



# emframes

November 4, 2014

## Abstract

Analyse frame information 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

**emframes** analyzes the frames (auxiliary) file, adding four columns (a quality flag, the dead time fraction, the time and the GATTI value), performing various checks and computing the specific (to the CCD node) Good Time Intervals. The flag value allows to identify why the frame was flagged (using binary coding). **emframes** does not normally modify the events file (except in the case of frame renumbering as explained below). Events belonging to frames flagged as bad are themselves flagged for rejection by CUT\_GTI in **emevents**.

**emframes** may be applied as is to slew data.

**emframes** may renumber the frames in the case of long telemetry drops. Frame renumbering allows to compute the GATTI value correctly, and to flag the events with truncated energy (as **REJECTED\_BY\_GATTI**) in **emevents**. Those flagged events are the best way to detect proton flares. Frame renumbering requires altering the events file as well.

When it is launched on an auxiliary file (straight from the ODF), **emframes** needs to access the ODF directory where the data comes from. This should be specified through the SAS\_ODF environment variable, or the generic **odf** parameter on the command line. In that context, **emframes** also needs an events file (**odfeventset** parameter) to define the CCD/node and set the OAL state. In that case **emframes** writes to the output frames file keywords filled using values taken from the



summary file via OAL calls. It also copies the `FILTER` keyword to the events file (for the CAL) if the events file was modified (`newevent=Y` or frame renumbering). If the events file was not modified the `FILTER` keyword is not copied to avoid the overhead of rewriting the full file.

On the other hand, `emframes` launched on its own output does not need an ODF directory nor an events file. All functions described below may be called that way except `FRAMES`.

`emframes` calls (in order) the following subroutines, all of which can be individually switched off:

- `FRAMES`. The time transmitted in the ODF is still in `FTCOARSE/FTFINE` form (`FTFINE` is in units of  $40 \mu\text{s}$ ). `FRAMES` starts by converting that in seconds (double precision real) and adding the sequencing delays, creating a `TIME` column. `FRAMES` computes the precise frame integration time and writes it into the `FRMTIME` keyword if it is significantly different from the original `FRMTIME` value. It adds the (constant) time offset to all frame times after wrap-around in the event of a long exposure ( $> 32767$  s), and converts the times into standard XMM times (running from 01/01/1998).

In `TIMING` mode the times are corrected for the delay necessary to transfer the data through the 600 rows in the framestore area, and to transfer the data to the framestore area, assuming the vertical binning is 101. By default the source position is taken from the target coordinates (`RA_OBJ`, `DEC_OBJ`). This may be overridden by the user setting the source position manually via the parameters `srcra` and `srcdec`. If no `RA_OBJ`, `DEC_OBJ` keyword is present and `srcra/dec` are not set the source is assumed to be at the centre of the CCD. The `NPIXEL` column is recomputed to give the number of pixels above threshold per cycle (in the auxiliary file `NPIXEL` gives the integrated number of pixels above threshold since the beginning of the exposure).

Finally, `FRAMES` tests whether the data was obtained with `GATTI` on or off and writes a `GATTI_ON` keyword to reflect that.

- Frame renumbering. The frame numbers are first scanned for regular increase, and a permutation array is created if some subset of frame numbers needs to be sorted. If a forward jump is detected then the time difference between the frames across the jump is examined. As the frame number is known only modulo 16 in the telemetry, a multiple of 16 frames may need to be inserted. How many times 16 frames is known by dividing the time difference by the frame integration time. This (-1) gives the most likely value of (and an upper bound to) the true number of missing frames (each extended frame reduces that number). If the interruption was due to counting mode, and the counting mode file was entered via the `countingset` parameter, then the number of missing frames is taken directly from the corresponding entry in that file. The number of missed frames is added to the `FRAME` columns in the frames and events files after the jump.

If a frame number is repeated then `FRAMES` attempts to find one of the set with the expected time value; failing that, to find one of the set that might represent a cycling of the time; and failing that the frame with the smallest increase in time available. This “good frame” is marked with `flag_mulfid` and retained in the output data, while the other frames in the set are marked with `flag_badfid` and rejected.

Frames with extended ( $n$  times) integration time are detected by looking at the time difference between successive frames ( $n$  times the frame integration time for extended frames). A statistical test on `NPIXEL` (comparing the local value with the overall distribution in the file) is performed to tell extended frames from undetected telemetry drops (integer multiple of 16 frames). `NPIXEL` (total number of pixels above threshold) must be larger in an extended frame.

One row per frame (including dummies for missing frames) is created in output. This allows direct access by `emevents`. A dummy first row is always added (giving the estimated start time of the first frame). The first and last frames are flagged (they are usually not reliable).

- `FLAG_HK`. Outside normal operating conditions the instrument performances would presumably be degraded, possibly so much so that the following operations do not even make



sense. Some of the later tasks (CCDBKG in **emenergy**) build integrated images over the whole exposure, from which the frames judged bad by **tabgtigen** must be excluded. All frames whose start and end times are not inside the same good time interval (defined by **tabgtigen**) are flagged as bad.

- FIFO tests all the frames for a possible FIFO overflow flag and flags them as bad.
- VALID checks the number of events in the events file corresponding to a given frame versus the NVALID field in the frames file and flags as bad incomplete frames with the wrong number of events. In that case NVALID is set to the number of events in the events file.
- CR\_DEAD. Every cosmic ray interaction with a CCD prevents a genuine X-ray from being detected there. This amounts to a source of dead time, which should be quite small on average (< 1%). The number of pixels affected can be readily calculated by subtracting the number of pixels above threshold in the true events (known from their pattern, excluding “cosmic-ray” patterns) from the total number of pixels above threshold (NPIXEL) in the frame. The number of events below the lower EMDH threshold (NBELOW) should also be subtracted (those are mostly single noise excursions and incur no loss of efficiency). This allows to check the coherence of NPIXEL with the other data, since the subtraction must always remain positive. If it is not then the frame is flagged for rejection. Since all pixels neighbouring cosmic ray events are also lost, a statistical factor (COSMIC-SIZE field in the XMM\_MISCDATA CCF file) must be applied. Another statistical correction must be applied because only part of the CCD surface is in view of the sky (because it is partly outside the field of view or because the edges are masked by other CCDs above), and because the dark part sees cosmic rays differently (COSMICOUTOVERIN field in the XMM\_MISCDATA CCF file). The list of “cosmic-ray” patterns is derived from the patterns’ definition by looking for all non-isolated patterns (where pixels around the central event are not necessarily below threshold) and is written into keywords CRPATi. In Compressed Timing mode where the pattern number is not transmitted to the ground it is taken to be 0 (single event, most likely value). As the true number of pixels per event can only be larger, this means the dead time is slightly overestimated in that mode.
- MAKE\_GTI forms good time intervals for the current CCD, excluding all frames flagged as bad by FRAMES, FIFO, VALID or CR\_DEAD (but not those flagged by FLAG\_HK). It finally computes and writes the LIVETIME and ONTIME keywords corresponding to the total good time corrected or not for dead time, and rejecting the bad frames and those flagged by FLAG\_HK.
- PUT\_GATTI recomputes the GATTI value along its periodic triangle variation from 0 to 255 and back, using the GATTI flag as a marker, into GATTIVAL. This prepares SP\_GATTI of **emevents**, which allows to check how the GATTI correction works. If the number of frames is less than 510 (this is often true for calibrations), no GATTI flag appears and this technique is not applicable. In that case the GATTI value is set to the input row number (best guess). In free run modes (Timing or free run Window) the GATTI is not used and PUT\_GATTI just sets GATTIVAL to 0.

Recapitulation of flag definitions (flags below 64 are just warnings):



| Value | Meaning  |
|-------|--|
| 1     | Extended frame integration time                                    |
| 2     | Telemetry drop before this frame                                   |
| 4     | Frame kept from a sequence of duplicated data with increasing IDs  |
| 8     | No attitude available (Timing mode only)                           |
| 16    | Frame thought to contain good data, whose ID number was duplicated |
| 64    | Frame thought to contain bad data, whose ID number was duplicated  |
| 128   | NPIXEL too small or NABOVE too large                               |
| 256   | Frame is not inside Good Time Interval from Housekeeping           |
| 512   | FIFO overflow  |
| 1024  | Number of events in the events file is not NVALID                  |
| 2048  | Time negative or aberrant leap in time tag                         |
| 4096  | Missing frame inserted after detection of telemetry drop           |
| 8192  | First or last frame  |
| 16384 | Time decreased unexpectedly  |

## 4 Parameters

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

| Parameter | Mand | Type | Default | Constraints |
|-----------|------|------|---------|-------------|
|-----------|------|------|---------|-------------|

|                     |     |         |     |      |
|---------------------|-----|---------|-----|------|
| <b>auxiliaryset</b> | yes | dataset | ' ' | none |
|---------------------|-----|---------|-----|------|

Name of input auxiliary or frames file

|                    |    |         |     |      |
|--------------------|----|---------|-----|------|
| <b>odfeventset</b> | no | dataset | ' ' | none |
|--------------------|----|---------|-----|------|

Name of events file

|                    |    |         |     |      |
|--------------------|----|---------|-----|------|
| <b>countingset</b> | no | dataset | ' ' | none |
|--------------------|----|---------|-----|------|

Name of counting mode file

|                    |    |         |     |        |
|--------------------|----|---------|-----|--------|
| <b>newframeset</b> | no | boolean | yes | yes/no |
|--------------------|----|---------|-----|--------|

Create output frames file (no for overwriting input)

|                 |    |         |              |      |
|-----------------|----|---------|--------------|------|
| <b>frameset</b> | no | dataset | 'frames.out' | none |
|-----------------|----|---------|--------------|------|

Name of output frames file (**newframeset**=yes)

|                    |    |         |    |        |
|--------------------|----|---------|----|--------|
| <b>neweventset</b> | no | boolean | no | yes/no |
|--------------------|----|---------|----|--------|

Create output events file (no for overwriting input)

|                    |    |         |              |      |
|--------------------|----|---------|--------------|------|
| <b>outeventset</b> | no | dataset | 'events.out' | none |
|--------------------|----|---------|--------------|------|

Name of output events file. If this parameter is set, then **neweventset**=Y is automatic

|                    |    |         |     |        |
|--------------------|----|---------|-----|--------|
| <b>checkframes</b> | no | boolean | yes | yes/no |
|--------------------|----|---------|-----|--------|

Activate FRAMES ?

|                      |    |         |    |        |
|----------------------|----|---------|----|--------|
| <b>withsrccoords</b> | no | boolean | no | yes/no |
|----------------------|----|---------|----|--------|

Supply source position (Timing mode only) ?

|              |    |       |    |      |
|--------------|----|-------|----|------|
| <b>srcra</b> | no | angle | 0. | none |
|--------------|----|-------|----|------|

Source right ascension (J2000). Timing mode only

|               |    |       |    |      |
|---------------|----|-------|----|------|
| <b>srcdec</b> | no | angle | 0. | none |
|---------------|----|-------|----|------|



Source declination (J2000). Timing mode only

|                 |    |         |     |      |
|-----------------|----|---------|-----|------|
| <b>ingtiset</b> | no | dataset | ' ' | none |
|-----------------|----|---------|-----|------|

Name of input good time intervals file from HK (activate FLAG\_HK)

|                        |    |         |     |        |
|------------------------|----|---------|-----|--------|
| <b>flagfifoverflow</b> | no | boolean | yes | yes/no |
|------------------------|----|---------|-----|--------|

Activate FIFO ?

|                   |    |         |     |        |
|-------------------|----|---------|-----|--------|
| <b>checkvalid</b> | no | boolean | yes | yes/no |
|-------------------|----|---------|-----|--------|

Activate VALID ?

|                    |    |         |     |        |
|--------------------|----|---------|-----|--------|
| <b>setdeadtime</b> | no | boolean | yes | yes/no |
|--------------------|----|---------|-----|--------|

Activate CR\_DEAD ?

|                   |    |         |    |        |
|-------------------|----|---------|----|--------|
| <b>wrightiset</b> | no | boolean | no | yes/no |
|-------------------|----|---------|----|--------|

Write good time intervals ?

|                  |    |         |              |      |
|------------------|----|---------|--------------|------|
| <b>outgtiset</b> | no | dataset | 'ccdgti.out' | none |
|------------------|----|---------|--------------|------|

Name of output good time intervals due to the CCD itself (**wrightiset=yes**)

|                 |    |         |     |        |
|-----------------|----|---------|-----|--------|
| <b>setgatti</b> | no | boolean | yes | yes/no |
|-----------------|----|---------|-----|--------|

Activate PUT\_GATTI ?

## 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.

### **getParamValues01** (*error*)

**checkframes=yes** and no input events file

### **readEvents01** (*error*)

invalid input events file

### **frames01** (*error*)

**checkframes=yes** and non-ODF style input frames file

### **frames02** (*error*)

invalid input auxiliary file

### **frames03** (*error*)

no data for CCDID/CCDNODE of events file in auxiliary file

### **frames04** (*error*)

input events file incompatible with auxiliary file

### **frames05** (*error*)

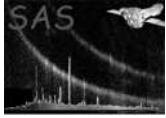
non increasing frame numbers over entire auxiliary file



- frames06** (*error*)  
invalid input counting mode file
- frames08** (*error*)  
a timein value larger than the cycling time has been found
- readFrames03** (*error*)  
invalid input frames file
- readFrames04** (*error*)  
input events file incompatible with frames file
- getParamValues10** (*warning*)  
`checkframes=yes` and `newoutput=no` (overwrite). Skip FRAMES  
*corrective action:* restart from auxiliary file if you wish to reapply FRAMES
- getParamValues15** (*warning*)  
`odfeventset` not set and `checkinvalid=Y` or `setdeadtime=Y`. Skip VALID and CR\_DEAD  
*corrective action:* run **emframes** with `odfeventset` set if you wish to apply VALID or CR\_DEAD
- readEvents10** (*warning*)  
invalid input events file. Skip VALID and CR\_DEAD  
*corrective action:* check input events file
- flagHk10** (*warning*)  
invalid input HK GTI file. Skip FLAG\_HK  
*corrective action:* check the HK GTI file
- frames10** (*warning*)  
time interval not constant in data, or input file has fewer than 4 frames. Do not check FRMTIME  
*corrective action:* check FRMTIME manually
- frames11** (*warning*)  
the value of `CLOCK_WRAP_AROUND` in the summary file is invalid. Use 32767. This is normally all right  
*corrective action:* check FRMTIME manually
- frames12** (*warning*)  
some frames were dropped from the end of the file in analysing the data due to non-increasing frame numbers  
*corrective action:* check FRMTIME manually
- frames13** (*warning*)  
duplicate frame numbers found in the input file, all but one were dropped.  
*corrective action:* check in the input auxiliary file that the proper frames were selected for analysis
- frames14** (*warning*)  
some frame numbers were found out of sequence, so the input data were sorted.  
*corrective action:* none
- frames15** (*warning*)  
frame integration time significantly different from FRMTIME keyword. Update FRMTIME  
*corrective action:* none
- frames16** (*warning*)  
aberrant time in the auxiliary file. Continue, flag such frames and ignore or set their time approximately  
*corrective action:* none



- frames17** (*warning*)  
non-increasing time in the auxiliary file. Continue, flag such frames and ignore or set their time approximately  
*corrective action*: none
- valid10** (*warning*)  
**checkvalid**=yes and VALID already applied. Option ignored  
*corrective action*: restart from auxiliary file if you wish to reapply VALID
- valid11** (*warning*)  
**checkvalid**=yes and events have frame number outside frame interval in frames file. Continue  
*corrective action*: none
- crDead10** (*warning*)  
**setdeadtime**=yes and NPIXEL – NBELOW – NABOVE < sum of pixels in valid events. Flag as bad and continue  
*corrective action*: none
- makeGti13** (*warning*)  
all frames flagged as bad. Empty output GTI file. Continue  
*corrective action*: check the log (with verbosity set to 4 at least) to know why those frames were rejected
- testDrop12** (*warning*)  
more than 50% time lost. Continue  
*corrective action*: check in the log that nothing went wrong
- putGatti10** (*warning*)  
**setgatti**=yes, but less than 255 frames. set GATTI=ROW  
*corrective action*: if this results in systematic spGatti11 warnings in **emevents**, you may add the offset manually
- putGatti11** (*warning*)  
**setgatti**=yes, GATTI on but no GATTIFLG=1. Skip PUT\_GATTI. The truncated events cannot be identified  
*corrective action*: none. This is hopeless
- putGatti12** (*warning*)  
**setgatti**=yes, GATTI on and GATTIFLG not found at expected periodicity. Continue, it may have occurred within a missing frame  
*corrective action*: if this results in systematic spGatti11 warnings in **emevents**, do not trust the flare screening light curve
- putGatti14** (*warning*)  
**setgatti**=yes and interval between two successive GATTI flags not equal to 510. Skip PUT\_GATTI. The truncated events cannot be identified  
*corrective action*: check the log for frame renumbering messages. If you see where **emframes** erred, try renumbering the frames manually and run **emframes** again
- createOutput10** (*warning*)  
incoherence between FRMTIME and GATTIFLG. Continue anyway (FRMTIME is probably wrong, this does not affect the processing)  
*corrective action*: inform SOC (this should not occur in any mode)
- adjustTimetag10** (*warning*)  
reconstructed source position is outside CCD. Flag frame and continue (most likely an attitude error)  
*corrective action*: if this is systematic, the target position RA\_OBJ / DEC\_OBJ may be wrong. Try providing the source position manually setting **srcra/dec**



## 6 Input Files

1. EPIC MOS auxiliary file or frames file (from an earlier run of **emframes**). Uses all columns and keywords TELESCOP, INSTRUME, OBS\_ID, EXP\_ID, DATE-OBS, DATE-END.
2. EPIC MOS event list file for one CCD/node (from ODF/SDF) if **odfeventset** is set. Uses columns FRAME and PATTERN, and keywords TELESCOP, INSTRUME, OBS\_ID, EXP\_ID, CCDID, CCDNODE, WINDOWDX, WINDOWDY, FRMTIME, DATATYPE, plus those required by **OAL\_setState** and **CAL\_setState**.
3. EPIC MOS counting mode file if **countingset** is set. Uses columns HBRID, FRAMCNTR, ETCOARSE, and ETFINE.
4. good time intervals from housekeeping (from **tabgtigen**) if **ingtiset** is set.

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

## 7 Output Files

1. frames file with additional rows and following items:
  - general keywords OBS\_MODE, OBJECT, OBSERVER, RA\_OBJ, DEC\_OBJ, RA\_NOM, DEC\_NOM, REVOLUT taken from summary file, FILTER (taken from the HK), EXPIDSTR (taken from the original file name in the ODF), DATAMODE (deduced from DATATYPE in event list) and SUBMODE (Guest Observer mode, CCD 1 only) in the primary header (for PRODUCT: EPIC event list)
  - columns FRAME, NPIXEL, NBELOW, NABOVE, GATTIFLG, FIFOOVF and header propagated from auxiliary file
  - NVALID column updated (for **emevents**)
  - REAL\*8 column TIME (s) (for **emevents**)
  - INTEGER\*2 column FLAG (for **emevents**)
  - INTEGER\*2 column GATTIVAL (for **emevents**)
  - REAL\*4 column CRRATIO (dead-time fraction for **emevents**)
  - CCD specific keywords propagated from event list file
  - keyword CCDMODE expliciting CCD operating mode
  - keyword GAIN\_CCD (when set to LOW, the PHA values are approximately divided by 10, and the data is not suitable for scientific use)
  - keyword FRMTIME (ms) (frame integration time, for PRODUCT: EPIC event list)
  - keywords TSTART, TSTOP, TELAPSE, ONTIME and LIVETIME (start and end times, exposure duration, sum of good time intervals and dead-time corrected on time), TIMEUNIT, TIMESYS, MJDREF, TIMEREF, TASSIGN, TIMEZERO and CLOCKAPP (origin and nature of times)
  - keywords ATT\_SRC, ORB\_RCNS, TFIT\_RPD, TFIT\_DEG, TFIT\_RMS, TFIT\_PFR set by the OAL.
  - keywords SRC\_RAWX and SRC\_RAWY (source position on CCD in Timing mode), with associated SRC\_RA and SRC\_DEC (source coordinates) if manually set
  - keyword GATTI\_ON (boolean indicating whether the GATTI was on or off, for PRODUCT: EPIC event list and **arfggen**, **rmfgen**)
  - keywords CRPATi expliciting “cosmic-ray” patterns (for **emevents**)





- keywords detailing which subroutines were activated
  - comment lines with names of input files
2. events file with same structure as in input, added **FILTER** keyword, modified **FRAME** column and possibly deleted rows (in case frames were renumbered).
  3. GTI file specific to that CCD/node (for **evselect**, [2]), if **writegtiset=yes**. The GTI extension is called **STDGTInn**, where nn is the CCD number + 10 times the CCD node (as in **evlistcomb**). Keywords are copied from the frames file.
  4. Temporary copy of the input auxiliary file (**emframes.temp**), normally removed by the task on exit.

## 8 Algorithm

MODULE em\_frames\_module

Read the file names of frames files (input and output) and events file

Opening of input auxiliary and events file

Select CCD/node in auxiliary file

Copy of input events file header keywords to output frames file

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 FRAMES

frame time calculation as difference between successive read-out times

use only if constant 3 times in a row

otherwise keep original value

Read counting mode file if any

Renumber frames and associated events if times indicate  
that frame number was lost.

Build complete arrays of flags and times

including missing frames and correcting wrong times

Write columns to output file

Put the keyword FRMTIME on file

SUBROUTINE FLAG\_HK

if flag\_hk requested then

read the gti file name parameter

Read GTI file

Loop over the rows of frames file

Loop over good time intervals

flag frame outside intervals

end loop

end loop

endif



```
SUBROUTINE FIFO  check the FIFOOVF
  if fifo requested then
    Loop over frame rows
      flag frames with FIFOOVF not equal to 0
    end loop
  endif

SUBROUTINE VALID  check the number of events for each frame
  if valid requested then
    Loop over frame rows
      count the number of rows in the events file for each frame
      and compare with the NVALID value
      flag the frame if not equivalence
    end loop
  endif

SUBROUTINE CR_DEAD
  identify the ‘cosmic-ray’ patterns,
  and get the number of pixels above threshold for each type of pattern
  for patterns CRPATi we put 0 to avoid subtracting cosmic-rays
  if cr_dead requested then
    Read cosmicsize and cosmicoutoverin values from CAL
    Loop over frame rows
      calculate crratio as
        ( NPIXEL(frame) - NPIXEL(events) - NBELOW ) / ( DX * DY )
      check  crratio > NABOVE / ( DX * DY )
      apply correction factor
      crratio = crratio * cosmicsize / (ratarea+(1-ratarea)*cosmicoutoverin)
      ratarea = fraction of window in open view of the sky
    end loop
    write CRRATIO column on file
  endif

SUBROUTINE MAKE_GTI  Build new GTI from unflagged frames
  if make_gti requested then
    Loop over the frames
      Reconstruct new GTI intervals excluding all flagged frames
    end loop
  endif

SUBROUTINE PUT_GATTI  check the gatti flag and write the gatti value
  if put_gatti requested then
    Loop over frame rows
      Look for GATTI flag = 1
      recompute the gatti value in previous 510 frames
    end loop
    Recompute GATTI in last frames
    write GATTIVAL column on file
  endif

write FLAG column on file

Closing files
```



end module

## 9 Comments

None.

## 10 Future developments

## 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.