Infrared Spectrograph
Technical Report Series

IRS-TR 04006: The Double-Star Experiment and Pointing to Short-Low Order 1

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3 September, 2004

Abstract

We use the double-star experiment conducted in IRS Campaign 7 to confirm the existence of a systematic offset in pointings to Short-Low Order 1 (SL1), which was previously discussed and roughly estimated in IRS-TR 04005. The double-star experiment consisted of a scan of one star across both nod positions of SL1 with a second star in the blue peak-up field. This experiment allows us to measure the systematic offset as $-0\overset{''}{.}27 \pm 0\overset{''}{.}03$ in the dispersion direction (i.e. along the short axis of the slit, the v direction).

1 Introduction

The narrow entrance apertures on the Infrared Spectrograph (IRS) on the Spitzer Space Telescope result in partial blockage of radiation from a point source onto the detector arrays. As described by Sloan et al. (2003, IRS-TR 03001) the throughput is a function of both wavelength and position of the source in the aperture. They refer to the resultant errors in the spectra as Spectral Pointing-Induced Throughput Error, or SPITE. Prior to the launch of Spitzer, Nerenberg & Sloan (2003, IRS-TR 03003) analyzed how SPITE would behave with wavelength and source position in the slit using a simple model for the Point Spread

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Function (PSF) and spectrographic slit. While the knowledge gained has been useful, what is really needed is an actual measurement of how SPITE behaves using observations made in orbit.

In IRS Campaign 7 (2004 May 11–16), a special calibration test known as the double-star experiment was performed. This set of observations scanned one star (HD 269352) across the narrow axis of the SL1 aperture (in $0.''2$ steps) while a second star (MSX LMC 338, referred to hereafter as the reference star) appeared in the blue peak-up aperture.

This experiment allows a detailed examination of the detailed spectral variations of SPITE while the star moves across the slit. The presence of the reference star in the peak-up field enables an accurate measurement of the relative offsets from one scan position to the next.

The effects of SPITE in SL1 have been analyzed using repeated observations of the standard stars HD 173511 and δ UMi (Sloan 2004a, IRS-TR 04002; 2004b, IRS-TR 04005). The second report, IRS-TR 04005, documents what we have known since March, that the centroid of the pointings to SL1 are offset from the central axis of the slit (in the v or dispersion direction), and it makes a preliminary estimate of this offset error as $-0.''44 \pm 0.''13$ in the v direction.

The double-star experiment provides a means of measuring this systematic offset error in the v direction with a high degree of precision, and that is the objective of this report.

2 Method

The double-star experiment included a total of 50 measurements with HD 269352 in (or near) the SL1 aperture in two scans of 25 steps each, one scan across each nod position in the slit from a requested offset of $-2.''4$ to $+2.''4$ in the dispersion direction (v). The telescope performed the scans by moving HD 269352 to (1) the peak-up array, then (2) a position offset from the first nod position in SL1 (Nod 1) by an amount v, and then (3) a similar position with respect to the second nod position (Nod 2). These three observations (peak-up, Nod 1, Nod 2) produced three exposures (also referred to as an exposure IDs or EXPIDs), and the three exposures were repeated for each of the 25 requested values of v. The full double-star experiment provides 50 exposures with HD 269352 in or near the SL1 aperture; it took 5621 seconds.

For each exposure, we extracted the spectrum of HD 269352 using the offline pipeline and calibrated it using the method described in IRS-TR 04002. We also determined the position of the reference star by using IDP3 to find the Gaussian centroid of the the Airy pattern in pixel coordinates. These coordinates were converted to v,w coordinates in the SL1 reference system by scaling the pixels to arcseconds ($1''.8$/pixel), correcting for distortion effects in the blue peak-up array (by multiplying the x coordinate by 1.8% and the y coordinate by 2.5%), and rotating the result by $86^\circ.4169$. This gives the position of the reference star in the peak-up array in the same coordinate system as HD 269352 in SL1, except for an offset in v and w.

To determine the offset across the short axis of the SL1 slit (v), we measure the strength of the spectrum of HD 269352 in the SL1 slit at each position, summed from 7.7 to 14.0 μm. We assume that the brightest observation is closest to the center of the slit. To locate the center more accurately, we fit a Gaussian to the spectral signal strength as a function of the v position and define the center of the slit to be the Gaussian centroid.

3 Results

Figure 1 shows that the dependence of the signal with v offset from the center of the slit is indistinguishable from a Gaussian. Fitting a Gaussian to the data from the two nod positions separately produces a difference in v of only $0''.0375 \pm 0''.0534$. We combined the data from the two nods, accounting for the slight difference in the center of the distribution by subtracting the Gaussian centroid from each nod from the v offsets separately. We then fit a Gaussian to the combined set.

The throughput as a function of offset in the v distribution has a σ=$1''.47$, which corresponds to a Full Width at Half Maximum (FWHM) of $3''.45$. This value is close to the actual width of the SL slit ($3''.60$), which is expected since the throughput should be exactly 50% when the source has been offset $1''.8$ to either side of the central axis of the slit.

Figure 2 plots the offset of the source from the center of the slit in each scan position along with the offsets as requested. The mean of the differences between the requested and actual offsets measures the systematic pointing error to SL1; this offset error is $< \Delta v >= -0''.271$, and the uncertainty in this measurement is only $0''.017$. Table 1 provides the details for both nod positions. If we take as our uncertainty the standard deviation of the mean offset for the two nod positions, then it is $0''.027$, slightly larger but still relatively small. An offset of $-0''.27 \pm 0''.03$ is smaller than our rough estimate of $-0''.44 \pm 0''.13$ from IRS-TR 04005, and the uncertainties do not overlap, but the previous result was based by admit-

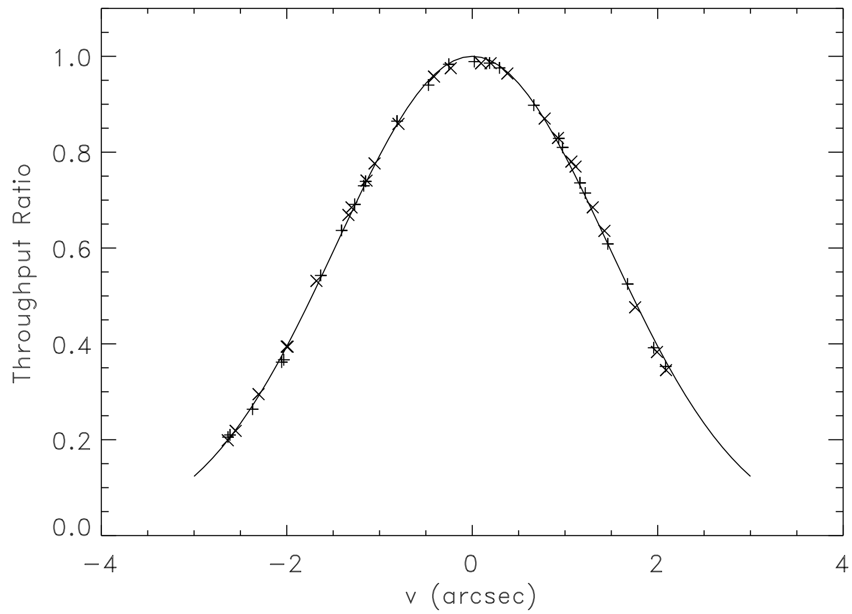

Figure 1 —Throughput as a function of source position in the dispersion direction (*v*) in the SL1 slit. Data from the first nod position are plotted as plus signs; data from the second are plotted as crosses. Both follow the same Gaussian, which appears as a solid line. The zero point of this Gaussian defines the center of the slit in the *v* direction.

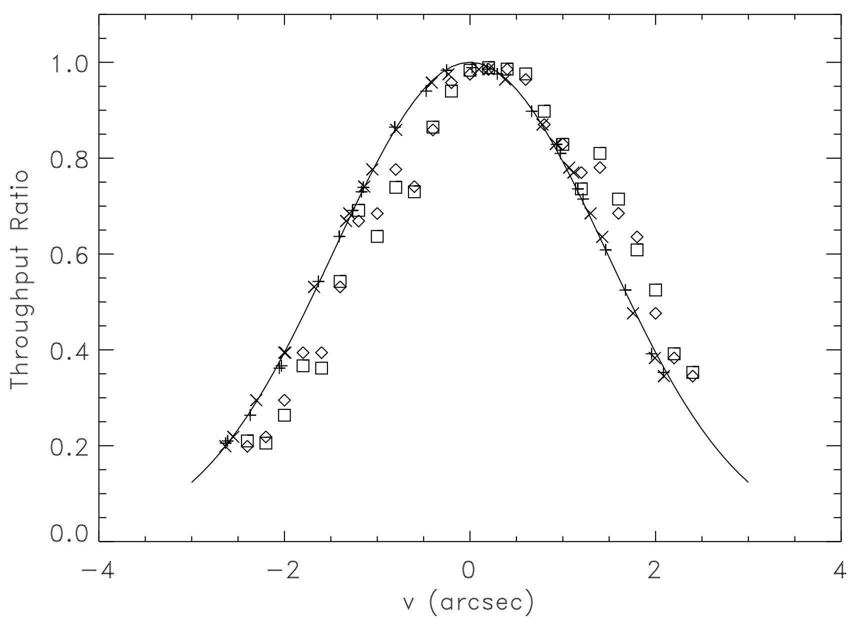

Figure 2 —As Fig. 1, except that the requested positions have been added, with the first nod position in rectangles and the second in diamonds. The mean offset is $-0.''27$, and the uncertainty in this measurement is less than $0.''03$.

TABLE 1
MEAN Δv AND UNCERTAINTY

Nod	Mean	Standard deviation	Uncertainty in mean
1	$-0\farcs290$	$0\farcs132$	$0\farcs026$
2	$-0\farcs252$	$0\farcs117$	$0\farcs023$
Both	$-0\farcs271$	$0\farcs125$	$0\farcs017$

tedly crude methods.

The results from IRS-TR 04005 are more useful in ruling out the possibility the systematic pointing error we have quantified here somehow changes in time. Any temporal variations must be small with respect to the $-0\farcs3$ pointing error, or else Figures 2a, 3a, 4a, and 5a would not show much dependence of the apparent flux on Δw_{LL}, which is in the same direction as Δv_{SL}.

4 Conclusion

We have shown that the average of all pointings to SL1 in the double-star experiment are offset from the central axis of the SL slit by $-0\farcs27 \pm 0\farcs3$ in the v direction. This result both confirms and significantly refines the results of IRS-TR 04005. The appropriate solution to this problem is probably an update of the frame table on the Spitzer spacecraft.

References

Nerenberg, P.S., & Sloan, G.C. 2003, IRS-TR 03003: Correcting for Spectral Pointing-Induced Throughput Error

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