Glitches observed with the SPIRE Proto-Flight Model
SPIRE-UOL-REP-002513

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1. Scope

Results are reported on flagging and characterizing glitches in the data from the SPIRE Proto-Flight Model (PFM) test campaigns. While there may be low-frequency variations in the signal due to thermal drifts, noise in the lab, etc., this report focuses only on short-lived transients.

2. Reference Documents

#	Title	ID
RD1	Herschel SPIRE Detector Subsystem Specification Document	SPIRE-JPL-PRJ-000456, issue 3.2
RD2	Herschel SPIRE Detector Control Unit Design Document	SPIRE-SAP-PRJ-001243, issue 1.0

3. Applicable Documents

#	Title	ID
AD1	SPIRE Detector Response and Glitch Characterization	SPIRE-UOL-REP-002207, v0.2
AD2	Data analysis of glitches from CQM testing	SPIRE-UOL-REP-002208, v2.0

4. Modeling and flagging glitches

The response of the SPIRE bolometers to a Dirac input was modeled as the transfer function of the thermal response of the bolometers and the electrical filter (see AD1). The recently updated specifications for the bolometers and the read-out electronics were used for this model (RD1, RD2). Depending on the time constants of individual bolometers, the resulting impulse response functions (IRF) are given by Figure 1.

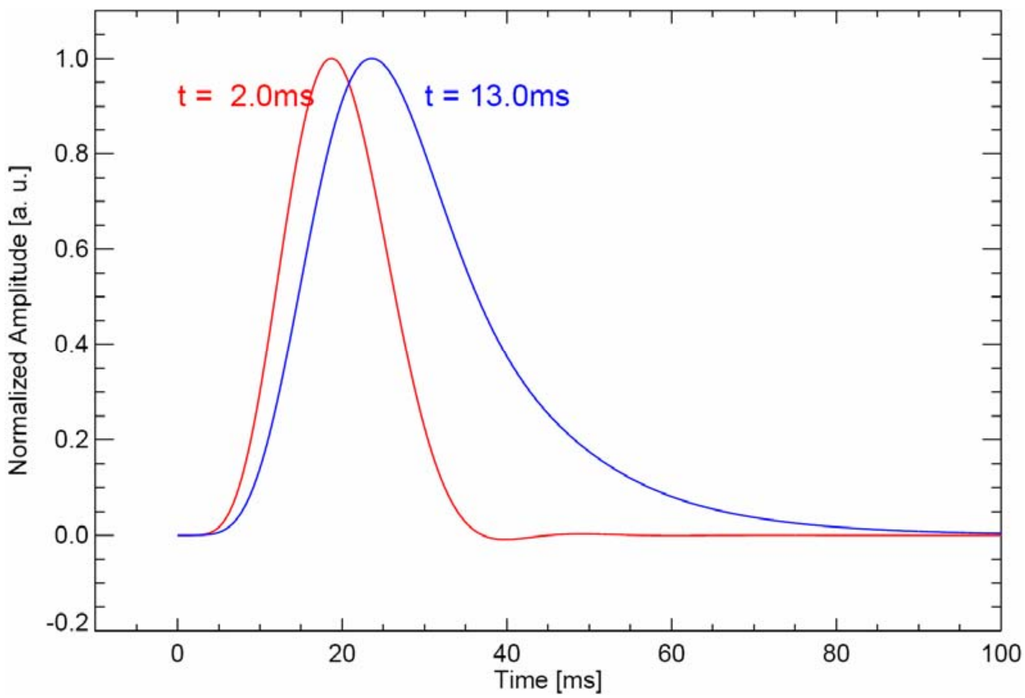

Figure 1: Modeled Impulse Response Function for the spectrometer for a 2 and 13 ms time-constant of the bolometer. Note how the downward dip after the glitch disappears for a large thermal time-constant.

Empirically, glitches were flagged as outliers in slope.

The following procedure was used to further study the identified glitches:

1. The baseline for all identified glitches was established as a robust fit of a straight line (IDL's LADFIT) to 31 points with the glitch peak at the center.
2. The glitch amplitude is determined from fitting a parabola to the glitch peak and its two neighbors. The glitch amplitude is set to the difference between the baseline under the glitch peak and the extremum of this parabola.
3. For all accepted glitches, the points during the 75ms before and the 112.5ms after the glitch peak are registered relative to the minimum of the fitted parabola. The baseline is subtracted and the glitch amplitude is normalized to 1.
4. The resulting data points are binned in 10ms wide bins. The average values and their standard deviations, as well as the median and the median difference from the median are computed per bin. The result is the empirical IRF for PFM.

5. Proto-Flight Model 1, March 2005

Data during the performance tests with the PFM1 were taken at a sampling rate of ~80Hz or at time intervals of 12.5ms. Overall, more than 220 hours of single-pixel data were analyzed. The 5σ criterion identified 2367 glitches.

The histogram of the amplitude distribution for the glitches (see Figure 2) shows an initial rise in number of glitches due to the 5σ cut-off threshold and a subsequent steep decline in frequency with amplitude.

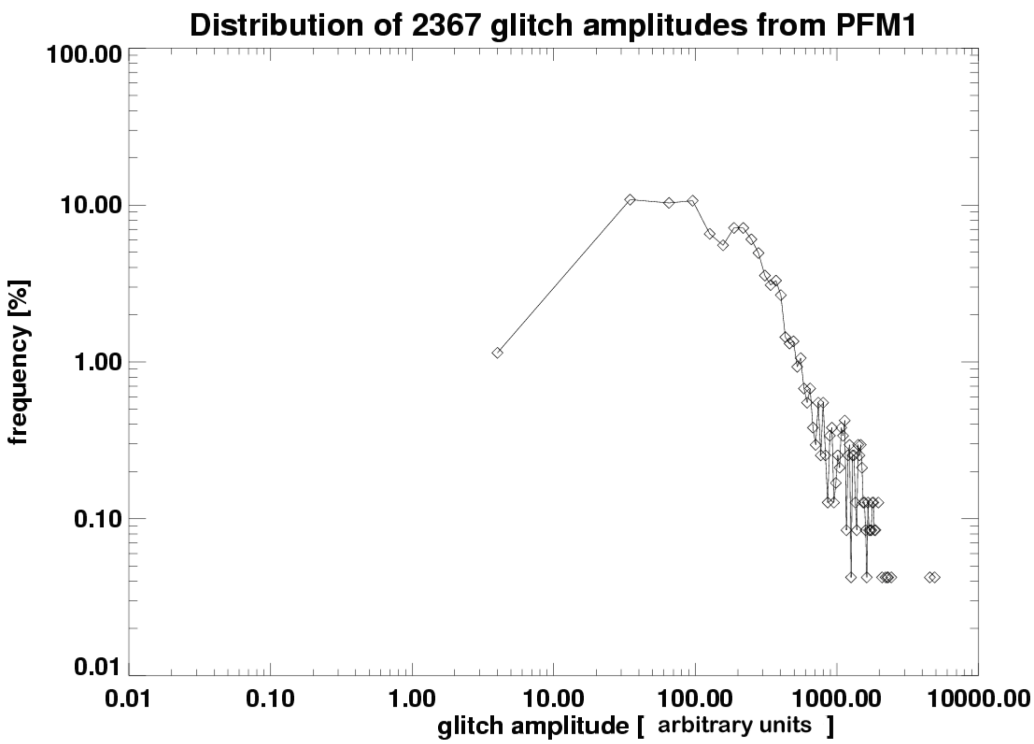

Figure 2: Amplitude distribution of the 2367 glitches from the PFM1 test campaign

The resulting average, normalized response at steep slopes for the pre-vibration test campaign is shown in Figure 3.

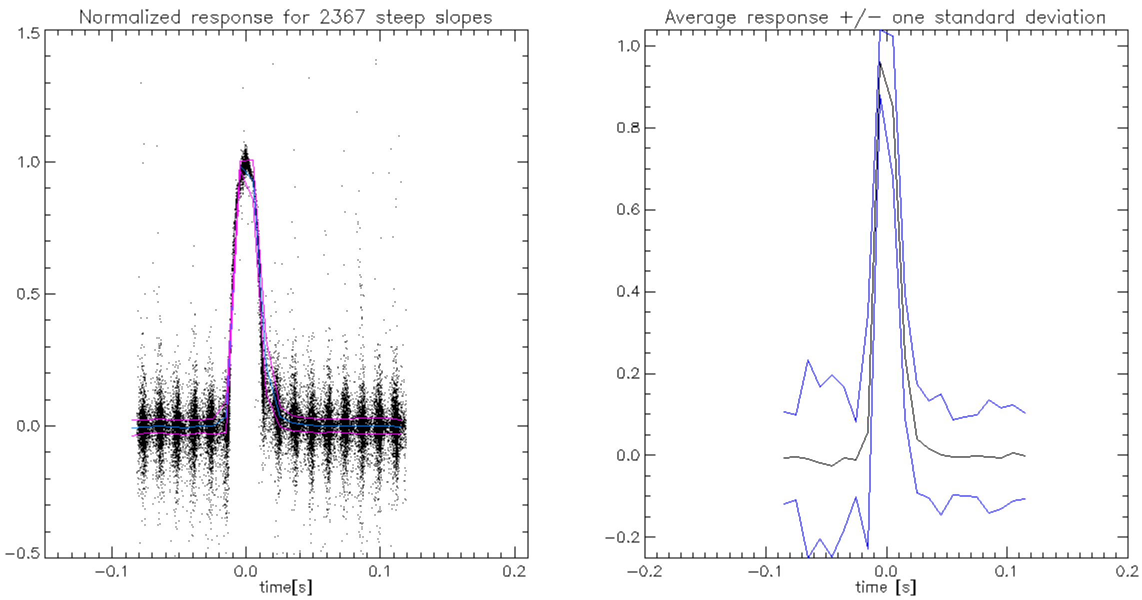

Figure 3: Normalized and inverted timeline of measured points at steep slopes. Left: median (blue) ± the median of the differences (magenta). Right: average (black) ± one standard deviation (blue).

The generic shape of the measured IRF is due to the marginal sampling of the detectors. Finer details of a characteristic shape cannot be resolved.

What is the source of the measured glitches? Since SPIRE features bolometric detectors it is a reasonable to assume that glitches are due an instantaneous depositions of energy in the bolometer crystal, for example by cosmic rays or high-energy radiation. In this case, the signal should spike downwards, indicating an increase in heat on the bolometer crystal. Alternatively, the read-out electronics of the detector arrays may be disturbed and lead to upward glitches in the data. The PFM data give some indication what elements of the instrument are affected:

Of the 2367 flagged glitches, 2359 glitches were negative and only 8 glitches positive. 99.66% of the glitches are consistent with the model that something disturbs the bolometer crystal. The positive glitches (0.34%) indicate that something other than the bolometer crystal, quite likely the read-out electronics, is disturbed. The shape of such an upward glitch is very narrow and shows the dip characteristic of the profile of the Bessel filter without an additional RC-term (see Figure 4).

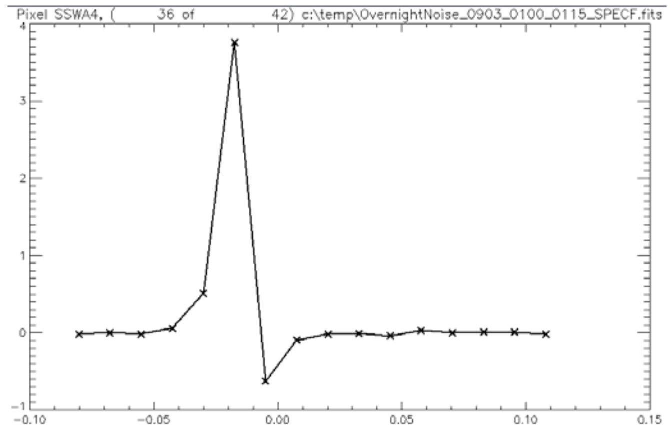

Figure 4: Normalized (and not inverted!) timeline of a positive spike with time in seconds on the x-axis and the detector signal in arbitrary units on the y-axis

However, the glitch shows too a large dip after its initial rise when compared to the modeled IRF of the Bessel filter (see Figure 5).

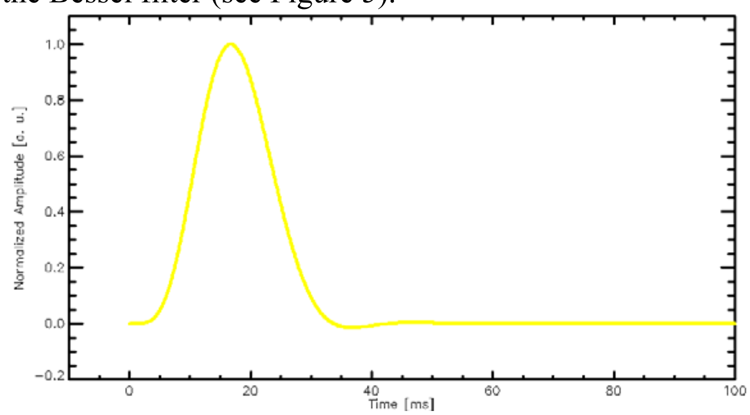

Figure 5: Impulse Response Function of the seven-pole Bessel filter of the SPIRE spectrometer

The glitch rate per hour single pixel data is 10.7. However, the 2367 glitches, flagged for 42 of the electronic channels from the SLW and SSW detector arrays, occurred at only 151 unique moments in time! In other words: All but 46 glitches co-occur with glitches at the same time in other bolometers.

Overall glitch count	Negative glitches	Positive glitches
2367 – 100%	**2359 – 99.66%**	**8 – 0.34%**
	Co-occurring glitches	Single glitches
2367 – 100%	**2321 – 98.06%**	**46 – 1.94%**

Table 1: Summary of negative/positive and single/co-occurring glitches

Defining an event as an instant in time when one or more signal timelines show a glitch, one can define a respective event rate. The average event rate for the detector arrays is 1.4 per hour single pixel data. The latter value is much closer to the observed glitch rates during CQM testing, which were 0.6 and 1.5 per hour single pixel data during the pre- and post-vibration test campaign respectively (AD2). However, these numbers should be interpreted with caution as the noise level of the CQM array was much higher than for the PFM1 arrays and therefore the 5σ glitch detection routine would have been less sensitive.

The fact that glitches co-occur across both spectrometer arrays suggests that, at least in those cases, the read-out electronics played a role in spreading the effect on individual bolometers. A more thorough analysis of a single observation with the spectrometer confirms the suggestion that the read-out electronics were the main target of disturbances rather than individual crystals: The deglitching routine for interferograms is much more sensitive to glitches than the 5σ criterion used above. Operating at its limit, errors such as non-detection of disturbances and false positives must be expected more frequently. For the randomly selected test observation HR_0803_2036_2059 a total of 151 glitches was detected. 147 or 97.4% of these glitches co-occurred at only seven instants in time. 3, or 2.0% of all detected glitches, were false positives on visual inspection, and only one glitch (0.6% of all glitches) occurred with no obvious counter-parts in other pixels. It is instructive to look at the distribution among pixels when co-occurring glitches appear in the data.

The SLW and SSW detector arrays are read out through one and two lock-in amplifiers respectively. For SSW the boundary between LIA_S1 and LIA_S2 is roughly between the top and bottom part of the array (see Figure 6).

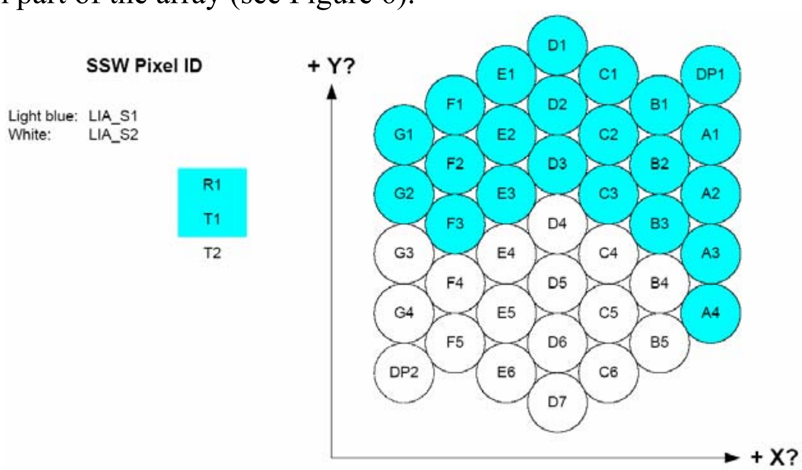

Figure 6: Distribution of SSW's pixels onto two lock-in amplifiers

For all seven co-occurring glitch events, pixels from both detector arrays are affected. For five out of the seven events, only pixels read out through LIA_S1 are affected for SSW (see Figure 7 and Figure 8). Some of the data show very clear correlation between the lock-in amplifier in use and glitch occurrence.

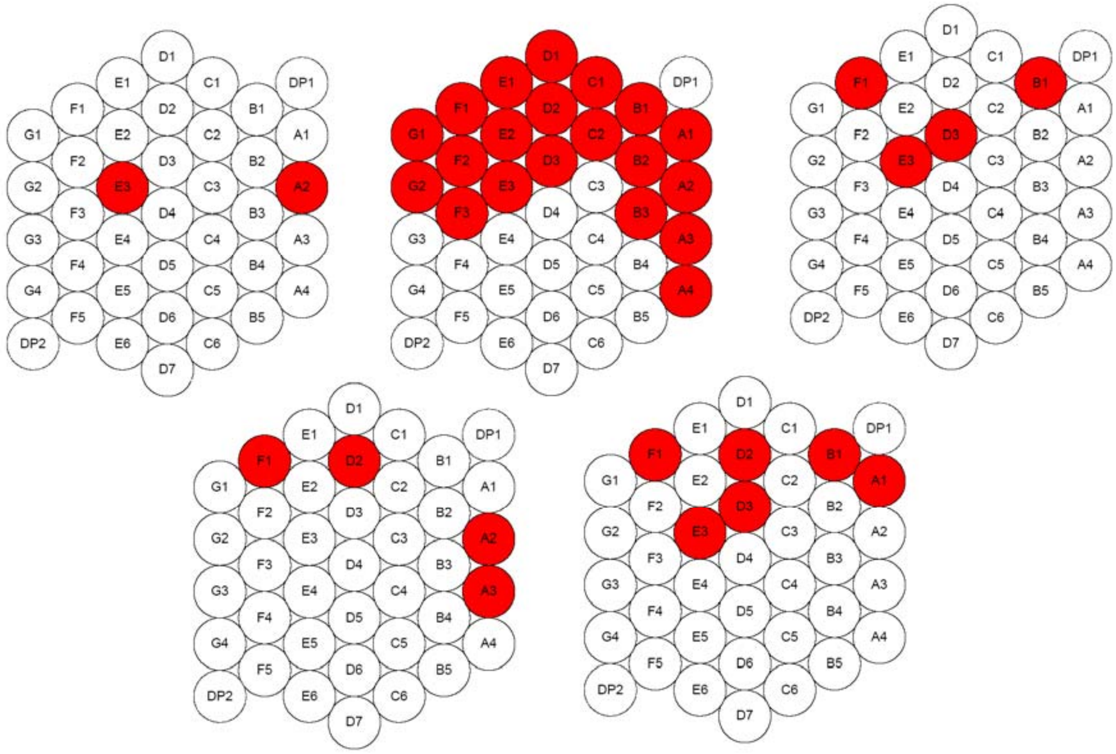

Figure 7: Five of the seven events only affect pixels from LIA_S1

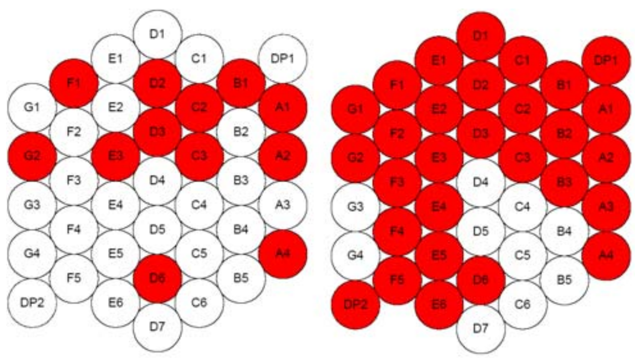

Figure 8: Two of the seven events affect pixels from both amplifiers

The noise in the LIA_S2 was much higher during the measurements which may explain why most glitches were found in the upper and not the lower section of SSW.

6. Conclusions

Some conclusions can be drawn from the above analysis:

- At the prescribed sampling rate of ~80Hz a glitch will have a noticeable effect on up to four sample points, but more likely only two.

- During PFM1 testing, glitches commonly co-occurred across both detector arrays. Co-occurrence of glitches in the pixels clearly correlates with the lock-in amplifier in use. If this persists during the upcoming test campaigns and after launch, deglitching algorithms should be able to profit and apply more rigorous detection routines to other pixels at the time when a glitch has been detected.

- There was a small number of narrow upwards glitches indicating a disturbance of the read-out electronics and not a deposition of heat in the bolometer crystals.

- More work is necessary in order to understand the mechanism how glitches co-occur across both detector arrays. In some cases, the glitch profile in these co-occurring glitches suggests that only the read-out electronics are involved. In other cases, the characteristic dip after the glitch is not visible which may suggest that the bolometer crystals are affected as well.

- The observed profile, in particular of very large glitches, deviates from the modeled IRF. The modeled IRF predicts a much smaller dip or bounce-back in the opposite direction of the glitch than was observed during PFM1 testing.