W4 Bias Experiment: pixel space analysis

F. Masci, 04/27/2010

1. Method

1. For each level-1b frame, we used the pipeline QA metrics: "SigLTMADFM" (=robust sigma estimator using Lower-Tail Median Absolute Deviation from Fuzzy Mode) and "intFuzMode" (=Fuzzy Mode). Given that we have good statistics in this study (smallest sample size = number of pixels in a W4 frame), these metrics are not as "fuzzy" as their name implies. Furthermore, we explored other robust metrics for the noise-sigma: the 0.5*(84%-16%) percentile method and the "SigLTMADMED" metric (Lower Tail Median Absolute Deviation from the Median). All these give the same conclusion.

2. The variance (Var = square of the robust sigma in DN^2) was compared to the mode (in DN) per frame. A simple Poisson + Readnoise model was fit using robust MLE regression to: Var = S*mode + Var_rn where S = 1/G and G = electronic gain in e-/DN; Var_rn = read-noise (RN) variance in DN^2. See Table 1 and Figure 1 for a summary, and Figure 4 for plots of fits to the data.

3. The median Signal-to-Noise ratio over pixels, defined as: SNR = $mode_{frame}/robustsigma_{frame}$ was used as the primary metric to determine if there were gains in sensitivity relative to the nominal bias. The relative SNR between any two bias settings should carry over to source (photometry) space, so the analysis presented here is generic.

4. The run of SNR vs frame# for pairs of overlapping nominal and experimental-bias scans were compared (Figures 2 and 3). The median %-differences in SNR are summarized in Table 1.

5. We also computed the median SNR over all frames in a scan and plotted this against scan# (see Figure 5). Note that only the red-points (the bias-experiment scans) overlap on the sky. Astrophysical background variations, anneals, and SAA passages will increase the scatter in the median SNR in general. Therefore, the blue points in this plot (survey scans at nominal bias) are not strictly representative of the bias-experiment scans.

2. Conclusions

- The electronic gain (e-/DN) decreases with increasing bias voltage. This means more DNs per photon for a fixed QE. In other words, more DN per Jansky. The electronic gain at the highest bias voltage (2.25V) has decreased by ~10.8% relative to the nominal on-orbit value.

- Both the signal (#DN) and noise increase with increasing bias, however the #DN increases faster than the noise, so the global S/N per pixel increases with bias voltage. The S/N at bias 2.25V is greater than at the nominal bias by ~10.4%. This is expected to carry over to source space when integrated over the effective size of the PSF.

- There is tentative evidence that at the highest bias setting (2.25V), more long-term latents and/or bad-pixel transients are accumulated, presumably because the array is more responsive. This is seen as an increase in the number of dynamically flagged transients. See Figures 8 and 9.

- These conclusions pertain to L1b's that were processed with all nominal survey calibrations (dark, relative responsivity, and linearity). It is uncertain whether there are significant changes in these calibrations, and if so, if such changes would conspire to offset the conclusions above.

3. Results

Case [see below for details]	**Gain [e-/DN]**	**Read-Noise [DN]**	**Median pixel S/N relative to nominal pre-expmt [%]**
1. nominal bias: pre-expmt	24.94	8.65	0
2. bias = 1.68V	26.51	8.64	-10.98
3. bias = 1.82V	25.37	8.66	-6.60
4. bias = 2.11V	23.39	8.67	+3.83
5. bias = 2.25V	22.25	8.71	+10.38
6. nominal bias: post-expmt	24.25	8.70	-

Table 1: Summary of noise-model fits and scan-medianed percentage difference of frame SNR relative to the nominal pre-experiment scan, i.e., the difference of the red and blue curves in Figures 2 *or* 3. These look at the same swath of sky and are expected to be relatively unbiased.

<u>Table 1 row information:</u>

1 = two scans at nominal bias (1.97V), *pre-experiment*
[these overlap on the sky with the experimental bias scans and define the nominal baseline for comparison with the below]:
/wise/fops/scans/2a/03752a/fr
/wise/fops/scans/3a/03753a/fr

2 = two scans at 1.68V Bias:
/wise/fops/scans/4a/03754a/fr
/wise/fops/scans/5a/03755a/fr

3 = two scans at 1.82V Bias:

/wise/fops/scans/6a/03756a/fr
/wise/fops/scans/7a/03757a/fr

4 = two scans at 2.11V Bias:
/wise/fops/scans/8a/03758a/fr
/wise/fops/scans/9a/03759a/fr

5 = two scans at 2.25V Bias:
/wise/fops/scans/0a/03760a/fr
/wise/fops/scans/1a/03761a/fr

6 = two scans at nominal bias (1.97V), immediate *post-experiment*
[these do not overlap with the experimental bias scans – only used to get another estimate of the nominal gain]:
/wise/fops/scans/1b/03761b/fr
/wise/fops/scans/2a/03762a/fr

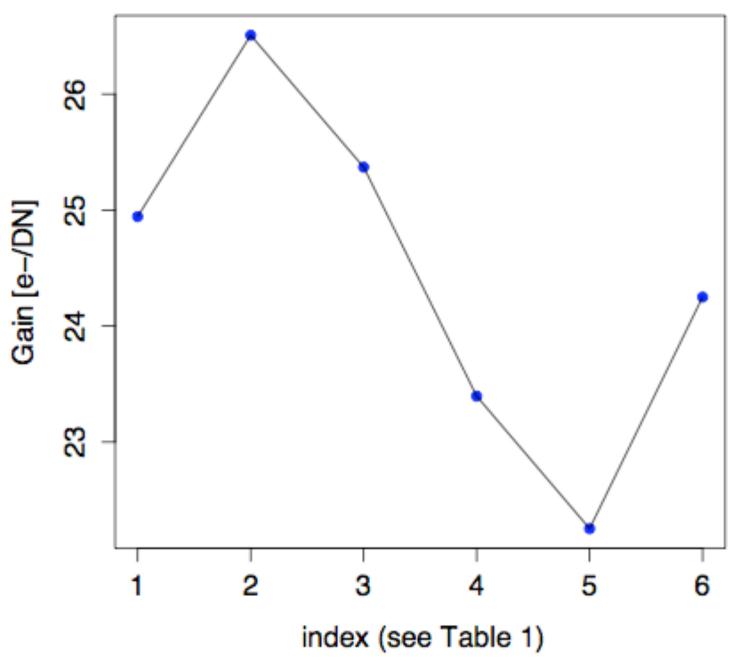

Figure 1: Gain values from noise-model fitting at the different experimental bias settings and at the nominal bias before and after experiment. Each point is based on two scans worth of frames. See Table 1 for a summary and Figure 4 for plots of the noise-model fits.

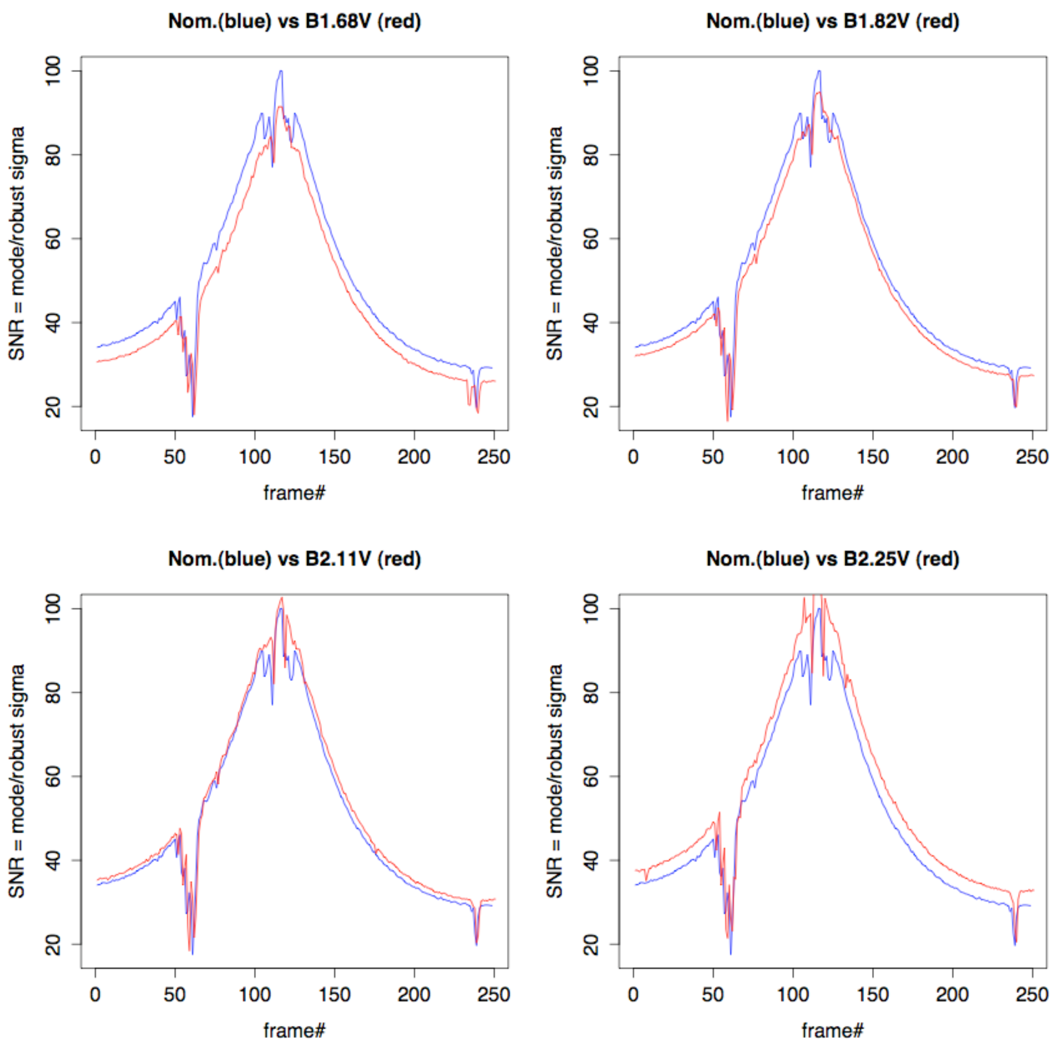

Figure 2: Robust frame SNR (per pixel) vs frame number for nominal first pre-expmt scan [blue] compared to bias scans [red] <u>all at same ecliptic long: 297.53</u>°.

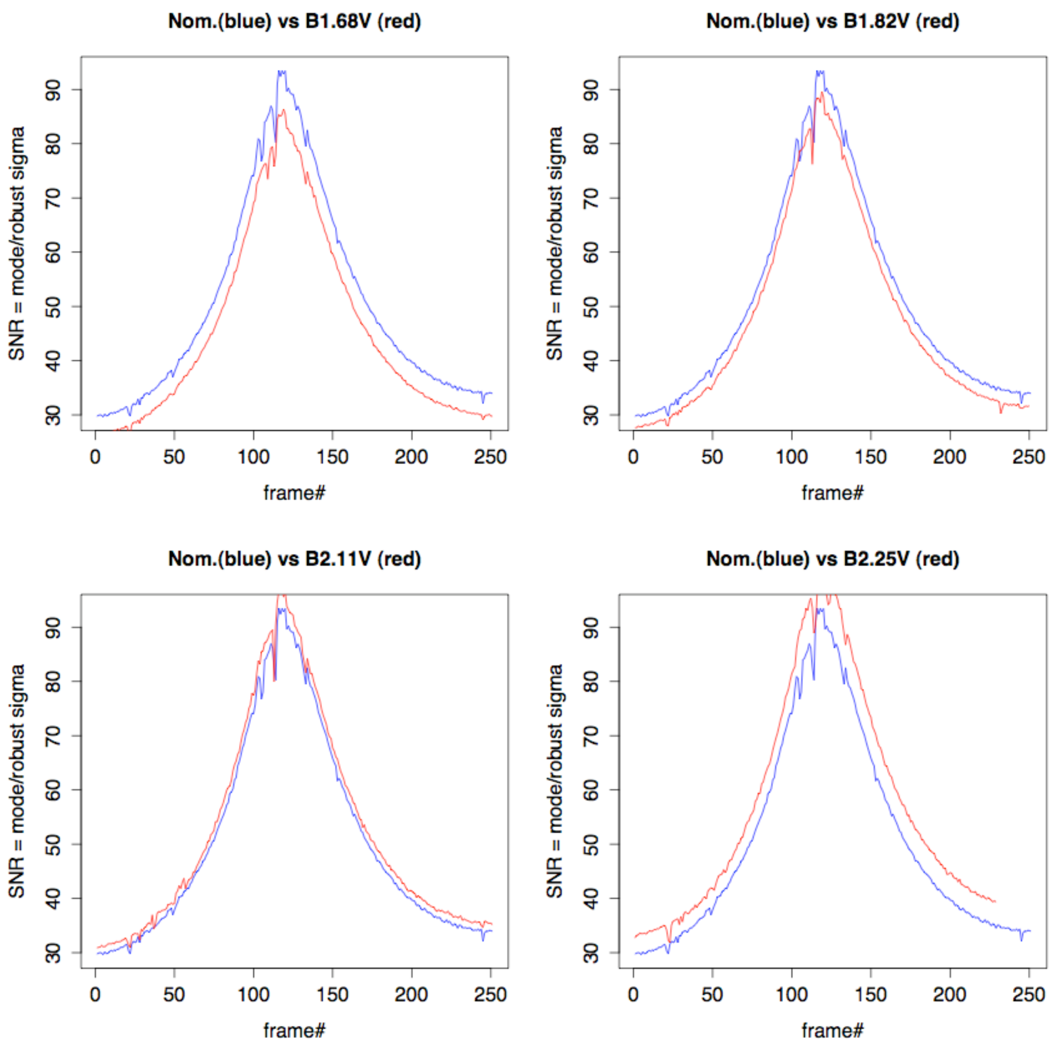

Figure 3: Robust frame SNR (per pixel) vs frame number for second nominal pre-expmt scan [blue] compared to bias scans [red] all at same ecliptic long: 122.53°.

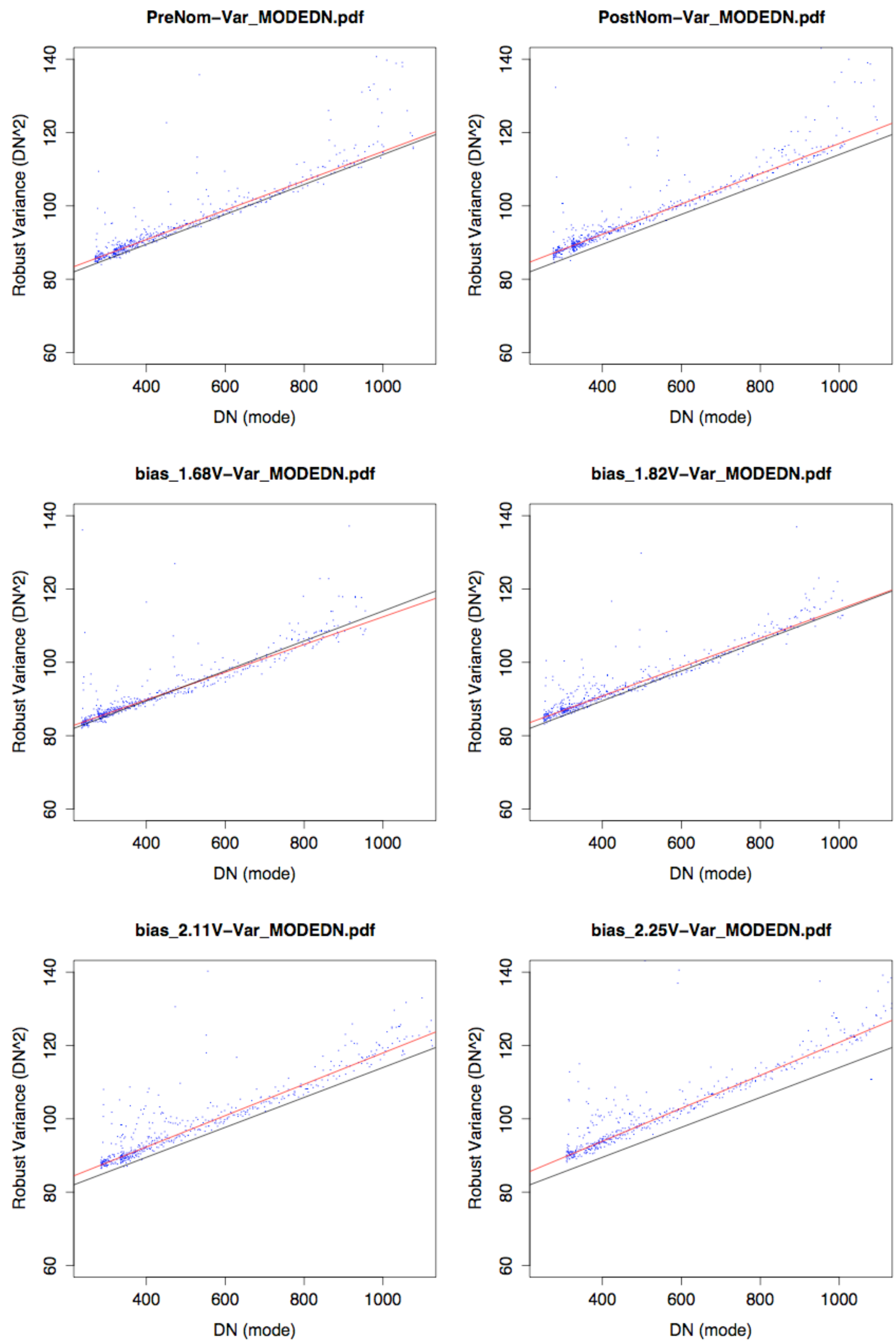

Figure 4: Fits of the noise-variance model to pairs of scans at each bias setting as well as at nominal bias pre/post experiment. Red lines are fits from the robust linear regression. Black lines are fits to earlier survey scans and are included to guide the eye (same in all plots).

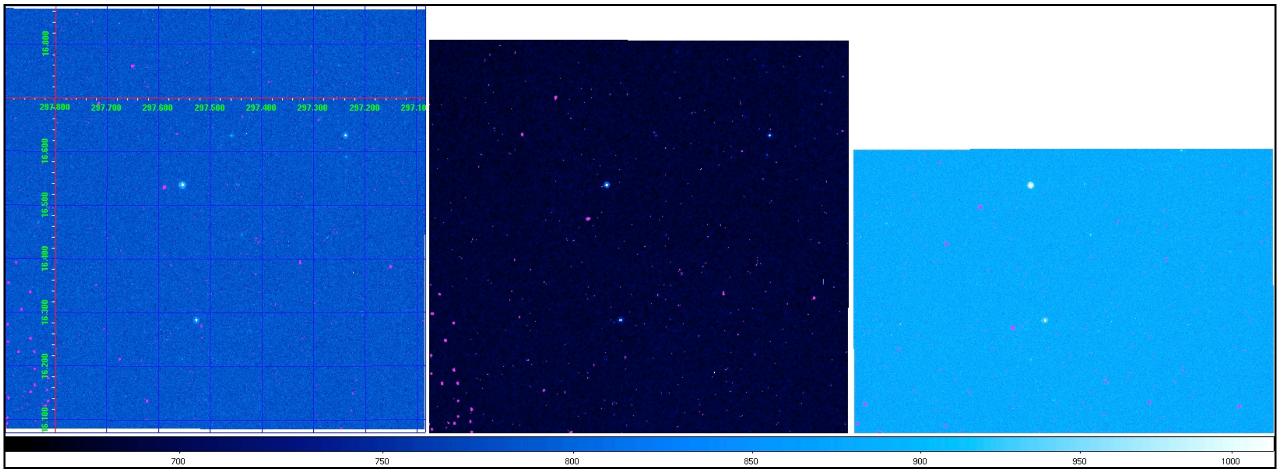

Figure 5: frames that saw ~ the same region of sky from the nominal bias (pre-expmt) scan 03752a [left], lowest bias scan 03754a at 1.68V [middle], and highest bias scan 03760a at 2.25V [right]. Color-bar is to scale. See Figure 6 for corresponding histograms.

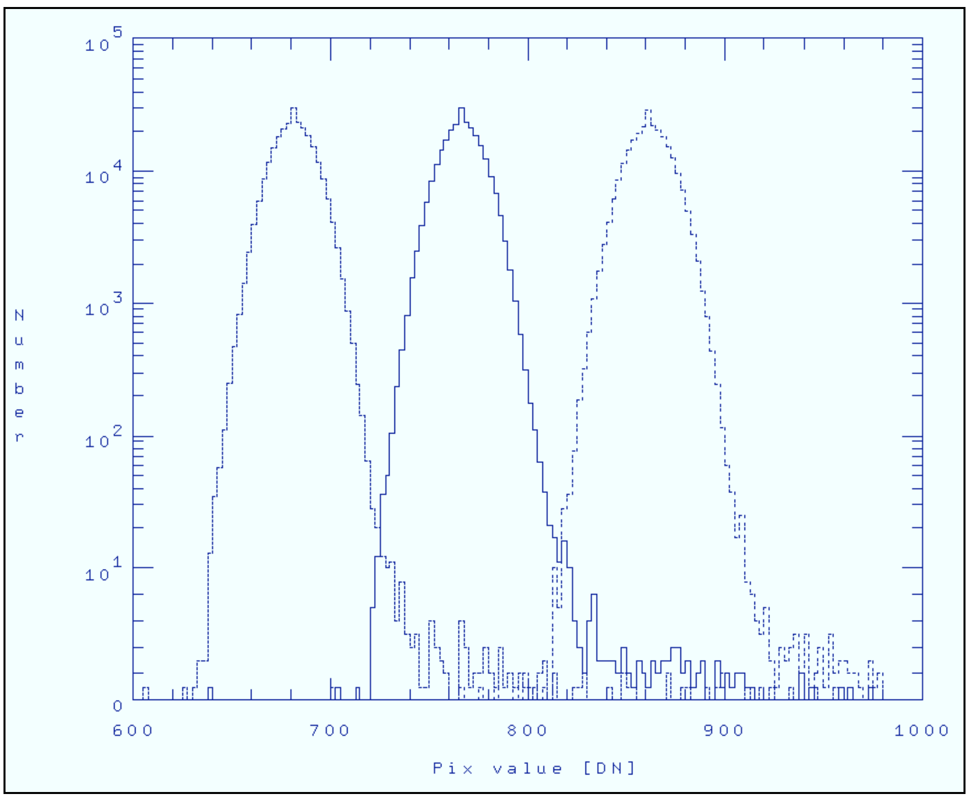

Figure 6: Pixel intensity histograms corresponding to the frames in Figure 5. Nominal is in the middle, lowest bias is at left, and highest bias is at far right. The widths (robust σ) from left to right are: 10.28, 10.73, 11.29 DN. Another observation is that there *does not* seem to be a significant change in the number of low or high tail outliers (that may indicate new bad pixels) between the different biases. This does not rule out new noisy/transient pixels.

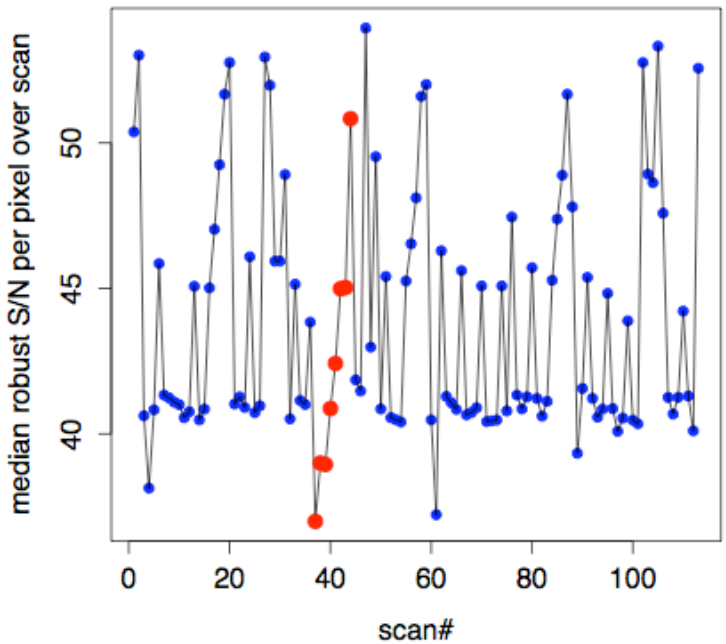

Figure 7: Median robust S/N of all frames in a scan vs. scan#. Red points are the bias-experiment scans and the blue points are survey scans at nominal bias. Note that the two blue points preceding the start of the red trend are part of the bias-experiment. These are at ~ the same ecliptic longitudes as the bias-experiment scans. Note: anneal affected frames and SAA passes *have not* been filtered from the blue points. In particular, the last bias-experiment scan (the highest of the red points) is known to have ~30% of its frames contaminated by a SAA pass. As mentioned in section 1, it is meaningless to compare the red and blue points here since the latter are at a different sky location and the anneals are also known to increase the absolute responsivity – almost as much as that indicated by the highest bias setting (2.25V).

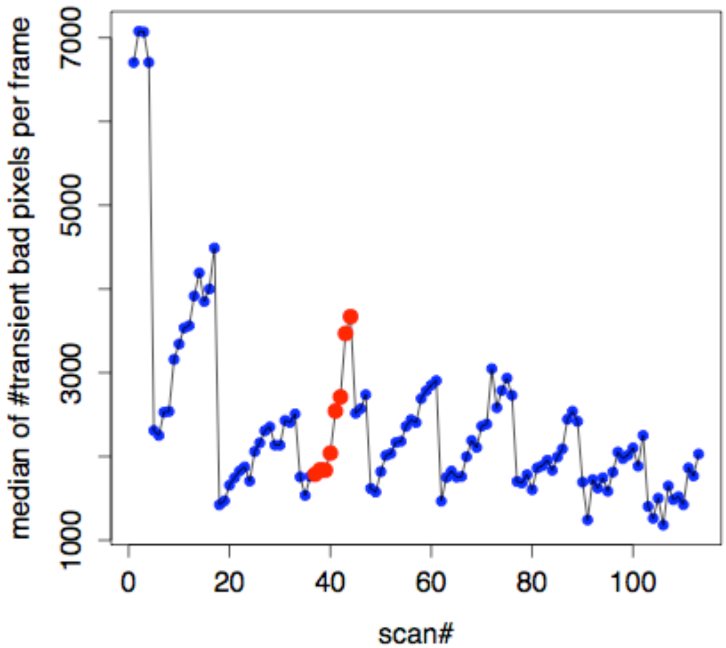

Figure 8: Median number of dynamically flagged "bad" pixels per frame in a scan vs. scan#. Red points are the bias-experiment scans and blue are nominal survey scans. This uses the same data as in Figure 7. The periodic pattern is due to the accumulation of long-term latents. They reach a peak just before the next anneal. The counts also include hi/lo spike-glitch detections [see Fig. 9], but the variation is dominated by long-term latents. The excess number of transients in the 2.25V bias scan relative to the neighboring nominal scans may be due to a more responsive array. The responsivity to latents appears to have been restored following the bias experiment.

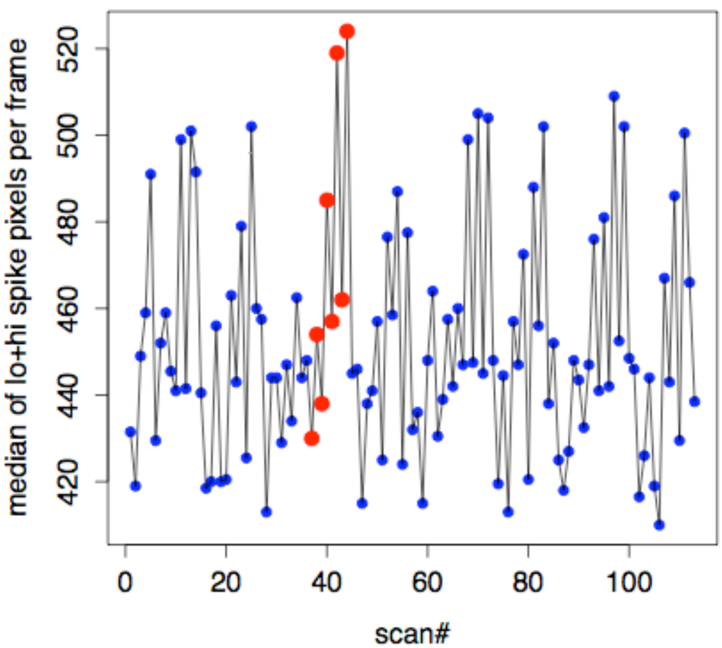

Figure 9: Median number of hi+lo single-pixel spike glitches per frame in a scan vs. scan#. Red points are the bias-experiment scans and blue are nominal survey scans. This uses the same data as in Figures 8 and 9. The periodic pattern is due to SAA passes. There appears to be an excess count in the 2.25V bias scan relative to the neighboring nominal scans – perhaps due to a more responsive array or more bad-pixel transients being stimulated. This metric would have included any new bad pixels. There appears to be no degradation following the experiment.