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SPIRE FTS Telescope model correction

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Abstract

Herschel[1]/SPIRE[2] FTS data are dominated by emission from the Telescope, which must be removed precisely during data reduction. A 'dirty' Telescope model was adopted pre-launch, with time invariant mirror emissivity. Examination of observed FTS data showed a clear evolution of the Telescope contribution over the course of the mission and the strong need for a correction to the Telescope model to reduce residual background. Assuming a perfect Telescope subtraction results in dark sky data consisting of random noise distributed about zero flux, changes between repeated dark sky observations provide a measure of the difference between the Telescope emission and pre-launch model.

Data

Dark sky observations were used to construct ratios (r) of daily to generic Telescope RSRFs (R_{Tel}, see poster by Fulton et al.) as:

$$r = \frac{1}{R_{Tel}}\frac{V}{M_{Tel}}$$

V = data post instrument correction
M_{Tel} = Telescope Model

where V/M_{Tel} gives an R_{Tel} specific to that operational day (OD). Assuming the generic R_{Tel}, constructed from dark sky data covering the whole mission, offers a bench mark for any daily R_{Tel}, taking this ratio for many ODs provides a measure of systematic residual over the mission and a means to derive an empirical Telescope model correction.

Figures

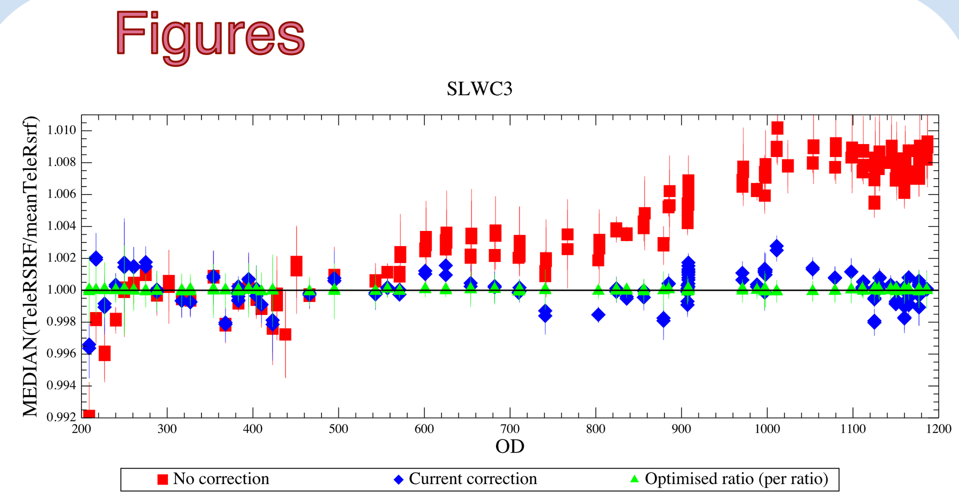

Figure 1. Daily to generic Telescope RSRF ratios for SLWC3, without correction (red), with the telescope model correction (blue) and optimised to 1.0 (green).

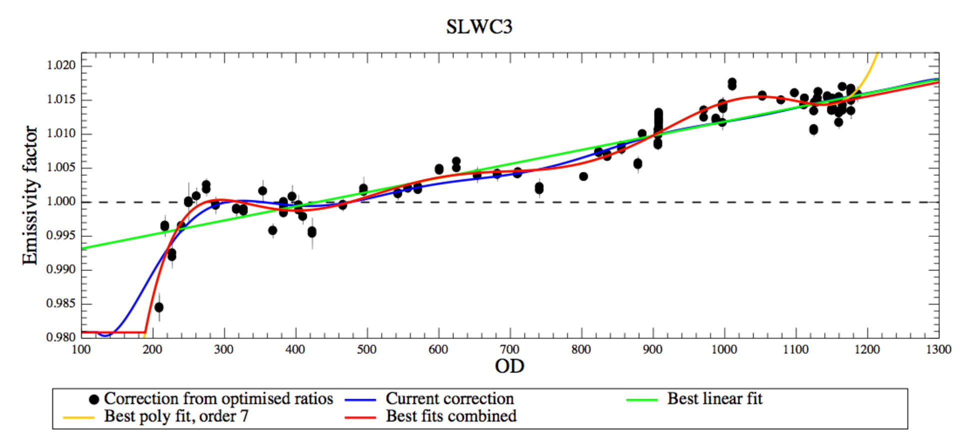

Figure 2. Black points show the optimised corrections corresponding to the ratios of 1.0 in figure 1. Best linear fit (green), best polynomial fit (orange), initial correction (blue), new correction (red) for SLWC3.

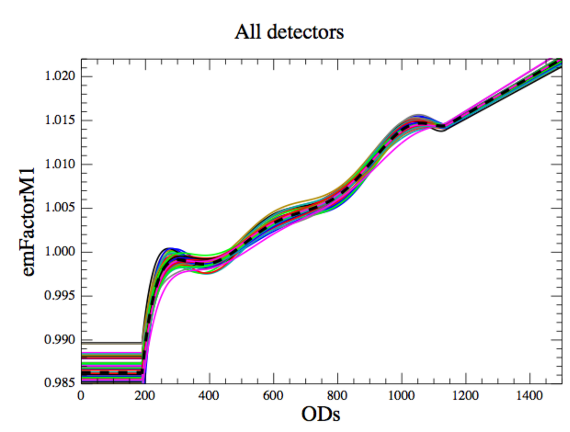

Figure 3. HIPE10 Telescope model corrections for all detectors and the mean correction (red dashed line).

Deriving the correction

To optimise the Telescope model correction for any given detector the following steps are taken:

- a set of observations is defined
- for each observation r is found (see figure 1)
- a multiplicative factor is adjusted to correct each r to 1.0 (within 10^{-4})
- the set of optimised corrections are fitted with a linear fit and a high order polynomial
- the final model correction (see figure 2) is constructed as a function of OD using
  - the fitted polynomial at OD189, fixed over the performance verification phase
  - the fitted polynomial, between OD189 and OD1280 for SSW and OD1308 for SLW
  - the best linear fit for days above the polynomial OD limit, after normalizing to the final polynomial value used
- for noisy detectors without a good polynomial fit, a mean correction is used (see figure 3)

Applying the correction

The derived correction (E_{corr}) is applied to M_{Tel} as a multiplicative factor to the M1 Telescope mirror emissivity (ε_{M1}) as:

$$M_{Tel} = (1-\varepsilon_{M2})(E_{corr}\varepsilon_{M1}B1) + (\varepsilon_{M2}B2),$$

where B1 and B2 are plank functions and

$$\varepsilon_{M1} = \varepsilon_{M2} = 0.0336(c/\lambda)^{-0.5} + 0.273(c/\lambda)^{-1}$$

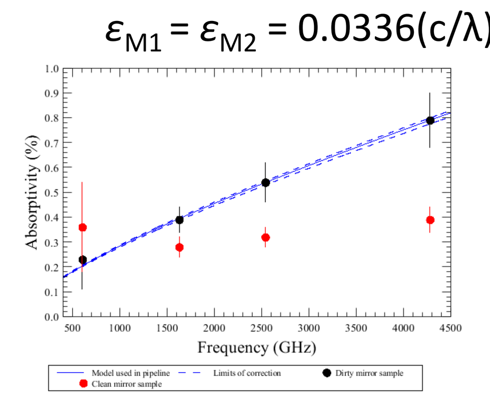

Figure 4. Emissivity model, fitted to the dirty mirror sample[3]. The change seen in the emissivity due to the E_{corr} is <1%.

Results

A comparison of the Telescope model correction, applied to centre detectors for point source calibrated long dark sky observations, against uncorrected data is shown in figure 5. For SLWC3 the Telescope residual is reduced by up to 7 Jy and around 5 Jy for SSWD4. The mean spread for all vignetted detectors is shown in figure 6, highlighting the improvement across all detectors and the need for this correction.

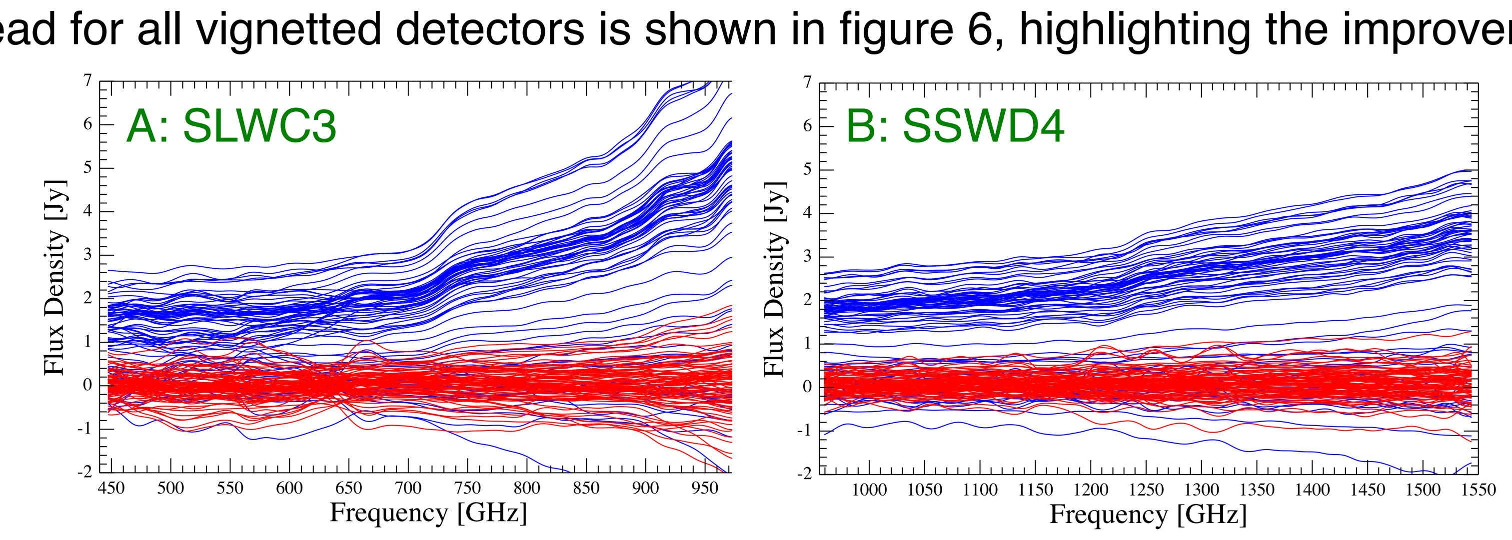

Figure 5: Point source calibrated dark sky spectra without (blue) and with (red) the HIPE10 Telescope model correction applied. The data is smoothed as the correction is most significant for the low frequency shape. SLWC3 (A) sees a reduction in the background residual of up to 7 Jy and around 5 Jy for SSWD4 (B).

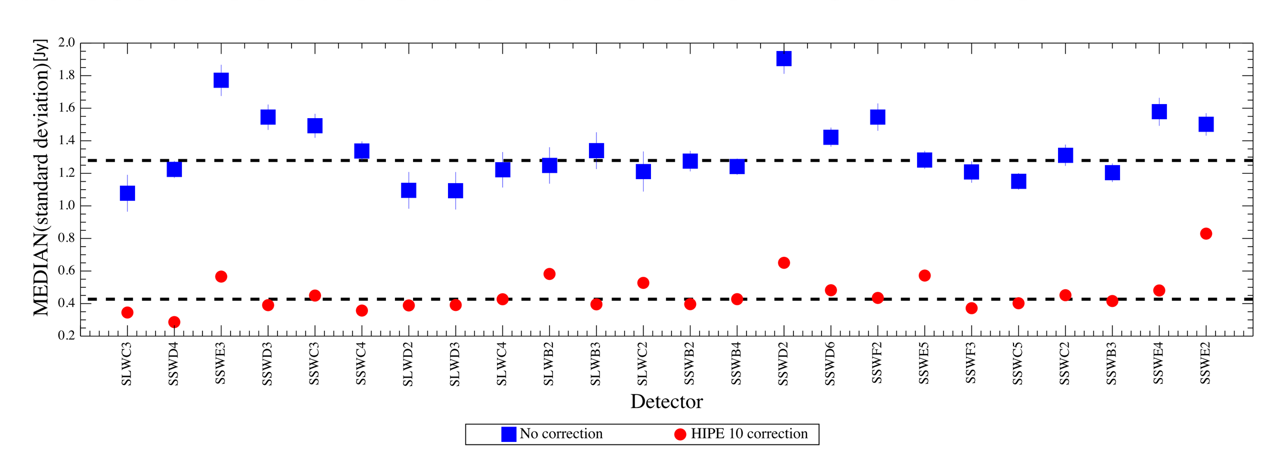

Figure 6. Average continuum offset error (median standard deviation across spectra shown in figure 5) for all unvignetted detectors for uncorrected (blue) and corrected with the HIPE10 Telescope model correction (red). The black dashed lines show the median error on the continuum for all detectors and indicates an average reduction of 1 Jy when applying the Telescope model correction.

Conclusions

An empirical correction to the Telescope emissivity has been derived to compensate for changes in conditions of the *Herschel* Telescope over the course of the mission.

This correction is essential for FTS data, to avoid significant background residual in the reduced spectra. Applying the correction to data across the mission gives an improvement of up to 7Jy for SLWC3 and a significantly improved background subtraction for all detectors, with an average continuum offset error reduction of 1 Jy.

A precise empirical correction is currently limited by outlying observations and flux drift related to small changes in temperature. Both of these issues are to be addressed in future work and will provide a means to fine tune the existing correction.

SPIRE ICC

References: 1. G. L. Pilbratt, et al., 2010, *Herschel Space Observatory. An ESA facility for far-infrared and submillimetre astronomy*, A&A, 518, L1; 2. M. J. Griffin et al., 2010, *The Herschel-SPIRE instrument and its in-flight performance*, A&A, 518, L3; 3. Fischer, J. et al., 2004, *Cryogenic far-infrared laser absorptivity measurements of the Herschel Space Observatory telescope mirror coatings*, Applied Optics, 43, 3765; Fulton et al. 2013, *Relative Spectral Response Function Calibration for the Herschel/SPIRE Imaging Fourier Transform Spectrometer*