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WFC3 Cycle 21 Calibration Program

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ABSTRACT

The Cycle 21 WFC3 Calibration Program runs from November 2013 through October 2014 and is designed to measure and monitor the behavior of the UVIS and IR channels based on actual WFC3 usage. Our goal is to provide the best calibration data and reference files for the approved scientific programs. During Cycle 21 the WFC3 team is using 98 external and 1907 internal orbits of HST time divided into 33 different programs, grouped in eight categories: UVIS Detectors, IR Detector, CTE Characterization and Calibration, Astrometric Calibrations, Characterization of IR Traps, WFC3 Photometric Performances, WFC3 Grisms, and, Flatfields Calibrations.

Introduction

Wide Field Camera 3 (WFC3) is the panchromatic (wavelength coverage ranging from 200 nm to 1700 nm) 4th generation instrument of the Hubble Space Telescope (HST), that replaced the Wide Field Planetary Camera 2 (WFPC2) during the last HST servicing mission (SM4) in May 2009.

WFC3 has two independent channels:

- The UVIS channel is sensitive to wavelengths between 200 nm and 1000 nm , uses two 4096×2051 pixel CCD detectors with a pixel scale of 0”.0395 and a field of view (FoV) of 162”×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 at wavelengths between 0.8 and 1.7microns. It consists of

a 1024×1024 pixel HgCdTe detector array, of which the central 1014×1014 pixels are used for imaging. The FoV is 136”×136” and the spatial resolution is 0”.135×0”.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. 2014). Instructions on how to reduce WFC3 data can be found in the Data Handbook (Rajan et al. 2010).

Usage of WFC3 in Cycle 21

With more than 50% of the total number of HST orbits available for science (Table 1), in Cycle 21 (CY21) WFC3 continues to be the most widely requested HST instrument. Table 2 shows the usage of the available WFC3 observing modes (UVIS vs. IR channel, imaging vs. spectroscopy) in the past five cycles.

HST Cycle	GO Programs* % of HST orbits	Calibration** # External orbits	Calibration** # Internal orbits
CY17	46.1%	256	>2000
CY18	41.9%	134	1719
CY19	48.6%	125	1497
CY20	56.3%	83	1833
CY21	53.6%	98	1907

Table 1: WFC3 usage since the installation on HST. The usage is expressed as percentage of HST orbits. *Multi Cycle Treasury (MCTs) Programs, Snapshot (SNAP) proposals and Frontier Fields are not included in the estimate of the GO time. **Delta Calibration Programs are not included in the estimate of the time assigned for calibration activities. The number of calibration orbits is divided into internal and external, because they have a different impact on the execution of the GO programs.

Both the WFC3 channels are very popular. Figure 1 shows how the filter request is changed over time, while Figure 2 highlights the usage of the WFC3 filters in CY21.

CY21 confirms the appreciation of the WFC3 IR spectroscopic capabilities by General Observers (GOs). With ~8,000 exposures, the grism G141 is the most requested filter for the IR channel (followed by the F160W filter). Alone, it accounts for 52% of the data acquired with the IR channel, and, when combined with the G102 grism, pushes the requests for spectroscopic data up to more than 60% of the IR data. As in previous Cycles GOs are using 14 out of the 15 IR filters. The most noticeable change compare to the previous Cycles is the high request (35% of the exposures) for spatially scanned IR data.

The appreciation for the WFC3 flexibility and panchromatic capabilities from the GOs is confirmed by the fact that GOs will use 71% of the UVIS filters, with 44% of the UVIS exposures being in the near UV. GOs request post-flash to mitigate the effects of the decreasing charge transfer capabilities of 48% 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%
Cycle 21	33%	67%	59%	41%

Table 2: WFC3 usage since the installation on HST from GOs. The usage is expressed as percentage of WFC3 number of exposures, and has been divided in UVIS vs. IR channels, imaging vs. spectroscopy. Multi Cycle Treasury (MCTs) Programs, Snapshot (SNAP) proposals and Frontier Fields are not included.

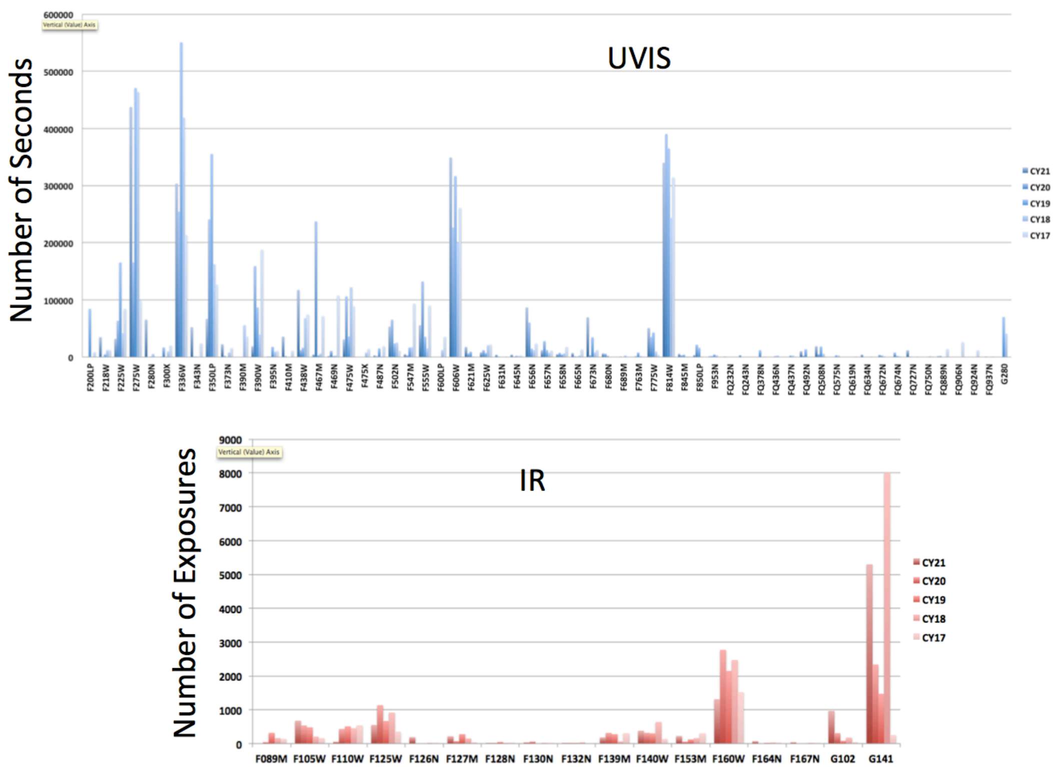

Fig. 1: Filter usage from Cycle 17 to 21 for the UVIS channel (upper panel) and the IR channel (lower panel). Note that UVIS data are measured in number of seconds, while the IR channel is in number of exposures.

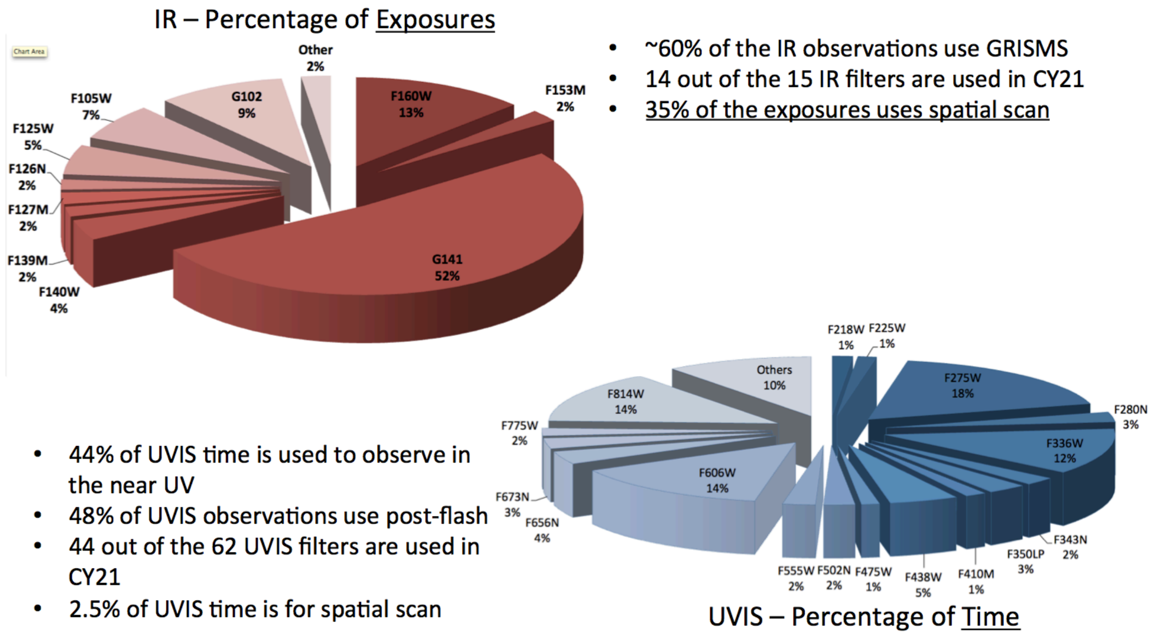

Fig. 2: Percentage the filter usage in CY21 for the IR channel (upper-left, red pie plot) and UVIS channel (lower-right pie-plot). As in Figure 1 UVIS data are expressed as percentage of time, while the IR channel is expressed as percentage of exposures.

Calibration Requirements

The WFC3 calibration plan for CY21 was built to support the variety of observational modes requested by the GOs, and to monitor the performance of both WFC3 channels. The 33 calibration activities are grouped into eight different categories: UVIS Detectors, IR Detector, CTE Characterization and Calibration, Astrometric Calibrations, Characterization of IR Traps, WFC3 Photometric Performances, WFC3 Grisms, and, WFC3 Flatfields Calibrations (Table 3).

Program Title	Ext. Orbits	Int. Orbits		Program Title	Ext. Orbits	Int. Orbits
UVIS anneal	0	85		IR persistence model tests*	8	8
UVIS bowtie monitor*	0	243		Trapping mitigation in spatial scan observations of exosolar planets*	15	0
UVIS CCD daily monitor*	0	644		WFC3 contamination & stability monitor	10	0
UVIS CCD un-flashed monitor*	0	140		WFC3 UVIS & IR photometry*	18	0
UVIS post-flash monitor	0	60		IR Grism: cross checking sensitivity function of hot and cool star*	1	0
UVIS CCD gain stability	0	18		UVIS Grism: flux calibration*	2	0
IR dark monitor	0	95		UVIS Grism: wavelengths calibration & stability*	2	0
IR linearity monitor	3	9		IR Grisms: flux calibration*	4	0
IR gain monitor	0	16		IR Grisms: wavelengths calibration & stability*	4	0
UVIS CTI monitor (EPER)	0	12		IR Grisms sky characterization*	2	20
UVIS CTE monitor (star cluster)*	6	0		Recalibration of the IR Grism wavelength ZPs*	2	0
CTE characterization with post-flashed darks*	0	15		UV flats via spatial scan*	8	0
Characterization of the charge-level dependence of CTE losses*	0	13		UV flat field validation*	4	0
Characterization of UVIS traps with CI*	0	72		CCD anomalous QE pixels*	0	24
UVIS & IR geometric distortion	6	0		UVIS internal flats	0	15
High precision astrometry*	3	0		IR internal flats	0	18
				CMS monitor with earth flats*	0	400

CY21 Total external orbits=98; Total internal orbits=1907

Table 3: List of the CY21 calibration activities. For each program the number of used external and internal orbits is listed. Programs belonging to the same calibration category are grouped together. Different colors in the table correspond to different categories: UVIS Detectors is in light blue, IR Detector in red, CTE Characterization and Calibration in yellow, Astrometric Calibrations in grey, Characterization of IR Traps in orange, WFC3 Photometric Performances in green, WFC3 Grisms in purple, and WFC3 Flatfields Calibrations in dark blue.

UVIS Detector

One of the main goals of CY21 is to continue to monitor the main properties of the instrument. The health of the two UVIS CCDs is checked using 1190 internal orbits divided as follow:

1. **UVIS Anneal:** 85 internal orbits, whose cadence is synchronized with the other HST instruments, are allocated to perform an anneal every month. During the anneal the UVIS detectors are warmed up to ~20C. This procedure restores a large fraction of hot pixels to normal levels. IR darks have been dropped to reduce the number of Channel Select Mechanism (CSM) movements.
2. **UVIS Bowtie Monitor:** 243 internal orbits are used to mitigate the hysteresis that affects the UVIS channel. This result is achieved by acquiring a series of unsaturated and saturated internal flats are acquired. The frequency was increased compare to the previous year to allow better scheduling and reduce the number of CSM movements.
3. **UVIS CCD daily monitor:** 644 internals orbits are used to perform a daily monitoring of the CCDs behavior using a series of dark and biases. At the same time the data provide updated darks and hot-pixels maps.
4. **UVIS CCD un-flashed monitor:** 140 internals orbits are used to assess how well

post-flash is mitigating CTE with time using a series of un-flashed darks

5. **UVIS post-flashed monitor:** 60 internal orbits are used to monitor the stability of the post-flash LED with time.
6. **UVIS CCD gain stability:** 18 internal 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 times.

IR Detector

The health of the IR detector is monitored through 120 internal and 3 external orbits:

1. **IR Dark Monitor**: 95 internal orbits are used to obtain IR dark calibration files. The number of orbits is dictated by the observing modes requested by GOs.
2. **IR Linearity Monitor:** 3 external + 9 internal orbits. A series of saturated internal flats are used to monitor the IR non-linearity and update the calibration files. In addition low and high signal ramps of 47 Tuc are used to validate the calibration files.
3. **IR Gain Monitor:** 16 internal orbits are used to verify the stability of the IR channel gain via a series of lamp flats. Different orbits are required to avoid persistence effects.

CTE Characterization and Calibration

This part of the calibration program requires 6 external and 112 internal orbits. As in CY20, GOs can mitigate CTI effects using post-flash. Anderson's CTE correction algorithm will be implemented in CALWF3 during FY2014. To support these efforts we have 5 programs: :

1. **UVIS CTI Monitor:** 12 internal orbits are used for an every other month measurement of the CTE via Extended Pixel Edge Response (EPER).
2. **UVIS CTE Monitor with Star Clusters:** 6 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 CTI corrections.
3. **CTE Characterization with Post-flashed Dark:** 15 internal orbits of short and long darks are used to confirm the predictions of the Anderson's algorithm before its implementation in the calibration pipeline CALWF3.
4. **Characterization of the Charge-Level Dependence of CTE losses:** 13 internal orbits with post-flashed charge injected darks are used to characterize the response of charge traps at different background levels.
5. **Characterization of UVIS Traps with Charge Injection:** 72 internal orbits with charge-injected bias to monitor the length of the CTE trails. This information will be used as an input for the Anderson's algorithm.

Astrometric Calibration

A total of 9 external orbits are used to:

1. **UVIS and IR Geometric Distortion:** 12 external orbits are used to monitor the stability of the geometric distortion for both the UVIS and IR channels.

2. **High Precision Astrometry: 3** external orbits with spatial scan are used to increase our knowledge of the internal distortions of the UVIS channel, and their time dependency.

Characterization of IR Traps

Over the past Cycles the WFC3 team has developed a model and an internal pipeline to generate calibration files to correct individual IR exposures affected by persistence. A total of 23 external and 8 internal orbits will be used to:

1. **IR Persistence Model Tests:** 8 external + 8 internal orbits are used to improve our current model for persistence.
2. **Trapping Mitigations in Spatial Scan Observations of Extrasolar Planets:** 15 external orbits are needed to characterize the effect of traps in extrasolar planet studies.

WFC3 Photometric Performance

One of the most appreciated qualities of WFC3 is the stability of its photometric performance. In CY21 we are using 28 external orbits to

1. **WFC3 contamination and Stability Monitor:** 10 external orbits are used to measure the photometric throughput of WFC3 in a series of key filters every 5 weeks and validates the instrument throughput stability.
2. **WFC3 UVIS and IR photometry:** 18 external orbits are needed to check the photometric zero-points for all the WFC3 UVIS and IR filters.

WFC3 Grisms

We have designed 7 small programs to continue to monitor all the WFC3 grisms: A total of 17 external orbits are needed to:

1. **IR Grism: Cross Checking Sensitivity Function of Hot and Cool Stars:** 1 external orbit is used to provide a cross check on the sensitivity functions of the -1^{st} and $+1^{st}$ IR grism spectral orders.
2. **UVIS Grism: Flux Calibration:** 2 external orbits are used to monitor the UVIS grism flux in chip2 and calibrate its flux in chip 1.
3. **UVIS Grism: Wavelength Calibration & Stability:** 2 external orbits are used to monitor the UVIS grism wavelengths stability in chip2 and calibrate the wavelength in chip 1.
4. **IR Grisms: Flux Calibration:** 4 external orbits are used to improve the flux calibration for both the IR GRISMs
5. **IR Grisms: Wavelength Calibration & Stability:** 4 external orbits are used to improve the wavelength calibration for both the IR GRISMs
6. **IR Grism Sky Characterization:** 2 external orbits are necessary to characterize the two-dimensional structure of the IR background.
7. **Recalibration of the IR Grism wavelength Zeropoints:** 2 external orbits are necessary to confirm the wavelength zeropoints of the IR grisms.

WFC3 Flatfield Calibrations

The WFC3 team needs 14 external orbits and 555 internal orbits to:

1. **UV Flats via Spatial Scan:** 8 external orbits are used to improve inflight UVIS flatfields for the filters F218W and F280N via spatial scan.
2. **UV Flatfield Validation:** 4 external orbits have been assigned to evaluate the accuracy of the UVIS flatfields for the filters F218W and F280N by stepping a spectrophotometric calibration standard across the detector.
3. **CCD Anomalous QE pixels:** 24 internal orbits are used to monitor a population of UVIS pixels with anomalous QE.
4. **UVIS Internal Flats:** 13 internal orbits are used to monitor the health of the UVIS filters via internal flats
5. **IR Internal Flats:** 18 internal flats are used to monitor the health of the IR filters via internal flats.
6. **CMS Monitor with Earth Flats:** 400 internal orbits are used to monitor the health of the CMS mechanism by observing the bright earth.

Data, Analysis and Results

As in previous cycles all analysis and results from the Cycle 21 Calibration Program 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 CY21 WFC3 Calibration Proposals can be found at http://www.stsci.edu/hst/wfc3/calibration/CY21/ApprovedCY21 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. Proposal IDs, titles and direct links to the proposal status can be found at http://www.stsci.edu/hst/wfc3/calibration/CY21/.

References

Dressel, L. 2012, "Wide Field Camera 3 Instrument Handbook, Version 6.0" (Baltimore: STScI)

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