Accounting for Dark Current Accumulated during Readout of Hubble's ACS/WFC Detectors

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Abstract

We study dark current accumulated during the100-second full-frame readout of the Advanced Camera for Surveys (ACS) Wide Field Channel (WFC) detectors. This excess dark current, called "readout dark", gives rise to background gradients and hot columns in each WFC image. While readout dark signal is removed from science images with bias correction, the noise from readout dark has not been taken into account. The ERR extensions of superbiases have been updated to include the appropriate noise from readout dark background gradients and stable hot columns. Only unstable hot columns are now flagged in the DQ extensions of the superbiases. A new reference file pipeline for WFC including these changes was recently completed.

Full analysis in ACS Instrument Science Report 2017-13:
http://www.stsci.edu/hst/acs/documents/isrs/isr1713.pdf

Background & Observations

Bias frames are used to characterize readout dark because only bias structure and readout dark are present. ~24 biases taken between anneals are combined into a superbias. Previously, superbias ERR extensions were the quadrature-averaged readnoise, and DQ extensions flagged any pixel above some threshold in the smoothed SCI extensions. To characterize readout dark:

1. Determine the variance increase due to readout dark in each detector quadrant.
2. Identify hot columns in the superbias and calculate the mean excess signal for each.
3. Determine the stability of each hot column over the set of bias frames.

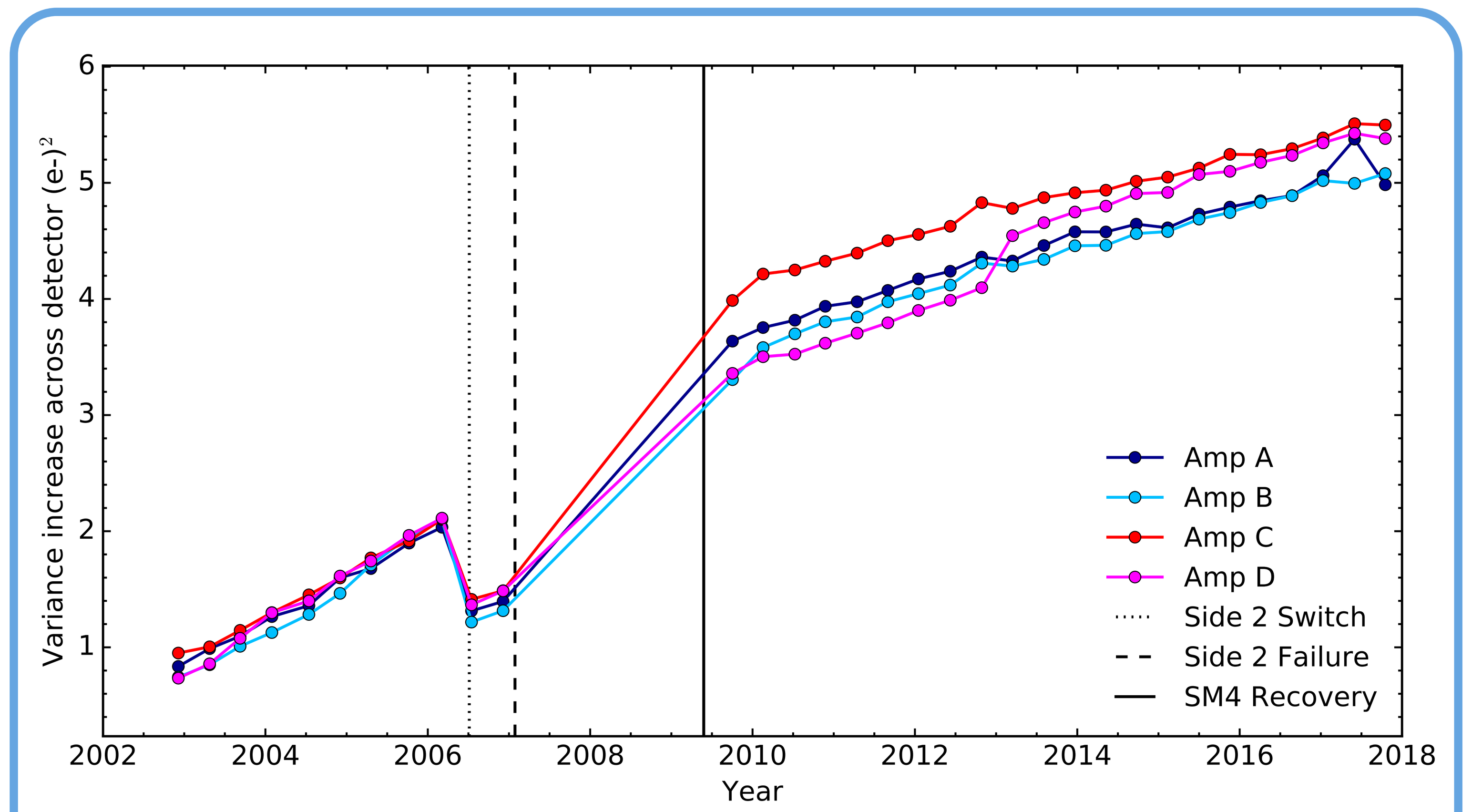


Figure 1: Observed variance increase across the detector in (e-)^2 due to readout dark as measured from raw biases over the lifetime of ACS. The dates of the switch to and failure of side 2 electronics, and the SM4 recovery of ACS/WFC are also indicated.

Background Noise Gradients

To calculate the increase in readout dark variance, we remove the bias gradient (Golimowski et al. 2011) by differencing pairs of consecutive biases. We sigma-clip by column to reject CRs and ignore columns hotter than 3xNMAD from the median column in the overscan. We fit a straight line to the noise in each row as a function of row number, and difference the squares of the fit endpoints to find the ambient variance increase across each quadrant. The variance increase values from all bias pairs in an anneal are averaged for each quadrant. In general, readout dark noise has been increasing since ACS was installed on HST, with the exception of a short period in 2006-2007 when the operating temperature decreased.

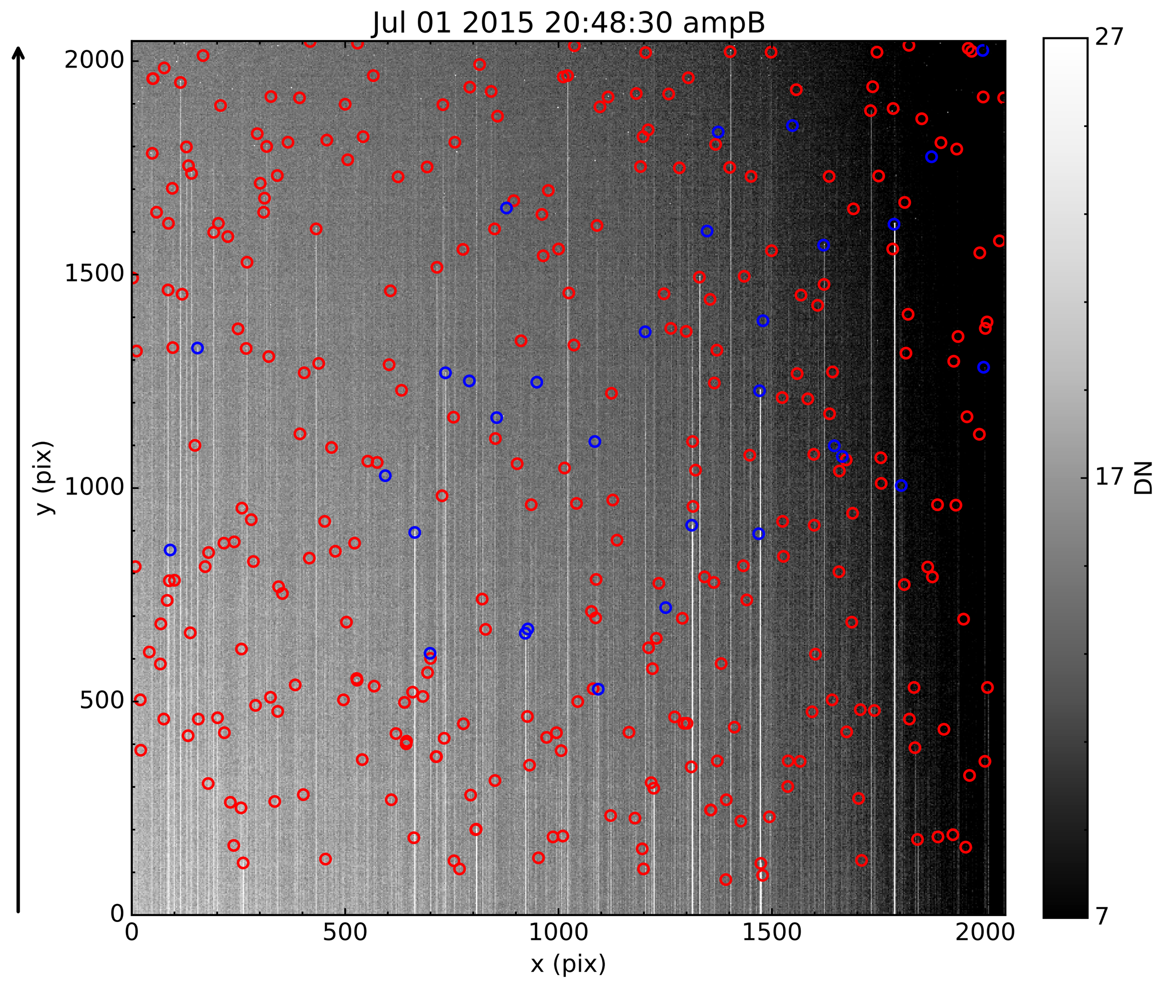


Figure 3: Top right quadrant (amp B) of the superbias from the 2015-07-01 anneal cycle. Hot columns extend upward from the bottom of the frame. Circles mark the starting point of each hot column, with the red and blue circles representing stable and unstable columns, respectively. The black arrow represents the readout direction.

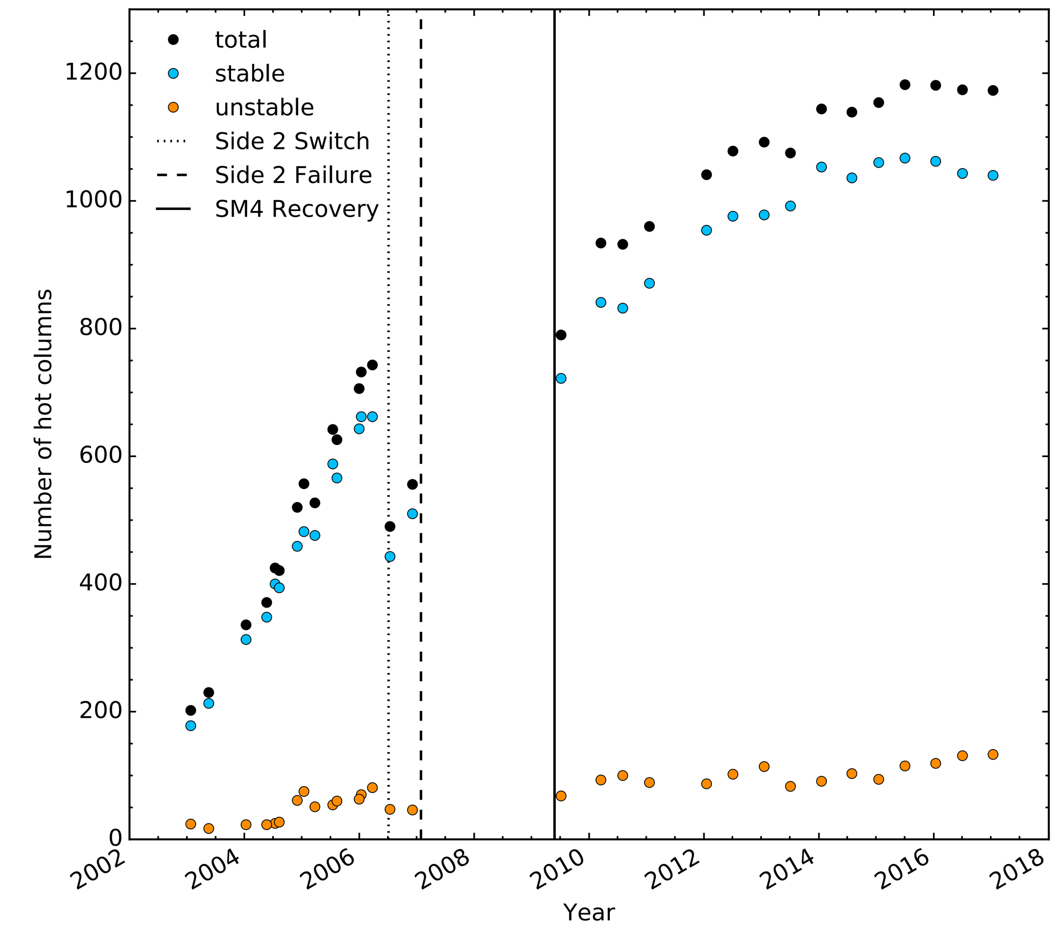
Identifying Hot Columns

We identify hot columns by running an edge detection filter over every local-background subtracted column. The maximum of the filtered column corresponds to the y-coordinate at which the hottest section begins. We find the mean excess above the background and the S/N in the hottest section of each column. Thresholds of mean excess > 1e- and S/N > 10 allow us to locate well-detected hot columns.

Stability of Hot Columns

To determine if each hot column is stable over each anneal, we define a stability metric (*m*) comparing the expected to observed noise. If the column varies as expected, *m* should be zero. For recent anneals, we find that the distribution of *m* peaks at ~0.3. We select a threshold of *m*<2 to designate a hot column as stable. While the number of hot columns identified in superbiases has increased dramatically over ACS's lifetime, the proportion of stable (~90%) to unstable (~10%) hot columns has remained fairly constant.

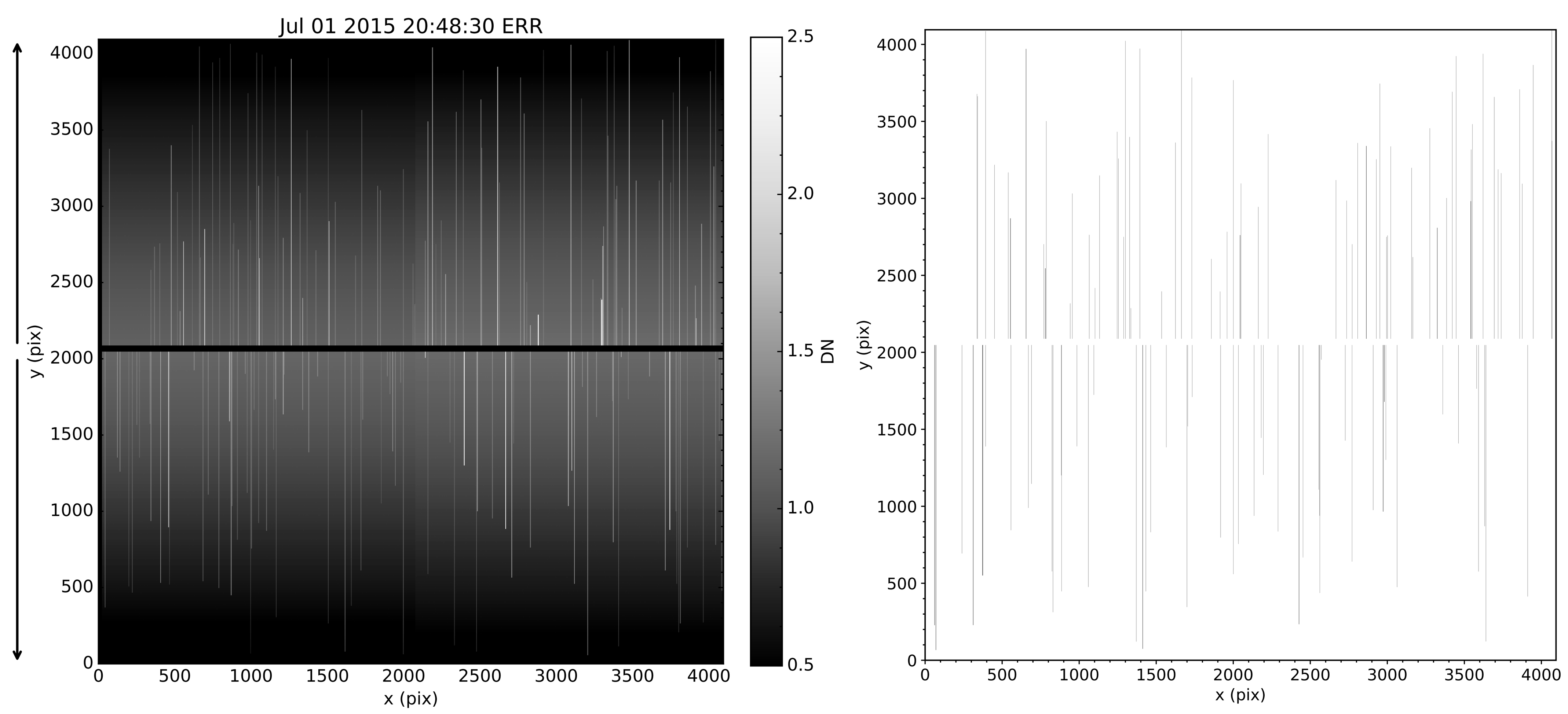
Figure 4: Number of hot columns identified in superbiases as a function of time. The black, blue, and orange points are the total, number of stable, and number of unstable hot columns, respectively. The dates of the switch to and failure of side 2 electronics, and the SM4 recovery of ACS/WFC are also indicated.



New Superbiases

Background readout dark gradients and stable hot columns are removed from science data via superbias subtraction. Unstable hot columns cannot be properly subtracted from science images. To account for these features, new superbiases will contain:

1. ERR extensions populated by the combination of stable hot column noise, background variance gradients, and readnoise.
2. DQ extensions that flag only unstable hot columns with the bias structure flag, 128.



ERR and DQ Comparison

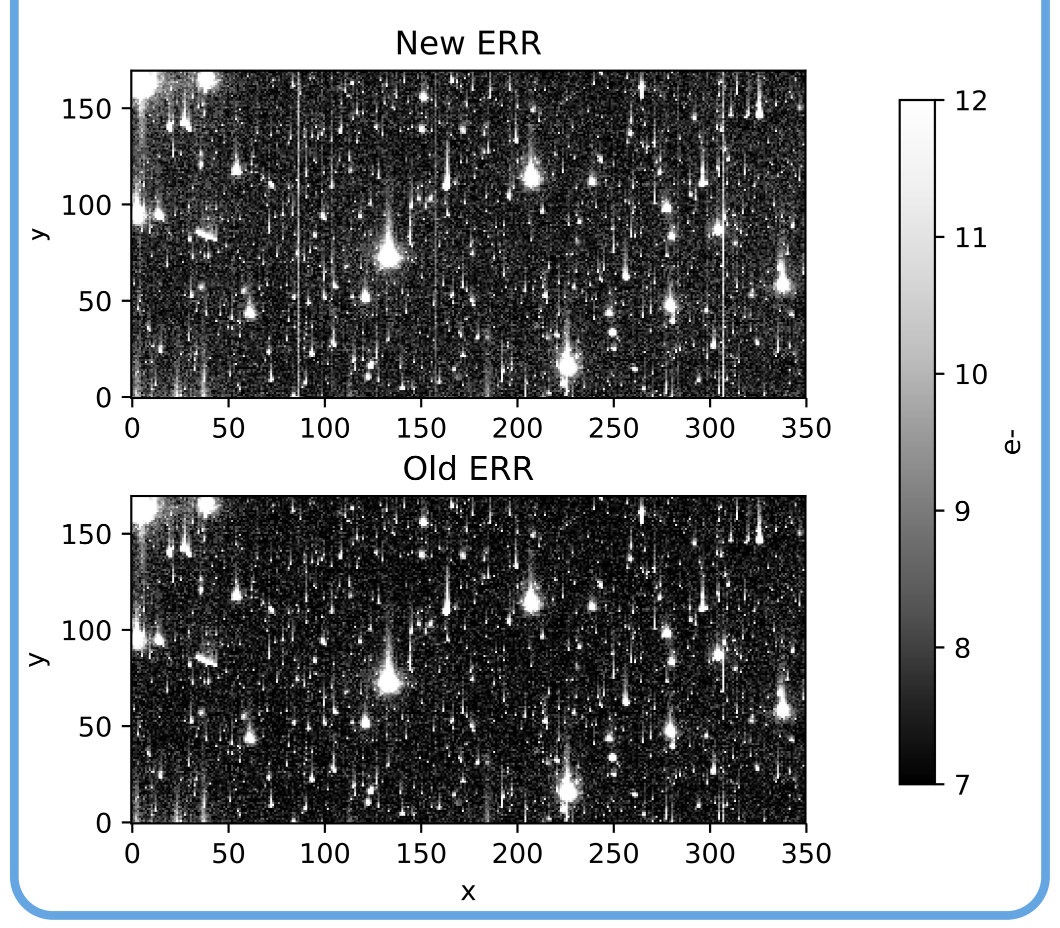
We processed a 336-sec F555W image of 47 Tuc through CALACS with a new and old superbias. A comparison of ERR and DQ in the resulting FLCs are given below.

ERR

	Near serial register	Far from serial register
Median Difference (new – old)	0.05 e-	0.3 e-
% Increase	0.7%	4%

DQ

	Old		New	
	WFC1	WFC2	WFC1	WFC2
% of Detector Flagged	0.20%	0.13%	0.82%	0.75%



Conclusions

Excess dark current accumulated during readout of the ACS/WFC detectors is significant, and in general has been increasing since ACS was installed on HST, likely due to radiation damage. New superbiases generated by a new reference file pipeline account for this readout dark with added noise in the ERR arrays and flagged unstable hot columns in the DQ arrays.

References

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