SWS-DETECTOR GLITCH EFFECT CORRECTION

E. WIEPRECHT
ISO Science Operations Centre, ESA SSD, Villafranca, 28080 Madrid, Spain

AND

E. WIEZORREK AND L. HASER
Max Planck Institut fuer extraterrestrische Physik, Giessenbachstrasse 1, 85740 Garching, Germany

Abstract.

We describe how the ISO-SWS (Infrared Space Observatory - Short Wavelength Spectrometer) software packages detect various glitch events i.e. high energy particle hits effecting the SWS detectors. A rough classification of glitch types is given.

The events cause an instantaneous change in the slope of the SWS detector read outs followed by a distortion of the further samples, so called glitch tails. As a consequence the S/N ratio and photometric accuracy are reduced.

Different strategies how to remove the resulting distortion of the detector read-out-ramp after a hit are presented. The methods of the basic SWS software packages, the Pipeline and Interactive Analysis, will be discussed. The Pipeline has to treat glitch effects automaticaly. The Interactive Analysis system provides the user with a comfortable Graphical User Interface (GUI) for Trend Analysis, detailed analysis of certain glitches and testing of new algorithms.

1. Characteristic of glitch events

A description of the SWS instrument and data products is given in the *ISO Observer's Manual* (Leech, 1996) and the *ISO Data Product Document* (Saxton, 1997).

Glitches occur within the integrating ramps or during the reset pulse. The resulting change in the slope of the ramp might have positive or negative polarity.

As seen after amplification and high-pass filtering they may have any amplitude between telemetry resolution and telemetry saturation.

The response to a glitch usually is visible in one or two samples but strong glitches can affect up to 4 samples. The pulse response of the analog electronics has a time constant equivalent to 1.5 times the sampling interval.

The glitch examples are taken from SWS detector band 4 (Ge:Be) as it suffers most from glitch effects. The detector glitch rate is about 0.18 +/- 0.05 detected glitches per second (gain setting 16). This is 36 times higher than for SWS detector band 1 (In:Sb) (Heras, 1998).

Figure 1 shows a standard glitch event. The x-axis is scaled in 1/24 of a second, the frequency of the SWS detector read outs. The y-axis describes the digital numbers of the raw ramp between 0 (+10V) and 4095 (-10V).

The upper curve shows the raw telemetry outcome of a two second reset interval. The first samples are effected by the reset pulse. The second curve shows the actual reset interval and a few reset intervals before and after.

The first step in the standard data processing (Pipeline and Interactive Analysis system) is to mark the usable data range for slope calculation. A number of samples is flagged as invalid within and after the reset pulse. Experimental studies have shown that in the case of SWS the flagging of seven samples gives the best result. Also saturation is marked as invalid.

The second step removes reset pulse shape effects. The effect, that the reset pulse causes on the shape of the ramp can be fit with a decaying exponential. The samples are calibrated to a defined digital zero voltage value.

The next steps remove the effects of the highpass filter (AC correction) and corrects for cross talk between neighbouring detectors due to parasitic capacitance.

The third curve in figure 1 shows the ramp of the selected reset interval after this basic data reduction steps.

The last curve shows the environment of the selected processed ramp.

A similar set of plots is shown in figure 2 but with two glitches within one reset interval.

Figure 3 shows a glitch event where a few consecutive samples are involved.

Figure 4 shows the processed and unprocessed ramp of a glitch which ends up in saturation. The resets following this large glitch are affected by it. The system recovers after a few intervals.

After a strong glitch event which pushed the detectors into saturation it can take more than one reset interval to recover. Figure 5 shows a better

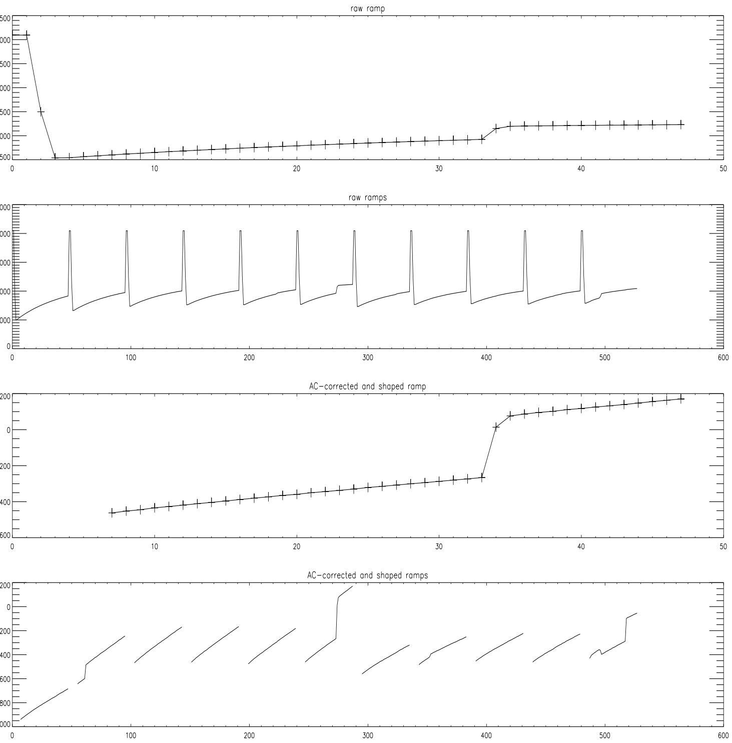

Figure 1. Standard Glitch on SWS detector

example. The reset pulses are marked by vertical lines. During the second reset interval after the glitch event the signal recovers from the glitch.

A glitch in an array detector channel affects virtually all detectors in the array by crosstalk. Crosstalk is a capacitive coupling between detector channels happening mainly in the IA12 J-FET arrays. The Fabry-Perot detector channels seem to have no crosstalk. Crosstalk corrections on the non-AC-corrected telemetry level remove a considerable amount of small spike signals from array detector channels.

Figure 6 to figure 9 show non crosstalk corrected ramps over neighbouring detectors and the same detectors with active cross correction. The actual particle hit happened on detector 42. The not crosstalk corrected neighbouring detectors show cross talk induced glitches. This effect is almost corrected by the cross correction algorithm.

However, the correction can introduce some new spikes reversed in polarity. This is due to the fact that the cross talk matrix has been computed out of a large number of glitch events, and averaged values have been filled into the calibration file. Thus some glitch events are undercorrected others

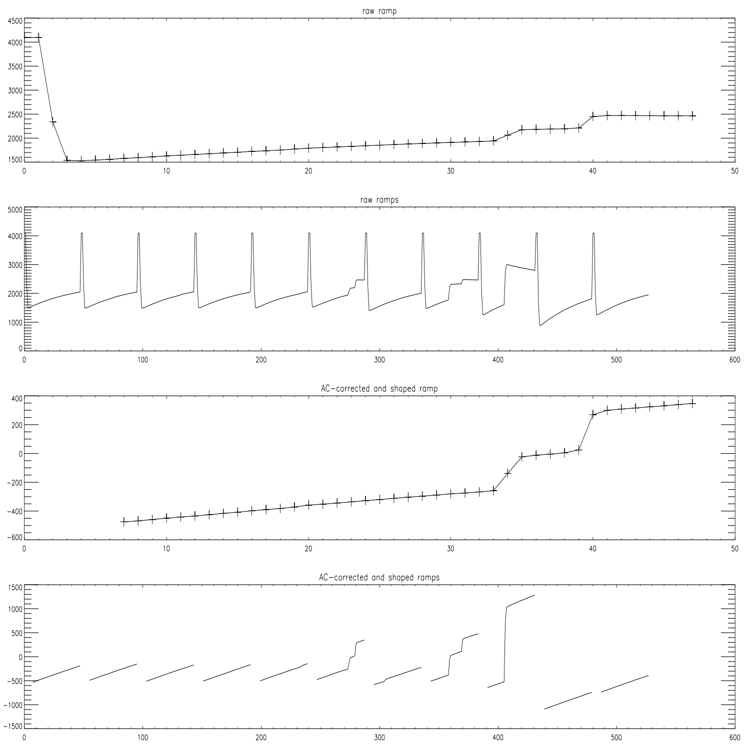

Figure 2. Two glitches during one reset interval

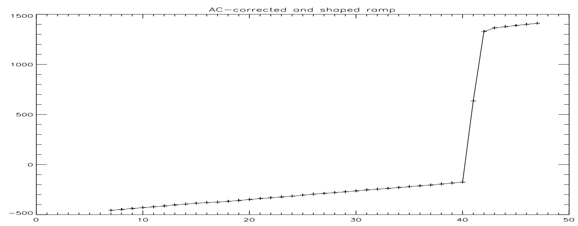

Figure 3. Consecutive glitches

overcorrected. An example of a slight overcorrection is given in figure 6 and figure 8.

Negative glitches might be caused by the described overcompensation of the cross correction algorithm or a hit in the electronics.

Figure 10 shows such a case. No glitch has been detected on the other detectors of this detector band, thus cross talk overcompensation can be excluded.

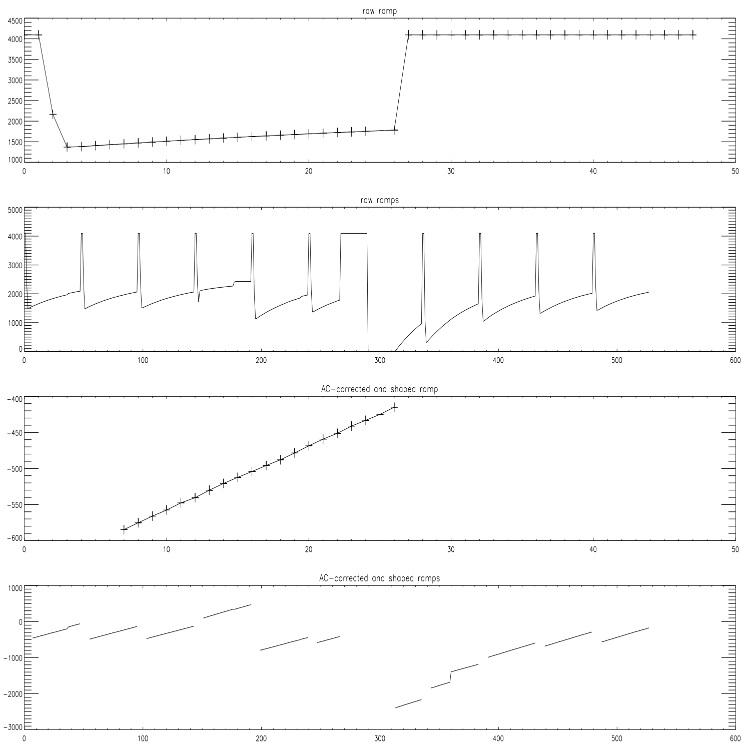

Figure 4. Saturating glitch

On the other hand a hit on the electronics might introduce fake glitches in the other channels after crosstalk correction.

The complexity of these glitch patterns precludes the establishment of a physical model which could be used to recognize glitches and remove their effect. Statistical methods have to be used to recognize glitches. Proper glitch correction algorithms to rescue glitch affected data are still under development.

2. SWS Pipeline glitch detection and removal

The pipeline software is coded in FORTRAN, to work within an environment designed by the European Space Agency (ESA). It is used for bulk processing of ISO data without human interaction, the final product being distributed to the observers. The pipeline software is designed in a modular way, with all major steps separated in software sub-modules.

The pipeline glitch recognition procedure is applied to the data after data range determination, pulse shape correction, AC-correction and

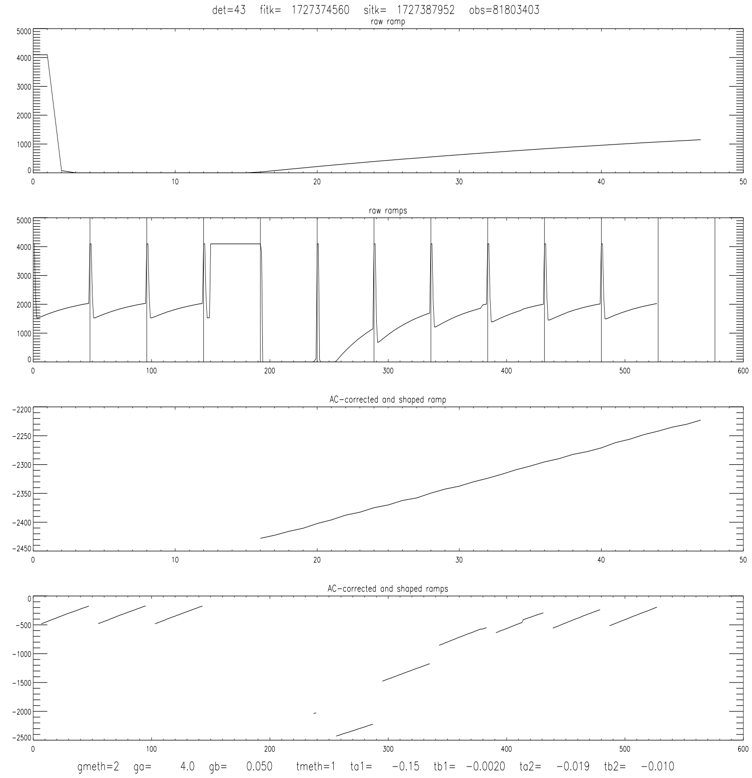

Figure 5. Recovery after saturating glitch

crosstalk correction. It follows an optimizing statistical approach. First the differences between the consecutive 24 Hz samples are computed. The differences are sorted and the median is calculated. If a difference deviates more than a certain sigma from the median the corresponding sample is flagged as glitch. The procedure loops back and starts again ignoring flagged differences.

All differences below a certain minimum value are not treated as glitches. This avoids wrong detections on low signal data.

For slope calculation a least square fit is performed to the data. In the case of indicated glitches the samples flagged as glitch and one sample before and after the glitch are skipped. Partial ramps before and after the glitch event are computed. The partial ramps are combined to one slope result using weight factors according to the number of samples used for one partial ramp. This number is written into a flag entry of the actual data product. The standard deviation of the slope of the partial ramps is also averaged and copied to the data product.

A typical observation before and after pipeline glitch removal is shown in figure 11.

The pipeline glitch recognition and removal is working very successful in most of the cases. Using clipping methods on the number of used samples to compute a ramp, glitch number or standard deviation of the slope might furthermore improve the result.

But there are a few exceptions where this algorithm might confuse the resulting product.

The observing mode where the grating is stepping within a reset interval will be discussed below.

Figure 12 and figure 13 show Auto Analysis results (flux calibrated data over wavelength) with and without glitch removal activated after flatfielding and rebinning (Heras, 1997). For a few strong lines some points at the wings of the line are mistakenly flagged as glitches and corrected. The line profile in this region deviates from the non-deglitched result. In figure 12 the asterisks represent the non-deglitched result, crosses the result after applying the glitch correction procedure. The solid line shows a Gauss-fit to the de-glitched result.

In other few cases points belonging to the line are mistakenly flagged as glitched. Here the glitch removal procedure disturbs the line flux and line profile. In figure 13 the asterisks represent the result with non active glitch removal, the crosses represent the outcome applying the glitch removal method. These few special cases are not yet considered in the Pipeline, but within the Interactive Analysis system it is possible to switch off the glitch removal algorithm and reprocess the data interactively.

In order to analyse glitches and to do extensive trend studies the pipeline provides a glitch Trend Analysis table. It is an interface to a Sybase table where the trend glitch data are stored for every observation. Table 1 shows the contents of the Trend Analysis file.

3. SWS Interactive Analysis glitch detection and removal

The IA system is set up as a tool box in the Interactive Data Language environment (IDL- a trademark of Research Systems Inc. (RSI)). IA has been developed to fullfil tasks like debugging of pipeline software, monitoring and improvement of the instrument performance and related software, as well as for scientific analysis of SWS data. The FORTRAN Pipeline modules are included in this system. It is therefore possible to run the Pipeline step by step within the IA system (Wieprecht *et al.*, 1997).

IA contains a number of tools which are basing on simple clipping methods. Clipping on the used number of samples to compute the slope, number of glitches or standard deviation of the slope are improving data which are

TABLE 1. SWS pipeline glitch Trend Analysis Table

Table entry	Description
TDT	TDT number
OSN	Observation sequence no.
LENGTH	Time since start of observation in seconds
DETECTOR	Detector number
GLITCHRATE	Number of glitches during obervation
NRESETS_G	Number of resets affected by glitches
GLITCH_MED	Median value of the glitch height
GLITCH_STDEV	Standard deviation of the glitch height
GAIN	Gain for a certain interval
FLUX	Averaged flux of a time interval
TIME	Start UTK of a time interval

[1] A time interval is a period with constant GAIN and observation.

still glitch affected at the expenses of datapoints.

To find new strategies to tackle the problem of glitches a highly interactive tool has been written to test and visualize results of old and new glitch detection and removal strategies. The GUI is shown in figure 14. Every part of the observation can be selected by mouse. Zooming in and scaling is supported. After applying a deglitch algorithm it is possible to inspect the result.

The left part shows five plots of the SPD (Standard Processed Data) output.

It contains the slope of the ramps per reset [uV/sec]. The window at the top shows the raw SPD data without applying glitch recognition and removal algorithms. The window below represents the deglitched slopes, but no de-tailing has been done. The following window shows the de-glitched and de-tailed slopes. The result after applying the standard Pipeline glitch correction is shown in the window below. The last window allows a selection of difference-plots of the above figures.

The four plots on the right side from top to bottom present the already for figure 1 described outputs for a certain reset interval which has been selected in the SPD outputs on the left side.

The modular design allows implementations of other glitch recognition and removal algorithms. The current installed glitch detection method tries to distinguish between temporary changes in slope and long term changes. Long term changes could indicate changes in slope due to scanning within a reset interval.

An additional feature tries to tackle the so called glitch tails. Studies have shown that this detector behaviour contribute significantly to the overall noise, especially for detector band 4 (Ge:Be).
Further analysis indicate that tail effects might have an in-reset and long term component. The in-reset effect is increasing the partial slope after a glitch within the same reset interval. This increase in slope is linear correlated with the glitch height and might be up to 40 % compared to the undisturbed partial slope.
The long term component might last even over a few reset pulses. An explanation might be the changing detector responsivity or change in dark current due to the particle hit.
Investigations to characterize the tail effects are ongoing.

Regardless ongoing tail characteristic studies the IA tool tries to correct for tail effects by fitting two exponential functions. One short term mostly within the actual reset interval (up to 10 samples) and one long term working beyond the end of a reset interval. Up to now it was not possible to identify one set of parameters for the glitch model, which will apply to all data sets.

Currently no automatic de-tailing is performed in the Pipeline.

References

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Leech, K. et al.(1996) ISO Short Wavelength Spectrometer Observer's Manual, *http://isowww.estec.esa.nl/manuals/SWS_man/obsman.html*

Saxton,R. et al.(1997) The ISO Data Product Document, *ftp://ftp.estec.esa.nl/pub/iso/doc/idpd/idpd.txt*

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Figure 6. Detector 41 /not crosstalk corrected: left /crosstalk corrected:right

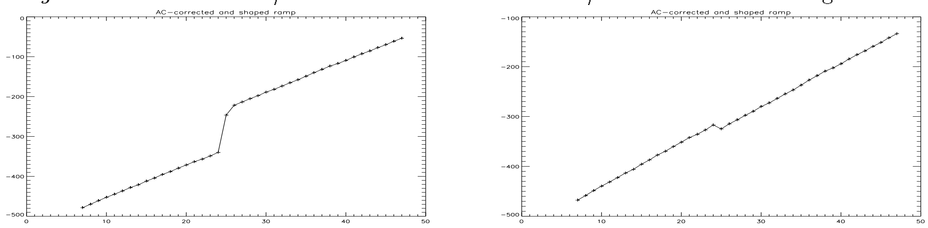


Figure 7. Detector 42 /not crosstalk corrected: left /crosstalk corrected:right

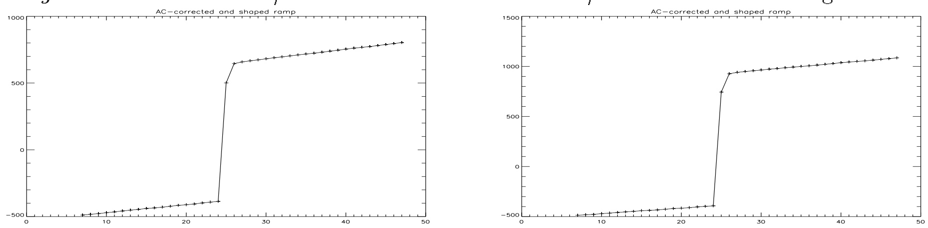


Figure 8. Detector 43 /not crosstalk corrected: left /crosstalk corrected:right

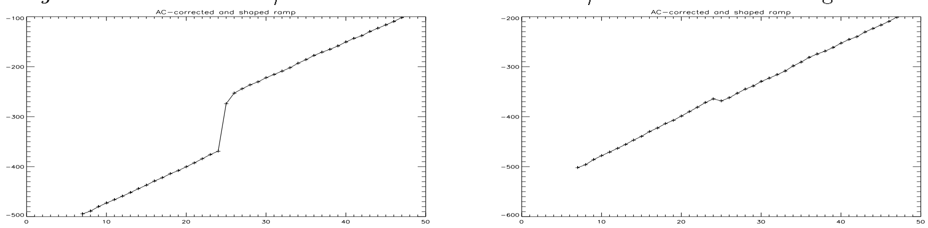
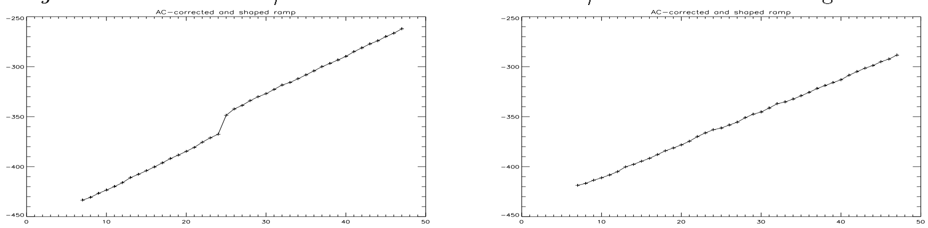


Figure 9. Detector 44 /not crosstalk corrected: left /crosstalk corrected:right



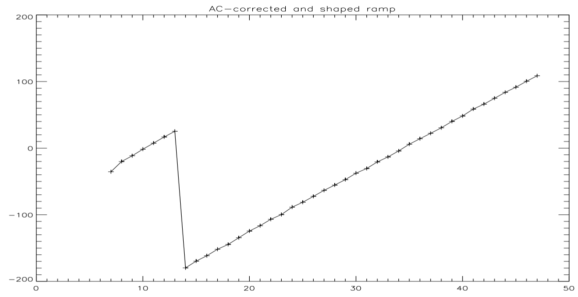


Figure 10. detector :41 negative glitch (GeBe)

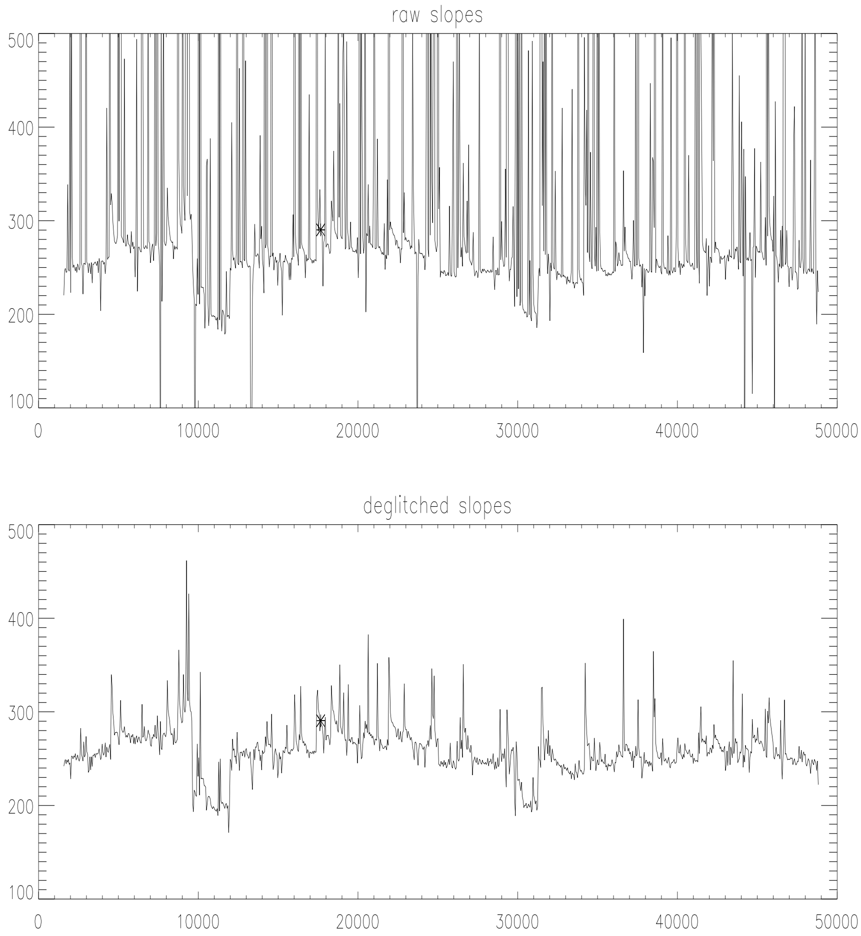


Figure 11. SPD with and without glitch removal

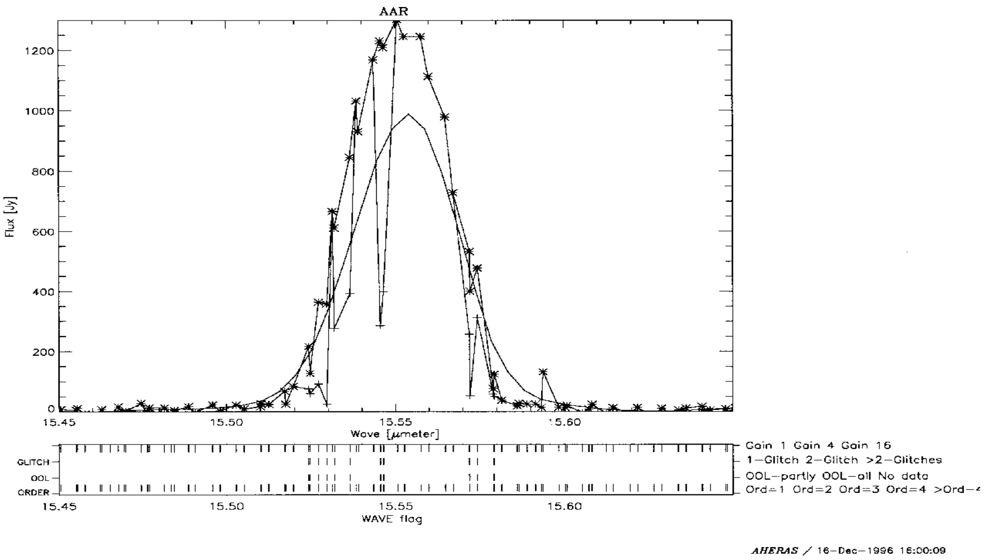


Figure 12. Auto Analysis Result deglitched (crosses) , non-deglitched (asterisks), Gauss-fit to deglitched data

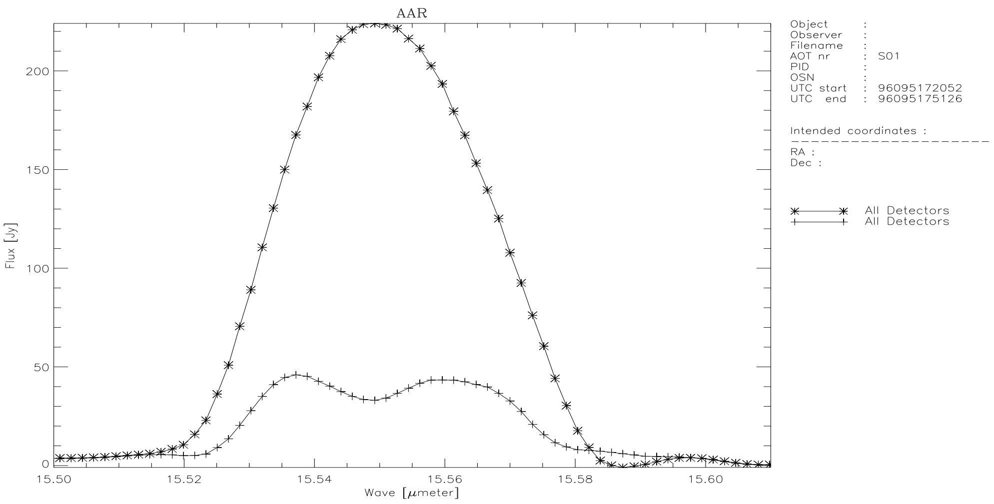


Figure 13. Auto Analysis Result deglitched (crosses) , non-deglitched (asterisks)

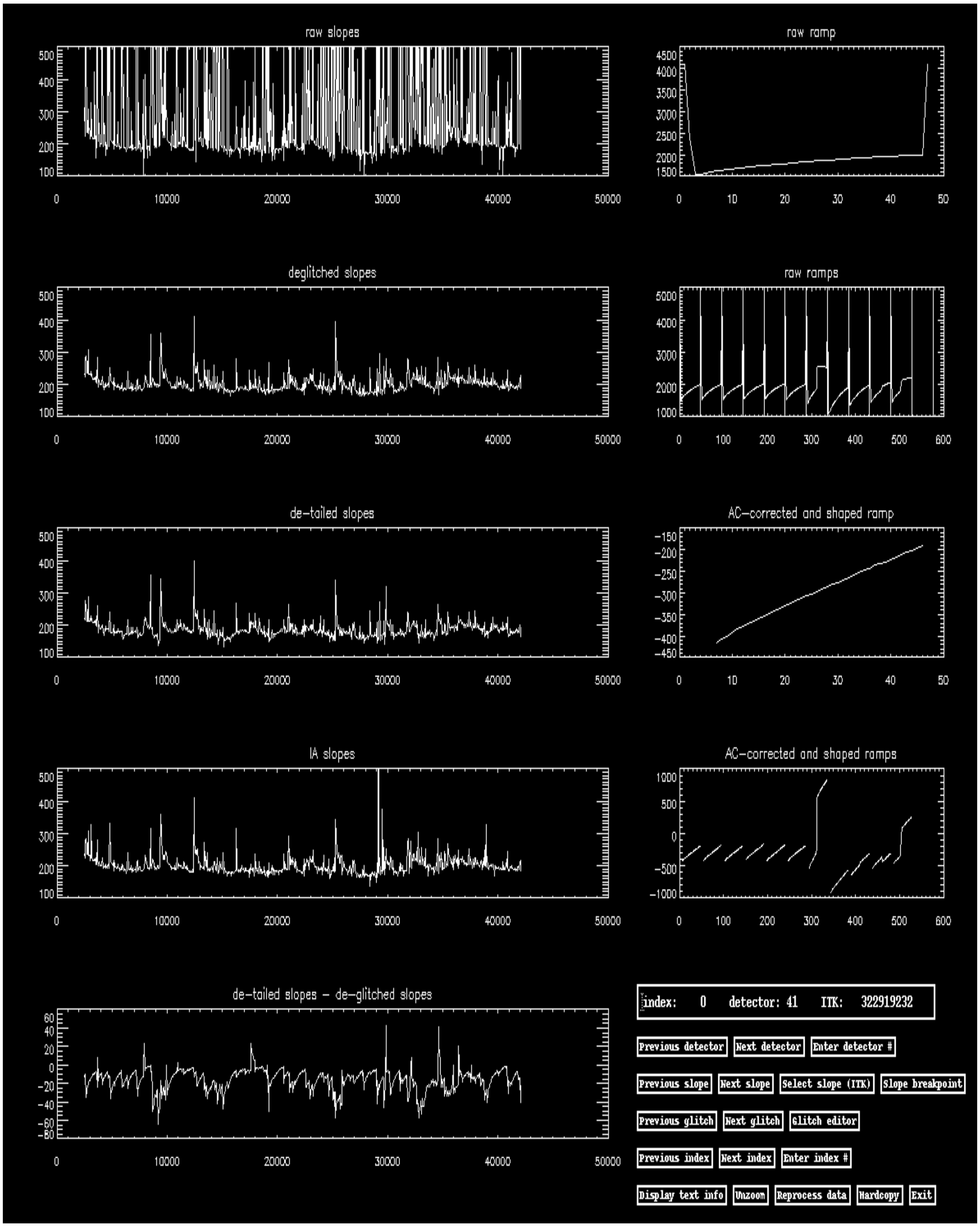


Figure 14. Interactive Analysis de-glitch tool