Zero-Point Correction for Herschel-SPIRE Maps via Planck-HFI Cross Calibration

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Two of the three broadband photometric channels of the SPIRE instrument on-board the Herschel Space Observatory, centred at 350 and 500 µm, have filter profiles overlapping with those of the 857 and 545 GHz channels of Planck-HFI. Although the Herschel telescope is passively cooled to around 88 K and has a very low emissivity, it still emits a strong thermal background that can not be easily separated from the celestial component. Thus SPIRE photometry is only meaningful in a differential way. The prospect of providing HFI, through cross calibration with COBE-FIRAS, with absolute celestial backgrounds, offered the possibility to also zero-point correct the SPIRE maps using the HFI 857 and 545 GHz all-sky maps as part of the standard pipeline processing. Early comparisons of photometric gains showed considerably higher HFI fluxes than those by SPIRE for the same fields. Because of this and other inconsistencies the Planck team decided to change the calibration scheme for the 545 and 857 GHz channels, using planets for photometric gains and the correlation between 857 GHz and the HI column for zero-point calibration. Below we present the methodology adopted for a software upgrade that enables the SPIRE standard pipeline (from HIPE 10) to provide zero-point corrected extended source flux maps from a comparison with Planck-HFI maps. This upgrade was made possible through a collaboration of the SPIRE Consortium with the Herschel Science Centre and the Planck Collaboration. We find the Planck photometric gains in excellent agreement with the SPIRE ones within 3.5%, which is well within the 10% absolute calibration uncertainty (including 5% from planetary model) quoted for the HFI maps.

Zero-point correction in the SPIRE pipeline

1. SPIRE data is calibrated on Neptune data. As a first step, maps need to be converted to surface brightness by dividing by the beam areas and applying a small colour correction for extended sources (see Fig. 1).
2. Maps are then enlarged and convolved with an 8' FWHM Gaussian.
3. HFI data corresponding to SPIRE maps are extracted, re-projected and colour corrected to SPIRE wavebands assuming a Grey Body of spectral index β=1.8. The dust temperature is obtained from the ratio of Planck 545 and 857 GHz maps
4. PLW and PMW convolved maps are subtracted from the corresponding colour corrected HFI maps and the 1st offsets are calculated as median of the difference maps within a mask where edge effects are <0.1%.
5. As a 2nd iteration, the original SPIRE maps with the 1st estimation of the offsets subtracted are embedded in the HFI colour-corrected maps and are convolved again. This time the median offset is determined for the entire area of the SPIRE map. This dataset is also used for gain comparison.
6. In the same way we extrapolate the Planck 857 GHz map to 250 µm to zero-point correct the SPIRE PSW map. Gains are also calculated for comparison and due to the extrapolation show a larger spread.

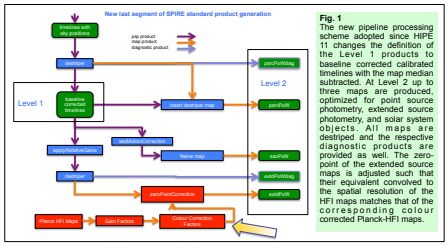
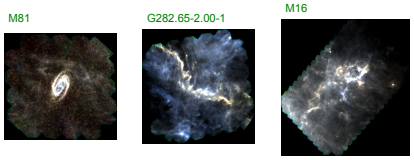


Fig. 1 The new pipeline processing scheme adopted since HIPE 11 changes the definition of the Level 1 products to baseline corrected calibrated timelines with the map median subtracted. At Level 2 up to three maps are produced, optimized for point source photometry, extended source photometry, and solar system objects. All maps are destriped and the respective diagnostic products are provided as well. The zero-point of the extended source maps is adjusted such that their equivalent convolved to the spatial resolution of the HFI maps matches that of the corresponding colour corrected Planck-HFI maps.



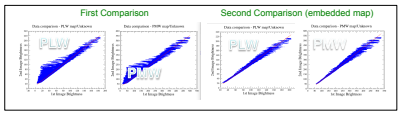
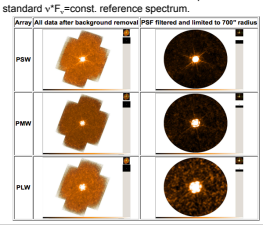


Fig. 4: Embedding the SPIRE map into a Planck map and performing a second iteration of convolution improves the comparison substantially. The diagrams above show fluxes of corresponding HFI and SPIRE map pixels plotted against each other. The artefacts on the left come from bad convolution along the map edges and disappear after the second iteration. To the right the same comparison is shown for another field (HIGAL 341), including plots of the residuals.

SPIRE Solid Angles

Fig. 2: The SPIRE maps are calibrated by the point source Neptune in Jy/beam. For a comparison with HFI an accurate determination of the SPIRE beam solid angles is needed to convert the SPIRE fluxes into surface brightness units.

- Re-built fine scan map of Neptune with 1" pixel size.
- Removed sky background structure (tilt and background galaxy removal.)
- Integrated solid angle to 600" radius.
- Estimated uncertainty is +/- 4%.
- Recently (Nov 2012) obtained "shadow" observation of the same region should improve accuracy further.
- Monochromatic extended source fluxes are quoted assuming the standard $\nu * F_\nu$=const. reference spectrum.



Solid angles in [arcsec^2]	PSW	PMW	PLW
Measured with Neptune spectrum	450	795	1665
SPIRE photometer reference spectrum (nu*F_nu = const.)	465	822	1768

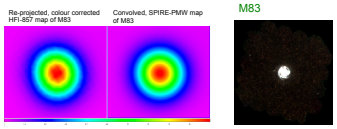
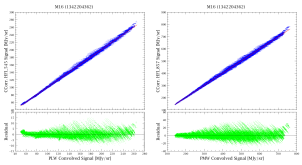


Fig. 5: Although the spatial resolution of the HFI-857 and HFI-545 filters is around 5', we use coarser HFI maps that were convolved to an effective Gaussian beam profile of 8' FWHM. Thus we don't need to treat the complex dependence of the effective HFI beam profile on sky position. Above shows the map of M83: (Left) as interpolated from the HFI maps, (Middle) convolved with an 8" Gaussian, and (Right) as original SPIRE map. A small, for our purposes negligible elongation is still visible.



Flux ranges of compared celestial maps

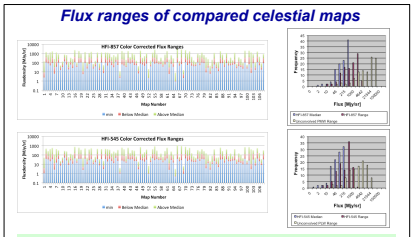


Fig. 3: The data consist of the largest SPIRE maps found in the Herschel Science Archive. They were selected to cover sufficient dynamic ranges to keep the errors low for a gain comparison, and to cover a good range of different zero-points as well. The plots on the left show flux minima, and ranges below and above the flux median (~background level) of the HFI maps for each map. On the left histograms indicate the distributions of median flux levels and flux ranges of HFI maps and the unconvolved SPIRE input maps. The convolution to the HFI beam-size reduces the flux ranges by more than an order of magnitude.

The fields included in the gain comparison are listed below.

Obj #	Field Name
1	LMC-epoch2-6
2	Field 330_0
3	Field 321_0
4	Field 290_0
5	Field 336_0
6	OrionA-C-1
7	Field 39_0
8	Field 292_0
9	G164.71-5.64-1
10	Field 105_1
11	M16
12	Field 77_0
13	l59
14	Field 209_0
15	Field 143_0
16	Field 312_0
17	higal_343
18	Field 35_0
19	Field 101_1
20	Cham1
21	Field 81_1
22	Field 147_0
23	Field 17_0
24	Field 325_0
25	Field 129_1
26	Field 66_0
27	Field 341_0
28	Field 213_0
29	Field 6_0
30	higal_341
31	G155.80-14.24-1
32	Field 305_0
33	Field 343_0
34	Field 301_0
35	Main2
36	Field 79_1
37	higal_303
38	mB1
39	Field 33_0
40	higal_305
41	Field 138_1
42	Field 8_0
43	Field 52_0
44	Field 347_0
45	Field 308_0
46	Field 92_1
47	T3
48	Lampethia
49	higal_159
50	GP299
51	Field 312_0
52	M83
53	Field 4_0
54	Field 96_1
55	Field 41_0
56	Field 13_0
57	G82.65-2.00-1
58	Field 83_1
59	Field 103_1
60	Field 46_0
61	Field 11_0
62	OrionA-S-1
63	Field 319_0
64	Field 63_0
65	MESIER101
66	Field 15_0
67	Field 94_1
68	l30
69	UrsaMajor
70	Field 303_0
71	Field 334_0
72	Field 28_0
73	Field 70_0
74	Field 99_1
75	Field 88_1
76	Field 356_0
77	Field 74_0
78	Field 314_0
79	Field 345_0
80	OrionB-N-1
81	Field 136_1
82	G210.90-36.55-1
83	Field 151_0
84	Field 26_0
85	Field 149_0
86	OrionB-NN-1
87	Field 323_0
88	Field 338_0
89	AFGL4029sulrh
90	Field 19_0
91	Field 90_1
92	Field 85_1
93	Field 72_0
94	Field 316_0
95	Field 127_1
96	Field 294_0
97	Field 140_0
98	Field 145_0
99	Field 22_0
100	Field 24_0
101	G139.60-3.06-1
102	OrionB-S-1
103	G202.02-2.85-1
104	Field 310_0
105	Field 327_0
106	Field 297_0
107	Field 211_0
108	Field 37_0

Comparison of HFI and SPIRE photometric gains

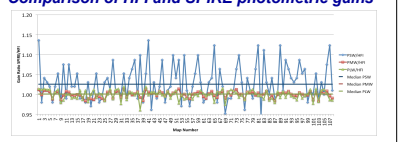


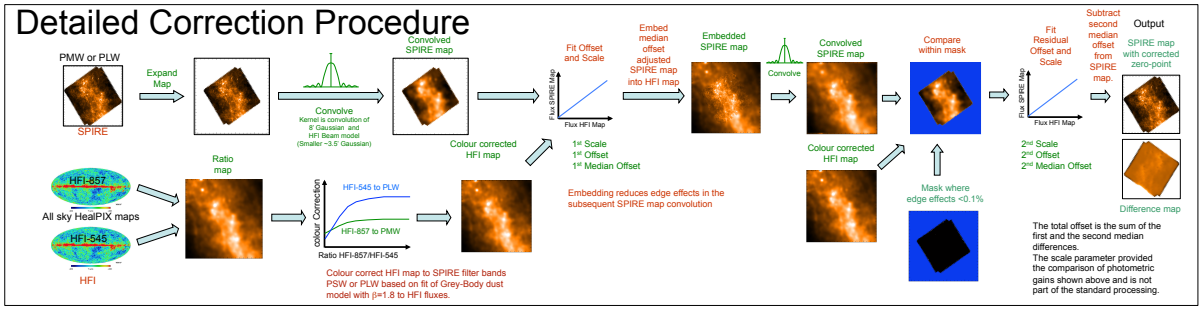
Fig. 6: Residual photometric gain comparison of 108 large SPIRE PSW (250µm), PMW (350µm), and PLW (500µm) maps, converted to extended source units, with the corresponding colour-corrected maps derived from the HFI 857 and 545 GHz maps respectively. The HFI 857 and 545 filter-bands were multiplied by the gain factors 0.965 and 1.000, yielding residual median gains of 1.000 compared to SPIRE-PMW and PLW respectively, with standard deviations of 0.008 and 0.012, i.e. only the HFI 857 channel differs from the SPIRE PMW photometry by 3.5%.

An extrapolation of the HFI maps to 250µm and comparison with the PSW band, based on a simple dust model assuming a Grey Body with β=1.8, shows a median gain ratio of 1.026 with a standard deviation of 0.045. These gain ratios are in substantially better agreement than the 10% absolute flux calibration uncertainty quoted for the HFI maps. The larger scatter in the PSW gains is likely due to extrapolation errors and the simple nature of the dust model used.

Conclusions

- The new zero point correction is functional since HIPE 10. Since the Planck maps became public in April 2013, astronomers can exercise the algorithm on their own computer.
- The new maps fit into the new Level 2 product structure adopted by SPIRE for HIPE 10.
- The new Level 2 product structure contains zero-point corrected SPIRE maps in [MJy/sr] and keywords specifying the median and the standard deviation of the difference map.
- New solid angles for the conversion to extended source fluxes have been determined to an accuracy of 4%.
- New "shadow" observations will improve the accuracy further and are being analysed.
- The current HFI maps are excellent photometric agreement with the SPIRE maps within 3.5%, substantially better than the quoted 10% absolute photometric accuracy of the HFI maps.

Detailed Correction Procedure



The total offset is the sum of the first and the second median differences.
The scale parameter provided the comparison of photometric gains shown above and is not part of the standard processing.

References

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Griffin, M. et al. 2010, A&A, 518, L3
Pilbratt, G. L., et al. 2010, A&A, 518, L1

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