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ISO–SWS Data Analysis

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Abstract. We present aspects of the Data Analysis of the Short Wavelength Spectrometer (SWS) on-board ESA's Infrared Space Observatory (ISO). The general processing from the raw telemetry data of the instrument, up to the final calibrated product is described. Intermediate steps, instrument related aspects and data reduction techniques are highlighted.

1. The SWS Instrument

The Short-Wavelength Spectrometer (de Graauw et al. 1996) is one of the four instruments on board ESA's Infrared Space Observatory (Kessler et al. 1996), launched on November 17, 1995 and operational till approximately April 1998. SWS covers the wavelength range from 2.38 to 45.2 μm with two nearly independent grating spectrometers with a spectral resolution ranging from 1000 to 2000. In the wavelength range from 11.4 to 44.5 μm Fabry-Perot filters can be inserted which enhance the resolution by a factor 10 to 20.

2. SWS Data Processing

The processing of the SWS data can roughly be split into three distinct parts. The first part is the processing from the raw telemetry data to Standard Processed Data (SPD). The second part starts with the SPD and results in a spectrum of wavelength versus flux, the Auto Analysis Result (AAR). The last stage

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involves post-processing and scientific analysis using the AAR. The first two steps form part of the ISO Standard Product Generation 'pipeline' and the products mentioned (e.g., ERD, SPD and AAR) form part of the data sent to the ISO observer. This processing is also part of the SWS Interactive Analysis System IA^3 which is described in detail by Wieprecht et al. (this volume).

2.1. ERD to SPD

The raw data are stored in FITS files containing the Edited Raw Data (ERD) and status and house-keeping parameters. Additional files containing information on e.g., the pointing of the satellite and the status of the instrument and satellite exist and can be used as well if required.

The ERD data consist of digital readouts at a rate of 24 per second for each of the 52 SWS detectors (four blocks of 12 detectors for the grating and two blocks of 2 detectors for the FP). The data is checked for saturation, corrected for reset pulse after-effects, linearized (AC correction), cross-talk corrected and converted to voltages. Next a slope is fitted for each detector and reset interval and wavelengths are assigned for each of these points. The data are extracted per reset interval and stored in a SPD.

2.2. SPD to AAR

For each reset interval the SPD contains a value for the slope in μV/sec and a wavelength in μm plus ancillary information about timing, instrument settings, data quality etc.

As a first step memory effects should be corrected. For the time being this is still in an experimental phase and not included in the standard processing. Next the dark currents are determined and subtracted. The relative spectral response of the instrument (RSRF) is corrected and the absolute flux calibration is applied (i.e., conversion from μV/sec to Jy). The wavelengths are corrected for the ISO velocity towards target and finally the data is sorted by wavelength, extracted and stored in an AAR.

2.3. AAR Processing

The processing using the AAR involves steps like aligning the signals of different detectors which cover the same spectral region, sigma clipping, rebinning, line and continuum fitting etc. All this is possible within IA^3 and the ISO Spectral Analysis Package (ISAP) (Sturm et al. this volume).

3. Edited Raw Data (ERD)

Figure 1 shows ten seconds of data from one detector. The data is taken with a reset time of two seconds. This means that we have 48 data-points per reset per detector. This plot illustrates the correction steps required at this stage of the processing. The two main corrections are the correction of the ramp curvature and the correction of glitches, caused by the impact of charged particles.

One source of curvature is the after-effect of the applied reset pulse (here at 0,2,4,6, and 8 seconds). This effect can be fit with a decaying exponential and can be determined from the data (this is required since the pulse-shapes appear

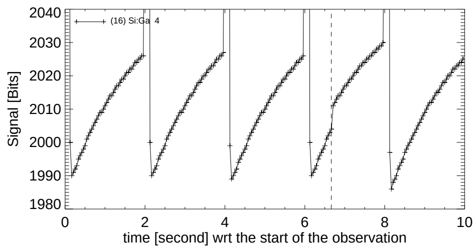

Figure 1. *Sample of Edited Raw Data (ERD) data illustrating the curvature in the uncorrected slopes and an example of a glitch (in the fourth slope) as a result of a charged particle impact.*

to change from observation to observation). The pulse-shape is an additive term to the slope and thus introduces an offset to the calculated signal. Since this affects all slopes in a similar manner it has no direct impact on the signal since it will be corrected by the subtraction of the dark currents. The main reason for correcting for the pulse-shape is to maximally linearize the slopes. This helps to improve the detection and correction of glitches. The other source of curvature can be found in the electronics in the form of a high-pass filter. The time constant for this is known to a fairly high accuracy and experiments have shown that this time constant appears to be fairly constant from observation to observation (for most detectors less than 5-10%).

In the hostile environment of outer space, there is a constant impact of charged particles. These show up in the data as a sudden increase in the raw detector signal (as illustrated in figure 1). These are recognized, corrected and flagged in the data. The flagging gives the user the ability to check the validity of affected slopes in a later stage of the processing.

4. Relative Spectral Response

An important step in the processing from SPD to AAR is the application of the Relative Spectral Response Function (RSRF). Part of the long wavelength section of the SWS (from 12 μm to 29 μm) the spectrum is highly affected by instrumental fringing as a result of Fabry Perot effects within the instrument.

Directly applying the RSRF to the data quite often gives unsatisfactory results. The fringe residuals are significantly large and this limits the detection and analysis of weak spectral features. The main reason for this is that the RSRF has a limited accuracy, the fringes as they appear in the data are sometimes shifted with respect to the fringes in the RSRF when the source is not exactly in the center of the aperture or if the source is extended. Also the width of the features (i.e., the resolution of the data) can change depending on the extent of the source.

A number of methods have been developed within IA^3 to adapt, change or correct the effects mentioned above. These can reduce the residuals down to a level of 1–2%. The following techniques can be applied:

- shift correlation/correction between the RSRF and the data
- adapting the resolution of the RSRF
- fitting cosine functions to the RSRF corrected data
- Fourier filtering of the RSRF corrected data
- modeling the instrumental FP effects

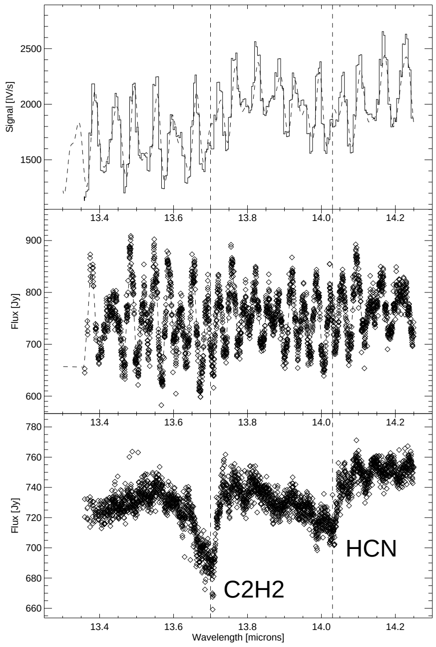

Figure 2. *The impact of fringes in part of the spectrum. In the top plot, the signal from one of the twelve detectors covering this spectral range is shown. Overplotted with the dashed curve is the scaled RSRF signal. The second plot shows the result for all twelve detectors as produced with the standard processing: large fringe residuals remain. In the last plot the result of improved data reduction is shown. The fringe residuals are low and allow detection of weak spectral features. Here the detection of the C_2H_2 ν_5 and the HCN ν_2 vibration-rotation bands towards a deeply embedded massive young star are shown (Lahuis et al. 1998).*

Figure 2 shows an example utilizing two of the techniques mentioned here. In this case first a shift correction and enhancement of the RSRF was applied. After this the residual fringes were removed by fitting cosine functions.

5. Future Developments

The data analysis of SWS has not reached its final stage. The knowledge about the instrument is continuously increasing and consequently the software is evolving. After the satellite has ceased to function a post-operations phase starts in which the improvement of the calibration and data-reduction of SWS will continue.

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