# eimagecombine

April 16, 2023

**Abstract**

EPIC vignetting-corrected background-subtracted image production.

# 1   Instruments/Modes

| Instrument | Mode |
|---|---|
| EPIC PN | FF, eFF |
| EPIC MOS | FF, CCD 2-7 |
| RGS | no |

# 2   Use

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

# 3   Description

The meta-task **eimagecombine** combines the individual output images from the task **eimageget** to produce a background-subtracted, vignetting-corrected, and smoothed image of EPIC exposures.

**eimagecombine** uses all images, which are found in the directory the script is executed in and follow the naming convention of the output of **eimageget**. Note that alternatively the file-name extension ".fits.gz" is allowed to enable the usage of compressed input images. Compression becomes very efficient for larger mosaic images. In the case of existence of both files, the uncompressed file will be used.

The script can be started and interrupted at several steps. In this case, the user must ensure that the output files of the previous steps were created properly and not removed (`keepinterstage`=1).

The task operates as follows:

- Step 1 (Optional, `withcheckinput`=1):
  The individual input-image sets are checked for completeness.

- Step 2 (Optional, `maskindividual=1`):
  All images of an individual exposure will be multiplied with the corresponding mask (if existing and having the file name P<obsid><expid>_ima_mask.fits). This can e.g. be used to remove artefacts or point sources.

- Step 3 (`withaddimages=1`):
  For each energy band (0,1,...), for each image type (observed image, exposure map, filter-wheel-closed image, and out-of-time image), and for each instrument (pn, MOS1, MOS2) the images of the individual exposures are merged into one mosaic image.

- Step 4 (`withcombineimages=1`):
  The exposure maps will be weighted according to the `epn_weight`, `em1_weight`, `em2_weight` parameters. Default is 0.4 for MOS and 1.0 for pn. The weights allow to account for differences in the effective area, which can e.g. cause CCD gaps being visible in the combined images. For instance, at the location of an EPIC-pn CCD gap which is covered by one EPIC-MOS CCD with same exposure time, the (unweighted) combined exposure will decrease to ~50% in the gap, but the counts in the combined image will decrease to ~28% resulting in a lower count rate in the CCD gap.
  A mask will be created to ensure the total (weighted) exposure to be above the cut value `ecut`. This mask is applied to the mosaic images and allows to remove areas with low exposure, which would appear noisy in the final images.
  The background mosaic images (filter-wheel-closed and out-of-time) are subtracted from the observation images and the images of all instruments are finally combined.

- Step 5 (`withasmooth=1`):
  The combined images will be smoothed using **asmooth**. Per default, a constant smoothing is applied. When setting `smoothstyle` to "adaptive", a smoothing template will be created using all energy bands defined in `templatebands` and used to smooth all individual output images consistently with this template.
  The final images are divided by the weighted mosaic exposure maps to correct for vignetting effects.

## 3.1 Examples

### 3.1.1 Simple image combination

```
eimagecombine
```

In this simple call, the task will merge all images in the current working directory and use default parameters.

### 3.1.2 More sophisticated

```
eimagecombine prefix='M31_' \
              maskindividual=1 \
              epn_weight='1.0 1.0 1.0 1.0 1.0' \
              em1_weight='1.0 1.0 1.0 1.0 1.0' \
              em2_weight='1.0 1.0 1.0 1.0 1.0' \
              templatebands='0 2 3' \
              exposureband='2' \
              ecut=2000. \
              keepinterstage=0 \
```

```
smoothstyle='adaptive' \
minwidth=2.0 \
maxwidth=50.0 \
desiredsnr=6.0 \
nconvolvers=50
```

Here, only the final images are kept and have the prefix "M31_". EPIC-pn and MOS exposures are not weighted. The images are smoothed adaptively, using one smoothing template for all energy bands. The template is calculated to have a desired signal to noise ratio of 6.0 for the combination of the energy bands 0, 2, and 3. The images are masked to ensure a total (pn + MOS1 + MOS2) exposure above 2000 sec.

# 4   Parameters

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

| Parameter | Mand | Type | Default | Constraints |
|---|---|---|---|---|
| **prefix** | no | string | 'MERGED_' | |

File name prefix for the output files.

| **withcheckinput** | no | boolean | true | true\|false |
|---|---|---|---|---|

Whether to check the individual input images for consistency.

| **maskindividual** | no | boolean | false | true\|false |
|---|---|---|---|---|

Boolean to choose whether or not the images of individual exposures will be masked, if a corresponding mask for this exposure exists.

| **withaddimages** | no | boolean | true | true\|false |
|---|---|---|---|---|

Whether to add the images of individual exposures.

| **withcombineimages** | no | boolean | true | true\|false |
|---|---|---|---|---|

Whether to combine the individual EPIC instruments.

| **ecut** | no | real | 1000. | $0.0 <$ ecut |
|---|---|---|---|---|

Exposure cut (in seconds). Areas with less exposure will be masked.

| **exposureband** | no | integer | first band | |
|---|---|---|---|---|

Energy band of the exposure map, which is used to create the mask.

| **epn_weight** | no | real list | 1.0 | $0.0 <$ epn_weight |
|---|---|---|---|---|

A weight for the exposure of each energy band of EPIC-pn.

| **em1_weight** | no | real list | 0.4 | $0.0 <$ em1_weight |
|---|---|---|---|---|

A weight for the exposure of each energy band of EPIC-MOS1.

| **em2_weight** | no | real list | 0.4 | $0.0 <$ em2_weight |
|---|---|---|---|---|

A weight for the exposure of each energy band of EPIC-MOS2.

| **withasmooth** | no | boolean | true | true\|false |
|---|---|---|---|---|

Whether to create the smoothed and corrected images.
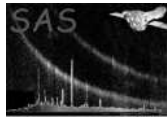
| **smoothstyle** | no | string | adaptive | simple—adaptive |
|---|---|---|---|---|

**asmooth**: The type of smoothing desired.

| **convolverstyle** | no | string | gaussian | gaussian — tophat — squarebox |
|---|---|---|---|---|

**asmooth**: This parameter is read if `smoothstyle`='simple' is chosen and prescribes the shape or type of convolver to use to smooth the image.

| **width** | no | real | 5.0 pixels | $0.0 \leq$ `width` $\leq 100.0$ pixels |
|---|---|---|---|---|

**asmooth**: This parameter is read if `smoothstyle`='simple' is chosen. It governs the width of the various types of simple convolver.

| **withuserwidths** | no | boolean | no | |
|---|---|---|---|---|

**asmooth**: This parameter is read if `smoothstyle`='adaptive' is chosen. If set, the task reads a list of gaussian-convolver sigma values from the `userwidths` parameter.

| **userwidths** | no | real list | 0 | $0.0 \leq$ `userwidths` $\leq 100.0$ pixels |
|---|---|---|---|---|

**asmooth**: The list of gaussian-convolver sigma values read when `withuserwidths`='yes'. The values must occurr in a monotonically increasing sequence.

| **minwidth** | no | real | 0.0 pixels | $0.0 \leq$ `minwidth` $\leq 100.0$ pixels |
|---|---|---|---|---|

**asmooth**: If `smoothstyle`='adaptive' is chosen but `withuserwidths`='no' the task constructs a library of gaussian convolvers which have sigma values ranging from `minwidth` to `maxwidth`.

| **maxwidth** | no | real | 10.0 pixels | $0.0 \leq$ `maxwidth` $\leq 100.0$ pixels |
|---|---|---|---|---|

**asmooth**: If `smoothstyle`='adaptive' is chosen but `withuserwidths`='no', the task constructs a library of gaussian convolvers which have sigma values ranging from `minwidth` to `maxwidth`.

| **desiredsnr** | no | real | 10.0 | $0.0 <$ `desiredsnr` |
|---|---|---|---|---|

**asmooth**: Desired signal-to-noise ratio in an adaptively-smoothed image.

| **nconvolvers** | no | integer | 20 | $2 \leq$ `nconvolvers` $\leq 126$ |
|---|---|---|---|---|

**asmooth**: If `smoothstyle`='adaptive' is chosen but `withuserwidths`='no', the task constructs a library of `nconvolvers` gaussian convolvers.

| **templatebands** | no | integer list | all bands | |
|---|---|---|---|---|

If `smoothstyle`='adaptive' is chosen, the parameter defines the energy bands, which are used to estimate the statistics for the smoothing template.

| **keepinterstage** | no | boolean | true | true|false |
|---|---|---|---|---|

Boolean to choose whether or not intermediate products will be removed.

| **n_parallel** | no | integer | 1 | |
|---|---|---|---|---|

Experimental tuning parameter to define the maximum number of parallelly executed processes.

# 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.

**error1** *(error)*

**warning1** *(warning)*

> *corrective action:*

# 6   Input Files

The output images of **eimageget** from one or more exposures.

# 7   Output Files

For each energy band, the background-subtracted, exposure-divided, and smoothed image follow the convention <perfix>_ima_<band>_subdiv_smooth.fits Earlier stage products can be removed automatically by setting `keepinterstage` to "no".

# 8   Algorithm

```
- Check input
- Mask individual images
- Add individual images to mosaics
- Weight exposures
- Create a mosaic mask
- Combine mosaic images
- Smooth images
```

# References