



# edetect\_chain

January 12, 2017

## Abstract

The task **edetect\_chain** performs source detection on a user specified set of EPIC images using the tasks **eexpmap**, **emask**, **eboxdetect**, **esplinemap**, **emldetect**, and **esensmap**.

## 1 Instruments/Modes

Instrument	Mode
EPIC MOS:	IMAGING
EPIC PN:	IMAGING

## 2 Use

pipeline processing	yes
interactive analysis	yes

## 3 Description

This chain script runs the SAS tasks **eexpmap**, **emask**, **eboxdetect** (local mode), **esplinemap**, **eboxdetect** (map mode), **emldetect**, **esensmap** in sequence.

### 3.1 Overview on detection chain constituent tasks

#### **eexpmap:**

The task **eexpmap** uses the attitude file, the CAL vignetting information, and the exposure and bad pixel extensions of the photon event files to calculate an exposure map corresponding to the input image.

#### **emask:**

Creates a detector mask (values 0 or 1) based on exposure or exposure-gradient cutoff values. The detection tasks optionally use the mask to limit the detection to areas where the mask is 1.



**eboxdetect** (local mode):

In local mode, (parameter `usemap="no"`), **eboxdetect** uses a 5x5 (or 3x3) pixel box and a surrounding (+2 pixels) background area to search for significant sources simultaneously in all input images.

**esplinemap**:

**esplinemap** uses the source list from **eboxdetect** (local mode) to remove sources from the input images and creates smooth background maps by fitting a 2-D spline to the images. The parameter `nsplinenodes` determines the number of nodes per dimension. With `nsplinenodes=16`, **esplinemap** is able to model the approximate shape of large extended objects. This is necessary for the reliable detection of point sources. For the detection of extended objects (e.g. clusters of galaxies), it is recommended to use a smoother background map (`nsplinenodes=10 – 12`).

From version 3.2 on, **esplinemap** can read an EPIC PN event set and calculate the background caused by out-of-time events (visible as streaks on both sides of bright sources in readout directions). This works only (and is only necessary) for PN images. This feature is switched on with the **esplinemap** parameter `withootset=yes`, parameter `ooteventset` specifies the name of the event set. The event set should have the same selections in `TIME` and `FLAG` as the **esplinemap** input image.

**eboxdetect** (map mode):

In map mode, (parameter `usemap="yes"`), **eboxdetect** uses a 5x5 (or 3x3) pixel box and the values from the background map to search for significant sources simultaneously in all input images.

**emldetect**:

This task uses the output list from **eboxdetect** and determines parameters for each input source by means of a maximum likelihood fit to the input images. The fit is performed on a subimage around the source with the radius defined by `eml_ecut`.

Several source parameters can be set to define the source model:

- `eml_fitextent` determines whether a point source or an extent model (`eml_extentmodel`) convolved with the PSF is modelled.
- `eml_nmulsou` determines the maximum number of sources used to fit one input source.
- `eml_nmaxfit` is the maximum number of input sources which can be fitted simultaneously, if their positions are within a circle defined by `eml_scut`.

Since the fitting of extent models and multiple source models are CPU intensive, the following parameters can be used to limit the computation time:

- If flag `eml_withtwostage` is set and `eml_nmulsou > 1`, the fitting is performed in two stages: In the first run only one source model is fitted to the image. Only if this source is significantly extended, a second fit with `eml_nmulsou` sources is performed.
- If flag `eml_withthreshold` is set, a threshold defined by `eml_threshold` is applied to the values in input column `eml_threshcolumn`. Only sources above the threshold are fitted with a multiple source model (maximum number `eml_nmulsou`).

From the likelihood of the best fit and the likelihood of the NULL model (source count rate zero) a detection likelihood is calculated (see the documentation of **emldetect** for details). If the detection likelihood exceeds the threshold set by `likemin`, the source is written to the final source list (`eml_list`).



### **esensmap:**

For each input image **esensmap** calculates a sensitivity map in units of counts/sec for a likelihood threshold given by the parameter **esen\_mlmin**.

## **3.2 Use of edetect\_chain**

The user can specify an arbitrary combination of images from different energy bands and different EPIC instruments. All images must have identical binning and WCS keywords. **Up to three instruments** (MOS1, MOS2, PN) **with up to six images in different energy bands** can be processed simultaneously (but beware of the memory limitations of your machine). Users are encouraged not to use more than five energy bands.

The detection tasks **eexpmap**, **eboxdetect**, and **emldetect** require the energy boundaries of the input images as input parameters **pimin** and **pimax**. **edetect\_chain** checks whether the number of input values for **pimin** and **pimax** matches the number input images. Otherwise **edetect\_chain** will be terminated with an error. Details on the individual tasks are given in their respective documentations.

The most important parameters of the detection tasks are accepted as input parameters by **edetect\_chain** and passed on to the tasks. Nevertheless **edetect\_chain** can be run with a relatively small set of mandatory parameters, leaving the parameters of the constituent tasks at their default values.

If the exposure maps have already been created in an earlier run of **edetect\_chain** (or the PPS produced exposures maps have been renamed to the **edetect\_chain** standard file names), the calculation of exposure maps can be omitted by setting **witheexpmap="no"**.

If the event lists corresponding to the images are not available, a dummy EPIC file (e.g. the image itself) can be given as parameter **eventsets**. This will lead to a less accurate calculation of the exposure maps.

## **3.3 Examples**

1. Simultaneous detection run on the 5 standard energy bands of the MOS1 detector:

```
edetect_chain imagesets='M1IMAGE_1000.FIT M1IMAGE_2000.FIT M1IMAGE_3000.FIT
                        M1IMAGE_4000.FIT M1IMAGE_5000.FIT' \
eventsets=M1EVLI.FIT \
attitudeset=atthk.dat \
pimin='200 500 1000 2000 4500' \
pimax='500 1000 2000 4500 12000' \
ecf='1.8118 1.8837 0.75057 0.15077 1.42326'
```

Note: Here we use energy conversion factors for the thin filter (see the 2XMM and 3XMM documentations at

[http://xmmssc-www.star.le.ac.uk/Catalogue/2XMM/UserGuide\\_xmmcat.html#EmldetFit](http://xmmssc-www.star.le.ac.uk/Catalogue/2XMM/UserGuide_xmmcat.html#EmldetFit) ,  
[http://xmmssc-www.star.le.ac.uk/Catalogue/3XMM-DR4/UserGuide\\_xmmcat.html#ProbleCFs](http://xmmssc-www.star.le.ac.uk/Catalogue/3XMM-DR4/UserGuide_xmmcat.html#ProbleCFs) ;  
in particular

[http://xmmssc-www.star.le.ac.uk/Catalogue/3XMM-DR4/UserGuide\\_xmmcat.html#TabECFs](http://xmmssc-www.star.le.ac.uk/Catalogue/3XMM-DR4/UserGuide_xmmcat.html#TabECFs)  
for other ecf values).

The default value of the ecf parameter is 1.0 (in units of  $10^{11}$  counts  $\text{cm}^2$   $\text{erg}^{-1}$ ), using the default value will lead to incorrect values in the **FLUX** columns of the **eboxdetect** and **emldetect** output source lists.



2. Simultaneous detection run on energy bands 2 and 3 and all EPIC detectors, use event set PNEVLI.FIT to calculate background due to out-of-time events:

```
edetect_chain imagesets='M1IMAGE_2000.FIT M1IMAGE_3000.FIT
                        M2IMAGE_2000.FIT M2IMAGE_3000.FIT
                        PNIMAGE_2000.FIT PNIMAGE_3000.FIT'
eventsets='M1EVLI.FIT M2EVLI.FIT PNEVLI.FIT' \
attitudeset=atthk.dat \
pimin='500 2000 500 2000 500 2000' \
pimax='2000 4500 2000 4500 2000 4500' \
esp_withootset=yes \
esp_ooteventset=PNEVLI.FIT
```

Note: The calculation of the background due to out-of-time events is only used for EPIC PN data, the events set given in `esp_ooteventset` has to be an EPIC PN event list and should have the same `TIME` and `FLAG` selections as the EPIC PN input images.

3. Simultaneous detection run on PN images 2 and 3, using `emldetect` to determine the extent of the sources:

```
edetect_chain imagesets='PNIMAGE_2000.FIT PNIMAGE_3000.FIT'
eventsets=PNEVLI.FIT \
attitudeset=atthk.dat \
eml_fitextent=yes \
pimin='500 2000' \
pimax='2000 4500' \
esp_nsplinenodes=12 \
eml_fitextent=yes \
eml_ecut=15.
```

Note: The parameter `eml_ecut` determines the cutout radius of the sub-image used for the ML fit. The image cut-out radius `eml_ecut` is given in pixels.

4. Simultaneous detection run on 15 input images. Use a 2 component model for background fitting. This model is a linear combination of the exposure map and the unvignetted exposure map. Set `emldetect` to fit the extent of each source and allow 2-PSF fitting. In order to save computing time, select the 'two stage' option: only if a source is detected as extended in a first fit, 2-PSF fitting is applied. Also a threshold of `LIKE > 30` is set, only for these sources 2-PSF fitting is used.

```
edetect_chain imagesets='PNIMAGE_1000.FIT PNIMAGE_2000.FIT PNIMAGE_3000.FIT PNIMAGE_4000.FIT PNIMAGE_
                        M1IMAGE_1000.FIT M1IMAGE_2000.FIT M1IMAGE_3000.FIT M1IMAGE_4000.FIT M1IMAGE_
                        M2IMAGE_1000.FIT M2IMAGE_2000.FIT M2IMAGE_3000.FIT M2IMAGE_4000.FIT M2IMAGE_
eventsets='M1EVLI.FIT M2EVLI.FIT PNEVLI.FIT' \
attitudeset=atthk.dat \
pimin='200 500 1000 2000 4500 200 500 1000 2000 4500 200 500 1000 2000 4500' \
pimax='500 1000 2000 4500 12000 500 1000 2000 4500 12000 500 1000 2000 4500 12000' \
esp_withootset=yes \
esp_ooteventset=PNEVLI.FIT \
esp_fitmethod='model' \
eml_fitextent=yes \
eml_nmulsou=2 \
eml_withtwostage=yes \
```



```
eml_withthreshold=yes \  
eml_threshold=30
```

## 4 Parameters

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

Parameter	Mand	Type	Default	Constraints
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<b>attitudeset</b>	yes	filename	attitude.fits	
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Name of attitude file

<b>eventsets</b>	yes	filename list	events.fits	
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Names of event list files

<b>imagesets</b>	yes	filename list	image.fits	
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Names of input images

<b>pimin</b>	yes	integer list	500	0,20000
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Lower energy boundaries of images; units: eV; one value per input image and up to six energy bands per instrument.

<b>pimax</b>	yes	integer list	4500	0,20000
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Upper energy boundaries of images; units: eV; one value per input image and up to six energy bands per instrument.

<b>likemin</b>	no	float	10.	0.0,1.E10
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**emldetect**: Detection likelihood threshold

<b>withexpmap</b>	no	boolean	true	
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create new exposure maps?

<b>ecf</b>	no	float	1.	0.,1000.
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**eboxdetect**, **emldetect**: Energy conversion factors

<b>eex_attrebin</b>	no	float	4.0	0.0,60.0
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**eexpmap**: Positional accuracy of attitude rebinning [arcsec]

<b>emask_threshold1</b>	no	float	0.3	0.0,1.0
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**emask**: Threshold parameter 1: fraction of maximum exposure

<b>emask_threshold2</b>	no	float	0.5	0.0,10.0
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**emask**: Threshold parameter 2: threshold for gradient of exposure

<b>eboxl_list</b>	no	filename	eboxlist.l.fits	
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**eboxdetect**: Name of local mode source list

<b>eboxm_list</b>	no	filename	eboxlist.m.fits	
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**eboxdetect**: Name of map mode source list



<b>eboxl_likemin</b>	no	float	8.	1.0,50.0
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**eboxdetect:** Local mode minimum detection likelihood

<b>eboxm_likemin</b>	no	float	8.	1.0,50.0
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**eboxdetect:** Map mode minimum detection likelihood

<b>ebox_withdetmask</b>	no	boolean	true	
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**eboxdetect:** Detection mask flag

<b>ebox_withexpimage</b>	no	boolean	true	
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**eboxdetect:** Exposure image flag

<b>ebox_boxsize</b>	no	integer	5	3,5
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**eboxdetect:** Detection box size: permitted values: 3 or 5

<b>esp_withcheese</b>	no	boolean	false	
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**esplinemap:** Flag for output of cheesed image

<b>esp_withdetmask</b>	no	boolean	true	
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**esplinemap:** Flag to use detection mask

<b>esp_nsplinenodes</b>	no	integer	13	5,20
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**esplinemap:** Number of spline nodes

<b>esp_nfitrun</b>	no	integer	3	1,5
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**esplinemap:** Number of iterations

<b>esp_excesssigma</b>	no	float	4.0	1.0,6.0
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**esplinemap:** Threshold for excess with respect to spline

<b>esp_withexpimage</b>	no	boolean	true	
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**esplinemap:** Flag to use exposure map

<b>esp_withexpimage2</b>	no	boolean	false	
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**esplinemap:** Flag to use non-vignetted exposure map in “model” mode

<b>esp_fitmethod</b>	no	string	“spline”	spline—model
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**esplinemap:** Method for background fitting

<b>esp_scut</b>	no	float	0.005	0.0,10.0
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**esplinemap:** Source cut-out flux level, [counts/arcsec<sup>2</sup>]

<b>esp_withootset</b>	no	boolean	false	
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**esplinemap:** Flag to use out-of-time event set

<b>esp_ooteventset</b>	no	filename	events.fits	
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**esplinemap:** EPN out-of-time event set

<b>eml_list</b>	no	filename	emllist.fits	
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**emldetect:** Name of source list

<b>eml_fitextent</b>	no	boolean	true	
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**emldetect:** Fit source extent



<b>eml_fitnegative</b>	no	boolean	false	
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**emldetect:** Allow fitted count rates to become negative

<b>eml_dmlextmin</b>	no	float	6.	0.0,100.
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**emldetect:** Extent likelihood threshold

<b>eml_ecut</b>	no	float	15	0.4,100.
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**emldetect:** Event cut-out radius (if .lt. 1.0: fraction of encircled energy, else pixels)

<b>eml_scut</b>	no	float	15	0.4,100.
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**emldetect:** Source cut-out radius for multiple source fits (if .lt. 1.0: fraction of encircled energy, else pixels)

<b>eml_determineerrors</b>	no	boolean	true	
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**emldetect:** Determine statistical errors

<b>eml_nmaxfit</b>	no	integer	1	1,6
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**emldetect:** Maximum number of sources to be fit simultaneously in multi-source fits

<b>eml_nmulsou</b>	no	integer	1	1,3
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**emldetect:** Maximum number of sources per input source position

<b>eml_withsourcemap</b>	no	boolean	true	
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**emldetect:** Creation of output source map

<b>eml_withdetmask</b>	no	boolean	false	
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**emldetect:** Use detector mask(s)

<b>eml_extentmodel</b>	no	string	“beta”	gaussian—beta
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**emldetect:** Model function for source extent

<b>eml_withthreshold</b>	no	boolean	true	
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**emldetect:** Flag to use likelihood/brightness threshold for multi-PSF fitting

<b>eml_threshold</b>	no	float	20.	0.0,1.E10
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**emldetect:** Threshold above which multi-PSF fitting is used

<b>eml_withtwostage</b>	no	boolean	true	
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**emldetect:** Use two stage process for multi PSF (eml\_nmulsou > 1) fitting

<b>eml_threshcolumn</b>	no	string	“LIKE”	LIKE—RATE—SCTS
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**emldetect:** Input list column to apply threshold

<b>eml_maxextent</b>	no	float	20.	0.1,300.
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**emldetect:** Maximum extent value in pixels

<b>psfmodel</b>	no	string	ellbeta	ellbeta—medium
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**emldetect:** Model PSF – fully 2d parameterized analytical EPIC PSFs or medium accuracy PSF

<b>imagebuffersize</b>	no	integer	640	100<param<10000
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**eboxdetect, emldetect:** Controls memory requirements for raster scan data.

<b>withimagebuffersize</b>	no	boolean	no	
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**eboxdetect,emldetect:** Allow user-defined values of imagebuffersize.



<b>esen_mlmin</b>	no	float	10.	0.1,1.E10
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**esensmap**: Upper limit likelihood

## 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.

### **ParameterError** (*error*)

**imagesets**, **pimin**, **pimax** must have same number of values

### **ParameterError** (*error*)

maximum number of eventsets (3) exceeded

### **TooManyImages** (*error*)

**eboxdetect** and **emldetect** accept up to 240 input images.

### **TooManyBands** (*error*)

**eboxdetect** and **emldetect** accept up to six energy bands per instrument.

### **CIFMissing** (*error*)

Environment variable SAS\_CCF is not set.

## 6 Input Files

1. EPIC FITS images
2. EPIC event list files
3. attitude file

## 7 Output Files

1. exposure maps (from task **eexpmap**)
2. unvignetted exposure maps (optional, from task **eexpmap**)
3. detector mask images (from task **emask**)
4. background maps (from task **esplinemap**)
5. “cheesed” images (optional, from task **esplinemap**)
6. **eboxdetect** source list (local mode)
7. **eboxdetect** source list (map mode)





8. **emldetect** source list
9. source maps, (optional, from task **emldetect**)
10. sensitivity images (from task **esensmap**)

The task **edetect\_chain** uses the following hardcoded extensions to the input image names for the output products:

Exposure maps: <input root>exp.<input extension>

Non-vignetted exposure maps (optional): <input root>expnovig.<input extension>

Mask images: <input root>mask.<input extension>

Background images: <input root>bkg.<input extension>

“Cheesed” images: <input root>cheese.<input extension>

Source maps: <input root>smap.<input extension>

Sensitivity images: <input root>sen.<input extension>

The names of the output source lists from **eboxdetect** and **emldetect** can be specified via the parameters **eboxl\_list**, **eboxm\_list**, and **eml\_list**.

## 8 Algorithm

see descriptions of individual tasks

## 9 Comments

## 10 Future developments

## References