Calibration and Performance of the LWS

M. J. Burgdorf, E. Caux, P. E. Clegg, G. R. Davis, R. J. Emery, J. D. Ewart, M. J. Griffin, C. Gry, A. S. Harwood, K. J. King, T. Lim, S. Lord, S. Molinari, B. M. Swinyard, D. Texier, E. Tommasi, N. Trams, S. J. Unger

ESLAB 97 015

To be published in "Advances in Space Research"

CALIBRATION AND PERFORMANCE OF THE LWS

M. J. Burgdorf[1], E. Caux[2], P. E. Clegg[3], G. R. Davis[4], R. J. Emery[5], J. D. Ewart[1,5], M. J. Griffin[3], C. Gry[1,6], A. S. Harwood[1,5], K. J. King[5], T. Lim[1,3], S. Lord[7], S. Molinari[1,8], B. M. Swinyard[5], D. Texier[1], E. Tommasi[1,8] N. Trams[1], S. J. Unger[5]

[1]*ISO Science Operations Centre, Astrophysics Division of ESA, Villafranca, P.O. Box 50727, 28080 Madrid, Spain*
[2]*CESR, 9, avenue du Colonel Roche, 31029 Toulouse, France*
[3]*QMW, University of London, Mile End Road, London E1 4NS, UK*
[4]*Institute of Space and Atmospheric Studies, University of Saskatchewan, 116 Science Place, Saskatoon, Saskatchewan, S7N 5E2, Canada*
[5]*Rutherford Appleton Laboratory, Chilton, Didcot, Oxon OX11 0QX, UK*
[6]*Laboratoire d'Astronomie Spatiale, BP 8, 13376 Marseille, France*
[7]*IPAC/Caltech, ms 100-22, Pasadena, CA 91125, USA*
[8]*CNR/I.F.S.I., CP 27, 00044 Frascati, Italy*

ABSTRACT

The status of calibration and performance of the ISO Long-Wavelength Spectrometer eleven months after launch is described. The strategy followed for the calibration observations and first results are summarized. The overall performance of the instrument essentially fulfills the expectations; certain changes in sensitivity of the detectors are reported. Some improvements in the way observations are executed, which resulted from the in-flight experience, are explained.

INTRODUCTION

The Long-Wavelength Spectrometer (LWS, Clegg et al., 1996) on board the European Space Agency's Infrared Space Observatory (ISO, Kessler et al.,

1996) operates in the far infrared band between 43 μm and 197 μm. Its resolving powers vary between 150 and 330 in grating mode and between 6800 and 9700 in Fabry-Perot (FP) mode. The infrared radiation is detected with photoconductive detectors made of doped Germanium, whose photocurrents are integrated at the input nodes of JFET amplifiers (Delettrez et al., 1994). Their output voltages are in first approximation proportional to the fluxes on the respective detectors. In almost all observations one elementary integration period lasts half a second and each detector output is sampled 44 times during that time.

An astronomer defines his observations with LWS by use of Astronomical Observing Templates (AOT's) which represent the different observing modes: line scan and range scan for both grating and FP. As it is often necessary for calibration observations to put the instrument into a special configuration that is outside the scope of an AOT, the Calibration Uplink System with its much higher flexibility in commanding was used in those cases instead. The following chapters describe some details and results of the calibration observations.

WAVELENGTH CALIBRATION

The wavelength calibration for the LWS was a stepwise procedure in which measurements covering decreasing wavelength ranges with increasing spectral resolution followed one another. Beginning with end to end grating scans over a variety of planetary nebulae and HII-regions, the lines which were strong enough to be used as wavelength standards were identified. In a second step observations of these lines with 13 spectral samples per spectral resolution element were executed. Using this knowledge the grating could be put into the right position for the wavelength calibration of the Fabry-Perots which again began with end to end scans and ended with high resolution measurements of sources with the strongest and narrowest lines. Besides, the optimum, parallel position of the Fabry-Perot-mirrors had to be found, and it turned out that only for the short wavelength system one single position was valid over the whole scan range, whereas for the long wavelength Fabry-Perot the offsets of the mirrors have to be adjusted while changing their distance. This phenomenon made some replanning of the calibration revolutions necessary and is the main reason for the delay in the commissioning of the AOT's using the FP's.

In routine phase the wavelength calibration of the grating is checked with weekly end to end grating scans of the planetary nebula NGC6543, where the [OIII] lines at 52 μm and 88 μm and the [NIII] line at 57 μm are observed with five different detectors. Also the calibration of each Fabry-Perot is checked once per week; it is expected, however, that this frequency can be reduced in the future. The primary standard here is the narrow line HII-region G0.6-0.6, because its lines are strong and only half as broad as a resolution element of the FP's. Since this source is not visible with ISO all the time, sources with broader lines have to be used as well.

At the time of writing the products of the pipeline for AOT's L01 and L02 had a wavelength accuracy of $\sigma = 0.046\mu m$; the errors in wavelength for the FPS (FPL) are $8 \times 10^{-4} (2.7 \times 10^{-3}) \mu m$.

FLUX CALIBRATION AND DETECTOR BEHAVIOUR

The flux calibration is based on end to end grating scans on Uranus with a signal to noise ratio of more than 100. Stars (HR5340 and HR6705), asteroids (Ceres, Pallas and Vesta), Neptune and bright HII-regions (G298.228-0.34 and S106) have been observed as well in order to check the calibration on a wide range of fluxes, to establish secondary standards for the case of Uranus not being visible with ISO and to enable cross-calibration with other instruments on ISO. Photometric measurements will remain an essential part of the weekly routine calibration of the LWS until the end of the mission.

Summary of Performance				
Detector	Wavelength	System Responsivity	Noise	NEFD
	μm	A $cm^2 \mu m/W$	Electrons	$W/cm^2/\sqrt{Hz}$
SW1	46.1	86	100	7.6E-20
SW2	56.2	46	125	1.8E-19
SW3	66.1	58	70	7.9E-20
SW4	75.7	46	125	1.8E-19
SW5	84.8	45	100	1.5E-19
LW1	102.5	280	125	6.1E-20
LW2	122.2	830	100	1.6E-20
LW3	141.8	2000	100	6.8E-21
LW4	160.6	1500	125	1.1E-20
LW5	178.0	230	100	5.9E-20

The table summarizes the results for responsivity and noise-equivalent flux density (NEFD) for the whole system in grating mode, i. e. referring to the flux at the entrance of the telescope. For the noise-equivalent spectral density, see Swinyard et al., 1996. The absolute flux as calculated in the pipeline using these values is accurate to within 40 percent.

As a result of hits by high energy particles from cosmic-rays and the solar wind the sensitivity of the detectors is about a factor three lower than predicted before launch. As the detectors in the LWS are relatively big (volume $= 1\ mm^3$), their glitch rate is particularly high and the LWS has to stop gathering science data one hour before the other instruments. Each hit affects several ramps at the output of the integrating amplifiers resulting in short term memory effects. In order to stabilize the detectors the bias for most of them had to be lowered, although this caused a reduction in their responsivity as well. In addition the normal scan mode was abandoned in order to decrease the probability that too many ramps at the same position of the spectrum were ruined. For the same reasons every observer is well advised to have at least six scans in every measurement and not to use elementary integration times of more than 0.5 sec.

For sources with fluxes higher than 10^4 Jy it is necessary to use a ramp length of only 0.25 sec, because the charge accumulated at the input node of the amplifier reduces the bias voltage across the detector. This causes deviations from linearity in the ramp shape and reduces the photometric accuracy for strong sources.

Changes in responsivity and dark current caused by the accumulated effects of particle hits are monitored in every AOT with a standard sequence of illuminator flashes which irradiate the detectors with different fluxes. Unfortunately the detector signal is dependent on the illumination history, and it became apparent during the mission that the flux levels chosen for these illuminator flashes caused significant memory effects. Therefore a new sequence with a medium-sized flux and a longer measurement of the dark current has been tested in several calibration observations.

When calculating the flux at a given wavelength it is important to account for the effects of fringes, too. They do not appear for a point source in the center of the field of view, but moving it off-axis causes a modulation of the spectrum with varying amplitude. Therefore grating scans with Uranus at different positions in the field of view were performed in order to investigate this problem in detail, and based on them a defringing algorithm has been written. The analysis of this complex topic is still ongoing, but every observer should include a range scan in his proposal for those cases where there is substantial off-axis emission.

CONCLUSIONS

The essential requirements on the calibration of the LWS have been fulfilled. In routine phase some fundamental photometric and spectroscopic measurements need to be repeated every week to check the stability of the subsystems, and occasionally new observations are added to test improvements in the way the instrument is operated. Where unexpected phenomena affected the performance in flight, their consequences could be minimized by changes in the observing strategy.

REFERENCES

Clegg, P. E., *et al.*, The ISO Long-Wavelength Spectrometer, *Astronomy and Astrophysics*, **315**, L38 (1996).

Delettrez, C., Griffin, M. J., Le Naour, C., Church, S., Chabaud, J.-P., Detector Signal Processing Chain for the ISO Long Wavelength Spectrometer, *Experimental Astronomy*, **4**, 213 (1994).

Kessler, M. F., *et al.*, The Infrared Space Observatory (ISO) mission, *Astronomy and Astrophysics*, **315**, L27 (1996).

Swinyard, B. M., Clegg, P. E., *et al.*, Calibration and Performance of the ISO Long-Wavelength Spectrometer, *Astronomy and Astrophysics*, **315**, L43 (1996).