CHAPTER 1:

WFPC2 Instrument Handbook Update

In this book. . .

1.1 WFPC2 and Two-Gyro Mode

Two-gyro mode is expected to have no impact whatsoever on WFPC2 imaging performance. This expectation is based on extensive on-orbit imaging tests carried out with both ACS and WFPC2 in 2005.

There are, however, significant impacts from two-gyro mode on target scheduling. These are discussed in the *HST Two-Gyro Handbook* and are implemented in the APT planning tools.

HST fine-pointing and instrument performance in two-gyro mode is expected to be indistinguishable from the performance observed in three-gyro mode.

1.2 STIS Availability

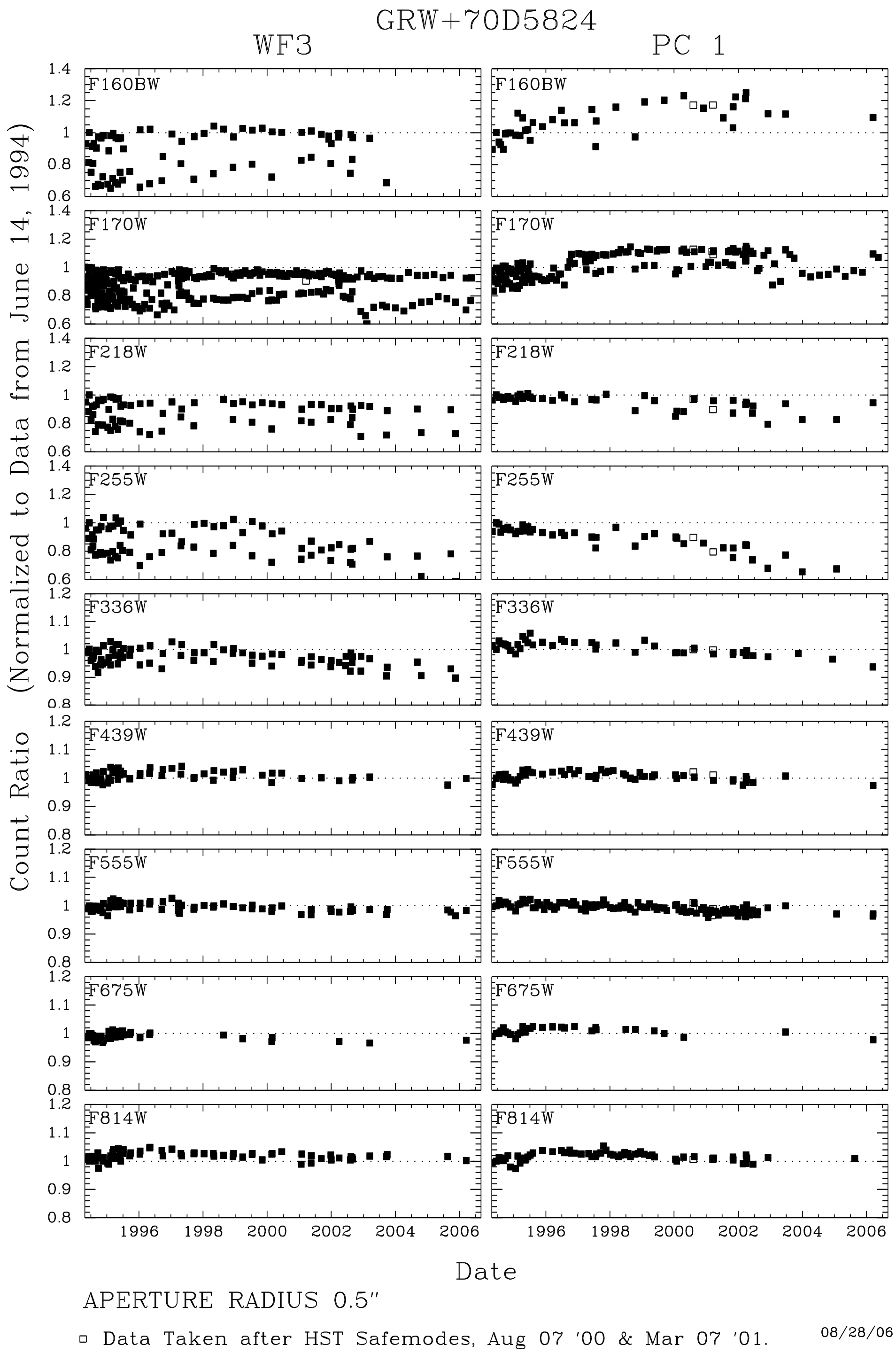
While the full version of WFPC2 Instrument Handbook (Cycle 14) compares the properties of WFPC2 and STIS, observers are reminded that STIS is not available in Cycle 16.

1.3 Photometric Stability

The long-term photometric stability of WFPC2 has been evaluated by examining the photometric monitoring data collected over the lifetime of the instrument. Our primary standard, GRW+70D5824, has been observed roughly every four weeks, before and after decontamination procedures, both in the far UV and in the standard photometric filters. Early observations were taken monthly in both the PC and WF3. Observations starting in Cycle 6 were on a rotating schedule, where observations are taken in a different CCD each month. Starting in Cycle 11 (starting Fall 2002) these observations were taken every ~49 days either before or after a decontamination procedure. In Cycle 14 the decontamination and monitoring schedule became more irregular due to reduced target visibility in 2-gyro mode. Decontaminations are performed every 45 to 60 days, but monitor observations are sometimes omitted when GRW+70D5824 is unavailable.

Figure 1.1 on page 3 shows the photometric monitoring data for the standard star GRW+70D5824 (a white dwarf classified DA3; B-V = -0.09) in the WF3 and PC1 for the set of filters which are routinely monitored. Only data after April 24, 1994, when the CCD operating temperatures were lowered from -76˚C to -88˚C, are shown.

Figure 1.1: Photometric Monitoring Data for WFPC2.



1.4 Cycle 14 WFPC2 Calibration Plan

The overall goals of the Cycle 14 WFPC2 Calibration Programs are to monitor health and safety of the instrument, and to maintain required calibration accuracies for the science modes used in Cycle 14. The use of 2-gyro mode in starting in Cycle 14 has had some impact on the scheduling of routine monitor observations and decontaminations. Decontamination procedures are performed every 45-60 days, but monitor observations are sometimes omitted when GRW+70D5824 is unavailable. Table 1.1 on page 5 shows the Cycle 14 Calibration Plan.

1.5 Cycle 15 + 16 WFPC2 Calibration Plan

It is anticipated that WFPC2 will be de-orbited during SM4 which is nominally scheduled for December 2007. Here we summarize the WFPC2 calibration plans for its remaining time on-orbit, which covers Cycles 15 and 16 together. This calibration plan is essentially identical to that for Cycle 14, though it covers a longer time period. Since there is some uncertainty about the schedule for SM4, we have included 2 years worth of monitor observations in this plan, so as to allow for various contingencies. The Cycle 15 + 16 Calibration Plan is summarized in table 1.2 on page 6.

1.6 WFPC2 Closeout Calibrations

Special "closeout" calibrations are planned prior to de-orbit of WFPC2 during SM4. These are designed to improve the accuracy of WFPC2 data taken throughout its lifetime, and enhance the archival value of WFPC2. These calibrations will serve to (1) provide final data on long-term trends in the calibration, (2) provide additional data in areas with known calibration deficiencies, (3) attempt new types of calibration, (4) provide continuity between WFPC2 and current / future HST instruments, and (5) support post-mission ground calibrations of the instrument. A preliminary summary of the closeout calibration plan is given table 1.3 on page 7. More detailed plans will be available on the instrument web site as they become available.

Observers are also encouraged to submit calibration proposals in areas where they feel WFPC2 calibration can be improved. These proposals could include new calibration observations, or address existing archival calibration observations.

Table 1.1: WFPC2 Cycle 14 Calibration Plan.

ID	Proposal Title	Frequency	Estimated Time (orbits)		Scheduling Required	Products	Accuracy Required	Notes
			"External"	"Internal"				
10744	WFPC2 Decons & Associated Observations	Decons every 50-60d	6	94	every 50-60d	CDBS, IHB, Synphot, WWW reports	1-2%	Decons, phot.monitor, internals, UV throughput, VISFLATS and UVFLATS, darks.
10748	Standard Darks	weekly, exc. decon wk		264	every 7 days, exc.decon wk	CDBS	1 e-/hr	CDBS updates and weekly WWW hot pixel lists.
10745	Internal Monitor	weekly, exc. decon wk		44	every 7 days, exc.decon wk	CDBS	0.8e-/pix	BIAS, INTFLATS in F555W for gain and throughput stability measurements
10749	Visible Earth Flats	continuous		50	mid-to-late	CDBS	0.3%	F502N only (time dependence only)
10750	UV Earth Flats	continuous		20	mid-to-late	CDBS	0.3%	F300W only
10751	Intflat & Visflat Sweeps, Filter Anomaly Check	1/cycle		80	mid-cycle	TIR	0.3%	Flats in all the filters used in Cycle 14, both gain settings/shutters.
10746	CTE Monitor	1/cycle	4		mid-to-late	ISR	0.03 mag	Continue CTE monitor. Test for chip dependence.
10747	Photometric Monitor	1/cycle	7		mid-cycle	ISR, Synphot	1%	GRW+70D5824 in filter/chip combos used for science in Cycle 14.
	~10% reserve		2					Placeholder for unexpected items.
TOTAL TIME (including all executions)			**19**	**552**				

Table 1.2: WFPC2 Cycle 15 + 16 Calibration Plan.

ID	Proposal Title	Frequency	Estimated Time (orbits)		Scheduling Required	Products	Accuracy Required	Notes
			"External"	"Internal"				
11022	WFPC2 Decons & Associated Observations	Decons every 40-60d	12	188	every 40-60d	CDBS, IHB, Synphot, WWW reports	1-2%	Decons, phot.monitor, internals, UV throughput, VISFLATS and UVFLATS, darks.
11023, 11070	Standard Darks	weekly, exc. decon wk		528	every 7 days, exc.decon wk	CDBS	1 e-/hr	CDBS updates and weekly WWW hot pixel lists.
11024	Internal Monitor	weekly, exc. decon wk		88	every 7 days, exc.decon wk	CDBS	0.8e-/pix	BIAS, INTFLATS in F555W for gain and throughput stability measurements
11027	Visible Earth Flats	continuous		100	mid-to-late	CDBS	0.3%	F502N only (time dependence only)
11028	UV Earth Flats	continuous		40	mid-to-late	CDBS	0.3%	F300W only
11029	Intflat & Visflat Sweeps, Filter Anomaly Check	1/year		160	mid-cycle	TIR	0.3%	Flats in all the filters used in Cycle 15 & 16, both gain settings/shutters.
11025	CTE Monitor	1/cycle	4		mid-to-late	ISR	0.03 mag	Continue CTE monitor. Test for chip dependence.
11026	Photometric Monitor	1/cycle	3		mid-cycle	ISR, Synphot	1%	GRW+70D5824 in filter/chip combos used for science in Cycle 15 & 16.
	~10% reserve		2					Placeholder for unexpected items.
TOTAL TIME (including all executions)			**21**	**1104**				

Table 1.3: WFPC2 Closeout Calibration Plan.

ID	Proposal Title	Frequency	Estimated Time (orbits)		Scheduling Required	Products	Accuracy Required	Notes
			"External"	"Internal"				
11030	WF4 Anomaly	as needed	2	54	as needed	CDBS, IHB, WWW reports	1-2%	Two additional WFPC2 temperature adjustments to keep WF4 CCD functioning, if needed.
11031	CTE & Background Dependence	once	16		mid-to-late	ISR, IHB	0.03 mag	Evaluate CTE corrections near mission end.
11032	CTE Extended Targets	once	8		mid-to-late	ISR, IHB	0.03 mag	Evaluate extended target CTE near mission end.
11033	Full Moon Earth Flats	continuous		200	mid-to-late	CDBS, ISR	0.3%	Test / improve broadband flats.
11034	Photometric Closeout	once	4		mid-to-late	CDBS, ISR	1%	Filters not calibrated recently.
11035	Photometric Zero Points	once	8		mid-to-late	CDBS, ISR	1%	Final cross-calibration vs. ACS
11036	Red Leaks	once	6		mid-to-late	CDBS, ISR, Synphot	1%	Improve calibration.
11037	Red Filters	once	4		mid-to-late	CDBS, ISR, Synphot	1%	Cross-calibrate WF3 CCD vs ACS.
11038	Narrow-Band and Ramp Filters	once	10	20	mid-to-late	CDBS, ISR, Synphot	1%	Check for long-term changes in bandpasses.
11039	Polarizers	once	2	2	mid-to-late	CDBS, ISR, Synphot	3%	Check for changes in polarizer performance.
11040	Geometric Distortion	once	8		mid-to-late	CDBS, ISR	0.05"	Better astrometry in red and blue; skew terms.
TOTAL TIME (including all executions)			**68**	**276**				

1.7 WF4 CCD Anomaly

A serious electronic anomaly has appeared in the WF4 CCD electronics of WFPC2 wherein sporadic images have a low bias level and low photometric counts. In most cases the bias level itself is automatically corrected in the calibration pipeline, but the photometry remains low. In more severe cases the bias level can drop to zero (i.e. below the A-to-D converter zero level) and the resulting image appears blank (though bright objects and cosmic rays are sometimes visible).

The very first hint of the problem occurs after Service Mission 3B in March 2002 when a few images are seen with a bias level one or two DN below the normal 311 DN in WF4. The frequency and severity of the problem gradually increased with time. By 2003 the lower envelope of WF4 bias levels is clearly drifting downwards, and by 2004 there are many images with bias below 300 DN. By early 2005 a few blank images with zero bias level began to appear. By late 2005 nearly all images have significantly low bias levels, and 10 to 20 percent have zero bias and are blank. The WF4 bias levels at gain 7 are plotted in Figure 1.2 on page 10. Bias levels at gain 15 show similar behavior.

The problem appears to be closely correlated with the temperature of the warm electronics board inside the WF4 CCD camera head. Specifically, images with low or zero bias are associated with peaks in the temperature, which occurs as heaters within WFPC2 cycle on and off. Apparently some failing component in the CCD signal chain has developed a hyper-sensitivity to temperature. While we do not have direct control of the temperature of this circuit board, we do have some ability to adjust the overall operating temperature of WFPC2. In January 2006 an experiment was performed where we lowered the operating temperature of WFPC2, and the WF4 anomaly was greatly reduced, as hoped. Base on this success a second downward temperature adjustment was made on February 20, 2006, and this was adopted as a new permanent operating temperature for WFPC2. At this temperature the WF4 bias level is still slightly low, but the photometry is thought to be correctable, and most importantly, there are no blank images.

The downwards temperature adjustment was achieved by modifying the replacement heater set points. These heaters are located throughout WFPC2 and have a single control. The heaters are turned on when the WFCP2 temperature drops to a lower limit, and are turned off when an upper temperature limit is reached. These limits are set in the WFPC2 software. Previous to January 2006 the limits were 10.9 and 14.9 degrees C, and after the second adjustment in February 2006 they are 10.0 and 11.3 degrees C.

The temperature reduction appears to have had no adverse impact on WFPC2 performance. The PSF size is the similar to that before the adjustment. Some small motion of the CCDs in the focal plane did occur, but these are small (0.01") and similar in size to long-term drifts in the CCD positions.

The photometric impacts of the anomaly are illustrated in Figure 1.3 on page 10. Near the normal bias level of 311 DN the photometric scale is normal. However, as the bias level drops, the observed counts decrease. The amount of decrease is somewhat dependent on the pixel brightness. For bright pixels, say near 1000 DN the photometric loss at bias 150 DN is about 13%, while near zero bias it is about 20%. Faint pixels suffer larger losses. A pixel with 15 DN suffers about 25% loss at bias 150 DN, and about 40% loss near zero bias. This figure is for gain 7; at gain 15 the losses are roughly double those at gain 7 (for a given bias level in DN). The figure is generated by comparing internal flats which are impacted by the anomaly against “normal” internal flats. To the extent the curves in Figure 1.3 on page 10 are well-defined and repeatable over time, we believe the photometry is correctable. Preliminary corrections are given in Instrument Science Report WFPC2 2005-02, which contains additional description of the anomaly.

Besides the photometric effects, WF4 images with low bias levels will also suffer increased background noise in the form of faint horizontal streaks and stripes. These can have an amplitude up to ~1 DN RMS at low bias levels (bias <200 DN), and are generally weaker at higher bias levels. Usually these artifacts can be removed with suitable spatial filtering of the image (see above mentioned Insturment Science Report for details).

As of this writing we expect WF4 to continue to produce good data for several more years, but there is some possibility the hardware failure might accelerate with WF4 being completely lost. The other three CCDs appear unaffected, and in fact small targets are usually placed on the PC1 or WF3 CCDs, so the WF4 anomaly has much less impact than it otherwise might. Large targets and surveys do benefit from the added sky area contributed by WF4, and would be more impacted by its failure. In addition, some specialized filters (polarizers, ramps, quad filters) rely on WF4 and would be severely impacted, were it to fail completely.

Figure 1.2: WF4 CCD Bias Levels as Function of Time.

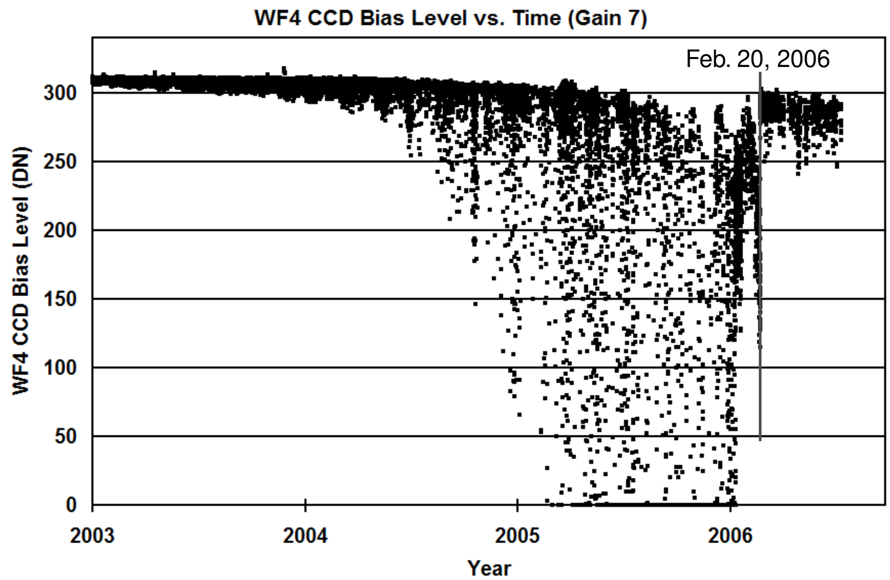


Figure 1.3: Photometric Impact of the WF4 Anomaly (Gain 7).