



emchain

January 27, 2025

Abstract

Generate the EPIC-MOS event list product.

1 Instruments/Modes

Instrument	Mode
EPIC MOS	IMAGING, TIMING

2 Use

pipeline processing	no
interactive analysis	yes

3 Description

The **emchain** script chains and loops over all first-level EPIC MOS tasks to produce event lists for all exposures, ready to be exported as PPS products. It is meant to work on a single observation, and it is not recommended to merge several observations in the same directory.

3.1 Generalities

By default all events flagged for rejection during the chain are physically removed from the output file (to save space) except those `OUT_OF_FOV` (useful for cosmic-ray background subtraction) and `REJECTED_BY_GATTI` (used for proton flare rejection). To keep all events in output set `rejectbadevents=N`. To use a different mask on `FLAG` set `rejectionflag` to another hexadecimal value (binary flags are described in **evatt**, and in the header of the `EVENTS` table of the event lists).

All text output is sent to standard error, and may be redirected to a file (very useful to investigate problems). It is good practice to look at the warnings sent by the tasks and **emchain** itself. If the `SAS_VERBOSITY` environment variable is set to 1, **emchain** will tell which tasks it called. If `SAS_VERBOSITY` is set to 4 (suggested value), its constituent tasks will provide useful information.



Larger values of `SAS_VERBOSITY` may result in large output files. If `SAS_VERBOSITY=0`, **emchain** will be mute, except for warnings and error messages.

All files are recognized by their name. Input files are looked for in the directory entered via the `odf` parameter or the `SAS_ODF` environment variable, which must also contain the general ODF files (attitude, time, summary file). Output files are created in the current directory. Intermediate files are removed at the end, unless `keepintermediate=Y` or an error occurred. Intermediate and output files are overwritten unless `clobber=N`.

If one constituent task ends in error, **emchain** will continue anyway with the next CCD, exposure or instrument unless `stoponerror=Y`.

3.2 Main loop

The main subroutine (`processOdf`, Fig 1) loops over all exposures and instruments (MOS1/MOS2) present in the input directory (looking for event list files).

If `withatthkgen` is true or if the tracking history file does not exist already, **atthkgen** is run first. **tabgtigen** is run on the output to generate the attitude GTI. The tolerance on attitude variations may be modified via `atttol`. **hkgtigen** is run if the HK GTI does not exist already. Those GTI files are not applied by default, they are generated for information. They can be applied by setting `filteratt=Y` and/or `filterhk=Y`. They are then merged with the user GTI (if `ingtiset` is set) into the external GTI used by **emframes**.

`processOdf` creates one (or two, if a CCD is operated in TIMING mode) event list for every selected exposure, from all relevant ODF material and (if they exist) the good time intervals generated by **tabgtigen** and the list of bad pixels (from the CCF or produced internally).

In a first step it loops over all CCD/nodes, calling in sequence, as shown in Fig 2:

1. **emframes** on the auxiliary file, the events file and the external GTI file (if any), creating a frame file as expected by **emevents** and a CCD/node specific GTI file which will be reinjected in the final call to **evselect**.
2. **badpix** on the events list, adding the `BADPIX` extension. If a bad pixels file exists, it is used instead of the `CAL` calls for the non-uplinked bad pixels, (*i.e.* **badpix** is called with `getuplnkbadpix=Y` `getotherbadpix=N` `getnewbadpix=Y`).
3. **emevents** on the events list, the offset/variance file and the frame file, creating a new events list which will be propagated through **attcalc** and **emenergy** to **evlistcomb**.
4. **gtialign** on the external GTI file and the events file, then **gtimerge** to merge the resulting aligned GTI and the CCD/node specific GTI.
5. **attcalc** on the new events list, filling the X/Y columns.
6. **emenergy** on the new events list, filling the FLAG, PHA and PI columns.

By default position, energy and time of each photon are randomised within their respective bins (one CCD pixel for position, one ADU for energy, one frame for time).

Then (Fig 1) all the event list files created (one per CCD/node) are merged by **evlistcomb**, creating one events list per mode (IMAGING, TIMING). Finally **evselect** is called on the resulting events list(s),

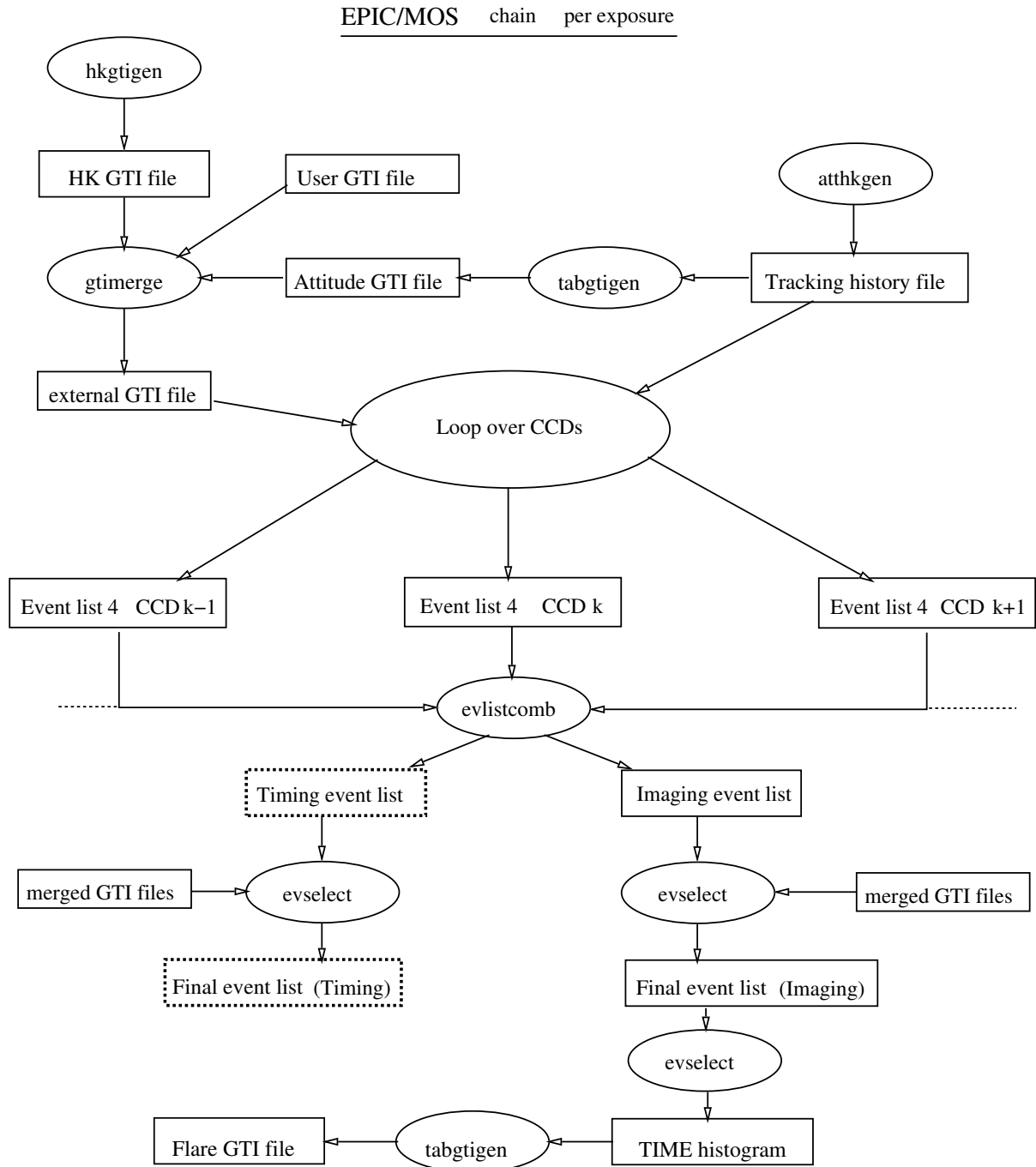
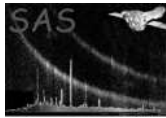


Figure 1: Organisation of the EPIC-MOS chain: merging the event lists. The files in boldly dashed boxes are used (or produced) if they exist. The files in simply dashed boxes are options of the individual tasks not used in the current chain.



EPIC/MOS chain per CCD

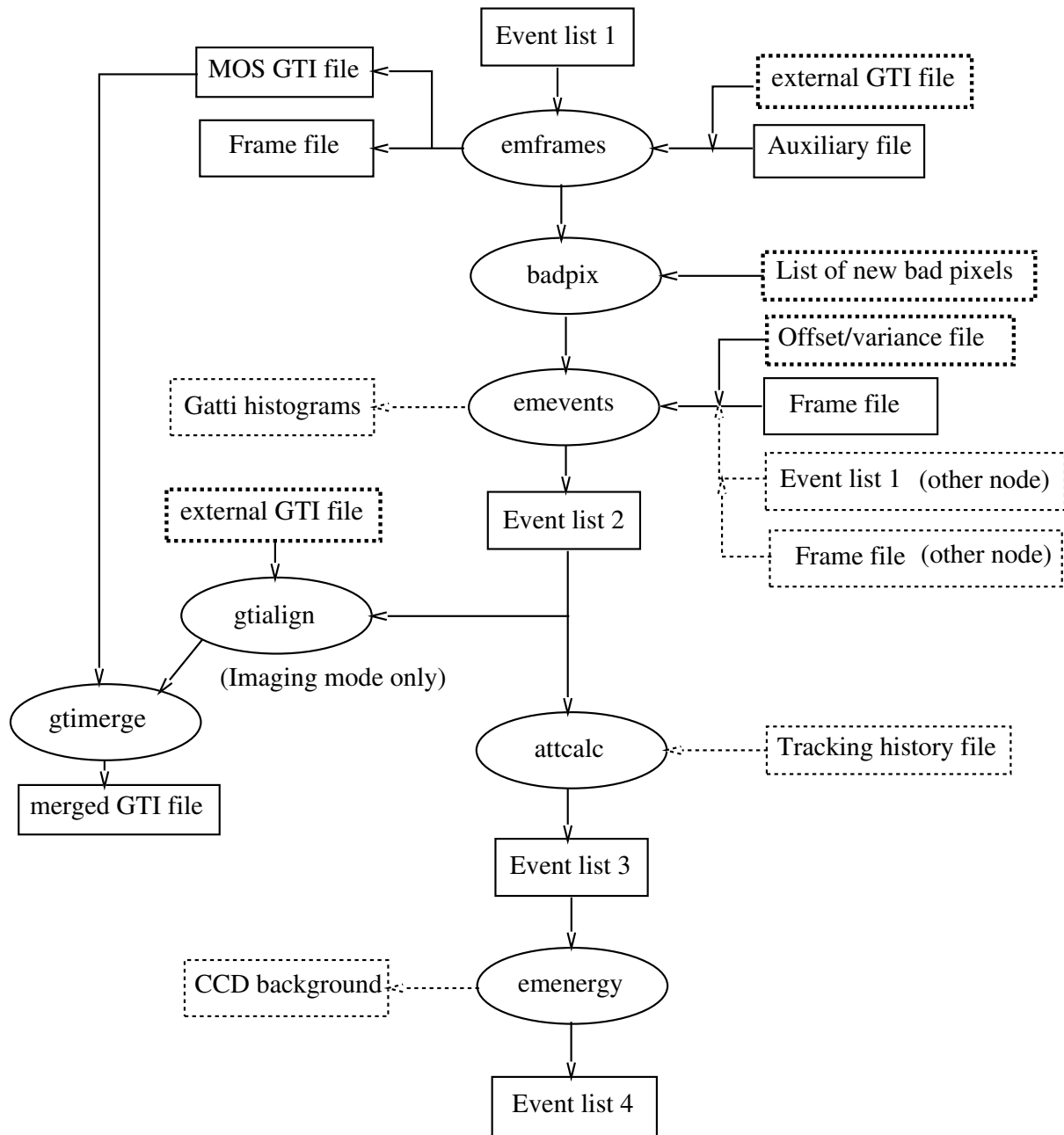
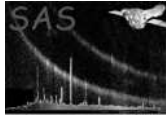


Figure 2: Organisation of the EPIC-MOS chain at CCD/node level with file inputs. Same conventions as in Fig 1



with `(CCDNR==$node$ccd) && GTI(merged GTI file,TIME)` for all CCD/nodes. **emtaglenoise** loops over all CCDs (except the central one) to check occurrence of low-energy electronic noise and write the **LENOISnn** keyword, set to 1 if a CCD is affected. The list of calibration files used to analyse the data is added to the output files as a **CALINDEX** extension.

3.3 Flare rejection

If `makeflaregti=Y`, for all merged files (*MIEVLI*), an additional call to **evselect** (Fig 1) produces a light curve of single events from CCDs in Imaging mode flagged with **REJECTED_BY_GATTI** (with actual energy above 14 keV), with time bins defined by **flaretimebin** (if that time bin is too small to give reasonable statistics per bin, it will be increased automatically). This is aimed at finding efficiently periods of flaring activity when the focal plane is illuminated by low-energy protons. Those are mostly singles and are not cut-off by the mirror efficiency above 10 keV (contrary to astronomical sources). The result is divided by the area of the external CCDs within the field of view, and expressed in `cts/ks/arcmin2`. A fractional exposure column **FRACEXP** accounts for incomplete time bins.

If `globalflare=Y` (default), timeseries are built for all MOS event lists in the current directory, then summed together (the **ERROR** columns are summed quadratically) to build a single global timeseries. This allows to apply the same GTI to both MOS instruments, and to improve the statistics in the timeseries.

This light curve is sent to **tabgtigen** which selects all intervals when the number of `cts/ks/arcmin2` is lower than **flaremaxrate**, and produces a Good Time Intervals file. This file is filtered to avoid intervals only one **flaretimebin** long, which are usually negative fluctuations during a moderately strong flare. This file is NOT applied to the events list, unless `applyflaregti=Y`.

The quiet level is around 0.8 `cts/ks/arcmin2`. The default value of **flaremaxrate** is conservative (to avoid rejecting too many intervals) and should be all right in most situations. The default value of **flaretimebin** is such that it covers an integer number of frames (20). It should not be chosen too small if **TIME** is not randomised (no 'T' option in **randomize**).

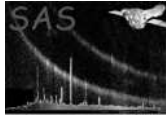
If `applyflaregti=Y`, the resulting Good Time Intervals are applied only if they total more than 10% of the exposure time. Otherwise the events list is left unscreened. This applies in particular to the bad pixels detection (Sect. 3.4).

3.4 Bad pixels detection

In most cases relying on the bad pixels registered in the CCF is not enough. This is because the CCF stores only the bright pixels of relatively high occurrence, but bright pixels at a low level may be a nuisance as well.

If `badpixfindalgo=EM` (default) or **EP**, the whole analysis of one exposure (Fig 1) is run first with **emevents** and **emenergy** in a simplified mode, and skipping **badpix** and **attcalc**. Then one of two bad pixel finding algorithms is called (Fig 3), depending on **badpixfindalgo**.

- If **badpixfindalgo** is set to 'EP', **badpixfind** is called. This is a conservative algorithm which will find clear-cut bright pixels or columns.
- If **badpixfindalgo** is not set or set to 'EM', **embadpixfind** is called. This is a more sensitive algorithm which will detect bad pixels, segments of columns or rows down to the statistical limit of Poisson counts.



EPIC/MOS bad pixels finder choice

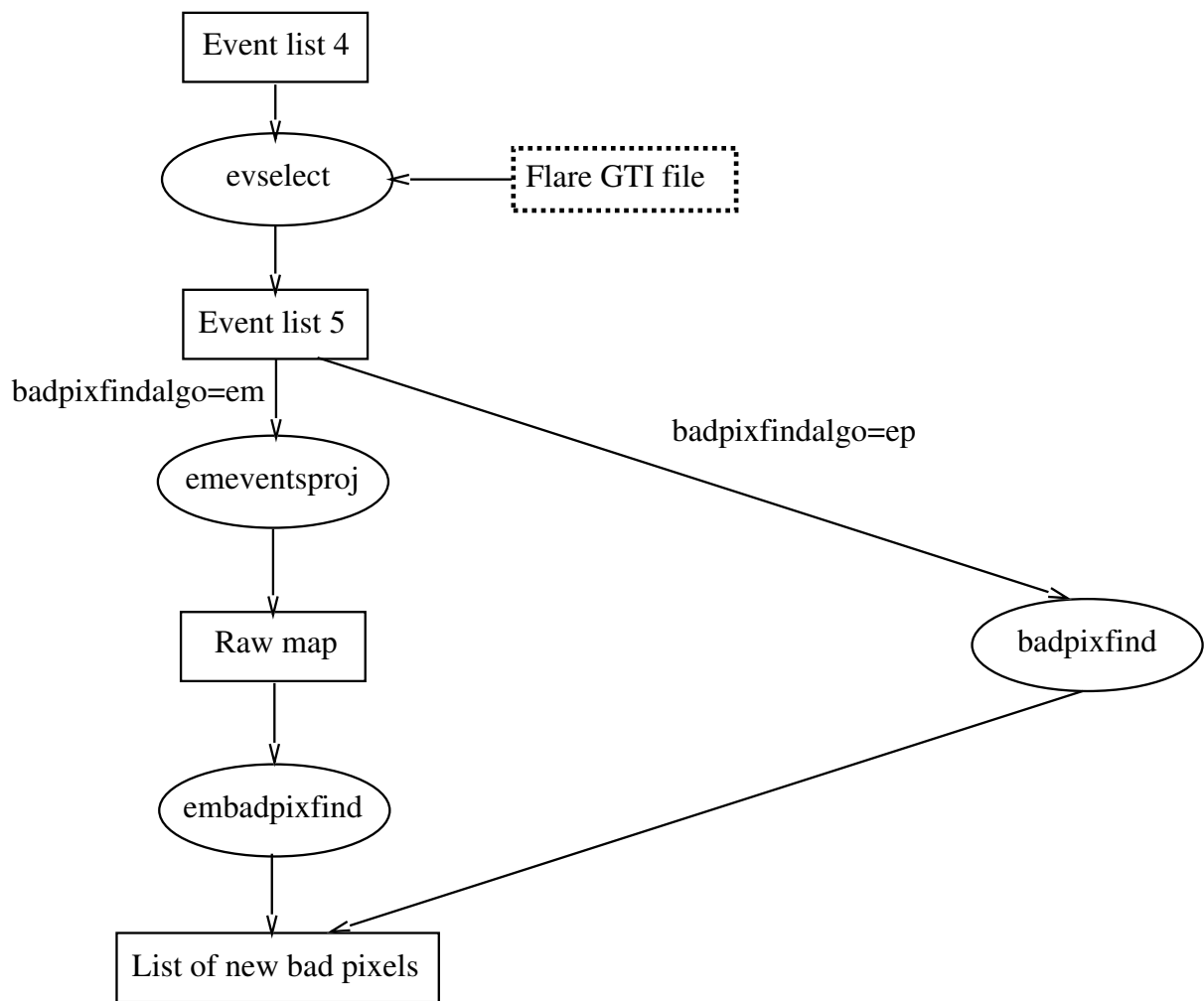
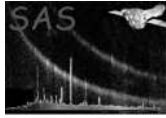


Figure 3: Organisation of the EPIC-MOS chain: Bad pixels search. Same conventions as in Fig 1



Flare screening for bad pixels search

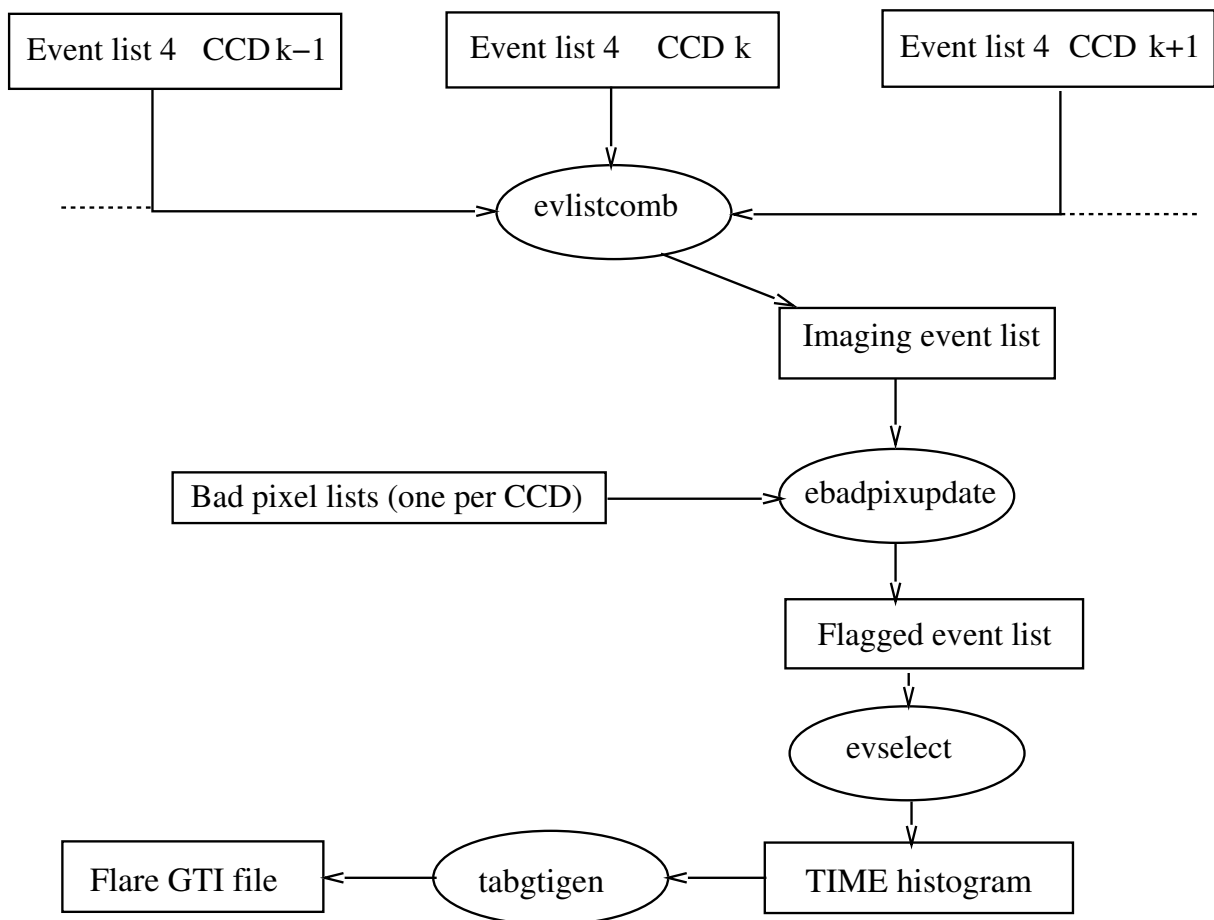
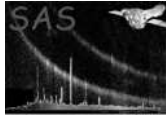


Figure 4: Organisation of the EPIC-MOS chain: Flare screening between first and second bad pixels searches. Same conventions as in Fig 1



If part of the exposure is affected by flares, this can seriously reduce the power of the bad pixels search (flares act as noise for the bad pixels and make detecting them more difficult). Therefore an intermediate flare screening (like in Sect. 3.3) is necessary (Fig 4). The bright pixels (which can perturb the flare screening) are flagged using **ebadpixupdate**. The resulting files are used to generate Good Time Intervals outside flares. Those Good Time Intervals are exposure specific whatever the value of **globalflare**. Then the bad pixel search is run a second time on the data outside flares, in incremental mode.

For **badpixfindalgo=EM** (or not set), the algorithm is called a third time (incrementally) on energies below 500 eV (and after flare screening), unless **lowenerbadpix=N**. This sometimes detects bad pixels more easily, because most appear at low energy.

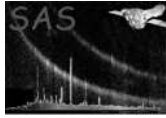
The resulting bad pixels file is then used by **badpix** in the main pass on the data (Fig 1). Bad pixels declared in the CCF are read as well, and merged with those found in the local search. This second pass restarts just after **emframes**. The **stopafterbadpixfind** parameter allows to stop **emchain** before the main pass, to investigate in detail how the bad pixels detection worked.

If **badpixfindalgo** is set to NO, then the first loop is not done and the bright pixels are read from the CCF.

3.5 Customisation

Many options allow to run **emchain** on a subset of the data, restart from previous output, change the options of constituent tasks.

- The **exposures**, **instruments** and **ccds** parameters allow to run **emchain** on a subset of the data files (select an explicit list of exposures, instruments or CCDs).
- If **addvigweight=Y**, then **evigweight** is called to add a **WEIGHT** column to the events list (for extended source analysis).
- All individual steps in **emchain** except **emframes** may be skipped (**withbadpix**, **withemevents**, **withattcalc**, **withemenergy**, **runevlistcomb**, **applyccdgti**, **makeflaregti**). The whole loop over CCDs may be skipped if **runccdloop=N** (the only available functionalities are then those of Fig 1).
- If **runevlistcomb=N**, the merged event files are not built and the output is the collection of individual event and frame files.
- If **randomize** does not contain the letter P, **emevents** is run with **randomizeposition=N**. If **randomize** does not contain the letter T, **emevents** is run with **randomizetime=N**. If **randomize** does not contain the letter E, **emenergy** is run with **randomizeenergy=N**.
- Parameters may be passed to constituent tasks. The syntax is 'taskname:paramname=soandso', where 'paramname' is the parameter name for task 'taskname'. This will be passed as 'paramname=soandso' when calling 'taskname'.
For example, 'emenergy:useccfdarkframe=Y' allows using the CCF dark frame for the CCD background correction (this corrects for variations at the pixel scale, whereas the E₄ data allows to correct for variations on scales larger than 5 pixels).
This syntax does not allow to specify different parameter values on different occurrences of 'taskname' within **emchain**. The additional parameter will be passed on all occasions.
Parameters specified in that way supersede possible settings of the same parameters by **emchain** itself.
- For calibration purposes (offsets' evolution), or checking optical loading, it can be useful to look at the background (base level) of a CCD. If **writeccdbackground=Y**, then **emchain** writes one file per



CCD and per exposure, containing the CCD background (as determined by **emenergy**). This is similar to passing **backgroundset** to **emenergy**, but allows to save all such files under a different name.

- **emchain** normally ignores data obtained with CCD read-out gain set to low (/10). This behaviour may be overridden by setting **processlowgain=Y**. Low gain data is then treated as if it was normal data, and included in the merged events file in output, in addition to normal data. Its PI will still be wrong, and the flare screening mechanism will not work normally (because there are very few events at energy more than 100 keV even during flares).
- If **fulloutput=Y**, all columns originally present in the events files (in the ODF) are preserved in the output file (this about doubles the size of the file).
- If intermediate files from a previous call to **emchain** still exist (for example **T0000000000M1S001CLEVLI00m.FIT** files), **emchain** may use them as a starting point instead of the ODF (**startfromodf=N**).

3.6 Examples

emchain takes some time to run. It is usually better run as a batch job (at command). Here are a few examples of how to use it. They assume that the **SAS_CCF** environment variable was set to the relevant Calibration Index File.

- Standard run (get calibrated event files from an ODF located in **your_odf_dir**), sending the output to a log file:

```
emchain odf=your_odf_dir > emchain.log 2> emchain.err (sh shell)
emchain odf=your_odf_dir > emchain.log >& emchain.err (csh shell)
```

- Same, but getting the bad pixels from the CCF instead of the data and applying attitude and HK GTIs:

```
emchain odf=your_odf_dir badpixfindalgo=NO filteratt=Y filterhk=Y
```

- Select particular exposure, instrument and CCDs, keep intermediate files and stop at first error:

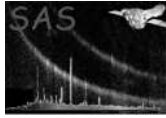
```
emchain instruments=M2 exposures=S002 ccds='1 3 4' stoponerror=Y \
keepintermediate=Y
```

- Keep events flagged for rejection and all original columns in the ODF, apply user GTI and no TIME randomization:

```
emchain rejectbadevents=N fulloutput=Y randomize='PE' ingtiset=hkgti.ds
```

- Rebuild the flare GTI files with different settings, keep them exposure specific and add the **WEIGHT** column:

```
emchain runccdloop=N runeplistcomb=N addvigweight=Y \
globalflare=N flaretimebin=104 flaremaxrate=1.2
```



- Run `attcalc` with fixed attitude:

```
emchain attcalc:attitudelabel=fixed attcalc:fixedra=204.6877 \  
attcalc:fixeddec=-27.6984 attcalc:fixedposangle=59.378
```

- Specify source position manually (instead of using `RA_OBJ` and `DEC_OBJ`) for Timing mode:

```
emchain emframes:withsrccoords=Y \  
emframes:srcra=204.6877 emframes:srcdec=-27.6984
```

- Run bad pixels finder on existing intermediate files:

```
rm *BPXFLI* *IMAGPR*  
emchain startfromodf=N clobber=N stopafterbadpixfind=Y
```

- Regenerate event files, using new bad pixels files and intermediate files (this will remove the intermediate files on successful output):

```
rm T*M*EVLI*.FIT  
emchain startfromodf=N
```

- Relaunch `emchain` after an error which occurred on MOS 2, exposure 4, using already existing intermediate files:

```
rm PoooooooooM2S004*.FIT  
emchain instruments=M2 exposures=4 clobber=N
```

- Revert to simple pre-v12 names of intermediate files (see Sect. 8) overwritten at each exposure (avoids creating too many files, but risks interference if several instances of `emchain` are called at the same time in the same directory):

```
emchain usecanonicalnames=N
```

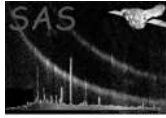
3.7 How to deal with an error

If an error occurred, the very last output of `emchain` will be something like

```
emchain: BEWARE: One or more of the tasks ended in error !
```

You should then look into the log file for a specific message like

```
emchain: BEWARE: That task ended in error !
```



The associated messages may help you understand what happened. The intermediate files will not be erased, you may inspect them.

If you think you have found a workaround (editing a file for example), you may relaunch the task which ended in error, duplicating the call written after 'CMD:' in the log file. You may also relaunch emchain from the intermediate files (see example above).

If the error is of general significance (not just a corrupted file at your site), feel free to send an Observation Report.

4 Parameters

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

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

General parameters

ingtiset	no	string		none
-----------------	----	--------	--	------

user-supplied good time intervals

filteratt	no	boolean	no	yes/no
------------------	----	---------	----	--------

filter data on bad attitude

filterhk	no	boolean	no	yes/no
-----------------	----	---------	----	--------

filter data on bad housekeeping

badpixfindalgo	no	string	EM	none
-----------------------	----	--------	----	------

EP for **badpixfind**, EM for **embadpixfind**, NO for nothing

randomize	no	string	PET	
------------------	----	--------	-----	--

randomize multiswitch (P for position, E for energy, T for time). " " for no randomisation at all

applyflaregti	no	boolean	no	yes/no
----------------------	----	---------	----	--------

apply the proton flare GTI

Selection parameters

odf	no	string	SAS_ODF	none
------------	----	--------	---------	------

input directory name (this is a standard SAS parameter)

exposures	no	list of strings	all	none
------------------	----	-----------------	-----	------

selected exposures (like S004, or simply 4 if non ambiguous)



instruments	no	list of strings	both	M1/M2
--------------------	----	-----------------	------	-------

selected instruments

ccds	no	list of integers	all	1-7
-------------	----	------------------	-----	-----

selected CCDs

Parameters for running part of emchain

runccdloop	no	boolean	yes	yes/no
-------------------	----	---------	-----	--------

loop over CCDs

startfromodf	no	boolean	yes	yes/no
---------------------	----	---------	-----	--------

analyse raw ODF files

stopafterbadpixfind	no	boolean	no	yes/no
----------------------------	----	---------	----	--------

stop just after bad pixels detection to investigate

runevlistcomb	no	boolean	yes	yes/no
----------------------	----	---------	-----	--------

merge the CCD-specific events files

makeflaregti	no	boolean	yes	yes/no
---------------------	----	---------	-----	--------

build GTI for proton flare rejection

Parameters for debugging or calibration

rejectbadevents	no	boolean	yes	yes/no
------------------------	----	---------	-----	--------

reject events with any of the flags in **rejectionflag** set

rejectionflag	no	string	762aa000	none
----------------------	----	--------	----------	------

hexadecimal representation of the flags triggering deletion

writeccdbackground	no	boolean	no	yes/no
---------------------------	----	---------	----	--------

save CCD background for offset calibration (one file per CCD)

processlowgain	no	boolean	no	yes/no
-----------------------	----	---------	----	--------

process data obtained in low gain read-out mode (as well as normal)

fulloutput	no	boolean	no	yes/no
-------------------	----	---------	----	--------

keep all columns in event list (rather than only the ones in SSC products)

applyccdgti	no	boolean	yes	yes/no
--------------------	----	---------	-----	--------

apply the CCD-specific GTI

usecanonicalnames	no	boolean	yes	yes/no
--------------------------	----	---------	-----	--------



give product-like names (starting with T) to intermediate files

keepintermediate	no	boolean	no	yes/no
-------------------------	----	---------	----	--------

keep intermediate files (or remove them on output)

stoponerror	no	boolean	no	yes/no
--------------------	----	---------	----	--------

stop at first error in task call

clobber	no	boolean	yes	yes/no
----------------	----	---------	-----	--------

overwrite existing output files

Parameters for individual tasks

withatthkgen	no	boolean	no	yes/no
---------------------	----	---------	----	--------

rerun **atthkgen**

atttol	no	real	0.05	> 0
---------------	----	------	------	-----

tolerance for attitude filtering (degrees)

withbadpix	no	boolean	yes	yes/no
-------------------	----	---------	-----	--------

run **badpix**

withemevents	no	boolean	yes	yes/no
---------------------	----	---------	-----	--------

run **emevents**

withattcalc	no	boolean	yes	yes/no
--------------------	----	---------	-----	--------

run **attcalc**

withemenergy	no	boolean	yes	yes/no
---------------------	----	---------	-----	--------

run **emenergy**

lowenerbadpix	no	boolean	yes	yes/no
----------------------	----	---------	-----	--------

run **embadpixfind** a second time for energies < 500 eV

addtaglenoise	no	boolean	yes	yes/no
----------------------	----	---------	-----	--------

run **emtaglenoise**

addvigweight	no	boolean	no	yes/no
---------------------	----	---------	----	--------

run **evigweight**

globalflare	no	boolean	yes	yes/no
--------------------	----	---------	-----	--------

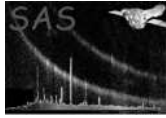
build single flare screening timeseries for the whole observation

flaretimebin	no	real	52.0	> 2.6
---------------------	----	------	------	-------

time bin for flare rejection (s)

flaremaxrate	no	real	2.0	> 0
---------------------	----	------	-----	-----

threshold on rate of truncated singles for **tabgtigen** (cts/ks/arcmin²)



The syntax `taskname:parametername=soandso` may be used to pass parameters to individual tasks called by **emchain**. See Sect. 3.5 for details.

Standard SAS parameters

Because **emchain** is a standalone Perl script, it does not deal with the standard SAS parameters (see **taskmain**) in exactly the same way as normal SAS tasks do:

- It does not support the `'-d'` (dialog) option. Actually **emchain** may not be called at all via the SAS GUI.
- It does not support the `'-c'` (noclobber) option because some constituent tasks do not work with that option set. That option is replaced by the `clobber` parameter specific to **emchain**.
- It emulates the `'-h'` (help), `'-m'` (manpage), `'-p'` (param), `'-v'` (version) parameters giving information on **emchain** itself.
- It passes all other standard SAS parameters to its constituent tasks. Specific OAL (`'-o'`) and CAL (`'-a'`, `'-f'`, `'-i'`) options are passed only to the tasks making use of the OAL or CAL, respectively. By default constituent tasks are called with `'-w 10'` (at most 10 warnings per task).
- All syntaxes (*e.g.* `'-o your_odf_dir'`, `'odf=your_odf_dir'`, `'--odf your_odf_dir'`) are supported.

Some SAS options are also interpreted at **emchain** level before being passed to its constituent tasks:

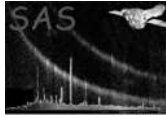
- `'-V'` (verbosity) is used in the same way as the `SAS_VERBOSITY` environment variable (see Sect. 3.1).
- `'-o'` (odf) is used to define the directory where the data resides in the same way as the `SAS_ODF` environment variable (see Sect. 3.1).
- `'-i'` (ccf) is used in the same way as the `SAS_CCF` environment variable to append a `CALINDEX` extension to the output file.

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.

odf (*error*)

No or non existing or empty input directory

**odfiles** (*error*)

No ODF-like file in input directory

lowGain (*warning*)

a CCD was operated in low gain mode. It is scientifically useless and **emchain** will normally not process it. If **processlowgain** is set, it will be processed but the flare screening light curve will be wrong unless this is the central CCD

corrective action: set **processlowgain**=Y if you want that CCD to be processed

badexposure (*warning*)

the T*EVLI*.FIT files are incompatible with the requested exposure. The merged events list will not be created. This is possible only when **clobber**=N and T*EVLI*.FIT files exist

corrective action: check the T*EVLI*.FIT files and rerun

badinstrument (*warning*)

the T*EVLI*.FIT files are not MOS files. The merged events list will not be created. This is possible only when **clobber**=N and T*EVLI*.FIT files exist

corrective action: check the T*EVLI*.FIT files and rerun

protonflare (*warning*)

The GTI fraction after flare screening is less than 10%. It is not applied

corrective action: reassess the flare GTI manually, or change **flaremaxrate** if you wish

noIN_FOV (*warning*)

the EXPOSUnn extensions of the merged events file do not contain the IN_FOV keyword. The flare detection cannot proceed

corrective action: rerun emchain on the ODF to regenerate the merged events file

badstring (*warning*)

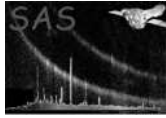
a keyword does not have the expected length. It is truncated or padded with .. This should not happen on a regular ODF

corrective action: check whether a file is not corrupted in the ODF (you may know which file contains the offending keyword by looking at the messages), and that the substitution is all right

6 Input Files

1. event list files *_Mn*xxE.FIT (one per CCD/node and per exposure), straight from the ODF (n is 1 or 2, xx is IM or TI).
2. auxiliary files *_Mn*AUX.FIT (one per exposure), straight from the ODF.
3. offset/variance files *_Mn*OVE.FIT (one per CCD/node and per mode), straight from the ODF.
4. optionally, a user-supplied GTI file (entered through **ingtiset**) with **STDGTI** extension.
5. optionally, bad pixels files with **BADPIX** extension (one per CCD/node and per instrument). They are looked for in the current directory and their names must be P????????DD????BADPIX00ji.FIT, where i is the CCD number and j the node number. A file with matching observation and exposure fields is preferred, but any observation and exposure is accepted.

The structure of files in the ODF is described in [1]. The event and offset files in the ODF may be gzipped (end in .gz or .FTZ).

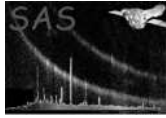


7 Output Files

1. event list files (one per instrument, exposure and per mode), as in the SSC Data Products ICD [2], except they are uncompressed. Their names are P0000000000DDUEEEEMIEVLI0000.FIT (IMAGING mode) and P0000000000DDUEEETIEVLI0000.FIT (TIMING mode). If `addvweight=Y`, a `WEIGHT` column is added.
2. timeseries files (one per instrument and per exposure) in RATE format of truncated single events per ks per arcmin², which are used to generate the good time intervals for flare screening. Their names are P0000000000DDUEEEFBKTSR0000.FIT. They contain the columns `RATE`, `ERROR`, `TIME` and `FRACEXP`. If `globalflare=Y`, a global timeseries is created in addition, named P0000000000OEMX000FBKTSR0000.FIT. In that one `FRACEXP` may be larger than 1.
3. good time interval files (one per instrument and per exposure) which may be used to select out proton flares in the data. Their names are P0000000000DDUEEEFBKGTI0000.FIT. If `globalflare=Y`, a single GTI file is created, named P0000000000OEMX000FBKGTI0000.FIT.
4. tracking history file P0000000000OBX000ATTTSR0000.FIT generated by `atthkgen` (also useful for later tasks like `eexpmap`).
5. attitude GTI file P0000000000OBX000ATTGTI0000.FIT generated by `tabgtigen` from the tracking history file.
6. HK GTI files (one per instrument) generated by `hkgtigen`. Their names are P0000000000ODDX000HK_GTI0000.FIT.
7. Optionally (if `writeccdbbackground=Y`), CCD background maps (one per CCD and per exposure) which may be used to check optical loading and the offsets map. Their names are P0000000000DDUEEECCDBKG00ji.FIT, where `i` is the CCD number and `j` the node number.

8 Intermediate Files

1. T0000000000DDUEEEFRAMLI00nn.FIT: frame file for a given CCD/node in output of `emframes`, where `nn` is the same as the `CCDNR` column in the final output file (`10*node + CCD`). `framenn.out.mos` if `usecanonicalnames=N`.
2. T0000000000DDUEEEIMAGPR00nn.FIT: reprojected map for a given CCD/node in output of `emeventsproj`. `evmap.in.mos` if `usecanonicalnames=N`.
3. T0000000000DDUEEEBPXFLI00nn.FIT: bad pixels file for a given CCD/node in output of `badpixfind` or `embadpixfind`. `badpixnn.out.mos` if `usecanonicalnames=N`.
4. T0000000000DDUEEERAWGTI00nn.FIT: GTI file for a given CCD/node in output of `emframes`. `ccdgtinn.in.mos` if `usecanonicalnames=N`.
5. T0000000000DDX000EXTGTI0000.FIT: external GTI file for a given instrument (merged from user, attitude and HK GTIs). `extgti.in.mos` if `usecanonicalnames=N`.
6. T0000000000DDUEEEHKXGTI00nn.FIT: external GTI file aligned to frame readout boundaries for the current CCD/node in output of `gtialign`. `hkgti.in.mos` if `usecanonicalnames=N`.
7. T0000000000DDUEEELCGTI00nn.FIT: GTI file for a given CCD/node, intersection of `RAWGTI` and `HKXGTI`. `gtinn.out.mos` if `usecanonicalnames=N`.
8. T0000000000DDUEEERWEVLI00nn.FIT: input event list file for a given CCD/node in output of `emframes`, with `BADPIX` extension appended by `badpix`. `eventnn.in.mos` if `usecanonicalnames=N`.



9. T000000000DDUEEECLEVLI00nn.FIT: event list file for a given CCD/node in output of **emevents**, with BADPIX, OFFSETS0, OFFSETS and EXPOSURE extensions. **eventnn.out.mos** if **usecanonicalnames=N**.
10. T000000000DDUEEECAEVLI00nn.FIT: calibrated event list file for a given CCD/node in output of **attcalc** and **emenergy**. **eventnn.out.mos** if **usecanonicalnames=N**.
11. T000000000DDUEEEFTEVLI00nn.FIT: filtered event list file for a given CCD/node for input to **emeventsproj**. **event.in.mos** if **usecanonicalnames=N**.
12. T000000000DDUEEEMIEVLM0000.FIT: merged event list in IMAGING mode in output of **evlistcomb**. **merged.img.mos** if **usecanonicalnames=N**.
13. T000000000DDUEEETIEVLM0000.FIT: merged event list in TIMING mode in output of **evlistcomb**. **merged.tim.mos** if **usecanonicalnames=N**.
14. T000000000DDUEEETREVLIO000.FIT: selection of events with truncated energy (for flare screening). **merged.truncated.mos** if **usecanonicalnames=N**.

9 Algorithm

```
subroutine emchain
```

```
    Read parameters.
```

```
    if startfromodf then call processOdf
    else if runevlistcomb then call mergeEvents
```

```
    if makeflaregti then
        Loop over the *MIEVLI0000.FIT files
            call makeFlareTS
            if globalflare call mergeTS else call tsToGTI
        end loop
    if globalflare call tsToGTI
endif
```

```
    Loop over the *MIEVLI0000.FIT files
        if addtaglenoise call emtaglenoise
        if withflaregti call applyFlareGTI
        if addvigweight call evigweight ineventset=eventfile
    end loop
```

```
    if not keepintermediate then rm -f *.in.mos *.out.mos merged.*.mos
```

```
end subroutine emchain
```

```
subroutine processOdf
```

```
    Set SAS_ODF to odf (for OAL).
```

```
    Call atthkgen if no tracking history file or withatthkgen is true.
    Call tabgtigen with expression='!isNull(DAHPNT) && DAHPNT<atttol'
    Call hkgtigen if no HK GTI is present.
    gtiext = 'T' // obsid // inst // 'X000EXTGTI0000'.FIT'
    Call gtimerge gtitable=$gtiext on attitude GTI (if filteratt),
```



```
HK GTI (if filterhk) and user GTI (if present)

Look in odf for ODF files pertaining to selected instrument,
ending in IME, TIE, RIE or CTE.FIT (possibly .gz or .FTZ).
Deduce all exposures present.

Loop over selected exposures
  if badpixfindalgo ne 'NO' then
    call ccdLoop (forbadpixfind=Y)
    call badpixLoop (no flare screening)
    call mergeEvents
    call ebadpixupdate
    call buildFlareGTI
    call badpixLoop (with flare screening and low energy run)
  endif

  call ccdLoop (forbadpixfind=N)
  if runeplistcomb then call mergeEvents
end loop over exposures

end subroutine processOdf

subroutine ccdLoop

  Loop over selected CCDs and nodes

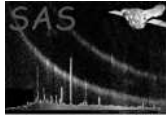
  Identify event file name event0 ending in IME, TIE, RIE or CTE.FIT.
  Deduce ccd and node. nccd = node // ccd
  core = obsid // inst // expid

  aux = substring($event0 - last 9 characters) // '00AUX.FIT'
  gtiin = 'T' // core // 'RAWGTI00' // nccd // '.FIT'
  gtiout = 'T' // core // 'LOCGTI00' // nccd // '.FIT'
  frameout = 'T' // core // 'FRAMLI00' // nccd // '.FIT'
  eventin = 'T' // core // 'RWEVLI00' // nccd // '.FIT'
  eventout = 'T' // core // 'CLEVLI00' // nccd // '.FIT'
  eventcal = 'T' // core // 'CAEVLI00' // nccd // '.FIT'
  emframes auxiliaryset=frame.in odfeventset=$event0 \
    outeventset=$eventin frameset=$frameout outgtiset=$gtiin
  if ($gtiext exists) then
    flagbadtimes=Y ingtiset=$gtiext

  if (not processlowgain and GAIN_CCD='LOW') next

  bad = 'T' // core // 'BPXFLI00' // nccd // '.FIT'
  if $bad does not exist then
    bad = 'P*' // instid // '*BADPIX00' // nccd // '.FIT'

  if withbadpix and not forbadpixfind then
    mv $eventin $eventout
    badpix eventset=$eventout outset=$eventin windowfilter=Y
    if ($bad exists) then
      getuplnkbadpix=Y getotherbadpix=N getnewbadpix=Y badpixset=$bad
    rm $eventout
```



```
endif

off = odff // * // instrument // * // ccd // node // 'OVE.FIT'
emevents frameset=$frameout odfeventset=$eventin eventset=$eventout
if ($off exists) then offvarsets=$off
if not randomizeP then randomizeposition=N
if randomizeT then randomizetime=Y
if forbadpixfind then analysepatterns=N flagbadpixels=N \
    splitdiagonals=N randomizeposition=N

if ($gtiext exists) then
  hkgti = 'T' // core // 'HKXGTI00' // nccd // '.FIT'
  gtialign gitable=$gtiext:STDGTI eventset=$eventout \
    outset=$hkgti
  extname = 'STDGTI' // node // ccd
  gtimerge tables="$hkgti $gtiin" mergemode=and \
    gitable=$gtiout:$extname

cp $eventout $eventcal
if withattcalc and not forbadpixfind then
  attcalc eventset=$eventcal

emenergy ineventset=$eventcal
if not imaging mode then getccdbkg=N
if not randomizeE then randomizeenergy=N
if forbadpixfind then correctcti=N correctgain=N randomizeenergy=N
bkg = 'P' // core // 'CCDBKG00' // nccd // '.FIT'
if writeccdbbackground then backgroundset=$bkg

if rejectbadevents or forbadpixfind then
  evselect table=$eventcal destruct=Y keepfilteroutput=Y \
    expression="(FLAG & 0x$rejectionflag) == 0"

end loop over CCDs and nodes

end subroutine ccdLoop

subroutine badpixLoop

Loop over selected CCDs and nodes

bad = 'T' // core // 'BPXFLI00' // nccd // '.FIT'
eventfilt = 'T' // core // 'FTEVLI00' // nccd // '.FIT'
evmap = 'T' // core // 'IMAGPRO0' // nccd // '.FIT'

evselect table=$eventcal filteredset=$eventfilt \
  keepfilteroutput=Y destruct=Y writedss=Y updateexposure=Y \
  expression="TIME in GTI($gtiflare)"

if badpixfindalgo == 'EM' then
  emeventsproj eventset=$eventfilt rejectbadevents=Y evimageset=$evmap
  embadpixfind evimageset=$evmap badpixset=$bad

  if (lowenerbadpix) select PHA < 150 and run again incrementally
```



```
else
    badpixfind eventset=$eventfilt thresholdlabel=rate \
               badpixset=$bad \
               hithresh=0.005 narrowerthanpsf=3.0 backgroundrate=1.E-5
endif

end loop over CCDs and nodes

if stopafterbadpixfind stop

end subroutine badpixLoop

subroutine mergeEvents

    imerge = 'T' // core // 'MIEVLM0000.FIT'
    tmerge = 'T' // core // 'TIEVLM0000.FIT'

    evlistcomb eventsets='T'//core//'CAEVLI00*.FIT' imagingset=$imerge \
                 timingset=$tmerge maintable='EVENTS OFFSETS'
    if fulloutput then
        emosingcolnames="TIME RAWX RAWY DETX DETY X Y PHA PI FLAG PATTERN
                        FRAME ENERGYE1 ENERGYE2 ENERGYE3 ENERGYE4 PERIPIX OFFSETX OFFSETY"
        emosingcoltypes="double int16 int16 int16 int16 int32 int32 int16
                        int16 int32 int8 int32 int16 int16 int16 int16 int8 int16 int16"
    endif

    if applyccdgti then
        Loop over 'T'//core//'LOCGTI00*.FIT' files
        expr = expr // '|| (CCDNR== ' // nccd // ' && GTI($gtiout,TIME))'
    endif

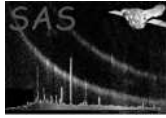
    eventim = 'P' // core // 'MIEVLI0000.FIT'
    evselect table=$imerge filteredset=$eventim \
             expression=$expr destruct=Y keepfilteroutput=Y

    fparkey "EPIC MOS IMAGING MODE EVENT LIST" $eventim[0] CONTENT \
           add=Y insert=DATE"
    fappend $sasccf[CALINDEX] $eventim

    if ($tmerge exists) then
        eventti = 'P' // core // 'TIEVLI00000.FIT'
        evselect table=$tmerge filteredset=$eventti \
                expression=$expr destruct=Y keepfilteroutput=Y
        fparkey "EPIC TIMING MODE EVENT LIST" $eventti[0] CONTENT \
               add=Y insert=DATE"
        fappend $sasccf[CALINDEX] $eventti
    endif

end subroutine mergeEvents

subroutine makeFlareTs
    expr = "(PATTERN==0) && ((FLAG & 0x762b8000) == 0) && #XMMEA_22"
    flarets = 'P' // core // 'FBKTSR0000.FIT'
    check that expected counts per bin in quiet conditions is > 10,
```



```
        otherwise increase $flaretimebin
    evselect table=$eventim expression=$expr updateexposure=N \
            rateset=$flarets timebinsize=$flaretimebin \
            timecolumn=TIME maketimecolumn=Y makeratecolumn=Y
    add FRACEXP column (currently done by looking at full timeseries)
    divide by CCD area (IN_FOV keyword) and FRACEXP
end subroutine makeFlareTs

subroutine mergeTs
    globts = 'P' // obsid // 'EMX000FBKTSR0000.FIT'
    if $globts exists then
        multiply by CCD area and FRACEXP
        merge columns of $flarets and $globts:
        RATE      = RATE1 + RATE2
        ERROR     = SQRT(ERROR1**2 + ERROR2**2)
        FRACEXP   = FRACEXP1 + FRACEXP2
        divide by CCD area and FRACEXP
    endif else then
        cp $flarets $globts
    endelse
end subroutine mergeTs

subroutine tsToGTI
    gtiflare = timeseries prefix // 'FBKGTI0000.FIT'
    tabgtigen table=$flarets expression="RATE<$flaremaxrate" \
            gtiset=$gtiflare
    evselect table=$gtiflare writedss=N updateexposure=N keepfilteroutput=Y \
            expression="(STOP - START) > 1.5*$flaretimebin"
end subroutine tsToGTI

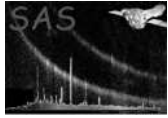
subroutine applyFlareGTI
    expr = "GTI($gtiflare,TIME)"
    evselect table=$eventim destruct=Y keepfilteroutput=Y expression=$expr
    evselect table=$eventti destruct=Y keepfilteroutput=Y expression=$expr
end subroutine applyFlareGTI
```

10 Comments

The script does not use the SAS' parameter and error interfaces, to allow easy modifications by users.

11 Future developments

The chain will adapt to the evolution of its constituents and to the organisation of the pipeline.



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.
- [2] SSC. XMM Survey Science Centre to Science Operations ICD for SSC Products. Technical Report XMM-SOC-ICD-0006-SSC Issue 2.1, SSC, Mar 2000.