

# WFPC2 Dark Current Evolution

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S. Baggett, S. Casertano, M.S. Wiggs  
November 11, 2008

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## ABSTRACT

*The dark current level in WFPC2 has been slowly increasing over the instrument's life. The cold junction temperatures have also been slowly increasing, but the temperature increase can only account for a very small part of the increase in dark current. Most of the dark current increase is likely caused by radiation damage in the CCDs and/or increased luminescence in the CCD windows.*

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## 1. Introduction

The following naming convention is used in this TIR:

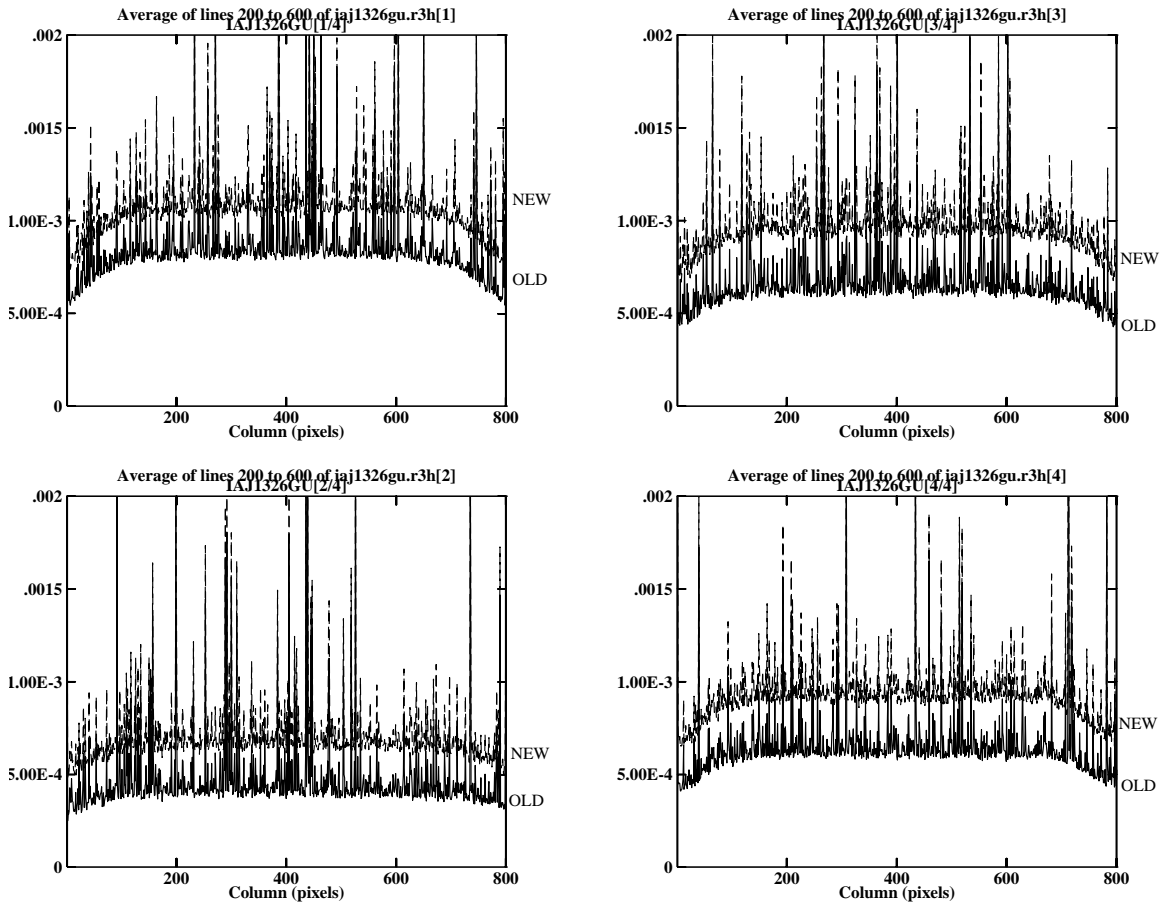
- Dark frame: a single WFPC2 exposure, 1800 seconds, with the shutter closed.
- Weekly dark: the cosmic-ray corrected image formed from a set of 5 darks taken within ~48 hours during any given week.
- Superdark: the cosmic-ray corrected image formed from a set of 120 input dark frames.
- Pipeline dark: reference file delivered to OPUS for use with calwp2.

Pipeline darks are generated and delivered to OPUS about once a week; they consist of a superdark image plus all new hot pixels identified from a weekly dark. The superdark image was recently updated from the HDF epoch (July 1995 to December 1995) to a superdark appropriate for the HDF-S epoch (May 1998 through August 1998). During the routine pre-delivery checks, the overall level in the new pipeline dark was found to exceed that of the old pipeline dark, by a factor ~1.3 (PC) to ~1.8 (WF2) or 0.2-0.3 DN in the 1800 sec dark frames.

Figure 1 presents the average count rates (in DN/sec) of rows 200-600 for the old and new pipeline darks (the pipeline darks in the figure are normalized to 1 sec for use with calwp2 in OPUS). Note the prominent drop in the dark current at the edges of the chip ("droop"), which is normal for WFPC2. A major component of the WFPC2 dark current is

thought to be due to luminescence generated in the CCD windows by cosmic rays (see WFC2 Instrument Handbook, Chapter 4); optical vignetting gives rise to the decrease in dark current at the chip edges.

**Figure 1:** Count rate levels, in DN/sec, for pipeline darks based on HDF and HDF-S superdarks (marked old and new, respectively). Curves represent averages of rows 200-600; the camera is indicated by the group number in each plot's title.



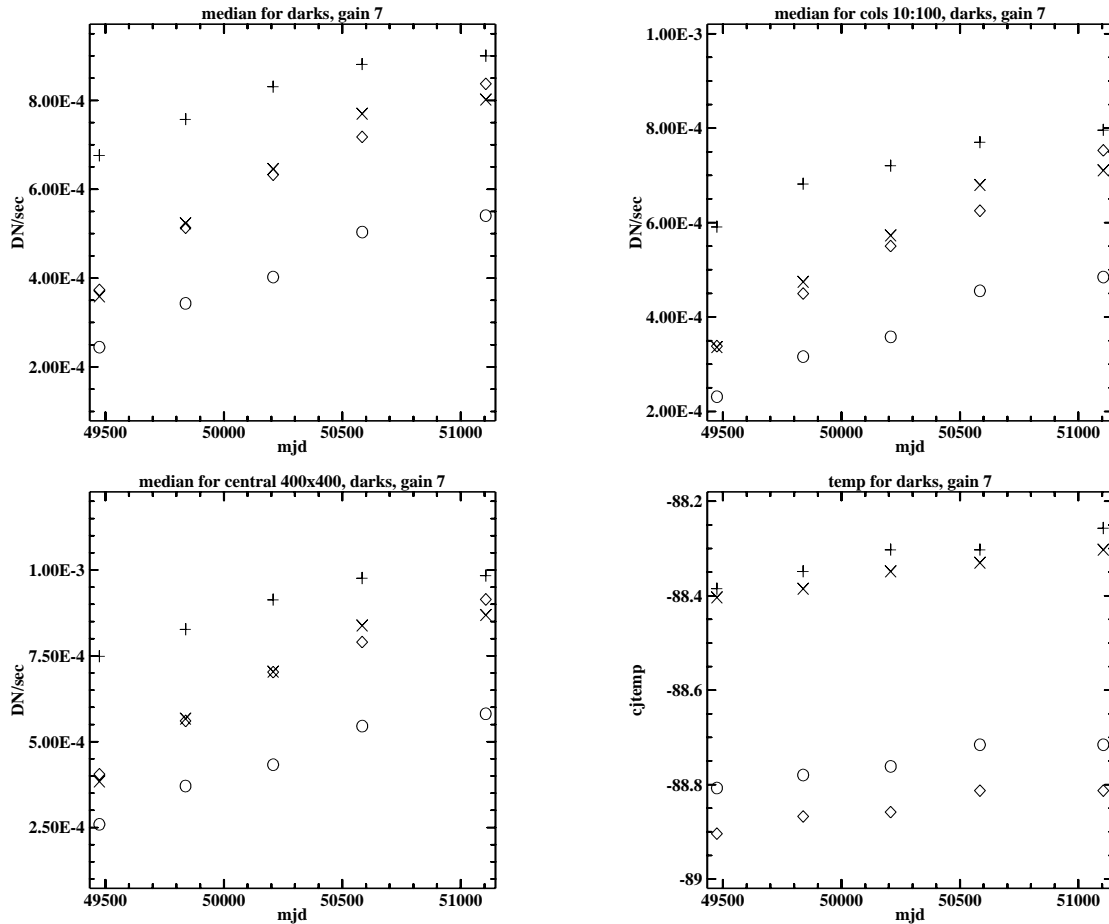
## 2. Analysis and Results

To verify the increase in dark current level, five sets of 5 dark frames from each year (1994 through 1998) were retrieved from the archive, recalibrated, and processed through the STSDAS task mkdark to generate cosmic-ray cleaned images. The mkdark parameters were set as they are set for the generation of weekly darks, that is,  $\sigma=4,4,3,2$ ,  $\text{radius}=0$ ,  $\text{pfactor}=0$ ,  $\text{hotthresh}=4096.$ ,  $\text{minval}=-99.$ ,  $\text{initial}=\text{min}$ ,  $\text{readnoise}=1.714$ ,  $\text{gain}=7$ , and  $\text{scalenoise}=0$ . The median values of the dark current in the 1800 sec dark frames are presented in Table 1; statistics are listed for the entire chip, and the central 400x400 region. The diff column contains the difference between the median of the central 400x400 region and the median of columns 10 to 90 on the left side of the chip (one of the droop regions). Variations in this difference over time are presumed due to changes in the luminescence. The last row in the table contains the total amount of increase since 1994; the changes in dark current are plotted in Figure 2.

**Table 1.** Median dark current levels, in DN, for the 1800 sec dark frames. Medians are given for the entire chip and for the central 400x400 pixel region. Diff column contains the difference between the median value of the central region and the median value of columns 10 to 90 on the left side of each chip (one of the droop regions).

MJD	date	PC (DN)			WF2 (DN)			WF3 (DN)			WF4 (DN)		
		entire chip	central 400x400	diff	entire chip	central 400x400	diff	entire chip	central 400x400	diff	entire chip	central 400x400	diff
49474.4	5/2/94	1.25	1.38	0.30	0.45	0.48	0.05	0.66	0.71	0.09	0.69	0.75	0.13
49838.3	5/1/95	1.40	1.52	0.28	0.63	0.68	0.10	0.96	1.05	0.18	0.95	1.03	0.21
50207.9	5/4/96	1.53	1.68	0.38	0.74	0.80	0.15	1.19	1.30	0.25	1.17	1.30	0.29
50584.1	5/16/97	1.62	1.80	0.40	0.93	1.01	0.18	1.42	1.55	0.31	1.32	1.46	0.32
51105.1	10/19/98	1.66	1.81	0.38	1.00	1.07	0.19	1.48	1.60	0.31	1.54	1.69	0.32
	total change	0.41	0.43		0.55	0.59		0.82	0.89		0.85	0.94	

**Figure 2:** Changes in the normalized dark current (in DN/sec) and cold junction temperatures in  $^{\circ}\text{C}$  over time. PC, WF2, WF3, and WF4 values are plus, circle, cross, and diamond symbols, respectively.



Since the dark current is a strong function of temperature, we have also examined the TEC cold junction (CJ) temperatures for the darks. Table 2 summarizes the CJ temperatures; they are averages of the 5 dark frames for each year. Most dark frames for a given year had identical CJ temperatures; those sets of 5 dark frames with a range of temperatures had typical standard deviations of  $\sim 0.02^{\circ}\text{C}$ . Total increases in temperature were  $\sim 0.1^{\circ}\text{C}$ . For completeness, the bay 4 temperature (gain 7 a-to-d converter) is listed in Table 2 as well; no correlation was expected or seen in the bay 4 temperature, since that would be affecting all types of images, not just darks.

Assuming a linear increase of 0.0001 DN/sec/°C at gain 7 for the temperature change from -88 to -83°C (WFPC2 Instrument Handbook, Table 4.2, pg. 73), one would expect only ~0.02 DN/pixel increase in the dark current of the 1800 sec dark frames from 1994 to 1998. The increase in CJ temperatures appears to account for only a very small portion of the increase in dark current.

If the increased dark current were due solely to radiation damage in the CCDs, we would expect no change in the edge droop (since the droop is due to luminescence and vignetting). The fact that the droop does increase with time, particularly in the WFC CCDs, suggests that increased luminescence may play some role.

**Table 1: Cold Junction Temperatures from 1994-1998**

	CJ 1		CJ 2		CJ 3		CJ 4		ubay4temp	
date	mean (°C)	stddev	mean (°C)	stddev	mean (°C)	stddev	mean (°C)	stddev	mean(°C)	stddev
5/2/94	-88.39	0.02	-88.81	0.	-88.40	0.02	-88.90	0.	15.59	1.96
5/1/95	-88.35	0.	-88.78	0.03	-88.39	0.02	-88.87	0.02	13.69	0.61
5/4/96	-88.30	0.	-88.76	0.	-88.35	0.	-88.86	0.	15.47	2.50
5/16/97	-88.30	0.	-88.72	0.	-88.33	0.03	-88.81	0.	14.84	3.43
10/19/98	-88.26	0.	-88.72	0.	-88.30	0.	-88.81	0.	15.17	3.07
total change	0.13		0.09		0.1		0.09		--	

### 3. Conclusions

The WFPC2 dark current has been slowly increasing over the instrument's lifetime. The cold junction temperatures are rising as well but not as quickly as required to account for the entire increase in the dark current level. Radiation damage to the chips is probably a contributing factor (Clampin, private communication) and temporal variations in the dark glow (radiation damage to the CCD windows) may play a role as well. We note that the rate of increase appears to have slowed between 1997 and 1998 in all four CCDs.

Future pipeline dark generation will include an examination of the current level in the weekly darks, in order to more closely monitor the temporal evolution. If necessary, and if resources allow, super darks could be generated more frequently, in order to incorporate the dark current changes into the pipeline darks.