SPIRE Spectrometer Bright Mode Calibration Products

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1.1 Reference Documents

RD1	SPIRE Bolometer Phase Calibration Product, SPIRE-RAL-NOT-03266, Issue 1, 10 August 2011

1.2 Introduction

This technical note describes the Spectrometer Bright Mode calibration products, *SCalSpecBrightGain* and *SCalSpecNomPcal*. The aim of these calibration products is to contain the factors needed to correct observations made using “bright mode” detector settings.

The standard bright mode uses the bolometers with a dephased high bias setting (previously a dephased nominal bias setting was testing during PV phase) – the bright mode settings are described in RD1. The calibration products contain the parameters necessary to process the high bias mode observations in the temperature pipeline. The gain is corrected in the pipeline by comparing the PCAL flash measurements with the average nominal mode flash value, which is contained in the *SCalSpecNomPcal* product. In addition, the wavenumber dependent gain is corrected using the gradient and intercept of a straight line which is stored in the *SCalSpecBrightGain* product.

1.3 PCAL factors

The correction for the dephase angle, and the conversion to temperature using the bolometer model does not completely correct for the responsivity difference of the detectors in the high bias mode. The remaining gain is taken into account empirically using the PCAL flash that is made at the beginning of each observation. The separation in observed signal between the two PCAL levels is determined using the “pcal” task in the pipeline. The following plots (Figure 1) show the results for the actual PCAL values for all bright mode (old and high bias) observations up to OD857, and the day by day ratio of nominal/bright PCAL value. The processing was done using the in flight bolometer parameters that will be used in the v8 calibration tree, and the updated engineering conversion with phase correction from v8.

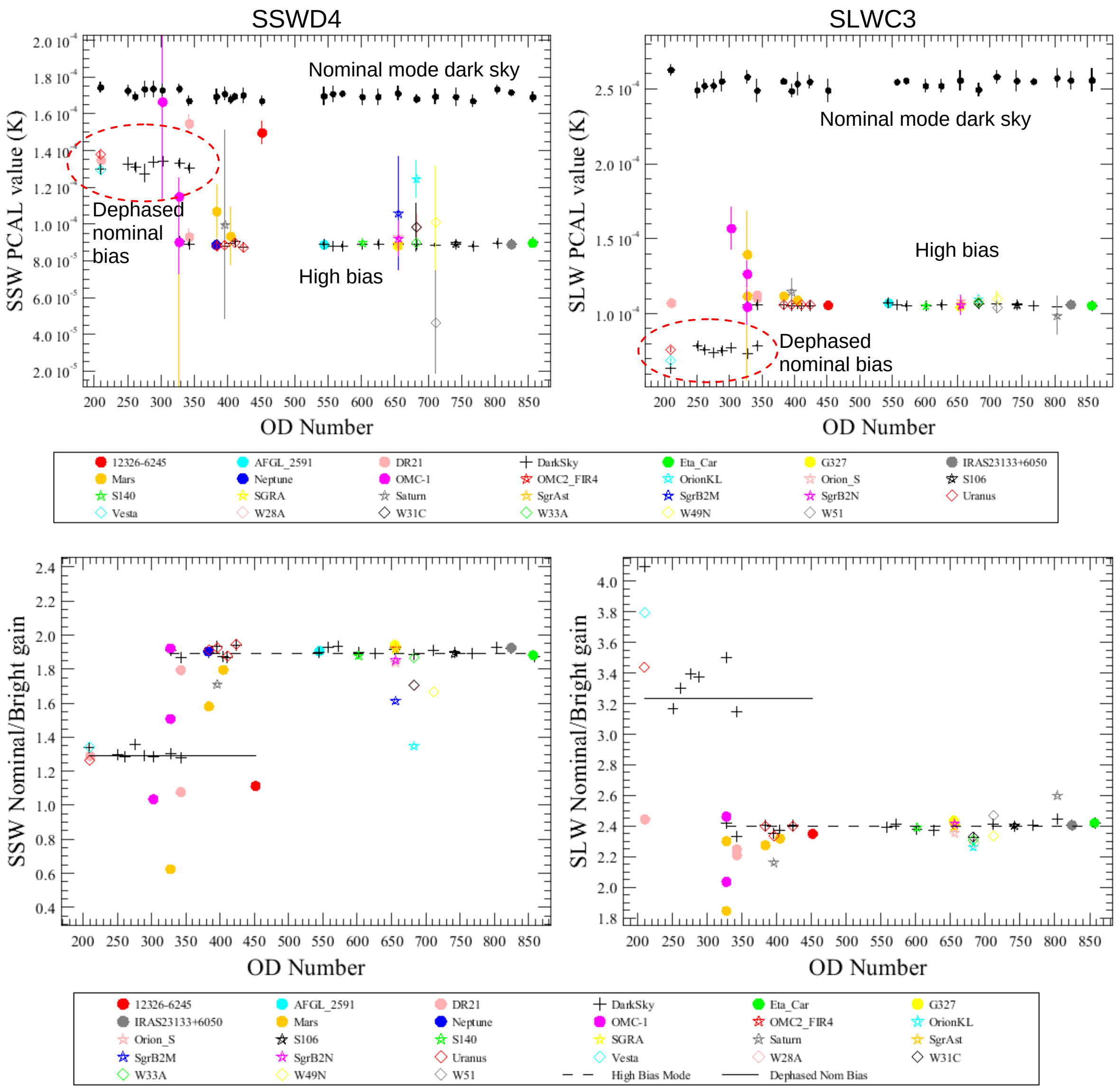

***Figure 1:** PCAL values and ratios for SSWD4 and SLWC3 for all bright mode observations observed up to OD741 (both the dephased nominal bias mode and the high bias mode).*

Figure 1 shows that not all of the nonlinearity has been removed by using the bolometer model to convert voltage to temperature units (the brighter sources have a higher PCAL value and a lower nominal/bright ratio). Applying these PCAL ratios, which are lower for brighter sources, is an empirical way of correcting the non-linearity.

In calculating this ratio, the nominal flashes were taken from dark sky observations, rather than observations including the source. This is the way that the flashes should be compared – the PCAL ratio in the pipeline to determine the bright mode gain should be the ratio from a good nominal calibration, to that of the bright mode with the bright source in the beam. Taking the ratio from the nominal PCAL value with the bright source in the beam, would assume that the nominal calibration is good up to the brightness of the source, which may not be true. It certainly isn't true for Mars – a test was performed on OD383 where a nominal mode PCAL flash was observed towards Mars. The PCAL value is **lower** than for observations of dark sky – this is clear for SLWC3 where the errors on the derived PCAL values are small (errors for SSWD4 are larger). It is in contrast to the High Bias mode, where the PCAL value is higher for brighter sources.

The plots of the PCAL ratio in the lower panels of Figure 1 show the median value for each of the two bright source modes (dashed and solid lines). These median values (nominal/bright) are given in Table 3 for the centre detectors. Note that for real bright sources, the PCAL ratio changes.

Mode	SSWD4	SLWC3
High Bias	1.8963	2.3980
Dephased Nom Bias	1.2918	3.2365

***Table 3:** Median gains calculated from the PCAL flash ratios for the central detectors.*

The PCAL ratios in Figure 1 were calculated day by day, using the nominal mode dark sky observation from the day of the bright source observation. However, in the pipeline, it is better to store an average nominal PCAL value in the calibration product and apply it to all bright observations. Figure 2 shows the PCAL value for the nominal mode dark sky observations (just from ODs which also had a bright mode observation – the list of obsids used is given in the Nominal mode column of Table 4) for all detectors divided by the weighted mean value for each detector. This shows that the PCAL value in nominal mode does have some OD to OD variations that seem to be correlated between detectors. The standard deviation over the period from OD 250 to OD 857 for each detector is between 1 – 2%.

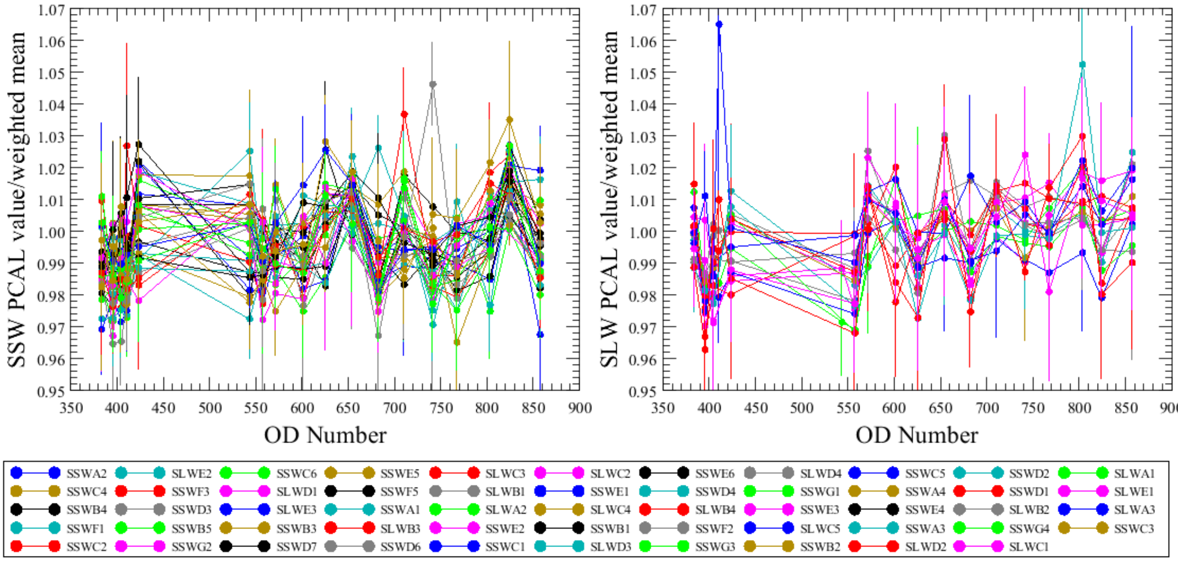

***Figure 2:** Nominal mode PCAL flashes for all detectors (compared to weighted mean) for OD 250 to OD 847.*

The weighted mean PCAL value for each detector is entered into the calibration product. Note that deglitching was applied after conversion to temperature units for the nominal PCAL flashes entered into the calibration product.

1.4 Wavenumber dependent gain

After applying the PCAL factors, there is another additional gain effect that depends on wavenumber. This can be determined by processing observations of Dark Sky in both nominal and bright modes and taking the ratio. The ratio should be calculated immediately after Fourier Transform before subtraction of any contribution from the telescope or instrument and flux conversion (relying on the two observations being taken very close together in time). This dark sky ratio is also an independent check of the gain calculated from the PCAL flashes for sources not brighter than the telescope. The nominal mode observations are sometimes much longer than the bright mode ones, and so only the first 10 scans from the nominal observation were used for the comparison. Forward and reverse scans were averaged together.

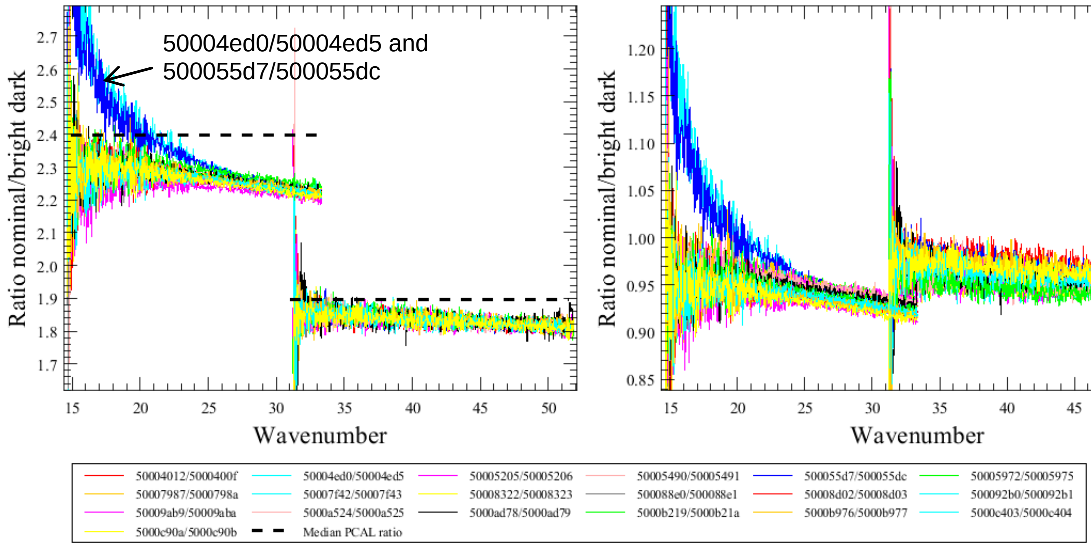

Figure 3: *Ratio of the signal observed on dark sky with nominal and high bias bright modes (before any subtraction of instrument and telescope, or any flux calibration) for SLWC3 and SSWD4. The left plot shows the result without applying the PCAL gain, and the right plot is with the PCAL gain included.*

Figure 3 shows that the ratio of the darks almost agrees with the median PCAL ratio from Table 3 at the low wavenumber end of each band, and that there is a linear decrease in the gain through the band. There are two pairs of observations for SLW where the contribution to the spectrum from the instrument seems to have changed between the nominal and bright mode observations: 50004ed0/50004ed5 and 500055d7/500055dc.

Looking in more detail shows that the median PCAL ratio does not exactly agree with the dark sky ratio. Figure 3 (right) shows the ratio of the dark sky spectra after applying the PCAL gain ratio. The spread between different observations is now higher, and most observations don't cross 1.0. This shows that the PCAL calculation is introducing some uncertainty in the gain correction – maybe this is due to the limited S/N in the bright mode PCAL flashes, or due to the method of using the mean nominal PCAL value rather than the value from the day of the observation. However, the overall gain must be still be derived from the PCAL ratio in the pipeline, because the value changes for sources brighter than the telescope and so could not be determined directly from the dark sky ratios.

There is no way to measure the wavenumber dependent gain for real bright sources (as the calibration in nominal mode is not good), and so the gradient derived from dark sky must be assumed to be applicable to all sources.

To derive the calibration file, a straight line was fitted to the dark sky ratios after applying the PCAL gain correction. For SLW, only wavenumbers above 24 cm^{-1} were used in the fit to avoid the noisy region at low wavenumbers. The two pairs of observations with a large deviation in SLW (50004ed0/50004ed5 and 500055d7/500055dc) were excluded from the fit for SLW. The observation 0x500092b1 had a problem with the SLW processing so was not included in the final value. The observations used are shown in Table 4. The final values entered into the calibration file are the mean intercept and gradient over all of these observations. These mean values for SSWD4 and SLWC3 are given in Table 5 and the results for the other detectors shown in Figure 5.

OD	Bright Mode Obsid	Nominal Mode Obsid	Comment
327	0x5000400f	0x50004012	
383	0x50004ed5	0x50004ed0	excluded for SLW
395	0x50005206	0x50005205	
404	0x50005491	0x50005490	
410	0x500055dc	0x500055d7	excluded for SLW
423	0x50005975	0x50005972	
543	0x5000798a	0x50007987	
557	0x50007f43	0x50007f42	
571	0x50008323	0x50008322	
601	0x500088e1	0x500088e0	
625	0x50008d03	0x50008d02	
654	0x500092b1	0x500092b0	excluded for SLW
682	0x50009aba	0x50009ab9	
710	0x5000a525	0x5000a524	
741	0x5000ad79	0x5000ad78	
767	0x5000b21a	0x5000b219	
803	0x5000b977	0x5000b976	
824	0x5000c404	0x5000c403	
857	0x5000c90b	0x5000c90a	

Table 4: *Observations used to calculate the wavenumber dependent gain.*

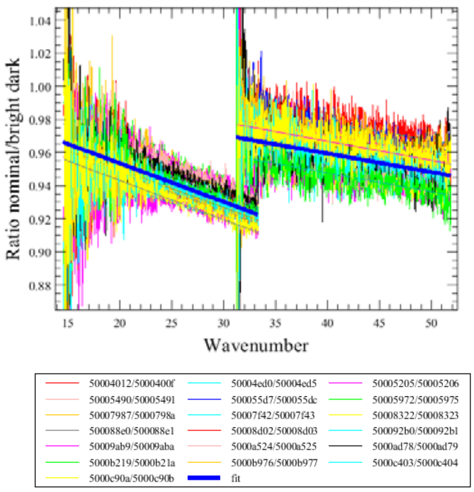

Figure 4: *The nominal/bright ratio for observations from Table 4 showing the fits and final mean fit (thick blue line) for detectors SLWC3 and SSWD4.*

	SLWC3	SSWD4
intercept	1.00017268986	1.00418759493
gradient	-0.00232927332286	-0.00111796538707

Table 5*: Average intercept and gradient for central detectors*

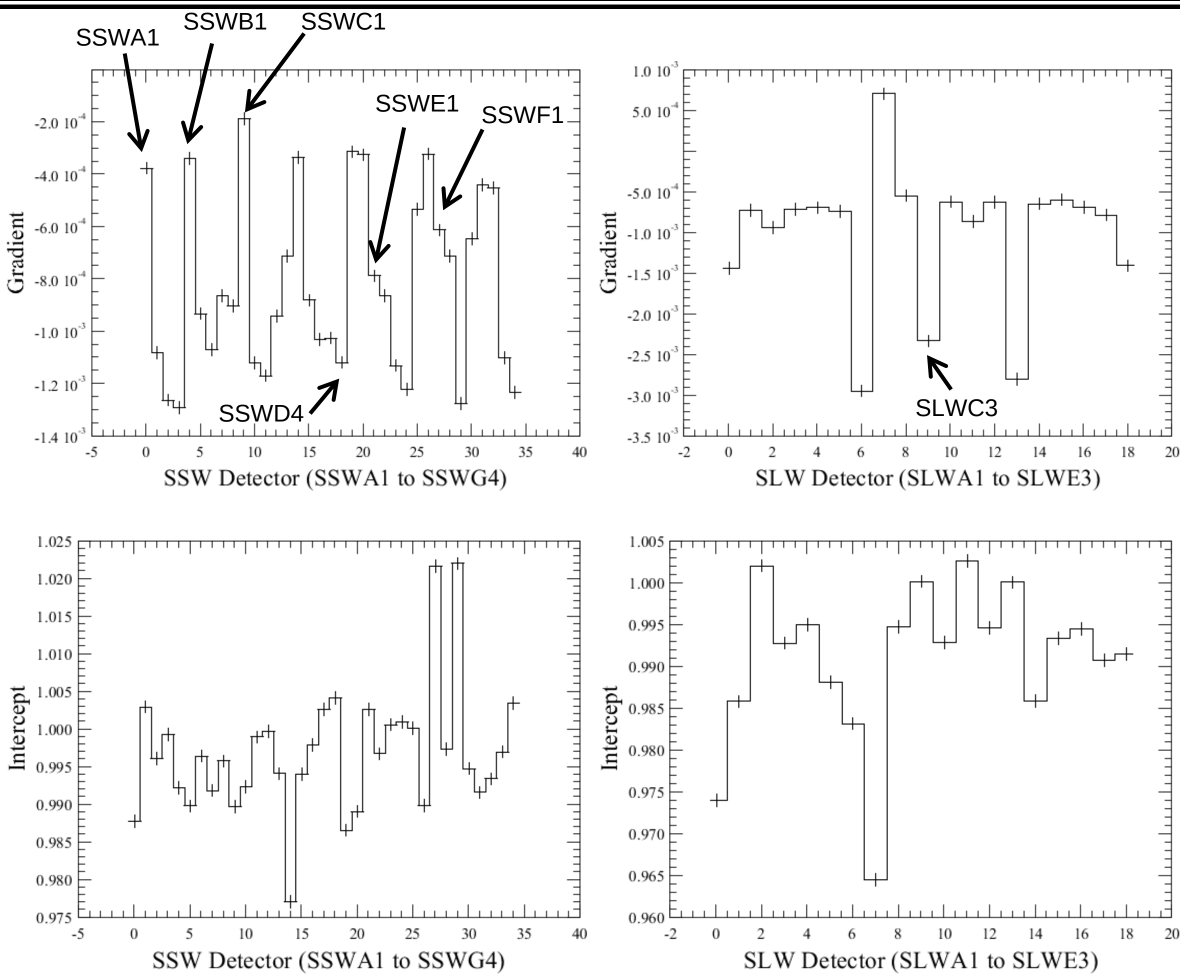

Figure 5: *Mean gradient and intercept for all detectors as entered into the calibration product.*