How to reduce SWS AOT07 Data in the ISAP GUI

Eckhard Sturm

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Before you begin:

This guide is intended to give a basic description of how to use ISAP in the GUI mode to reduce the Auto Analysis Results (AARs) for SWS AOT07 data: it explains the basic principles and shows in a representative way how and in which order to work through each of the possible steps of data processing. It assumes that you are working with ISAP version 2.0. For a full description and alternate uses of a particular routine, consult the ISAP help. This help is accessible on the web: http://www.ipac.caltech.edu/iso/isap/isap.html or http://www.mpe.mpg.de/www_ir/ISO/observer/isap/isap.html. From within the GUI simply use the "Help!" button and select "WWW pages." The help pages contain - among other things - a beginners' GUI guide, a description of all the GUI Buttons, and links to the detailed help text of each individual ISAP routine ("Command Line Routines"). Here you'll also find the necessary information about routines that are not mentioned in this recipe. A lot of fundamental information about the SWS instrument and its behaviour is contained in the SWS Handbook. The latest version is always available on the web: http://www.iso.vilspa.esa.es/ (folow the link to "ISO Documentation"). Before trying to reduce SWS data we **strongly recommend** to carefully read at least the beginners' GUI guide, which will make you familiar with the basic principles of the ISAP GUI, and the handbook!

If your AAR has been produced with a pipeline version earlier than 7, you should seriously consider/ask for a reprocessing of your data. The pipeline version can be found in the header of the FITS file. Note that the data in the official ISO Post Mission Archive are all processed with version 8 (or higher). Also note, OSIA and IA3 do not update the pipeline version in the header (but you can use the header editor in ISAP to overwrite it manually).

These instructions suggest saving the intermediate products of the data processing after particularly time-consuming steps; the user should weigh the value of additional saves against the constraints of disk space.

Before starting ISAP, you should close all applications which use color (e.g., Netscape, or additional IDL sessions), as they will interfere with the ISAP color table. After ISAP has been started, you may restart these applications without affecting the ISAP session.

Finally: Whenever you have comments, suggestion or complaints about this manuscript (e.g., if you are missing some information), please let me know! Please check the web site for modifications of this document - from time to time.

1) **getting started / data input**

Start ISAP in the GUI mode (possibly "isap" or "isap_gui" - see the readme text of your installation). The first thing to do of course is to read in the data: Click on "Read data..." and then select "FITS" (provided you have your AAR available in its original FITS format). Choose the desired file from the file selection tool which pops up (i.e. double click on the file name). If your AOT7 observation contains a merged AOT6 part, this part will be loaded as a separate spectrum and a message will be issued. You should process the AOT6 part separately, just as you would process any regular AOT6 spectrum (see the recipe "How to reduce SWS AOT06 Data in the ISAP GUI"). (Note, however, that sometimes (prior to pipeline 7) this AOT 6 part contains nothing but invalid band 3 and 4 data, which can be ignored).

2) **Note on line and scan counting / data tag ambiguity**

For AOT 7 pipeline 7 (and higher) data the line and scan counting is different from the counting in AOT 1's and AOT 2's. If a "line", i.e. a certain wavelength range is scanned several times, the line counter is increased instead of the scan counter. The scan counter will always be 1. The scans for one wavelength range are therefore found under different line numbers.

Contrary to other AOT modes, AOT 7 spectra cotain only scans of one scan direction (up = +1, but see step 3 below). There is also just one detector used (instead of 12), which defines the band: Detector 49 = band 5, detector 51 = band 6. There is, hence, some ambiguity between the tags (buttons). For AOT 7 data it is best to simply ignore the "band" button (i.e. switch them off), and to just use the "detector" and "line" buttons for data selection. Since there is just one scan and scan direction (but see step 3 below), you can ignore these buttons as well (they should be on, though).

3) **Wrong scan direction tag**

Some AOT 7 spectra prior to pipeline 7 may contain data points with an assigned scan direction -1 (down), although the true scan direction in an AOT 7 is always +1 (up). You can overwrite this wrong scan direction: Click on "Special Fns..." and select "Fix SWS07". This will set all scan directions to +1 (i.e. the -1 button will disappear). STORE this fixed AAR.

4) **Quick look - I**

To see the full data set, select all detectors and lines, then click on plot. If you have more than one wavelength region you can use the left mouse button to zoom into your data and to plot the different wavelength ranges in more detail. You can also make use of the different color coding options offered by ISAP (click on "Select Plot Style"). Note, that **plotting** of large data sets in plot modes **other than the default** "dot cloud" mode can take a **long time**. If you want to interrupt a plotting process, and you are running UNIX, type "Ctrl-c" in the command line of your IDL window, and then type "return". You should now be able to reset the plot style and to plot again.

Here follow some criteria you can use for a first cut evaluation of the data quality and to spot potential problems:

- *Are the flux values non-negative (on average)?*
  If the answer is NO, then the dark current subtraction in the automatic pipeline processing has not been optimal (the dark current has been over-subtracted). In this case you could very likely improve the result by going back to OSIA (the Observer's SWS Interactive Analysis system, which operates on SPD level) and performing an interactive dark current subtraction (with OSIA's routine dark_inter). Note that *on average* means that many individual points might still be negative in the case of a faint, noisy source.

- *Are there inconsistent trends in the continuum shape?*
  If some of the detectors within a line have continuum slopes that are tilted with respect to the other detectors, this could again be due to problems in the automatic dark current correction. Going back to OSIA is recommended, if a sustantial part of your data is affected.

5) **Remove bad data - I**

Sometimes the pipeline AAR (prior to version 7) contains data with a scan counter 0, line number 0, and/or a scan direction 0. Those data usually can be dropped. In this case select all scans, lines, and scan directions, except those with a zero value, plot everything (select the default plotmode, i.e. unconnected, no color preference, which is fastest), and catch everything with the right mouse button. Choose "make aar" in the tool box, enter a new name and store the result.

6) **Split**

If you have more than one spectral range, it is recommended to process the individual ranges separately. Zoom in to one range after the other. Catch the data with the right mouse button, click on "make aar" to make a new sub-aar, give it a descriptive name, and store it.

7) **Start loop**

Now you can select the first of the sub-spectra: click on "stored data sets...", then on the name of the first sub-spectrum, and then on "make prime" (under "Apply function to:"). The following steps describe what should be done for each of the parts separately (i.e. in a loop).

8) **Remove bad data - II**

The next step should be the removal of all kinds of bad data. You can choose between "Tippex", "Mask" and "Zap" (invoked via the tool box which pops up if you select some data with the right mouse button). With TIPPEX a single point is replaced by a linear interpolation between the two corresponding neighbouring points. This is done as unique as possible, i.e. the two points choosen as basis for the linear interpolation are of the same detector, scan and scan direction, if any of this information is available. MASK simply masks out the selected data, i.e. they will not be taken into account for the computation of correction functions in the subsequent processing steps (e.g. in AVERAGE they won't contribute to the average). But the masked data stay in the data set, and shift, for instance, shifts masked points as well (without using them for the computation of the correction). With ZAP you really get rid of the data, they are thrown away. If you do not have many scans of a line, i.e. if you don't have much redundancy in your data, you might prefer using TIPPEX instead of ZAP, but judge the result critically.

In a first step you should plot all the data, with the plot mode set to "connected, color code = lines". You will probably see many clear outliers, which you can zap away right now. With the MIDDLE MOUSE BUTTON you can always get information about a single data point. Just click on the desired point (or near to it). In the info field at the bottom of the GUI you'll get e.g. the detector number, and line number. In a second step, you should have a detailed look at every single scan (i.e. "line"). This is usually one of the most important steps. You can significantly improve the quality of the final spectrum.

Besides single outlying points another kind of "bad data" can be sudden jumps in flux (a glitch) followed by a subsequent exponential-like decrease over several seconds/data points, due to memory effects. Remember this are all up scans, i.e. they are going down in wavelength (up in mechanism position). Hence, a typical memory tail will start at some glitch and then decrease towards lower wavelengths (from right to the left). You should zap the entire memory tail.

If you have to zap (mask/tippex/etc.) a lot you can make use of the "Preselect" button: Click on it and choose "Zap". From now on ISAP will automatically zap whenever you catch data points with the right mouse button. Don't forget to switch preselect off when you are done with zapping. (If you do forget, the "undo" button in the upper right corner of the GUI might come in handy...).

An alternative to zapping "by hand" is automatic "Clipping".

9) **Shift lines**

There may be differences in the average flux density of each of the scans of one range (i.e. between the different "lines" in the AOT 7 terminology). According to the current flux calibration accuracy for the Fabry-Perot the scatter should be no more than 20 to 35 %. You might improve the quality of the final product, if you normalize the lines to a common level, before you average them in the next step. This can be done with the ISAP routine "shift". The common level is defined such that the mean value of all data together is preserved. If the signal is weak the differences between the lines can be attributed to uncertainties in the dark current subtraction. Hence, the "offset" mode should be choosen. Only for strong signals (above several 100 Jy) the dark current can be neglected and differences are due to gain effects, i.e. multiplicative effects. In this case "scaling" would be the right option. No general rules can be given here to decide which of the modes is the best. Examine the result very critically.

Be aware that shifting in offset mode, i.e. adding or subtracting a constant, at this stage of processing is in principal wrong, because the relative spectral response function has been applied to the data (multiplicative).

(If the scatter between the lines of one wavelength range is not significant, you can skip this step.)

10) **Average**

To average all the lines of one range select the corresponding data and choose "Average". For a detailed description of the average tool please read the web pages (see "GUI Buttons"). Switch off the "lines" box.

The bin size should correspond to the spectral resolution (or FWHM = spectral resolution element). The resolution of an AOT 7 observation can be found e.g. in the SWS Handbook. It is roughly in the range between 20000 and 35000 (resolution element (FWHM) = 0.0005 to 0.001). The scanner performs 4 steps per resolution element, so the step size is roughly FWHM/4. Note that the default values that are offered by average are FWHM/5 (or resol x 5) values. If you want to determine a bin size yourself, zoom into the plot of the data in the left plot window of average. With the cursor you can read off the spacing between the wavelengths. The bin size should be a little bit smaller than this spacing.

To adjust the plot ranges in both windows use "Replot Max" in the left window, then use "Copied Range" in the right window. If the oplot button is checked, ISAP overplots the result of averaging directly in the left hand side plot window. If you use the oplot mode you will also see the points that have been clipped by the clipping routine. Note, that the small bin sizes associated with sws spectra can be too small for a significant clipping. In this case try to lower the sigma value (e.g. 2 or 1). Alternatively, there are two stand alone clipping routines available. A very basic one is available under the "arithm" button (in the tool box). It performs a kapp x sigma clipping on the basis of all selected data (i.e. the bin size is the entire selected wavelength range). Kappa can be specified by the user (e.g. 2.5). Outliers more than kappa x sigma off will be masked. You can then use the plot option "show masked data" to view the result. If you like it: "zap masked", if not: "unmask". A more advanced clipping tool is available under "Clipping". This routine allows you to adjust a bin size.

You can choose between different methods of averaging (see the description on the web). Try all of them to find the best method for your data set.

Don't forget to STORE!

11) **Smooth**

This function reduces the noise in the flux values of an AAR (either in unique parts, such as detectors, or all together) by convolution with a selected function: Boxcar, Gaussian, Lorentzian, Median, Hanning, or Sinc. If you are interested in line profiles you should, however, be very careful when choosing the function width (in other words: don't smooth too much!). Stay well below the FWHM of your lines (or try using the boxcar or median filter).

12) **Increment scan tag**

After averaging the line tag is gone. If you want to merge the different parts of the data set together (see next step), you could use the scan tag to distinguish between the different parts in the merged spectrum. Click on "Special Fns..." and select "Increment Data Tag". Increment the scan tag of different parts to different values as you cycle through the loop.

13) **Loop over all AOT bands**

Store the processed spectrum and go back to step 7) to reduce the other ranges in the same manner. Be aware of the plot style. Large data sets should be plotted in the "unconnected, without color preference" mode, which is the fastest (remember the "Ctrl-c" + "return" option, see step 3)

14) **Further steps**

After you have cycled through all ranges in the way described above, the basic reduction of SWS07 data is complete. If you wish to combine all the single spectra to one complete spectrum again, you can do so: make one of the spectra the prime data set and then select the other bands one after the other ("Stored Data Sets") and use "Stored Data Sets" →"Merge with Prime Data Set". This operation simply combines all selected data into one, larger AAR. A quicker way is provided by "Merge group of AARS" under "Special Fns...". Before you merge, you should consider to to increment the scan tag (see step 12 above).

A further option of data processing is REBINning (see the web documentation). ARITHM may be helpful for all kinds of arithmetic operations (e.g. to subtract or add two spectra or to add a constant, etc.).

Finally you may wish to analyse the processed spectrum, e.g. measure some line fluxes. The "LINE FIT" tool, accessible via the tool box for selected data, provides all you need to fit a baseline and the line itself, it returns the fit parameters, line fluxes etc., and suggests several possible line identifications, based on the specified redshift (radial velocity) and a built in line list (including unidentified infrared bands – UIBs – and some unidentified lines).

The unit conversion tool (accessible under "Special Fns...") may also be of interest for you.

"Zodiacal" can be used to subtract the dominant foreground at SWS wavelengths. "Dered" (available in the command line mode only) allows to deredden the spectrum according to a given extinction law.

When you exit the GUI you will be in ISAP's command line mode. By typing *aar=gui_output()* you'll get the aar which was prime on exit of the GUI. You can then work on your aar just like in a normal IDL command line environment. You can go back to a GUI session any time by typing *start_gui* or *start_gui,aar_in=aar*. The latter command passes an aar from your command line session directly into the GUI (see the information on the ISAP web page under "IDL-ISAP interface").

If you need more help, you should contact (or consider to schedule a visit to) IPAC, MPE, VILSPA or one of the other national ISO data centers. Informations about IPAC, MPE or the VILSPA IDC can be found on the web:
http://www.ipac.caltech.edu/iso/
http://www.mpe.mpg.de/www_ir/ISO/
http://isowww.estec.esa.nl/
You can also email us any kind of problems with ISAP and any suggestions you have: isap_dev@ipac.caltech.edu. (Within the GUI just click on "Send Mail".)
The author of this recipe can be contacted via: sturm@mpe.mpg.de

If you are going to publish results which are based on a data reduction and/or analysis with ISAP we would very much appreciate the following acknowledgement:
"The ISAP Spectral Analysis Package (ISAP) is a joint development by the LWS and SWS Instrument Teams and Data Centres. Contributing institutes are CESR, IAS, IPAC, MPE, RAL and SRON."

And now: Good luck with the reduction and analysis of your ISO data!