70μm Warm Campaign Sensitivity Tests: Part 2

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Abstract

Data were taken to quantify the 70μm sensitivity and data quality for the proposed warm MIPS campaigns. On 2005 May 25, 70μm data of the xFLS were taken with a telescope temperature of 9.5 K, instead of the normal operating temperature of about 5.6 K. We found that the new xFLS data had a degradation in sensitivity of about 20%. Accounting for the increased background level at the time of the observations, the measured excess noise for the 9.5 K xFLS data is $13 \pm 5\%$ (see original report, 2005-Jun-16, Version 1.). Given the time-lag between the xFLS observations, the different backgrounds, and different bias settings, it was not clear what fraction of the degradation in sensitivity was due to the warm optics. We have recently taken additional 70μm xFLS data at both 8.5 K and at 5.6 K (2005 August) to directly compare the sensitivity at similar backgrounds and instrument settings. The latest data sets at 8.5 K and 5.6 K have the similar noise levels for the filtered-BCDs (sensitivity measurement appropriate for point sources) and have similar pixel scatter for the BCD data (sensitivity measurement appropriate for extended sources). We find no measurably change in sensitivity of the 70μm data as a function of temperature below 8.5 K.

1 Warm Test Data

1.1 xFLS

Warm xFLS 9.5 K data (21.2MC) were taken in 2005 May and additional data at 8.4 K (23.2MC) were taken in 2005 August. The original xFLS data were taken in 2003 December (1MC). For direct comparisons with the recent warm xFLS test data, 3 AORs at 5.6 K were taken in latest MIPS Campaign (24 MC, 2005 August). One of these AORs matched the 8.4 K AOR and two additional xFLS AORs were taken in 24MC to compare side-B compressed verses uncompressed 70μm data. Since the compression of side-B has been shown to have no measurably effects on side-A, all three 24MC AORs can be used for comparison with the warm xFLS data. Table 1 shows a listing of the xFLS AORs.

1.2 Cal-star HD163588

Cal-star data from campaigns 21–24MC, including observations from the short ToO campaigns, were analyzed to help quantify the effects of sensitivity as a function of temperature. The cal-star observations are short (few minutes) in comparison to the xFLS data which represent 1.5-3 hours of observations per AOR, but provide an additional check on the results. Table 2 list the cal-star AORs.

2 Data Reduction

The data were reduced by processing the RAW data from the SSC sandbox through the public offline GeRT (version 050405). The calibration files were the standard files used for S11+S12 online processing, and the software and cdf files are consistent with the current SSC S12 processing. The filtered and non-filtered data cubes (intermediate pipeline data products) were used for sensitivity measurements.

Table 1: xFLS Data

MC	AORKEY	Temp.	SPOT Bkg	BCD Bkg	σ(BCD)	rms(fBCD)
		[K]	[MJy/sr]	[MJy/sr]	[MJy/sr]	[MJy/sr]
(1)	(2)	(3)	(4)	(5)	(6)	(7)
1	3863808	5.28	4.049	5.069	0.875	1.057
1	3864064	5.28	4.049	5.116	0.955	1.067
1	3864320	5.28	4.049	5.073	0.935	1.060
1	3864576	5.28	4.049	5.047	0.902	1.059
1	3864832	5.28	4.049	5.006	0.796	1.036
1	3865088	5.28	4.049	5.184	1.000	1.058
1	3865344	5.28	4.049	5.093	0.937	1.056
1	3865600	5.28	4.049	4.990	0.811	1.044
1	3865856	5.28	4.049	4.632	0.522	1.027
1	3866112	5.28	4.049	6.055	1.635	1.119
1	3866368	5.28	4.049	4.520	0.433	1.016
1	3866624	5.28	4.049	5.965	1.597	1.124
21.3	13787136	9.53	4.614	5.682	0.260	1.245
21.3	13787392	9.53	4.614	5.656	0.316	1.274
21.3	13787648	9.53	4.614	5.611	0.312	1.289
21.3	13787904	9.53	4.614	5.497	0.255	1.223
21.3	13788160	9.53	4.614	5.590	0.300	1.281
21.3	13788416	9.53	4.614	5.565	0.317	1.289
23.2	15715328	8.39	4.531	4.782	0.321	1.145
24	15820288	5.62	3.963	4.526	0.356	1.246
24	15820544	5.62	3.962	4.849	0.370	1.255
24	15819520	5.58	4.397	4.510	0.275	1.248

(1) MC is the MIPS Campaign number. (2) AORKEY is the AOR number. (3) Temp is the temperature of the primary mirror given by telemetry channel O-2222. (4) The SPOT Bkg is the predicted total background level at the time of observations. (5) The BCD Bkg is the measured background level derived from the BCDs. BCD Bkg is derived by taking a median of the stacked BCD data cube per pixel (i,j), ignoring stims and outliers, yielding a $\mathrm{BCD(i,j)}_{\mathrm{median}}$ image, and then by taking the median of $\mathrm{BCD(i,j)}_{\mathrm{median}}$ image to derive an array average BCD level. (6) σ(BCD) is the pixel-to-pixel scatter of the background level given by the standard deviation of the $\mathrm{BCD(i,j)}_{\mathrm{median}}$ image; σ(BCD) represents the error measurement appropriate for extended sources/regions. (7) rms(fBCD) is the error measurement appropriate for point sources based on the stacked filtered BCD data cubes (fBCD products). The rms for each pixel is derived by calculating a clipped standard deviation (ignoring stims and outliers of more than 3σ) through the data cube. The median of the resulting rms(i,j) image is used to derive an array average rms.

3 Results

3.1 DARK Level

From the DARK measurements for the 17 MIPS campaigns (post bias change), we find an average DARK signal for cold MIPS data of 4.15 ± 0.13 MJy/sr (where the error is the standard deviation of the measured values for the campaigns) with a range of values of 4.02–4.34 MJy/sr. The DARK measurement taken during the warm 9.5 K warm campaign is 4.48 MJy/sr. Currently, this suggests a small but measurable change in the DARK level. The difference in the DARK signal (warm−cold) is 0.33±0.18 MJy/sr (where we have assumed $2^{0.5} \times \sigma(cold)$ for the error). We would need additional campaigns to quantify the repeatability of the DARK level for warm campaigns. If a warm DARK calibration file is needed, it would be made by the IST and would be implemented online as a fall-back calibration file as currently being done for the cold campaigns. Currently, all data were reduced using the cold DARK calibration file.

Table 2: Calibration Star HD163588

MC	AORKEY	Temp. [K]	SPOT Bkg [MJy/sr]	BCD Bkg [MJy/sr]	σ(BCD) [MJy/sr]	rms(fBCD) [MJy/sr]
(1)	(2)	(3)	(4)	(5)	(6)	(7)
21.1	13586432	6.00	5.208	7.323	0.609	1.788
21.1	13587200	5.62	5.184	8.461	1.364	1.845
21.1	13585664	5.48	5.157	7.603	0.678	1.877
21.1	13587968	5.48	5.156	7.630	0.677	1.883
21.2	15355392	9.78	5.112	8.463	0.876	1.905
21.3	13786880	9.53	5.105	8.595	1.454	1.971
21.4	15356160	9.36	5.088	8.449	1.066	1.907
22	15217408	5.69	4.972	7.361	0.704	1.907
22	15221760	5.48	4.860	7.056	0.605	1.967
23.1	15413504	5.64	4.627	7.021	0.663	1.982
23.1	15414528	5.54	4.599	6.937	0.675	1.951
23.1	15415552	5.49	4.564	7.707	1.214	1.950
23.2	15718144	8.39	4.532	6.903	0.559	1.764
24	15815424	5.61	4.400	6.649	0.598	1.798

3.2 Filtered BCD Sensitivity

The stacked filtered BCD data cubes (fBCD products) were used to quantify the sensitivity. The rms for each pixel was derived by calculating a clipped standard deviation (ignoring stims and outliers of more than 3σ) through the data cube. The median of the resulting rms(i,j) image was used to derive an array average rms. This rms corresponds to the average noise per detector for the filtered products. By using the stacked fbcd cubes, we can detect smaller variations in sensitivity than from measurements of the coadded mosaics.

Figure 1 shows the fBCD sensitivity for the xFLS AORs as a function of temperature. The early 1MC data at 5.28 K have a sensitivity that is about 20% better than the warm test data (9.5 K and 8.4 K), but the recent cold xFLS data taken in 24MC have similar sensitivities as the warm data. The early 1MC data were taken with the old bias setting which yielded significant data artifacts. Interesting, the scatter in BCD data [σ(BCD) in Table 1] due to the artifacts is much larger in 1MC, but after filtering the rms is actually better for the 1MC data than for any other xFLS data taken to date, regardless of temperature. The reason for low 1MC fBCD rms is not known; it could be related to the bias setting and/or other effects. For a direct comparison of sensitivity as a function of temperature, the 1MC data should be ignored.

Since the background changes as a function of time (zody level varies from campaign to campaign), the measurements need to be placed on the same level for accurate comparisons. The range of predicted backgrounds from SPOT (at the effective wavelength of 71.4μm of the MIPS-70 band) vary from 3.96 to 4.61 MJy/sr. Although this represents a relatively small change in the background (16%), the predicted change in sensitivity is significant (8%, assuming $\sigma \propto \mathrm{Bkg}^{0.5}$ which is applicable for Ge data with short integration times). The predicted backgrounds from SPOT are only approximate at longer wavelengths and tend to be lower than the actual background measure-

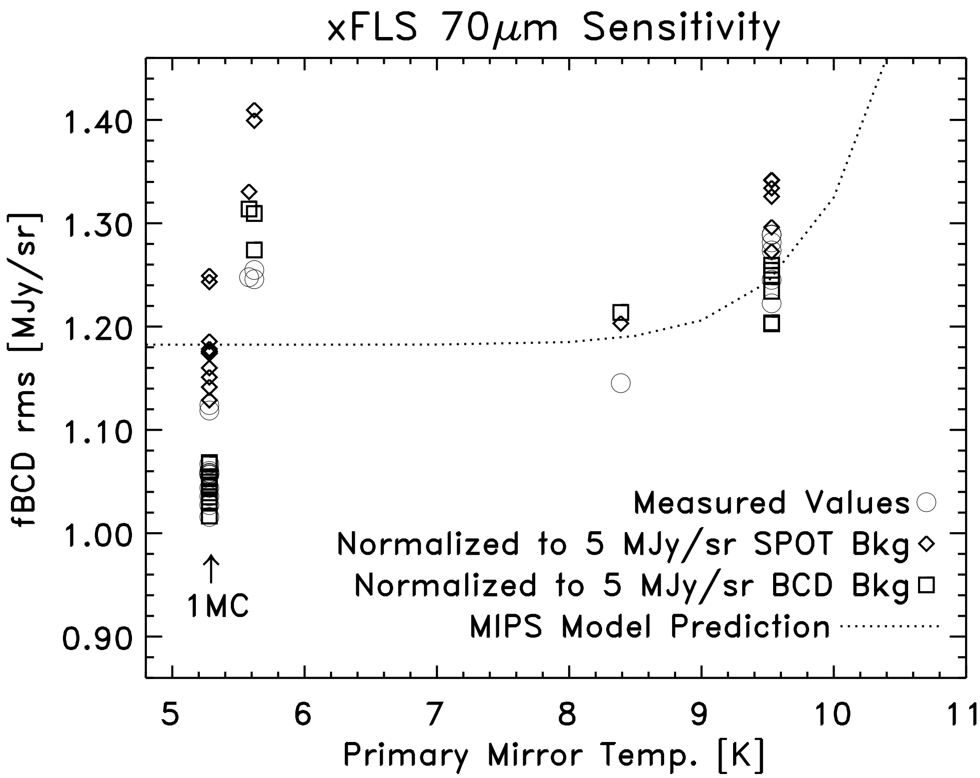

Figure 1: The average xFLS 70μm 1σ noise level per pixel for the fBCD (filtered-BCD) data as a function of mirror temperature. Each data point represents an AOR. The open circles are the actual measurements. The squares are normalized to place the data on the same 5 MJy/sr background level as observed for the BCDs (after correcting for extra DARK signal for the warm data and assuming $\sigma \propto \mathrm{Bkg}^{0.5}$). The diamonds are normalized to place data on same 5 MJy/sr background level as predicted by SPOT at the time of the observations. The dotted line represents predictions from the MIPS model for low background regions. The data at the lowest temperature is the pre-bias change data of 1MC.

ments given by the BCDs for these data (Table 1&2). We scaled the measurements to both the backgrounds predicted by SPOT and the observed BCD level. For the WARM AORs (21.3MC and 23.2MC), we corrected the measured BCD level by the elevated warm DARK signal (0.33 MJy/sr, Sec. 3.1) before scaling the sensitivity values to the same background level. The data scaled to the BCD background level yielded the smallest scatter (squares in Figure 1). Based on the data normalized to the same BCD level, we derive a ratio in the rms of WARM/COLD$= 0.95 \pm 0.04$. The WARM AORs are from 21.3MC and 23.2MC, while the COLD AORs are from 24MC. For comparison, normalization to the SPOT background yields WARM/COLD$= 0.94 \pm 0.07$, and the observed data points give WARM/COLD$= 1.00 \pm 0.06$. The results are consistent with no change in sensitivity as a function of temperature, over the observed range of temperatures.

In Figure 1 we show the predicted noise level as a function of temperature based on the MIPS model from the MIPS Instrument Team. No significant changes to the model were made to match the data. We simply updated a few input parameters to match the in-flight performance of the array. In particular, the reset period was changed to 4 sec to match the medium scan rate xFLS data, the cosmic ray rate was increased to 0.1 CR/sec per pixel, and the "flat fielding" error was increased to 0.05 to match the stim repeatability measurements. For those familiar with the details of the MIPS model, we used the default SSC fudge factor of 1.2 and the default background parameter of 1.2 above the minimum background (represents values for low backgrounds). The predicted noise levels with these updated parameters are consistent with the measured noise values and are 3.8× larger than the predictions from the default pre-flight parameters. Using this model, we would predict a degradation in sensitivity of about 5% at 9.5 K and less than 1% at 8.5 K.

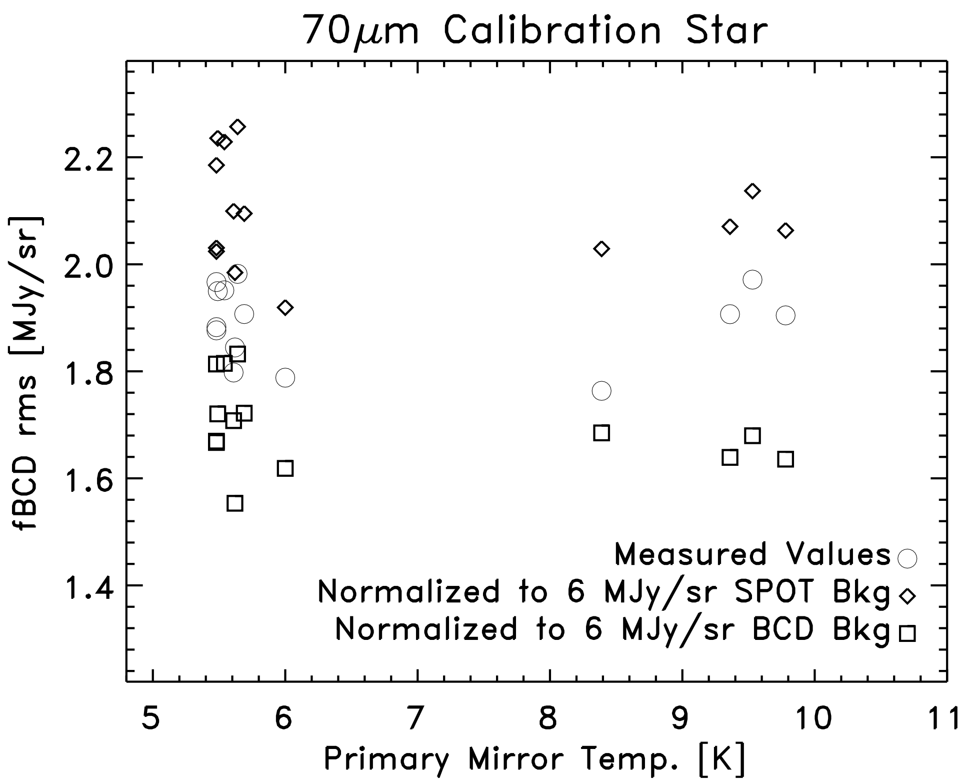

Figure 2: The average 70μm 1σ noise level per pixel for the fBCD (filtered-BCD) data of the calibration star as a function of mirror temperature.

For an independent check on sensitivity, similar noise measurements were made for fBCD calstar data (Fig. 2). Based on the data normalized to the same BCD level, we derive a ratio in the rms of WARM/COLD$= 0.97 \pm 0.04$. For comparison, normalization to the SPOT background yields WARM/COLD$= 1.00 \pm 0.16$, and the observed data points give WARM/COLD$= 1.00 \pm 0.10$. Again, the results are consistent within errors with no change in sensitivity. We find that the scatter in sensitivity from campaign to campaign is larger than any sensitivity variations as a function of mirror temperature (over the observed temperature range); e.g., the cold data from 21MC and 24MC have measurably lower noise levels than the noise levels of the cold data from 22MC and 23MC.

3.3 Unfiltered BCD Sensitivity

The filtered BCD products are excellent for point-source science, but the unfiltered (default) BCDs are needed for extended sources. To estimate the sensitivity for the BCDs, we also used the stacked data products, similar to the analysis done with the filtered-BCDs. However, instead of using the rms as a function of time per pixel (as done for the fBCDs), we derived an extended source sensitivity by measuring the pixel-to-pixel scatter of the observed BCD level (background measurement). The BCD level is derived for each pixel (i,i) by taking a median of the stacked BCD data cube (ignoring stims and outliers) yielding a $BCD(i,j)_{median}$ image. The BCD noise [σ(BCD)] is then derived by taking the standard deviation of the $BCD(i,j)_{median}$ image.

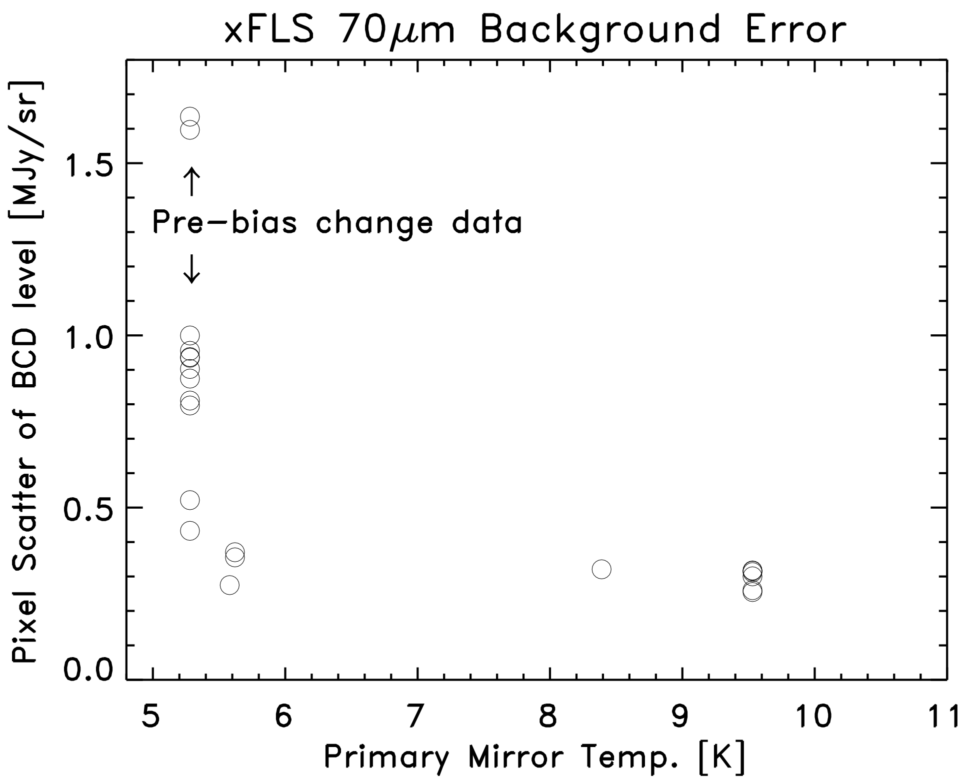

Figure 3: The average 70μm 1σ pixel scatter of the BCD level of the xFLS observations. Each data point represents an AOR. The pre-bias change data are noisy due to data artifacts. The WARM and COLD data taken after the bias change are similar.

Figure 3 shows the measured BCD errors as a function of temperature for the xFLS. The early 1MC data have large BCD errors due to data artifacts (pre-bias data). There is no observed variation in the BCD errors as a function of temperature. We do not show the noise values re-scaled to the BCD and/or SPOT backgrounds since the points would lie nearly on top of each other (and since no additional information is provided by these points). Figure 4 shows similar results for the calibration star data. The BCD errors are more dependent on the degree of data artifacts than the mirror temperature (over the observed range of temperatures). BCD data taken right after an anneal are generally less noisy than data taken long after an anneal (e.g., see previous Ge telecon discussion: daveF_06aug04 which reports a decrease in the 70μm BCD sensitivity of 20% after ∼6 hours from an anneal).

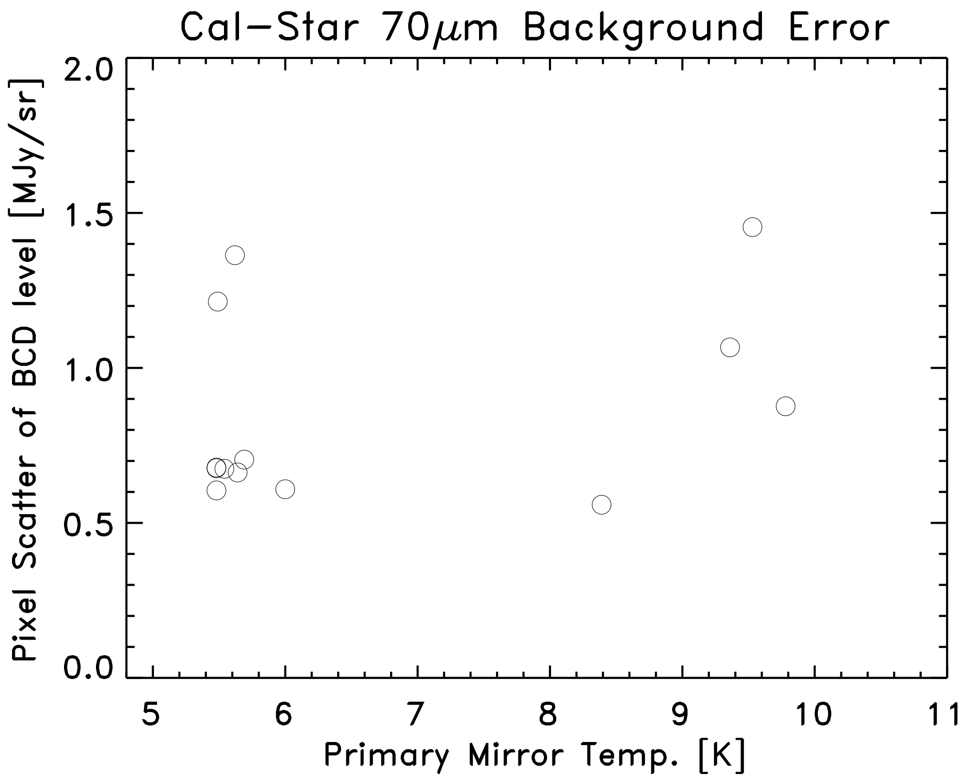

Figure 4: The average 70μm 1σ pixel scatter of the BCD level of the cal-star observations. Each data point represents an AOR. The WARM and COLD data are similar.

4 Conclusions

The 70μm sensitivity and data quality will not be dramatically affected for the warm MIPS campaigns (~ 8.5 K). No change in the absolute flux calibration was detected. The DARK level may be slightly elevated by 0.33 ± 0.18 MJy/sr. If the DARK level is found to be consistently higher for the warm-MIPS campaigns, we will need an updated warm DARK fall-back calibration file for pipeline processing (not a big impact on downlink/IST resources).

The largest concern for warm MIPS data was the potential impact on the 70μm sensitivity. From the previous report, there was evidence for a possible degradation in sensitivity at the warmer temperatures. The recent data shows no measurable change in sensitivity as a function of temperature. The new cold xFLS data have similar noise levels as the warm xFLS data, and the rms levels of the cal-star data over several campaigns show variations in noise levels that are larger than differences based on temperature. The data at 8.5 K and 5.6 K have the similar noise levels for both the point-source and extended-source noise. This is consistent with models that predict less than a 1% change in sensitivity at 8.5 K. In summary, we find no measurably degradation in sensitivity of the 70μm data as a function of temperature below 8.5 K.