The SMEC Step Factor Calibration Product
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Abstract

This document summarizes the method by which the SCalSpecSmecStepFactor calibration file for the SPIRE Spectrometer data processing is populated. This product is required to correct the optical path difference sampling of an interferogram on the detector level, which, in turn will correct for obliquity related errors in the resultant spectrum.

Contents

1 Document Revision History

Issue	Date	Changes
00.10	2010-10-27	First version

2 Introduction

Obliquity correction is needed to account for differences in the optical path modulation sampling of SPIRE FTS interferograms. Off-axis detectors observe a different effective optical path difference (OPD) than that of the on-axis case due to variations in the divergence of light traversing the FTS. Upon Fourier transformation of the recorded interferograms, this results in the frequency sampling and spectral content of the spectra varying across the array. If uncorrected, obliquity effects can result in degrading the available spectral resolution, reducing integrated line flux upon averaging spectra from neighboring detectors, and even incorrect determination of scene dynamics.

The obliquity correction adopted for the SPIRE FTS is a single scaling factor for each detector. This document describes how these factors are determined and verified. The basic steps are as follows:

1. Determine the observed transition frequencies for the CO lines within the OD302 Orion observations. This is done separately for each line and each detector.
2. Correct the observed frequency for the source and telescope line-of-sight velocities.
3. The relative difference in observed and theoretical frequency provides an estimate of the correction factor.
4. Combine the correction factor data for each observed line to determine the correction factor and its uncertainty.

3 Calibration Data

The CO rotational lines from Orion were selected for the obliquity calibration. The observed transition frequency is compared to the expected, and the residual differences provide the correction factors. The Orion CO transitions are used for several reasons: the CO rotation lines span both of the SLW and SSW arrays with good signal-to-noise ratio (S/N), and the rotational transition frequencies are well studied. Table 1 lists the SPIRE FTS observations used to determine the obliquity correction factors. Orion was selected as a calibration source as it is has a strong contribution to the SPIRE spectral bands from CO, and, as Orion is a relatively local source, it's velocity with respect to our solar system is both small and known ($\sim$10 km/s). CO is observed in each of the 16 pointings of each of the three full spatial resolution maps. A sample of the SPIRE FTS spectra provided by these data is shown in Figure 1. The CO transitions are the dominant features of the spectrum.

In all there were 3 x 16 unique pointings, however, only 43 positions are available in total due to processing issues.

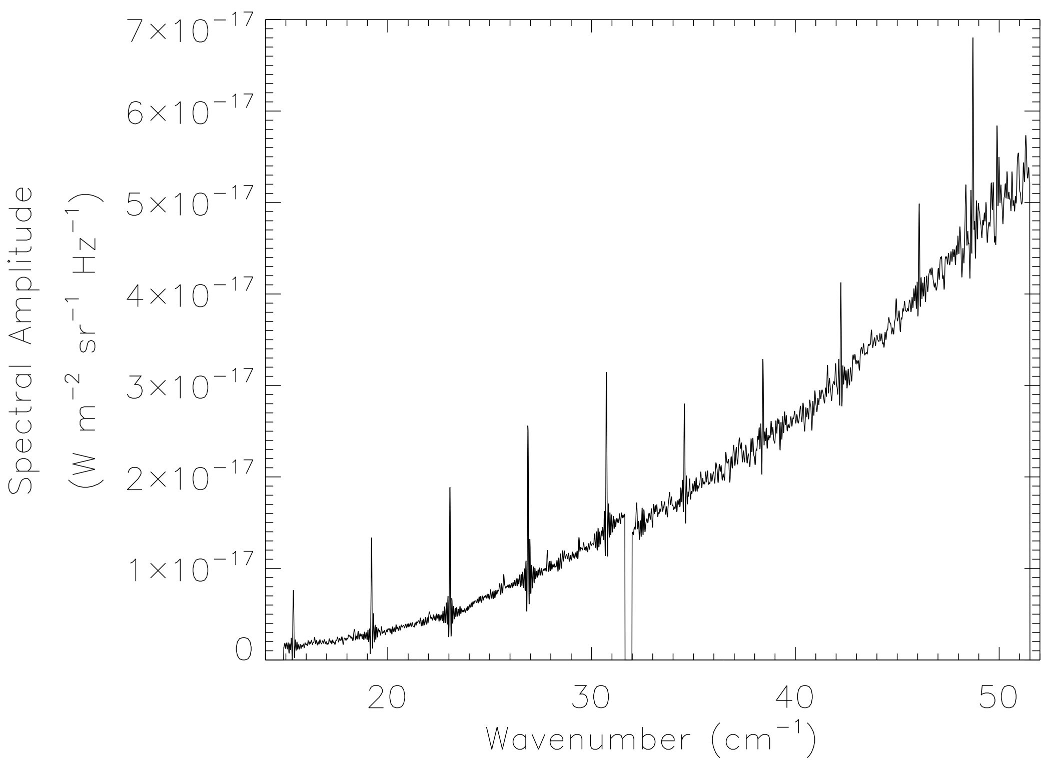

Figure 1: Sample Orion spectrum.

4 Spectral Line Fitting

A least-squares minimization routine was used to fit a continuum background and unresolved spectral lines to the provided input spectrum. This routine was used to determine the best-fit line centres, widths, amplitudes, and integrated flux for each CO line of each detector of each jiggle position of the data set (i.e. 5/4 x 19/32 x 43 SLW/SSW). The spectra used as input for this routine were obtained by the standard pipeline processing. The output of the fitting routine is saved in an array for evaluation discussed below.

5 Correction Factor Calculation

For a given CO transition frequency, σ_{CO} [cm^{-1}], and observed frequency σ', a velocity shift, Δ_{kps}, is determined as follows:

$$\Delta_{kps} = \frac{\sigma_{CO} - \sigma'}{\sigma_{CO}}(c) \quad \text{[km/s]}. \tag{1}$$

The shift is corrected for the source and telescope velocities and converted back into frequency units.

$$\sigma'_{cor} = \sigma_{CO} - \left(\frac{\Delta_{kps} - v_{\text{tel}} - v_{\text{src}}}{c}(\sigma_{CO}) \right) \quad \text{[cm}^{-1}\text{]}, \tag{2}$$

Table 1: Observations of Orion used to determine the SMEC correction factors.

OD	OBSID	Target	Number of Reps	Resolution	Detector Mode	Spatial Sampling
302	0x50003A2D	HD37041	2	High	Nominal	Full
302	0x50003A2E	OrionBar_map2	2	High	Nominal	Full
302	0x50003A2F	OrionBar_map3	2	High	Nominal	Full

where v_{tel} and v_{src} represent the telescope and source velocities, respectively. The velocity of the telescope with respect to the line of sight during these observations was taken to be 44.37 km/s and the velocity of the source was taken to be 9.9 km/s. Given that the width of a SPIRE FTS spectral resolution element is $\sim$400 km/s, sub-km/s accuracy is not necessary at this stage.

A frequency domain factor is determined through the ratio of the observed and theoretical frequencies as follows

$$f_{\text{freq}} = \frac{\sigma'_{cor}}{\sigma_{CO}}. \quad (3)$$

In practice, the observed line centres for each detector were determined for each of the 43 spectra and then averaged together. This resulted in a mean observed frequency for each line, for each detector. These mean observed frequencies were then used to determine the correction factors for each detector as described above. To obtain the SMEC step factor correction, the frequency correction factor is multiplied by 4, the on-axis mechanical position to optical path difference conversion factor.

$$f_{\text{SMEC}} = 4 f_{\text{freq}}. \quad (4)$$

6 Correction Factors

The correction factors determined via the above method are provided in Tables 2 & 3. The uncertainties are determined using the standard deviation of the observed line centres, propagated through the various steps in the calculation.

Table 2: SMEC step correction factors for SLW.

Detector	Factor
SLWA1	3.99019 ± 0.00002
SLWA2	3.99142 ± 0.00003
SLWA3	3.99002 ± 0.00003
SLWB1	3.99269 ± 0.00002
SLWB2	3.99642 ± 0.00002
SLWB3	3.99646 ± 0.00002
SLWB4	3.99279 ± 0.00003
SLWC1	3.99148 ± 0.00002
SLWC2	3.99663 ± 0.00002
SLWC3	3.99913 ± 0.00002
SLWC4	3.99729 ± 0.00003
SLWC5	3.99201 ± 0.00003
SLWD1	3.99203 ± 0.00002
SLWD2	3.99645 ± 0.00002
SLWD3	3.99674 ± 0.00002
SLWD4	3.99323 ± 0.00003
SLWE1	3.98968 ± 0.00002
SLWE2	3.99163 ± 0.00003
SLWE3	3.99125 ± 0.00003

Table 3: SMEC step correction factors for SSW.

Detector	Factor
SSWA1	3.99156 ± 0.00003
SSWA2	3.99334 ± 0.00003
SSWA3	3.99294 ± 0.00003
SSWA4	3.99074 ± 0.00003
SSWB1	3.99271 ± 0.00003
SSWB2	3.99597 ± 0.00003
SSWB3	3.99681 ± 0.00003
SSWB4	3.99554 ± 0.00003
SSWB5	3.99189 ± 0.00002
SSWC1	3.99230 ± 0.00003
SSWC2	3.99670 ± 0.00002
SSWC3	3.99869 ± 0.00003
SSWC4	3.99837 ± 0.00002
SSWC5	3.99576 ± 0.00002
SSWC6	3.99122 ± 0.00002
SSWD1	3.98994 ± 0.00003
SSWD2	3.99520 ± 0.00003
SSWD3	3.99844 ± 0.00002
SSWD4	3.99923 ± 0.00001
SSWD6	3.99444 ± 0.00002
SSWD7	3.98934 ± 0.00003
SSWE1	3.99162 ± 0.00002
SSWE2	3.99614 ± 0.00002
SSWE3	3.99824 ± 0.00002
SSWE4	3.99803 ± 0.00002
SSWE5	3.99569 ± 0.00001
SSWE6	3.99154 ± 0.00002
SSWF1	3.99157 ± 0.00002
SSWF2	3.99512 ± 0.00002
SSWF3	3.99627 ± 0.00002
SSWF5	3.99191 ± 0.00002
SSWG1	3.99033 ± 0.00002
SSWG2	3.99245 ± 0.00002
SSWG3	3.99260 ± 0.00002
SSWG4	3.99099 ± 0.00003

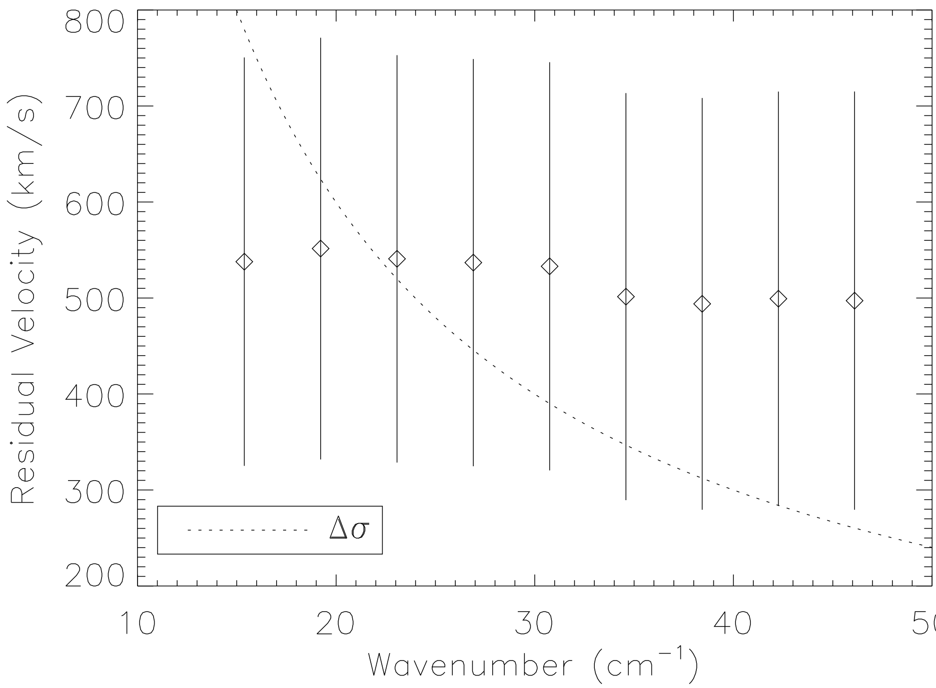

Figure 2: Residual velocity of the CO lines in the OD302 Orion observations prior to obliquity correction. The dashed line shows the spectral resolution, converted into velocity units.

7 Correction Verification

To verify that the performance of the obliquity correction factors, the spectral line fitting was repeated using the corrected spectra as input. The observed line centres for each CO line were averaged for each scan as well as for each detector in both the SLW and SSW arrays (producing one frequency per array for each CO line, i.e. averaging on the array level rather than detector level). The residual velocity for each CO transition is shown in Figure 3 where each line is in agreement with 0 km/s residual velocity. For reference, Figure 2 illustrates the same analysis performed on the pre-corrected spectra.

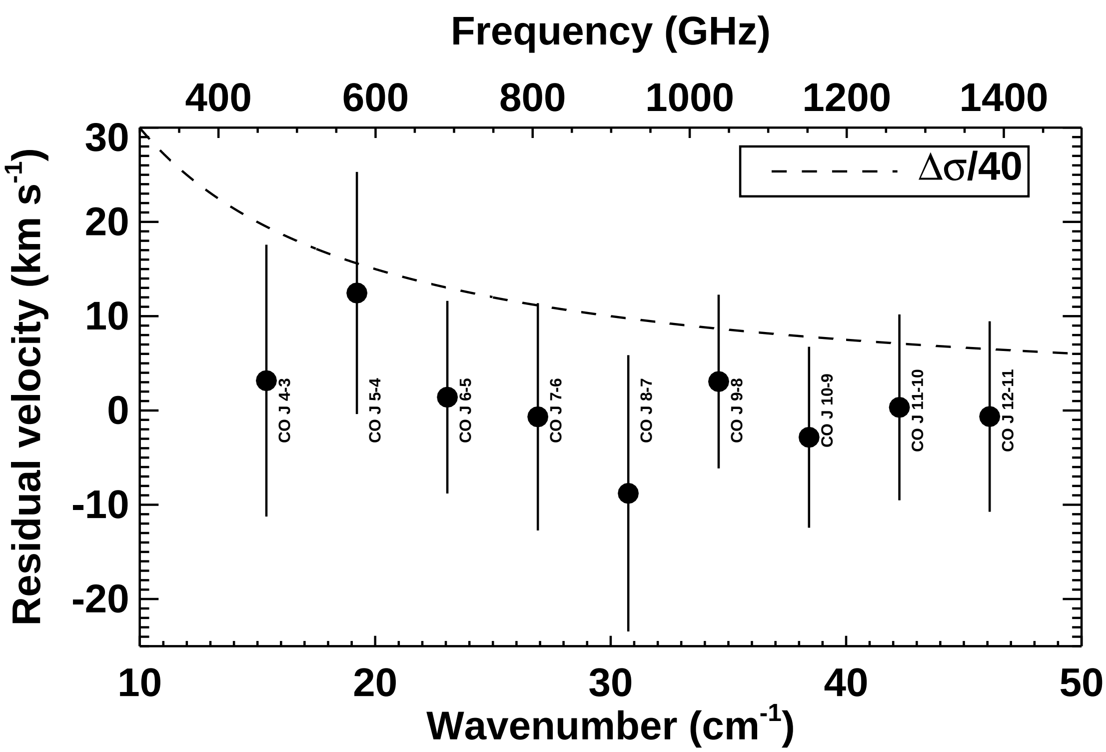

Figure 3: Residual velocity of the CO lines in the OD302 Orion observations. The dashed line shows the spectral resolution, divided by 40, converted into velocity units.

8 Conclusions and Future Work

The SMEC step factor calibration data product has been shown to improve the accuracy of SPIRE FTS spectra. This has been demonstrated by illustrating the improved residual velocity between pre- and post-corrected spectra.

More details are required to introduce the source of the obliquity effect itself. References need to be added. Greater detail of the spectral line fitting needs to be included.