esplinemap

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Abstract

ESPLINEMAP uses the **eboxdetect** local mode source list to derive spline background maps from the non-source regions.

1 Instruments/Modes

Instrument	Mode
EPIC MOS	IMAGING
EPIC PN	IMAGING

2 Use

pipeline processing	yes
interactive analysis	yes

3 Description

Sources found in the local detection step (task **eboxdetect**) at significance levels (column SIGMA of eboxdetect source list) exceeding a user-specifiable threshold (input parameter `mlmin`) in the respective energy band are removed from the image using a suitable PSF and source brightness dependent cut-out radius (determined to be the radius at which each source contributes more than a user-specifiable number of counts/arcsec^2 to the background; parameter `scut`; default value: 0.01). The resulting image can optionally be output for diagnostic purposes. After the removal of the sources the image is rebinned to a grid of the dimension `nsplinenodes` $\times$ `nsplinenodes`.

Division of the image by the exposure image removes gradients due to spatial variations of the exposure from the image which otherwise would not be well represented by the spline fit. A two dimensional spline fit of the rebinned and exposure corrected image is performed. The number of spline nodes (default value: 16) is user-selectable. Finally, the resulting spline image is again multiplied by the exposure images. If the parameter `nfitrun` is set to values > 1, remaining excesses of the input image over the result of spline fit can be removed iteratively: if pixels of the rebinned image deviate from the spline fit by more than a specifiable number of sigmas (default value: 4 sigmas) the excesses are removed by setting their statistical weights to zero and the spline fit is repeated (maximum number of iterations may be specified).

The number of removed bins and the reduced chi^2 values are displayed when using verbosity level 5 or higher. Note that removal of a large number of contiguous bins will lead to areas where the spline fit is unconstrained.

The reduced chi^2 and corresponding number of degrees of freedom of the background map with respect to the input image is stored in the keywords CHISQR and NDOF of the output background map.

From version 3.0 esplinemap is able to determine the background caused by out-of-time events registered during the readout process of the PN CCDs. If the flag `withootset` is set, the photon event table specified in `ooteventset` is read and the background caused by OOT events is included in the output background map. As input table **esplinemap** can use either a normal photon event data-set or a photon events table created with **epevents** with flag `withoutoftime` set. Note that in both cases a photon event set has to be filtered with the same temporal and flag selections as the image used as input to **esplinemap**. The parameters `pimin` and `pimax` are used to specify the energy range of the input image and to select those photons from the input event list that fall into this energy range. If the input event table contains only photons within the energy range of the input image, the parameters can be left at their default values `pimin`=1 and `pimax`=30000.

With version 4.0 an alternative method to fit the background of an image has been implemented: If the option `fitmethod`=model is set, a 2-component model for the detector (particle) and the cosmic X-ray backgrounds is fit to the masked and binned input image. This model consist of a linear combination of the vignetted exposure map and the unvignetted exposure mask of the input image. The exposure maps are specified by the user via the parameters `expimageset` and `expimageset2`. An example call of **eexpmap** and **esplinemap** is given here:

```
eexpmap imageset=image.fits eventset=events.fits attitudeset=attitude.fits \
        withvignetting=yes expimageset=expmap1.fits pimin=500 pimax=2000

eexpmap imageset=image.fits eventset=events.fits attitudeset=attitude.fits \
        withvignetting=no expimageset=expmap2.fits pimin=500 pimax=2000

esplinemap imageset=image.fits boxlistset=eboxlist.fits withexpimage=yes \
           bkgimageset=bkg_model.fits \
           withexpimage2=yes expimageset=expmap1.fits expimageset2=expmap2.fits \
           pimin=500 pimax=2000  \
           fitmethod=model
```

If only one exposure map is provided, it is assumed to be a vignetted exposure map and a flat image is used as the second model component. All other parameters of **esplinemap** can be used as in the case of `fitmethod`=spline.

A third `fitmethod` has been introduced with version 5.0. `fitmethod`=smooth invokes an adaptive smoothing of the cheesed background image. It is convolved with an Gaussian kernel whose width is increased by factors of $\sqrt{2}$ in eight consecutive steps. For each image position, the layer with the best signal-to-noise ratio is chosen out of the eight smoothed image layers. Neighboured layers are interpolated to achieve the final smoothed background map. The adaptive smoothing is particularly useful if the background is varying strongly over the field of view and set as default in **edetect_stack**.

4 Parameters

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

Parameter	Mand	Type	Default	Constraints
boxlistset	yes	filename	eboxlist.fits	
Name of eboxdetect source list				
imageset	yes	filename	image.fits	
Names of input EPIC fits images				
bkgimageset	yes	filename	bkgimage.fits	
Name of output spline background map				
fitmethod	no	string	spline	spline—model—smooth
Fitting method: spline fit, 2-component background model, or adaptive smoothing.				
expimageset	no	filename	expimage.fits	
Name of input exposure map				
expimageset2	no	filename	expimage.fits	
Name of second input exposure map for option "fitmethod=model"				
detmaskset	no	filename	detmask.fits	
Name of input detection mask				
scut	no	float	0.01	$[0.0 \leq param \leq 10.0]$
Source cut-out flux level; [counts/arcsec^2]				
idband	no	integer	1	$[0 \leq param \leq 9]$
Band id from eboxdetect source list				
mlmin	no	float	1.0	$[0.0 \leq param \leq 50.0]$
Minimum single band detection likelihood for sources to be cut out				
nsplinenodes	no	integer	16	$[10 \leq param \leq 20]$
Number of spline nodes				
excesssigma	no	float	4.0	$[1.0 \leq param \leq 6.0]$
Threshold for excesses sigmas with respect to background spline fit				
nfitrun	no	integer	3	$[1 \leq param \leq 5]$
Number of iterations for removal of excesses, nfitrun=1 means no removal				
withdetmask	no	boolean	true	
Flag to use detection mask				
withexpimage	no	boolean	true	
Flag to use exposure map				
withexpimage2	no	boolean	true	
Flag to use second exposure map for option "fitmethod=model"				

snrmin	no	float	30.0	[1.0 ≤ *param* ≤ 1000.0]

Desired minimum signal to noise ratio during adaptive smoothing

smoothsigma	no	float	6.0	[0.0 ≤ *param* ≤ 100.0]

Minimum width of Gaussian smoothing kernel

withcheese	no	boolean	false	

Controls optional output of photon image where sources have been masked out and, if `withootset`=true for EPIC/pn, the modelled out-of-time events have been subtracted (so called cheesed image)

cheeseimageset	no	filename	cheese.fits	

Name of diagnostic output cheesed image.

withcheesemask	no	boolean	false	

Controls optional output of mask image, value=0 for masked areas, value=1 for valid image areas

cheesemaskset	no	filename	cheesemask.fits	

Name of diagnostic output cheese mask image.

withootset	no	boolean	false	

Flag to use event table to calculate background due to out-of-time events.

ooteventset	no	filename	events.fits	

Name of photon event table used for background due to out-time-events

pimin	no	integer	1	[1<param<30000]

Lower PI channel limits of input images.

pimax	no	integer	30000	[1<param<30000]

Upper PI channel limits of input images.

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.

SplineFitError *(error)*
Less than 1 data point for chi**2

SplineFitError *(error)*
Error condition in spline fit

SplineFitError *(error)*
Error in LPSROS

SplineFitError *(error)*
Error in CALBCS

SplineFitError *(error)*
Error in ERPLPS

WrongType *(error)*
Input image has wrong type

WrongRefPix *(error)*
Reference pixel is outside of FOV

FileMismatch *(error)*
Exposure map has wrong instrument

FileMismatch *(error)*
OOT list is not an EPN event list

FileMismatch *(error)*
Exposure map has wrong size

FileMismatch *(error)*
Detection mask has wrong size

6 Input Files

1. PPS product (from task **eboxdetect** run in local detect mode): EPIC eboxdetect local mode source list
2. PPS product (from task **evselect**): EPIC FITS image
3. PPS product (from task **eexpmap**): EPIC exposure image
4. from task **emask**: Detection mask
5. Filtered photon event list from **evselect**.

7 Output Files

1. Spline background map (to be used by the tasks **eboxdetect** (map mode), **emldetect**, and **esensmap**)
2. Photon image where sources have been removed (so-called cheesed image; optional diagnostic output)

8 Algorithm

```
subroutine esplinemap

  1) If out-of-time events flag is set: Calculate background due to
```

```
    OOT events and subtract from image.
  2) Remove source count dependent circular area around EBOXDETECT
    (local mode) sources
    which have detection likelihoods greater than a specifiable
    threshold from the image.
  3) If exposure flag is set, divide image by exposure map.
  4) Perform spline fit of image, using a user-specifiable
    number of spline nodes. If detection mask flag is set,
    only use image regions marked by detection mask.
  5) If exposure flag is set, multiply spline image by exposure map.
  6) IF rebinned image pixels contain excesses above spline fit
    THEN
      remove excesses from image and repeat (2) - (5) a specifiable
      number of times
    END IF
   7) If out-of-time events flag is set: Add OOT events background to background map.

end subroutine  esplinemap
```

9 Comments

10 Future developments

References