Fringes in SPIRE/FTS Spectra and How You Can Get Rid of Them

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Abstract

Using the SPIRE/FTS staring observations of 125 galaxies in the sample for our *Herschel* program (OT1_nlu_01), we study how the inferred systematic noise (or fringes) behaves for the two central detectors, SLWC3 and SSWD4. We found that this systematic noise varies significantly from one FTS cycle to another, but generally remains more or less stable during an FTS observing cycle. For long FTS observations (i.e., with FTS repeats N_r > 100), the systematic noise is always the dominant noise. For observations of medium durations (e.g., 20 < N_r < 100), the spectral noise could still be influenced or even dominated by fringes, depending on the observing day. We give simple instructions on how to check if your particular observation suffers from fringes, and if so, how to remove or eliminate the fringes from your spectrum.

1. Data analysis and results

The flux-limited sample of local luminous IR galaxies for our OT1 program (OT1_nlu_01) consists of 125 targets that have been observed with SPIRE spectrometer in its sparse mode. The sample targets were observed over observing days (ODs) 200-1300 (including 32 early observations from the archive). We used this data set to study how systematic noise (or fringes) in FTS spectra behaves across observing days, and explore ways to reduce or eliminate this systematic noise from a spectrum.

Fig. 1 shows that the observed systematic noise of SLWC3 varies significantly across ODs and that the noise magnitude generally correlates between the two detector arrays. The systematic noise, σ_s, is given in Eq. (1):

$$\sigma_s^2 = \sigma_{tot}^2 - \sigma_r^2, \qquad (1)$$

where σ_{tot} and σ_r are respectively the observed spectral r.m.s. noise and the mean random noise calculated over some line-free frequency interval. For this poster, these values were calculated over rest-frame frequencies between CO(6-5) and CO(7-6) for SLWC3 and CO(11-10) and CO(12-11) for SSWD4. The random noise, estimated from the repeated scans, is given per spectral sample as part of the Level-2 product. Note that some ODs have higher systematic noise, e.g., OD1032. It is also observed that, if an FTS cycle contains two consecutive ODs, both days show comparable systematic noise.

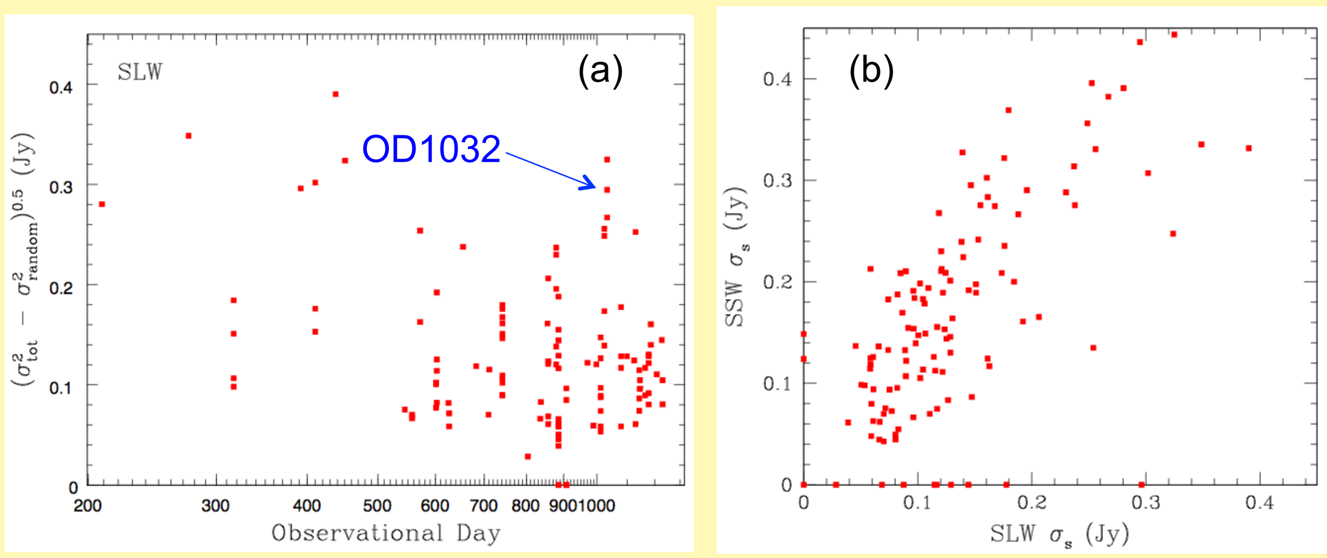

Fig. 1. Plots of (a) the inferred systematic noise, σ_s, as a function of observing day for SLWC3, and (b) of the systematic noise of SSWD4 vs. that of SLWC3.

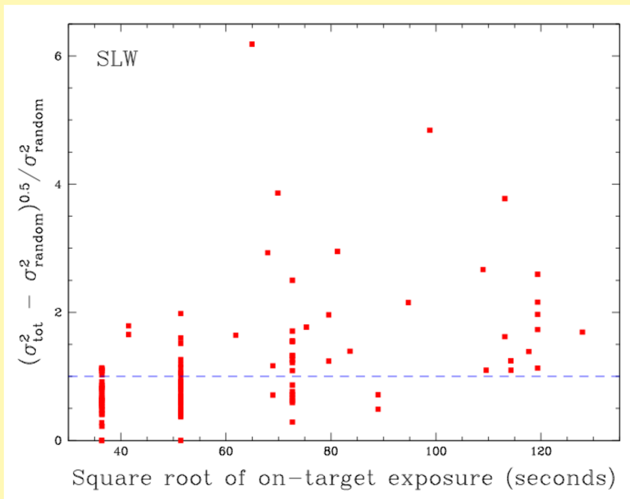

Fig. 2. Plot of the observed systematic noise to random noise for SLWC3, as a function of the on-target integration time squared. The dashed line marks the ratio of 1.

Fig. 2 shows (a) that systematic noise usually dominates for observations with on-target integration longer than ~ 2 hrs (or the number of FTS repeats > 100 or so), and (b) that, even for a moderate duration observation, systematic noise could be significant, depending on specific OD.

2. How do you know if your data suffer from fringes or not?

There is a user script in HIPE as shown in Fig. 3, which let you easily do a quick comparison of the total spectral noise with the random noise and the HSPOT-predicted noise.

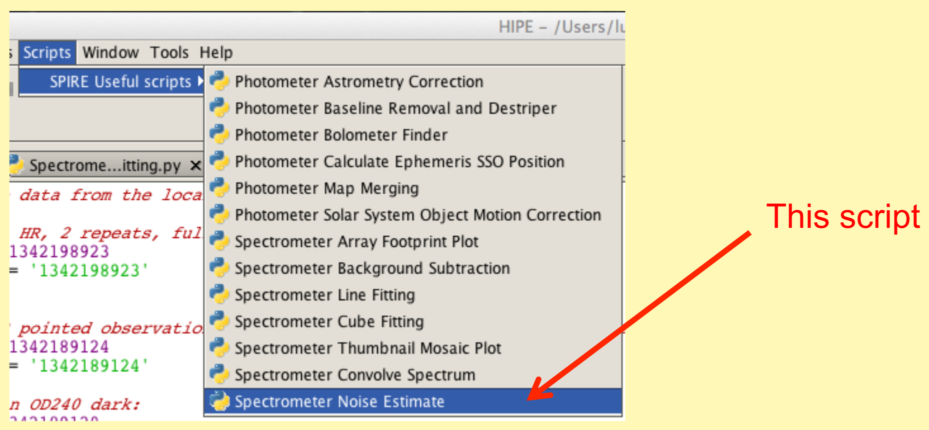

Fig. 3. HIPE user script available to quickly calculate total spectral noise, random noise, and HSPOT predicted noise.

You may find your observation with little systematic noise, as in the example shown in Fig. 4, or an elevated total spectral noise with respect to the random noise as shown in Fig. 5. In the latter case, you may consider to take extra steps to reduce or remove the systematic noise in your spectrum.

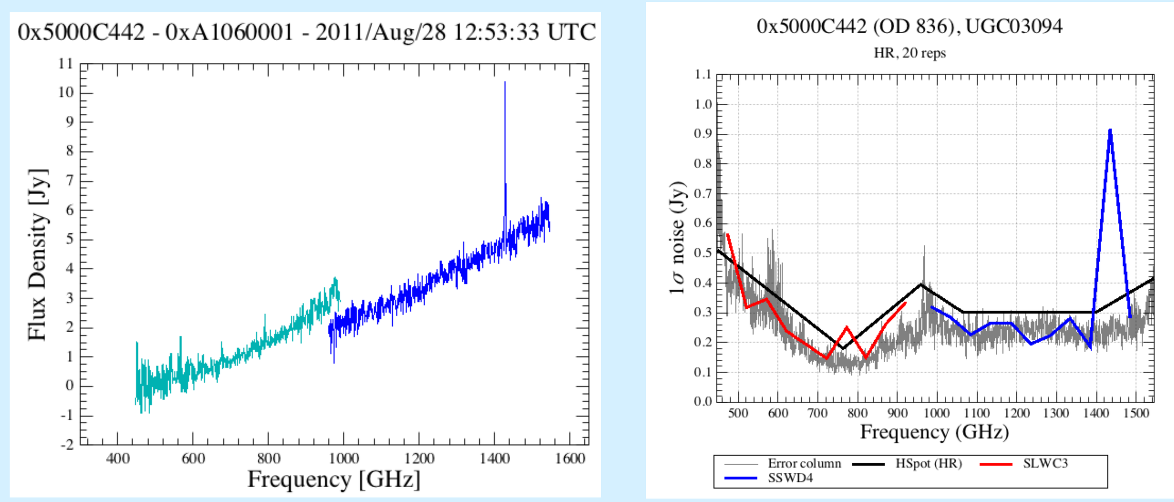

Fig. 4. An example with little systematic noise. The spectrum is on the left, and various noise calculations on the right.

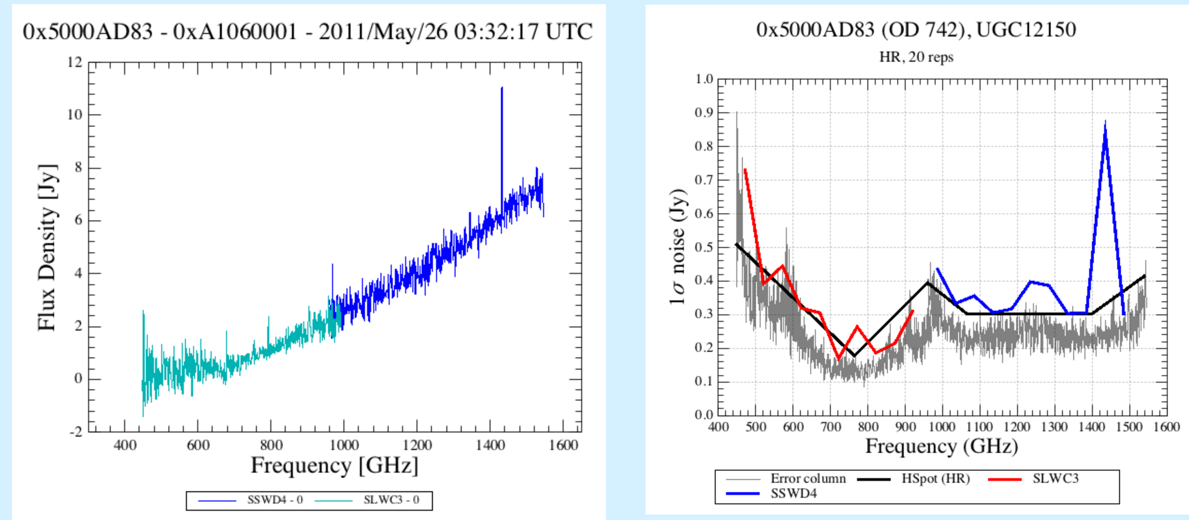

Fig. 5. An example with elevated total noise over the random noise. The spectrum is on the left-hand side, and various noise calculations on the right.

3. What can you do to reduce or eliminate fringes in your spectrum?

There are currently two methods to reduce or eliminate the fringes in your spectrum: (a) a direct subtraction of a facility, long-exposure dark observation from the same observing cycle as your own observation, or (b) median filtering a number of long observations of galaxies from the same observing cycle as your own observation, preferably faint galaxies. This generates a fringe template that can be then subtracted from your own spectrum.

3.1. Direct subtraction of a facility dark observation

Prior to OD1079 (April 27, 2012), a facility dark observation was taken in the CR mode. This dark may not be suitable for reproducing the fringes in your spectrum that has always been carried out in the so-called HR mode. On and after OD1079, the facility dark has been taken in the HR mode. You can subtract this dark observation directly from your spectrum. This usually remove some of the fringes, but at the cost of adding some random noise to your results. An example is shown in Fig. 6.

3.2. Noise template method

For spectra taken prior to OD1079, the HR facility dark is generally not available, except for a few ODs (e.g., OD1032) when both HR and CR darks were taken. If there are a sufficient number of faint galaxy observations during the observing cycle, you can use these spectra to generate a fringe template spectrum that can be subtracted from your own spectrum. This noise template method can be applied to any OD in principle as long as there are suitable data. An example is shown in Fig. 7.

You can obtain a copy of our noise template script by contacting the authors at: lu@ipac.caltech.edu. The script generates noise templates on the fly by fetching Level-2 spectra from Herschel archive directly and subtracts the result from your target spectrum.

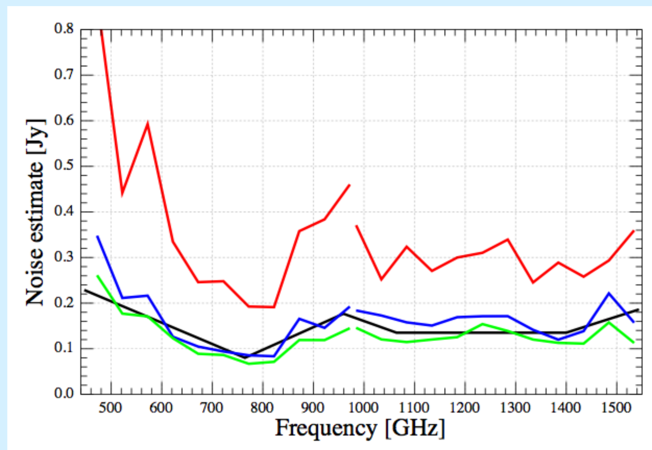

Fig. 6. A deep observation from OD1032 showing how the systematic noise can be reduced using the two methods. The red curve is the HIPE 9 pipeline spectral noise, the blue is the spectral noise after subtracting the facility HR dark from the same OD, and the green curve is the resulting spectral noise after using the noise template method. The black curve is the HSPOT-predicted noise.

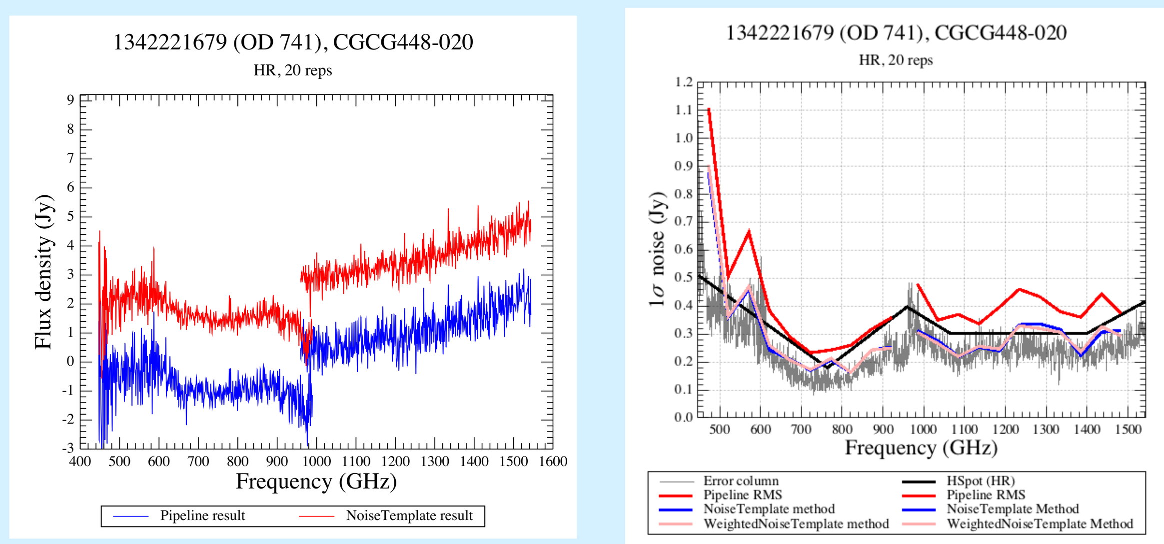

Fig. 7. Application of the noise template method to an observation from an early OD. The pipeline spectrum is shown in blue. The fringe-removed spectrum is shown in red. Various noise calculations are shown in the plot on the right-hand side.