LWS02 HPDP Report

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1. Introduction

The ISO Data Archive contains 877 LWS02 mode observations where the grating was scanned, and for which valid Auto-Analysis Result (AAR) products were produced by the OLP (Off-line processing) pipeline. These AAR products contain un-averaged data, and have been the best products available to users since the completion of the ISO Post-Operations Phase. Since 2002, efforts have been undertaken during the ISO Active Archive Phase (AAP) to produce improved data products, using systematic post-processing methods.

During 2005 and 2006, an extension to the LWS01 Highly Processed Data Product (HPDP) Pipeline [1] was developed at the UKIDC, led by Christopher Lloyd. The method used to produce the L01 HPDP was extended to allow LWS02 grating scan datasets to be reduced. It was found to be possible to produce HPDP for 864 datasets. The HPDP have now been delivered to the ISO Data Archive, where they are now the 'default' products for these observations. The data reduction method is described in section 2, and the data products are described in section 3.

During the reduction process, data quality flags were automatically assigned by the pipeline. Additionally, some further flags were computed by separate algorithms or manual inspection of the datasets. The delivery of HPDP to the ISO Data Archive was accompanied by the compiled flag lists, which may be searched by users via the archive web interface. The quality flags are described in section 4.

2. Data Reduction

LWS02 mode data consists of repeated grating scans, generally made over a smaller wavelength range than LWS01. The observations were targeted at specific wavelength ranges corresponding to spectral lines of interest to the observer. One or more different wavelength ranges was covered in each observation. In general, high spectral sampling was used (4 or 8 points per spectral element), and many repeated scans were typically made within each wavelength range. Figure 1 shows a typical LWS02 observation, where 3 atomic lines were observed at different wavelengths.

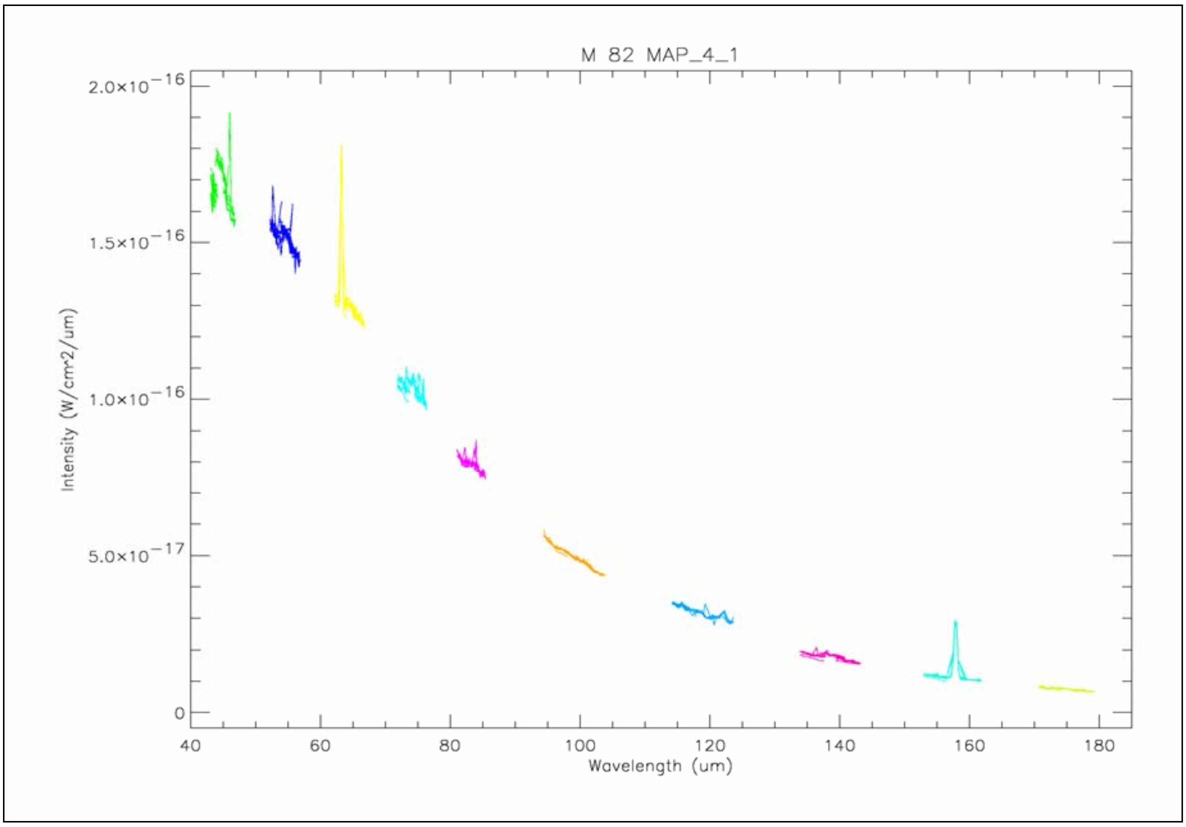

Figure 1 - Example LWS02 Observation – TDT 19400310

The starting point for the data reduction was the LSAN product [2, chapter 7] from the OLP, as available in the ISO data archive. These products contain all flux data from every scan, with no averaging performed. OLP included basic de-glitching, responsivity drift correction, dark current subtraction, RSRF-removal and correction for the absolute response of the detectors at the time of the observation. As described in the LWS01 pipeline report [1], such data still typically contains glitches, and sometimes significant remnants of responsivity drift trends.

The core of the L02 pipeline is the same as that used in the LWS01 HPDP production. The overall goal remains the same – to remove as much bad data as possible, and to average the remaining, good data. The process is described in the LWS01 pipeline report [1], but several modifications were necessary for the LWS02 data:

- Where data in different lines in the same detector was found to overlap, the scans were combined together in the averaging. The original line labelling was retained for the active detector.

- Due to the smaller wavelength coverage, it was not possible to uniformly apply a de-fringing routine to the data. Data in the final products may need de-fringing by users, but typically the wavelength coverage is insufficient to see a significant fringing effect.
- Near-infrared leaks were found in several TDTs, but the features were not removed prior to reduction with the pipeline. Such observations are flagged in the archive (see section 4).

As in the L01 pipeline, removal of SW1 detector RSRF features was performed.

2.1 Data Quality

The LWS01 pipeline report [1] presents an extensive study of the performance of the pipeline data reduction method, versus manual data reduction methods. No repeat of this study was performed for the LWS02 data. However, an extensive inspection of the data was carried out to look for spurious features produced in the data reduction. During the inspection, a number of observations were found to contain no useful data. This was because the wavelength ranges selected in the original observations were outside what was later defined as the 'nominal' range, in which the calibration could be scientifically validated. Such data is automatically excluded by the pipeline, so the resulting products contained no better data than the original LSAN files. The LSAN product remains the default for these observations in the ISO data archive. The list of TDTs is below in table 1.

TDT
04700236
24600521
35601406
37003302
48101402
48101403
64000717
64000718
66000222
79900210
85700411
85700603
85900713

Table 1 - TDTs for which no useful HPDP could be produced

3. Data Products

The format of the products produced by the pipeline is very similar to that for the LWS01 HPDP. Two files are produced per observation, one binary FITS file and one ASCII file. The filenames have the format: 'l02_TDT.fits' and 'l02_TDT.txt', e.g. l02_19400310.fits and l02_19400310.txt

In both products, flux values are included for the forward and reverse scans averaged separately, and as a combined average. This allows the possibility for the user to inspect any transient effects in the data, which are seen as differences in the spectral shape between forward and reverse scans. Additionally, any significant transient effects are automatically flagged.

For all datasets, browse products were also produced from the HPDP FITS files. This was done using a modified version of the ISO-LWS Browse Product Generation Software (BPGS).

An example of LWS02 HPDP averaged data is shown in figure 2.

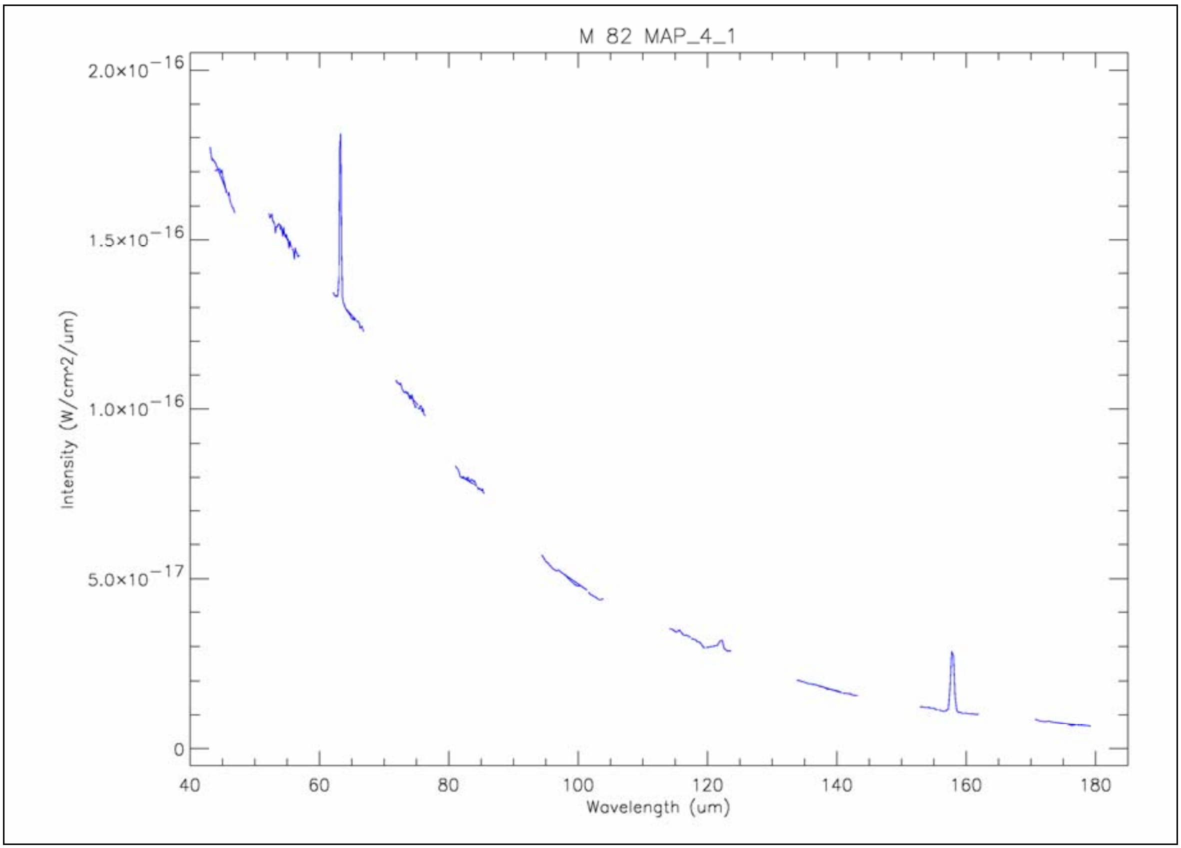

Figure 2 - Example LWS02 HPDP spectrum - TDT 19400310

3.1 FITS Products

The FITS files contain the full LSAN structure, but some tags contain different data to standard OLP LSAN files:

Tag Name	Type	Description
LSANUTK	INT(32)	Not used
LSANRPID	2 * INT(8)	Raster point ID (x, y)
LSANFILL	INT(16)	Not used
LSANLINE	INT(32)	Line number
LSANDET	INT(32)	Detector number (0-9)
LSANSDIR	INT(32)	Scan direction: 0 = Forward, 1 = Reverse, 2 = Combined
LSANSCNT	INT(32)	Same as LSANSDIR
LSANWAV	FLT(32)	Wavelength (µm)
LSANWAVU	FLT(32)	Not Used
LSANFLX	FLT(32)	Flux ($W.cm^{-2}.\mu m^{-1}$)
LSANFLXU	FLT(32)	Standard deviation in Flux ($W.cm^{-2}.\mu m^{-1}$)
LSANSTAT	INT(32)	LSAN status flag
LSANITK	INT(32)	Not Used

Table 2 - FITS File Columns

The FITS primary and secondary headers contain the same information as in the input LSAN file, with the data length altered as appropriate for the shorter, averaged file. Additional keywords and comments are inserted into the primary header, providing quality flag information for each raster in the observation. An example set of keywords is shown in table 3.

L02PROC = 'v2.60124' / L02 pipeline version
L02PDATE= '26Jan2006 15:43' / Processing date
L02TRACK= 'P ' / Pointed observation
L02RAST = '1 1 ' / Raster position 1 1
L02SLOW = F / Normal scan speed
L02SAMP = F / Sampling 4 times oversampled
L02SCANS= F / 14 forward 12 reverse scans
L02GLITC= F / Data not severely affected by glitches
L02TRANS= T / Large transient effects in 2 detectors TFFFFFFFTF

Table 3 - Example set of keywords added to FITS primary header

‘T’ and ‘F’ indicate true and false, i.e. flags are set when the value is true. The keyword comments include extra information, such as the number of detectors over the flag threshold or the exact value of the spectral over-sampling.

3.2 ASCII Products

The ASCII files contain a reduced number of columns, with the contents replicating those in the FITS files. The equivalent contents of the FITS primary and secondary headers are also included at the top of the file.

Tag Name	Type	Description
LSANRPID	2 * INT	Raster point ID (x, y)
LSANLINE	INT	Line number
LSANDET	INT	Detector number (0-9)

LSANSCNT	INT	Scan direction 0 = Forward, 1 = Reverse, 2 = Combined
LSANWAV	FLT	Wavelength (µm)
LSANFLX	FLT	Flux (W.cm^{-2}.µm^{-1})
LSANFLXU	FLT	Standard deviation in Flux (W.cm^{-2}.µm^{-1})

Table 4 - ASCII File Columns

3.3 Browse Products

A human-machine readable ‘Survey’ product was produced to accompany ISO LWS science products. This is a simplified spectral product, containing wavelength and flux data, with a single flux value per wavelength. For LWS02 HPDP, this is the same data as scan ‘2’, the combined average data in the FITS and ASCII files. The product format is the same as standard LWS survey products, which use an ASCII FITS format. The filenames have the format ‘lsphTDT.fits’.

Two graphical products are also produced by the BPGS: a ‘Postcard’ product and an ‘Icon’ product. Postcard filenames have the format ‘lpchTDT.gif’, and an example is shown in figure 2. Icon filenames have the format ‘lichTDT.gif’. Both products are used in the ISO data archive to illustrate observations returned by queries. The archive displays these graphics by default, whenever LWS02 observations with HPDP are queried.

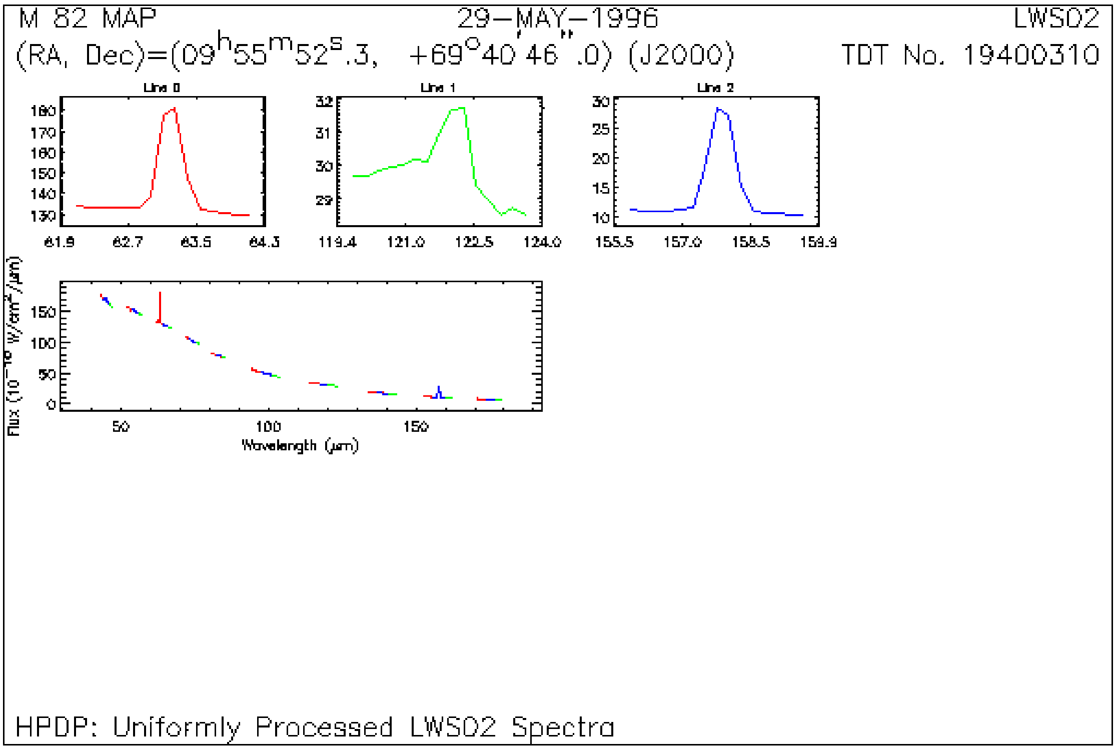

Figure 3 - Example Postcard Graphic – TDT 19400310

3.4 Support

The staff at the UKIDC can provide support with the understanding and use of the LWS02 HPDP dataset. Please contact: isouk@rl.ac.uk

4. Quality Flags

As shown in table 3, five different quality flags were computed and recorded by the L02 pipeline. These were set in the same way as for the L01 pipeline. In addition, two flags were set by inspection of the data products, and three more by separate analytical processes. The flags assigned are summarised in the table below, and described in the subsequent paragraphs. Note that the flag lists are based on all 877 observations, and not just the 864 for which HPDP were produced.
All the flag lists are populated in the ISO data archive, and may be queried through the archive web interface.

Flag	Number of TDTs	% of TDTs
Slow Scanning	54	6.2
Low Sampling	172	19.6
Low Number of Scans	20	2.3
High Glitch Rate	15	1.7
Significant Transient Effects	151	25.8
Near Infrared Leak	17	19.4
Warm-Up Features	44	5.0
Strong Source Effects	2	0.2
Negative Fluxes	686	78.2
High Dark Current	65	7.4

Table 5 - Summary of LWS02 Quality Flags

Slow Scanning

In a few observations made early in the mission, data was collected using multiple integrations at each grating position (wavelength). This method was prone to increased data loss from cosmic ray hits (glitches), so was not used later in the mission. This flag is set by the L02 pipeline.

Low Sampling

Most observations in LWS02 mode were made with an over-sampling factor of 4 or higher, representing the number samples per spectral element. For over-sampling factors of just 1 or 2, the data are prone to increased transient effects, and the confidence in any detected spectral lines will be lower. This flag is set by the L02 pipeline for an over-sampling factor of 2 or lower.

Low Number of Scans

Repeated scans were used to gather sufficient information to automatically identify and exclude spurious data in the pipeline. When fewer than 4 scans were used in an observation (fewer than 4 repeat measurements at each wavelength), the rejection of spurious features is more difficult. The calculated averaged flux is considered to have a higher uncertainty in these cases. This flag is set by the L02 pipeline where fewer than 4 scans were made per line.

High Glitch Rate

The OLP pipeline flagged data points where glitches were detected, by adding status information to the output data products. The L02 pipeline counts the numbers of glitches flagged in the input LSAN file. If more than 40% of the data points are flagged in an observation, the observation itself is flagged as having a high glitch rate. This is an indication of higher uncertainties in the flux values, and possibly a higher than normal detector dark current.

Transient Effects

Transient effects are seen in the data as a systematic difference in flux between forward and reverse scans. The L02 pipeline assesses this difference, and compares it to the noise level in the continuum. If the differences are significantly higher than the noise, the data in the detector is flagged. If significant transient effects are found in 1 or more detector, the observation is flagged by the pipeline.

Near Infrared Leak

In LWS observations of some stars, spurious features are seen in the grating spectra at certain wavelengths. These are well documented in the LWS handbook [2], but are difficult to detect automatically. A manual inspection of candidate LWS02 observations found these features in a small number of cases. The L02 pipeline was augmented to add a keyword to the header of the corresponding HPDP:

LNIRLEAK= T / NIR-Leak Features Present

Detector Warm-Up Features

During the latter stages of the mission, as the Helium supply gradually depleted, there were occasional problems in the cooling of the LWS long wavelength detectors. The effect is documented [2], and results in an increase in detector dark current and changes in responsivity. The effect cannot be corrected, so affected datasets are considered to contain untrustworthy data in the long wavelength detectors. A manual inspection of datasets was performed in order to compile the flag list.

Significant Strong Source Effects

When LWS observed very bright sources in grating mode, the high flux caused the long wavelength detectors to partially de-bias, causing the detector response to change. A systematic search of the LWS02 observations was made, based on the mean photocurrents in the detectors in each observation. A separate study has been made to determine a strong source threshold, above which the data are significant affected. Sources above the threshold are flagged in the ISO data archive.

Negative Fluxes

When faint sources were observed, the detector photocurrents were comparable to the dark currents. This meant that the calibration accuracy was dominated by the uncertainty in the dark current measurement. If the dark current measured is too big, too much is subtracted from the measured photocurrents, resulting in large numbers of negative fluxes. This flag was computed by checking the percentage of negative flux values in the LSAN files, and comparing the value for each detector to a threshold. If one or more detectors were over the threshold, the flag was set.

High Dark Current

The dark current behaviour of each detector was monitored during the mission, and nominal dark behaviour was determined for each one. By analysing the calibration data (which includes dark current measurements) from each observation, some have been identified where the dark current was abnormally high. In general, these correspond to observations of strong sources or where detector warm-up features were seen. The flag indicates that the detector calibration is less reliable for the observations affected.

References

[1] M. Lerate, C. Lloyd, 2003, Final Report on the L01 Pipeline

[2] C. Gry, B. Swinyard, A. Harwood et al, 2002, The ISO handbook Volume III - LWS - The Long Wavelength Spectrometer, ed. T.G. Mueller, J.A.D.L. Blommaert, and P. Garcia-Lario. (ESA SP-1262)

Glossary

AAP – Active Archive Phase, the phase of ISO work from 2002-2006
AAR – Auto-Analysis Results, produced by final stage of the OLP pipeline
BPGS – Browse Product Generation Software
CCLRC – Council for the Central Laboratory of the Research Councils
FITS – Flexible Image Transport System
HPDP – Highly Processed Data Products
ISO – Infrared Space Observatory
LSAN – LWS Science ANalysis, the main LWS science product
LWS – Long Wavelength Spectrometer
OLP – Off-Line Processing, the pipeline used to produce ISO data products
RAL – Rutherford Appleton Laboratory, part of the CCLRC
RSRF – Relative Spectral Response Function
TDT – Target Dedicated Time, the unique reference number for each ISO observation
UKIDC – UK ISO Data Centre, located at RAL