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Improvements and Updates to the WFC3/IR Bad Pixel Tables: Cycle 28-30

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Abstract

Our study focuses on the generation and validation of IR bad pixel table reference files (IR BPIXTAB) for Cycles 29 (Nov 2021) and 30 (Nov 2022), along with the revision and redistribution of two existing IR BPIXTABs to rectify anomalies observed in 2021 and 2022. We also address the issue of an unusual spike in cold and unstable pixels detected during Cycle 28 (Nov 2020), attributing it to algorithmic discrepancies within the pipeline utilized for BPIXTAB generation. We identify that the variance in input darks, sourced from three distinct BPIXTAB reference files, can artificially increase the number of pixels that appears to be cold and unstable. By generating a Cycle 28 IRBPIXTAB where all input dark frames have been processed with the same set of calibration reference files, we observe a substantial reduction in the flagged pixel percentage (from 2.85% to less than 1%), affirming the presence of an algorithmic error rather than an intrinsic detector issue and mitigating the abnormal pixel spike observed in Cycle 28. Furthermore, we provide an updated Cycle 28 IR BPIXTAB, utilizing input darks calibrated `53514239i_bpix`, to reflect the corrected cold and unstable pixel counts.

Introduction

The WFC3/IR detector exhibits pixel variations across the entire field of view that may affect the quality of individual pixels. All pixels and regions found to be anomalous enough to negatively impact the scientific data are flagged as bad pixels and are listed in the IR bad pixel table (hereafter IR BPIXTAB) reference file. The IR BPIXTAB is generated through two annual on-orbit calibration programs that are used to identify bad pixels and regions on the IR detector. The IR BPIXTABs are propagated into the data quality (DQ) arrays of the observation's `ima` and `flt` files (Sahu 2021, section 2.1) produced by `calwf3`, the WFC3 data calibration pipeline (Sahu 2021, section 3.1).

We measure the heat and the stability of bad pixels in tandem with the creation of the IR BPIXTAB in order to monitor the health of the detector over time. Flagged hot pixels exhibit signal levels that are 8 times higher than the innate thermal background present in all images (B. Sunnquist et al. 2019). An unstable pixel exhibits inconsistencies in signal from one identical dark observation to another, and can be caused by a variety of reasons such as random telegraph noise and sporadic variability.

The last IR BPIXTAB was generated, and analysis on the heat and stability of IR pixels was conducted, on Cycle 28 (Nov 2020): where the proportion of flagged cold and unstable pixels was reported to be higher by 1.7% (to 2.8%) from Cycle 27 (Khandrika 2022). In this report, we generate IR BPIXTABs for Cycles 29 and 30 and revisit the large increase in cold and unstable pixels exhibited in Cycle 28.

Data

Similar to previous cycles, we use full-frame darks and flat images from internal WFC3/IR calibration programs to generate the IR BPIXTAB and analyze pixel behavior for Cycles 29 and 30. We use 24 full-frame darks each taken in SPARS200 mode with 16 sample ramps and exposure times of 2800 seconds. In addition, we use 8 internal flat-fields taken in F140W with exposure times of 38 seconds each. The darks are obtained twice monthly throughout the year and the internal flat images are taken at three epochs during each cycle: in December, March/April, and September. Input darks and flats are processed through `calwf3` with standard calibration steps (reference pixels, lienarity, bad pixel table, CR removal, and conversion to countrates). Table 1 summarizes the proposal IDs and observation dates for both the dark and flat data sets for Cycles 28, 29, and 30.

An IR BPIXTAB is made annually with updated flagged pixels for each cycle, identifying bad-in-zeroth read, dead, hot, and unstable pixels using the full-frame darks and flats observed in that specific cycle's calibration program. In addition, every time an "IR blob" (a small, circular region with decreased sensitivity) appears on the detector, a new bad pixel table is generated immediately to correct for the blob (Ben Sunnquist 2018). The IR BPIXTABs made in previous programs are propagated back into the input darks used to make the next annual and blob IR BPIXTABs. The full methodology on the generation of IR BPIXTABs and the resulting analysis is described in more detail in WFC3 ISR 2019-03 (B. Sunnquist et al. 2019).

Table 1: *Proposal IDs and observation dates for the dark (D) and flat (F) data set for Cycles 28, 29, and 30. Full-frame darks are taken twice a month. The flats used are taken in three cadences: December, March or April, and September of the following year.*

	Cycle 28	Cycle 29	Cycle 30
Proposal ID	D: 16403 F: 16411	D: 16575 F: 16586	D: 17011 F: 17201
Obs-Date	D: Nov 2020 - Oct 2021 F: Dec 2020 - Sep 2021	D: Nov 2021 - Oct 2022 F: Dec 2021 - Sep 2022	D: Nov 2022 - Oct 2023 F: Dec 2022 - Sep 2023

Results

Figure 1 shows all pixels flagged in the IR BPIXTAB made using Cycle 30 input darks and flats. Two "IR blobs" have been discovered in between Cycle 28 and 30 time frame, the first appearing on June 13, 2021 (which is also flagged in the new Cycle 29's BPIXTAB) and the second on Oct 8, 2022.

Initial IR BPIXTABs (`57m1910ei_bpx.fits` and `71c1928ri_bpx.fits`[1]) that were made to immediately correct for these two blobs were generated using Cycle 27 IR BPIXTABs due to Cycles 28 and 29 BPIXTABs not being generated at the time of the blob's appearance. These IR BPIXTABs are redelivered and replaced to reflect the correct Cycle (BPIXTAB with Cycle 28 data for the first blob, and BPIXTAB with Cycle 29 data for the second blob) on the HST Calibration Reference Data System (CRDS).

[1] A list of delivered IR bad pixel tables and other reference files used in `calwf3`, their `USEAFTER` dates, and their reason for delivery can be found at https://hst-crds.stsci.edu.

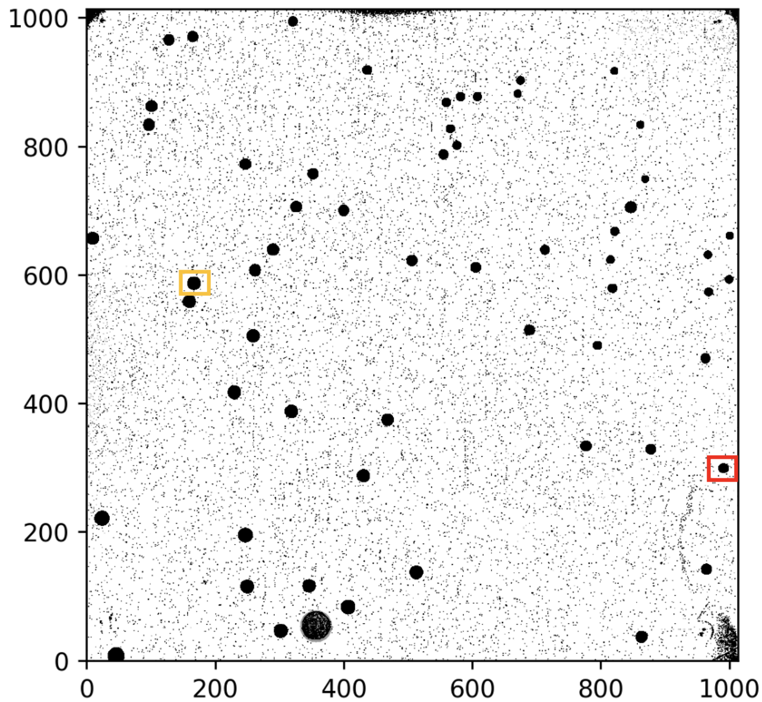

Figure 1: *Pixels flagged in the Cycle 30 (Nov 2022) IR bad pixel table. The x and y axis represents the detector's field of view. Since Cycle 28, two "IR blobs" have appeared on the detector. The one highlighted in yellow first appeared on June 13, 2021 and the one highlighted in red appeared on Oct 8 2022. Both of these blobs are corrected using the IR BPIXTAB from Cycle 27 on CRDS. Redeliveries are made to reflect the correct cycle for each of the current IR BPIXTABs that accounted for the blobs. The blob highlighted in yellow is corrected for in Cycle 29's annual IR BPIXTAB (`USEAFTER`: Nov 2021) and both blobs are corrected for in Cycle 30's annual IR BPIXTAB (`USEAFTER`: Nov 2022).*

Cold and Unstable Pixel Analysis

We revisit the high percentage of pixels that are cold and unstable shown in Figure 1 in Khandrika 2022 that appeared in Cycle 28, hereafter referred to as the "the spike". We investigated the input darks that were used to make the BPIXTABs for Cycles 27 (before the spike), 28 (the spike), and 30 (after the spike). We compared header values for discrepancies in reference files for Cycles 27, 28, and 30 and find that every input dark shares the same reference files within their respective cycles except for the `BPIXTAB` used in Cycles 28 and 30. For Cycle 30, two different `BPIXTAB`s are used: five input darks used `57m1910ei_bpx`, while 18 used `71c1928ri_bpx`. Both of these `BPIXTAB`s were made using the same input darks (Cycle 27 input darks), and accounted for two different blobs (Figure 1). This did not seem to negatively impact the flagging of bad pixels, as all `BPIXTAB`s used accounted for the first blob, and a majority (18/23) accounted for both blobs, so pixels were being flagged appropriately.

However, Cycle 28 exhibits much more variation. The 24 total input darks used in

Cycle 28 use three different BPIXTABs that are split more evenly among them: nine darks used 47m1519ni_bpx (Cycle 25 annual IR BPIXTAB), seven used 53514239i_bpx (Cycle 27 annual IR BPIXTAB), and eight used 57m1910ei_bpx (IR BPIXTAB made to account for the IR blob that appeared on June 13, 2021 using Cycle 27 input data). This is due to the different USEAFTERs of each BPIXTAB, and the monthly cadence in which the input darks are observed.

To investigate the effect of the input darks utilizing different BPXITAB reference files, we created 3 different Cycle 28 IR BPIXTABs, each using only darks with the same reference files. The percentages of cold and unstable pixels flagged on the detector in the three newly generated IR BPIXTABs is shown in Figure 2 along with the percentage of cold and unstable pixels flagged in the BPIXTAB using all of the input darks in Cycle 28. The fraction of cold and unstable pixels flagged on the detector dropped from 2.85% to 0.87% when using every input darks versus using input darks of only the most recent correct BPIXTAB of the three, 53514239i_bpx.

It is clear that the previously reported (Khandrika 2022) large increase in cold and unstable pixels in Cycle 28 is due to the input darks being calibrated with different BPIXTAB reference files, and is not an indication of a increase in unstable pixels. Khandrika 2022 theorized that the rise in cold and unstable pixels is due to highly temporally variable pixels and telegraph noise. Although these factors likely do contribute to occasional additional flags, they probably are not playing a significant role: the differing BPIXTAB reference files used to calibrate the input darks causes the majority of the discrepancy seen in cold and unstable pixels flagged in Cycle 28 compared to previous cycles.

The mechanism through which the difference in the reference files propagated to create the discrepant flagging is yet to be understood, however it is most likely to due to the algorithm that is used to generate the IR BPIXTABs. The slight decrease in flagged cold and unstable pixels in the new Cycle 28 IR BPIXTAB compared to cycles around it (0.86% flagged pixels for Cycle 28 compared to 1.12% and 0.98% in Cycles 27 and 29) could in part be due to the sample size of the darks decreasing from 24 to 9, leaving the Poisson noise to be $\sim \sqrt{3}$ higher than other cycles. Despite this, the statistics are still in family with subsequent cycles, deviating by about 0.1-0.2%. The percentages of cold and unstable pixels flagged also seem to slightly decrease with more recent BPIXTAB used in the input darks, by about ∼0.1%.

The IR BPIXTAB 61s2016oi_bpx for Cycle 28 (with the anomalous spike) was generated from every input dark, and over-flags cold and unstable pixels. A re-delivery is made using only input darks calibrated with 53514239i_bpx BPIXTAB reference file to correct the spike. We choose to use 53514239i_bpx out of the three due to the fact that 47m1519ni_bpx is outdated and 57m1910ei_bpx needs to be redelivered with Cycle 28 data.

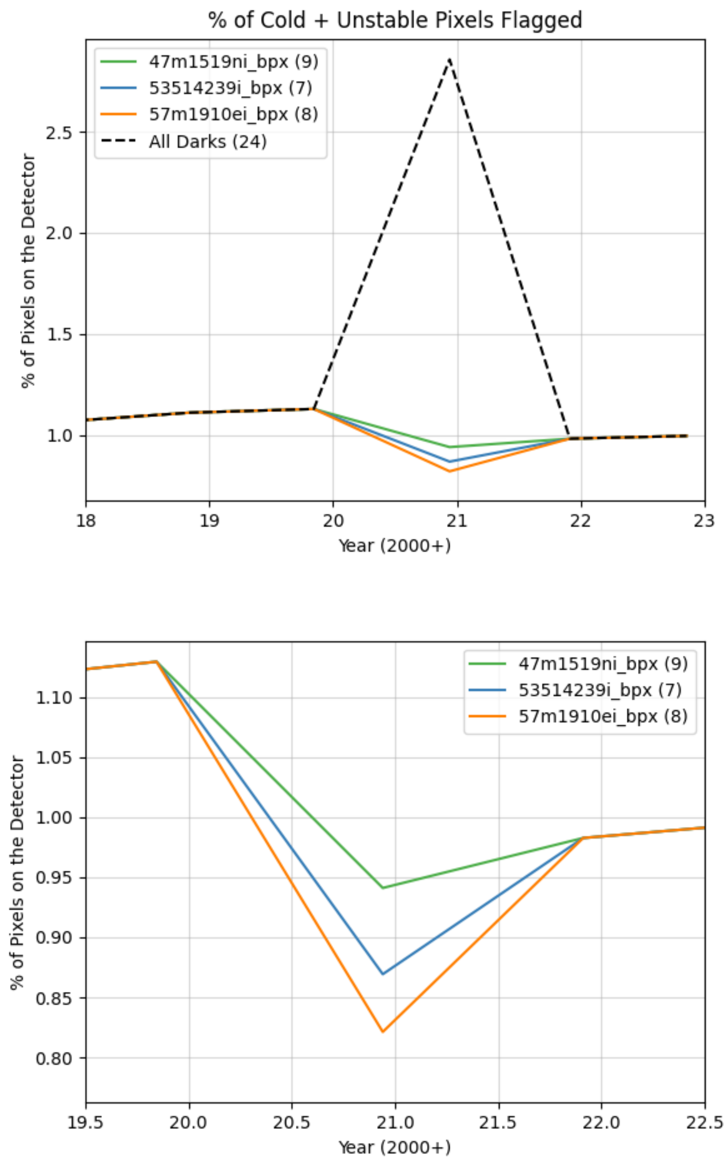

Figure 2: *Percentages of cold and unstable pixels for Cycle 28 using input darks that are calibrated with one of three different* **BPIXTAB** *reference files:* **47m1519ni_bpx**, **53514239i_bpx**, *and* **57m1910ei_bpx**. *The percentages of cold and unstable pixels for Cycle 28 using every input dark is also plotted for comparison. The number in parentheses specifies how many total darks are incorporated into making that specific Cycle 28 IR BPIXTAB. The percentages of cold and unstable pixels using all input darks drops from 2.85% to 0.82% - 0.94% when using only input darks calibrated with the same* **BPIXTAB** *reference file. It is clear that the large increase in cold and unstable pixels flagged reported previously in Cycle 28 is due to the input darks using different* **BPIXTAB** *reference files, and is not an actual indication of an increase in unstable pixels.*

Figure 3 shows the percentages of WFC3/IR detector pixels that are cold, hot, stable, and unstable in a stack plot from 2009 - November 2022 (an update of Figure 1 from Khandrika 2022) with the corrected Cycle 28 values using darks with `BPIXTAB` reference file of `53514239i_bpx` only. The percentages of pixels flagged in all cases for Cycle 28 has returned to family after incorporating our findings, and IR bad pixels continue to remain stable through Cycles 29 and 30.

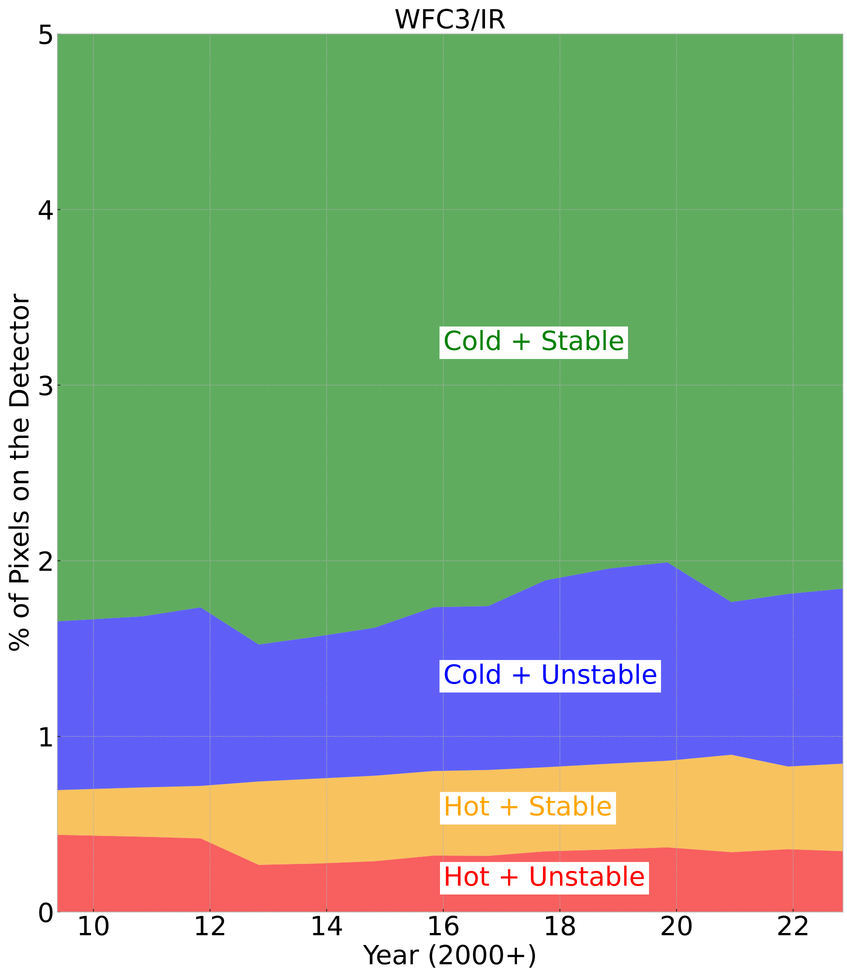

Figure 3: *Stack plot of the percentage of WFC3/IR detector pixels that are cold, hot, stable, and unstable versus time (2009 - November 2022). This plot is an update of Figure 1 from Khandrika 2022. Cycle 28 is corrected using darks with* ***BPIXTAB*** *reference file* ***53514239i_bpx****. The percentages of cold and unstable pixels for Cycle 28 returned to family with this correction. The percent of cold and unstable pixels in Cycles 29 and 30 IR BPIXTABs are also added, and the IR bad pixels continue to remain stable through these cycles.*

Conclusion

We generate new, annual IR bad pixel tables for Cycles 29 (`USEAFTER: NOV 2021`) and 30 (`USEAFTER: NOV 2022`). In addition, we regenerate two existing IR BPIXTABs `57m1910ei_bpx.fits` and `71c1928ri_bpx.fits` that were made using Cycle 27's IR BPIXTAB to correct for two IR blobs that appeared on June 2021 and October 2022. The regenerated IR BPIXTAB will now use the appropriate Cycle's data for the year in which the blobs appeared (Cycle 28 for June 2021, and 29 for October 2022) and will replace the old ones with the same `USEAFTER` moving forward.

We revisit the spike in cold and unstable pixels reported in Cycle 28 and shown in Figure 1 of Khandrika 2022. We found that the large increase in cold and unstable pixels flagged was due to the input darks of Cycle 28 having been calibrated with three different `BPIXTAB` reference files. We regenerated three separate Cycle 28 IR BPIXTABs using input darks calibrated with the same `BPIXTAB` reference files, and found that the percentage of cold and unstable pixels flagged decreased from 2.85% to 0.82% - 0.94%, depending on which sets of dark is used. Using the most recent correct `BPIXTAB` of the three, `53514239i_bpx`, the percentage of cold and unstable pixels flagged in Cycle 28 returned to family, and the percentage continues to remains stable throughout Cycles 29 and 30. Thus, the large increase in cold and unstable pixels previously reported is due to algorithmic issue with the pipeline used to generate the IR BPIXTAB, and does not reflect an increase in unstable pixels. A new annual Cycle 28 IR BPIXTAB has been delivered to the operational pipeline, based only on darks calibrated with reference file `53514239i_bpx` to fix the over flagging of cold and unstable pixels.

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