



edetect_chain

April 16, 2023

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`.

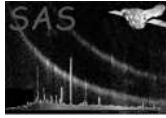
Several source parameters can be set to define the source model:

- `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.

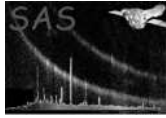
3.3 Examples

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 <https://xmmssc.aip.de/cms/documentation/catalogue-structure/#ECFs> for the default values in the catalogues).

The default value of the `ecf` parameter is 1.0 (in units of 10^{11} counts cm^2 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.

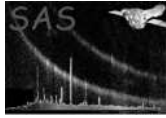
3. Simultaneous detection run on PN images 2 and 3, using `emldetect` to determine the extent of the sources:

```
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_5000.FIT
                        M1IMAGE_1000.FIT M1IMAGE_2000.FIT M1IMAGE_3000.FIT M1IMAGE_4000.FIT M1IMAGE_5000.FIT
                        M2IMAGE_1000.FIT M2IMAGE_2000.FIT M2IMAGE_3000.FIT M2IMAGE_4000.FIT M2IMAGE_5000.FIT'
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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attitudeset	yes	filename	attitude.fits	
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Name of attitude file

eventsets	yes	filename list	events.fits	
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Names of event list files

imagesets	yes	filename list	image.fits	
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Names of input images

pimin	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.

pimax	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.

likemin	no	float	10.	0.0,1.E10
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emldetect: Detection likelihood threshold

witheexpmap	no	boolean	true	
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create new exposure maps?

ecf	no	float	1.	0.,1000.
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eboxdetect, **emldetect**: Energy conversion factors

eex_attrebin	no	float	4.0	0.0,60.0
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eexpmap: Positional accuracy of attitude rebinning [arcsec]

emask_threshold1	no	float	0.3	0.0,1.0
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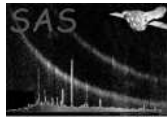
emask: Threshold parameter 1: fraction of maximum exposure

emask_threshold2	no	float	0.5	0.0,10.0
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emask: Threshold parameter 2: threshold for gradient of exposure

eboxl_list	no	filename	eboxlist.l.fits	
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eboxdetect: Name of local mode source list



eboxm_list	no	filename	eboxlist_m.fits	
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eboxdetect: Name of map mode source list

eboxl_likemin	no	float	8.	1.0,50.0
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eboxdetect: Local mode minimum detection likelihood

eboxm_likemin	no	float	8.	1.0,50.0
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eboxdetect: Map mode minimum detection likelihood

ebox_withdetmask	no	boolean	true	
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eboxdetect: Detection mask flag

ebox_withexpimage	no	boolean	true	
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eboxdetect: Exposure image flag

ebox_boxsize	no	integer	5	3,5
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eboxdetect: Detection box size: permitted values: 3 or 5

esp_withcheese	no	boolean	false	
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esplinemap: Flag for output of cheesed image

esp_withdetmask	no	boolean	true	
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esplinemap: Flag to use detection mask

esp_nsplinenodes	no	integer	13	5,20
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esplinemap: Number of spline nodes

esp_nfitrun	no	integer	3	1,5
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esplinemap: Number of iterations

esp_excesssigma	no	float	4.0	1.0,6.0
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esplinemap: Threshold for excess with respect to spline

esp_withexpimage	no	boolean	true	
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esplinemap: Flag to use exposure map

esp_withexpimage2	no	boolean	false	
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esplinemap: Flag to use non-vignetted exposure map in “model” mode

esp_fitmethod	no	string	“spline”	spline—model
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esplinemap: Method for background fitting

esp_scut	no	float	0.005	0.0,10.0
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esplinemap: Source cut-out flux level, [counts/arcsec²]

esp_withootset	no	boolean	false	
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esplinemap: Flag to use out-of-time event set

esp_ooteventset	no	filename	events.fits	
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esplinemap: EPN out-of-time event set

eml_list	no	filename	emllist.fits	
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emldetect: Name of source list



eml_fitextent	no	boolean	true	
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emldetect: Fit source extent

eml_fitnegative	no	boolean	false	
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emldetect: Allow fitted count rates to become negative

eml_dmlextmin	no	float	6.	0.0,100.
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emldetect: Extent likelihood threshold

eml_ecut	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)

eml_scut	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)

eml_determineerrors	no	boolean	true	
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emldetect: Determine statistical errors

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

eml_nmulsou	no	integer	1	1,3
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emldetect: Maximum number of sources per input source position

eml_withsourcemap	no	boolean	true	
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emldetect: Creation of output source map

eml_withdetmask	no	boolean	false	
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emldetect: Use detector mask(s)

eml_extentmodel	no	string	“beta”	gaussian—beta
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emldetect: Model function for source extent

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

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

eml_withtwostage	no	boolean	true	
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emldetect: Use two stage process for multi PSF ($\text{eml_nmulsou} > 1$) fitting

eml_threshcolumn	no	string	“LIKE”	LIKE—RATE—SCTS
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emldetect: Input list column to apply threshold

eml_maxextent	no	float	20.	0.1,300.
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emldetect: Maximum extent value in pixels

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

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

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

esen_mlmin	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*)

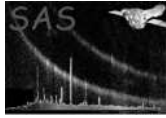
Environment variable **SAS_CCF** is not set.

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