Relative gain corrections for SPIRE photometer: follow-up analysis

C. Darren Dowell (JPL/Caltech)
for Scanmap Pipeline Validation Team
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1. Context

This report is a follow-up to "Relative gain correction for SPIRE bolometers – extended analysis", by H. Roussel, 2011 April 11 ("report_gains_2.pdf"). The goals here are to confirm the gain correction factors for extended emission using an independent map maker and alternative gain solution code, to make sure each gain correction value is sensible, and to move in the direction of releasing a calibration product.

2. Confirmation of Results from H. Roussel

I used Level 1 data provided by M. Pohlen on 2011 Apr 20, processed by his v52 pipeline (HIPE version 5[1]; temperature drift correction on; no baseline removal; without recent improvements to the jumpIdentifier and Tdrift correction). I processed all provided obsid's* using my unreleased map_destripe.c code, version 1.6. Analysis was done on 2011 May 2 and 3. I did 20 total iterations, fit for constant baselines per scanline per detector starting with iteration 1, fit for relative gains per detector starting on iteration 10, and fit for weights per scanline per detector starting on iteration 15.

*List of obsid's analyzed:

- 0x50001901 (CasA, OD 121, LargeScan)
- 0x50002A96 (CasA, OD 217, LargeScan)
- 0x50006A05-6 (N6334, OD487, SpirePacsParallel)
- 0x50006BAD-E (M17, OD492, SpirePacsParallel)
- 0x50006BAF-B0 (N6357, OD492, SpirePacsParallel)

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[1] M.P., 2011 May 16: "v52 is run on a patched HIPE 4.0.1367 having the 5.0 flux calibration plus tempdrift_1.36, sigjump_1.8, and deglitch_5.3, so it should mimic a very late (I think even the latest) 5.0 HIPE"

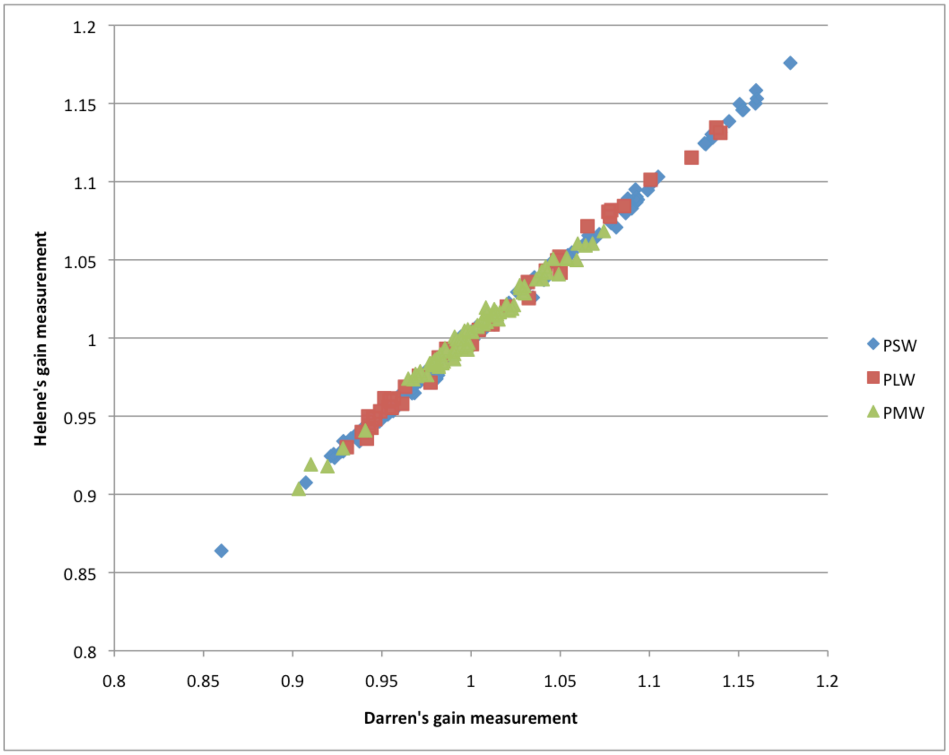

Figure 1. Scatter plot of Helene's gain measurements vs. mine.

In this analysis, I adopt Helene's convention of plotting the multiplicative correction factor for the V/Jy gain of the bolometer; in other words, the Jy/V entry in the calibration product needs to be *divided* by the values reported here to accomplish flat gains for extended emission. The mean relative gain correction in my analysis is 1.003, with a standard deviation of 2.8%, similar to Helene's analysis. On a detector-by-detector basis, the agreement between my results and Helene's is quite good (Figure 1). The largest disagreement is 1.1%, and this does not appear to be a particular outlier.

Anomalies:

1) The following bolometers were masked in the Level 1 product and not used in the map making and gain fitting (both for me and for Helene): PSW-D15, PSW-A13, PSW-C12, PSW-A11, PSW-A10, PSW-G8, PSW-G11, PLW-A6, PMW-A13. In the extended source calibration product, they could be given some sort of average gain, consistent with the practice for the standard (point source) calibration product.
2) In obsid 0x50002A96, PSW-E14 was masked out of the Level 1 data and omitted from the gain analysis, for unknown reason.
3) The detector with the largest standard deviation (2.1%) of my relative gain solutions is PLW-A2. For obsid 0x50006A05-6, its gain appears to be an outlier, for unknown reason, but it was not omitted from my analysis. My result is within 0.6% of Helene's for this detector.
4) The detector with the next largest standard deviation (1.9%) in my analysis is PMW-G1. Also for obsid 0x50006A05-6, its gain appears to be an outlier, for

unknown reason, but it was not omitted from my analysis. My result is within 0.7% of Helene's for this detector. No other detector has a standard deviation larger than 1.5%.

3. Correlation with Beam Shape

Since the flux calibration product has ~1% accuracy for point sources, we expect that differential correction factors >> 1% must have something to do with the beam shape. To explore that, I used the PSW beam maps provided by Andreas on 2010 Dec. 7.

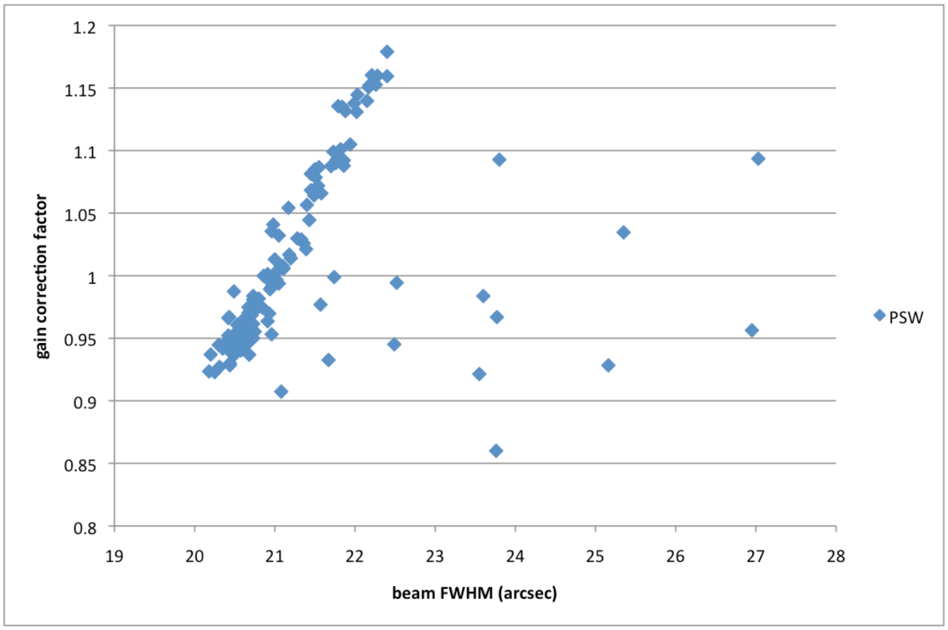

Figure 2. Scatter plot of gain correction factor vs. beam FWHM.

For perfect gaussian beams, we would expect a correlation of *correction factor* $\propto$ *beam area* $\propto$ *FWHM*^{2} in this plot; the observed exponent for the main relation in Figure 2 is more like 2.4.

There are many outliers: PSW-D12, -G1, -H2, -G3, -F4, -B5, -A4, -D2, -F12, -E14, -J14, -E10, -C6, -G5, and -G10, all with unexpectedly large FWHM. As Helene pointed out in her 2011 Jan 27 SDAG presentation, there is a high degree of correlation of the outliers with noisy beam maps. Until the source of the noise in those beam maps is understood, and until we also have PMW and PLW beam maps to use, I think this topic has to be considered unfinished.

4. Recommendations

I recommend that, going forward, we adopt Helene's gain measurements, since they are done on a larger set of obsid's. The next step is to use those gains to modify a flux calibration product, then to study the integrated emission from a calibration standard.

Here is a start on the documentation for the users' manual:

The standard SPIRE photometer pipeline carefully calibrates the detector signals so that each produces the correct peak flux (in Jy/beam) for standard point-like calibration sources, to ~1% precision. If each detector produced exactly the same beam shape as a result of mapping a point source, then there would be no need to discuss alternative calibration for extended sources. However, due to aberrations within the telescope and instrument optics, there is variation in the beam area[2] across the SPIRE focal planes. As a result, when using the default calibration, it is possible to see small striping artifacts in maps of extended emission that already had their detector baselines optimized to minimize the striping (Figure D1). The purpose of this alternative flux calibration product is to further reduce those striping artifacts, and also to achieve percent-level precision in flux density calibration of spatially-integrated emission.

<need an image here>

Figure D1. "Before" and "after" images of an extended source. In the image at left, the default (point-source-based) flux calibration has been used. In the image at right, the extended source flux calibration product has been used. In both cases, the Level 1 data was run through a "destriper" to optimize the constant baselines subtracted from each detector for each scanline, prior to mapping.

The detector gains appropriate for extended emission have been determined from SPIRE maps of extended sources and of flux calibration standards. Compared to the standard calibration, the corrections are fairly small (Figure D2), but well determined.

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[2] Beam area is defined as the integral over solid angle of the detector response, with the response normalized to unity at its peak.

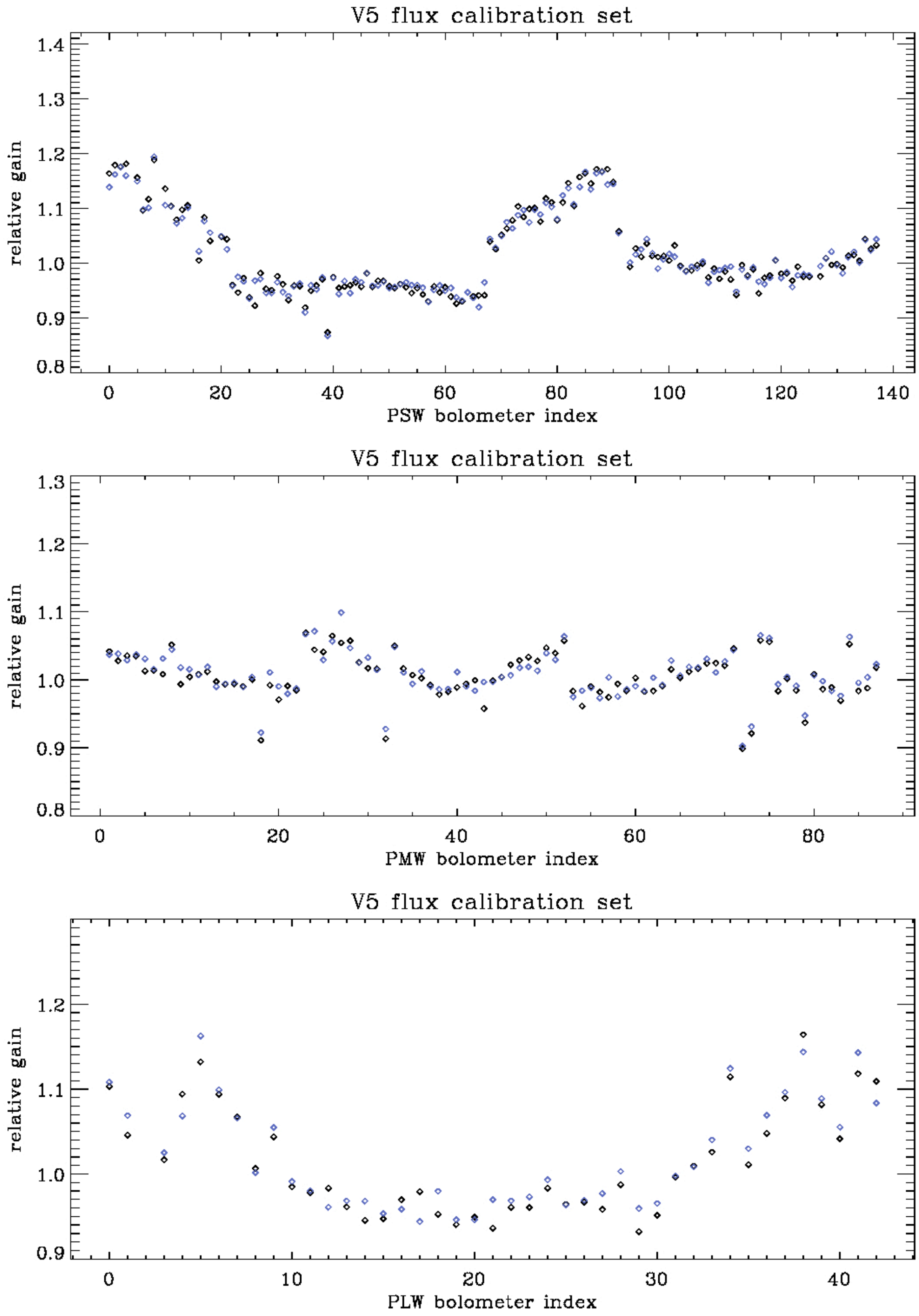

Figure D2. For each detector, ratio of gain (V/Jy) in the extended-source calibration product vs. that in the standard point-source calibration product. (The bolometer indices include only those which respond to light, excluding the diagnostic channels, *but otherwise run in the order as given in the SPIRE Level 0.5 and Level 1 products. Results provided by H. Roussel.)*

To use the alternative calibration for extended emission, use the following statement within the SPIRE pipeline:

<need the HIPE line here>

To measure the total flux density of an extended source, first define “source” and “background” apertures, then apply the following formula:

$F_{tot} = \Sigma_{\text{over } i}(M_{source,i} - \langle M_{background} \rangle) * (\text{pixel\_area} / \text{nominal\_beam\_area})$,
where $M_{source,i}$ is the map value of a pixel within the source aperture,
$\langle M_{background} \rangle$ is the average pixel value within the background aperture,
pixel_area is the area of a single map pixel, in arcsec^2,
nominal_beam_area is given in Table XXX.

Using the alternative flux calibration product for extended emission, we find XX% precision in the measurement of the integrated flux of <GIVE THE SOURCES STUDIED HERE>.