# ebkgreg

January 27, 2025

**Abstract**

EPIC background selection for Source Products extraction

## 1 Instruments/Modes

| Instrument | Mode |
|---|---|
| EPIC PN | IMAGING |
| EPIC MOS | IMAGING |

## 2 Use

| | |
|---|---|
| pipeline processing | yes |
| interactive analysis | yes |

## 3 Description

The task **ebkgreg** searchs for the most suitable position of a region to get the background estimation of any source in an EPIC image (PN or MOS).

This task has two processing modes: multiple sources from an input source list file or single-source from command-line arguments.

In the multiple sources case the input source list has to contain the following basic parameters for each source: celestial coordinates (`RA`, `DEC`), EPIC-pn counts (`PN_CTS`) and EPIC-pn offaxis information (`PN_OFFAX`). The extraction region radius for each source is obtained from a tabulated table and it depends on the counts and the off-axis values of the source. All of that mandatory information is included in the 'EPIC summary source list' from the standard distribution of the pipe-line processing. Additionally that source list can be created from **srcmatch** (follow the link for further information).

Alternatively the extraction region radius for each source can be present in the input source list as `SRC_RAD`. In this case this is the mandatory column in the input, but not `PN_CTS` and `PN_OFFAX`.

Only in the single-source mode the source basic information can be given via the command-line arguments, `x`, `y` and `r`, where x,y are the celestial coordinates of the source and r is the source extraction radius for

Table 1: **FITS Region file structure**

| SHAPE | X | Y | R | Comment |
|---|---|---|---|---|
| CIRCLE | include_X | include_Y | include_R | Included region |
| !CIRCLE | exclude_X1 | exclude_Y1 | exclude_R1 | Excluded region |
| !CIRCLE | exclude_X2 | exclude_Y2 | exclude_R2 | Excluded region |
| ... | ... | ... | ... | ... |

source products in arcsec. Depending on the `coordtype` the source position could be RA,Dec or X,Y Sky coord.

The algorithm will search for a circular background region in the same CCD where the source is located, except for the source in the central CCD of a MOS observation in SmallWindow mode (`PrimePartialW2/3`). In that case the background is estimated from an annulus (inner radius = 5.5 arcmin, outer radius = 11 arcmin) centered in the center of the image. Thus the background is estimated from the peripheral CCDs and the central CCD is completely excluded. For EPIC-pn sources the algorithm avoids the same RAWY column of the source in order to exclude out-of-time events from the background estimate.

It is very important to notice that the algorithm search for the best background region (position and size) only based on geometrical criteria, but not looking for a source-free region in the image. The algorithm assumes that some contaminating sources could be contained in the background region. It is the user's responsability to exclude those contaminating sources from the background estimate calculation. That is very critical for some crowded sky regions.

Contaminating sources could be found by the source detection task **edetect_chain** and then the FITS Region file created by the task **region**.

Any SAS task which accepts an input FITS Region file allows also to specify exclusion regions (e.g.: **evselect**, **especget**). Those exclusion regions are identified by an exclamation mark "!" before the region shape (e.g.: !CIRCLE) and they must appear in the next rows after the including region in the Region file (see Table 1).

Example: evselect expression=region(FITSRegionFile.fits,X,Y) ...

The XMM Pipeline is able to exclude any contaminating source from the selected background region in an automatic process. That excluding process is based on the knowledge of the brightness and position of all of the sources in the image.

The background extraction region always have a radius larger than 3 pixels, otherwise no background is calculated.

## 3.1 Input

### 3.1.1 Image

The source image may be input in detector or sky (X/Y) coordinates. The task expects to find astrometry keywords in a certain part of the primary header and will exit with an error if the keywords are not found. Standard images produced by evselect and xmmselect and the pipeline will process ok. The background spline maps produced by the pipeline source detection chain and the exposure maps produced by eexpmap need to be pre-processed before they can be used within ebkgreg (see ecoordconv task).

Table 2: **Input and Output quantities**

| Value | Description | Units |
|---|---|---|
| x | Source RA or X Sky coord | deg. or 0.05 arcsec pixel |
| y | Source Dec or Y Sky coord | deg. or 0.05 arcsec pixel |
| r | Source extraction radius | arcsec |
| | | |
| bkg_ra_out | Background region center RA | deg. |
| bkg_dec_out | Background region center Dec | deg. |
| bkg_rad1_arcsec_out | Background region: circle or inner annulus radius | arcsec |
| bkg_rad2_arcsec_out | Background region: outer annulus radius | arcsec |
| bkg_x_out | Background region center X sky coord | 0.05 arcsec pixel |
| bkg_y_out | Background region center Y sky coord | 0.05 arcsec pixel |
| bkg_rad1_phys_out | Background region: circle or inner annulus radius | 0.05 arcsec pixel |
| bkg_rad2_phys_out | Background region: outer annulus radius | 0.05 arcsec pixel |

Table 3: **Input Source List. Mandatory Columns (case 1)**

| Src number | Right-ascension | Declination | PN counts | PN Off Axis | M1 counts | M1 Off Axis | M2 counts | M |
|---|---|---|---|---|---|---|---|---|
| SRC_NUM | RA | DEC | PN_CTS | PN_OFFAX | M1_CTS | M1_OFFAX | M2_CTS | |

That image has to contain keywords INSTRUME, DATE-OBS, RA_PNT, DEC_PNT and PA_PNT. It also needs to contain the WCS keywords, CRPIX1 etc. to allow conversion to image pixels. A further set of keywords, REFXCRPX etc. allow translation to an X/Y tangential plane coordinate system.

### 3.1.2 Source list

Source positions are read from the input source list file which has to contain celestial coordinates (RA, DEC), EPIC-pn or EPIC-mos1/2 counts (PN_CTS or M1_CTS or M2_CTS) and EPIC-pn or EPIC-mos1/2 offaxis information (PN_OFFAX or M1_OFFAX or M2_OFFAX). This is the default method.

Alternatively the extraction region radius for each source can be present in the input source list as SRC_RAD.

The resulting Background information will be added to the input Source List in extra columns. (see Section 3.2 for information about those extra columns).

Table 4: **Input Source List. Mandatory Columns (case 2)**

| Src number | Right-ascension | Declination | Source extraction radius |
|---|---|---|---|
| SRC_NUM | RA | DEC | SRC_RAD |

Table 5: **Source position + extraction radius**

| | | |
|---|---|---|
| x | Source RA or X Sky coord | deg. or 0.05 arcsec pixel |
| y | Source DEC or Y Sky coord | deg. or 0.05 arcsec pixel |
| r | Source extraction radius | arcsec |

#### 3.1.3 Source position

A single-source position can be given from the command-line arguments. Celestial coordinates plus a source extraction region radius is needed:

## 3.2 Output

In case of a single-source input the results are thrown to a stdout string.

The strings shown may be searched for in a script and every effort will be made to keep them constant between versions of this task.

Background extraction region: CIRCLE

```
ebkgreg withsrclist=no withcoords=yes imageset=pnimagexy.ds x=26025 y=26411 r=12 coordtype=POS
------------------------------------------------------------------------------
#
# Instrument: EPN
#
# Source position RA, Dec  (deg.)  : 79.148, 46.0275
# Source extraction radius (arcsec): 12
#
Best background extraction region estimate:
  Extraction region shape    : CIRCLE
  RA, Dec (deg.)             : 79.193, 46.0159
  Extraction radius (arcsec) : 97.8999

  X,Y Sky Coord.                      : 23770.6, 25575
  Extraction radius (X,Y Sky Coord.) : 1958


------------------------------------------------------------------------------
```

Background extraction region: ANNULUS

```
ebkgreg withsrclist=no withcoords=yes imageset=pnimagexy.ds x=24730 y=24184 r=40 coordtype=POS
#
# Instrument: EMOS1
#
# Source position RA, Dec  (deg.)  : 79.1739, 45.9966
# Source extraction radius (arcsec): 40
#
```

Table 6: **Background information. Extra columns to the input file**

| Column | Description | Units |
|---|---|---|
| BKG_DETX | Bkg Linearised Camera X-Coordinate | 0.05 arcsec |
| BKG_DETY | Bkg Linearised Camera Y-Coordinate | 0.05 arcsec |
| BKG_RA | Bkg Right-ascension | deg |
| BKG_DEC | Bkg Declination | deg |
| BKG_IMX | Bkg Image X | pixel |
| BKG_IMY | Bkg Image Y | pixel |
| BKG_X | Bkg X | 0.05 arcsec |
| BKG_Y | Bkg Y | 0.05 arcsec |
| BKG_RAD1 | Bkg extraction region: circle or inner annulus radius | 0.05 arcsec |
| BKG_RAD2 | Bkg extraction region: outer annulus radius | 0.05 arcsec |

```
Best background extraction region estimate:
  Extraction region shape    : ANNULUS
  RA, Dec (deg.)             : 79.176, 46.0001
  Inner radius (arcsec)      : 330
  Outer radius (arcsec)      : 660

  X,Y Sky Coord.                : 24624, 24437.1
  Inner radius (X,Y Sky Coord.) : 6600
  Outer radius (X,Y Sky Coord.) : 13200


-------------------------------------------------------------------------------
```

In case of multiple-sources from a source list input file the results are included in the input file as extra columns:

### 3.3 Task requirements

Because this task performs several coordinates conversions by using **esky2det** and **edet2sky**, access to the CCF components relevant to the dates of observation and analysis is required. (follow the links for further information). This is achieved in the usual way by constructing a cif file with cifbuild and pointing to it with the environment variable SAS_CCF.

## 4 Parameters

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

| **Parameter** | Mand | Type | Default | Constraints |
|---|---|---|---|---|
| **imageset** | yes | string | image | |

Input image FITS file (eg., P0123456789PNS003IMAGE_8000.FIT/FTZ).

| withsrclist | no | boolean | true | |
|---|---|---|---|---|

Whether to use the source list in the observation.

| srclisttab | yes | table | | |
|---|---|---|---|---|

Mandatory if `withsrclist` is true. Source list (e.g., P0123456789EPX000OBSMLI0000.FIT/FTZ) in the observation.

| withsrcrad | no | boolean | false | |
|---|---|---|---|---|

Extraction region radius for each source (`SRC_RAD`) from input Source List, instead the tabulated LOOKUP.FITS table. This parameter is read if `withsrclist` is true.

| withcoords | no | boolean | false | |
|---|---|---|---|---|

Whether to give the coordinates in the command-line arguments. This parameter is read if `withsrclist` is false.

| coordtype | yes | string | eqpos | eqpos pos |
|---|---|---|---|---|

The coordinate system for which the source position, specified by the parameter `x` and `y`, is defined. If `coordtype` is set to `eqpos`, then `x, y` correspond to RA and DEC respectively in decimal degrees. If `coordtype` = `pos`, then `x,y` correspond to POS coordinates. (Note that the POS coordinates are defined relative to a nominal pointing position; this is taken from the global attributes `REFXCRVL` and `REFYCRVL` of the image dataset.)

| x | yes | real | | |
|---|---|---|---|---|

The X coordinate of the source position.

| y | yes | real | | |
|---|---|---|---|---|

The Y coordinate of the source position.

| r | yes | real | | |
|---|---|---|---|---|

Source extraction region radius in arcsec.

# 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.

**invalidImageType** *(error)*
The DATAMODE keyword is not IMAGING in the image file header.

**invalidModeType** *(error)*
The INSTRUME keyword is not EPN in the image file header.

**invalidCoordType** *(error)*
Coordinate type unknown. Only POS or EQPOS are allowed.

**invalidSourceList** *(error)*
Input Source List already has background region information or Needed column not found in input Source List

**smallBkgRadius** *(warning)*

*corrective action:* Background extraction radius too small ( ¡ 3 pix ). No background region produced.

**SubTaskError** *(warning)*

*corrective action:* Error in an internal called SAS task.

# 6 Input Files

1. An EPIC image produced by evselect or xmmselect or the pipeline.
2. A Source list (optional).

# 7 Algorithm

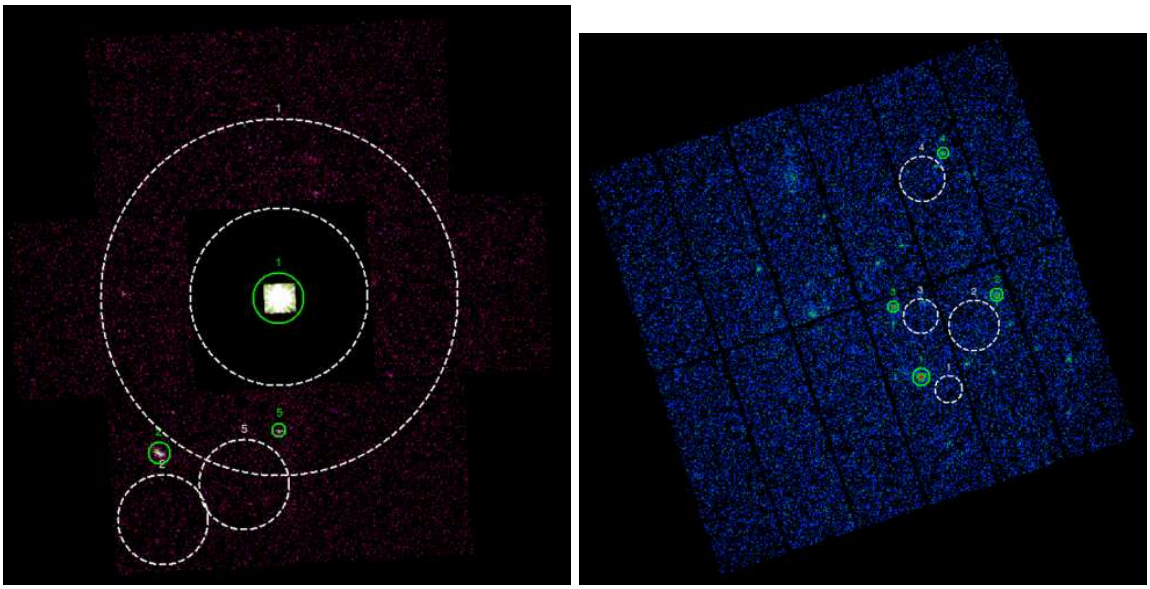
The algorithm searchs for a circular background region in the same CCD where the source is located, except for the source in the central CCD of a MOS observation in SmallWindow mode (`PrimePartialW2/3`). In that case the background is estimated from an annulus (inner radius = 5.5 arcmin, outer radius = 11 arcmin) centered in the center of the image. Thus the background is estimated from the peripheral CCDs and the central CCD is completely excluded. For EPIC-pn sources the algorithm avoids the same RAWY column of the source in order to exclude out-of-time events from the background estimate.

It is very important to notice that the algorithm search for the best background region (position and size) only based on geometrical criteria, but not looking for a source-free region in the image. The algorithm assumes that some contaminating sources could be contained in the background region. It is the user's responsability to exclude those contaminating sources from the background estimate calculation. That is very critical for some crowded sky regions.

An example of that is the source number 5 in the below MOS image (left side image). This source must be excluded from the background estimate of the source 1 because it falls into the background region of the source 1 (the big annulus).

The XMM Pipeline is able to exclude any contaminating source from the selected background region in an automatic process. That excluding process is based on the knowledge of the brightness and position of all of the sources in the image.

The background region always has a radius larger than 3 pixels, otherwise no background is calculated.



## References