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WFPC2 Calibration and Close-Out

A. M. Koekemoer

Space Telescope Science Institute, 3700 San Martin Drive, Baltimore, MD 21218

Abstract. This work summarizes the overall calibration strategy for WFPC2, covering the design of the observational programs as well as analysis of the results and their incorporation into the calibration pipeline. This strategy comprises routine long-term calibration monitoring programs, including darks, biases, flat fields, photometric and astrometric monitoring, as well as special calibration programs such as CTE and PSF characterization, and photometric cross-calibration with ACS and ground-based systems. In addition, we discuss special close-out calibration programs planned for the remaining cycles of WFPC2 operation, and describe ways in which community input can play a key role in further defining these plans.

1. Introduction

The Wide Field and Planetary Camera 2 (WFPC2) has been the principal imaging camera on board the *Hubble Space Telescope* (*HST*) for the past nine years, after being installed during the first Servicing Mission in December 1993. Its comprehensive suite of 48 filters, spanning wavelengths from the far ultraviolet to one micron, and including wide, medium and narrow-band as well as polarimetric and linear ramp filters, have facilitated an exceptionally wide range of scientific projects, with over 125,000 science exposures obtained to date.

Cycle 12 is currently planned to be the last full cycle for WFPC2 operation, since it will be removed in 2005 during Servicing Mission 4 and replaced with the Wide Field Camera 3 (WFC3). Therefore we are currently planning the final cycle of special "Close-Out" calibration programs and related activities, aimed at maximizing the scientific value of the wealth of archival WFPC2 data. In addition to our normal calibration plan for WFPC2 that is performed during each cycle, we are soliciting general input from the community as to whether there are any additional calibration programs that should be carried out with WFPC2 during this final cycle, in order to improve or augment our current calibration accuracies or explore new types of calibration. Here we describe the normal WFPC2 calibration plan along with the special calibration programs that are currently underway, and some ideas for other possible programs that may help to maximize the archival legacy of WFPC2.

2. Overview of WFPC2 Calibration Strategies

The general philosophy of WFPC2 calibration is divided broadly into three areas:

- Basic activities aimed at maintaining the general health and safety of the instrument. Examples of this include the regular "decontamination" procedures (DECONs), along with associated photometric observations and internal measurements to ensure that the instrument continues to function as expected.

- Routine calibration monitoring programs, which are carried out with sufficient frequency to allow the calibration accuracy to be maintained for instrument characteristics that are time-dependent. Examples of these include flatfields, bias and dark frames, and additional photometric monitors, supplementing those obtained during the regular DECONs.
- Special calibration programs, aimed at characterizing anomalous behavior or improving our knowledge of some aspect of the instrument. Examples of these have included programs aimed at characterizing the Charge Transfer Efficiency (CTE) problem, or astrometric measurements of the camera distortion, or photometric cross-calibration with other instruments and filter systems.

At the start of each *HST* observing cycle, the WFPC2 group has assembled a calibration plan outlining the various programs to be carried out for that cycle, along with a budget of how many orbits would be required. The orbits are divided into "external" orbits (observations of real astronomical targets) along with "internal" exposures (such as darks, biases and flats using the internal lamps) that may be obtained during occultation or in parallel with another instrument observing as the prime instrument. In addition, after the completion of each cycle the WFPC2 group has issued a Calibration Close-Out report, describing the principal results from the programs during that cycle. In Table 1 we present a summary of all the WFPC2 calibration plans and close-out reports that have been published to date by the WFPC2 group. During the first few on-orbit cycles for WFPC2, the total number of external orbits allocated to these programs generally ranged between about 70 and 90 for each cycle, while the number of internal exposures typically ranged between about 2000 and 3000 per cycle. The decreased demand for WFPC2 during recent cycles has led to a decrease in the allocation of external orbits (61 and 40 orbits for Cycles 10 and 11 respectively), while the number of internal exposures remains at ~2000 per cycle.

Table 1. WFPC2 Calibration Plans and Close-Out Reports, as of October 2002

ISR Number	Date	Title	Authors
ISR WFPC2-96-08	Jul 23, 1996	WFPC2 Cycle 6 Calibration Plan	Casertano et al.
ISR WFPC2-97-06	Aug 18, 1997	WFPC2 Cycle 7 Calibration Plan	Casertano et al.
ISR WFPC2-99-02	May 19, 1999	WFPC2 Cycle 8 Calibration Plan	Baggett et al.
ISR WFPC2-00-01	May 25, 2000	WFPC2 Cycle 9 Calibration Plan	Baggett et al.
ISR WFPC2-01-03	May 15, 2001	WFPC2 Cycle 10 Calibration Plan	Baggett et al.
ISR WFPC2-02-05	Aug 15, 2002	WFPC2 Cycle 11 Calibration Plan	Gonzaga et al.
ISR WFPC2-95-07	Dec 22, 1995	WFPC2 Cycle 4 Calibration Summary	Baggett et al.
ISR WFPC2-97-02	Feb 3, 1997	WFPC2 Cycle 5 Calibration Closure Report	Casertano et al.
ISR WFPC2-98-01	Apr 21, 1998	WFPC2 Cycle 6 Calibration Closure Report	Baggett et al.
ISR WFPC2-99-05	Dec 23, 1999	WFPC2 Cycle 7 Closure Report	Baggett et al.
ISR WFPC2-01-06	Jun 11, 2001	WFPC2 Cycle 8 Closure Report	Baggett et al.

For Cycle 12, we plan to continue the routine monitoring programs for WFPC2, with a similar orbit allocation to Cycle 11. The plan for Cycle 12 will be finalized in Spring 2003, therefore we are now soliciting from the community ideas for "special" calibration programs that should be included, which can be either external (most likely limited to a few orbits), or internal.

3. Routine WFPC2 Calibration Monitoring Programs

The routine calibration programs for WFPC2 can be divided into DECONs (and the observations directly associated with them), and longer-term monitoring programs aimed at extending or supplementing the observations obtained during the DECONs. Here we describe both classes of programs, currently executing for Cycle 11 and planned for Cycle 12.

3.1. Decontaminations and Related Observations

The WFPC2 is continually subject to the deposition of contaminants on the cold CCD windows (−88° C) inside the camera, and the absorption from these contaminants significantly reduces the throughput of the instrument at Far-UV and Near-UV wavelengths. The contaminants deposit gradually, typically producing ~ 0.5–1% loss in throughput per day in the F170W filter. Throughput losses of up $\sim 30\%$ can be tolerated, thus throughout the on-orbit life of WFPC2 we have scheduled "decontamination" visits (DECONs) approximately once per month, where the camera heads are heated to +22° C, usually for a 6 hour period. This has been shown to completely evaporate the contaminants, after which they start to deposit once more as soon as the instrument is cooled down to −88° C. Thus far no permanent contamination has ever been observed in the instrument. In Cycle 11 the time interval between DECONs was increased to 49 days, since the contamination rate has been shown to have decreased considerably over recent years (McMaster & Whitmore 2003, this volume).

In addition, the temperature increase during the DECONs serves to "anneal" most of the hot pixels that form on a daily basis as a result of radiation damage (usually several tens of pixels/day for each CCD). Therefore, the calibration programs associated with the DECON visits include not only external photometric monitoring observations, but also internal darks, biases and INTFLATs, to verify basic instrument performance. Finally, these visits contain observations of the Kelsall spots (KSPOTS) in the WFPC2 pyramid, that can be used to obtain valuable information on long-term movements of the four cameras with respect to one another. In Table 2 we show all the observations that are associated with each DECON visit, as described more fully in Cycle 11 calibration programs 9589 and 9590.

Table 2. WFPC2 DECON Visits and Observations, executed once every 49 days

Type of Exposure	Filter	Notes
(*Pre-and Post-DECON Observations*)		
GRW+70D5824 (WD star)	F170W	all 4 CCDs
GRW+70D5824	F160BW, F218W, F225W, F300W, F336W, F439W, F555W, F814W	Rotates among the 4 CCDs with each DECON visit
DARK	—	GAIN = 7
BIAS	—	GAIN = 7, 15
INTFLAT	F555W	GAIN = 7, 15
KSPOTS	F555W	GAIN = 15
(*Additional Post-DECON Observations*)		
INTFLAT	F336,F439,F555W, F675W, F814W	GAIN = 7

3.2. Other Routine Monitoring Programs

Although the observations associated with the DECON visits provide sufficient information to verify the basic operational functionality of the instrument, they are not performed with sufficient frequency to allow us to base our calibration on these data alone, nor do they cover the entire range of capabilities of the instrument. Instead, routine monitoring of the full suite of WFPC2 capabilities is provided by two classes of additional programs: (1) relatively frequent internal observations, and (2) full sweeps of the entire WFPC2 filter set, performed once during each cycle. Here we summarize these programs.

Daily and Weekly Internal Monitors. The internal monitors consist primarily of weekly programs that provide 30 minute DARK frames (five with CLOCKS=NO and one with CLOCKS=YES), along with INTFLATS and BIAS frames taken at both gain settings (Cycle 11 programs 9592 and 9596). The darks with CLOCKS=NO are used to create the weekly darks, while those with CLOCKS=YES are simply obtained as a service to those observers who wish to use the less-supported mode of leaving the serial clocks on during the exposure. The weekly darks are in turn used to create the superdark that is the basis for the dark reference file for each DECON cycle that is used in the calibration pipeline, while the biases are used to create the superbias on an approximately annual basis. The INTFLATs are used to monitor the gain stability of the instrument. In addition, we obtain up to 3 shorter exposure darks (1000s each) on a daily basis, as a service to GOs who may wish to create their own darks from data that may be closer to the time of their observations than the standard weekly darks. During Cycle 11 these supplemental daily darks are obtained in programs 9593, 9594 and 9595. In Table 3 we summarize all these exposures.

Table 3. WFPC2 Daily and Weekly Internal Monitors

Type of Exposure	Frequency	Notes
DARK	3 times/day	GAIN = 7; exptime=1000s
DARK	5 times/week	GAIN = 7; exptime=1800s
BIAS	4 times/week	GAIN = 7, 15
NTFLAT	2 times/week	GAIN = 7, 15

In addition to the internal monitors, we regularly obtain exposures of the bright earth (EARTHFLATs) when WFPC2 is not observing as prime instrument. These are taken continually throughout the year in a range of narrow-band optical and UV filters (Cycle 11 programs 9598 and 9599 respectively), and are aimed at monitoring long-term changes in the flatfields. The optical EARTHFLATs consist of 200 exposures in each of four narrowband filters (F375N, F502N, F656N, F953N), and 50 exposures in each of 10 other filters (F160BW, F336W, F343N, F390N, F437N, F469N, F487N, F631N, F658N, F673N). The UV program contains 100 exposures in each of 6 filters (F170W, F185W, F218W, F255W, F300W, and F336W) along with 20 exposures in each of 4 crossed filter sets (F170WxF606W, F218WxF450W, F300WxF814W, F336xF814W) in order to assess and remove the redleak contribution. These observations have been used to update the pipeline flatfield reference files, and also allow the possibility of substantial improvements in the pixel-to-pixel flatfields (Koekemoer, Biretta & Mack 2002).

Annual Routine Monitoring Programs. A number of monitoring calibration programs are carried out on a less regular basis, either because they use limited resources (external orbits, or usage of the VISFLAT lamps which are decaying with time), or because they track changes that are relatively slow.

The annual photometric filter sweep (Cycle 11 program 9590) contains exposures of the WFPC2 standard star GRW+70D5824 at GAIN=15 in the filters F675W, F450W, F467M, F606W, F791W, F850LP, and F1042M, in all four CCDs, with exposure times ranging between 2s and 40s (except for F1042M which has 2x300s). Other filter sweeps include the UVFLAT sweeps in the filters F160BW, F185W, F122M, F170W, and F336W (generally with exposure times ranging from 400 to 1000s, except for F336W which is 30s), and VISFLAT sweeps in the filters F439W, F555W, F675W, F814W, and FR533N. The

UVFLAT sweeps are predominantly aimed at characterizing the long-term evolution of the filters, for example the F160BW which is known to have been developing pinholes over time.

The other annual filter-related program involves a complete sweep of all the standard optical and UV filters through the INTFLAT lamps (Cycle 11 Program 9597). These provide long-term monitoring of the pixel-to-pixel response of the flatfields, and also provide a backup database in the event that the VISFLAT lamp can no longer be used. This program also contains a linearity check of the CCDs, consisting of a series of exposures in F555W covering a range of exposure times (6–18 s at GAIN=7, and 8–36 s at GAIN=15), and using both Blade A and Blade B for the flat. In addition to the linearity check, these allow for long-term monitoring of the shutter behavior.

This program also contains a set of EARTHFLAT observations through the linear ramp filters FR418NxF437N, FR533P33xF520N, FR680NxF631N, and FR868NxF953N, as well as VISFLAT observations of the same set of ramps uncrossed with any other filters, along with VISFLAT exposures through additional filters (FQUVN and FQCH4N). In addition to providing long-term monitoring of the calibration of these filters, these exposures allow checks of the repeatability of the filter wheel positioning mechanism.

4. Examples of Some Special WFPC2 Calibration Programs

In addition to the routine monitoring programs related to instrument health and safety, we also have a variety of "special" calibration programs during each cycle, which are generally aimed at better characterizing some specific aspect of the instrument. These may either be carried over from one cycle to the next, or otherwise need to be done in only one or two cycles. Examples of these programs have included characterization of CTE, improved photometric zeropoints, and astrometric characterization. In Table 4 we summarize the special programs from recent cycles along with the current cycle, after which we briefly describe some of the current programs. Further details of all the programs and their products are available from the WFPC2 web site: http://www.stsci.edu/instruments/wfpc2/.

Table 4. WFPC2 Special Calibration Programs since Cycle 7

Program Title	Cycle	Program IDs
Photometric Characterization	7,8,9,10,11	7628, 8451, 8818, 9251, 9601
PSF Characterization	7,8,9,10,11	7629, 8452, 8819, 9257, 9600
CTE Characterization	7,8,9,10,11	7630, 8447, 8821, 9254, 9591
Astrometric Monitor	7,8,9,10,11	7627, 8446, 8813, 9253, 9600
Polarization	8	8453
Noiseless Preflash	8	8450
Photometry of Very Red Stars	8	8455
CTE for Extended Sources	8	8456
Plate Scale Verification	8	8458
Wavelength Stability of LRFs and Narrow-band filters	8, 9	8454, 8820
Redleak Check	9	8814
Astrometric Effects of CTE	10	9255
Clocks ON Verification	10	9252
Methane Quad Filter Check	10	9256
WFPC2-ACS Photometric Cross-Calibration	11	9601

We next describe a *selection* of three of the more recent special calibration programs, which we present here primarily to serve as examples of the types of studies that these types of programs typically consist of. Space limitations do not permit us to include detailed descriptions of all the programs, but all this information, along with the results derived from these programs, are available at the aforementioned WFPC2 web site.

4.1. CTE Characterization

The principal aims of the CTE proposals for WFPC2 have been to characterize the effects of CTE on photometry and astrometry of point sources, along with some more recent proposals aimed at investigating CTE effects for extended sources. Not only do the data allow the effect to be described as a function of flux and location on the chip, but they also track its evolution over time. The first results from Cycles 5 and 6 (programs 6192 and 6937 respectively) also led to the identification of the "long-vs.-short" problem, an apparent non-linearity of the photometric calibration.

The observational approach has generally consisted of observing a relatively rich starfield (Omega Centauri) in a number of broad-band photometric filters, for a range of exposure times and also using a range of preflash levels. The details have varied from one cycle to the next, depending upon available orbit allocation as well as the specific tests to be performed during each cycle. An example is the Cycle 7 program 7630, which contained observations in F814W with exposure times of 10s, 40s, 100s, 300s, and 1000s, and preflash levels of 0, 5, 10, 100, and 1000 electrons for each exposure time. Smaller subsets of exposure/preflash combinations were obtained in the filters F555W and F300W, in order to provide photometric checks for the other filters. In subsequent programs the preflash tests were reduced, while serving to continue the essential monitoring observations. These programs have thus far led to a number of detailed discussions on how the photometric effects of CTE may be quantified (e.g., Whitmore, Heyer & Casertano 1999; Dolphin 2000, 2002; Whitmore & Heyer 2002 and references therein).

Although the photometric effects of CTE have now been well characterized, less is known about its effects on astrometry. A study by Riess (2000) showed that extended sources suffer some degree of distortion due to CTE, indicating that the astrometry of sources must also be affected. For example, the relative separation of a faint source from a bright source may depend on all the factors that influence CTE (position on detector, observing epoch, brightness in electrons, and image background). Therefore, some of the more recent CTE proposals have attempted to quantify the astrometric effects of CTE by measuring: (1) the relative separation of a bright source vs. a faint target at different positions on the PC1 CCD, and (2) the relative motion of a source on the CCD compared to very precise slews performed with the FGSs. These tests are conducted for point and extended targets at several different intensity levels.

For these astrometric tests, the target is observed with the PC chip in a 2×2 grid, $20''$ on a side, repeated over two orbits (with the second orbit being slightly offset by half a PC pixel). The 2-orbit sequence is done at different background light levels, using exposures from 100s in F450W to 1200s in F622W, repeated three times for two targets (total 12 orbits). The targets include the dense star field in Omega Centauri, and an extragalactic field of faint galaxies. Both fields are chosen to have a bright star surrounded by fainter objects. While most of the test is performed on the PC, the WFC CCDs are also important, as they can provide a sanity check on the motions made with the FGSs. The motions on the WFC CCDs is a smaller number of pixels, hence less subject to CTE variations.

The most recent CTE proposal (Cycle 11, program 9591) aims to do an additional check of CTE characterization, by carrying out the observations in the 2×2 on-chip binning mode. This mode has been seldom used on WFPC2 due to the relatively large size of the WFC pixels ($0.1''$). However, since the level of CTE depends upon the number of pixels that are being read out, it is possible that the severity of the effect can be reduced by using on-chip binning. This test is primarily intended with newer instruments in mind (ACS, WFC3) since their smaller native pixel size ($0.05''$) may make on-chip binning a more appealing option if it is indeed found to substantially mitigate CTE.

4.2. WFPC2 Astrometric Characterization

This program has been executing twice per year until Cycle 10, after which it has been executing once per year. It consists of observing a rich star field (Omega Centauri) with a pattern of large shifts designed to move the same set of stars onto each of the four detectors, as well as small shifts aimed at providing sub-pixel dithering to improve the sampling of the PSF. The principal part of the program has involved observations at F555W, which allows both the determination of a geometric solution as well as long-term monitoring of possible changes. This has been supplemented in some cycles by observations in two other filters, F300W and F814W, which are aimed at allowing the measurement of the color dependence of the solution. Observations are also obtained at a range of position angles, which can be used to constrain additional geometric parameters such as skew. Results from this program have been published in the form of an ISR by Casertano & Wiggs (2001), and by King & Anderson (2003, this volume), as well as Kozhurina-Platais et al. (2003, this volume).

4.3. WFPC2-ACS Photometric Cross-Calibration

This proposal is aimed at providing photometric zeropoint cross-calibration between the commonly used WFPC2 photometric filter sets and those that will be used for ACS programs. The proposal includes observations of globular clusters covering two extremes of metallicity: the metal-rich cluster 47 Tucanae and the metal-poor cluster NGC 2419. In addition, the proposal obtains WFPC2 observations of the primary ACS standard star BD+17D4708. This program will produce a valuable tie-in between the WFPC2, ACS and Sloan filter photometric systems.

The observations of 47 Tucanae are all at the same position and orientation as the observations in an earlier related proposal (8267), with the following filters: F300W, F336W, F410M, F439W, F450W, F467M, F547M, F569W, F606W, F675W, F702W, F850LP (note that extensive observations already exist for this object in the F555W and F814W filters). Similarly, the observations for NGC 2419 are at the same position and orientation as those in earlier related proposals 5481 and 7628, with these filters: F300W, F336W, F410M, F439W, F450W, F467M, F547M, F569W, F606W, F675W, F702W, F850LP (again, this object also has extensive F555W and F814W observations, therefore they do not need to be repeated here).

Finally, the observations of the Sloan primary standard star BD+17D4708 are obtained using the PC and WF3 chips, in all of the following filters: F300W, F336W, F410M, F439W, F450W, F467M, F547M, F555W, F569W, F606W, F675W, F702W, F814W, F850LP.

It is expected that this program will provide $\sim$ 1–2% zeropoint accuracy for baseline observations using most commonly-used filters (e.g., F439W, F555W, F675W, F814W), and will enable a direct photometric tie-in not only to the ACS but also to the ground-based SDSS system.

5. Possible Ideas for WFPC2 Close-Out Calibration Programs in Cycle 12

As was mentioned earlier, Cycle 12 is currently planned to be the final full cycle for WFPC2 operations before it is de-orbited. Therefore, it is *imperative* that the final "close-out" round of calibration programs address critical issues that may help to improve the quality of the science or otherwise aid in improving our understanding of the behavior of the instrument. Community input to this process is *essential*, and we actively solicit any ideas that observers in the general community may have.

5.1. Our "Top 10" Current Ideas for Close-Out Programs

In this section we summarize some of our current ideas for special close-out calibration programs during Cycle 12. If we receive sufficient community input then we may modify these or supplement them with additional programs. Our general philosophy is to improve the calibration accuracy of some filter modes that may provide enhanced scientific results, as well as carrying out observations aimed at improving our knowledge of specific aspects of the instrument (e.g, PSF behavior). We may also make use of this opportunity to carry out programs that may have been difficult to do earlier in the life of the instrument (for example, characterizing the nature of all the "permanent" hot pixels that are not easily removed by the regular DECONs), if such programs may be helpful for some of the newer instruments.

It is reasonably likely that we will carry out the first three or four programs in this list, depending somewhat upon the reactions that we receive from the community. We will attempt to carry out as many of the other programs further down the list as our orbital allocation will allow, although we may move some of these up in priority if there is sufficient interest from the community in a particular program. Finally, this list is not intended to be complete and we would be happy to consider adding additional programs that might be suggested by the community, if there is sufficient interest.

1. *Fully characterizing CTE behavior for extended sources.* While the effects of CTE on point sources are now relatively well understood for a wide range of count-rates and background levels, there are as yet no well-developed methods for calculating the effect of CTE on extended targets. This work would primarily consist of two parts, analytical and observational. The analysis effort would involve developing algorithms to perform iterative calculation of CTE to determine the true underlying flux distribution for an arbitrary source in an image. The observational component may consist of additional exposures to our Cycle 12 CTE calibration program to obtain data that may be used in testing the algorithms, although it is possible that such tests may be carried out using data already in the archives.

2. *Creating broad-band skyflats using data from external science exposures.* While observations of the bright earth are useful in creating flatfields for narrow-band filters, the optical broad-band filters generally saturate too quickly to enable useful data to be obtained. Therefore, on-orbit flats for the broad-band filters have to date been obtained using the internal lamps, but unfortunately these contain their own field-dependent variations that are not present in external exposures. This proposal would aim to analyze large numbers of archival external WFPC2 exposures in order to construct sky flats directly from the background light levels in the exposures.

3. *Improving the geometric distortion characterization.* Currently the WFPC2 distortion has been explicitly obtained for only three filters, namely F300W, F555W and F814W. Since the distortion is strongly color-dependent, it may be desirable to obtain observations at a wider range of filters, perhaps at even shorter wavelengths, in order to improve the constraints. Further work also needs to be done on determining the degree of skew in the solutions, which requires analysis of observations at a range of different orientation angles.

4. *Reducing the errors in photometric zero points between the WFPC2 filters.* Currently the photometric zero points between filters are known to levels of $\sim 2\%$. These may be reduced to less than 1% by examining measurements of larger numbers of stars in selected regions, as well as by improving the color terms and comparison with ground-based photometric systems.

5. *Improving the calibration of narrow-band and linear ramp filters.* Many of the narrow-band filters are calibrated to accuracies of only $\sim 5\%$, while the linear ramp filters can be off by as much as 10%. These levels of calibration may be improved by a program of observations aimed at bright emission-line photometric standards, such as

planetary nebulae or extragalactic objects (QSOs, AGN) that have been well-studied spectroscopically with other instruments, for example STIS. The flatfields for these filters could also be improved using wealth of on-orbit data currently in the archives.

6. *Improved characterization of the efficiency of some filters, for example the z-band, F785LP and 1042M.* The red broad-band filters suffer from unique limitations in that the objects of greatest interest for these filters are often extremely red, thus the color terms involved are much larger than for many of the other filters and the potential photometric errors are thus much higher. The calibration of these filters can potentially be significantly improved by programs aimed at observations of samples of red spectrophotometric standards.

7. *Improved measurements of filter red leaks, including characterization of their spatial dependence.* A number of the broad-band filters (F336W and blueward) are known to have significant red leaks, which are characterized only by their ground-based filter throughput traces. It is possible that these effects may vary spatially across the filters, which can be measured using observations of photometric standards at a range of locations across the chips. Similarly, the time evolution of the red leaks could be better characterized using the database of photometric calibration observations currently in the archive.

8. *Measuring possible changes in the central wavelengths of some of the narrow-band filters.* Ground-based tests reveal the possibility of changes in the photometric properties of the narrow-band filters due to the large numbers of coatings on these filters. Although they were extensively baked out prior to launch, some observations have suggested the possibility of subsequent changes on-orbit. This program would involve observations designed at measuring such changes if they have occurred.

9. *Measuring the extended wings of the point-spread function on large scales across the chips.* Some programs involve observations of faint targets in the vicinity of bright objects, for example objects near bright stars, or planetary moons in our own solar system. It is often desirable to model the PSF of the bright sources on large scales, to better constrain the properties of the faint targets of interest. This calibration program would aim at complementing the current suite of PSF library data by extending PSF information to scales of several hundred pixels. Care would need to be taken to properly account for the effects of scattered light and telescope focus variations.

10. *Characterizing the photometric effects of intra-pixel variations resulting from focus changes due to telescope breathing.* During an orbit the thermal "breathing" of the telescope can amount to a focus variation of several microns. This changes the amount by which a star's light is distributed among the pixels, and can potentially introduce time-dependent photometric variations if several exposures are obtained during the orbit. This program would likely involve analysis of a large number of suitable exposures from the archive to determine the magnitude of this effect, although new additional observations may be proposed if the current data are not adequate.

5.2. How the Observing Community Can Help

If anyone in the community would like to give us input for possible close-out programs to consider, please simply send email to "help@stsci.edu" with the subject of "WFPC2 Close-Out Calibration." We will gladly examine all the suggestions that we receive, and would be happy to discuss possible programs with interested observers.

In general, any proposals aimed at obtaining new observations will be performed by the STScI WFPC2 group as part of our calibration program for Cycle 12. Thus, feedback that we receive on observational aspects of close-out will be included in these programs.

If observers in the community would like to carry out calibration-related analysis on any archival WFPC2 data, then funding for such work can be obtained by submitting a "Calibration Outsourcing Proposal" as part of the general Phase I *HST* call for proposals. In this case, the WFPC2 group plays a consulting role but the actual analysis is done directly by the proposer, who then deliver the products back to STScI for inclusion in our calibration database (for example, improved zeropoints, or a refined geometric distortion solution, or software that deals with CTE).

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