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WFC3 Cycle 20 Calibration Program

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Abstract

The Cycle 20 WFC3 Calibration Program runs from November 2012 through October 2013 and is designed to measure and monitor the behavior of both the UVIS and IR channels. The program was prepared with the actual usage of WFC3 in mind, to provide the best calibration data and reference files for the approved scientific programs. During Cycle 20 the WFC3 team is using 83 external and 1833 internal orbits of HST time divided in 30 different programs, grouped in eight categories: UVIS and IR Detector Monitors, CTE Characterization and Calibration, IR Persistence, WFC3 Photometric Performances, Grisms, Flat-fields, and Astrometry

Introduction

The Wide Field Camera 3 (WFC3) is the panchromatic (wavelength coverage ranging from 200 nm to 1700 nm) 4^{th} generation instrument of the *Hubble* Space Telescope (HST), that has replaced the Wide Field Planetary Camera 2 (WFPC2) during the last HST servicing mission (SM4) in May 2008.

WFC3 has two independent channels:

- The UVIS channel is sensitive to the wavelength between 200 nm and $1m\mu$, uses two 4096×2051 pixel CCD detectors with a pixel scale of $0''.0395$ and a field of view (FoV) of $162'' \times 162''$. It is equipped with one UV grism and 62 narrow-, medium-, and broad-band filters, 42 of which cover the entire UVIS FoV, and the remaining 20 are organized in 5 sets of "quad" filters.
- The IR channel operates between 800 nm and $1.7m\mu$. It consists of a 1024×1024 HgCdTe detector array, of which the central 1014×1014 pixels are used for imaging. The FoV is $136'' \times 136''$ and the spatial resolution is $0''.135 \times 0''.121$. The IR channel is equipped with 15 broad-, medium- and narrow-band full-frame filters, and two grisms.

A complete description of WFC3 can be found in the WFC3 Instrument Handbook (Dressel, L. 2012). Instructions on how to reduce WFC3 data can be found in the Data Handbook (Rajan et al. 2010).

Usage of WFC3 in Cycle 20

With almost 50% of the total number of HST orbits available for science, in Cycle 20 (CY20) WFC3 continues to be the most widely requested HST instrument. Figure 1 shows the usage of the available WFC3 observing modes in the past four cycles. Both the WFC3 channels are very popular. The IR grism G141 is the second most requested filter for the IR channel (the first one being F160W). It accounts for 28% of the IR observing time and almost 20% of the total usage of WFC3.

A closer look at the approved proposals shows that in CY20 the GOs are using 14 out of the 15 IR filters and 70% of the UVIS filters. 43% of the UVIS exposures are in the near UV. Figure 2 shows the the fraction of UVIS and IR observing time dedicated to the most used filters.

UVIS detectors are aging and their charge transfer efficiency (CTE) is deteriorating. A study of warm pixels in dark exposures showed that CTE losses in UVIS can be largely mitigated for observations with background higher than 10-12 e^- (Anderson 2012). In May 2012 the WFC3 team and the Goddard Space Flight Center fast-tracked a procedure for adding post-flash flux to UVIS images, and the WFC3 team conducted an intense campaign to inform users observing with the UVIS channel in the near UV, with narrow-band filters, or in any situation where the sky background is very low (Baggett & Anderson 2012) about the benefit of adding post-flash to the observations during the summer 2012. As a result in CY20 post-flashed is now used with 44% of the UVIS observations.

PERCENTAGE OF EXPOSURES FOR WFC3 CHANNEL				
	UVIS	IR	IMAGING	SPECTROSCOPY
Cycle 17	49%	51%	92%	8%
Cycle 18	22%	78%	40%	60%
Cycle 19	44%	56%	77%	23%
Cycle 20	36%	64%	80%	20%

Fig. 1.— *Percentage of the WFC3/UVIS vs WFC3/IR exposures as a function of Cycle. The proportion of imaging vs. spectroscopy is also shown.*

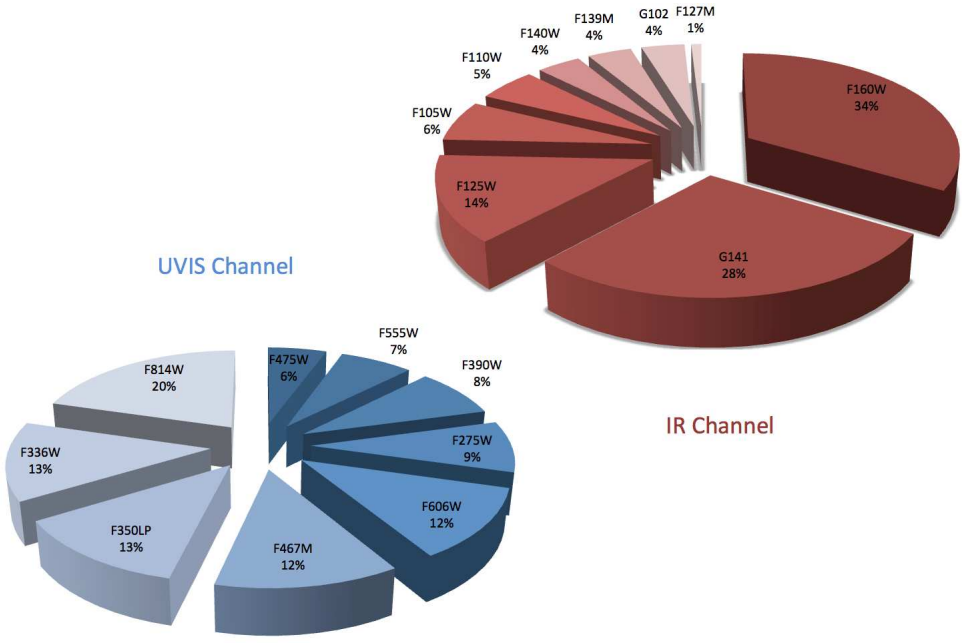

Fig. 2.— *Percentage of the WFC3/UVIS (in blue) and WFC3/IR (in red) most requested filters.*

Calibration Requirements

The WFC3 calibration plan for CY20 was built to support the variety of observational modes requested by the GOs, and to monitor the performances of both WFC3 channels. The

Program Title	Ext. Orbits	Int. Orbits		Program Title	Ext. Orbits	Int. Orbits
13071-UVIS Anneal	0	107		13088-WFC3 contamination & stability monitor	11	0
13072-UVIS Bowtie monitor	0	130		13089-WFC3 UVIS & IR photometry	16	0
13073-4-5-6-UVIS CCD daily monitor	0	805		13090-UVIS Grism: Flux calibration	2	0
13168-UVIS CCD gain stability	0	10		13091-UVIS Grism: Wavelength calibration and stability	2	0
13078-UVIS post flash monitor	0	64		13092-IR Grism: Flux/trace calibration and stability	2	0
13077-IR Dark monitor	0	120		13093-IR Grism: Wavelength calibration and stability	2	0
13079-IR linearity monitor	3	9		13094-IR Grism -1 Order calibration	7	0
130080-IR gain monitor	0	16		13095-UV L-Flats via Spatial Scans	8	0
13081-Guard Darks for MCT Programs	0	80		13096-UVIS Flat Field Validation	3	0
13082-UVIS CTI monitor (EPER)	0	24		13169-CCD Anomalous QE pixels	0	24
13083-UVIS CTE monitor (star cluster)	9	0		13097-UVIS Internal Flats	0	20
13084-Characterization of UVIS traps with CI	0	122		13098-IR Internal Flats	0	30
13085-Line 10 CI bias to support a GO program	0	60		13099-IR Earth Flats	0	100
13086-IR persistence behaviors as a function of saturation time	0	72		13100-UVIS & IR Geometric Distortion Calibration	5	0
13087-IR persistence model tests	0	40		13101-High Precision Astrometry	13	0

Fig. 3.— *Summary of the CY20 WFC3 Calibration Activities: UVIS detector monitors are marked in blue, IR detector monitors in red, UVIS CTE characterization in yellow, IR persistence in orange. Activities related to the photometric performances of WFC3 are in green, Grism calibrations are in purple, brown is for the flat-fields, and grey is for astrometry. Allocated external and internal orbits are reported.*

30 calibration activities are grouped in eight categories: UVIS and IR Detector Monitors, CTE Characterization and Calibration, IR Persistence, WFC3 Photometric Performances, Grisms, Flat-fields, and Astrometry (Figure 3)

UVIS Detector Monitors

As in previous Cycles (Deustua et al. 2009, Deustua 2010, Sabbi et al. 2011), one of the main goals during CY20 is to monitor the main properties of the instrument. The health of the two UVIS CCDs is checked using 1161 internal orbits, divided as follow:

1. 107 orbits, whose cadence has beed synchronized with the other HST instruments, are allocated to perform an anneal every month. During the anneal the UVIS detectors are warmed up to $\sim$ 20C. This procedure restores a large fraction of hot pixels to normal levels. The total number of orbits allocated to this program is higher than in the previous cycles, to include the transition towards "post-flashed" darks.

2. 130 orbits are used to mitigate the hysteresis (a.k.a. bowtie, Baggett & Borders 2009) effect via a series of unsaturated and saturated internal flats.

3. 850 orbits are used to perform a daily monitor of the CCDs behavior using a series of dark and biases. At the same time the data provide updated darks and hot-pixel maps. The total number of orbits allocated to this program is higher than in the previous cycles, to include the transition towards "post-flashed" darks.

4. 10 orbits are used to verify the stability of the gain in the 4 UVIS quadrants for all the available binning modes by taking a series of internal flats over a range of integration time.

5. 64 orbits are used to monitor the stability of the post-flash LED with time.

IR Detector Monitors

The health of the IR channel is monitored through 216 internal and 3 external orbits divided as follow:

1. 120 internal orbits to obtain IR dark calibration files. The number of orbits is dictated by the observing modes requested by GOs. This program has been reduced by half compared to CY19 because of IR darks are now known to be stable.

2. 3 external (low and high signal ramp of 47 Tuc) and 9 internal orbits (saturated internal flats) are used to monitor the photometric non-linearity of the IR channel and update the calibration reference file.

3. 16 internal orbits to verify the stability of the IR channel gain via a series of lamp flats. Different orbits are required to avoid persistence effects.

4. 80 internal orbits are allocated to collect guard darks for the Multi Cycle Treasury (MCT) programs (full darks). These darks are collected before each visit in two MCT programs. These darks are used to verify the presence of any residual persistent signal resulting from former observations, which may affect MCT data.

CTE Characterization and Calibration

For the first time in Cycle 20, WFC3 GOs have 2 ways to mitigate the impact of the degrading UVIS CTE: post-flash and Andersons correction algorithm (Anderson & Bedin 2010). In order to support these observing modes the WFC3 team is using 9 external and 206 internal orbits:

- 24 internal orbits are used for a monthly measurement of the CTE via Extended Pixel Edge Response (EPER).
- 9 external orbits are used to observe stellar fields characterized by different crowding and background (2 fields in 47 Tuc and 1 in NGC 6791) to calibrate the photometric and astrometric CTE corrections.
- 122 internal orbits with charge-injected bias are used to monitor the length of the CTE trails. This information is used as an input for the Andersons algorithm.
- 60 internal orbits with charge injected bias are needed to support the single remaining GO program using charge injection.

Characterization of IR Persistance

The WFC3 team has developed a model and an internal pipeline to generate calibration files to correct individual IR exposures affected by persistence. We plan to use 112 internal orbits to

- Characterize the behavior of persistence as a function of the saturation time (72 internals)
- Attach darks after GO exposures to test the model (40 internals). This replaces the nearly unschedulable Cycle 19 calibration program.

WFC3 Photometric performance

A total of 27 external orbits will be used to:

- Measure the photometric throughput of WFC3 in a series of key filters every 5 weeks to validate instrument throughput stability – 11 orbits.
- Check photometric zero-points for all WFC3 UVIS and IR filters – 16 orbits.

GRISM Calibrations

The WFC3 team has designed 5 small programs to continue to monitor WFC3 Grisms. A total of 15 external are used as follow:

- Monitor the flux calibration of the G280 UVIS grism in both chips – 2 orbits.
- Monitor the wavelength calibration of the G280 UVIS grism in both chips – 2 orbits.
- Monitor the flux calibration of the G102 and G141 IR grisms – 2 orbits.
- Monitor the wavelength calibration of the G102 and G141 IR grisms – 2 orbits.
- Derive the wavelength and flux calibration for the IR -1st order (both G102 and G141) – 7 orbits.

The first four programs monitor the stability of the calibrations already achieved in Cycle 17-19; the fifth is required to complete the precision calibration of Vega and enable the -1^{st} order for science observations.

Flatfield Calibrations

The WFC3 team is using 11 external and 174 internal orbits to monitor and validate WFC3 flatfields. Observations have been organized as follow:

- 8 external orbits are used to validate the UV inflight flatfield via spatial scan.
- 3 external orbits are to monitor the UVIS spatial sensitivity and validate the accuracy of the UVIS flats by stepping a spectrophotometric calibration standard across the detector.
- 24 internal orbits monitor a population of UVIS pixels with anomalous QE.
- 20 internal orbits are used to monitor the high spatial frequency variations via tungsten lamp in UVIS flats.
- 30 internal orbits monitor the high spatial frequency variations via tungsten lamp in IR flats.
- 100 internal orbits are used to observe the bright Earth and improve the IR inflight flats. The program also monitors the IR blobs (Pirzkal et al. 2010, Pirzkal & Hilbert 2012).

Astrometric Calibration

18 external orbits of HST time are used to monitor the stability of the geometric distortion for both the UVIS and IR channels and add the UVIS filter F621M to the set of calibrated filters. F621M is the first relatively narrow band filter used for this kind of calibrations by the WFC3 team. The total number of orbits used by the program is 5. In addition spatial scans are used to increase our knowledge of the internal distortions of WFC3/UVIS, better understand and measure the WFC3-FGS calibration, and to quantify the potential of this technique. A total of 13 external orbits has been allocated to this program.

Data, Analysis and Results

As in previous cycles all analysis and results from CY20 Calibration Programs will be described in Instrument Science Reports (ISRs) and will be available on the WFC3 web site at http://www.stsci.edu/hst/wfc3/documents/ISRs/. Updated reference files will be provided to the scientific community when appropriate.

A detailed description of all the CY20 WFC3 Calibration Proposals can be found at the url http://www.stsci.edu/hst/wfc3/calibration/CY20/ApprovedCY20_CalPlan.pdf. As for any other HST observation, the PhaseII's of these Calibration Proposals are public and can be consulted at
http://www.stsci.edu/hst/scheduling/program_information. Table 1 shows proposal IDs and titles.

References

Baggett, S., & Anderso, J. 2012, "WFC3/UVIS Sky Backgrounds", WFC3-ISR 2012-12

Dressel, L. 2012, "Wide Field Camera 3 Istrument Handbook, Version 5.0" (Baltimore:STScI)

Pirzkal, N., Viana, A., Rajan, A. 2010, "The WFC3 IR "Blobs" ", WFC3-ISR 2010-06

Pirzkal, N., & Hilbert, B. 2012, "The WFC3 IR "Blobs" Monitoring", WFC3-ISR 2012-15

Rajan, A. et al. 2010, "WFC3 Data Handbook", Version 2.1, (Baltimore: STScI)

Sabbi, E., & the WFC3 team 2012, "WFC3 Cycle 19 Calibration Program", WFC3-ISR 2012-04

ID	Program Title
13071	UVIS Anneal
13072	UVIS Bowtie Monitor
13073	UVIS CCD Daily Monitor A*
13074	UVIS CCD Daily Monitor B*
13075	UVIS CCD Daily Monitor C*
13076	UVIS CCD Daily Monitor D*
13168	UVIS CCD Gain Stability
13078	UVIS Post-Flash Monitor
13077	IR Dark Monitor
13079	IR Linearity Monitor
13080	IR Gain Monitor
13081	Guard Dark for MCT Programs
13082	UVIS CTI Monitor (EPER)
13083	UVIS CTE Monitor (star clusters)
13084	Characterization of UVIS Traps with CI
13085	Line 10 CI Bias
13086	IR Persistance Behaviours as Function of Saturation Time
13087	IR Persistence Model Tests
13088	WFC3 Contamination & Stability Monitor
13089	WFC3 UVIS & IR Photometry
13090	UVIS Grism: Flux Calibratoin
13091	UVIS Grism: Wavelength Calibration
13092	IR Grisms: Flux Calibration
13093	IR Grisms: Wavelength Calibration
13094	IR Grism -1 Order Calibration
13095	UVIS L-Flat via Spatial Scans
13096	UVIS Flat Field Validation
13169	CCD Anomalous QE pixels
13097	UVIS Internal Flats
13098	IR Internal Flats
13099	IR Earth Flats
13100	UVIS & IR Geometric Distortion
13101	High Precision Astrometry

Table 1: *CY20 Calibration Proposals. The UVIS CCD Daily Monitor program has bees divided in four parts for a more agile handling of the PhaseII APT file. Proposals that are part of the UVIS Daily Monitor are marked with a* * *symbol.*