ISO-SWS CALIBRATION ISSUES IN DIFFERENT OBJECT TYPES

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ABSTRACT

The Short Wavelength Spectrometer (SWS) on the Infrared Space Observatory (ISO) observed a wide range of astronomical objects, from star-forming regions to main-sequence stars to planetary nebulae and supernova remnants. These objects have fundamentally different spectral shapes in the mid-infrared. Because of this, different problems in the calibration process will affect different object types to varying degrees. The brightness of a source and the speed at which it was observed also influence which calibration issues dominate and which are relatively unimportant. For example, bright stellar sources are affected by memory effects in Band 2, but weak stellar sources are generally well-behaved. Intrinsically red sources, on the other hand, such as planetary nebulae or star forming regions, can be influenced by memory effects in Band 4 as well as Band 2. Corrections for the "glitches" present in all sources can corrupt important information in those with fine-structure lines present. Extended sources are more susceptible to pointing issues than point sources. We will discuss these and other issues related to the type of object observed.

Key words: ISO – SWS

1. INTRODUCTION

The Short Wavelength Spectrometer (SWS) on the Infrared Space Observatory (ISO) made over 1200 full-grating scans of a wide variety of object types and fluxes. Four detector types were used in SWS, to create four primary bands: Band 1 (2.38-4.08 μm) InSb, Band 2 (4.08-12.0 μm) Si:Ga, Band 3 (12.0-29.0 μm) Si:As, and Band 4 (29.0-45.2 μm) Ge:Be (Leech 2001). Each type of detector can be susceptible to different issues in calibration, dependent in part on the flux received. Due to the range of spectral shapes and fluxes observed with SWS, calibration issues can effect different types of sources in different ways. Because the calibration strategy changed during the mission, the reliability of the calibration will also depend on the revolution in which it was made.

The spectra were divided into categories based on their spectral shape and brightness. "Stellar" sources are dominated by photospheric emission, but may have dust emission. This category includes naked stars as well as AGB (asymptotic giant branch) stars with dust shells, and contains $\sim$ 400 spectra. In general, they emit more strongly in Band 1 than in Band 4. "Red" sources are dominated by dust emission, with their spectra typically rising in the 10-20 μm region. This category includes star forming regions and planetary nebulae, and contains $\sim$ 600 spectra. These sources emit more strongly in Band 4 than in Band 1. Within these two categories, the spectra were further separated into "bright" and "faint." "Bright" sources have a maximum flux greater than about 100 Jy while "faint" sources are dimmer. This flux cut is somewhat arbitrary, as weaker sources observed at slower speeds can be effected by calibration issues that only effect bright sources observed at high speeds. The data were reduced with the February 2001 version of SIA, starting at the SPD level, OLP 10.0. Additional normalization, masking, and averaging was performed in ISAP 2.0.

2. CALIBRATION ISSUES

Despite much work and significant progress, a number of calibration issues remain with the pipeline-processed data. Some of these can be alleviated through the use of the SWS InterActive (SIA) software, at the cost of time and, potentially, reproducibility. The dominant issues remaining in each Band are summarized below and in Table 1; software routines from SIA are in italics.

BAND 1:

- Dark current over-subtraction can lead to negative fluxes. The interactive (non-pipeline) routine *dark_inter* can help. However, its use is not encouraged by the SIA developers due to the sometimes subjective nature of the corrections. On the other hand, testing suggests that this concern is unfounded. Significant improvements can be made to problematic spectral segments (for example, when a flux discontinuity occurs in a small number of detectors) without compromising the reliability of the spectral shape or flux. Overall, Band 1 seems to have the fewest problems, and tends to be well-behaved.

BAND 2:

- Dark current over-subtraction can lead to negative fluxes; *dark_inter* can help.

Table 1. Spectral Shape and Brightness Dependences

	Stellar **Bright**	Stellar Faint	Red **Bright**	Red Faint
BAND 1				
dark current subtraction			x BAND 2	
dark current subtraction		x	x	**X**
memory effects	**X**		**X**	x
dynadark failure				x
fringes in 2C	x		x	
BAND 3				
light leak 3A→3D	**X**	x		
fringes	x		**X**	x
BAND 4				
memory effects			**X**	x
dark current subtraction	x	x	x	x
glitches	**X**	**X**	**X**	**X**
ALL BANDS				
sub-band discontinuities	**X**	**X**	**X**	**X**
emission lines flagged			**X**	x

x: sometimes a problem
X: usually a problem

- 2C: Memory effects in detectors can lead to differences between up and down scans. *Dynadark*, based on the Fouks-Schubert formalism (Fouks & Schubert 1995; Fouks 2001; Kester, Fouks, & Lahuis 2001), has been developed to model the dark current in Band 2 by accounting for the flux history experienced ("remembered") by the detectors. BUT
- 2A & 2B: *Dynadark* can introduce differences between up and down scans in segments that previously matched (Fig. 1).
- On faint sources, *dynadark* may fail to converge.
- 2C: Fringes can appear in some detectors, at $\lambda \gtrsim 10$ μm. For no obvious reason, the SIA routine *fringes* does not work (Fig. 2).

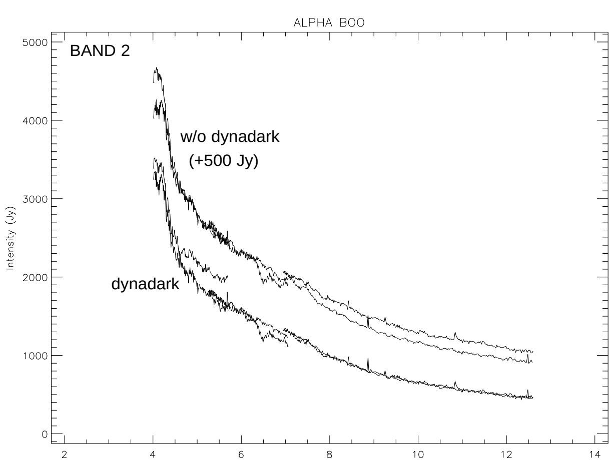

Figure 1. Memory effects in Band 2. Top: Dynadark *compensates for the effects in 2C, but overcorrects 2A past 4.5 μm, and 2B to a lesser extent (500 Jy offset). Bottom: Linear fits to the dark measurements produce poor results for 2C, and 2A below 4.5 μm.*

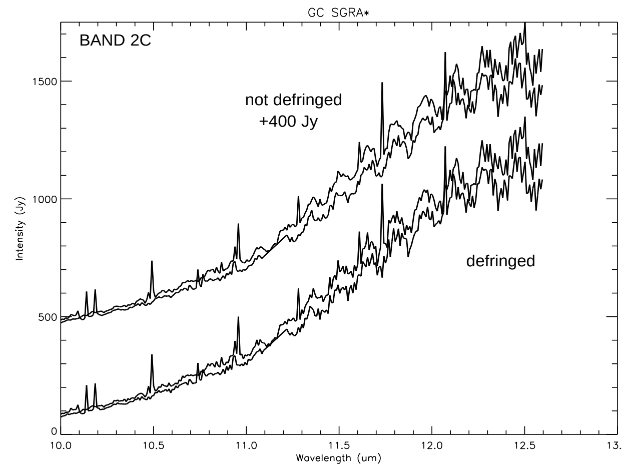

Figure 2. Fringes in Band 2C, detector 19. Top: Original data (400 Jy offset). Bottom: fringes *applied, with no apparent improvement.*

BAND 3:

- The ight leak in 3A can produce a spurious emission feature in 3D at $\lambda \sim 28$ μm in stellar sources or a false drop in red sources (Leech 2001).
- Fringes can be present in all sub-bands;*fringes* can help, although the correct number of fringes to remove can be difficult to determine (Kester, Beintema, & Lutz 2001) (Fig. 3).

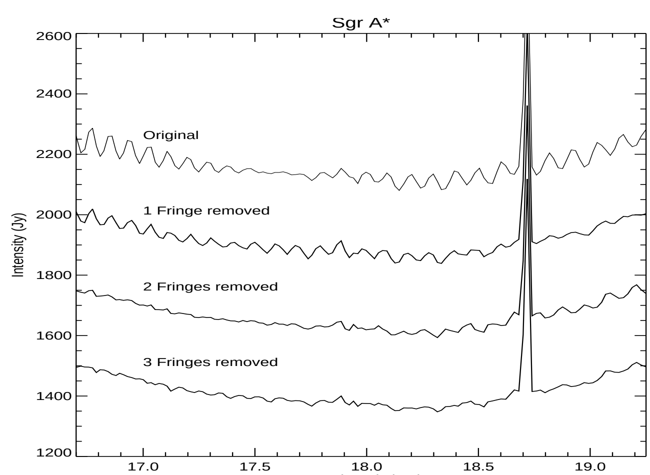

Figure 3. Fringe removal in Band 3C. Removal of 2 fringes leaves residuals at $\lambda > 18$ μm. While removal of a third helps $\lambda > 18$ μm, it introduces additional fringing near $\lambda \sim 17.4$ μm. (750, 500, and 250 Jy offsets)

BAND 4:

- Memory effects lead to differences between up and down scans (Fig. 4). No model comparable to *dynadark* has been developed to date.

- Glitches can leave bright tails; *mask_inter* and *patch_spd* can be used to mask these tails and additional glitches (Fig. 5).

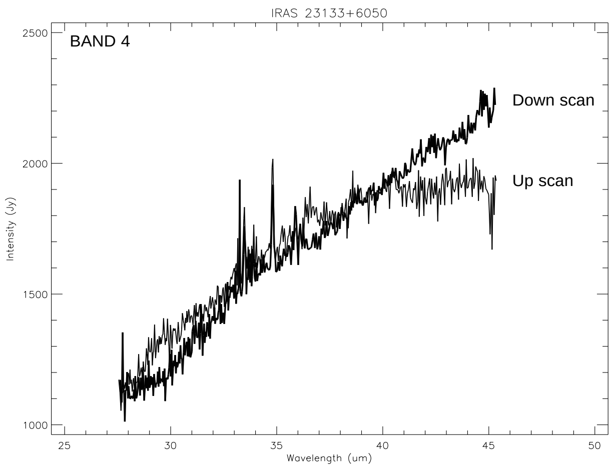

Figure 4. Memory effect in Band 4. Features at 33.5 and 34.8 μm are [S III] and [Si II], respectively.

ALL BANDS:

- Narrow fine-structure and recombination lines can be flagged as glitches. Updates to the glitch detection procedures in OLP 10 have reduced but not eliminated this problem.
- Flux discontinuities occur between bands and sub-bands. Some of these are caused by pointing problems, for which a model is being developed (Shipman 2001).

2.1. Revolution dependencies

The revolution in which an observation was made can also influence the calibration. During the first $\sim$ 150 orbits, strategies for the dark current measurements and photometeric checks were adjusted. Thus, for observations early in the mission, attempts to optimize these strategies sometimes led to additional problems with the data.

For many revolutions, the dark current was only measured prior to the data scan, as opposed to both before and afterwards. If the dark current drifted during the scan, as often occurred, a single measurement could be a poor characterization of the dark current. This could lead to differences in the up and down directions, for instance, and incorrect spectral shapes. For high speed observations (speeds 1 and 2), scan 3 had darks only prior to the scan until Revolution 123. For low speed observations (speeds 3 and 4), all three scans had only prior darks available until Revolution $\sim$ 190. After these orbits, measurements of the dark current were made both before and after each scan.

Until Revolution $\sim$ 190, low speed observations (speeds 3 and 4) also had photometric checks made before every scan in Bands 2, 3 and 4. Due to the memory effects in Bands 2 and 4, this led to problematic dark current and flux measurements. The development of *dynadark* helps counter this problem in Band 2, but the spectrum in Band 4 for some sources is currently irrecoverable (Fig. 5). Roughly 60 observations were made with this photometric pattern.

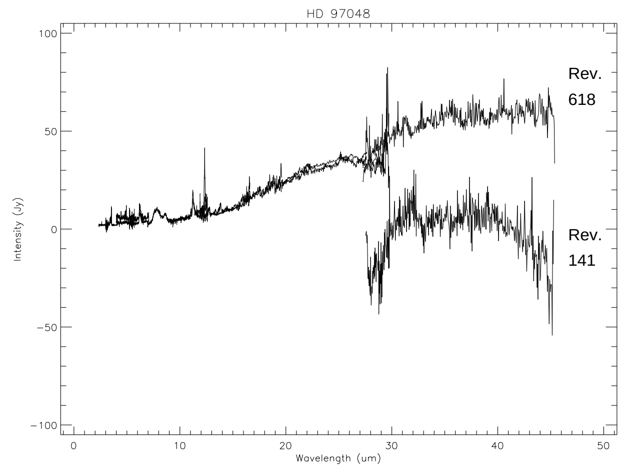

Figure 5. Memory effects in Band 4 due to bright photometric checks in Revolution 141, in contrast to Revolution 618. Small scale differences in Band 4 primarily result from glitches and glitch tails.

3. SUMMARY

- Bright sources, both stellar and red, are more susceptible to calibration artifacts, such as memory effects and fringing.
- Faint sources are more vulnerable to dark current errors, although observation at slow speeds can induce bright-object artifacts as well.
- For red sources, Band 4 memory effects can seriously compromise the shape of the continuum emission for $\lambda \gtrsim 30$ μm. Severe glitching can make the continuum shape and emission line fluxes problematic. Red sources make up more than half of the SWS full-grating scans.

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