



# espfilt

April 16, 2023

## Abstract

The task **espfilt** generates soft proton contamination-filtered products, including event lists, images, and lightcurves from pipeline-processed event lists.

## 1 Instruments/Modes

Instrument	Mode
EPIC MOS	IMAGING, TIMING
EPIC PN	IMAGING, TIMING

## 2 Use

pipeline processing	yes
interactive analysis	yes

## 3 Description

The task **espfilt** applies one of two user-chosen methods for filtering an XMM-Newton Event List (MOS or PN) of cosmic soft proton events. The methods both utilize corner (unexposed, outside of FOV) sections of the CCDs. Both methods extract a lightcurve from both the FOV and the corners.

The *histogram* method fits a roughly Gaussian to a histogram of the FOV lightcurve values. The peak of that Gaussian is taken as the nominal count rate. A user specified number of  $\sigma$  around the peak (default:2.5) are taken to be “flare-free”. The program then creates a GTI file for those “flare-free” time intervals and then creates a filtered event file using that GTI.

The *ratio* method takes the ratio of counts per pixel of an annulus near the edge of the FOV (and away from any bright central source) to that of the unexposed corners. The time intervals with a ratio below a user-defined threshold (default: 1.2) are taken to be “flare-free”. The program creates a GTI for the “flare-free” time intervals and then creates a filtered event file using that GTI.

In both methods, a new filtered event list, lightcurves of the FOV and corners, GTI FITS files, filtered images and a QDP plot of the lightcurves are created (histo method ONLY).



### 3.1 Generalities

This task takes an existing eventlist produced by `emchain` or `epchain`, applies one of two selectable methods, produces a GTI file, then creates a filtered event list, filtered image, QDP plot of the count rate histogram (for now, the QDP file must be converted to postscript, etc, by the user), FOV lightcurve and a 'Corners' (corner pixels of outer chips) lightcurve.

### 3.2 Main loop

This task assumes that SAS tasks `cifbuild`, `odfingest` and one of the event-list producing EPIC MOS or PN task (`emchain`, `epchain`) have previously been run.

An error will result if the `odfingest` ASCII output file or the `cifbuild` FITS file are not present and set using the proper SAS environment variables or command line options.

1. The task checks to see if event list is present and has the requisite keywords.
2. Define corner selection criteria for `evselect` calls.
3. Create `*all*` and corner images and `*fov*` lightcurves with `evselect`.
4. Depending on the method selected, the proper subroutine for processing via that method is invoked.  
For the Histogram method: Clean lightcurve in subroutine `CLEAN_LC`.

```
Clean the light curve by creating a histogram of rate values
from the light curve, finding the most likely value, assuming
that to be similar to the mean of the quiescent rate, then
fitting a Gaussian (or poissonian, or user defined curve) to
a small window around that value in the histogram to determine
the true mean and dispersion of the quiescent background rate.
Excludes time intervals with rate higher than a multiple of
the dispersion above the mean quiescent background and excludes
good regions shorter than some (currently hardcoded) limit.
```

For the Ratio Method:

- (a) Create FOV annulus and corner annulus images and lightcurves.
  - (b) Determine Counts per pixel Ratio between the FOV annulus and corners.
  - (c) For Time Intervals within user-selected ratio threshold ranges, select data using `evselect`.
5. Create an ASCII QDP format file (histogram method only)
  6. Run `gtibuild`.
  7. Run `evselect` to produce filtered, flare-free events file.
  8. Run `evselect` to produce filtered, flare-free image.
  9. Run `evselect` to produce corner-only events file.
  10. Run `evselect` to produce corner-only image.
  11. If PN, run `evselect` to produce cleaned OOT event file.



### 3.3 Methods

Currently, only the Histogram and Ratio methods described above operate as required. The Histogram method effectively cuts the light curve at some number of sigma above the mean nominal level and the Ratio method compares the count-rate per unit area in the obscured corners of the detector to the same in a FOV annulus within the 8-12 keV band.

The task leaves open the possibility to add new "methods" in future releases.

### 3.4 Cleaning lightcurves

For the Histogram Method, `clean_lc` was originally a FORTRAN 77 program developed by Steve Snowden and K.D. Kuntz in 2005-6. The task `espfilt` was originally a perl script that operated on an input event list then used a system call to invoke `clean_lc`. The perl script and the F77 program have been converted entirely to FORTRAN 95, accessing XMM-Newton datasets via the DAL.

`Clean_lc`'s purpose is to clean a light curve by creating a histogram of rate values from the light curve, finding the most likely value assuming that to be similar to the mean of the quiescent rate, then fitting a Gaussian to a small window around that value in the histogram to determine the true mean and dispersion of the quiescent background rate. The program then excludes time intervals with rate higher than a multiple of the dispersion above the mean quiescent background and excludes good regions shorter than some limit.

### 3.5 Examples

The following are several examples, with descriptions, of running `espfilt`:

- `espfilt eventfile=mos1S001.fits`

Invoking the task with only an event file will cause it to default to binning the data into 60 second bins and smoothing it. The default min and max channels will be 2500eV and 8500eV respectively.

- `espfilt eventfile=mos1S001.fits withsmoothing=yes smooth=25`

This will change the default smoothing from 60 to 25.

- `espfilt eventfile=mos2S002.fits elow=500 ehigh=8500`

This command will change the default minimum and maximum energy ranges.

- `espfilt eventfile=mos2S002.fits method=ratio ratio=1.5 withbinning=yes binsize=100`

This command will run `espfilt` in ratio mode with a user selected FOV to unexposed corner ratio of 1.5 instead of the default 1.2 and binning the data into 100 second time bins rather than the default of 60.



## 4 Parameters

This section documents the parameters recognized by this task (if any).

Parameter	Mand	Type	Default	Constraints
-----------	------	------	---------	-------------

### General parameters

<b>eventfile</b>	yes		dataset	none
------------------	-----	--	---------	------

Input FITS event list

<b>withoot</b>	no	boolean	no	yes—no
----------------	----	---------	----	--------

Input a PN OOT event list? (only for PN)

<b>ootfile</b>	no		dataset	none
----------------	----	--	---------	------

PN OOT FITS event list (only for PN)

<b>method</b>	no	string	histogram	ratio—histogram
---------------	----	--------	-----------	-----------------

fit method to use.

<b>withsmoothing</b>	no	boolean	yes	yes—no
----------------------	----	---------	-----	--------

Smooth data?

<b>smooth</b>	no	integer	51	$1 \leq \text{smooth} < 60$
---------------	----	---------	----	-----------------------------

Smoothing factor in seconds

<b>withbinning</b>	no	boolean	yes	yes—no
--------------------	----	---------	-----	--------

Bin data?

<b>binsize</b>	no	integer	60	$1 < \text{binsize} < 100$
----------------	----	---------	----	----------------------------

Bin width in seconds

<b>ratio</b>	no	real	1.2	$0 \leq \text{ratio} \leq 10.$
--------------	----	------	-----	--------------------------------

Flaring ratio of annulus counts

<b>elow</b>	no	integer	2500	$0 < \text{elow} \leq 11999$
-------------	----	---------	------	------------------------------

Low Band Energy

<b>ehigh</b>	no	integer	8000	$1 < \text{ehigh} \leq 12000$
--------------	----	---------	------	-------------------------------

High Band Energy

<b>rangescale</b>	no	real	6.0	$1. \leq \text{rangescale} \leq 25.$
-------------------	----	------	-----	--------------------------------------

Histogram fit range scale factor

<b>allowsigma</b>	no	real	2.5	$0.1 \leq \text{allowsigma} \leq 10.$
-------------------	----	------	-----	---------------------------------------

Limit in sigma for unflared rates

<b>limits</b>	no	real	0.1,6.5	$0.1 \leq \text{limits} \leq 10.$
---------------	----	------	---------	-----------------------------------

Parameter limits for gaussian fit (plim)

<b>keepinterfiles</b>	no	boolean	no	yes—no
-----------------------	----	---------	----	--------

Keep intermediary files produced?



Note that the *rangescale* parameter default is appropriate for the MOS, but not for the pn; for the pn the default should be 15.0

### Parameters for individual tasks

#### Standard SAS parameters

Some SAS options are also interpreted by **espfilt** before being passed to its constituent tasks:

- **'-V'** (verbosity) is used in the same way as the SAS\_VERBOSITY environment variable.
- **'-o'** (odf) is used to define the directory where the data resides in the same way as the SAS\_ODF environment variable. Normally, the task checks the environment variable SAS\_ODF, then checks if a valid **odfingest**-produced ASCII file is present, but the user can enter the odf directory or file on the command line with this option.
- **'-i'** (ccf) is used to define the directory where the Calibration (CCF) data resides in the same way as the SAS\_CCF environment variable. Normally, the task checks the environment variable SAS\_ODF, then checks if a valid **cifbuild**-produced ASCII file is present, but the user can enter the ccf directory or ccf.cif file on the command line with this option.
- There is emulation of the **'-h'** (help), **'-m'** (manpage), **'-p'** (param) parameters.

## 5 Errors

This section documents warnings and errors generated by this task (if any). Note that warnings and errors can also be generated in the SAS infrastructure libraries, in which case they would not be documented here. Refer to the index of all errors and warnings available in the HTML version of the SAS documentation.

#### **badEnergyChans** (*error*)

elow GT ehigh

#### **noClosed** (*error*)

Does not work with filter=Closed ODFs

#### **noOOTwMOS** (*error*)

Will not process PN OOT file for MOS input EVLI

#### **noPNFast** (*error*)

Espfilt does not support EPN Fast mode

#### **noPNSmallWindow** (*error*)

Espfilt does not support EPN Small Window mode

#### **UnsupportedMethod** (*error*)

Method must be either histogram or ratio

#### **badInfile** (*error*)

Input event list does not have necessary components.

**noGTI** (*error*)

GTI file does not exist

**badInfile** (*error*)

Problems reading, accessing table, columns in event file.

**badTable** (*error*)

Input or output file table missing critical Column

**evselect** (*error*)

Problems filtering one of the files with evselect.

**noCounts** (*error*)

All histo counts are zero! Check your FOV Lightcurve!

**textwrite** (*error*)

Error writing to a text file, \*.txt or \*.qdp.

**LCgtLIMITS(2)** (*error*)

Lowest count in lightcurve is GT limits(2)

**PNLargeWindow** (*warning*)

EPN PrimeLargeWindow SUBMODE may produce suspect results, but will attempt  
*corrective action:* attempts analysis

**RatioBinLT100** (*warning*)

Binsize for Ratio Method should be  $\geq 100$   
*corrective action:* attempts analysis

**noIntervals** (*warning*)

Did not find any intervals that meet criteria  
*corrective action:* attempts analysis

**lowOutOfRange** (*warning*)

low outside acceptable range  
*corrective action:* sets LIMME to -9.99E+99

**MaxPLCltHigh** (*warning*)

Max plc value outside acceptable range  
*corrective action:* sets HIMME to -9.99E+99

**HfitEvalBlownUp** (*warning*)

Components for calculating HIMME/H.TOTL may have blown up  
*corrective action:* suggest alternate IP params

**LfitEvalBlownUp** (*warning*)

Components for calculating LIMME/L.TOTL may have blown up  
*corrective action:* suggest alternate IP params

**NoOpenQDPfile** (*warning*)

Problem open/read/write output QDP file  
*corrective action:* attempts write to LUN

**SingularMatrix** (*warning*)

Singular matrix solution  
*corrective action:* No Count Rate Histogram Produced

**nnLTzero** (*warning*)

Close interval running problem. NN is LT 0?  
*corrective action:* suggest alternate IP params

**BadFittingParam** (*warning*)

Your choices for input params are causing gaussian fit to fail

*corrective action:* suggest alternate IP params

## 6 Input Files

1. A filtered event list FITS file created by the XMM-Newton Pipeline (PPS) or reprocessing via one of the EPIC chain tasks. These normally have the form P????????????????EVLI????FIT but this is not strictly necessary because the user may specify any valid event file using the **eventfile** parameter. In the examples, files such as “mos1S001.fits” are short form for these chain-produced long file name event lists.

The structure of files in the ODF is described in [1].

## 7 Output Files

Common files to both methods have the same names.

**Note well:** In instances where there are similar filenames, but where one has a 'c', that indicates the file is *cleaned*, e.g., mos1S001-fovev.fits is an event list before being cleaned by espfilt and the resulting cleaned event list from it will be mos1S001-fovevc.fits.

1. Filtered event list for the entire detector x-allevc.fits
2. Filtered image file for the entire detector (no other selection) x-allimc.fits
3. Lightcurve file for the FOV x-fovlc.fits
4. Unfiltered event list for the corners x-corev.fits (intermediary)
5. Filtered event list for the corners x-corevc.fits
6. Filtered image file for the corners (no other selection) x-corimc.fits
7. Lightcurve file for the corners x-corlc.fits
8. Post-filtering Good Time Interval (GTI) file x-gti.fits
9. Unfiltered FOV annulus event file x-annev.fits (ratio method only)
10. Unfiltered FOV annulus spectrum x-ann.pi (ratio method only)
11. QDP text file of histograms and lightcurves x-hist.qdp

“x” has the form {inst}{expid}, such as mos1S001.



## 8 Intermediate Files

There is a parameter, *keepinterfiles* that controls whether products produced from *evselect* calls are kept (true) or deleted (false).

1. Good Times Interval text file *x-gti.txt*
2. Unfiltered corner event list *x-corev.fits*
3. Unfiltered corner image file (no other selection) *x-corim.fits*
4. Unfiltered image file for the entire detector (no other selection) *x-fovim.fits*

## 9 Algorithm

Below is the algorithm for the CORNER METHOD

```
subroutine espfilt
  Read parameters.
  Create these with evselect
    FOV image
    FOV lightcurve
    Corner event list
    Corner image
    Corner lightcurve
  if (method .eq. ratio)
    Create FOV annulus event list
    Create FOV annulus image
    Create FOV annulus lightcurve
  endif
  Call method
  if (method .eq. histogram) then
call histogram_method
subroutine histogram_method:
  Construct intermediary file names (QDP, GTI)
  call clean_lc (based on clean_rel.pro)
subroutine clean_lc:
  extract columns TIME, RATE from FOV LC
  extract columns TIME, RATE from corners LC
  bin TIME, RATE columns from object LC
  bin TIME, RATE columns from corners LC
  smooth RATE column from object LC
  smooth RATE column from corners LC
    create histogram sortindex array
    fill sortindex as simple histogram of counts
    find peak of the distribution
    run downhill simplex multi-D minimization of
    gaussian fit function
    verify goodness of fit
    call write_qdp_gti to create output quicklooks
  end clean_lc
  call gauss_fit
```





```
        end histogram_method
elseif (method .eq. ratio) then
    call ratio_method
    subroutine ratio_method:
        extract corner spectrum
        backscale corner spectrum
        extract FOV annulus spectrum
        backscale FOV annulus spectrum
        read exposure, backscal, counts from Corner data.
        read exposure, backscal, counts from FOV Ann data.
    create ratio of FOV annulus to corner:
        ratio = fovann_counts / corner_counts * \
            (corner_time * corner_area) / \
            (fovann_time * fovann_area)
        call clean_lc as above
    create ratio of FOV annulus to corner LC
    create GTI for time intervals when FOV\corner
        ratio acceptable
        call write_qdp_gti to create output quicklooks
    end ratio_method
end call_method

Create these with evselect:
    FOV filtered (flare-free) event list
    FOV filtered (flare-free) image
    Corner filtered (flare-free) event list
    Corner filtered (flare-free) image
Add EHIGH, ELOW attributes to products
Add fit parameters attributes to products:
    NORM, WIDTH, CENTER
    H_IMME, H_TOTL, L_IMME, L_TOTL
end espfilt
subroutine write_qdp_fit
    open QDP output file
    write header, title information
    write out count rate histogram
        overlay selection and fit limits
    write out FOV lightcurve
        overlay GTIs
    write out Corner lightcurve
        overlay GTIs
    open ASCII gti.txt file
        write out GTIs to ASCII
    task gtibuild create GTI fits file
    end subroutine write_qdp_fit
```

## 10 Comments

The Ratio Method suffers from a speed difference with the Histogram Method due to the running of task backscale.



## 11 Future developments

- Test Snowden's Poissonian curve method.
- Allow user-specified corner and image boundary pixel definitions.
- Allow user-specified inputs to task evselect from command line.
- Use direct pgplot calls to produce PS output rather than QDP file.
- increase matrix efficiency using Mukai's Marquadt F90 subroutines.

## References

- [1] ESA. XMM Interface Control Document: Observation and Slew Data Files (XSCS to SSC) (SciSIM to SOCSIM). Technical Report XMM-SOC-ICD-0004-SSD Issue 2.5, ESA/SSD, June 2000. Found at the URL: [ftp://astro.estec.esa.nl/pub/XMM/documents/odf\\_icd.ps.gz](ftp://astro.estec.esa.nl/pub/XMM/documents/odf_icd.ps.gz).