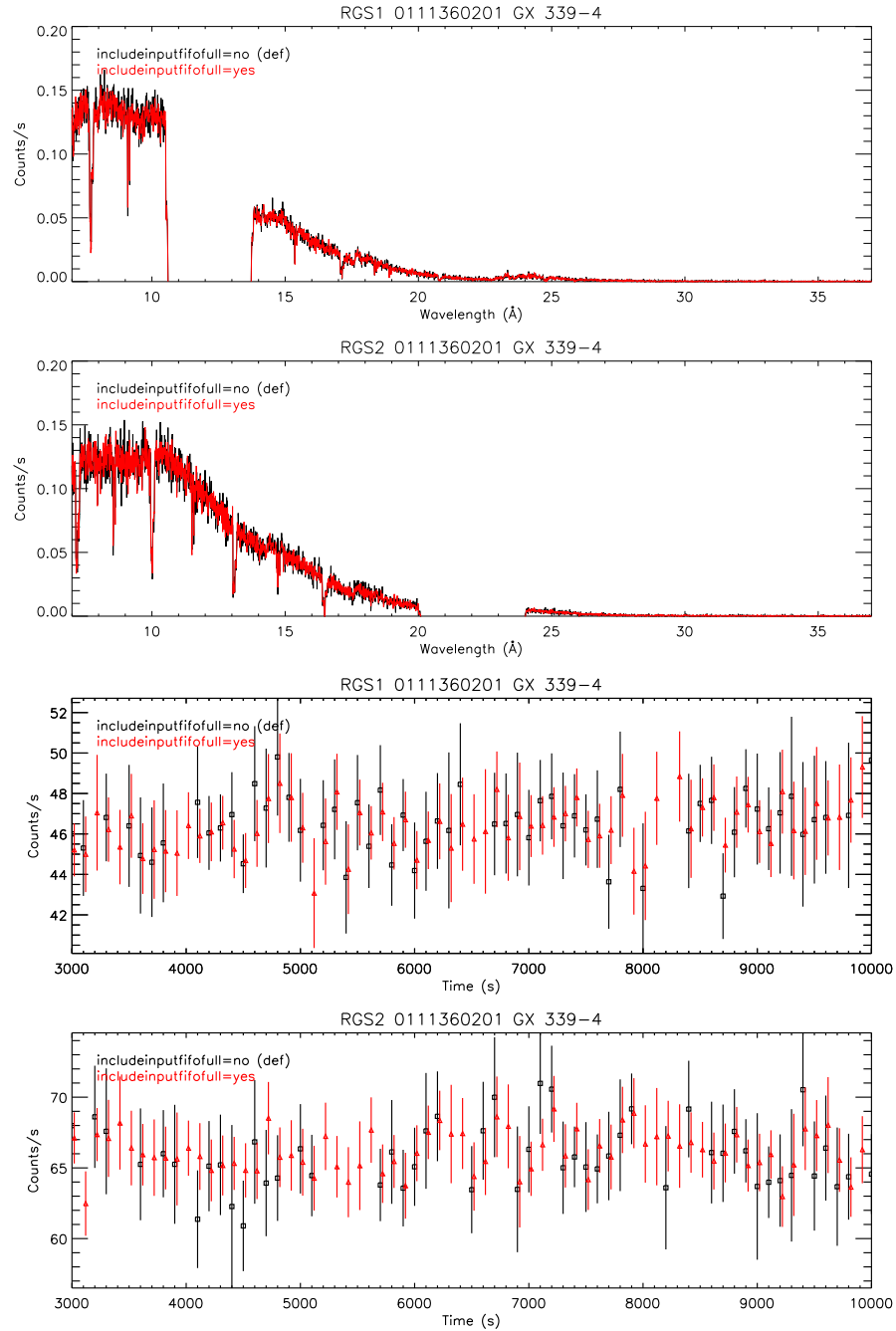


Figure 9: Example of processing with/without "FIFO full" periods for GX339-4 ObsId 01113602, top: spectra, bottom: lightcurves

Table 7: Details of selected observations

includeinputfifofull	texp s	RGS1 counts	rate cts/s	texp s	RGS2 counts	rate cts/s
Crab 01375508						
no	7583	432648	83±3	6999	512456	101±3
yes	13087	800629	83±3	13467	990221	101±3
RS Oph 04101803						
no	9838	1376761	103±2	18700	1987953	69±2
yes	14035	1924577	103±2	18746	1993185	69±2
GX 339-4 01113602						
no	2589	131736	47±1	2304	112458	66±2
yes	5123	266334	46±1	5416	256729	66±1

counts: counts in total first order extracted spectrum (source+background)

rate: average countrate in first order light curve created with `rgslccorr`, with 100 s bin for 013755080 and 0111360201, and 30 s bin for 0410180301

References

Papadakis, I.E. et al. 2010, A&A 510, A65

Sanz-Forcada, J., Micela, G., & Maggio, A. 2007, in XMM-Newton: The Next Decade, p3

Siebert, J. et al. 1999, A&A 348, 678

Tsujimoto, M. et al. 2011, A&A 525, A25