omsrclistcomb

April 16, 2023

Abstract

Combines OSW source list into an observation source list

1 Instruments/Modes

Instrument	Mode
OM	FAST
OM	IMAGING

2 Use

|	
pipeline processing	yes
interactive analysis	yes

3 Description

This task takes the output source lists from each OSW (filenames listed in input listFile) and combines them to form the whole-observation source list (outFile), which is the pipeline deliverable product OM observation source list. The OSW source lists will previously have been magnitude calibrated (in the instrumental system, task ommag) and have RA-DEC coordinates (task omatt)

This primarily involves identifying which source is which in each list, combining the positions from each pass-band/exposure to give a best estimate and a refined error, and calculating the optical/UV colours for those sources observed with multiple filters in both the instrumental and standard systems. The magnitudes in the OSW source lists are in the instrumental (natural) system, and a call to the CAL extracts the current colour transformation matrix, which is applied to the instrumental magnitudes to give magnitudes in the standard system. Other information (e.g. quality flags) is also propagated.

A new column (SRC-ID) is added to each OSW source list, containing the observation source list number for the OSW source.

The combined source list is sorted into ascending Right-Ascension order. For sources in a particular filter that the program has identified as being identical (using the parameter nsigma and the position errors of
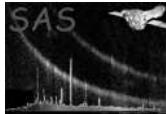
the sources), the average magnitude of the sources is computed from the averaged corrected count-rates, **using equal weights**.

4 Instrumental (Vega) Magnitudes and Colours

The tabulated magnitudes are those that have been computed by ommag- as mentioned in the previous section, omsrclistcomb will have averaged all the magnitudes from sources that it considers to be the same. Omsrclistcomb uses a colour table that it loops through to see if the relevant instrumental magnitudes (one of U, B, V, UVW2, UVW1 and UVM2) are present for the calculation of the instrumental colour. The colour list is :-U-B, B-V, U-V, UVW2-UVW1, UVW2-UVM2, UVM2-UVW1, UVW2-U, UVW2-B, UVM2-U, UVM2-B, UVM2-V, UVW1-U, UVW1-B, UVW1-V

5 Standard (Johnson) Magnitudes and Colours

Standard magnitudes can only be computed for the U, B and V filters and hence the only standard colours that can be calculated are U-B, B-V and U-V. An important point to note, is that these standard colours can be computed using the following instrumental colours - U-B, B-V, U-V, (UVW1-U), (UVW1-B), (UVW1-V), (UVW2-B) and (UVW2-V). Omsrclistcomb computes all possible standard magnitudes for each of the U, B and V filters and displays them in separate columns.

The program loops through these colours and if the relevant instrumental magnitudes are present computes the standard magnitudes and standard colour. Since it is possible that a particular source may have a standard magnitude computed twice for the same filter (eg standard B from U-B and B-V), the program will add, if necessary, a column for each of these standard magnitudes. These values should, of course, be identical to within the errors, but discrepancies may arise due to a number of reasons (eg an inaccurate instrumental magnitude).

6 AB Magnitudes and Fluxes

AB magnitudes (see Oke, J.B. 1974, ApJS, 27, 21) and fluxes are given for each filter (*in units of* $ergs sec^{-1} cm^{-2} \mathring{A}^{-1}$)

In the header of the table the keywords **ABM0X, ABF0X and E2JYX** are given for each filter (where X is a filter). The keywords give the AB magnitude zero-point, the conversion factor from count-rate to AB flux and the conversion factor from flux to Janskys, respectively. The first two values are obtained from the **OM calibration** files.

7 Astrometric alignment of the input source coordinates

If the parameter **alignaxes** is set to **true** (default) then the program will try to shift the **RA/DEC** origins of each source-list file to a common origin. This facility is included to try to remove any slight misalignment between the input source coordinates of each input source-list files due to small **OM** pointing errors. **Omsrclistcomb** uses the astrometrically uncorrected celestial coordinates to produce the merged source-list, and this routine can reduce mis-matching and improve the astrometric accuracy.

The routine works in the following way:

1. Get a list of the number of unique "windows" in the input source-list files (a window has a unique set of **WINDOWX0, WINDOWDX, WINDOWY0, WINDOWDY and BINBPE** parameters.

2. For each window do the following:

   (a) Find the source-list that has the most sources in that window.

   (b) For each other source-list in the window, compute the **RA/DEC** offsets that are needed to be added to their RAs/Decs to align with the reference source-list coordinates.

   (c) Compute the mean offsets.

   (d) Subtract the mean offsets from the RA/Dec coordinates of the reference source-list.

   (e) Subtract the mean offsets from the computed offsets.

   (f) Add these offsets to the RAs/Decs of the other source-lists.

3. having aligned the source-lists of each window with a reference source-list, the algorithm then tries to align the windows using the following algorithm:

   (a) Loop from i=1 to i=the number of windows

   (b) Loop from j=i+1 to the number of windows

   (c) If all the windows have been aligned exit the routine.

   (d) If both windows have been aligned move on to the next j

   (e) Otherwise, try to align window j with window i, by matching the source-list in window i having the maximum number of sources with the source-list in window j having the maximum number pf sources. If successful,

      - if neither window has been aligned, or window j has been aligned, add the offsets to the RA/Decs to all the sources in the source-list files of window j. Record that windows i and j have been aligned and move on to the next j.
      - If window j has been aligned, but not window i, subtract the offsets from the RA/Decs to all the sources in the source-list files of window i. Record that windows i has been aligned and move on to the next j.

8   Astrometric correction

The **RA** and **Dec** coordinates are computed using the pointing direction of the **OM** camera as the origin, and because the **RA** and **Dec** coordinates of this point may not be exactly the same as the coordinates deduced from reference to a catalogue (differences of a few arcsecs in **RA** and **Dec** are typical), **omsrclistcomb** (in a similar fashion to **omatt**) allows the user to determine these shifts and correct the source positions.

If the task parameter **usecat** is set to true, and the parameter **catfile** is set to the name of the fits catalogue file (or it has the default name usnocat.fit), **omsrclistcomb** attempts to match the **OM** sources with those from the catalogue, determine the **RA** and **Dec** shifts and correct the coordinates.

8.1 Successful Astrometry Correction

The correction is deemed to be a success if the following criteria are met:

- A sufficient number of stars have been matched (if the number of input sources (n) is less than 30, max(5, n/4), otherwise 10).

- The computed offset errors are no greater than the value of the input parameter **maxradecerr** (arcsecs).

- The computed RMS residual is no greater than the value of the input parameter **maxrmsres** (arcsecs).

The user can use the task parameters **maxradecerr** and **maxrmsres** to change the settings that decide if an astrometric fit is okay.

The columns **RA_CORR and DEC_CORR** will contain the corrected RAs and DECs, respectively, the key-word **POSCOROK** will be set to **t** (true) and the key-words **RAOFFSET, RAOFFERR, DEOFFSET, DEOFFERR, ROT_CORR, ROT_ERR, NMATCHES, RMSRESID** will contain the computed RA offset, RA offset error, DEC offset, DEC offset error, rotation, rotation error, the number of sources used in the astrometric fit and the root-mean-square residual of the fit, respectively.

Please note that from **SAS 7.2** the astrometric fit does not allow for any rotation between the **OM** and **USN0** coordinate axes, since the computed rotations were never more than a few arc minutes- hence the **FITS** keyword **ROT_CORR**, in the **SRCLIST** table will always be zero.

8.2 Unsuccessful Astrometry Correction

If the conditions for a successful astrometry correction (as defined in the previous section) have not been met, then the keywordPOSCORROK in the **SRCLIST** table will be set to **F** (False) and the columns **RA_CORR and DEC_CORR** will be set equal to the uncorrected values.

The key-words **RAOFFSET, RAOFFERR, DEOFFSET, DEOFFERR, ROT_CORR, ROT_ERR, NMATCHES, RMSRESID** will again contain the computed RA offset, RA offset error, DEC offset, DEC offset error, rotation, rotation error, the number of sources used in the astrometric fit and the root-mean-square residual of the fit, respectively.

8.3 Catalogue file format

Unfortunately, at the present time no catalogue file is included with an ODF to enable a user to re-compute the astrometry correction. However, CB is happy to create the file for anybody, on request. The **catalogue** file has to be in **FITS** file format and contain the following columns in a **RAWRES** table.:

- **CAT_RA**

- **CAT_DEC**

- **CAT_RADEC_ERR**

- **BMAG**

9 The SRCLIST table

This table will contain astrometric, photometric, source-parameterisation and source-flagging parameters. The number of columns will depend on the number of different filters that are present from the input source-list files.

The following sections describe the individual columns in the table.

9.1 SRCID

This column is a reference number that enables any source in an input source-list file to be identified as one of the input sources that was "merged" to make that source. (**omsrclistcomb** adds a column **SRCID** to each input source-list file.)

9.2 RA and DEC

These columns will contain the **Right Ascension** and **Declination** (**J2000**) of each **merged** source. If the parameter alignaxes was set to **true** (default) then the **RA** and **Dec** coordinates of each of the individual sources that constitute a merged source may have small corrections added.

All the entries in the table will be in order of increasing RA value.

9.3 RA_CORR and DEC_CORR

Please note that these columns will only be present if the parameter usecat was set to true.

Theese columns refer to the **Right Ascensions** and **declinations** (**J2000** with the astrometric correction applied (if correction successful, **POSCOROK = TRUE**). If the correction wasn't successful (**POSCOROK = FALSE**) then these coordinates will be the same as the uncorrected ones.

textbfNote that if a successful astrometry correction has been performed some of the RA values in the column may not be in increasing order.

9.4 POSERR

This column contains the standard error of the merged source position- ie $(1/n)\sqrt{\sum_{k=1}^{n} err_k^2}$, where err_k are the position errors of the n individual sources. **Note that input errors from the individual source-list files are first converted from pixels to arcsecs.**

9.5 LII and BII

These two columns will contain the **Galactic longitude** and **Galactic latitude** computed from the **RA_CORR** and **DEC_CORR** columns if present, otherwise from the **RA** and **DEC** columns.

9.6 FILTER_SIGNIFICANCE

For each filter there is a column for the source significances (signal-to-noise). These values are the averaged values from the individual sources that were merged into a source. The significance will be set to the negative of its value if the averaged corrected count-rate exceeds 1000 count per second and all the magnitudes will be set to null.

9.7 FILTER_RAW_RATE

There exists one **_RAW_RATE** column for each filter. They are populated by the unweighted mean raw count-rate of matched sources in units of counts/sec. These columns are required by the task **ommergelists**. Consequently, the **FILTER_RAW_RATE** columns will only be created in the output table if the input sources have been detected from mosaiced sky-images.

9.8 FILTER_CORR_RATE

For each filter there is a column for the source corrected count-rates. These values are the averaged, **without weighting**, values from the individual sources that were merged into a source. These rates have had all the necessary corrections applied. Again note that sources with negative significance values are ignored.

9.9 FILTER_CORR_RATE_ERR

For each filter there is a column for the source corrected count-rate errors. These values are the standard errors computed from

$(1/n)\sqrt{\sum_{k=1}^{n} err_k^2}$, where err_k are the corrected count-rate errors of the n individual sources.

9.10 FILTER_INS MAG

For each filter there is a column for the source instrumental magnitudes. These values are computed from the averaged **corrected count-rates** that are tabulated in the **CORR_RATE** columns values from the individual sources that were merged into a source, using the appropriate calibration constants for the filter that convert count=rates to instrumental magnitudes. These magnitudes can also be referred to as "**VEGA**" magnitudes. No magnitudes are computed if the corrected count-rate exceeds 1000.

9.11 FILTER_INS MAG_ERR

For each filter there is a column for the source instrumental magnitudes. These values are computed from the formula corrected count-rate errors of the n individual sources.
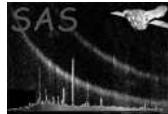
9.12 FILTERS_INS

Depending on what instrumental magnitudes are present, there will be various colours obtained from the instrumental magnitudes.

9.13 FILTERS_INS_ERR

The errors in the instrumental computed are computed from the formula $\sqrt{err_1^2 + err_2^2}$, where err_1 and err_2 are the errors in the two instrumental magnitudes.

9.14 FILTER_STD(COLOUR)

One standard colour for each filter will be given when there is at least one standard magnitude available for each filter. When more than one magnitude is available the magnitude from the first column will be used.

9.15 FILTER_STD_ERR(COLOUR)

These columns will contain the corresponding errors for the previous columns and are in fact the same as the corresponding **instrumental** magnitudes errors.

9.16 FILTER_AB_FLUX

For each filter there is a column for the source AB fluxes. These values are computed from the computed averaged count-rates in the **FILTER_CORR_RATE** columns.

9.17 FILTER_AB_MAG

For each filter there is a column for the source AB magnitudes. These values are computed from the computed averaged count-rates in the **FILTER_CORR_RATE** columns. No magnitudes are computed if the corrected count-rate exceeds 1000;

9.18 FILTER_MAJOR_AXIS

For each filter there is a column for the computed full-width-half-maximum of the source along the major-axis.

9.19 MEAN_MAJOR_AXIS

This column gives the computed value for the mean full-width-half-maximum of the source along the major-axis, using the values for each filter.
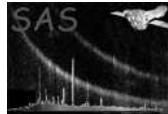
9.20 FILTER_MINOR_AXIS

For each filter there is a column for the computed full-width-half-maximum of the source along the minor-axis.

9.21 MEAN_MINOR_AXIS

This column gives the computed value for the mean full-width-half-maximum of the source along the minor-axis, using the values for each filter.

9.22 FILTER_POSANG

For each filter, this column gives the computed value for the position-angle of the major-axis source (measured anti-clock wise from the Right-Ascension axis).

9.23 MEAN_POSANG

This column gives the computed value for the mean position-angle of the major-axis source, using the values for each filter.

9.24 FILTER_QUALITY_FLAG

For each filter there is a column for the quality flag for each source, as determined from all the merged sources for that filter

9.25 QUALITY_FLAG_COMB

This column gives the **QUALITY FLAG** setting for each source as determined from the merged source-list.

9.26 FILTER_CONFUSION_FLAG

For each filter there is a column for the confusion flag for each source, as determined from all the merged sources for that filter.

9.27 CONFUSION_FLAG_MAX

This column gives the maximum **CFLAG** value of the confusion flag for the source.

9.28 FILTER_EXTENDED_FLAG

For each filter there is a column for the extension flag for each source, which is set equal to the extended flag of the source with the maximum significance (the negative value if a significance value is negative) for the particular filter.

9.29 EXTENDED_FLAG_MAX

This column gives the extended flag of the source with the maximum significance value (the negative value if a significance value is negative), from all the sources that were merged into a single source.

10 Notes on the Source Flags

10.1 QUALITY FLAGS

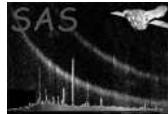Each source has an associated "quality flag". The flag settings are shown in the following table.

BIT NUMBER	REASON	INTEGER VALUE	Region Colour
0	BAD PIXEL	1	red
1	READ-OUT STREAK	2	magenta
2	SMOKE-RING	4	yellow
3	SOURCE ON STAR-SPIKE	8	white
4	Mod-8 pattern	16	black
5	Source within central enhancement	32	red
6	Source lies near to a bright source	64	black
7	Near an edge	128	blue
8	point-source within extended source	256	blue
9	Weird source	512	red
10	Multiple exposure values within photometry aperture	1024	red

10.1.1 Examples

1. Quality flag 1 - Source contains one or more bad pixels

2. Quality flag 3 - Source contains one or more bad pixels and lies on a read-out streak

3. Quality flag 7 - Source contains one or more bad pixels and lies on a read-out streak and lies within a "smoke-ring" region.

10.1.2 Notes on individual quality flags

1. **Bad Pixels** A point-source will have this flag set if any pixel within the photometry aperture, or any within the background annulus, has a corresponding pixel in the quality image with a non-zero value. Similarly, an extended source will have this flag set if any corrsponding pixel in the quality image has a non-zero value. The quality image was added to the image file by **omcosflag**, and a "bad" pixel may either be a damaged or dead one.

2. **Weird source** Indicates that the source has an isolated extremely bright pixel.

Notes

1. **QFLAG** The quality flag for each source in each filter obtained from the input source-lists.

2. **QFLAG_COMB** The quality flag for each source in each filter obtained using the combined source-list.

10.2 CONFUSION FLAGS

These flags are set for "point" sources by **omdetect** when the photometry is performed. The flags are stored in an 8-bit integer variable and the settings are:

BIT NUMBER	REASON	INTEGER VALUE
0	Point source has one or more sources within a radius of 6-12 unbinned pixels	1
1	Point source has one or more sources within a radius of 3-6 unbinned pixels	2

A source could have a confusion flag value of 3, indicating that both bits 0 and 1 are set.

11 Source matching

In order to produce the **merged** source-list from all the individual input source-list files, **omsrclistcomb** first produces a list of all the input sources sorted into order of decreasing source significance. To decrease the CPU time taken in the matching process, the distance (d) between two sources is computed from their equatorial-rectangulr coordinates (x, y and z), using the following formulae:

- $x = cos(\delta) \times cos(\alpha)$

- $y = cos(\delta) \times sin(\alpha)$

- $z = sin(\delta)$

- $d = \arccos(x_1 \times x_2 + y_1 \times y_2 + z_1 \times z_2)$

The equatorial coordinates are only computed once.

In order to deal with source-position errors that may be underestimated, and don't in fact take into account "offsets" between the coordinates in the different files, each source is assigned a new error based on the following:

- For a source with a likely strong **mod-8** pattern (Quality flag bit 4 set), the error in the position is taken to be the maximum of its computed position error and 1 arcsec.

- For extended sources the position error is taken to be the maximum of its computed position error and $0.25 \times$ its computed semi-major axis, or a minimum of 3 arc secs.
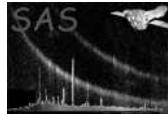
For each source in the list **omsrclistcomb** then tries to find a counterpart from the other sources in the list, excluding sources from the same source-list file from where the current source originated. Two sources are considered to "matched" if the distance between them satisfies the following:

$$distance <= \max\left(2.5, \min\left(4, \mathbf{nsigma} * \mathbf{error}\right)\right) \text{ arcsecs}$$

where **error** is computed from the formula $\sqrt{err_1^2 + err_2^2}$, where err_1 and err_2 are the errors in the two source positions and **nsigma** is the input parameter (default value=3). The matching algorithm may find several possible "matches" and will select the closest.

12   Parameters

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

Parameter	Mand	Type	Default	Constraints
sourcelistsets	yes	string	none	

List of product **OM** source-list files

outset	yes	string	none	

name of output PPS product OM observation source list

nsigma	no	real	3.0	

number of σ above which two sources are treated as different

usecat	no	boolean	F	

Attempt to do the astrometry correction using the usno catalogue data.

alignaxes	no	boolean	F	

If true then the program will attempt to align all the RA/DEC axes of each source-list to a common axis (ie try to correct for small astrometric shifts between the input source-list files)

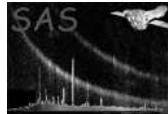| **catfile**	no	string	usnocat.fit	

name of the USNO catalogue fits

maxradec	no	real	1.0	

Maximum allowed RA/dec error in the computed astrometric offsets

maxrmsres	no	real	1.5	

Maximum allowed rms residual in the computed astrometric offsets

13 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.

Could not allocate memory for : name *(fatal)*
> Memory for an array could not be allocated

Failed to release memory for : name *(warning)*

> *corrective action:* Memory for an array could not be deallocated

two sources matched in same OSW *(warning)*
> warn user and use nearest source
> *corrective action:*

colExist *(warning)*

> *corrective action:* The source-ID column already exists in one of the input source-list files

14 Input Files

1. OM OSW source lists (produced by omatt). These files have an extra column added by omsrclist-comb.

15 Output Files

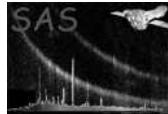1. PPS product OM observation source list

16 Algorithm

subroutine omsrclistcomb

Read in all OSW source lists

Collate all sources into a main list

For each source in the list, i

```
   if this source has not been identified with other sources
         list-of-same-sources(1) = i
         no-of-same-sources = 1
   endif

   Loop over all other sources in the main list, j

         if ( i /= j) then

         If the position of source i is the same as position of source j
         (to within  tolerance nsigma and systematic error) then

               no-of-same-sources++
               list-of-same-source(no-of-same-sources) = j

         Endif
   End loop

   Loop over same sources list, m

      Loop over rest of same source list, n

         if source m and n are in the same OSW

            flag as being in the same OSW

         endif
      end loop
   end loop

   Loop over sources in same OSW

        use nearest source and delete others from list_of_same_sources

   end loop

   now we have a list of sources that are the same


end for

create an index array giving the order of the sources in increasing
Right-Ascension.


create a matrix of magnitudes containing n independent sources and m filters

set matrix to NaN

Loop over all independent sources

   find weighted mean of source position

   For each filter
```

```
    if source has been observed in filter more than once
       find mean position and magnitude.
    endif

    add entry to magnitude matrix

  end for

end loop


Loop over matrix

    compute colours in standard system from CAL colour transformation
    matrices

end loop


define possible colours (mag1-mag2) e.g. (B-V) and (U-B) etc

for each colour combination

    if ANY(matrix(mag1) /= NaN) and ANY(matrix(mag2) /= NaN) then
        compute colour and error
     endif

endfor


for each independent source

  Convert any undetermined (eg standard magnitude, colour) parameter value
  to NULL and then insert the source information at its correct Right-Ascension
  position in table.

Endfor

add a SRC-ID column to each OSW source list
for each OSW source
 write the appopriate source number from the observation source list
endfor

end subroutine omsrclistcomb
```

References