Report Title Bad Pixel Report	**Document Number** SDL/09-099
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1. INTRODUCTION

This report presents the initial criteria for determining bad pixels in the WISE flight arrays. The resulting bad pixel maps were used in several subsequent analyses including dark, scatter source response, non-linearity, and peak radiance responsivity (the results from these analyses were not available at the time the bad pixel maps were generated). Final characterization results could be used to create an updated final bad pixel map. Summaries for signal, noise, and flatfield response are provided. For a full explanation of the results, see the respective characterization reports. The purpose here is to identify pixels that clearly can not be calibrated, and thus these criteria can miss some bad pixels. Additional pixels that are found to be bad when determining other calibration products (e.g. linearity) are discussed in those reports.

1.1 SOURCE DATA

I used DRK0282 for dark data, which is a long dark in flight configuration. It has some excess noise in B3, B4 so I also looked at CHK0119 (same configuration, but less noise).

For flatfields I use RSP0038_b1, RSP0030_b2, and RSP0020_b3 with RSP0001 subtracted as dark and I also use RSP0045 with RSP0041 subtracted as dark. The flatfields are normalized to have a median value of 1.0.

1.2 NOISE CALCULATION

Noise (RMS) is always calculated as $\sqrt{\dfrac{\sum_{n=0}^{N-1}\left(x_n - \langle x\rangle\right)^2}{N}}$.

1.3 SUMMARY OF RESULTS

From the dark data, I calculated an image with the mean pixel values over the set and an image containing the noise on each pixel. From the background subtracted extended source response data, I calculated a flatfield by dividing each pixel value by the median pixel value. The statistical results from the mean image, noise image and the flatfield are given in the table below. The range for signal, noise, and flat is an approximate range where most pixels fall. The histograms look approximately Gaussian, and further details are given in the sections for each band below.

The min and max signal, noise, and flat values are the limits used to define bad pixels. The value in parentheses is the number of pixels that fall outside of this limit. Sections 2 to 5 describe how these limits were determined.

Band	1	2	3	4
Sig Range	124 to 130	124 to 130	130 to 300	120 to 330
Mean Sig	129.77	131.06	270.56	305.09
Median Sig	126.80	126.88	273.95	298.39
Rms Sig	88.31	103.06	69.44	514.26
Noise Range	2 to 9	2 to 9	14 to 30	8 to 16
Mean Noise	3.22	3.10	21.63	11.83
Median Noise	2.96	2.82	21.52	11.76
Rms of Noise	5.39	4.27	2.21	22.05
Flat field range	0.8 to 1.1	0.75 to 1.15	0.9 to 1.2	0.92 to 1.09
Flat mean	0.978	0.976	0.984	0.979
Flat rms	0.133	0.144	0.127	0.127
Min sig (#)	10 (315)	10 (1357)	50 (7)	50 (3)
Max sig (#)	No limit	No limit	26000 (2)	26000 (65)
Min noise (#)	1.5 (323)	1.5 (1180)	12 (43)	6 (68)
Max noise (#)	15 (2437)	15 (2904)	36 (143)	18 (228)
Min flat value	0.5 (18521)	0.5 (20351)	0.8 (18906)	0.8 (5205)
Max flat value	1.2 (12)	1.3 (19)	1.6 (6)	1.5 (26)

2. BAND 1

2.1 DATA SUMMARIES

2.1.1 Signal

The signal histogram has a strong peak with a long, invisibly low tail (meaning that the histogram has to be scaled up in y to see this) to the right. 307 pixels are below 5, with hardly any between 5 and 115 (only 414 below this). Only 2204 pixels are above 180, but the tail goes out to 7000. 1264 pixels are above 1000. Columns are very faintly visible in an otherwise flat image.

2.1.2 Noise

The noise histogram has a strong peak with a long tail to the right. 309 pixels are zero, but hardly any between 0 and 1.6 (only 326 below this). The tail on the right is long and falls gradually. 9918 pixels are above 7, 4872 pixels are above 10, 2437 are above 15, 1346 are above 20, 712 above 30, and 203 above 100. The tail goes out to 1700. In the image, columns have differing noise levels, and start-of-row pixels have higher noise.

2.1.3 Flatfield

The flatfield has a peak at 1 and a second peak at zero. 770 pixels are below zero, 17936 are below 0.2 (these are mostly the reference pixels). 585 are between 0.2 and 0.5, and the main peak starts rising from here. 21258 are below 0.8. The cutoff is sharp on the other side—only 47 pixels are above 1.1, and 12 are above 1.2 with most of these at 2.25.

2.2 BAD PIXEL CRITERIA

Consider pixels with signal below 10 and noise below 1.5 to be bad. Too little noise means a pixel cannot be functioning properly. If the signal gets too close to zero, it may go negative from time to time and cannot have a correct reading. High dark value alone does not make a pixel bad, but pixels should be excluded for high noise.

The RMS deviation in a measurement of RMS is $\frac{\sigma}{\sqrt{2N_{pts}}}$.

With 120 points, this is only 0.19 for the median band 1 pixel noise. If all pixels had the same noise in reality, this would be the RMS of noise calculated for band 1. Not surprisingly, there is a real distribution of noise on a pixel.

A pixel with high dark current will have more noise. Since 128 is really zero counts (this is the DEB offset divided 8 for band 1), and using 3.829 e-/count, a pixel with 1000 counts should have noise of ~15, a pixel with 7000 counts should have noise of ~42, and a pixel with 180 counts should have a noise of 3.6. These RSS with the read noise (the increase of 1.041 in the dark current and photon noise due to sample up the ramp is ignored here). Of the 2437 pixels with noise above 15 counts, 996 have signal above 1000. This and the distributions above make it clear that most of the pixels that have high noise do not have it because of high dark current.

Call pixel with read noise above 15 bad. This is ~5 times median.

Pixels with a flatfield greater than 1.2 are bad. The other end of the range is more complicated. Clearly anything below 0.5 can be excluded. This removes most of the obvious clumps of bad pixels and the reference pixels and it overlaps with a fair number of low noise and high noise pixels, but it also excludes a few pixels randomly scattered around the array. Excluding below 0.8 removes a few more around the clumps but mostly removes pixels that are randomly scattered around the array. Thus I use 0.5 for the cutoff.

These criteria find 20476 bad pixels including the 16320 reference pixels. ~17700 of these are excluded due to low flatfield alone; another 1900 are too low noise alone. 520 have too low flatfield and too much noise, while 290 have too low signal, too low noise, and too low a flatfield value. Less than 100 are excluded by other combinations of criteria.

The file "Band1 Bads.deb" specifies which criteria exclude which pixels. The bad pixel mask is generated from this. Similar files exist for the other bands.

3. BAND 2

3.1 DATA SUMMARIES

3.1.1 Signal

The band 2 signal histogram has a strong peak with a long, invisibly low tail to the right. 1305 pixels are below 5, with a bunch uniformly distributed between 5 and 118 (2042 below this). Only 3227 pixels are above 230, and 3120 above 250 (where the fall from main peak pretty much flattens out). The tail goes out to 7000. 1831 pixels are above 1000. The image is quite flat, with columns faintly visible.

3.1.2 Noise

The noise histogram has a strong peak with a long tail to the right. 1080 pixels are zero, but few between zero and 1.7 (only 1190 below this). The tail to the right is long and falls gradually. 12033 pixels are above 7; 6131 pixels are above 10; 2904 are above 15; 1647 are above 20; 837 above 30; and 203 above 165. The tail goes out to 1200. Columns have different average noise levels in the image, and start-of-row pixels have more noise.

3.1.3 Flatfield

The flatfield has peak at 1, and a second peak at zero. 3808 pixels are below zero, 19828 are below 0.2 (these are mostly the reference pixels). There is a smooth rise from here to 0.7 where main peak starts rising rapidly. 20351 are below 0.5 and 21378 are below 0.7. The cutoff is sharp on the other side, only 19 pixels above 1.3 and 9 above 1.6.

3.2 BAD PIXEL CRITERIA

Band 2 is similar to band 1 but with somewhat more outlying pixels in all cases mentioned above. As for band 1, consider pixels with signal below 10 and noise below 1.5 to be bad. Use no maximum limit for signal, and limit noise to less than 15. The flatfield has the similar complexity on the low side. For cutoffs I use below 0.5 as for band 1 and above 1.3. Using 0.8 for the low cutoff again excludes more pixels randomly scattered around the array.

These criteria find 22768 bad pixels including the 16320 reference pixels. ~18500 of these are too low flatfield alone, while another 2300 are too low noise alone. 1200 have low flat, too low noise and too little signal, while 500 have too much noise and too low a flat. 170 have too little signal and too low a flat. Less than 100 are excluded by other combinations of criteria.

4. BAND 3

4.1 DATA SUMMARIES

4.1.1 Signal

The signal histogram has a strong peak with a long tail to the left. 16 pixels are below 5, with few between 5 and 105 (17 below this), where the numbers quickly start rising to form the tail. On other side of the main peak there is a sharp drop to 310 (only 135 above this) and only 84 are above 350. The tail goes out to 5000. 41 pixels are above 1000. The tail to the left is from the roll-off seen at the top and bottom of the image. The rectangular sections are visible in the image, but have no significant effect on the histogram.

4.1.2 Noise

The noise histogram has a strong peak with no tails. 28 pixels are zero, but few between 0 and 12 (only 43 below this), where main peak starts. On other side, main peak ends at ~32 (252 pixels above this). Only 143 are above 36 and 18 above 100. The noise image is flat except that each quadrant has a slightly different average noise level. The lowest median is 20.59, the highest is 22.27.

Individual images in DRK0282 show correlated noise (a chevron pattern) that is increasing the noise here so look at CHK0119, which is under similar conditions with less noise. The images and signal histograms look the same, but mean and median are slightly lower at 267.05 and 270.10. Noise range is now 9 to 34 and mean and median are 20.25, and 20.07. The best and worst quadrants have medians of 19.4 and 20.8. The number of outliers from the main peak is similar to DRK0282. The broadened peak is probably because CHK0119 has only 20 images, so the RMS in calculating noise is 3.17 here instead of 1.4 for DRK0282. The extra noise has only a limited effect on the statistics.

4.1.3 Flatfield

The flatfield has a peak at 1, and a second peak at zero. 9430 pixels are below zero, 16324 are below 0.3 (these are mostly the reference pixels). Few are between 0.3 and 0.4 (16503 below this). A very small third peak is present from 0.5 to 0.7. 18770 pixels are below 0.7, and 18992 are below 0.85 where main peak starts. The main peak ends at 1.3 and only 85 pixels are above this; only 6 are above 1.6. The image is mainly flat except for the bad pixel features, the hair feature and the semi-permanent latents. The latents are too weak to be significant here.

4.2 BAD PIXEL CRITERIA

Consider pixels with signal below 50 and noise below 12 to be bad. Use a maximum of 26000 for signal, which excludes only saturated pixels, and limit noise to 36. Exclude pixels with flatfield values above 1.6 and below 0.8. Using 0.8 instead of 0.5 for the cutoff removes mostly pixels in additional low response clumps in the image and only a few pixels randomly scattered around the array.

These criteria find 19058 bad pixels including the 16320 reference pixels. ~18900 of these are too low flatfield alone, and another 133 have high noise alone. 25 have low flat and low noise. 170 have too little signal and too low a flat. Less than 100 are excluded by other combinations of criteria.

5. BAND 4

5.1 DATA SUMMARIES

5.1.1 Signal

The signal histogram has a strong peak with a long tail to the left. 2 pixels are below 5, with only 1 between 5 and 105, where numbers quickly start rising. The tail shows complex, multi-peaked structure between here and the main peak.which starts rising rapidly at ~280 On the other side of the main peak, there is a sharp drop to 340 (only 337 above this) and only 275 above 350. The tail goes out to 11000. 205 pixels are above 1000. The tail at left is from the roll-off observed at the top and bottom of the image. The rectangular sections are visible in the image, but have no significant effect on the histogram.

5.1.2 Noise

The noise histogram has a strong peak with no tails. 67 pixels are zero, but only one between here and 6, where the main peak starts. On the other side, the main peak ends at ~16 (270 pixels above this). Only 184 are above 20, and only 47 are above 50. The noise image is flat except for obvious bad pixel clumps and the different quadrants have slightly different average noise levels. The lowest median is 11.44; the highest is 12.49.

Individual images in DRK0282 show correlated noise (a chevron pattern) that is increasing the noise here, so I look at CHK0119 which is under similar conditions with less noise. Images and signal histograms look the same, but mean and median are slightly lower at 299.23 and 295.95. The noise range is now 4 to 17 and mean and median are 9.88, and 9.81. Best and worst quadrants have medians of 10.2 and 9.7. The number of outliers from the main peak is similar to DRK0282, but slightly fewer (46 below 3, 87 above 20). The broadened peak is probably because CHK0119 has only 20 images, as for band 3. The extra noise has only a limited effect on the statistics.

5.1.3 Flatfield

Flatfield has a peak at 1 and a second peak at zero. 1370 pixels are below zero, 4143 are below 0.02 (these are mostly the reference pixels). Few are between 0.02 and 0.6 (4155 below this) where a very small third peak is present from 0.6 to 0.8. 5205 pixels are below 0.8, and 5229 are below 0.85, where main peak starts. The main peak ends at 1.1. Only 71 pixels are above this, and only 26 are above 1.5, with nothing above 1.73. Image is mainly flat except for the bad pixel features and dark spots associated with the filter. The few possible latents are too weak to be significant.

5.2 BAD PIXEL CRITERIA

I consider pixels with signal below 50 and noise below 6 to be bad. Use a maximum of 26000 for signal, which just excludes the saturated pixels, and limit noise to 18. Exclude pixels with flatfield values above 1.5 and below 0.8. Using 0.8 instead of 0.6 for the cutoff exlcudes mainly two columns from the left and right edges, a few low response clumps in the image and very few pixels randomly scattered around the array.

These criteria find 5425 bad pixels including the 4080 reference pixels. ~5100 of these are too low flatfield alone, and another 190 have high noise alone. 64 have low flat, low noise and high signal (several permanently saturated ones). Less than 100 are excluded by other combinations of criteria.