



# emevents

January 27, 2025

## Abstract

Define the final list of events, correct position and time for one node of one EPIC-MOS CCD over one exposure.

## 1 Instruments/Modes

Instrument	Mode
EPIC MOS	IMAGING, TIMING

## 2 Use

pipeline processing	yes
interactive analysis	yes

## 3 Description

**emevents** flags invalid events (following **evatt**), subtracts bad pixels, merges events split over two nodes, separates piled up diagonal events into two, adds the time column and monitors the GATTI performance. It also modifies the **RAWX** and **RAWY** coordinates to center the events and computes camera coordinates. **emevents** modifies the number of events. Therefore after it the event file is not consistent with the **NVALID** field of the frame file any more. It may be applied as is to slew data.

As a preliminary step, **emevents** rejects events with invalid **FRAME**, **RAWX**, **RAWY** and **PATTERN**. Those are the result of telemetry errors. They are removed from the list altogether (not only flagged).

**emevents** calls (in order) the following subroutines, all of which can be individually switched off (this is provided for calibration and debugging activities, the result will not in general be scientifically useful when not used with the default settings):

- **EV\_REC**. In EDU Threshold mode (associated to telemetry **REDUCED IMAGING** mode), all pixels above the **EMDH** lower threshold and below the **EMDH** upper threshold are transmitted individually (no event recognition is performed on board). **EV\_REC** performs the same pattern



analysis (Fig. 1) as on-board, with the difference that it is performed with the EDU threshold set at the EMDH lower threshold (everything below that was lost) and the energies  $E_3$  and  $E_4$  cannot be recovered.

EV\_REC generates the `ENERGYE1` and `ENERGYE2` columns (per event) from the original `ENGYE1E2` column (per pixel). It flags the events outside the EMDH thresholds with `OUTSIDE_THRESHOLDS`. In Imaging mode this pattern analysis is performed after `CUT_BAD` if `analysepatterns` is set to True.

In Timing mode this pattern analysis is used to reject events classified as singles or bipixels by the 1-D pattern analysis on board (Fig. 2), but which are actually part of a large track from a cosmic-ray in the framestore area. A 2-D pattern analysis, similar to that in Imaging mode (Fig. 1), is run locally around all events with `PATTERN` 0 or 1 and the event is accepted only if it would have passed the Imaging pattern analysis, with any `PATTERN` less than 30. Otherwise it is flagged as `COSMIC_RAY`. No such cosmic-ray rejection is performed if `analysepatterns` is set to False. This may not be applied in Compressed Timing mode because most events do not have a valid `RAWX` and `PATTERN` in that mode.

If Timing mode was configured on-board with `EDUMODE=3` and Imaging patterns (non-standard), then no additional pattern analysis is carried out within `emevents`. Instead the `PATTERN` values are converted to Timing patterns (Fig. 2) (between 0 and 3), and all events with vertical extension are flagged as `CLOSE_TO_BRIGHTPIX`. Those are true events, but their energy is wrong because it was added to that of another event.

- `CUT_BAD`. On-board all events centered on a bright pixel (declared in the on-board library) are rejected, but weak bad pixels (with low charge contents) can also be included in X-ray events next to them. Those events must be corrected for that. To that end all areas around bright pixels (declared or not in the on-board library), and next to borders, may be reanalysed, putting the bright pixels and the pixels outside the declared window to 0. In the process events corresponding to bright pixels not declared on board are flagged as `ON_BADPIX`. If a bright pixel is the main pixel of a split event, it may appear twice in output: the original event (flagged as `ON_BADPIX`) plus what remains after removing the bright pixel.

Bad pixels are read from the bad pixels extension added by `badpix`. Dead pixels are treated separately. Events on a pixel declared dead are flagged as `ON_BADPIX` whatever their `PATTERN`.

In `TIMING` mode there are no bad pixels, only bad columns. The events are not reanalysed, but simply flagged with `ON_BADPIX`. The same happens in Imaging mode when `analysepatterns` is set to False. This may not be applied in Compressed Timing mode because most events do not have a valid `RAWX` in that mode.

- `BINODAL`. If the CCD was read through both nodes (mode `PRI PART W6 IMAGING` only), X-rays interacting close to the median column of the CCD have their charge cloud split over both nodes. `BINODAL` recognizes as only one event those which have been detected on both sides, using the same patterns as on-board (Fig. 1). This means also rejecting events which become larger than the accepted patterns. Only events with their maximum on this side of the border are kept in the list (*i.e.* the event list remains formally associated to one node). If the frame for the other node is flagged as bad, then its events should not be merged. Instead events immediately next to the other half of the CCD should be flagged as `CLOSE_TO_CCD_BORDER`.

- `DIAGO`. Diagonal patterns (26 – 29 on Fig. 1) are mostly due to two close-by single events. `DIAGO` forms two events out of one in that case. Both events are flagged with `DIAGONAL` to distinguish them from true single events. The second event is created only if its charge (*i.e.*  $E_2$ ) is above the EMDH lower threshold. This operation does not respect the order of increasing `RAWY` within a frame. This routine is not applicable in `TIMING` mode.

When either  $E_1$  or  $E_2$  is within one HWHM of the energy of Si K (1740 eV), the event can be due to partial absorption associated with Si fluorescence, caught in a neighbouring pixel. This appears as a line at that energy in the spectrum of diagonals. If `keepsifluor` is set to True, these events are not split in two but their `PATTERN` is changed from diagonal to bipixel (so that it receives the



appropriate calibration), and it is flagged with `DIAGONAL` (to remember it was). As a side effect this creates a hole in the spectrum of diagonals at the energy of 1740 eV.

- `CUT_GTI`. All events whose frames were flagged for rejection by `emframes` (flag above 64) are flagged for rejection with `IN_BAD_FRAME`. Events whose frames were flagged below 64 by `emframes` are flagged with `IN_SPOILED_FRAME`. “cosmic-ray” events (patterns 30 and 31 in Fig. 1, read from `CRPATi` keywords) are flagged with `COSMIC_RAY`. `CUT_GTI` propagates the `FRMTIME` and `CRPATi` keywords.
- `PUT_XY` centers the events (telemetered positions are those of the upper-right corner of the 5x5 pattern area), subtracts the underscan (not relevant to the user) and adds 1 (for coherence with the FITS standard on images) so that coordinates run from 1 to 600. It also subtracts the underscans and adds 1 to the `WINDOWX0` and `WINDOWY0` keywords for coherence. Finally, it subtracts the under + overscans (in full frame mode) or 2 (in window mode) to the `WINDOWDX` and `WINDOWDY` keywords. It then computes the camera coordinates `DETX`, `DETY`, in the `CAMCOORD2` coordinate system as described in `cal`, in units of 0.05 arcseconds. This includes by default randomisation (within a CCD pixel) to avoid Moiré effects. Randomisation may be switched off using `randomizeposition=N`. In `TIMING` mode the missing coordinates are replaced by the `SRC_RAWX`, `SRC_RAWY` keywords (or the center of the CCD if those keywords do not exist) for computing the camera coordinates, and double events (always centered on the left pixel) are moved half a pixel to the right. `PUT_XY` flags the (false) events outside the window with `OUT_OF_CCD_WINDOW`.
- `PUT_TI` (`IMAGING` mode) copies for each event of a given frame the same time computed as the middle between the start and end times of the current frame. Optionally time randomisation (within a frame) may be performed using `randomizeposition=Y`. `PUT_TI` (or `PUT_TT`) creates and fills the `EXPOSURE` extension, with precise time and duration of each frame and the effective fraction of observing time, corrected for dead-time using the `CRRATIO` column of the frame file. The (small) frame transfer time (during which the sky is actually observed but smeared over a column) is subtracted from the frame duration `TIMEDEL`. Following OGIP/93-003, the time is that of the center of each frame (*i.e.* the same as that of the events).
- `PUT_TT` (`TIMING` mode) computes the time for each event as a reference time (the start time of the current cycle) plus  $(y_i + 0.5)$  times the clocking time. Precise corrections on the basis of the source position on the CCD are not done at this level. Times are computed as if the source was at the center of the CCD.
- `REJECT_ROWS`. Some instrumental effects result in several events following one another in the same row in one frame (particularly at small `RAWY`), while this is unlikely for normal X-rays. A simple way to reject this noise is to reject all events (of that frame) found in rows with many events in a given frame. This is done with flag `ON_BADROW`. The threshold may be set via `maxeventsperrrow`. To avoid rejecting true events for bright extended sources or strongly piled-up sources, the average number of counts in that row plus twice its square root ( $2\sigma$  security) is added to `maxeventsperrrow`. It is often the case that spurious events occur in nearby rows as well (in the same frame). This is addressed by checking rows within `widthnexttorow` of a bad one. As many events are rejected in those rows (by increasing distance to the bad row) as there are in excess of average.
- `REJECT_E3` (`IMAGING` mode, not reduced `IMAGING`). Some instrumental effects result in wrong events associated with pathological (usually negative) charge values next to it. This information is known through the `E3` data. A simple way to reject this noise is to reject all events whose `E3` is less than a lower threshold (read from the `E3THRESccd` field in the `XMM_MISCDATA` CCF file). This is done with flag `UNDERSHOOT`, and has very little effect on true X-rays. Sometimes the offsets applied by the EDU are much larger than what they should be for normal event detection. This can be intentional (to neutralise a noisy column, as is done on both sides of the window) but it can also happen serendipitously (bit flips in the EDU memory). `REJECT_E3` looks for such large offsets (64 or more above normal) by looking for systematically low `E3` along particular rows or columns and solving the linear equation relating `E3` to the offsets. The result (as well as the normal patched columns) is written in the `OFFSETS` extension. The events directly on



such rows or columns with wrong offset are flagged with `ON_BADOFFSET`. The test on  $E_3$  is applied after correction for the additional offsets. This automatic detection of bad offsets is not applied in Small Window mode because the additional electronic noise in that mode confuses the algorithm. The detection may also be switched off manually (in other modes) via the `detectbadoffsets` parameter.

- `REJECT_FLICKERING` (IMAGING mode). In several CCDs, a pixel may suddenly release charge over several frames, more or less randomly over the CCD. This can result in 10 events or so very close to each other, and can lead to spurious source detection. Because those events follow each other very closely in frame, they may be detected by looking at peaks in `FRAME`, `RAWX`, `RAWY` space. They cannot be mistaken with a flaring source because they are much more spatially peaked than a source (most events are in the same pixel).  
Cosmic-rays can also result in peaks in `FRAME`, `RAWX`, `RAWY` space. Many, but not all, associated events have a “cosmic-ray” `PATTERN`. They are not as spatially concentrated as the flickering events, but they can be distinguished from a flaring source because they are usually very elongated (they are due to particles at grazing incidence).  
The search is done in boxes whose half-size in `FRAME`, `RAWX`, `RAWY` is defined by triplets provided by the user via `tolfxy`. The default is optimised for the flickering events. `tolfxy=“5 2 2 2 5 5”` is better optimised for the cosmic-rays, but removes a small fraction of source counts (for that reason it is not default).
- `SP_GATTI`. In order to check the GATTI correction it is possible to compute the energy of events as it was seen by the ADC. This is done by adding the GATTI value and the offsets to all  $E_1$  energies (the other  $E_i$  are sums and therefore unsuitable to this purpose) and forming their spectrum (for events unflagged by `CUT_GTI`). All small scale (in energy) structures in the charge to ADU conversion should reappear in this spectrum. After dividing it by the direct spectrum of  $E_1$  energies convolved by the histogram of (`GATTI` + offsets) values, this can be compared with a reference spectrum to look for variations (outside **emevents**).  
In parallel, `SP_GATTI` has an active part, flagging for rejection with `REJECTED_BY_GATTI` all events with  $E_1 + \text{GATTI} + \text{offsetx}(\text{RAWX}) + \text{offsety}(\text{RAWY}) = 4095$  (range of the ADC), which should have been rejected by the EMDH upper threshold but were not due to the GATTI mechanism.  
In `TIMING` mode this test is restricted to single events, as `ENGYE1E2` is the total charge over all pixels above threshold in the event. This routine is not applicable in Compressed `TIMING` mode (no `PATTERN`).

`EV_REC`, `CUT_BAD`, `DIAGO` and `BINODAL` may run only on a fresh ODF event file, not on the result of a previous run of **emevents**.

`PUT_TIME`, `CUT_GTI` and `SP_GATTI` require an associated frame file. If `frameset` is not set then an empty `EXPOSURE` extension is created to allow propagating the CCD-specific keywords after **evlistcomb**.

`SP_GATTI` and `REJECT_E3` require an associated offset/variance file or extension. It is also advised to provide it for `CUT_BAD` and `BINODAL`. As it is not always obvious to know which offsets file is the right one (if several modes were used in an observation, there will also be several offsets files with different exposure numbers), **emevents** will select among a list of offsets files those compatible with the events file in terms of CCD, node, mode and window parameters. Among the compatible files **emevents** will select that with `DATE-OBS` closest to `DATE-OBS` of the events file, first within the offsets files obtained before the events file, then within those obtained after the events file if none was obtained before.

The first and last four column offsets (in the window) are patched to 4095 as is done in operations.

If no local offset/variance file is available (because the standard values were used), or if `offvarsetsis` not set **emevents** will read the offsets from the `cal`. If the offsets actually used were different, this will result in a large number of `spGatti11` warnings and the flagging of events with truncated energy will be wrong.



### 3.1 Patterns

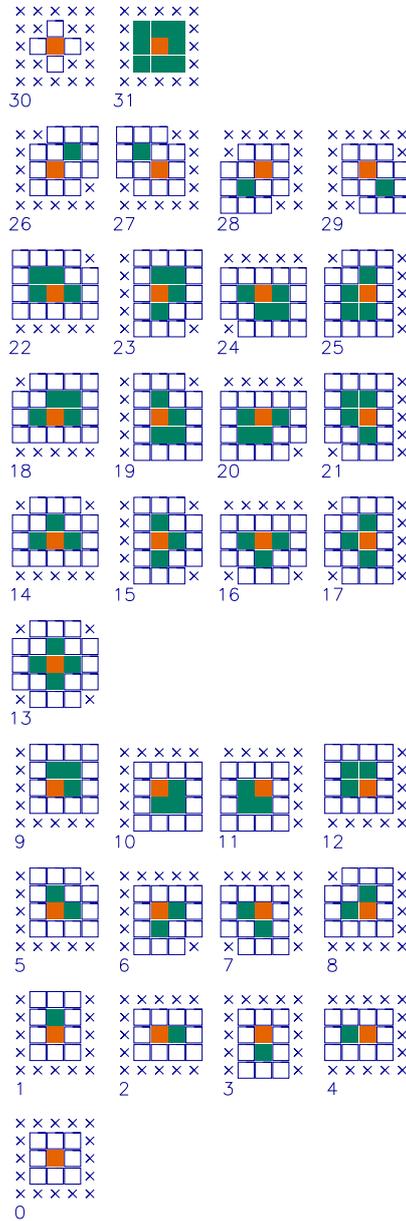


Figure 1: List of EPIC-MOS patterns (IMAGING mode)

Figure 1 for Imaging mode should be interpreted as follows:

- each pattern is included in a 5x5 matrix used for proximity analysis.
- a pattern is centered by definition on the pixel with highest charge.
- this central pixel is colored in red (its charge is  $E_1$ ).
- the other pixels above threshold in the pattern are colored in green (the sum of their charges is  $E_2$ ).



- all pixels colored in white must be below threshold.
- the crossed pixels are indifferent (they can be above threshold).
- the patterns are recognized in increasing order (this is important only for pattern 30, which comprises patterns 0 and 26-29).

The philosophy for patterns 0-25 is that a good X-ray pattern must be compact, with the highest charge at the center, and isolated (all pixels around are below threshold).

Patterns 26-29 are the so-called diagonal patterns, not expected from a genuine X-ray, but which can arise in case of Si fluorescence or of pileup of two monapixel events.

The E<sub>3</sub> and E<sub>4</sub> data in the ODF event lists have nothing to do with the "white" and "crossed" pixels.

- E<sub>3</sub> is the sum of charges of pixels below threshold in the 8 pixels of the 3x3 corona (their number is known from the pattern number).
- E<sub>4</sub> is the sum of charges of pixels below threshold in the 16 pixels of the 5x5 corona. Their number N<sub>4</sub> is known from the PERIPIX column in the event list, which stores the number of pixels above threshold in the 5x5 corona. Thus N<sub>4</sub> = 16 - PERIPIX.

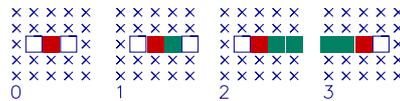


Figure 2: List of EPIC-MOS patterns (TIMING mode)

Figure 2 for Timing mode should be interpreted in the same way as in Imaging mode, with the difference that the place where maximum charge occurs is ignored. There are only crosses in the rows above and below that of the event. This means that the Timing pattern analysis is purely 1-D (it is insensitive to other rows), because each Timing 'row' is actually the sum of 100 true rows, so the rows are not physically related. Because there is no test for maximum charge, all doubles appear as PATTERN=1, whether leading or trailing.

Patterns 2 and 3 are not bounded. They are mostly not due to true X-rays, but to cosmic-ray tracks. After binning by 100 rows, cosmic-ray tracks appear as an horizontal string of pixels above threshold. Their beginning will be recorded by an event with PATTERN=2 and their end by an event with PATTERN=3. In other words, patterns 2 and 3 normally occur in pairs and define a horizontal string of pixels above threshold.

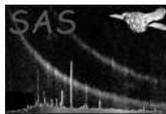
## 4 Parameters

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

Parameter	Mand	Type	Default	Constraints
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odfeventset	yes	dataset	' '	none
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Input events file



<b>frameset</b>	no	dataset	' '	none
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Input frames file from emframes

<b>newoutput</b>	no	boolean	yes	yes/no
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Create output events file (no for overwriting input)

<b>eventset</b>	no	dataset	'events.out'	none
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Output events file. If this parameter is set, then **newoutput=Y** is automatic

<b>offvarsets</b>	no	list of datasets	' '	none
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List of offset/variance files from ODF

<b>othereventset</b>	no	dataset	' '	none
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Input events file for other node (2-node CCD read-out only)

<b>otherframeset</b>	no	dataset	' '	none
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Input frames file for other node

<b>analyzepatterns</b>	no	boolean	yes	yes/no
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Use EV\_REC subtask

<b>flagbadpixels</b>	no	boolean	yes	yes/no
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Use CUT\_BAD subtask

<b>splitdiagonals</b>	no	boolean	yes	yes/no
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Use DIAGO subtask

<b>keepsifluor</b>	no	boolean	no	yes/no
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Keep Si fluorescence diagonals as one

<b>flagbadtimes</b>	no	boolean	yes	yes/no
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Use CUT\_GTI subtask

<b>setcoordinates</b>	no	boolean	yes	yes/no
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Use PUT\_XY subtask

<b>randomizeposition</b>	no	boolean	yes	yes/no
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Randomize DETX/DETY within a pixel

<b>settimes</b>	no	boolean	yes	yes/no
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Use PUT\_TI/PUT\_TT subtask

<b>randomizetime</b>	no	boolean	no	yes/no
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Randomize TIME within a frame

<b>rejectrows</b>	no	boolean	yes	yes/no
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Reject rows with too many events

<b>maxeventsperrow</b>	no	integer	4	> 0
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Maximum number of events per row in a frame

<b>widthnexttorow</b>	no	integer	10	≥ 0
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Number of rows next to bad rows to flag as well



<b>rejectbade3</b>	no	boolean	yes	yes/no
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Reject rows with too negative E3

<b>detectbadoffsets</b>	no	boolean	yes	yes/no
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Automatically detect bad offsets in the data (not in SW mode)

<b>rejectflickering</b>	no	boolean	yes	yes/no
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Reject flickering events

<b>tolfxy</b>	no	list of integers	5 2 2	$\geq 0$
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Triples of tolerances along FRAME, RAWX, RAWY

<b>flagtruncatede1</b>	no	boolean	yes	yes/no
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Use SP\_GATTI subtask

<b>writegattispecset</b>	no	boolean	no	yes/no
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Create output GATTI spectrum file

<b>gattispecset</b>	no	dataset	'gattispec.out'	none
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Output GATTI spectrum file

<b>blocksize</b>	no	integer	10000	$> 0$
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Size of event blocks

## 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.

### **getParamValues03** (*error*)

output event file name = input events file name

### **openEventsIn01** (*error*)

newoutput = no (overwrite) and ODF-style events file

### **openEventsIn02** (*error*)

Not event list extension name in events file

### **openEventsIn03** (*error*)

Not EPIC MOS extension name in events file

### **openEvents2In01** (*error*)

invalid event file from other node

### **copyColumnPart01** (*error*)

column of unknown type in events file



- getNvalid01** (*error*)  
frame number in events file outside those in frames file
- readFrames01** (*error*)  
non-regular frame numbers in frames file
- read2Frames01** (*error*)  
frame numbers not parallel for both nodes
- read2Frames03** (*error*)  
invalid frame file from other node
- initEdusoft01** (*error*)  
unexpected EDUTHR in events file
- initEdusoft02** (*error*)  
unexpected EDUMODE in events file
- initEdusoft03** (*error*)  
Imaging mode data and EDUMODE not 3
- initEdusoft04** (*error*)  
Timing mode data and EDUMODE not 1
- initEdusoft05** (*error*)  
Reduced Imaging mode data and EDUMODE not 2
- cutBad01** (*error*)  
more than 2 events created out of one in CUT\_BAD
- addOffsets01** (*error*)  
flagtruncatede1=Y but no offset/variance extension
- getParamValues10** (*warning*)  
flagbadpixels=Y but missing/invalid bad pixels extension in events file. Option is ignored  
*corrective action:* run **badpix** on input event file
- getParamValues11** (*warning*)  
splitdiagonals=Y or rejectbade3=Y but data not in Imaging mode. Option is ignored  
*corrective action:* none
- getParamValues17** (*warning*)  
analysepatterns=Y, flagbadpixels=Y, splitdiagonals=Y or othereventset is set but the input file already went through **emevents**. Option is ignored  
*corrective action:* restart from the output of **emframes** and **badpix** if you wish to reapply EV\_REC, CUT\_BAD, DIAGO or BINODAL
- getParamValues18** (*warning*)  
randomizetime=Y but data in Timing mode. Option is ignored  
*corrective action:* none
- getParamValues19** (*warning*)  
analysepatterns=Y, flagbadpixels=Y or flagtruncatede1=Y but data in Compressed Timing mode. Option is ignored  
*corrective action:* none
- getParamValues21** (*warning*)  
analysepatterns=Y but flagbadpixels=N and othereventset is not set. Option is ignored  
*corrective action:* none

**readFrames10** (*warning*)

no **FLAG** in frame file. Skip **CUT\_GTI**

*corrective action:* check what went wrong in **emframes**

**readFrames11** (*warning*)

**CR\_DEAD** not run on frame file. Continue assuming no dead time.

*corrective action:* run **emframes** with **setdeadtime=Y**

**readFrames12** (*warning*)

no **GATTIVAL** column in input frame file. Skip **SP\_GATTI**

*corrective action:* run **emframes** with **setgatti=Y**

**readFrames14** (*warning*)

The **CHECKFRA** keyword is not set in the frame file. Continue anyway

*corrective action:* check that the frame file was processed by **emframes**

**readFrames15** (*warning*)

the input frame file cannot be used. **CUT\_GTI**, **PUT\_TI/PUT\_TT** and **SP\_GATTI** are skipped

*corrective action:* the input frame file should be the output of **emframes**. Check what went wrong in **emframes**

**readFrames18** (*warning*)

**writegattispecset=Y** but **GATTI** off. Continue but no **GATTI** histogram will be produced

*corrective action:* none

**read2Frames10** (*warning*)

no **FLAG** in secondary frame file. Continue assuming all frames from secondary node are valid

*corrective action:* check what went wrong in **emframes**

**addOffsets10** (*warning*)

no offset/variance extension but **flagbadpixels=Y**, **rejectrows=Y** or **othereventset** is set. Assume constant and continue. This is non standard but has no major effect

*corrective action:* consider restarting from the output of **emframes** and **badpix**

**checkOffsets10** (*warning*)

offset/variance file does not exist. Continue

*corrective action:* check this was not a typing error

**checkOffsets11** (*warning*)

no valid offset/variance file but **flagbadpixels=Y**, **rejectrows=Y**, **flagtruncatede1=Y** or **othereventset** is set. Continue using offsets from **CAL**

*corrective action:* if you really need specific offsets, look for them in neighbouring ODFs

**findBestTime12** (*warning*)

no compatible offset/variance file older than current exposure. Consider files obtained after current exposure

*corrective action:* check you have not forgotten an **OVE.FIT** file

**checkRejected10** (*warning*)

more than 90% events rejected. Continue. This is unusual but may happen in normal conditions

*corrective action:* check the log (with verbosity set to 4 at least) to know why those events were rejected

**reanalyze13** (*warning*)

no event survived **CUT\_BAD** and **EV\_REC**

*corrective action:* check nothing went wrong

**reanalyze15** (*warning*)

**blocksize** smaller than number of events in a single frame. **blocksize** is increased internally  
*corrective action*: this is often the sign that something is deeply wrong with at least one frame. check **NVALID** in the frame file and remove the events belonging to frames with very large **NVALID**

**putXY10** (*warning*)

**PUT\_XY** was already applied before. This changes the **RAWX** and **RAWY** columns and may not be applied twice. **EV\_REC**, **CUT\_BAD** and **BINODAL** may not be reapplied either  
*corrective action*: restart from the output of **emframes** and **badpix** if you wish to reapply **PUT\_XY**

**rejectRows11** (*warning*)

**rejectrows=Y** but **PUT\_XY** not applied. **REJECT\_ROWS** not done  
*corrective action*: run **emevents** with **setcoordinates=Y**

**rejectRows12** (*warning*)

Exposure loss exceeds 1% at some rows (not corrected for)  
*corrective action*: run **emevents** with **-V 6** to know which

**spGatti11** (*warning*)

**ENERGYE1** incoherent with **GATTI** and offsets. Flag event for rejection and continue. This may affect the flare screening light curve, and may also leave a bump in the spectrum above 12 keV  
*corrective action*:

- if this warning is isolated, don't worry
- if this is an early observation (revolution 102 or before), or a mode other than full frame, then you probably need specific offsets. Restart **emevents** with **offvarsets** set to the list of all **OVE.FIT** files in the **ODF**
- if several happen in close sequence, it usually means that the frame number reconstruction in **emframes** failed at some point. The flare screening light curve will be wrong in that interval unless this is the central CCD
- if several happen along the whole exposure, but at the same X or Y, inform SOC (this is most likely a CCF error)

**checkValid14** (*warning*)

invalid **RAWX**, **RAWY** or **PATTERN**. Reject that event. This can only be the result of an error on board, in the transmission or on the ground  
*corrective action*: if several of those happen in close sequence, check **ODF** quality around those frames

**initSifluor11** (*warning*)

something went wrong in the Si fluorescence recognition. This affects a very small fraction of events  
*corrective action*: contact developer

**readBadpix15** (*warning*)

a bad pixel has invalid coordinates. Ignore it and continue  
*corrective action*: inform SOC (this is probably a CCF error)

**openEventsIn12** (*warning*)

the events file is empty. Continue anyway (the exposure may be useful)  
*corrective action*: check this is normal

**openEventsIn14** (*warning*)

**offvarsets** was set but the input file already went through **emevents**. Option ignored  
*corrective action*: restart from the output of **emframes** and **badpix** if you wish to change the offsets

**getNvalid10** (*warning*)

events were found beyond the last frame in the frame file. They are rejected  
*corrective action*: check the frame file was complete

**getNvalid11** (*warning*)

an event was found with invalid frame number. It will be rejected  
*corrective action*: check quality of neighbouring events as well

**getXmmDate13** (*warning*)

invalid or absent DATE-OBS keyword in file. Continue setting the date to 01/01/2000. This is used only for ordering event and offsets files  
*corrective action*: check DATE-OBS keyword

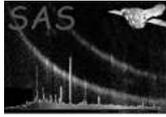
## 6 Input Files

1. EPIC MOS event list file for one CCD/node (from ODF/SDF, **emframes** or **oremevents**) with bad pixels extension (from **badpix**).
2. frame file for that CCD/node (from **emframes**). uses columns FRAME, TIME, FLAG, CRRATIO, GATTIVAL, and keywords TELESCOP, INSTRUME, OBS\_ID, EXP\_ID, CCDID, CCDNODE, GATTI\_ON, SRC\_RAWX, SRC\_RAWY.
3. EPIC MOS offset/variance file for that CCD/node (from ODF/SDF)
4. EPIC MOS event list file for the other node of the same CCD (from ODF/SDF) with bad pixels extension (from **badpix**).
5. frame file for the other node (from **emframes**)

The structure of files in the ODF is described in [1].

## 7 Output Files

1. new event list file with an **EVENTS** extension with a different number of rows and modified/additional items:
  - modified columns **RAWX**, **RAWY** (for **PRODUCT**: EPIC event list)
  - new **INTEGER\*2** columns **DETX**, **DETY** (0.05") (for **attcalc** and **PRODUCT**: EPIC event list)
  - new **REAL\*8** column **TIME** (s) (for **PRODUCT**: EPIC event list)
  - new **INTEGER\*2** column **FLAG** (for **emenergy**)
  - new **REAL\*4** columns **PHA** (ADU) and **PI** (eV) (for **emenergy**). In **TIMING** mode the original **ENGYE1E2** column is moved to **PHA**.
  - new empty **INTEGER\*4** columns **X**, **Y** (0.05") (for **attcalc**)
  - modified columns **ENERGYE1** and **ENERGYE2** ( $E_1$  and  $E_2$  in the text) These columns do not exist in **TIMING** mode.
  - modified **WINDOW** keywords (for **PRODUCT**: EPIC event list)
  - keyword **DET\_SYST** (for **attcalc**)
  - keywords **RAND\_XY** and **RAND\_TIM** telling which columns were randomised.



- keywords FRMTIME, GATTI\_ON, COSMICSI, COSMICOU, and CRPATi propagated from the frame file
- keyword BINODAL warning of 2-node read-out (for **emenergy**)
- XMMEA\_nn keywords detailing which flags were set, including XMMEA\_EM setting the EPIC MOS rejection mask
- keywords detailing which subroutines were activated, in particular SETCOORD indicates that RAWX/RAWY were changed.
- comment lines with names of input files

a BADPIX extension propagated from the input file, an OFFSETS0 extension propagated from the offset/variance file (if any, for **emenergy**), an OFFSETS extension containing the list of bad offsets (for **emenergy** and **eexpmap**, **arfgn**, **lccorr**), with the following items:

- INTEGER\*2 column RAWX giving the row (if OFFSETY<sub>i</sub>0) or column (if OFFSETX<sub>i</sub>0) of the bad offset
- INTEGER\*2 column OFFSETX giving the amplitude of the additional column offset (0 for row offsets)
- INTEGER\*2 column OFFSETY giving the amplitude of the additional row offset (0 for column offsets)

and an EXPOSURE extension specific to that CCD/node (for **evlistcomb** and **eexpmap**, **arfgn**, **lccorr**, [2]), with the following items:

- REAL\*8 column TIME (s) giving the central time of each frame
- REAL\*4 column TIMEDEL giving the integration time of each frame
- REAL\*4 column FRACEXP giving the fraction of effective time

2. a GATTI spectrum file (for calibration purposes) with a SPECTRUM extension with ADU as index (1-4096) and the following items:

- INTEGER\*4 column ORIGINAL giving the histogram of  $E_1$ \*GATTI
- REAL\*4 column SMOOTHED giving (normalised histogram of  $E_1$ ) convolved with (histogram of GATTI)

## 8 Algorithm

```
MODULE em_events_module
```

```
  Read the file names of event files (input and output) and frame file
```

```
  Open files
```

```
  Get keyword values
```

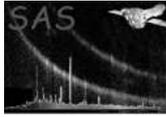
```
  parameters read : choice of sub_tasks to execute
```

```
  Loop over input task parameters
```

```
    Read the task parameter / 1 to perform the procedure,  
                                0 not to perform it /
```

```
  End loop
```

```
  Get the values of files columns in memory
```



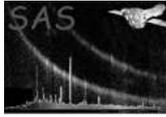
```
SUBROUTINE CUT_BAD
  if cut_bad requested then
    read bad pixels in extension
    Loop over frames
      Creation of image using inverse pattern definition
      Connection with binodal task
        in the case of 2 files (prime and redundant) analysis
      Set bad pixels to 0
      Loop over events
        Use of EDUSOFT code for new pattern reconstruction
        creation of new rows and destruction of old ones
      end loop
    end loop
  endif

SUBROUTINE DIAGO
  if diago requested then
    Loop over event rows for diagonal patterns
    Check if both E1 and E2 energies are different from Si K energy
    In this case :
      first correct the existing pattern
      pattern is 0, e2 is 0, others the same
      second create another pattern
      pattern is 0, e1 is old e2, X & Y to be calculated
      depending on pattern
      e2 is 0, others the same
      both patterns are flagged
      ( do not correct the NVALID in the file frame )
    end loop
    new rows have been created at the end of file
    now shift of lines in order to insert new events
    Loop over number of new lines
      Shift all rows following place of insertion
    end loop
  endif

  Check events with energy value below EMDHLOW or above EMDHHIGH

SUBROUTINE CUT_GTI
  if cut_gti requested then
    Loop over frame rows
      all events whose frames were flagged are flagged for rejection
    end loop
  endif

SUBROUTINE PUT_XY
  if put_xy requested then
    Loop over events
      center the events, subtract the underscan, add 1.
      flag the events outside the field of view
    end loop
    Modify window keywords
    Compute camera coordinates
  endif
```



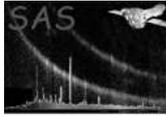
```
SUBROUTINE PUT_TI ( Imaging mode )
  if put_ti requested then
    Loop over frame rows
      Loop over events rows
        calculate the average time for the frame
        copy this time in the time column of events file
      end loop
    end loop
  endif

SUBROUTINE PUT_TT ( Timing mode )
  if put_tt requested then
    Loop over frame rows
      Loop over events rows
        calculate the new time as reference frame time plus Y offset
        copy this time in the time column of events file
      end loop
    end loop
  endif

SUBROUTINE REJECT_ROWS
  if reject_rows requested then
    Loop over frame rows
      Loop over events rows
        Build RAWY profile
      end loop
      Loop over events rows
        Flag events with RAWY profile larger than maxeventsperror
        If 2 or more, flag events within +/- widthnexttorow
          (in the same frame) as well
      end loop
    end loop
  endif

SUBROUTINE REJECT_E3
  if reject_e3 requested then
    if detectbadoffsets and not SW mode then
      Build median E3 on each row and column
      Look for successive rows/columns with median E3 < -100
      Solve  $E3(i) = -3*offset(i-1) - 2*offset(i) - 3*offset(i+1)$ 
      to deduce which offset is wrong
      Flag events on rows/columns with wrong offset
    endif
    Read e3threshold from CAL
    Loop over events rows
      Flag events with pattern <= 4 and E3 < e3threshold
    end loop
  endif

For each triplet in tolfxy, call REJECT_FLICKERING
SUBROUTINE REJECT_FLICKERING(ftol,xtol,ytol)
  Ignore events OUT_OF_CCD_WINDOW, IN_BAD_FRAME, ON_BADROW, ON_BADPIX
  volref = (2*ftol+1) * (2*xtol+1) * (2*ytol+1)
```



```
Get map of average event density, smoothed at xtol, ytol
Get number of events per frame, smoothed at ftol
Loop over events
  Count number of other events within ftol, xtol, ytol
  Estimate local average from larger of averages
    over FRAME (for sources) and RAWX,RAWY (for flares)
  If Poisson probability to get observed counts is > 1E-6, count as peak
end loop
Keep only local maxima among peaks
Loop over peaks
  Identify events closer than 2*ftol in FRAME, 10*(xtol,ytol) in RAWX,RAWY
  If spatial distribution is compatible with a source
    (not too peaked, not too elongated) don't flag
  else flag events close to the peak, up to the point
    where the density meets the average
end loop

SUBROUTINE SP_GATTI
  if sp_gatti requested then
    Loop over events rows
      calculate the E1 spectrum, the (E1+gatti) spectrum
      and the gatti spectrum
    end loop
    Convolution of E1 and gatti spectra
  endif

  sequence of instructions for outevent1 creation

  closing files

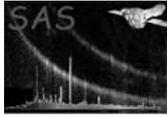
end module
```

## 9 Comments

- The reanalysis of events in EV\_REC, CUT\_BAD and BINODAL calls a C routine (edusoft) which interfaces to the C routine (edu\_simu, written by M. Lortholary of the EPIC/Saclay team) which simulates the EDU recognition.
- The search for new bad pixels in the data should be performed after **emevents** so that known bad pixels are removed and positions are correct.
- Instead of zeroing bad pixels in CUT\_BAD, it may be possible to subtract their average level (usually well defined), leaving only increased noise.
- In 2-node operation, the task must be run twice (once for each node). Thus the projection of events back to the CCD map in BINODAL is done twice. This is not expected to be a big overhead. The alternative would be to generate both output event lists in the same task.

## 10 Future developments

The following points are not considered final:



- To recompute properly the  $E_2$  energy across nodes (in 2-node operation) the differential gain of the nodes should be accounted for.

## References

- [1] ESA. XMM Interface Control Document: Observation and Slew Data Files (XSCS to SSC) (SciSIM to SOCSIM). Technical Report XMM-SOC-ICD-0004-SSD Issue 2.5, ESA/SSD, June 2000. Found at the URL: [ftp://astro.estec.esa.nl/pub/XMM/documents/odf\\_icd.ps.gz](ftp://astro.estec.esa.nl/pub/XMM/documents/odf_icd.ps.gz).
- [2] L. Angelini I. George. Specification of Physical Units within OGIP FITS files. Technical Report OGIP/93-001, NASA/GSC, May 1995.