THE CALIBRATION OF THE LWS PARALLEL AND SERENDIPITY MODES

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ABSTRACT

During ISO operations when LWS was not the prime instrument, science data was still contained in the telemetry stream but at a much reduced rate. Although this operation was continuous, when ISO was in a stable pointing configuration and another instrument was operating, LWS was defined as being in parallel mode. During other times, essentially when the satellite was slewing, LWS was defined as being in serendipity mode. The reduced data rate, along with very little dedicated calibration time, made these modes a challenging calibration problem. Where possible standard LWS calibration was applied. However for some aspects of the calibration, in particular for the recovery of the flux, some unique strategies had to be evolved. This paper details the approach taken for calibration of the LWS parallel and serendipity modes with respect to the pipeline processing and describes in detail those aspects of the calibration that are unique.

Key words: ISO – LWS

1. INTRODUCTION

The LWS (Clegg et al. 1996) parallel and serendipity data is science data contained in the LWS telemetry stream. This data was placed in the LWS housekeeping stream whenever the instrument was non-prime and had a far lower resolution than prime mode data. These modes operated from revolution 237 until the end of the mission, with two weeks (between revolutions 380 and 397) where LWS was switched off due a problem with its interchange wheel. In parallel mode, more than 100,000 pointings were made over the 17,000 individual observations and about 1% of the sky was covered. In serendipity about 2 million pointings were made and about 10% of the sky was covered. The LWS detectors used IA readouts and the photocurrent was determined from the slopes of the individual ramps. For the non-prime modes, instead of multiply sampled ramps, only two samples per telemetry format (2 s) per detector could be taken and hence the ramps were reduced on-board and the ramp slopes were contained in the telemetry.

For the data processing, a pipeline approach was adopted, where the parallel/serendipity processed data mirrored the prime pipeline (Burgdorf et al. 1998) in terms of the level of reduction. For standard processed data (SPD) the products contain the ramps reduced to photocurrents. For this stage standard conversions from engineering units were applied (Swinyard et al. 1996). The parallel and serendipity pipeline also applies deglitching at this stage. For the auto analysis stage (AAR) an astronomical photometric calibration was applied which had to be tailor made for parallel and serendipity data. Additional steps at this stage include transient correction for parallel data, unit conversion taking into account the beam for serendipity data and the addition of warning messages from real time events into the headers.

2. STANDARD PROCESSED DATA

The parallel and serendipity SPD data, like prime mode contains the ramps reduced to photocurrents flagged by time. The starting point is a single LPAR file which contains all non-prime science data for each revolution. This is split into parallel (LPSP) and serendipity (LSSP) observations in the SPD processing. The standard conversions between engineering units and photocurrents are applied and the pointings are calculated. The prime mode pipeline does a deglitching step by detecting glitches from the shapes of individual ramps. As only the reduced ramp slopes are downlinked this is not possible for the non-prime modes. Parallel mode data contains many ramps at a single pointing and for each pointing the parallel data is deglitched by checking for abnormally high values. Serendipity data is deglitched by identifying possible glitches from ramp photocurrents which are higher than the local (in time) noise values and if a similar peak does not appear in adjacent detectors.

3. AUTO-ANALYSIS

Auto-analysis acts on parallel and serendipity data differently. Both modes have a generic calibration applied, which consists of dark current removal, responsivity drift correction, conversion to flux using standard AAR cal-g files and wavelength determination. In addition there are specific calibration steps only applied to the non-prime data:

- Ramp photocurrent correction - This correction takes into account that for high fluxes the LWS ramps are non-linear and a correction factor is applied to all non-prime 1s ramp data to adjust to prime ramps based on 0.5 s integrations.
- Parallel Mode Transient Correction - A transient correction based on a fitting a double exponential is applied when sufficient ramps are available. Investigations have shown this

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Detector	Wavelength μm	Dark Signal (x10^{-16}) $\mathrm{Wcm^{-2}\mu m^{-1}}$	Beam HWHM
SW1	46.2	4.34	41.189
SW2	56.2	1.89	43.792
SW3	66.1	1.91	45.476
SW4	75.7	0.86	44.778
SW5	84.8	1.21	44.324
LW1	102.4	2.22	42.740
LW2	122.1	2.56	43.979
LW2	141.7	0.29	40.055
LW3	141.7	0.29	40.055
LW4	160.5	1.74	40.721
LW5	177.9	1.28	42.030

Table 1. The rest wavelengths, dark currents and beam widths for the ten LWS detectors.

to be a more suitable correction for LWS parallel data than using a Fouks-Schubert correction.

- Serendipity Mode Flux Conversion - The LWS beam parameters for each detector (see table 1) are used to convert serendipity AAR into MJy Sr^{-1}. This is needed as the effective beam size varies for serendipity data.
- Real Time Events - Where unusual events have occurred in real time, these are flagged and added to the headers of the products.

There are three product files produced. The serendipity product file consists of the ramps expressed in MJy sr^{-1} at a position given by the centre of the effective beam. The speed and roll angle are also given. Further processing software exists to extract candidate point sources (Cabañero & Lim 2003) and to produce maps (Lim et al. 2000). For parallel mode two auto-analysis products exist. The LPAA files contain all the data for each observation as reduced ramps, including the reduced fluxes (W $\mathrm{cm}^{-2}\mu\mathrm{m}^{-1}$), pointings and time. The LPAD files represent a further processing step where all ramps at each pointing have been averaged together. Maps can be produced from the parallel and serendipity mode fits files using interactive analysis packages developed in IDL.

3.1. Photometric Calibration

For all prime mode LWS observations, the LWS illuminators were used at the start and end of each AOT. The response of the detectors to these illuminator flashes could then be ratioed with a standard response derived using observations of Uranus. This calibration is needed in order to remove the effects of a drift upwards in responsivity due to charge building up on the detectors from glitches. These illuminator flashes also contain measurements of the dark signal which is subtracted before the ratio is ascertained. Non-prime observations were not done with dedicated illuminator flashes, therefore a new approach had to be adopted. Several revolutions of parallel and serendipity data were used to obtain a baseline 'dark signal' for each detector. Unlike the responsivity, the dark current of the LWS detectors did not change with time, therefore a single value could be adopted. The baseline signal was subtracted from all data (see table 1).

LWS was operated with a bias boost curing during the ground station handover period (approximately at apogee). Hence for each revolution the detectors have two periods of drift. Also the behaviour of detectors was slightly different before and after the LWS was switched off due to a problem with the interchange wheel. All illuminator flashes after revolution 237 were used to obtain a 'standard' drift by deriving a first order fit to all the data for each half revolution and for the periods before and after the switch off period (revolutions 237-380 and 442-874). Figure 1 shows the response to the illuminators ratioed with the standard Uranus response for LW2. This detector showed the most extreme behaviour change with a 40% decrease in responsivity after the switch off period. The standard drift was applied to recover the detector responsivity for those half revolutions containing no illuminator data. For half-revolutions containing one observation, the standard drift was scaled to that observation. For half-revolutions containing more than one observation, the drift was determined from the four or more illuminator flashes in that half revolution.

4. INTERNAL CALIBRATION CHECKS

The non-prime data could be checked in three ways. The stabilisation period before a prime observation while the instrument is still in serendipity mode can be used to directly compare the serendipity fluxes with the prime mode ones. A selection of sources of various types have been checked and the results agree very well, typically within a few percent. The area of overlap between parallel mode raster maps can be used to check that the photometric calibration, in particular the responsivity drift, has been correctly applied. There are a large number of occurrences of overlapping parallel maps, in the majority of cases the agreement is better than 10%, however there are some cases with a bad drift removal and if large numbers of maps are to be combined then manual intervention is needed. Comparison with prime mode observations is most easily done by finding prime mode observations within parallel mode raster maps. Five such observations were selected for study and the agreement between prime and parallel mode was found to be within 20%. Figure 2 shows the LWS prime data (dots) plotted for a position within the Rho Oph parallel raster map. The map fluxes are shown by diamonds and are in good agreement with the prime mode data.

5. CHECKS AGAINST OTHER INSTRUMENTS

In addition to checking the internal calibration, comparisons with IRAS, ISOPHOT and PRONAOS can be made. In all three cases, the comparison is difficult to interpret as the flux obtained from parallel observations is in a very narrow band (0.29 or 0.6μm) whereas the other instruments are observing in broad band. The three main wavelengths for comparison are 60μm, 100μm and 178μm. The Rho Oph region was selected for cross-comparison as it has been observed by all four instruments and

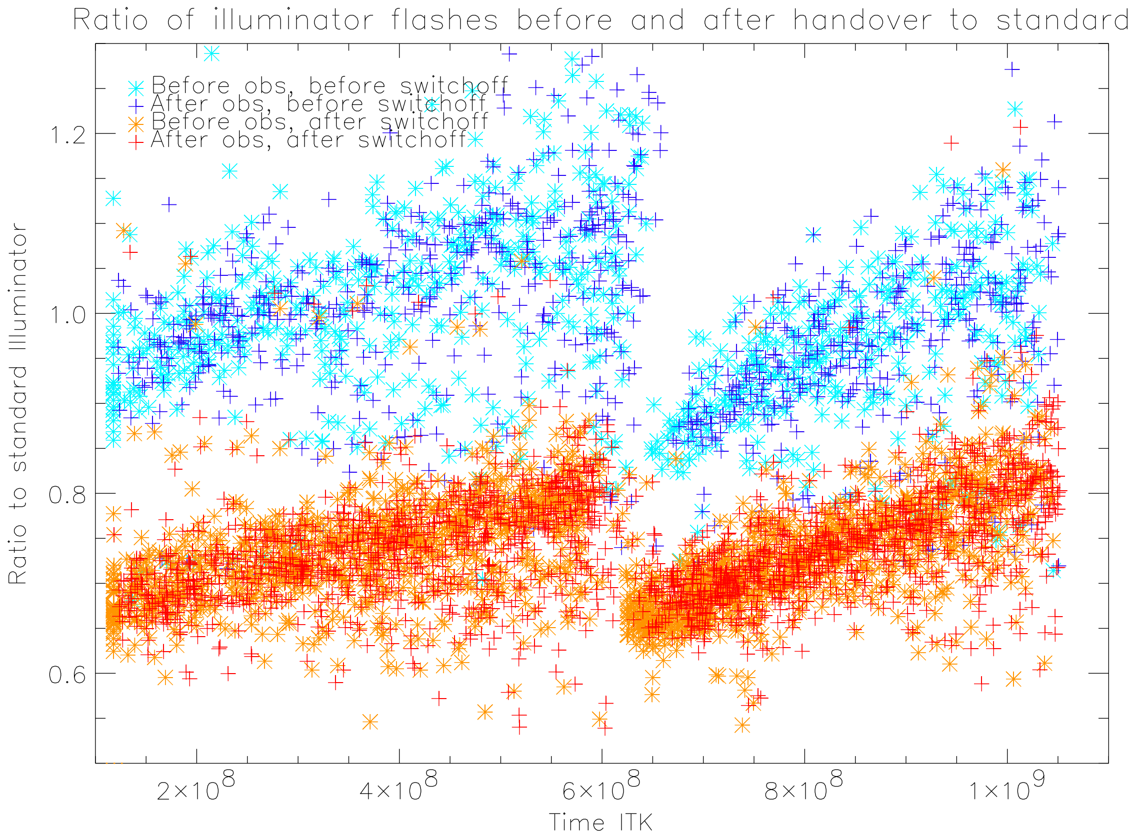

Figure 1. All mission data from revolution 237 onwards is combined to show the response of the LWS to its illuminators increasing with time during all revolutions.

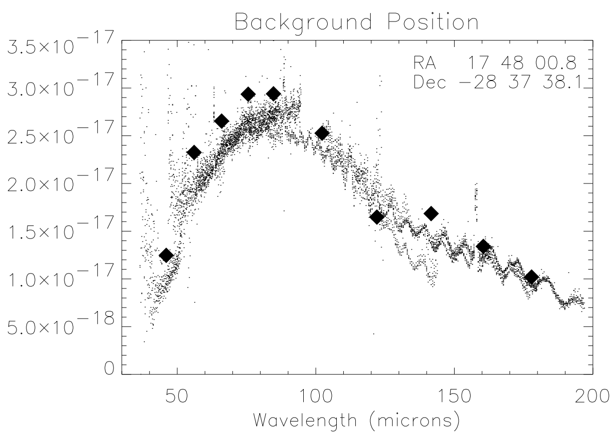

Figure 2. A prime mode observation of the galactic centre region (dots) and the data from a parallel mode map at the same pointing (diamonds).

is well covered by LWS parallel data. Figure 3 shows a cut through a LWS LW1 parallel image. The LWS detectors are, LW1 (102μm) shown in black, SW5 (85μm) in red and LW2 (122μm) in green. IRAS 100μm (light blue) and ISOPHOT 80-100μm (purple) points are shown for comparison. There is very good agreement between the LW1 flux and the IRAS flux. The SW5 and LW2 wavelengths are very different from the IRAS effective wavelength, therefore we would expect these points to agree less well. The ISOPHOT fluxes are also in good agreement with both the IRAS and LWS parallel mode adding confidence to the parallel mode calibration for this region.

The maps can also be used to check the spatial correlation between LWS and IRAS HIRES maps. This has been done for Rho Oph and the agreement is excellent giving confidence in the eight wavelength bands not covered by LWS. To make the comparison the parallel data was converted to MJy sr^{-1} and this was used to validate the unit conversion using the derived beam size. The serendipity data in this area was also been used to validate the unit conversion and to cross-check with the parallel data.

6. DISCUSSION

The LWS parallel and serendipity modes consisted of reduced rate science data in the LWS telemetry stream. This data was taken wherever LWS was pointing and through these modes LWS has successfully completed two partial sky surveys. A pipeline has been implemented which allows similar processing to prime mode with a extra steps of unique illuminator processing, unique deglitching, conversion of units for serendipity data, and transient correction for parallel data.

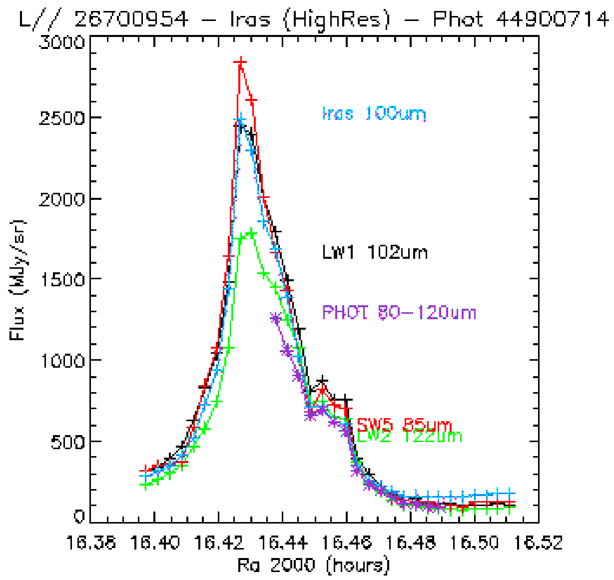

Figure 3. A cut through maps of the Rho Oph region showing LWS parallel data, IRAS data and ISOPHOT data in the 100μm band.

There are four main uncertainties in the data. When looking at faint sources the uncertainty in the dark signal can be large due to the measurement of the dark signal having a large spread of values. Hence when observing the background, the derived dark current subtracted from the data may be greater than the photocurrent measured from the source, leading to a negative flux.

A second major source of error can be an inaccurate responsivity drift removal. The majority of observations have a good responsivity calibration, however in some cases large glitches can affect the responsivity and if no illuminator flashes are present this cannot be picked up in the parallel mode calibration.

The third factor affecting calibration is glitch detection and removal. As points within ramps are not down-linked, we have to rely on a time series in the case of parallel data, and differences with adjacent detectors in the case of serendipity data. With parallel data, careful manual data reduction can remove most glitches, but this still remains a problem for serendipity mode where glitches can affect adjacent detectors and are not rejected.

An unknown effect on the data is the LWS fringing. We know from prime mode data that extended sources and point sources off-axis exhibit fringing. This affects the rest-position on different detectors differently i.e. one detector may have the rest-position sitting in a fringe trough while another may have it at a fringe peak. Only having one wavelength point on each detector we cannot determine the extent and amplitude of the fringing, therefore this effect is currently not calibrated.

Although there are many sources of uncertainty in the data, the parallel mode data is reliable, particularly within one observation. Differences between observations can occur due to poor responsivity drift correction but this can be corrected by hand. The serendipity mode data set has more uncertainties, particularly from glitches which are difficult to detect and remove. Again, with careful inspection of the data, scientifically useful results can be obtained.

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