edetect_chain

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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 cuased by out-of-time events (visible as streaks on both sides of bright sourcces 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 likehood fit to the input images. The following **edetect_chain** parameters are passed to **emldetect**:

`likemin`: Likelihood threshold (**emldetect** parameter `mlmin`).
`ecf`: Energy conversion factors for each input image (unit: $10^{11} cts\ cm^2\ erg^{-1}$).
`eml_list`: Output source list name.
`eml_fitextent`: Determine extent of sources?
`eml_determineerrors`: Determine statistical errors of source parameters?
`eml_nmaxfit`: Maximum number of sources to be fit simultaneously.
`eml_nmulsou`: Maximum number of model sources per input source position.
`eml_withsourcemap`: Generate a source map (background image + model sources)?
`eml_withhotpixelfilter`: Suppress detection of hot pixels?
`eml_usecalpsf`: Use PSF model from CAL? Otherwise use analytical PSF.
`eml_extentmodel`: Choose model for source extent: "gaussian" or "beta".

Please note that the using the options `eml_fitextent`, `eml_nmaxfit`, and `eml_nmulsou` can lead to significant increases in computation times. It is not advisable to use extent fitting with a full set of 5 images, instead run extent fitting on only 1 or 2 input images. Using the **emldetect** internal analytical PSF (`eml_usecalpsf`=no) saves computation time when performing extent fitting.

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 3 instruments (MOS1, MOS2, PN) with up to 5 images in different energy bands can be processed simultaneously (but beware of the memory limitations of your machine).

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.

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 2000 4500 7500''
              pimax=''500 2000 4500 7500 12000''
              ecf=''1.8035 1.9872 0.75557 0.26502 0.028794''
```

Note: Here we use energy conversion factors for the thin filter (see
`http://xmmssc-www.le.ac.uk/pubdocs/SSC-LUX-TM-0059.ps.gz`
for other ecf values). 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=0.93
              usecalpsf=no
```

Note: The parameter `eml_ecut` determines the cutout radius of the sub-image used for the ML fit. `eml_ecut` is given as encircled energy fraction (EEF) of the EPIC PSF. For an on-axis source `eml_ecut`=0.93 corresponds to a cutout radius of $\sim$ 45 arcsec. The use of the analytical PSF (`usecalpsf`="no" will save computing time when performing extent fitting.

4 Parameters

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

Parameter	Mand	Type	Default	Constraints
attitudeset	yes	filename	attitude.fits	
Name of attitude file				
eventsets	yes	filename list	events.fits	
Names of event list files				
imagesets	yes	filenamelist	image.fits	
Names of input images				
pimin	yes	integer list	500	0,20000
Lower energy boundary in PI channels				
pimax	yes	integer list	4500	0,20000
Upper energy boundary in PI channels				
likemin	no	float	10.	2.,1000.

emldetect: detection likelihood threshold

witheexpmap	no	boolean	true	

create new exposure maps?

ecf	no	float	1.	0.,1000.

energy conversion factors

eex_attrebin	no	float	4.0	0.0,60.0

eexpmap: Positional accuracy of attitude rebinning [arcsec]

eex_usedss	no	boolean	true	

eexpmap: use DSS info from input image

eex_withpatterns	no	boolean	true	

eexpmap: User selected event patterns?

eex_pattern	no	string	" "	

eexpmap: Event Pattern types

emask_threshold1	no	float	0.2	0.0,1.0

emask: threshold1 (fraction of maximum)

emask_threshold2	no	float	0.5	0.0,10.0

emask: threshold2 (gradient)

eboxl_list	no	filename	eboxlist_l.fits	

Name of eboxdetect local mode source list

eboxm_list	no	filename	eboxlist_m.fits	

Name of eboxdetect map mode source list

eboxl_likemin	no	float	6.	1.0,50.0

eboxdetect: local detect minimum detection likelihood

eboxm_likemin	no	float	6.	1.0,50.0

eboxdetect: map detect minimum detection likelihood

ebox_withdetmask	no	boolean	true	

eboxdetect: detection mask flag

ebox_withexpimage	no	boolean	true	

eboxdetect: exposure image flag

ebox_boxsize	no	integer	5	3,5

eboxdetect: detection box size: permitted values: 3 or 5

esp_withcheese	no	boolean	false	

esplinemap: flag for output of cheesed image

esp_withdetmask	no	boolean	false	

esplinemap: flag to use detection mask

esp_nsplinenodes	no	integer	16	5,20

esplinemap: number of spline nodes

esp_nfitrun	no	integer	3	1,5

esplinemap: number of iterations

esp_scut	no	float	0.005	0.0,10.0

esplinemap:source cut-out flux level [counts/arcsec^2]

esp_excesssigma	no	float	4.0	1.0,6.0

esplinemap: threshold for excess with respect to spline

esp_withexpimage	no	boolean	false	

esplinemap: flag to use exposure map

esp_withootset	no	boolean	false	

esplinemap: flag to use out-of-time event set

esp_ooteventset	no	filename	events.fits	

EPN out-of-time event set

eml_list	no	filename	emllist.fits	

emldetect: source list

eml_fitextent	no	boolean	false	

emldetect:fit source extent

eml_ecut	no	float	0.68	

emldetect: events cut-out radius

eml_scut	no	float	0.9	

emldetect: source cut-out radius for multiple source fits

eml_determineerrors	no	boolean	false	

emldetect: determine stat errors

eml_nmaxfit	no	integer	1	1,6

emldetect: max number of sources for multi-source fits

eml_nmulsou	no	integer	1	1,3

emldetect: max number of sources per input source position

eml_withsourcemap	no	boolean	false	

emldetect: creation of output source map

eml_withxidband	no	boolean	false	

emldetect: add xid band output

eml_withhotpixelfilter	no	boolean	false	

emldetect: use hot pixel filter

eml_withdetmask	no	boolean	false	

emldetect: use detector mask(s)

eml_extentmodel	no	string	"gaussian"	gaussian—beta

emldetect: source extent model

esen_mlmin	no	float	10.	1,20

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.

Parameter error *(fatal)*
imagesets,pimin,pimax must have same number of values

Parameter error *(fatal)*
maximum number of eventsets (3) exceeded

missingAttribute *(fatal)*
Attribute INSTRUME missing in file <image>

missingAttribute *(fatal)*
Attribute INSTRUME missing in file <eventlist>

NoEvlist *(warning)*
The task **eexpmap** needs exposure and bad pixel information from the event list, otherwise the exposure map will be inaccurate
corrective action: No event list for <INSTR> specified, no EXPOSURE information

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. detector mask images (from task **emask**)
3. background maps (from task **esplinemap**)
4. **eboxdetect** source list (local mode)
5. **eboxdetect** source list (map mode)
6. **emldetect** source list

7. source maps, if `eml_withsourcemap`="yes" (from task **emldetect**)
8. 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>
Mask images: <input root>mask.<input extension>
Background images: <input root>bkg.<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