Guide for use of the *images* script

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please send comments or questions to the XMM-Newton HelpDesk

Contents:

1   Purpose of this script

images is a bash shell script designed to reduce and combine data from the XMM-Newton pn and MOS cameras to produce X-ray images in several energy bands. OM data processing is also performed if required. It is adapted from the *mk_images* script by Wolfgang Pietsch and Michael Bauer (Max-Planck-Institut für extraterrestrische Physik, Garching).

The script performs several corrections to the data including:
- filtering for periods of high background
- removal of bad pixels and columns (from calibration files and user-specified)
- smoothing
- exposure correction
- merging of pn and MOS data

The script gives the user control over the parameters with which the images are produced:
- number and energy limits of the energy bands
- names of the MOS and pn directories where the event lists can be found
- name of object which is then used for file naming
- name of directory containing required input files
- the cut-off count rate used to produce good time interval (gti) files*
- pixel binning
- smoothing radius to be used in asmooth*
- removal of user-specified MOS camera CCDs from processing
- pattern upper limits*
- switch on/off cleaning of bad pixels and columns in MOS and pn event files*
- switch on/off processing of OM data

*The parameters marked with an asterisk can be set separately for the MOS and pn cameras.

This script has certain limitations in terms of the data for which it can be used. The script can only be run all the way through from start to finish if there is only one exposure per EPIC camera. However, if there is more than one the user can merge the files or process them separately to produce their own event lists and then run the relevant sections of the script (this is described in section 4 on running the script). The combination of MOS and pn data will not be possible if data is unavailable for any one of the three cameras. Finally, pn data in Small Window mode cannot be used.

If you would like to see an interesting image you have produced placed in the on-line XMM-Newton Image Gallery, please submit it through the gallery webpage at:
http://www.cosmos.esa.int/web/xmm-newton/image-gallery

2   The package

This package contains a number of component scripts, listed here:
- *images* – the main script which performs the processing and calls other scripts
- *images_input* – the file containing all the user-defined parameters
- *clean_col* – the script used to flag the bad columns in the pn event list
- *clean_pn* – the script used to flag the bad pixels in the pn event list
- *clean_mos1* – the script used to flag the bad pixels in the MOS1 event list
- *clean_mos2* – the script used to flag the bad pixels in the MOS2 event list

The following directory is also included:

- *image_tools* – this directory is used in flagging bad pixels and rows, and contains the files:
    - *badpix_col_1.fits* – used in flagging column one as bad for the pn camera
    - *badpix_col_64.fits* – used in flagging column 64 as bad for the pn camera
    - *badpix_row_12_13.fits* – used in flagging rows 12 and 13 as bad for the pn camera
    - *badpix_row_200.fits* – used in flagging bad pixels and row 200 as bad for the pn camera
    - *extract_EXTNAME_extensions* – used to extract flagged bad pixel lists for the pn camera
    - *merge_BADPIX_extension* – used to merge extensions containing flagged pixels
    - *write_badpix_row* – used to flag user-defined pixels as bad

3   S/W requirements

3.1   SAS Requirements

In order to use this script Science Analysis Software (SAS) must be correctly installed and the SAS environment set. Please see the SAS start-up thread in the SAS data analysis threads on the SAS documentation page available online at:
http://www.cosmos.esa.int/web/xmm-newton/sas-threads

4   Running the Script

Before using the script the user must download an Observation Data File (ODF) dataset, for example from the XMM-Newton Science Archive (XSA). It is assumed that before running the *images* script the user has decompressed the ODF and its component files using the *tar –xvf* and *gunzip* commands. The user should then change directory to the directory containing the *odf* subdirectory and run the *images* script from there as described next.

4.1   *images_input*: the input parameter file

The user-defined parameters used in the *images* script are read from the input file *images_input*. The parameters may be left unchanged from those contained within the example version of the file downloaded with the *images* script, or they may be changed by the user (except if cleaning is required, see section 5). The parameters are described below in the order they appear in *images_input*, and an example of the file is shown in Figure 1 in which the format should be noted: on one line a description of the parameter is written and on the next line its value is give. The default values are indicated below for each parameter – the values that will be used if the parameter value is not specified in *images_input*. However, not all parameters have default values and the *images* script cannot be run without specifying these. The example file in Figure 1 does not necessarily show the default values but illustrates how a user can change the values according to their preferences.

- run omichain

The user can choose whether to run omichain by writing 'yes' or 'no' in this space. The default is no.

- count rate threshold for pn gti

This number is a threshold used to generate the gti file for the pn camera. The number is the amount of counts with an energy 10-12 keV and pattern 0 above which the time is classed as 'high background' and data arriving in high background periods will be excluded from further processing. The normal value chosen for this is 0.4 for the pn camera, this is the default value.

- count rate threshold for MOS gti

As for the pn but for pattern 0 events with energy above 10 keV, and the default value is 0.35.
- name of directory containing cleaning files

The user must give the name of the directory where the following are stored: The directory *image_tools*, and the *clean_pn, clean_col, clean_mos1 and clean_mos2* files. If the user does not intend to clean the event lists these files will not be necessary and the warnings informing the user that the files have not been found can be ignored. No default is given as the user MUST specify the location of these files if cleaning is to be performed.

- name of pn directory

This is the name of the directory where the pn files can be found. Those needed for further processing are PN_gticleaned.fits and PNOoT_gticleaned.fits, where OoT signifies Out-of-Time. The *begin* section of the script will automatically generate these files in a directory called PN where the epchain command is run to generate the pn and OoT event lists.

However, the user may wish to use a different gti-filtering method from that in the *begin* section or this section may not run correctly if the observation is unusual such as having more than one exposure, for example. In this case the user should generate their own gti-filtered files, see section 4.2 for more details).

- name of MOS1 directory

As for the pn directory name, but without OoT files included.

- name of MOS2 directory

As for the MOS1 directory name.

- object name

The user may insert a string for the name of the object, e.g. M74, which should not contain spaces or be changed during processing and should not be 'test'. This name will be included in the filenames of the generated images. The default value is objectname.

- pn event lists to be cleaned

The user may write 'yes' or 'no' to decide whether or not to clean the pn and OoT event lists. The lists will be cleaned using pixels flagged as bad using information from the calibration files, and also bad pixels and columns flagged by the user in the clean_col and clean_pn files. The default is 'no'. See section 5 for more details on manual cleaning of the data.

- MOS1 event lists to be cleaned

The user may write 'yes' or 'no' to decide whether to clean the MOS1 event lists or not. The lists will be cleaned using pixels flagged as bad using information from the calibration files, and also bad pixels and columns flagged by the user in the clean_mos1 files. The default is 'no'. See section 5 for more details on manual cleaning of the data.

- MOS2 event lists to be cleaned

As for the MOS1 event lists, but the clean_mos2 file can be used by the user to flag bad pixels. The default is 'no'. See section 5 for details of manual cleaning of the data.

- bin size

The spatial binning given in units of 0.05". A larger number here will result in higher signal to noise but lower resolution in the final image. The default value is 40.

- FWHM for asmooth for pn camera

This parameter gives the width of smoothing performed by asmooth for the pn images. It is given as the full width at half maximum (FWHM) in arcseconds. The default value is 5" in this script.

- FWHM for asmooth for MOS cameras

As for pn but gives the smoothing width for the MOS images.

- MOS1 CCDs to be excluded

This parameter gives the opportunity to exclude user-specified CCDs from further processing, for example if there is bright low energy background. The numbers of the CCDs to be excluded must be all on one line separated with a space between each. This can be left blank if no CCDs are to be excluded, this is the default.

- MOS2 CCDs to be excluded

As for MOS1, but for the MOS2 camera.

- energy band lower limits in eV

These give the lower energy limits of each energy band, in eV. There is no default set so the user MUST specify these values. The values must all be on one line separated with a space between each.

- energy band upper limits in eV

These give the upper energy limits of each energy band, in eV. There is no default set so the user MUST specify these values. The values must be all on one line separated with a space between each.

For example to define five bands as follows: 200-500 eV, 500-1000 eV, 1000-2000 eV, 2000-4500 eV and 45000-12000 eV the energy band lower limits should read: 200 500 1000 2000 4500 and the upper limits: 500 1000 2000 4500 12000.

- pn pattern upper limits

These give the upper limits of permissible patterns in each energy band. There is no default set so the user MUST specify these values. For energy band limits of 200-500 eV, 500-1000 eV, 1000-2000 eV, 2000-4500 eV and 45000-12000 eV pattern upper limits of 0,4,4,4 and 4 may be used, for example. The values must be all on one line separated with a space between each.

- MOS pattern upper limits

These give the upper limits of permissible patterns in each energy band. There is no default set so the user MUST specify these values. For energy band limits of 200-500 eV, 500-1000 eV, 1000-2000 eV, 2000-4500 eV and 45000-12000 eV pattern upper limits of 12,12,12,12 and 12 may be used, for example. The values must be all on one line separated with a space between each.

- energy band of masks used in final image production

This is the number of the energy band (numbering in lists starts with element 0) for which masks will be used in the final image production. For energy band limits of 200-500 eV, 500-1000 eV, 1000-2000 eV, 2000-4500 eV and 45000-12000 eV the mask from energy band 2 (1000-2000 eV) could be used, for example. There is no default set so the user MUST specify this value.

- low threshold counts for mask in final image production

This gives the low threshold used when trimming the combined pn, MOS1 and MOS2 exposure maps to create a mask. By looking at the file objectname_exp.fits in *final_images* (the directory

where images generated by the *images* script are stored) the user can decide on this cut-off value, pixels with counts greater than it will be set to 1 and less than it will be set to 0.

- factor by which to multiply pn images when combining with MOS

This list of factors gives the number by which pn files are multiplied in final image production when combining the pn and MOS images. For energy band limits of 200-500 eV, 500-1000 eV, 1000-2000 eV, 2000-4500 eV and 45000-12000 eV the factors of 0.32, 0.28, 0.62, 0.37 and 0.25 could be given. These factors often need to be found by trial and error for each exposure by re-running the script with the *final* parameter (indicating that just the final processing should be repeated – see section 4 for details on specifying which section of the script should be run), with different factors given in this parameter. Increasing these values will change the appearance of the final images by darkening the gaps between the pn chips and lightening the gaps between the MOS chips. There is no default set so the user MUST specify these values.

Figure 1: Example of *images_input* file

```
run omichain
yes
count rate threshold for pn gti
0.9
count rate threshold for MOS gti
0.45
name of directory containing cleaning files
/home/rwillatt/images/cleaning_files
name of pn directory
PNS003
name of MOS1 directory
MOS1_merged
name of MOS2 directory
M2S002
object name
NGC4258
pn event lists to be cleaned
yes
MOS1 event lists to be cleaned
yes
MOS2 event lists to be cleaned
yes
bin size
50
FWHM for asmooth for pn camera
1.5
FWHM for asmooth for MOS cameras
2.5
MOS1 CCDs to be excluded

MOS2 CCDs to be excluded
3 4 5
energy band lower limits in eV
200 500 1000 2000 4500
energy band upper limits in eV
500 1000 2000 4500 12000
pn pattern upper limits
0 4 4 4 4
MOS pattern upper limits
12 12 12 12 12
energy band of masks used in final image production
2
low threshold counts for mask in final image production
8000
factor by which to mulitply pn images when combining with MOS
0.32 0.28 0.62 0.37 0.25
```
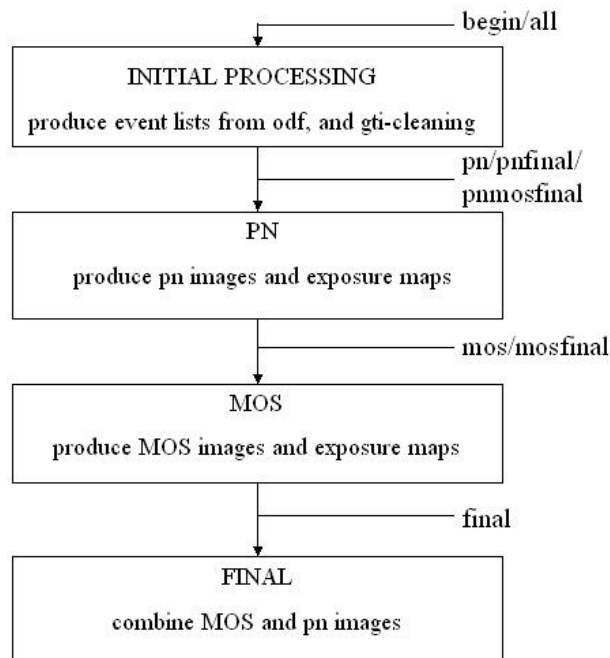
4.2   Running the Script

In the case that the user does not have execute rights for the *images* script the command:
chmod 744 /home/username/directory/images will give executive rights, assuming that the script has been installed under */home/username/directory*. The script should then be called with the command: */home/usernamedirectory/images < images_input section* where *section* is the part of the script the user wishes to run, from the directory containing the *odf* subdirectory. Only the *section* parameter is entered at the command line, all others are entered via the input parameter file *images_input*.

A description of the processing performed in each stage of the script is described in Appendix 1, whilst the next few paragraphs describe in what order the sections would be run for normal processing. Figure 2 shows how the section parameter controls the starting point from which processing is performed.

Figure 2: Flowchart showing use of *section* parameter

The user can choose whether to run the script from start to end using the option *all* as the section parameter when calling it (only possible if exactly one exposure has been taken with each camera) or to start by running the first section of the script using the *begin* option.

The *begin* option should be used if either more than one exposure has been taken with any camera or if the user was intending to gti-filter the data in another way than the script performs. If more than one event list is generated the script will inform the user and stop processing after the end of the *begin* section. The user may wish to choose one event file for further processing or to merge event lists using the SAS task *merge*. If the user wishes to inspect the effect of gti-filtering, rate curves before and after gti-filtering are generated and available named rateX.fits and rateX_gticleaned.fits, in the directory X where X is the camera name (PN, MOS1 or MOS2). For details of generating gti files and gti cleaning of event lists please see the thread Spectral Analysis of MOS/pn point sources on the SAS data analysis threads page available online at: http://www.cosmos.esa.int/web/ xmm-newton/sas-threads. The method specified on those pages is used in the *images* script, with the two MOS cameras filtered with a combined gti file including the gti windows for each of them and the pn camera filtered according to

the pn gti only. Each time the script is re-started with the *begin* option all the files generated in a previous run with the *begin* option will be deleted (including directories PN, MOS1 and MOS2 and their contents). A user should remove other remaining files before re-running the *begin* section.

If the user wishes to produce their own gti-filtered files, and/or has merged more than one event list, the event lists to be used for further processing must be gzipped and organised as follows:

- PN_gticleaned.fits.gz and PNOoTgti_cleaned.fits.gz, the pn event lists and OoT event lists filtered for periods of high background should be placed in the user's pn directory as named in *images_input.*
- MOS1_gticleaned.fits.gz, the MOS1 event list filtered for periods of high background should be placed in the user's MOS1 directory as named in *images_input.*
- MOS2_gticleaned.fits.gz, the MOS2 event list filtered for periods of high background should be placed in the user's MOS2 directory as named in *images_input.*
- See section 4.1 for details of naming the pn, MOS1 and MOS2 directories in *images_input*.

If the user has run the *begin* section of the script and wishes to continue, the *pn*, *mos*, *pnfinal mosfinal* or *pnmosfinal* sections of the script should be run (those ending in '*final*' once the user wishes to produce the final combined images also). The section parameter names indicate whether the pn, MOS and/or final processing should be run. Care must be taken if the *pnfinal* or *mosfinal* sections are to be run simultaneously and more than one camera's cleaning file has been updated in order to ensure that the final images are formed from the latest cleaned event lists (see section 5 for information about cleaning event lists). All images are produced in the directory *final_images*.

The *final* section of the script is run if the user has already run the *pn* and *mos* sections and wishes to produce the final images, or if the user wishes to regenerate the final images with new factors for the pn files to be multiplied by or a new low threshold value for producing the mask (as specified in *images_input* and discussed in section).

Once the final images (with 'final' in the title) have been produced they can be coloured and combined into a false-colour image. There are several programs which can be used to do this including Adobe Photoshop, ds9 and Gimp. Details of creating a false-colour image are given in the section 8 below.

5   Additional Manual Cleaning of the Data

5.1   Why clean the data manually?

Cleaning the data manually is not essential but will improve the appearance of images by eliminating pixels and columns which have not been flagged as bad in the calibration files. By saying 'yes' to cleaning the data (pn and/or MOS1 and/or MOS2) but not modifying the cleaning files the data will be cleaned using only the pixels flagged as bad from the calibration files. The user can specify more bad pixels and columns in the *clean_col* and *clean_pn* files for the pn camera, and the *clean_mos1*, *clean_mos2* files for the MOS1 and MOS2 cameras, respectively. These will then become flagged as bad and excluded when the event list is processed to form images. These files contain commented-out sections which show how bad pixels should be entered and for the pn file the list shows some pixels which frequently need to be flagged as bad.

If running from the start of the script *clean_col*, *clean_pn*, *clean_mos1* and *clean_mos2* must be placed with *image_tools* in the directory specified in the *images_input* file. Otherwise *image_tools*

must be located in the directory specified in the *images_input* file, *clean_pn* and *clean_col* must be placed in the pn directory and *clean_mos1* and *clean_mos2* in the MOS1 and MOS2 directories, respectively (if running the section *pn, mos*, *pnfinal*, *mosfinal* or *pnmosfinal)*. Generally the effects of bad pixels and columns in the pn camera are more noticeable than for the MOS cameras. The *clean_col* file for the pn camera gives the user the option to clean columns below a certain threshold energy only, if the column only appears particularly bright in low energy bands. Flagging bad pixels and columns may well be iterative with the user defining some columns and pixels to start with in the cleaning files, generating the diagnostic files (see section 5.2 below) and using them to define more bad pixels and columns until they are happy with the result.

5.2   How to choose bad pixels and columns

The script will automatically generate images in the 200-500 eV band after cleaning the event list with the *clean_col* and *clean_pn* files for the pn camera, and the *clean_mos1*, *clean_mos2* files for the MOS1 and MOS2 cameras, respectively. These images are named as follows: xxx_yy_test_nn.fits where xxx is the object name, yy is the camera (pn for the pn, m1 for MOS1, m2 for MOS2) and nn is the CCD number. A full-field image: xxx_yy_test_full.fits is also generated for each camera, showing the positions of any excluded MOS CCDs. These are displayed in ds9 as soon as they have been generated to give the user the opportunity to inspect the data to see if further pixels need to be flagged. Figure 3 shows an example ds9 display for the pn. When the mouse pointer is held over an image the filename and pixel coordinates are shown in the top left corner of the ds9 window, which can be used to find the CCD number (in the filename) and coordinates (labelled 'Physical') of bad pixels. The images of individual CCDs are produced in CCD (RAWX and RAWY) and in the full-field view the coordinate system is detector coordinates (DETX and DETY).

Figure 3: Example ds9 display of pn diagnostic images for cleaning of bad pixels and columns
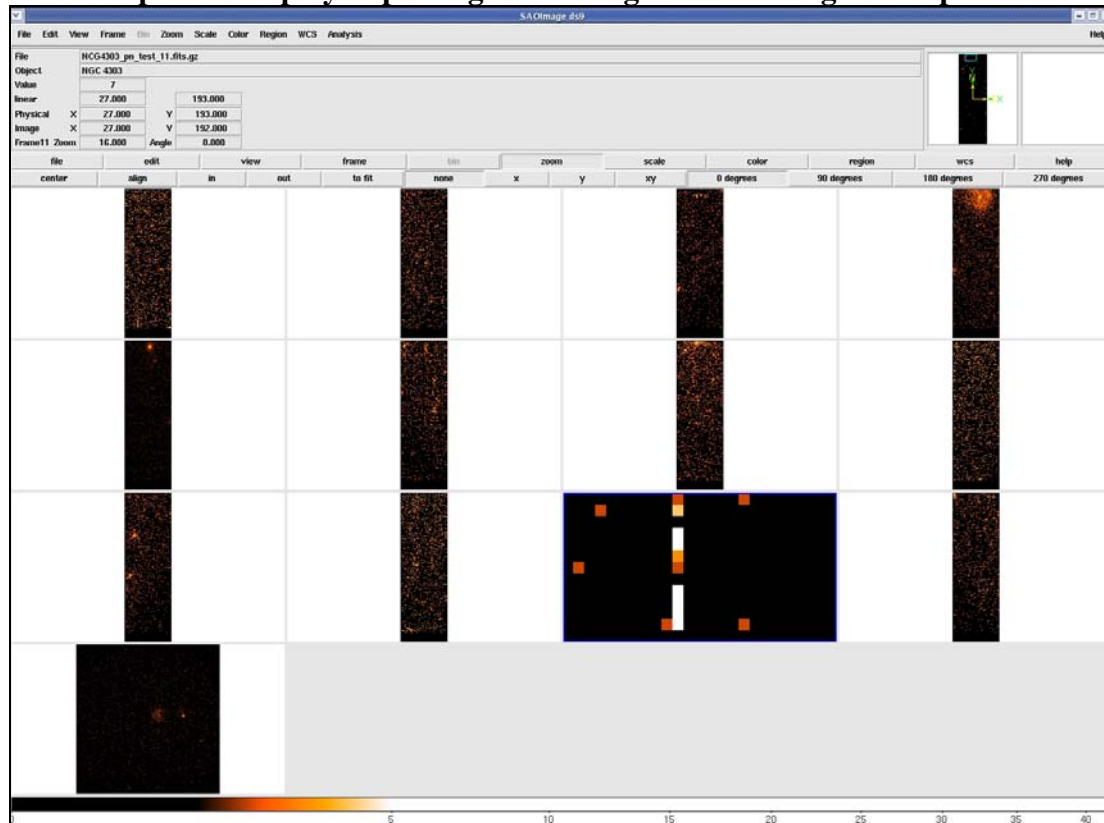
In this figure CCD 11 has been zoomed in on to show some bright pixels. The full frame image in detector coordinates can be seen in the lower left corner.

If the user wishes to add pixels or columns to be flagged as bad to the cleaning files the script can be stopped and the relevant cleaning file (*clean_col, clean_pn, clean_mos1* or *clean_mos2*) can be modified. These files contain commented-out examples to show how the bad pixels or columns can be specified. For the pn the examples show pixels previously found to be hot. *clean_col* does not contain commented-out examples but shows how the CCD number, column and threshold energy can be specified.

Once the user has updated the cleaning file the script can then be run again using the *pn/pnfinal*, *mos/mosfinal* or *pnmosfinal* option to create the images with the newly-flagged pixels eliminated. The sections of the script called with the options *pn* and *mos* can be run simultaneously, but of course care must be taken if the *pnfinal* or *mosfinal* sections are to be run and more than one camera's cleaning file has been updated in order to ensure that the final images are formed from the latest cleaned event lists.

6   Files produced in EPIC processing

The files produced by the commands *cifbuild* and *odfingest* (executed in the *images* script) have standard names as documented in the SAS documentation. In the *PN*, *MOS1, MOS2* and *OM* directories several files are generated by the *epchain*, *emchain* and *omichain* tasks respectively, the files are named as described in the SAS documentation for these tasks. The additional files produced for pn, MOS and combined pn and MOS images by this script are listed below; see section 7 for OM images. They are organised by the directory in which they appear: files in the *PN* directory in section 6.1, the *MOS1* and *MOS2* directories in section 6.2 and *final_images* directory in 6.3. The exceptions are log files which are all listed in Section 6.4 and diagnostic images produced to find bad pixels, listed in Section 6.5. The filename, meaning and *section* input when of the script where the files are produced are shown. Generally the user will see image files gzipped, i.e. with a .gz extension.

6.1   Files in *PN* directory

This section contains a list of the files which can be found in the *PN* directory. The directory also contains the standard products of epchain, named as indicated in the SAS documentation.

Filename	Meaning	Section
clean_col	file used in cleaning pn bad columns	begin
clean_pn	file used in cleaning pn bad pixels	begin
PN_gticleaned.fits	pn gti-filtered event list	begin
PNgti.fits	pn gti file	begin
PNOoT_gticleaned.fits	pn OoT gti-filtered event list	begin
ratePN.fits	pn count rate file, used to determine gti	begin
ratePN_gticleaned.fits	pn gti-cleaned count rate file	begin

6.2   Files in *MOS1* and *MOS2* directories

This section contains a list of the files produced in the MOS1 directory. The exact equivalents can be found in the MOS2 directory but with '2' instead of '1' in the filenames.

Filename	Meaning	Section
clean_mos1	File used in cleaning MOS1 bad pixels	begin/mos/ mosfinal/pnmosfinal
MOS1_gticleaned.fits	MOS1 gti-filtered event list	begin
MOS1gti.fits	MOS1 gti file	begin
MOSgti.fits	Combined MOS gti file	begin

esa

Guide for use of the *images* script

XMM-Newton
Science Operations Centre

Page 11

Version 1.1

Date: 26.10.2016

Filename	Meaning	Section
rateMOS1.fits	MOS1 count rate file, used to produce gti file	begin
rateMOS1_gticleaned.fits	MOS1 gti-cleaned count rate file	begin

6.3 Files in *final_images* directory

This section contains the files found in the final_images directory, the letter 'b' in the filename indicates the number of the energy band (starting from 0).

Filename	Meaning	Section
objectname_evli_m1_cleaned.fits	MOS1 event list with bad pixels and columns flagged	mos/mosfinal/ pnmosfinal
objectname_evli_m2_cleaned.fits	MOS2 event list with bad pixels and columns flagged	mos/mosfinal/ pnmosfinal
objectname_evli_pn_cleaned.fits	pn event list with bad pixels and columns flagged	pn/pnfinal/ pnmosfinal
objectname_exp.fits	combined exposure map for all cameras	final/pnfinal/ mosfinal/pnmosfinal
objectname_final_b.fits	final images (for use in further processing)	final/pnfinal/mosfinal/ pnmosfinal
objectname_m1_exp_b.fits	MOS1 exposure map	pn/pnfinal/mos/ mosfinal/pnmosfinal
objectname_m1_exps_b.fits	MOS1 smoothed exposure map	pn/pnfinal/mos/ mosfinal/pnmosfinal
objectname_m1_expv_b.fits	MOS1 exposure map with vignetting	pn/pnfinal/mos/ mosfinal/pnmosfinal
objectname_m1_ima_b.fits	MOS1 initial image	pn/pnfinal/mos/ mosfinal/pnmosfinal
objectname_m1_imadm_b.fits	MOS1 image smoothed with mask	pn/pnfinal/mos/ mosfinal/pnmosfinal
objectname_m1_msk_b.fits	MOS1 exposure mask	pn/pnfinal/mos/ mosfinal/pnmosfinal
objectname_m2_exp_b.fits	MOS2 exposure map	pn/pnfinal/mos/ mosfinal/pnmosfinal
objectname_m2_exps_b.fits	MOS2 smoothed exposure map	pn/pnfinal/mos/ mosfinal/pnmosfinal
objectname_m2_expv_b.fits	MOS2 exposure map with vignetting	pn/pnfinal/mos/ mosfinal/pnmosfinal
objectname_m2_ima_b.fits	MOS2 initial image	pn/pnfinal/mos/ mosfinal/pnmosfinal
objectname_m2_imadm_b.fits	MOS2 image smoothed with mask	pn/pnfinal/mos/ mosfinal/pnmosfinal
objectname_m2_msk_b.fits	MOS2 exposure mask	pn/pnfinal/mos/ mosfinal/pnmosfinal
objectname_mask.fits	mask for final images	final/pnfinal/mosfinal/ pnmosfinal
objectname_OoTevli_pn_cleaned.fits	pn OoT event list with bad pixels and columns flagged	pn/pnfinal/ pnmosfinal

XMM-Newton
Science Operations Centre

Guide for use of the *images* script

Page 12
Version 1.1
Date: 26.10.2016

Filename	Meaning	Section
objectname_PN_back.fits	pn event list after removing events around inhomogenous background lines	pn/pnfinal/ pnmosfinal
objectname_pn_exp_b.fits	pn exposure mask	pn/pnfinal/mos/ mosfinal/pnmosfinal
objectname_pn_exps_b.fits	pn smoothed exposure mask	pn/pnfinal/mos/ mosfinal/pnmosfinal
objectname_pn_expv_b.fits	pn exposure mask with vignetting	pn/pnfinal/mos/ mosfinal/pnmosfinal
objectname_pn_ima_b.fits	pn initial image	pn/pnfinal/mos/ mosfinal/pnmosfinal
objectname_pn_imadm_b.fits	pn image smoothed with mask	pn/pnfinal/mos/ mosfinal/pnmosfinal
objectname_pn_msk_b.fits	pn exposure mask	pn/pnfinal/mos/ mosfinal/pnmosfinal
objectname_pn_ooima_b.fits	OoT image produced from OoT event list	pn/pnfinal/ pnmosfinal
objectname_PNOoT_back.fits	pn OoT event list after removing events around inhomogenous background lines	pn/pnfinal/ pnmosfinal

6.4 Log files

Filename	Meaning	File location	Section
objectname_emchain_MOS1.log	log file of emchain run to produce MOS1 event list	MOS1	begin
objectname_emchain_MOS2.log	log file of emchain run to produce MOS2 event list	MOS2	begin
objectname_epchain_1.log	log file of epchain run to produce OoT event list	PN	begin
objectname_epchain_2.log	log file of epchain run to produce pn event list	PN	begin
objectname_final_processing.log	log file of final processing	final_images	final/pnfinal/ mosfinal/pnmosfinal
objectname_MOS1_images.log	log file of MOSl processing	final_images	mos/mosfinal/ pnmosfinal
objectname_MOS1gti.log	log file of processing to produce/apply MOS1 gti filtering	MOS1	begin
objectname_MOS2_images.log	log file of MOS2 processing	final_images	mos/mosfinal/ pnmosfinal
objectname_MOS2gti.log	log file of processing to produce/apply MOS2 gti filtering	MOS2	begin

Guide for use of the *images* script

Page 13

Version 1.1

XMM-Newton
Science Operations Centre

Date: 26.10.2016

Filename	Meaning	File location	Section
objectname_PN_images.log	log file of pn processing	final_images	pn/pnfinal/ pnmosfinal
objectname_odfingest.log	log of processing during *odfingest*	directory containing odf	begin
objectname_cifbuild.log	log of processing during *cifbuild*	directory containing odf	begin
objectname_PNgti.log	log file of processing to produce/apply PN gti filtering	PN	begin

6.5 Files produced as diagnostic images

The files are produced in the *final_images* directory with filenames: objectname_test_yy_nn.fits where yy indicates the camera (pn for the pn, m1 for MOS1, m2 for MOS2) and nn the CCD number (starting from 01) or 'full' for full-field view, see section 5 for details on cleaning bad pixels.

7 OM data

OM data is produced during the initial preparation part of the script, run using the section parameter *begin*. A log file of the processing using *omichain* can be found in the *OM* subdirectory named objectname_omichain.log. The OM files to be used in further processing are those whose filename terminates in SIMAGE1000.FIT. If the OM was operated in Imaging mode these are re-named by this script to be suffixed by the filter name (V, B, U, UVW1, UVM2, UVW2, from longest wavelength to shortest). There is also a white filter which covers the full wavelength range of the filters listed. Images from the same filter observed in Imaging can be combined using the SAS *ommosaic* task. Section 8 outlines the construction of a false-colour image.

8 Creating a false colour image

When making a false-colour image, the image in the longest wavelength band should be coloured red, an image at a shorter wavelength in green and shortest wavelength in blue as a representation of the way the image would look to human eyes. Often selecting a logarithmic scale when viewing the images will bring out fainter details such as the arms of a spiral galaxy which are almost invisible when seen with a linear scale. Several programs can be used to form an image displaying each energy band in a different colour. The three sub-sections below outline how this can be done in Photoshop, ds9 and Gimp.

8.1 ESA/ESO/NASA FITS Liberator

The ESA/ESO/NASA FITS liberator, see http://www.spacetelescope.org/projects/fits_liberator/, is a tool to load astronomical raw images (originally into Photoshop) and that allows the interactive generation of false-color images. Note that, as of version 3, the FITS Liberator has become a stand-alone application, which means that Photoshop is no longer required.

XMM-Newton
Science Operations Centre

Guide for use of the *images* script

Page 14

Version 1.1

Date: 26.10.2016

8.2 ds9

A false-colour image can be made in ds9 by selecting *Frame->New Frame RGB*. A small window entitled RGB with toggles for red, green and blue should appear as well as an empty frame. This window can be used to toggle the colouring given to the next opened file and the layers currently viewable.

The first file opened should be that in the lowest energy band. The image will be coloured red as red is automatically toggled on in the RGB window. The lowest energy band images should be opened with red toggled on, medium energy band images with green toggled on and high energy band images with blue toggled on. The image can then be seen in false colours and the contrasts of the layers can be adjusted by toggling each layer to be current and using the Scale menu to create the correct balance.

8.3 Gimp

The images in all energy bands should be opened. Using the options in *Layer->Colours* the appearance of the layer can be adjusted to make any interesting features optimally displayed. The Curves option may be particularly useful for adjusting the image to display features of astronomical interest. Once each layer has been adjusted they can be combined using the Filters->Colours ->Compose to combine the layers with the colours shown.

Appendix 1: Processing performed in each script section

A1.1 *begin*

This runs the script from the start up to the point of producing event lists, attitude files, gti files and includes OM processing if required.

- cifbuild and odfingest commands are executed
- epchain and emchain are run to produce event lists for the pn and MOS cameras
- gti files are produced using the user-specified values for the high background cut-off
- event lists are filtered for good time intervals (gtis)
- omichain is run (if user has requested this)
- directories are created named *PN, MOS1, MOS2* and *OM* which contain files relevant to each camera

A1.2 *pn*

This part of the script runs from the end of *begin* to the end of the pn processing stage where pn images have been produced and smoothed in the required energy bands and exposure images and masks have been produced. This part of the script can be run to see if the flagging of pixels and rows using information contained in the ccf file is sufficient.

- pn and OoT event lists are cleaned for bad pixels and columns (if required)
- diagnostic images are produced to enable user to examine data for bad pixels and columns

In each energy band:
- images and OoT images are made from event lists in specified energy bands
- exposure images are made (with and without vignetting), and smoothed
- masks are made

Guide for use of the *images* script

Page 15

Version 1.1

XMM-Newton
Science Operations Centre

Date: 26.10.2016

- images and OoT images smoothed with masks
- images and OoT images by masks multiplied by masks
- OoT images subtracted from pn images

A1.3 *mos*

As for pn (section A1.2) but for the MOS1 and MOS2 cameras.

- event list is cleaned for bad pixels and columns using clean_mos1 or clean_mos2 (if required)
- diagnostic images are produced to enable user to examine data for bad pixels and columns

In each energy band:
- images are made from event list (excluding any user-specified CCDs if required)
- exposure images (with and without vignetting) are made, and smoothed
- masks are made
- images are smoothed with masks
- images are multiplied by masks

A1.4 *final*

The final section combines the images from all three cameras to form one image per energy band. If data is not available from one or more of the three cameras this section cannot be run.
- mask is created by combining exposure maps from all cameras

In each energy band:
- pn images are weighted by multiplying by factors
- exposure corrections are made
- pn and MOS images are combined

A1.5 *pnfinal, mosfinal* **and** *pnmosfinal*

The *pnfinal*, *mosfinal* and *pnmosfinal* sections run the *pn, mos* or *pn* and *mos* sections respectively, followed by the *final* section.