



# srcmatch

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## Abstract

This task makes the final EPIC summary source list. It reads the **emldetect** source list and correlates, if applicable, the X-ray sources with the sources in the OM source list. Additionally, this task allows more **emldetect** source lists to be merged into one summary list, and/or it correlates the summary source list with source lists from the earlier stages of the EPIC detection pipeline.

## 1 Instruments/Modes

Instrument	Mode
EPIC MOS:	IMAGING
EPIC PN:	IMAGING
OM:	IMAGING

## 2 Use

pipeline processing	yes
interactive analysis	no

## 3 Description

The task combines four different functions:

- A one line summary for each source detected by the EPIC detection tasks is created. The summary information is a subset of the information given in the **emldetect** source list table.
- Cross-identification of the summary source list with source lists from earlier stages of the detection pipeline (i.e. to fill in the PN\_ML\_ID\_SRC, M1\_ML\_ID\_SRC,...,M2\_BOX\_ID\_SRC columns).
- **emldetect** source lists from different detection runs can be merged into one summary source list.
- A cross-identification of the EPIC sources with the sources listed in the OM observation source list is performed. The cross-correlation radius can be specified by an input parameter. Up to five OM source identification numbers can be listed in the output set.



Cross-correlating EPIC source lists for either merging or for correlating earlier pipeline source lists is done in two stages. The first stage is similar for both the merging of source lists and cross-identifying sources with earlier pipeline source lists. In this stage (subroutine `compare_srcs`) correlations are investigated and pointers between matching sources are set. Always the closest companion (in terms of sigmas) is chosen. Only sources within 3 to 5 sigmas will be correlated (the exact number can be set using input parameter `maxerr`). In order to avoid problems due to boresight effects an input parameter `systemerr` (for systematic error) has been introduced.

In the second stage, the cross identifications are either used to get the pointers to the source numbers from previous detection stages (e.g. the `PN_ML_ID_SRC` field), or the two lists are merged. The first option works for the data sets provided with the `crossidsets` command line parameter, whereas merging is done if more than one set is provided using the `inputlistsets` parameter. Both options can be used simultaneously.

Merging means that new sources will be added to the list and parameters of cross-identified sources will be averaged using weights based upon the statistical errors. The maximum likelihood parameters will be all listed separately using columns with dimension larger or equal to one, in the same manner as the cross-identification columns. The reason is that maximum likelihood values cannot be simply averaged or added without losing its meaning as a probability related parameter.

Both for merging and for cross-identification, the source lists are read one by one and are correlated separately. This ensures that not more than 2 source lists will be stored in memory. Upon execution the number of sources that can be stored in the summary source list is three times the number of sources in the first input set. If during the execution this turns out not to be enough, the source list will be copied to a new array with a three times larger capacity.

The output EPIC observation source lists are provided both in FITS and in HTML format, where the HTML list is intended to give a quick overview for each source detected, but does not provide instrument-specific data.

Combined values for all EPIC instrument and per individual EPIC instrument can be determined for several source parameters (described below). They are calculated if the parameter `allepicmode` is true and set to NULL otherwise.

Fluxes and flux errors from the input source lists are copied to the columns `inst_b_FLUX` and `ERR_inst_b_FLUX` (`inst=[PN,M1,M2]`, `b=[1,2,3,4,5,TOT,XID]`). Combined instrument fluxes and errors `inst_TOT_FLUX`, `ERR_inst_TOT_FLUX` are the sums of the fluxes and errors over all energy bands of the instrument. The columns `EP_b_FLUX` and `ERR_EP_b_FLUX` contain all-EPIC flux values and errors, calculated from the available single camera values using error-weighted averages.

As of version 3.10.2, the output FITS table contains the columns `inst_b`, `inst_b_ERR`, `inst_EXP`, with `inst=[PN,M1,M2]` and `b=[1,2,3,4,5,TOT,XID]`. These columns contain count rates, (`inst_b`), count rate errors (`inst_b_ERR`), and exposure map values (`inst_n_EXP`, `n=[1..5]`) from the individual instruments and up to 5 energy bands. Total count rates and errors per instrument `inst_TOT`, `inst_TOT_ERR` and total EPIC count rates and errors `EP_TOT`, `EP_TOT_ERR` are the sum of the count rates in the individual energy bands. In the case of several input source lists from one instrument, count rates are averaged and exposure map values are added.

The hardness ratios and errors from the input source lists are copied to output columns `inst_HRn` and `inst_HRn_ERR` (`inst=[PN,M1,M2]`, `n=[1,2,3,4]`). In addition, weighted averages of the single camera hardness ratios can be written to columns `EP_HRn`, `EP_HRn_ERR`, again controlled by the parameter `allepicmode`.

**Note:** Since the EPIC cameras have different energy dependent effective areas, the averaged HR values depend on the relative exposures and/or presence of the (sources in the) individual cameras.



As of version 3.10.5, the strings from the input columns `VAL_FLAG`, `VER_FLAG`, `VER_COMM` (set by task `dpssflag`) are copied into the columns of the output file `inst.VAL_FLAG`, `inst.VER_FLAG`, `inst.VER_COMM` (`inst=[PN,M1,M2]`).

## 4 Parameters

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

Parameter	Mand	Type	Default	Constraints
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<code>outputlistset</code>	yes	filename	summarylist.fits	
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Output summary source list in FITS format

<code>htmloutput</code>	yes	filename	summarylist.html	
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Output summary source list in HTML format

<code>inputlistsets</code>	yes	filename	inputlistset.fits	
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EPIC (`emldetect`) input source list(s). Specifying more than one list means that these lists will be merged.

<code>crossidsets</code>	no	filename	crossid.fits	
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Cross-identification source lists from earlier stages of the detection pipeline. These files will be used to fill in the pointers to the source identification numbers in these lists.

<code>usecrossidsets</code>	no	Boolean	no	
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Controls whether a cross correlation with X-ray source list from earlier detection stages should be performed.

<code>omlistset</code>	no	filename	omlist.fits	
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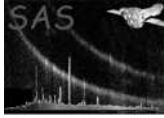
OM input source list. Setting `omlistset=-` means that no OM data set is available.

<code>useomlistset</code>	no	Boolean	no	
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Controls whether a cross correlation with an OM source list should be performed.

<code>systemerr</code>	no	float	1.0	[0.0<param<6.0]
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Systematic error for EPIC source matching [arcsec]



<b>maxerr</b>	no	float	1.0	[3.0<param<5.0]
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Maximum allowed error (stat. + syst.) for EPIC source matching [sigmas].

<b>omdist</b>	no	float	15.0	[0.0<param<60.0]
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Maximum distance EPIC-OM for correlation [arcsec]

<b>allepicmode</b>	no	Boolean	no	
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Needs to be set, if one of the source lists contains data from more than one EPIC camera, in order to calculate combined count rates, fluxes, and hardness ratios.

## 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.

### **noData** (*error*)

This error occurs when the data set is empty or cannot be read. Note that this may also be due to a wrongly formatted input set (e.g. no instrumental summary lines).

### **tooManySets** (*warning*)

The number of input data sets to be merged exceeded the maximum number (currently set to 9).

*corrective action:* Only the first nine input sets are processed.

### **emptyInputSet** (*warning*)

An input set has no data rows.

*corrective action:* Input file will be ignored.

### **singleInputSet** (*warning*)

Only one valid input source list has been found.

*corrective action:* Data set will be copied – no source matching.

### **noMatchingSources** (*warning*)

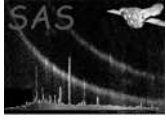
Normally one expects at least some of the sources in two input data sets to overlap. If this is not the case this warning message appears.

*corrective action:* Check the input sets by hand/eye whether it is useful to merge them.

## 6 Input Files

The following input files will be read:

1. EPIC **emldetect** source list(s), with a maximum number of 9 (at least one file is mandatory)



2. EPIC source lists from an earlier stage of the pipeline. These will be used for cross identifications only. (optional)
3. OM observation source list

This task requires that the EPIC input sets contain summary lines for each source, except if the input set contains only data from one instrument. Summary information has `ID_INST = 0` and `ID_BAND = 0`.

## 7 Output Files

The two output files are:

1. PPS product : final EPIC FITS observation source lists. Columns `RA_CORR` and `DEC_CORR` and – from version 3.18 on – `X_IMA`, `X_IMA_ERR`, `Y_IMA`, `Y_IMA_ERR` are only passed to the output summary source lists, when `srcmatch` is used on only one (X-ray) source list. The appropriate `eposcorr` / `catcorr` information is passed to the output source list (see below).
2. PPS product : final EPIC HTML observation source lists.

`srcmatch` allows more than one EPIC source list to be merged or cross-correlated with the summary source list. In order to keep track of the original source identifications of task `emldetect` we allow the columns `EP_BOX_ID` and `EP_ML_ID` and the columns (`PN_ML_ID_SRC`, `M1_ML_ID_SRC`, ..., `PN_BOX_ID_SRC`, etc.) to have more than one entry. Additionally, we use this scheme (but now with floating point data) for columns with maximum likelihood values (`PN_DET_ML`, etc, and `PN_EXT_ML`, etc.). The number of entries depends on the number of datasets, which will be stored using the keywords `NSETS` (for `EP_BOX_ID`, `EP_ML_ID` and the maximum likelihood parameters) and `NCROSSID` (for the other ID columns). The number of entries per row for a given column can also be retrieved from the FITS keyword `TDIMi` (*i* being the column index).

`srcmatch` will pass the columns `RA_CORR` and `DEC_CORR` (generated by `eposcorr` or `catcorr`) from the input X-ray source list to the summary output list, *only if the number of input source lists is one*. The reason for this restriction is that coordinates determined by different tasks should not be merged / averaged. The keywords generated by `eposcorr` will also be passed on. In case the input file was not modified by `eposcorr` or `catcorr`, the above mentioned columns and associated keywords will not be written to the output set.

Image coordinates `X_IMA`, `X_IMA_ERR`, `Y_IMA`, `Y_IMA_ERR` are passed and valid as well, if one X-ray input source list is provided, and set to `NULL`, if several X-ray source lists are merged.

The names of the merged datasets and their order can be retrieved from the header keywords `EP_SET1`, `EP_SET2`, ... with a maximum number stored in the internal parameter `max.nsets`. The datasets used for cross-identification can be retrieved from the `CROSSID1`, `CROSSID2`, ..., keywords. The following additional header keywords are present (they correspond to the input parameters with the same names): `SYSTEMR`, `MAXERR` and `OMDIST`.

Whether the input X-ray source list(s) was/were cross correlated with an OM source list, can be verified with the (logical) keyword `OMCROSS`. `OMCROSS = T` means it was cross correlated. The maximum number of associated optical sources (counterparts) from the OM source list is set to five (corresponding to five additional columns of the EPIC observation source list). If more correlations are found, the five counterparts with the smallest distance to the EPIC position will be listed and a label (column `OMFLAG`, see below) will be set accordingly.



In addition to the five columns giving the OM source numbers, a numeric column giving the total number of OM counterparts found for each EPIC source (which may be more than five) and a label column **OMFLAG** is added to the observation list.

The label **OMFLAG** can take the following string values:

- **OM\_SRC\_FND**: Counterparts found
- **NO\_OM\_SRCS**: OM data available, no counterpart found
- **NO\_OM\_DATA**: No OM data available at location of X-ray source

## 8 Algorithm

```
subroutine srcmatch
  call subroutine read_set in order to read set 1
  IF number of EMLDETECT datasets > 1 THEN
    LOOP over input EMLDETECT datasets
      call i/o subroutine for additional input sets
      call subroutine compare_src (correlates the two sets)
      call subroutine combine_src (merge two sets into one set)
      ! the first set is the main set and will finally constitute the
      ! summary set
    END LOOP
    LOOP over input CROSSID datasets
      call i/o subroutine for input sets
      call subroutine compare_src (correlates the two sets)
      call subroutine crossid_srcs (fills in cross id pointers)
    END LOOP
  END IF

  Copy source coordinate and source numbers from
  OM observation source lists to memory.

  LOOP over EMLDETECT source list

  IF (ID_INST=0).AND.(ID_BAND=0) THEN

    LOOP over OM source coordinates

      Find EPIC OM counterparts (distance < distance parameter)

      Increment 'number of counterparts' counter and copy
      to output record buffer

      Write OM source number to output record buffer

      Update OMFLAG and copy to output record buffer

    END LOOP

  Copy EMLDETECT source parameters to output record buffer.
```



```
END IF

IF (ID_INST>=0.OR.ID_BAND>=0) THEN
  Copy instrument and band specific EMLDETECT source parameters
  to output record buffer.
END IF

IF (ID_INST=0.AND.ID_BAND.AND..NOT.first pass through loop) THEN

  Write out output record buffer in FITS format
  (EPIC FITS observation source list).
  Write out output record buffer in HTML format
  (EPIC HTML observation source list).

END IF

END LOOP

end subroutine srcmatch

subroutine compare_srcs
  LOOP over two source lists
    IF two sources are within max_err sigma of each other THEN
      IF sources have no associations assigned yet THEN
        let the two sources point to each other
      ELSE
        IF New association is better than previous one THEN
          let the two sources point to each other
        END
      END IF
    END LOOP
  end subroutine compare_srcs
```

## 9 Comments

Users have noticed that in some cases the number of output sources depend on the order of the input lists. This is due to the fact that the first source list is used for position reference. Therefore, with more than 3 input lists the matching results can depend on the input order, if the distances between the candidates are near the matching radius.

## 10 Future developments

## References