Performance Characterization*

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Outline

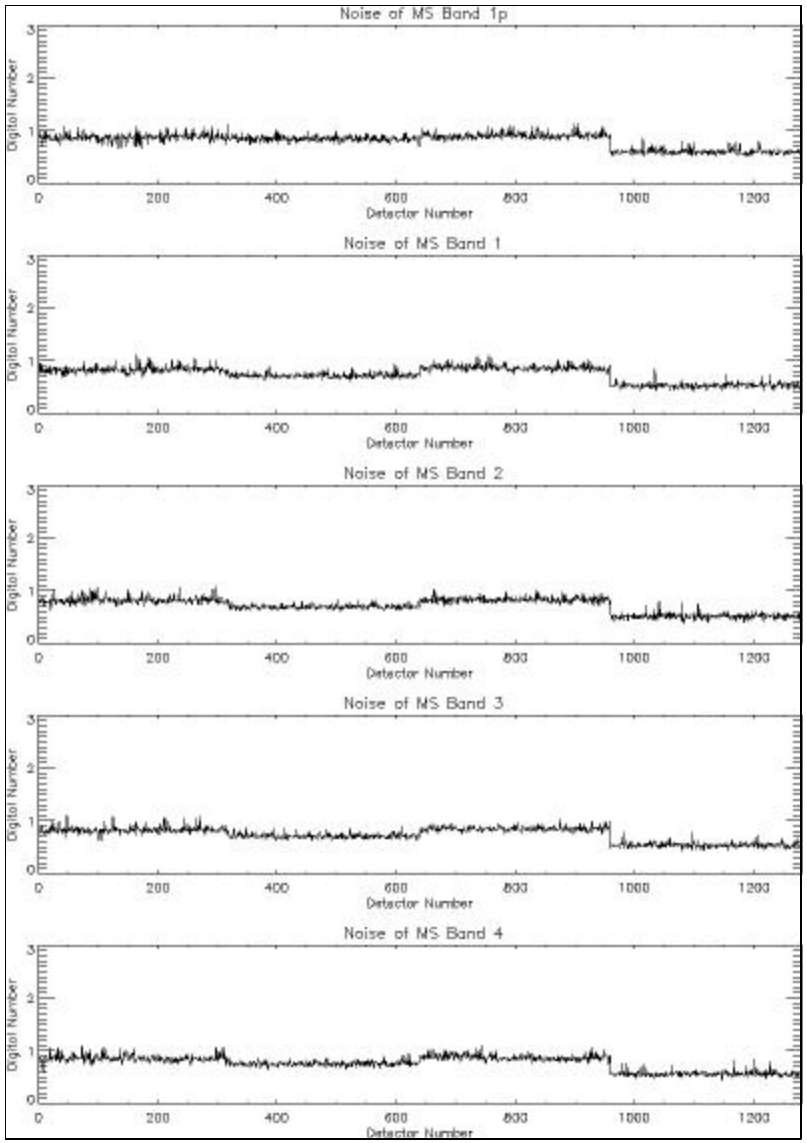
- Noise
  - Levels
  - Stability
- Dark Current
- Anomalous Detectors
- Summary

Noise

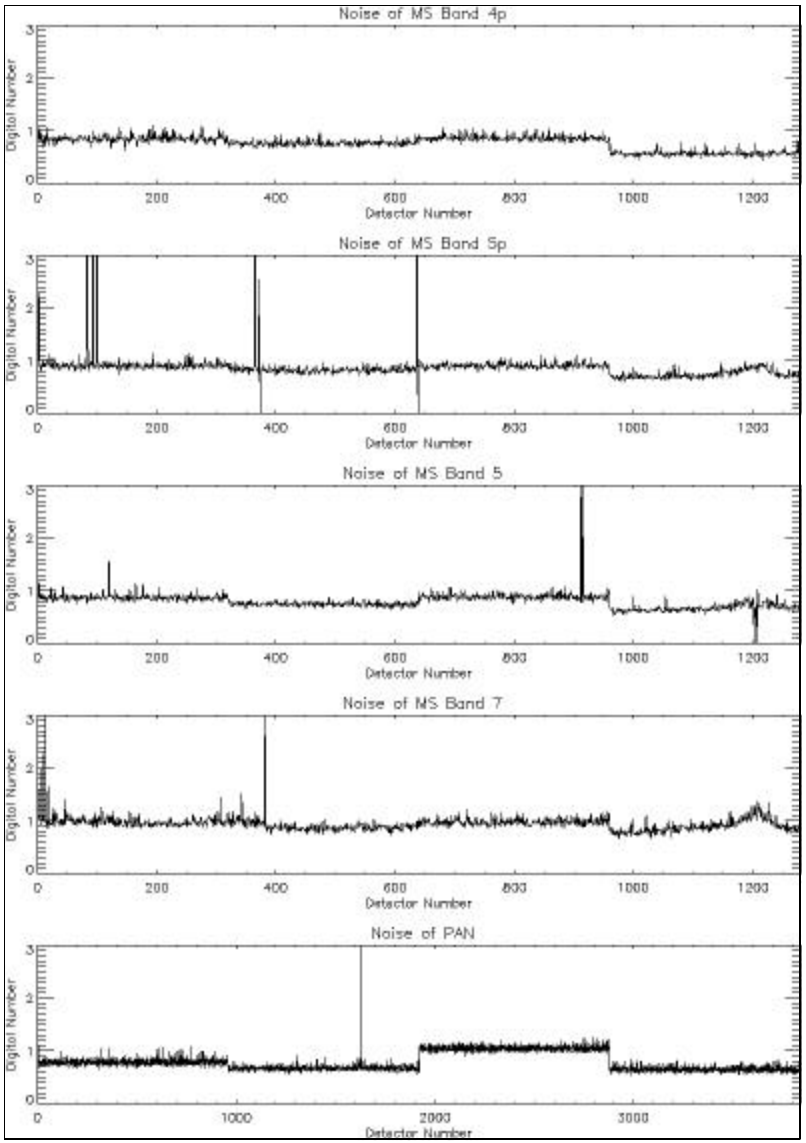
- Measured at the Laboratory during ground testing
  - 30 seconds of dark data
  - white, 1/f, coherent
  - FPA @ 215, 220, 225 K
  - Baseline values established

- Measured on orbit
  - 2 second dark collects prior to every observation
  - 30 seconds of dark data every 2 weeks
  - 9, 5 second periods every 5 minutes every 2 weeks
  - white, 1/f, coherent
  - FPA @ 220 K
  - Baseline values confirmed

White Noise at 220 K



White Noise at 220 K



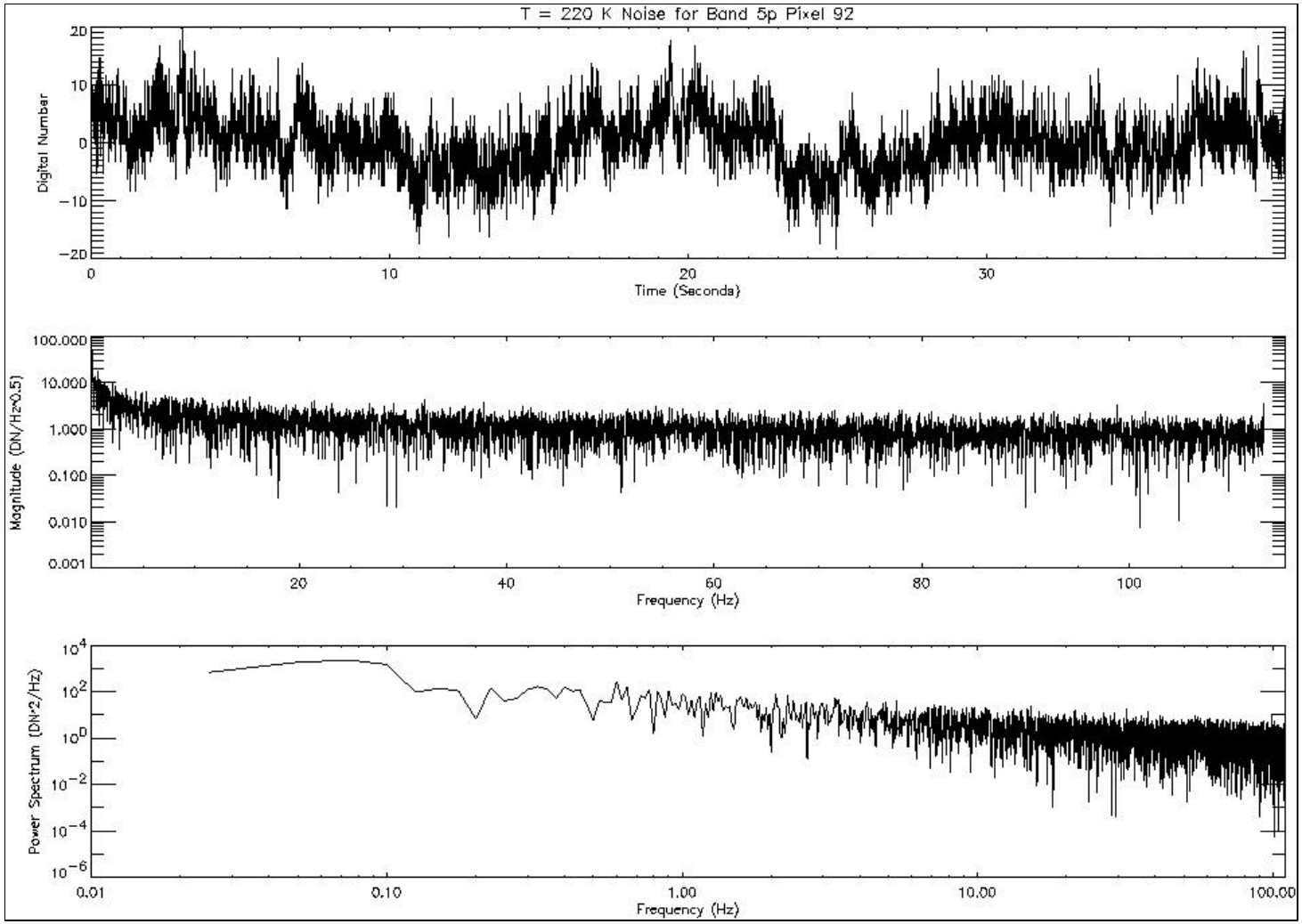
1/f Noise

- Detectors with white noise > 1.5 DN selected as 1/f noise candidates
  - 17 detectors at 220 K, 11 detectors at 215 K
  - All candidates SWIR detectors
- Fourier transform of 40 second dark scene for each detector
- Magnitude for each detector fit to 1/f noise function

$$M_P = A_0 (1. + (A_1 / f)^{A_2}).$$

- f is the channel frequency
- A_0 is the magnitude offset
- A_1 is the knee frequency
- A_2 is the slope of the low frequency component

1/f Noise


T = 220 K Noise for Band 5p Pixel 92
Digital Number
Time (Seconds)
Magnitude (DN/Hz^0.5)
Frequency (Hz)
Power Spectrum (DN^2/Hz)
Frequency (Hz)

1/f Noise

Band	Detector	Comment	A_0	A_1	A_2	S^*
5p	2	--	0.51	32.91	0.73	-0.0038
5p	82	Excess white noise	1.18	12.01	0.60	-0.0067
5p	83	--	0.53	5.37	0.48	-0.0028
5p	92	Excess white noise	1.04	9.04	0.71	-0.0049
5p	99	Excess white noise	0.95	35.54	0.43	-0.0055
5p	365	Excess Dark current Excess white noise	14.21	8.78	0.64	-0.0691
5p	372	Excess white noise , No 1/f component	1.61	5.20	0.53	-0.0004
5p	636	Excess white noise No 1/f component	1.79	5.13	0.53	0.0001
5	119	--	0.51	7.11	0.57	-0.0034
5	911	Excess dark current Excess white noise	1.93	6.59	0.66	-0.0093
5	913	Excess dark current Excess white noise	1.25	4.26	0.63	-0.0048
7	4	--	0.60	3.37	0.48	-0.0030
7	11	Excess white noise	1.30	36.67	0.53	-0.0100
7	17	--	0.68	1.70	0.73	-0.0028
7	126	--	0.54	2.28	0.94	-0.0026
7	307	--	0.53	1.51	0.55	-0.0020
7	382	Excess white noise	0.55	13.34	0.82	-0.0016

S^* = Slope used to normalize magnitude data before fit.

Coherent Noise

- Symptoms include recognizable patterns within image
- Characterized using 30 second dark collection
- 2D Fourier transform performed on dark ‘image’ of each band
- The percent of noise contributed by component *i* of Band *b*, $P_{i,b}$, may then be calculated as

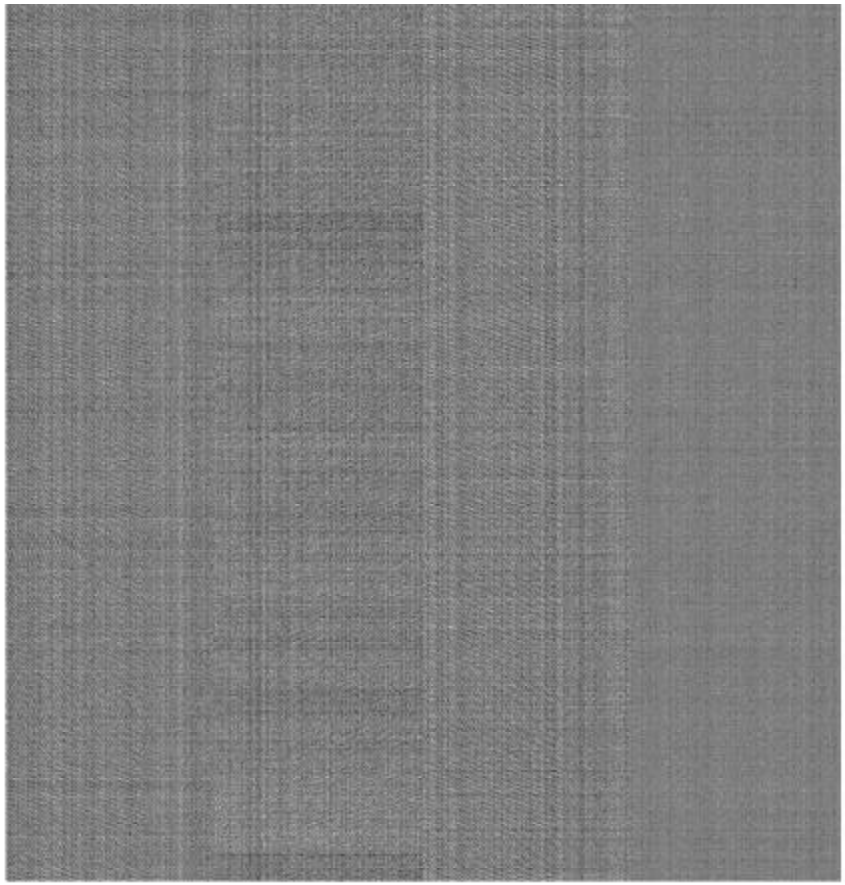
$$P_{i,b} = \frac{\sqrt{\int_{r1}^{r2}\int_{c1}^{c2} M_b^2 \, dr dc}}{\sqrt{\int\int M_b^2 \, dr dc}}$$

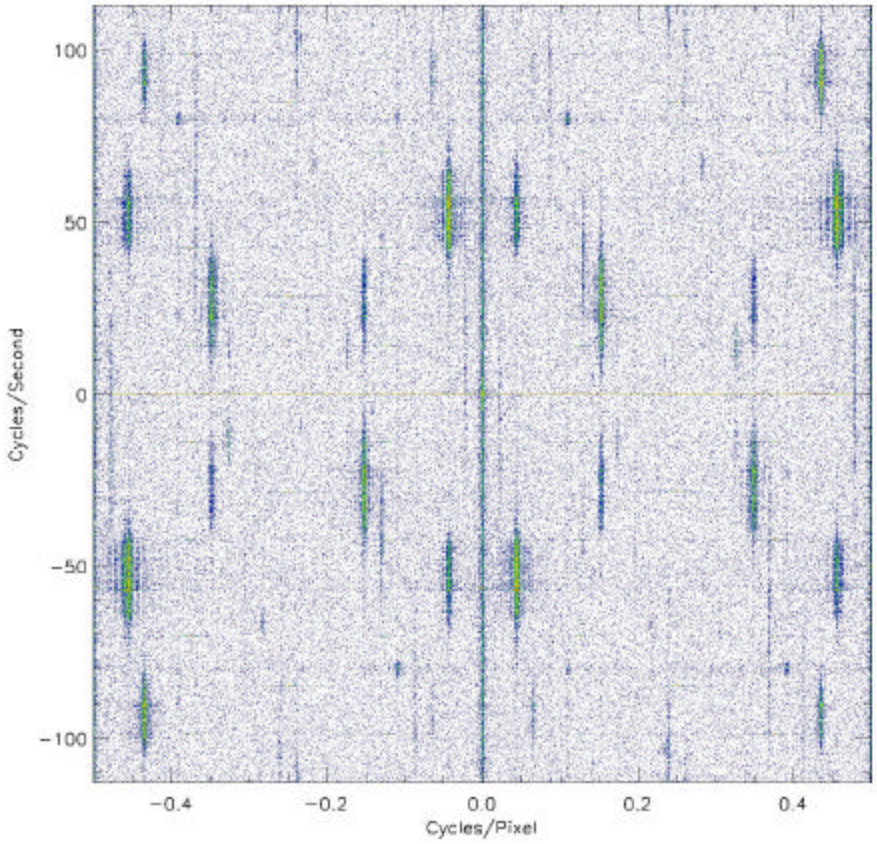
- The noise contribution of component *i* of Band *b* may be calculated in digital numbers as

$$N_{i,b} = P_{i,b} * N$$

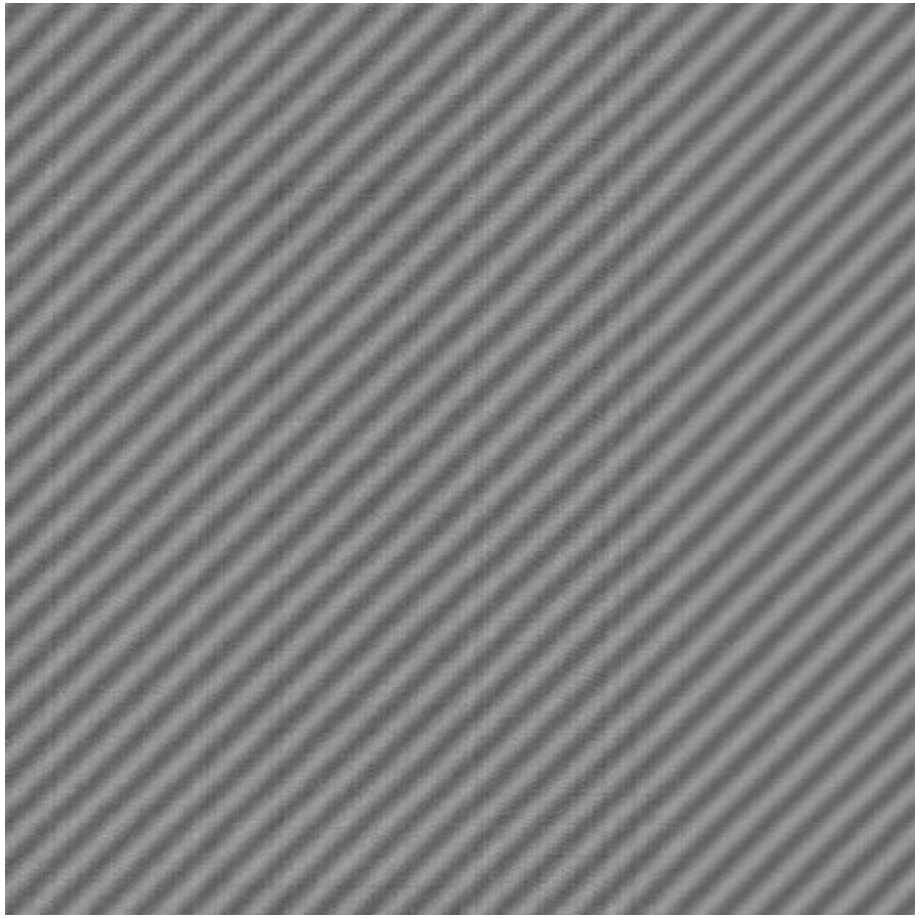
- N is the white noise of the dark image

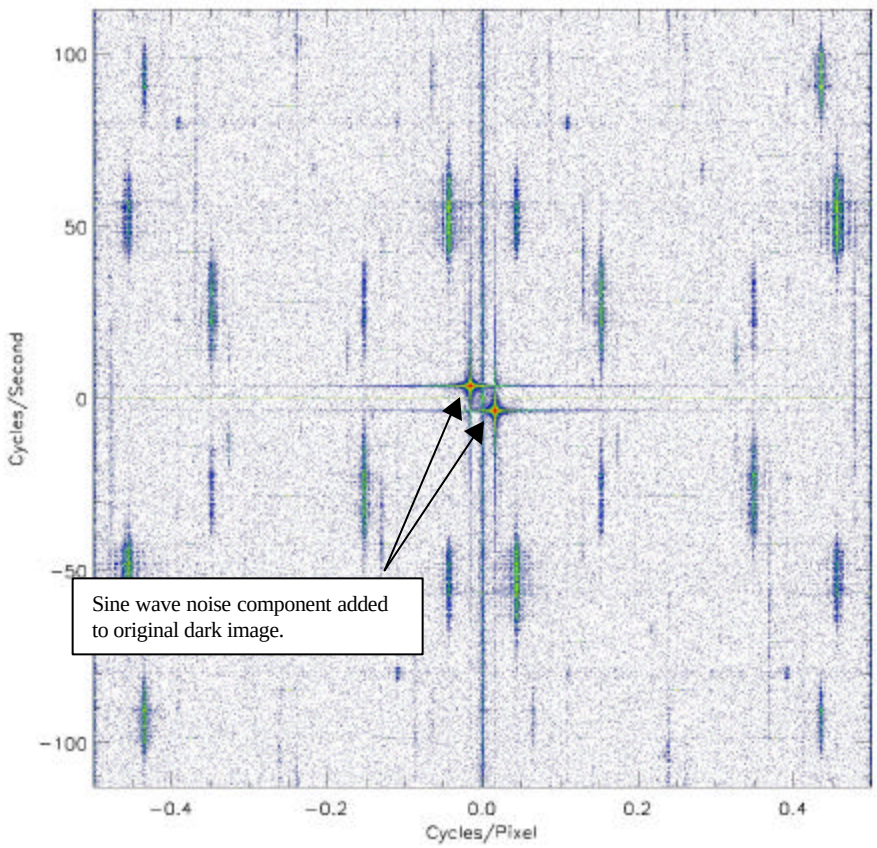
Coherent Noise - Band 1p





Coherent Noise - Synthetic Noise Added



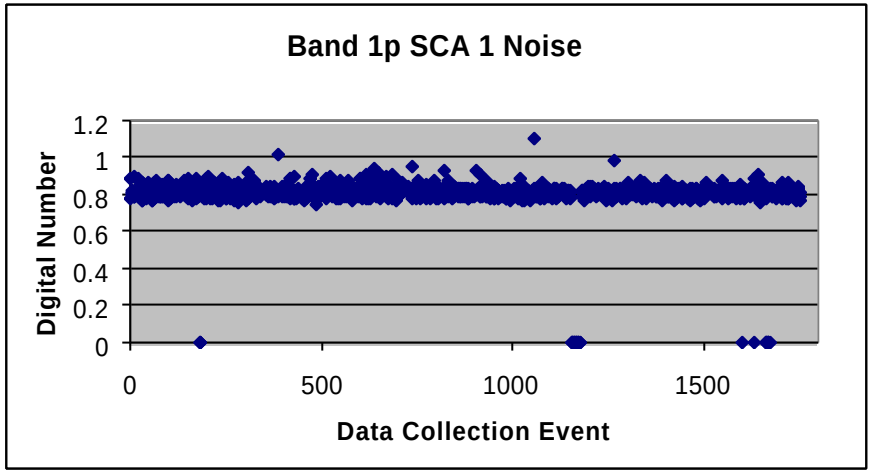


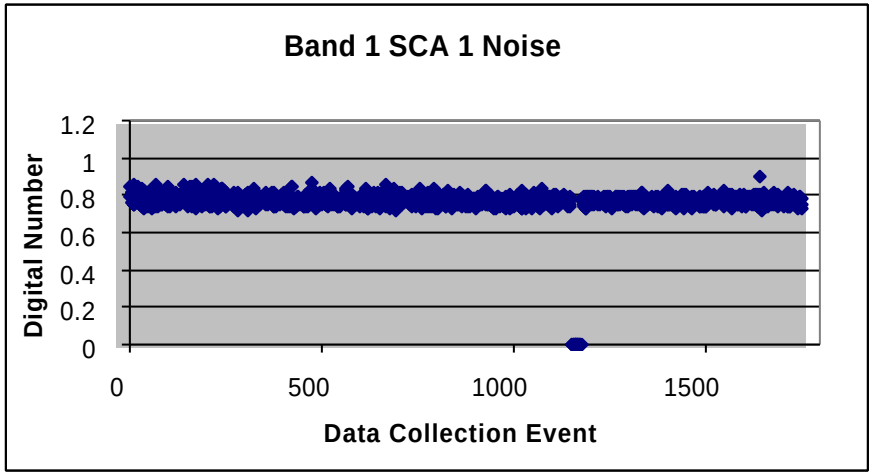
Coherent Noise

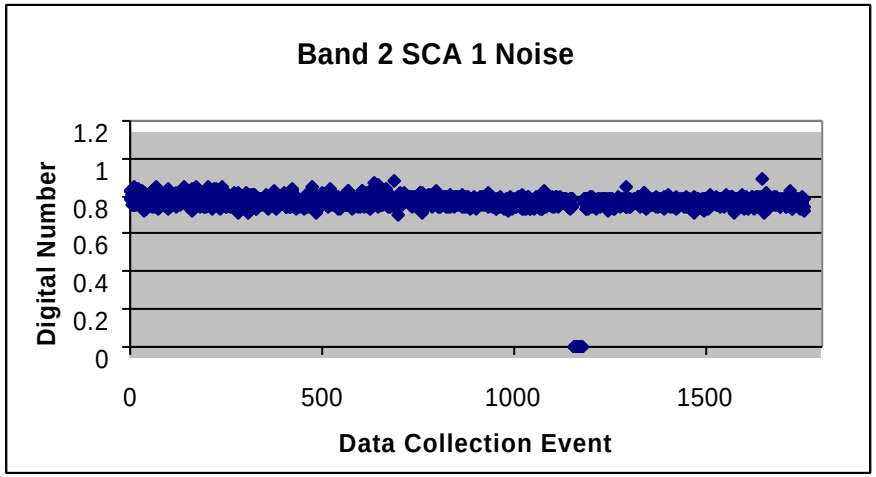
Band	Maximum Coherent Noise Contributor (% of Total Noise)	Combined Coherent Noise Effect (% of Total Noise)	Combined Coherent Noise Effect (Digital Number)
1p	19.3	49.0	0.40
1	26.4	56.1	0.42
2	23.4	55.6	0.41
3	19.6	56.8	0.42
4	21.0	50.7	0.39
4p	20.0	54.0	0.42
5p	17.4	47.8	0.42
5	23.4	45.3	0.37
7	16.4	43.4	0.42
Pan	21.0	53.0	0.60

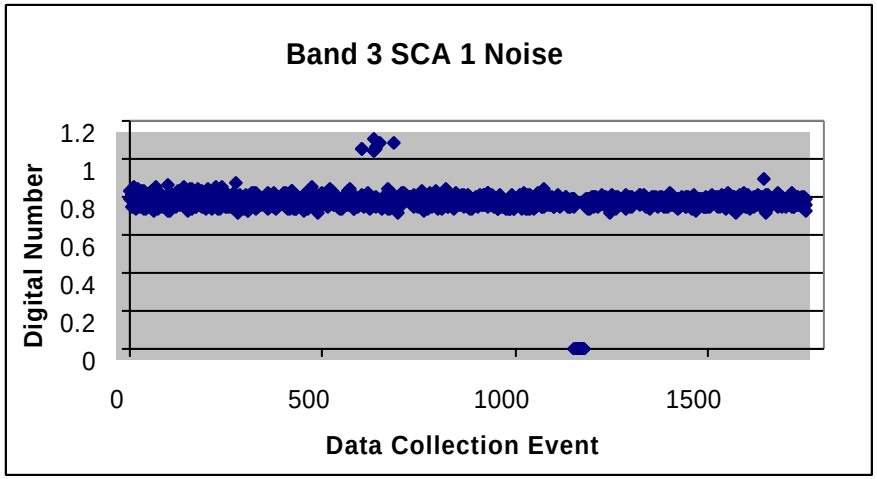
- **Individual/combined components spread over large frequency range, resulting in no obvious striping in images**

Noise Stability on Orbit

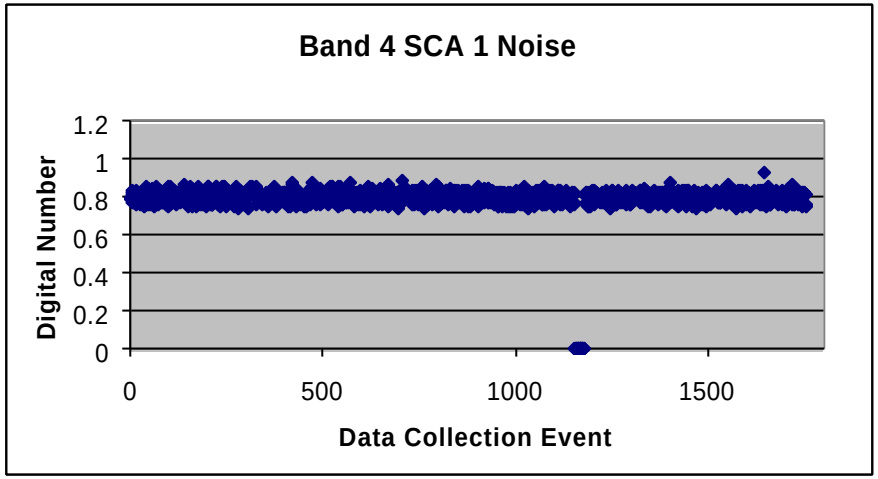


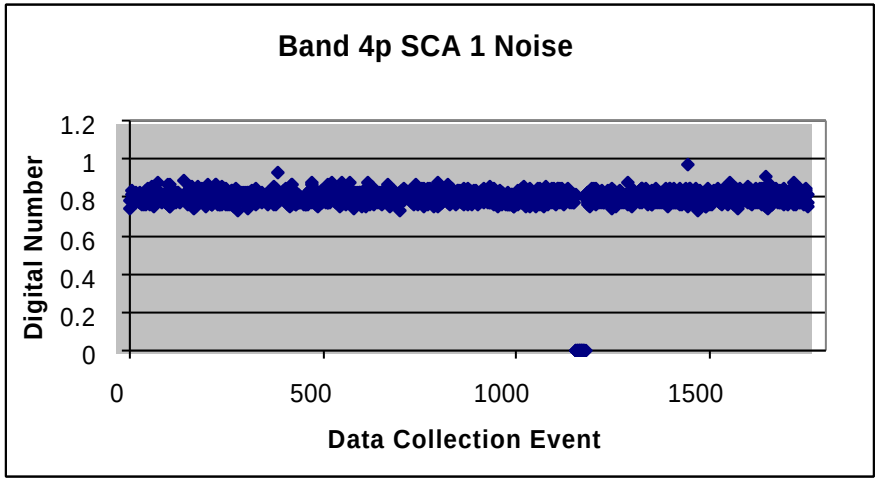


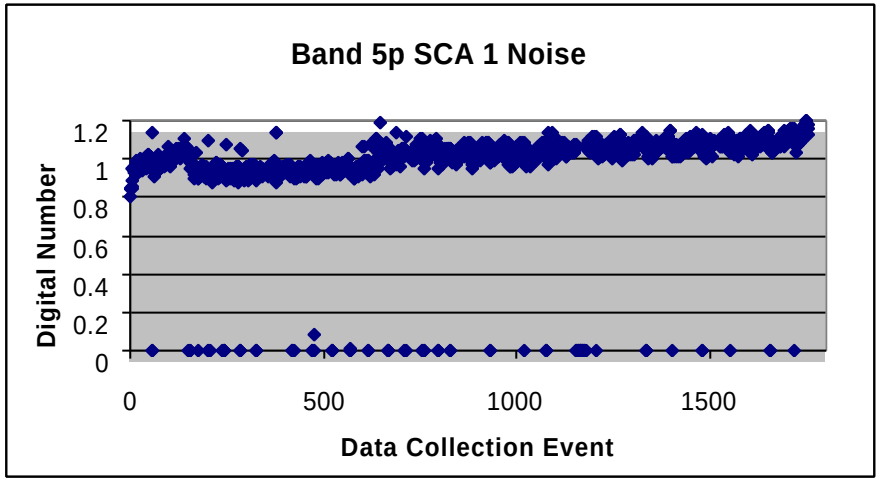


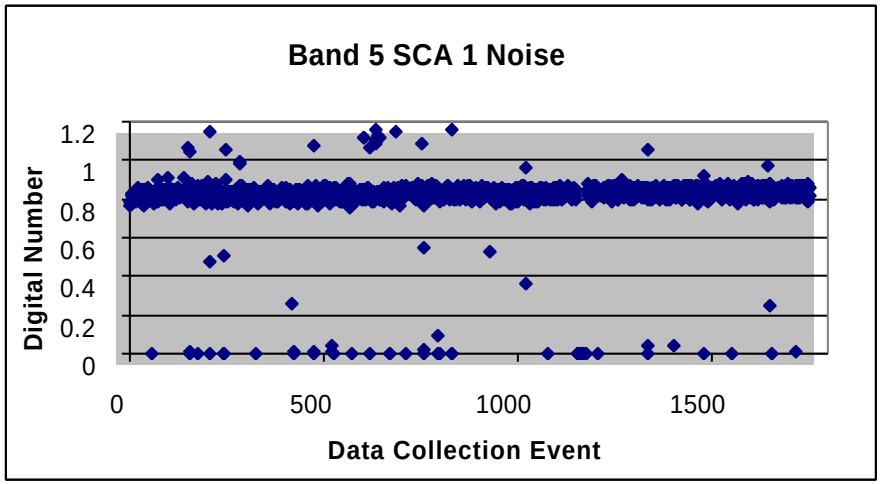


Noise Stability on Orbit

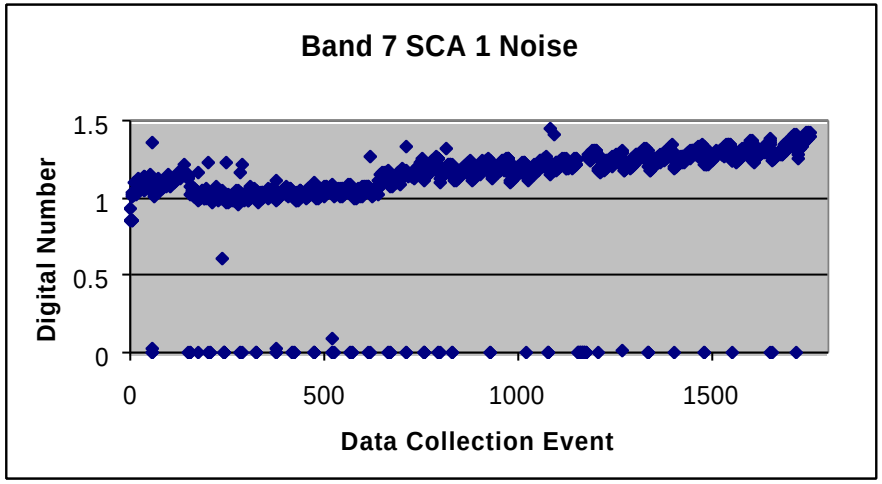


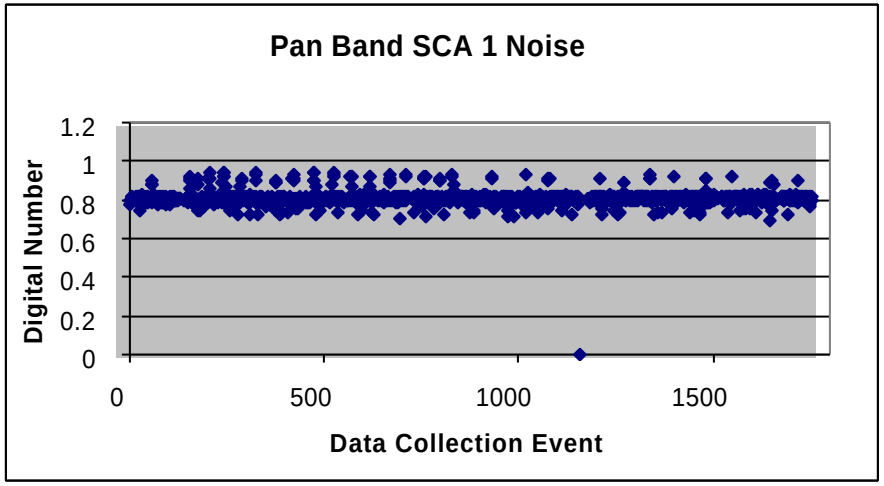






Noise Stability on Orbit





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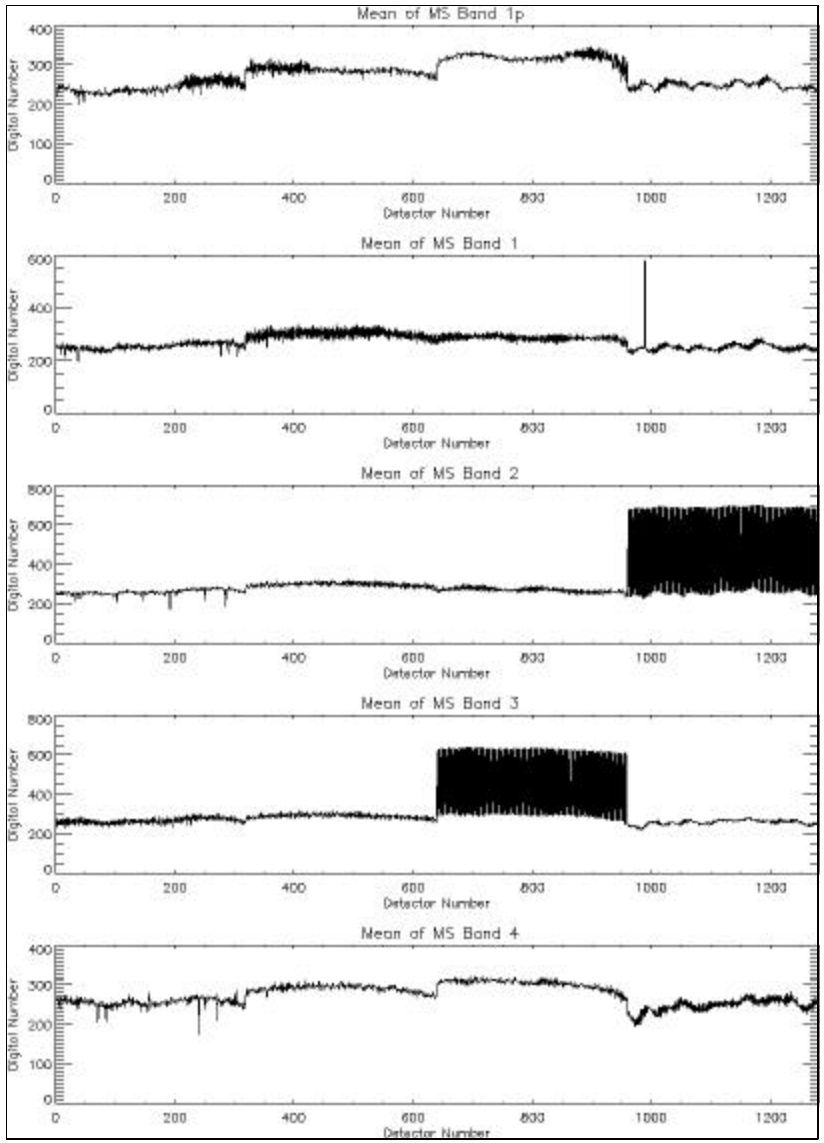
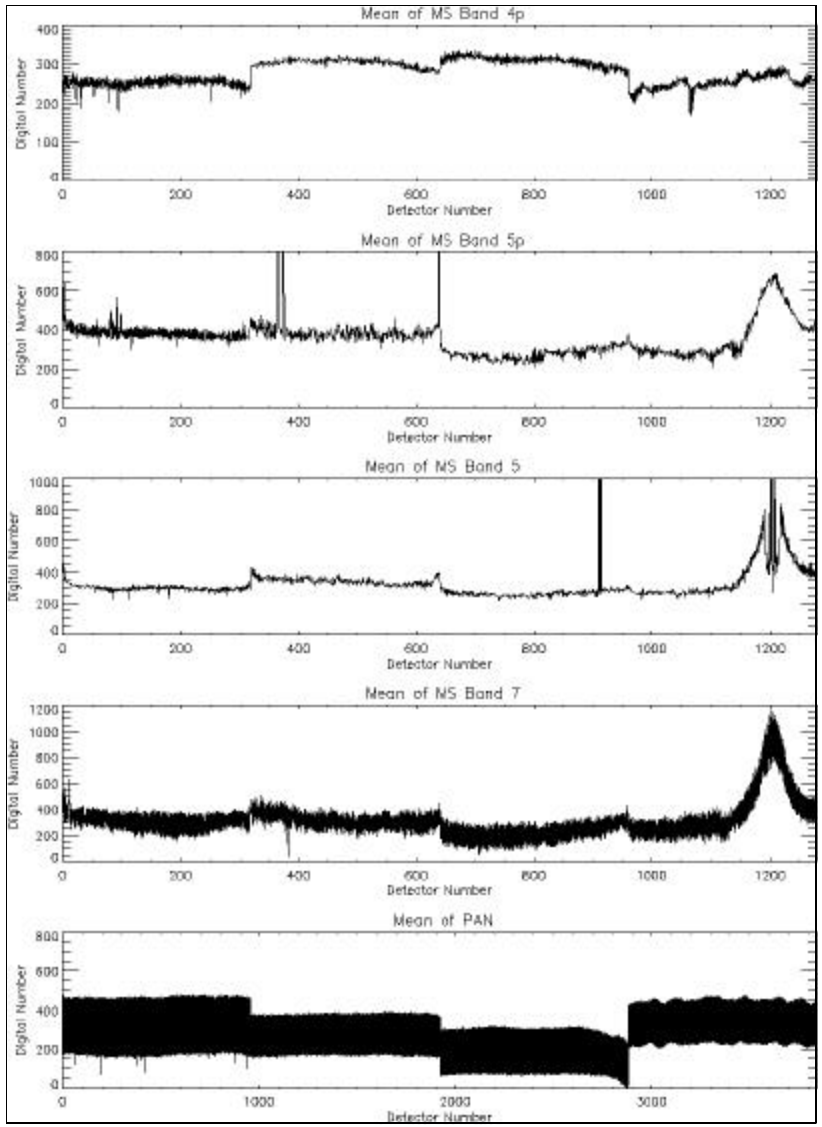
- Dark Current
  - Levels
  - Stability
- Anomalous Detectors
- Summary

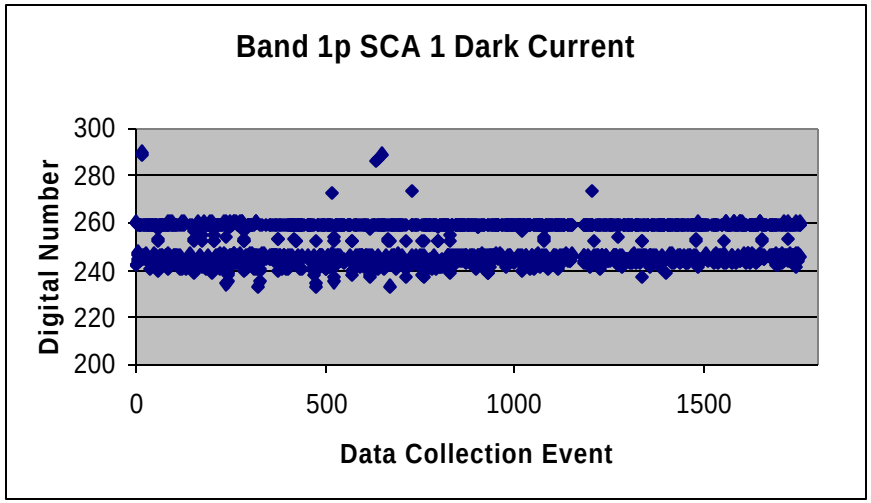
Dark Current @ 220 K

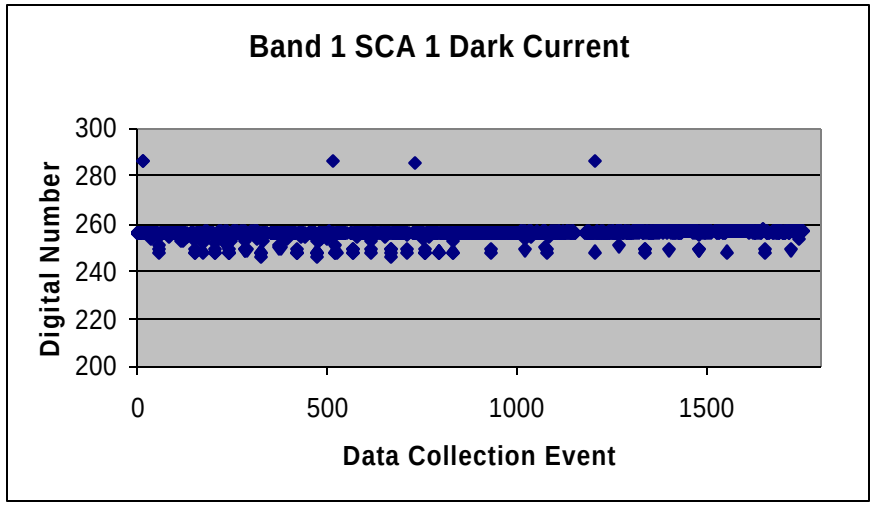


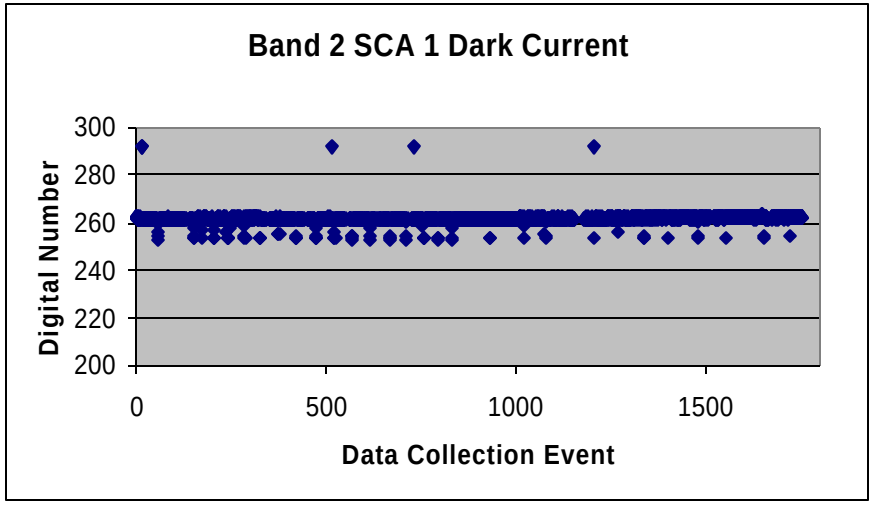
Dark Current @ 220 K

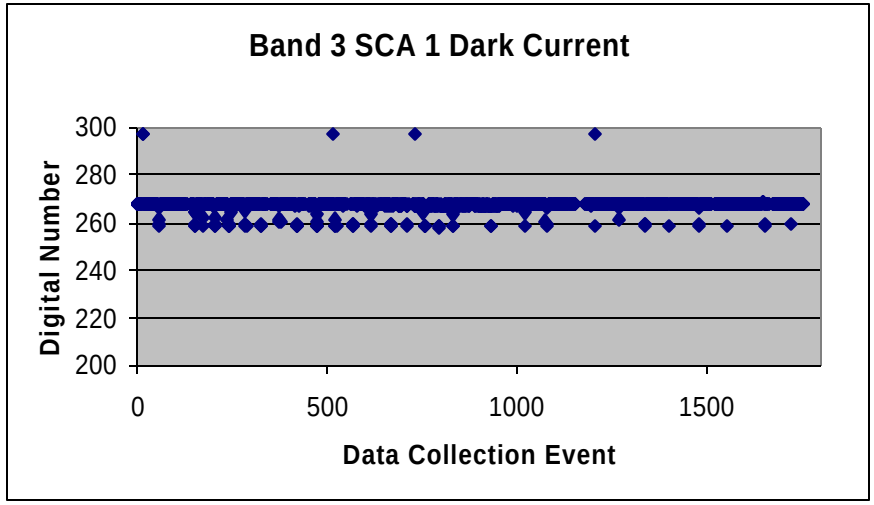


Dark Current Stability on Orbit

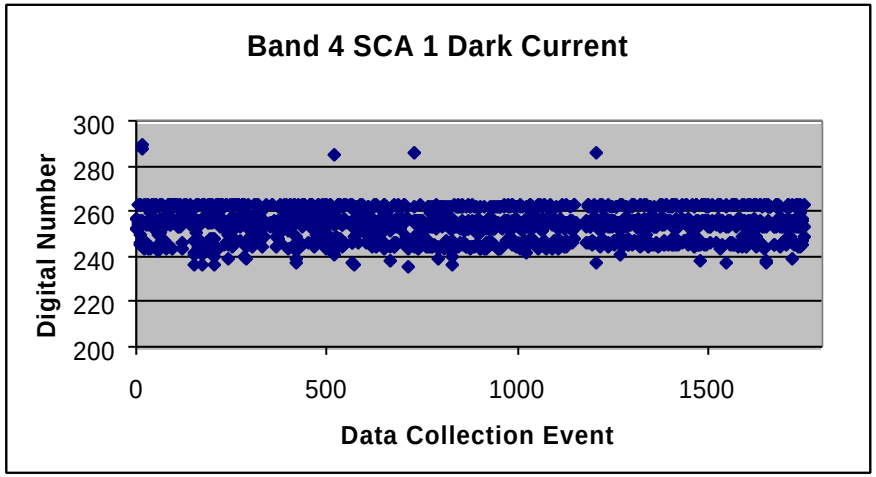


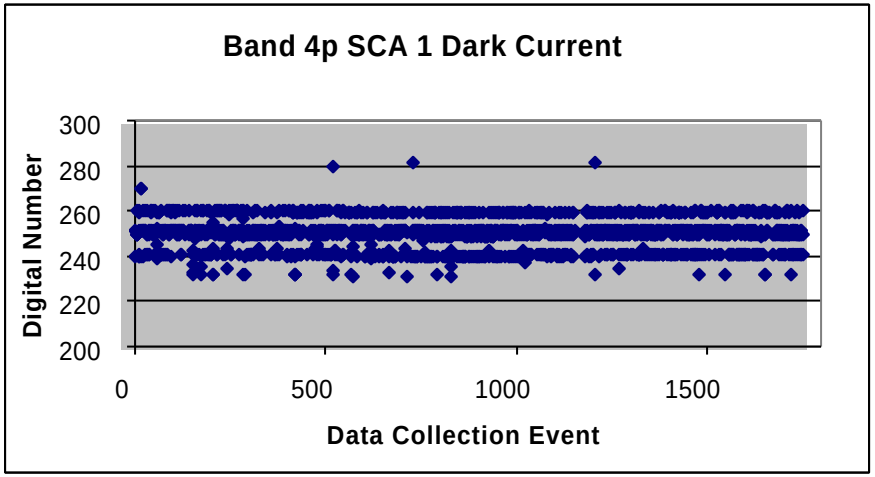


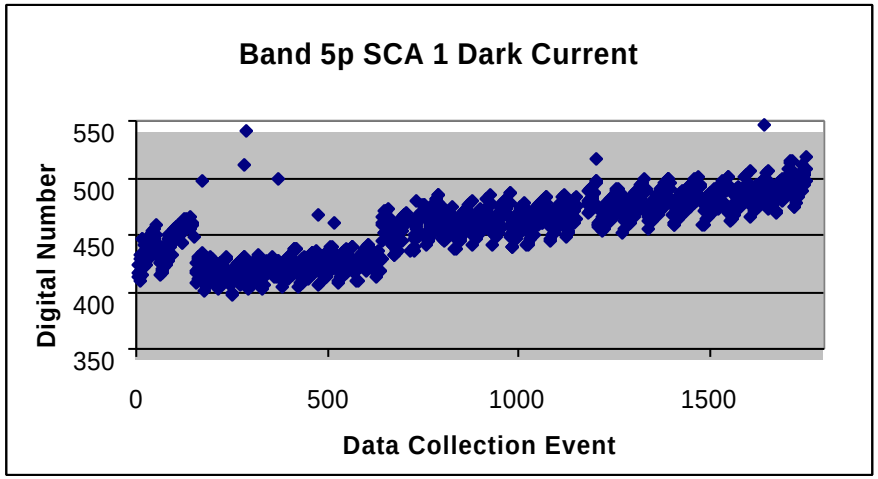


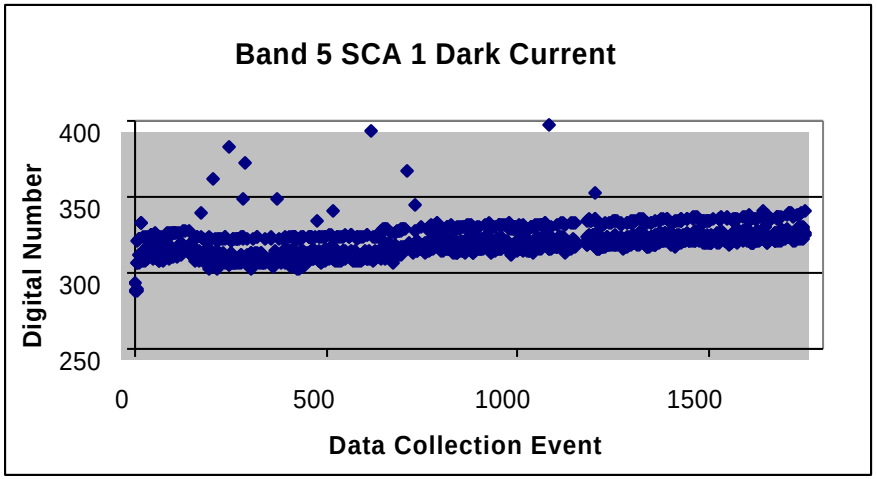


Dark Current Stability on Orbit

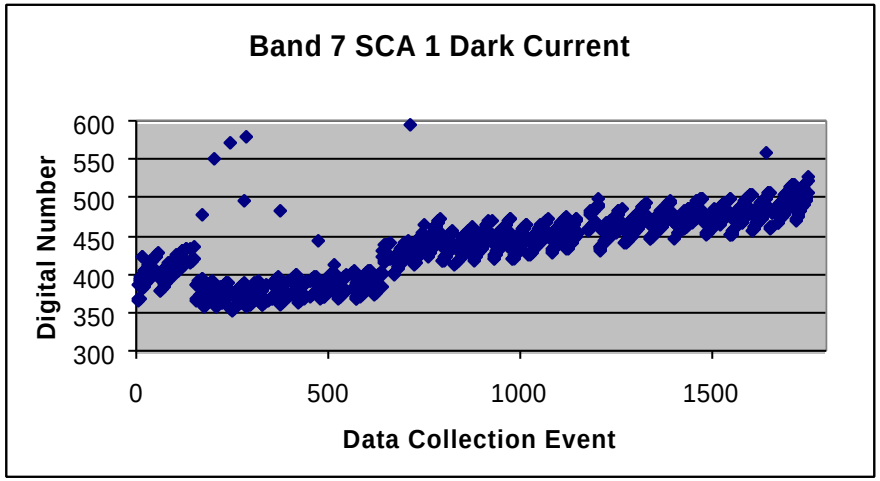


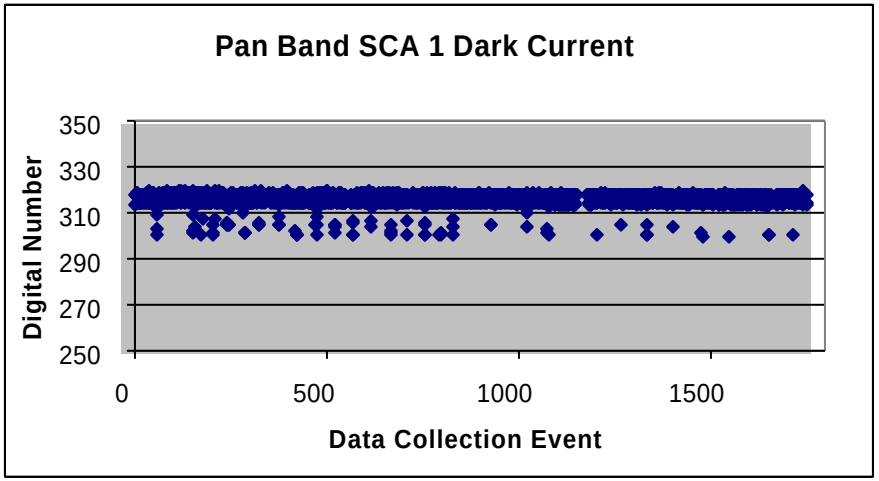






Dark Current Stability on Orbit

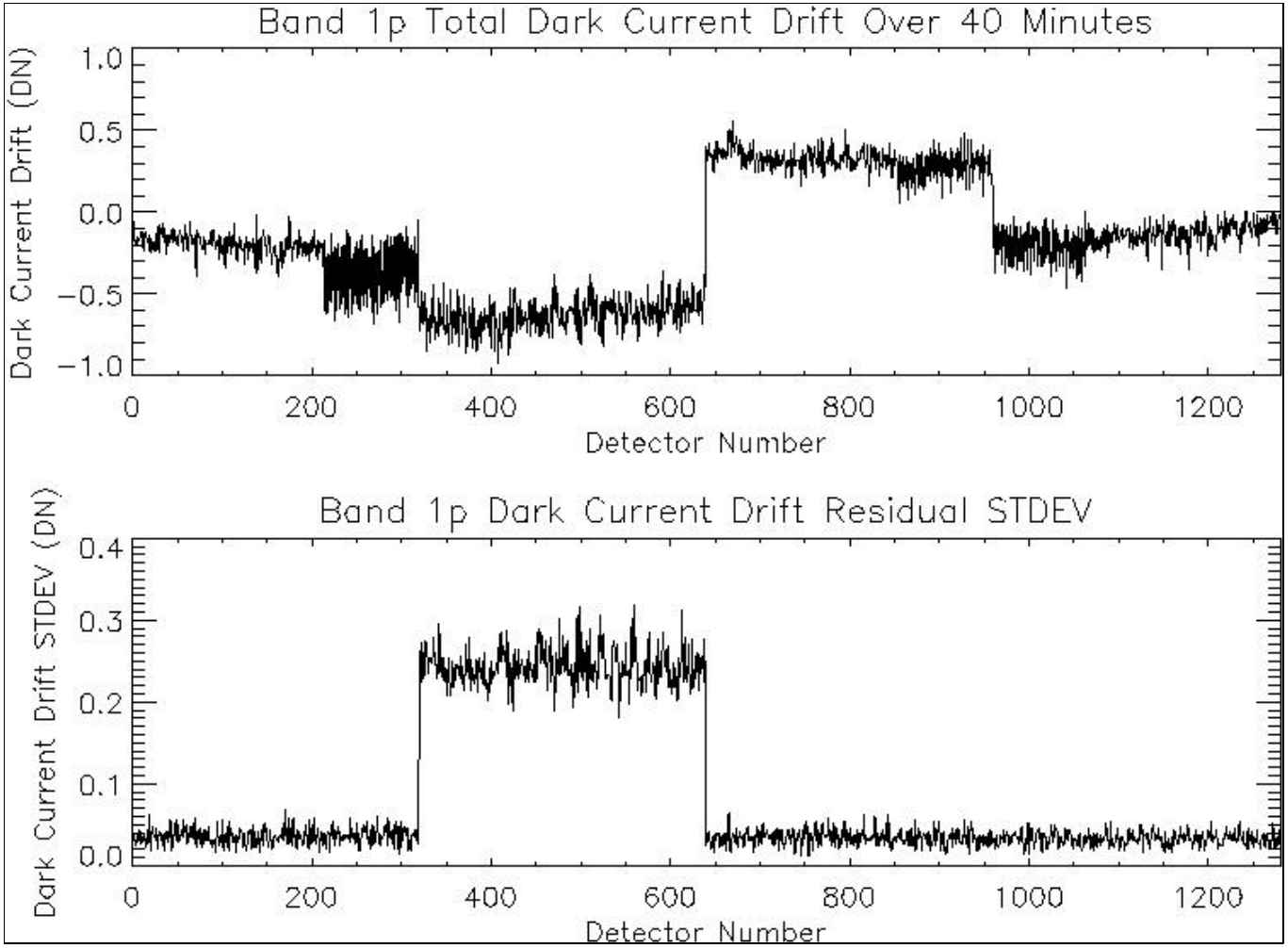




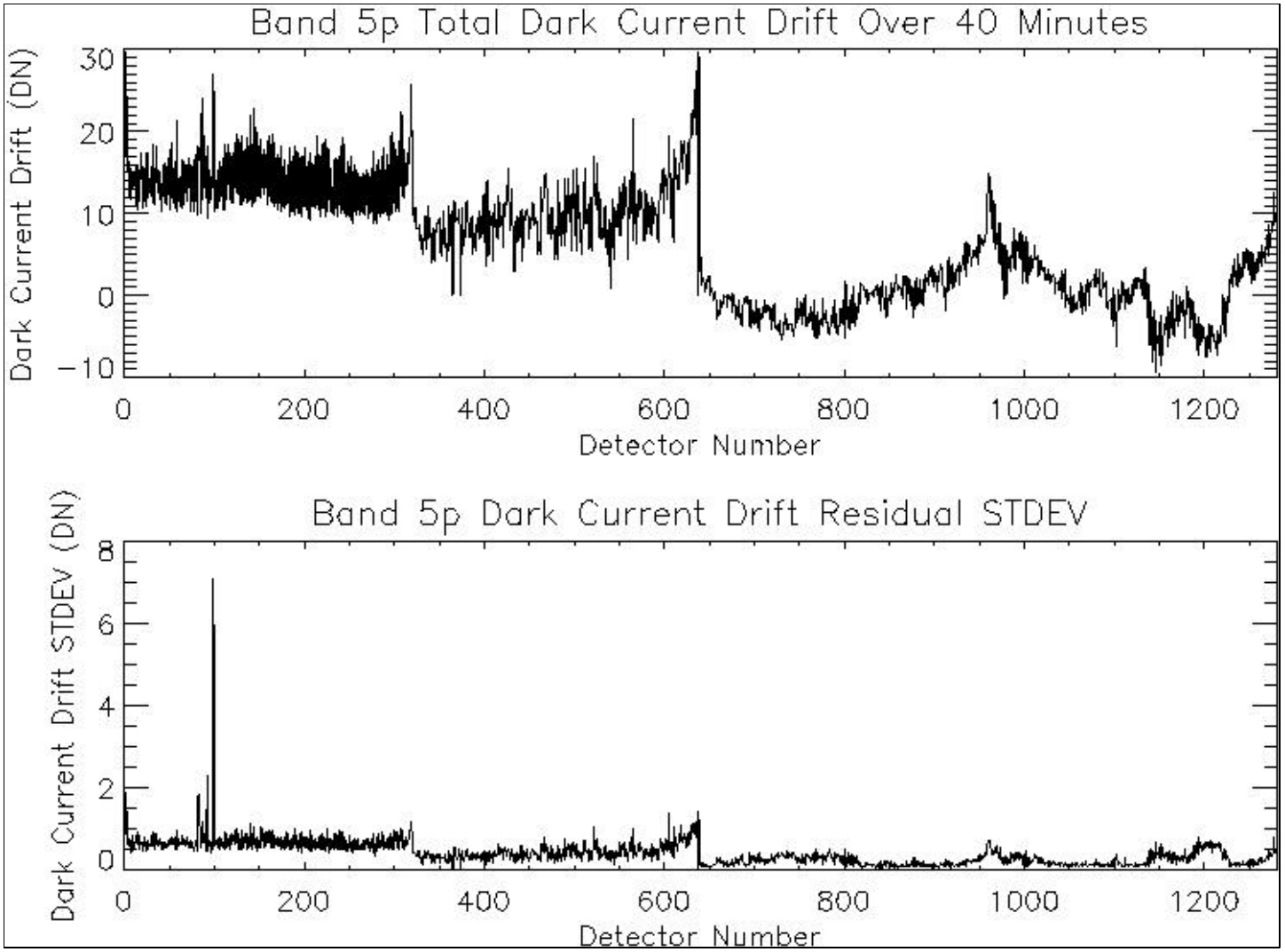
Dark Current Stability - 1/2 Orbit

- Collect 2 seconds of dark data every 5 minutes for 45 minutes every 2 weeks to monitor dark current stability
- Calculate dark current for each 2 second segment
- Fit linear function to complete data set
- Subtract function from data
- Any detector with a standard deviation > 1.5 DN is classified as a non-linear drifter

Dark Current Stability - 1/2 Orbit



Dark Current Stability - 1/2 Orbit



Dark Current Stability - 1/2 Orbit

Band	Detector Number	Residual Drift (Digital Number)
5p	2	1.86
5p	82	1.77
5p	83	1.87
5p	92	2.28
5p	99	7.07
5	119	6.16
5	911	1.86
7	0	1.57
7	4	1.63
7	11	4.72
7	17	1.61
7	126	2.86
7	285	1.81
7	292	2.32
7	295	1.64
7	297	1.88
7	301	2.09
7	305	1.55
7	307	4.58
7	315	1.52
7	319	2.01
7	638	1.65
7	639	1.64
7	951	1.60

Dark Current Stability - 1/2 Orbit

- All active VNIR and Panchromatic detectors are stable to within 1 DN for a period of 1/2 orbit
- All active SWIR detectors exhibit some linear drifting for a period of 1/2 orbit
- 99.4% of SWIR detectors drift linearly and may be easily accommodated by a simple drift subtraction using data collected in eclipse over the North and South poles
- 0.3% of remaining SWIR detectors drift non-linearly by < 2.3 DN
- Most non-linear drifting detectors have been previously associated with 1/f noise

Outline

- Noise
- Dark Current
- Anomalous Detectors
- Summary

Anomalous Detectors

- Inoperable
- Excessive noise (3X mean noise for SCA)
- Excessive dark current (1.25X mean for SCA)
- Anomalous gain
- Cross-talk

- 99.96% of focal plane functional
  - 6 inoperable
  - 21 with degraded performance
- 99.82% of focal plane has excellent performance

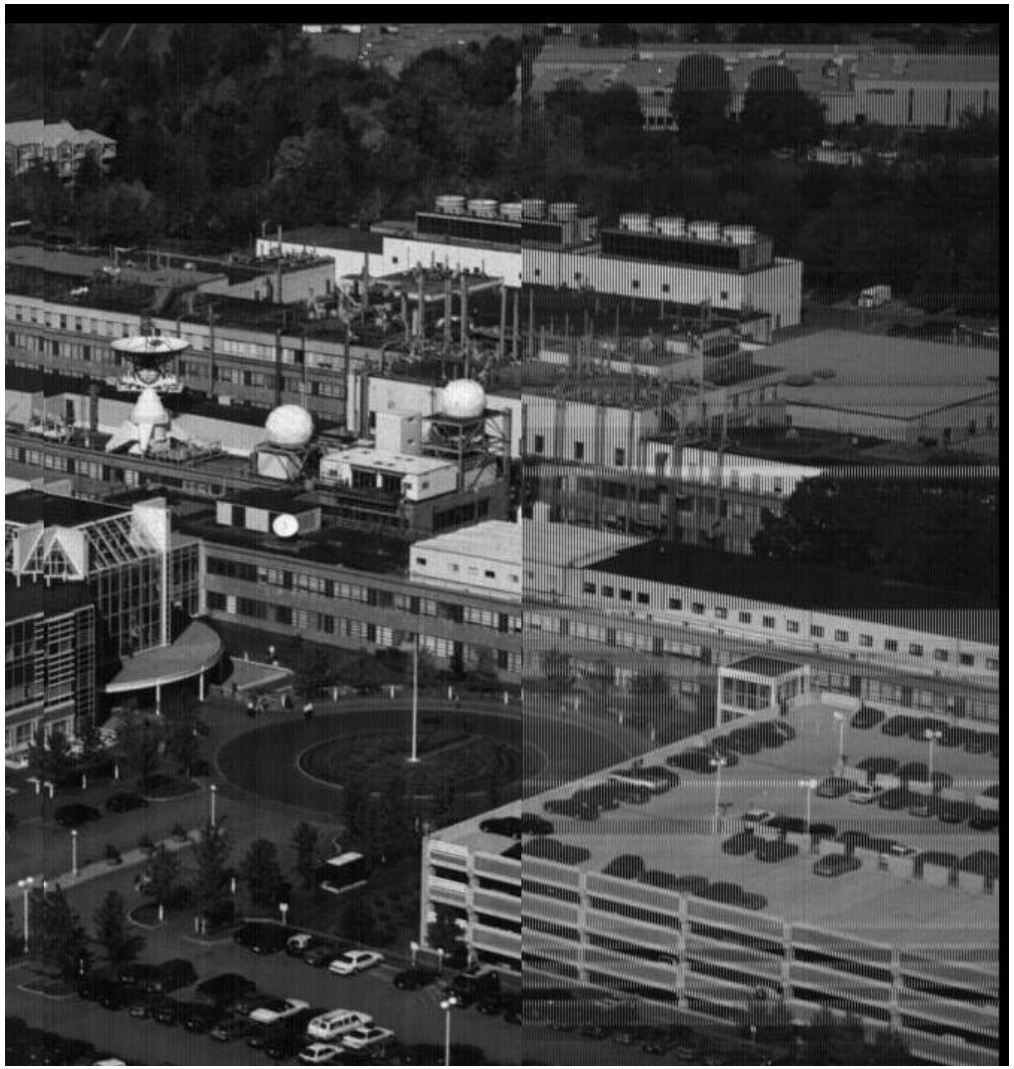
Anomalous Detectors

Band	Detector	Inoperable	Excess Dark Current	Excess Noise		High Cross-Talk	Anomalous Gain
				White	PRF		
1	989		X				
2	1149					X	
3	864					X	
5p	2				X		
5p	82			X	X		
5p	83				X		
5p	92			X	X		
5p	99			X	X		
5p	365		X	X	X		X
5p	372			X			
5p	374	X	X	X			
5p	636			X	X		
5p	638	X	X	X			
5	119				X		
5	911		X	X	X		X
5	913		X	X	X		X
5	982	X					X
5	1202	X	X	X			
5	1204	X	X				
5	1206	X	X	X			
7	4				X		
7	11			X	X		
7	17				X		
7	126				X		
7	307				X		
7	382			X	X		
Pan	1631			X			

Leaky Detectors

- Two detectors with high cross-talk (leaky) were identified during ground calibration.
  - Band 3 SCA 3 Detector 225
  - Band 2 SCA 4 Detector 190
- Detectors induce spurious signal onto neighboring odd (Band 3) or even (Band 2) detectors of the host SCA only.

Example of Band 2 Leaky Detector Effect



Example of Band 3 Leaky Detector Effect

Leaky Detector Correction Methodology

- Geometrically shift odd and even pixels
- Subtract dark current from each pixel
- Transform leaky and standard pixels to radiance space by radiometrically calibrating pixels
- Generate difference array for standard pixels to the left of leaky pixels
- Fit linear function *f* to standard pixel values v. difference array values
- Compute correction factor array for corrupted pixels

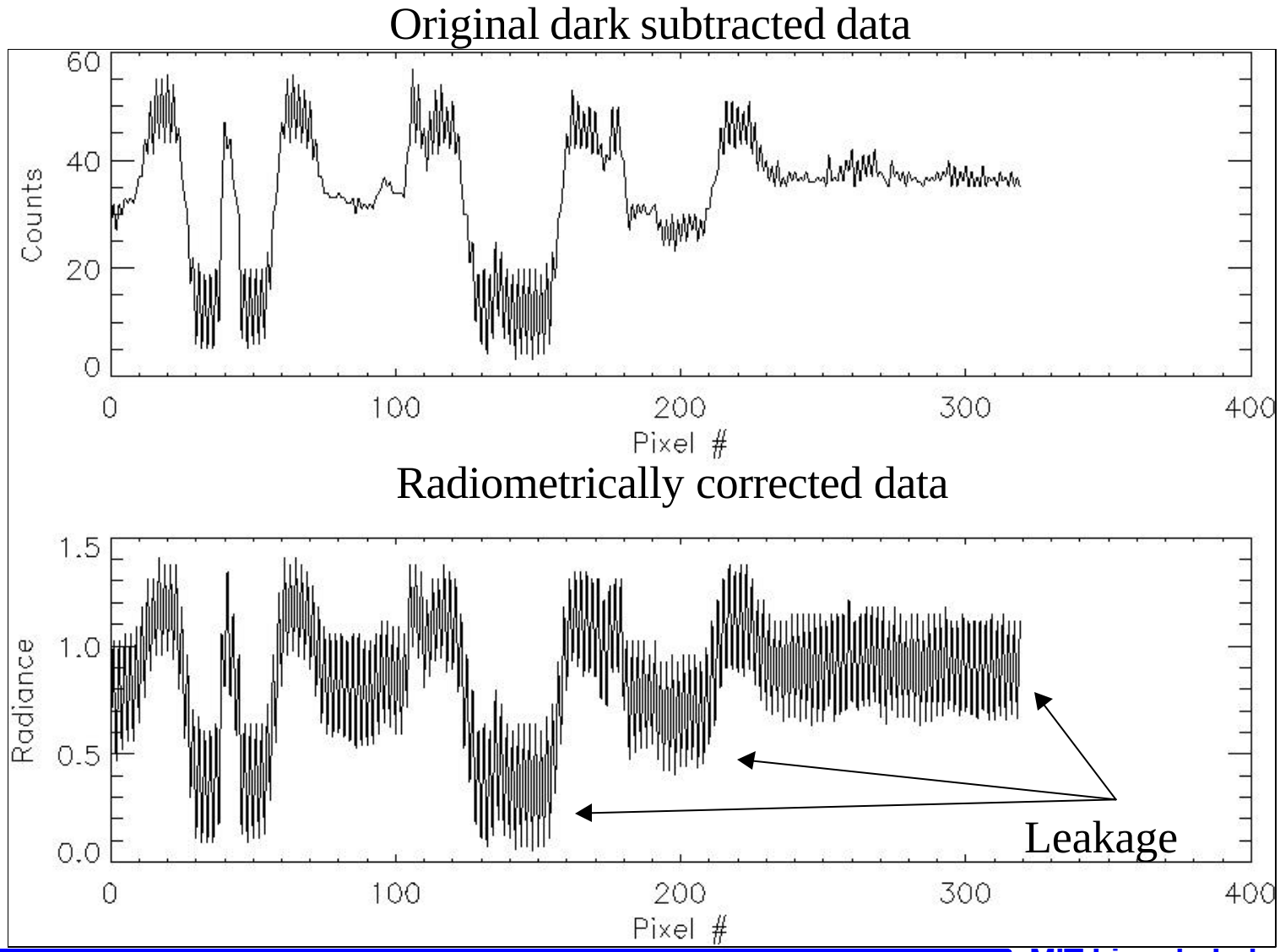
$$C(n) = f(0)+f(1)*L_S(n) \text{ for } n=0, 160$$

- Correct corrupted pixels

$$L_L(n) = L_L(n) - C(n) \text{ for } n = 0, 160$$

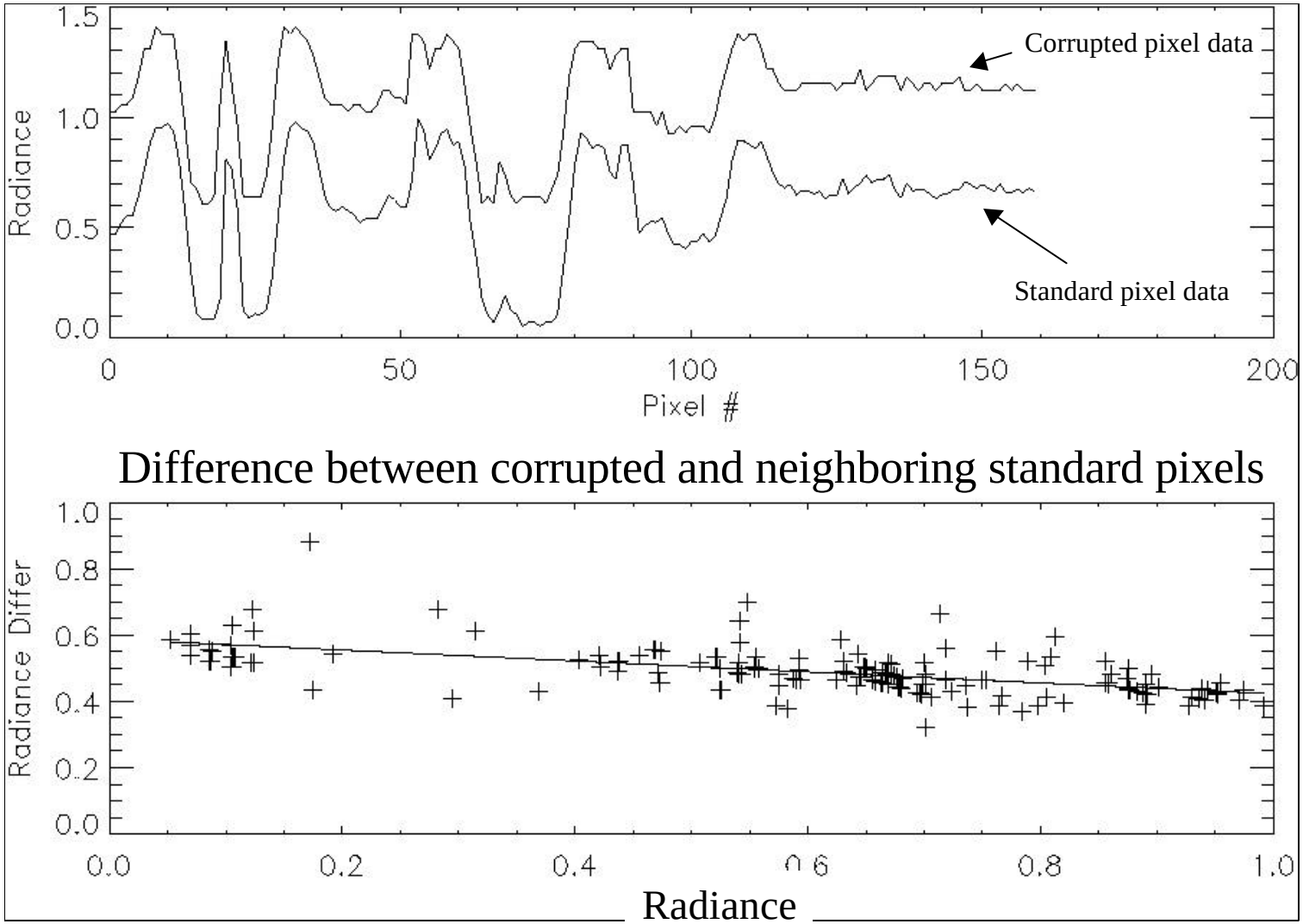
- Save corrected image

Leaky Detector Correction



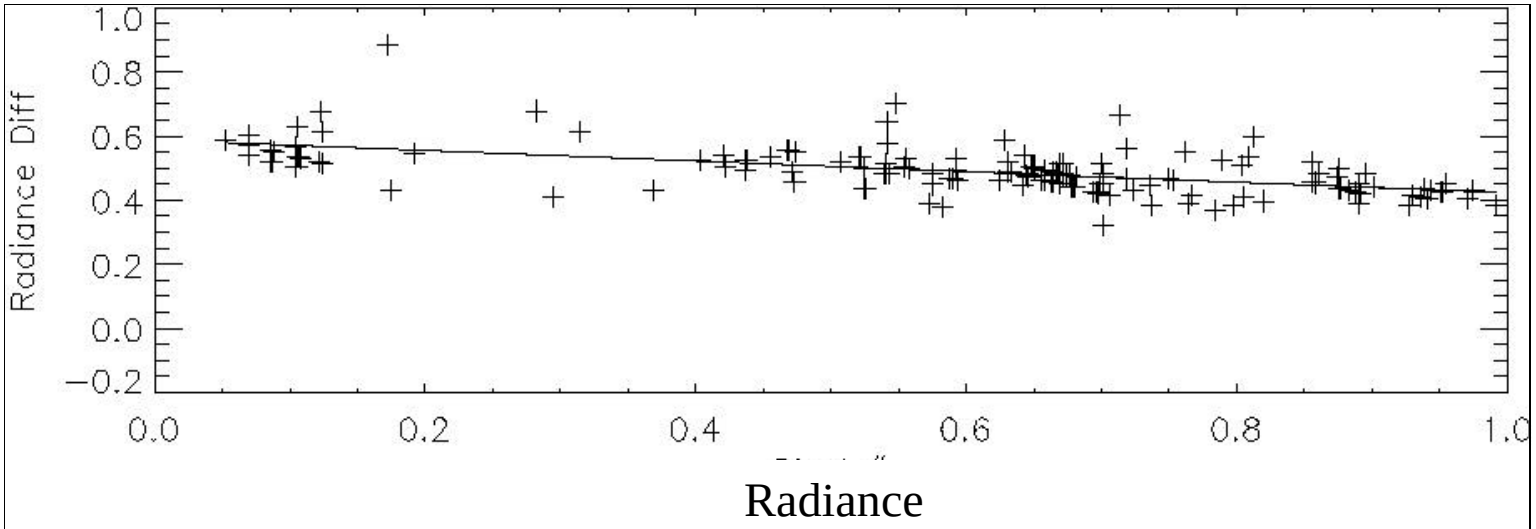
Leaky Detector Correction

Radiometrically corrected data

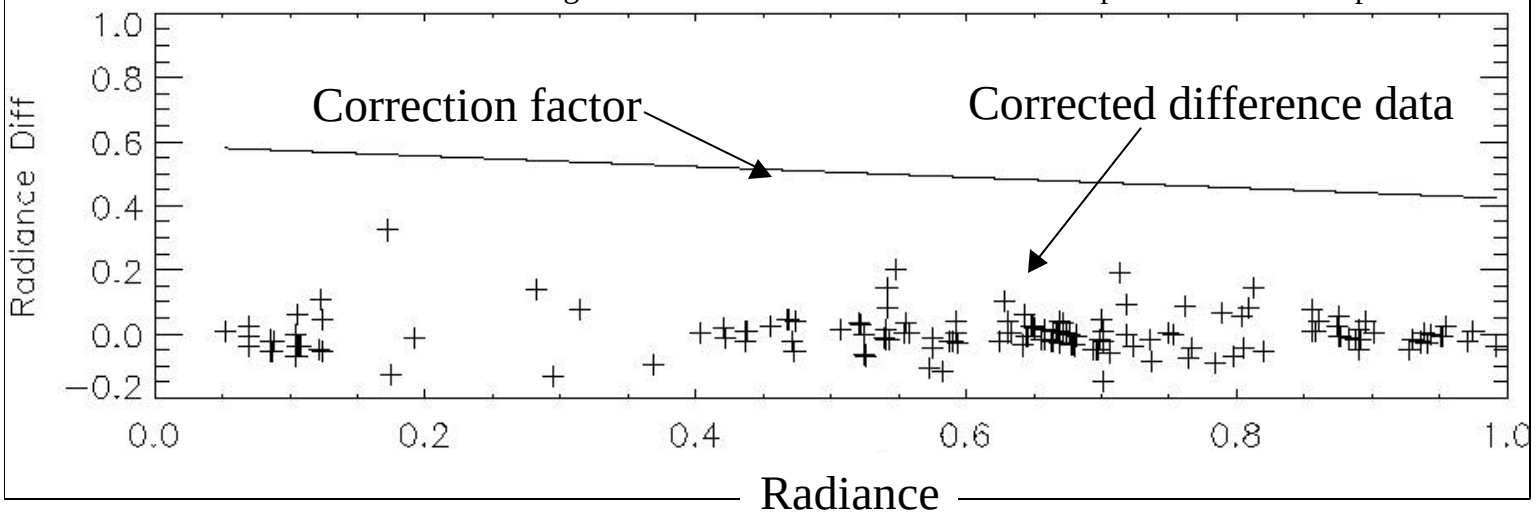


Leaky Detector Correction

Difference between corrupted and neighboring standard pixels

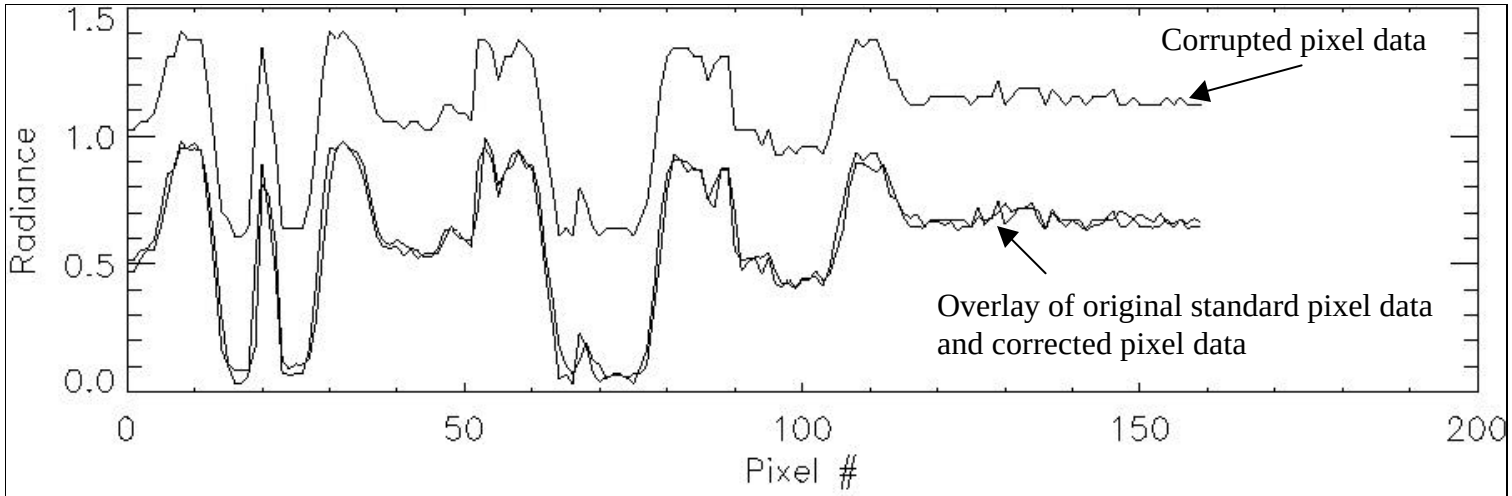


Demonstration of correction algorithm to difference data. Note: Pixel to pixel variations are preserved.

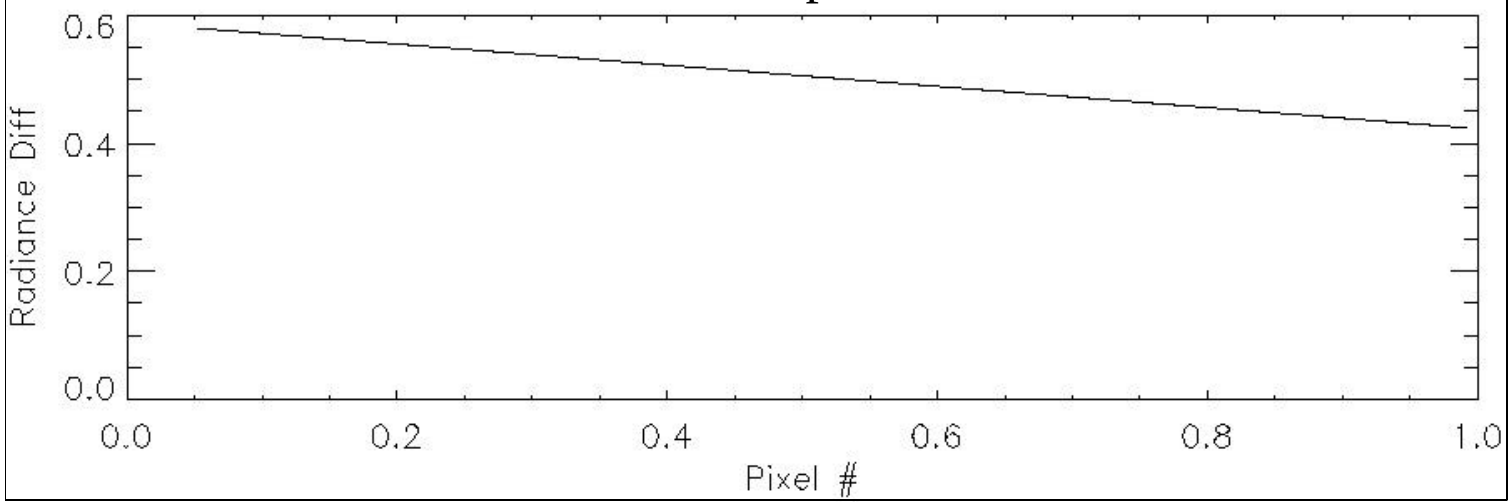


Leaky Detector Correction

Overlay of corrupted and corrected data.



Difference between corrupted and corrected data.



Leaky Detector Correction

Uncalibrated Image

Calibrated Image

Leaf Image

Leaky Detector Correction

Uncalibrated Image

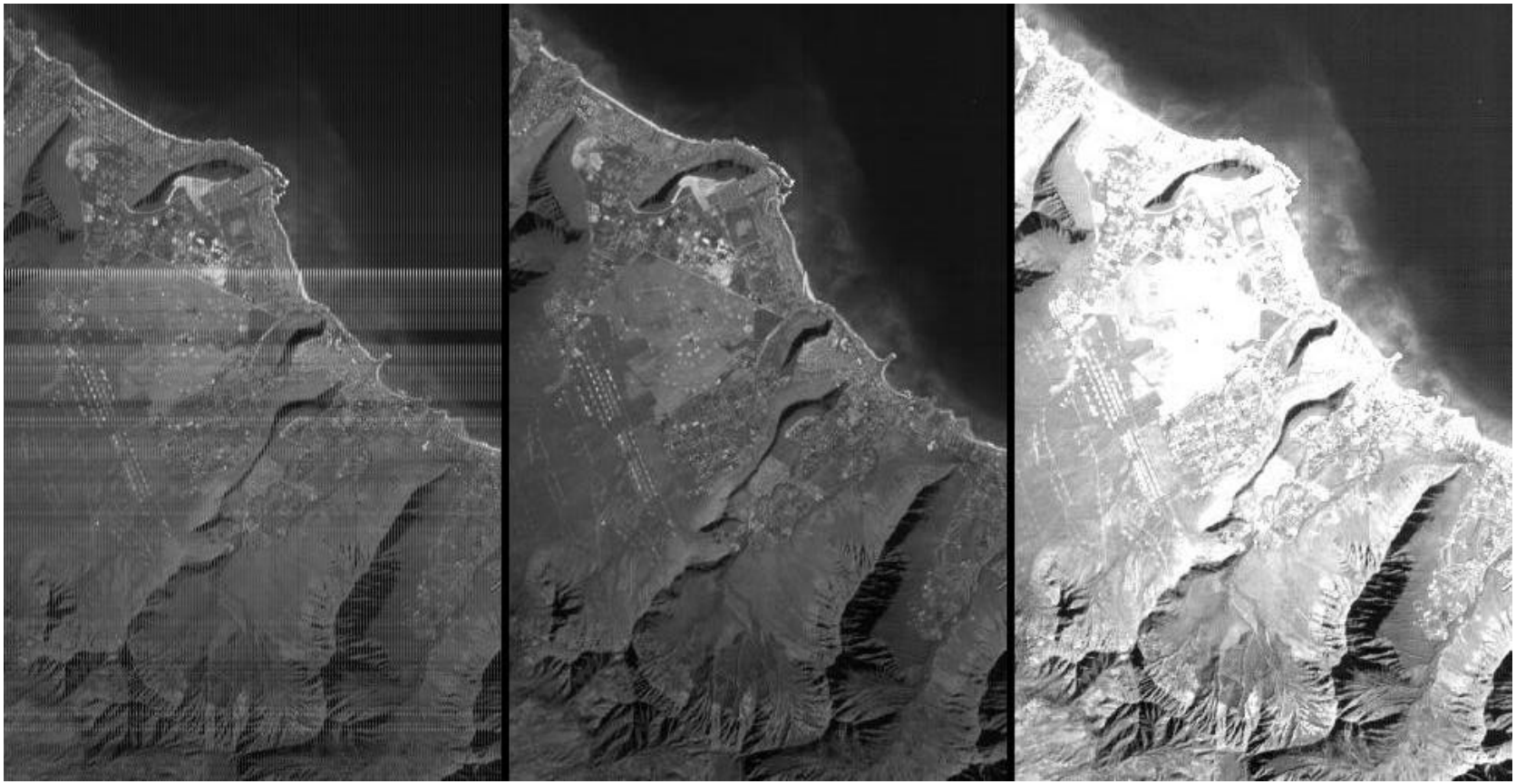
Calibrated Image

MIT/LL Image

Leaky Detector Correction

Oahu, 2000:354, Detail

Original **Corrected** **Corrected, high contrast**



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Summary

- ALI performance assessment during Laboratory ground testing closely matches on orbit measurements
- Small dark current deviations (<50 DN) observed between DCEs on orbit
- Dark current stability excellent (<1.5 DN) for all bands over 1/2 orbit period
- Only handful of detectors (0.18%) show anomalous behavior
- Two leaky detectors with high cross-talk have been problematic but an algorithm that removes this effect has been developed and implemented