Cycle 19 Calibration Plan

E. Sabbi, J. MacKenty & WFC3 team

8/8/2011

CY19 Calibration Programs

Program ID	Program Title	External Orbits	Internal Orbits	PI
12687	UVIS Anneal	0	91	Sylvia Baggett
12688	UVIS Bowtie Monitor	0	130	Tiffany Borders
12689	UVIS CCD Daily Monitor	0	730	Tiffany Borders
12690	UVIS CCD Gain Stability	0	13	Cheryl Pavlovsky
12691	UVIS CTI Monitor (EPER)	0	24	Vera Kozhurina-Platais
12692	UVIS CTE Monitor (Star Clusters)	14	0	Kai Noeske
12693	UVIS Charge Injection	6	50	Kai Noeske
12694	IR Persistance Strength	9	67	Knox Long
12695	IR Dark Monitor	0	235	Michael Dulude
12696	IR Linearity Monitor	6	18	Bryan Hilbert
12697	IR Gain Monitor	0	16	Bryan Hilbert
12698	WFC3 Contamination & Stability Monitor	17	0	Sylvia Baggett
12699	WFC3 Photometric Calibration & Calibration Flux Ladder	16	0	Susana Deustua
12700	Extending the Range & Precision of the Count Rate non Linearity	4	0	Adam Riess
12701	WFC3 PSF Wings	5	0	Linda Dressel
12702	IR Grisms: Flux/Trace Calibration & Stability	8	0	Janice Lee
12703	IR Grisms: Wavelength Calibration & Stability	8	0	Nor Pirzkal
12704	UVIS Grism: Flux Calibration	3	0	Nor Pirzkal
12705	UVIS Grism: Wavelength Calibration & Stability	3	0	Nor Pirzkal
12706	UVIS Flare Wavelength Dependence	2	0	Jennifer Mack
12707	UVIS Spatial Sensitivity	10	0	Abhijith Rajan
12708	IR Spatial Sensitivity	4	0	Abhijith Rajan
12709	UVIS & IR Moonlit Flats	0	50	Cheryl Pavlovsky
12710	UVIS Bright Earth Flats	0	20	Jennifer Mack
12711	UVIS Internal Flats	0	20	Abhijith Rajan
12712	IR Internal Flats	0	33	Tomas Dahlen
12713	Spatisal Scanned L-flat Validation Pathfinder	8	0	Peter McCullough
12714	UVIS & IR Geometric Distortion	2	0	Vera Kozhurina-Platais
	Total Orbits	125	1497	

CY19 Cal. Plan - Sabbi, MacKenty, & WFC3 team
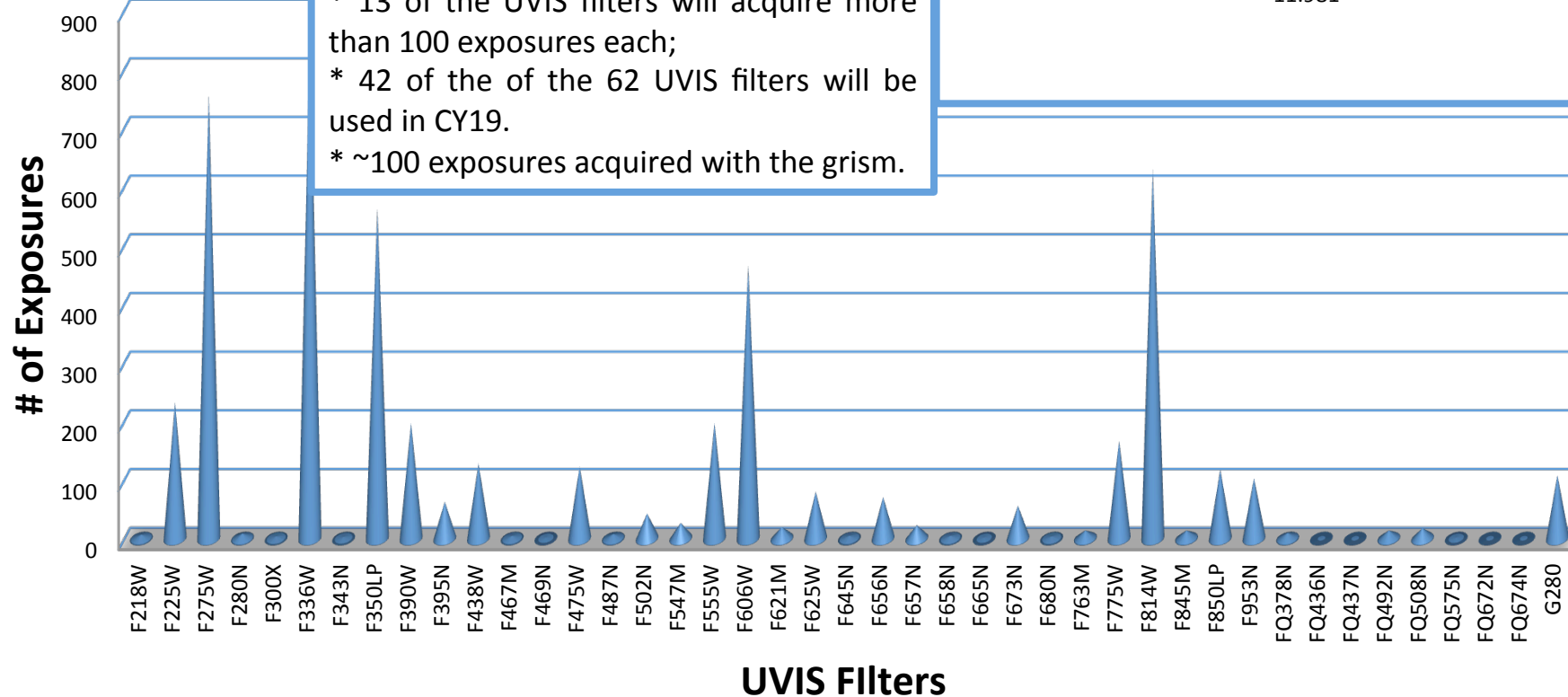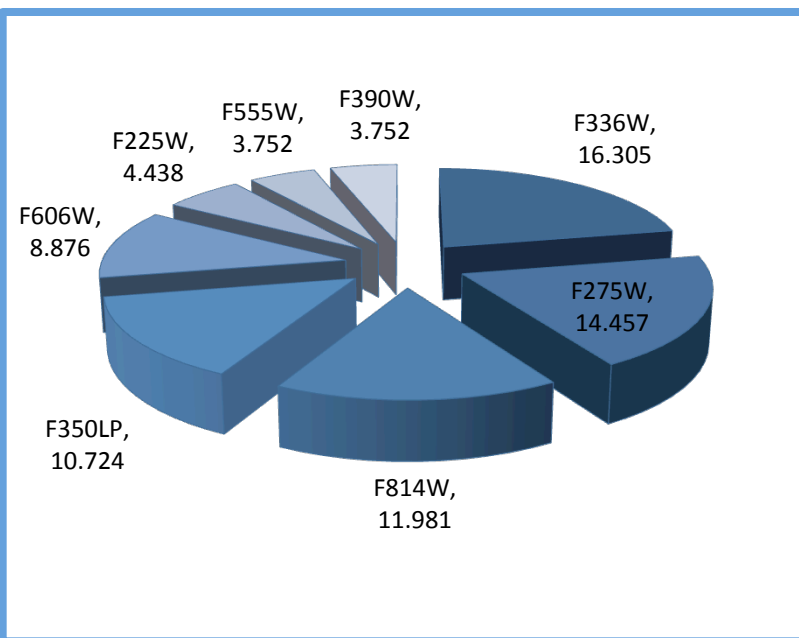
WFC3 Characteristics

WFC3 is extremely successful because of its:

- panchromatic capabilities (wavelength range from 200nm to 1700nm);

- multiple observing modes (imaging, spectroscopy, variety of readout modes, 80 different filters: narrow, medium, broadband, and grisms).

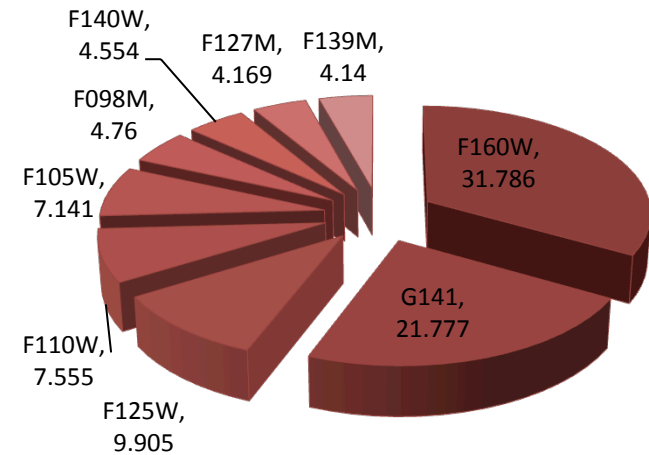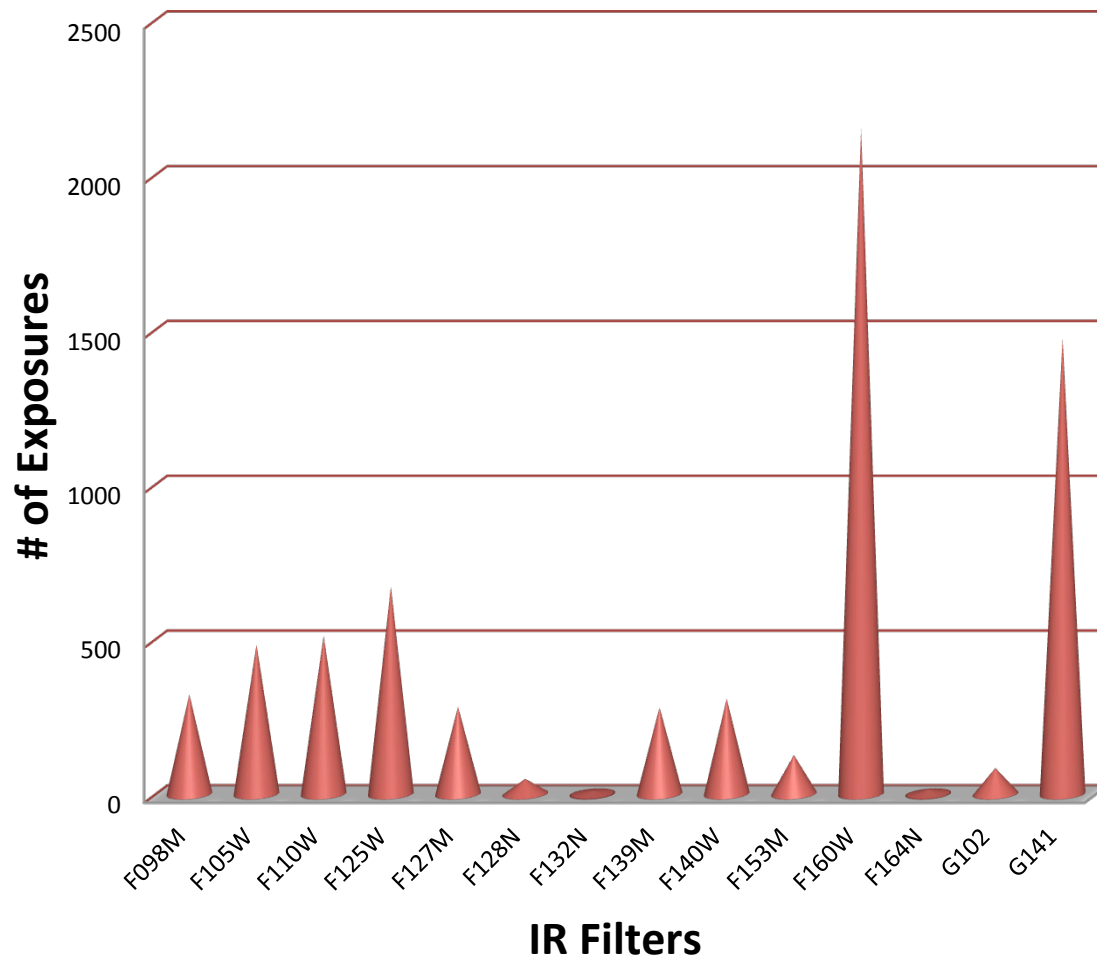- Both channels of WFC3 are very popular.

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%

Total Cy19 UVIS Filter Usage (GO+MCT)

* 50% of UVIS exposures use one of the UV filters;
* 25% of UVIS exposures are acquired with the filters F606W or F814W;
* 13 of the UVIS filters will acquire more than 100 exposures each;
* 42 of the of the 62 UVIS filters will be used in CY19.
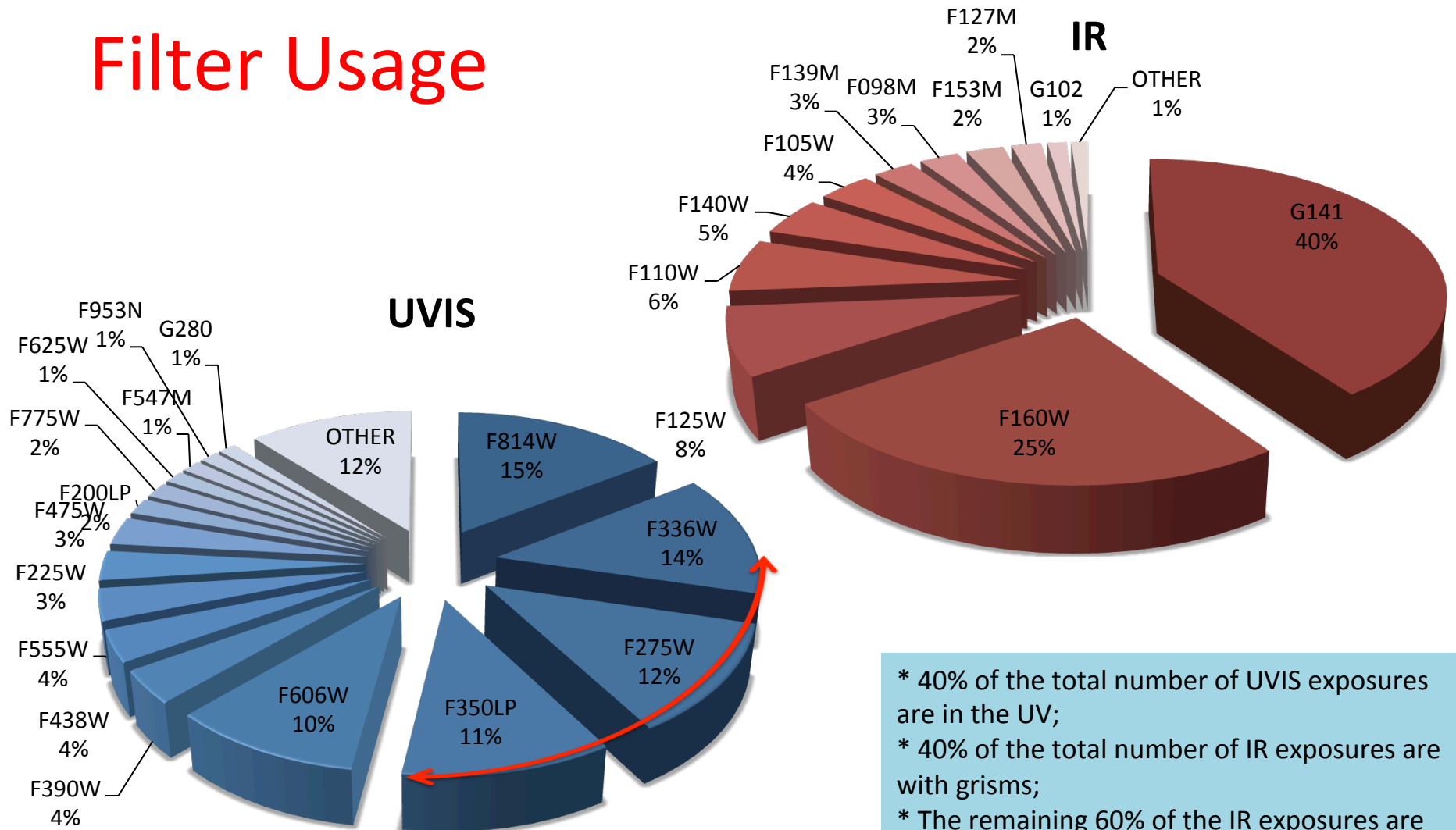* ~100 exposures acquired with the grism.

Pie chart labels:
- F336W, 16.305
- F275W, 14.457
- F814W, 11.981
- F350LP, 10.724
- F606W, 8.876
- F225W, 4.438
- F555W, 3.752
- F390W, 3.752

Bar chart y-axis: # of Exposures (0, 100, 200, 300, 400, 500, 600, 700, 800, 900)

Bar chart x-axis: UVIS FIlters
(F218W, F225W, F275W, F280N, F300X, F336W, F343N, F350LP, F390W, F395N, F438W, F467M, F469N, F475W, F487N, F502N, F547M, F555W, F606W, F621M, F625W, F645N, F656N, F657N, F658N, F665N, F673N, F680N, F763M, F775W, F814W, F845M, F850LP, F953N, FQ378N, FQ436N, FQ437N, FQ492N, FQ508N, FQ575N, FQ672N, FQ674N, G280)

Total Cy19 IR Filter Usage (GOs+MCT)

Bar chart — # of Exposures vs IR Filters: F098M, F105W, F110W, F125W, F127M, F128N, F132N, F139M, F140W, F153M, F160W, F164N, G102, G141

Pie chart:
- F160W, 31.786
- G141, 21.777
- F125W, 9.905
- F110W, 7.555
- F105W, 7.141
- F098M, 4.76
- F140W, 4.554
- F127M, 4.169
- F139M, 4.14

* More than 20% of the IR exposures are acquired with the grisms;
* 12 out of the 15 IR channel filters will be used in Cy19;
* 8 filters will acquire more than 200 exposures each.

Cumulative CY17+C18+C19 Filter Usage

IR

- F127M 2%
- F139M 3%
- F098M 3%
- F153M 2%
- G102 1%
- OTHER 1%
- F105W 4%
- F140W 5%
- F110W 6%
- G141 40%
- F160W 25%
- F125W 8%

UVIS

- F953N 1%
- G280 1%
- F625W 1%
- F547M 1%
- F775W 2%
- F200LP 2%
- F475W 3%
- F225W 3%
- F555W 4%
- F438W 4%
- F390W 4%
- F606W 10%
- F350LP 11%
- F275W 12%
- F336W 14%
- F814W 15%
- OTHER 12%

* 40% of the total number of UVIS exposures are in the UV;
* 40% of the total number of IR exposures are with grisms;
* The remaining 60% of the IR exposures are acquired through 9 of the 15 IR filters.

Calibration Requirements

In order to calibrate the variety of observational modes requested by the GOs and monitor the capabilities WFC3, we need to:

- Update the calibration reference files (bias, darks, IR non-linearity, geometric distortion table);
- Monitor the hysteresis effect (QE offset);
- Monitor the pixel-to-pixel response of both the channels, and validate the inflight flatfield correction;
- Validate the spatial and temporal photometric performances of the detectors;
- Characterize and model CTI for the UVIS channel, and persistence effects in the IR channel;
- Improve the wavelength and flux calibration of the grisms over the whole detectors;
- Improve the accuracy of the absolute photometric calibration.

These goals will be achieved using 125 external orbits and 1484 internal orbits.

PROGRAM HIGHLIGHTS

UVIS Detector Monitors

To monitor the health of the UVIS channel we ask for 964 internal orbits divided as follow:

1. 91 internal orbits (the cadence has been synchronize with the other HST instruments) to perform an anneal every month.

2. 130 internal orbits to monitor the hysteresis (bowtie) effect via a series of unsaturated and saturated int flats.

3. 730 internals to perform a daily monitoring the CCDs behavior using a series of dark and biases.

4. 13 internals 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.
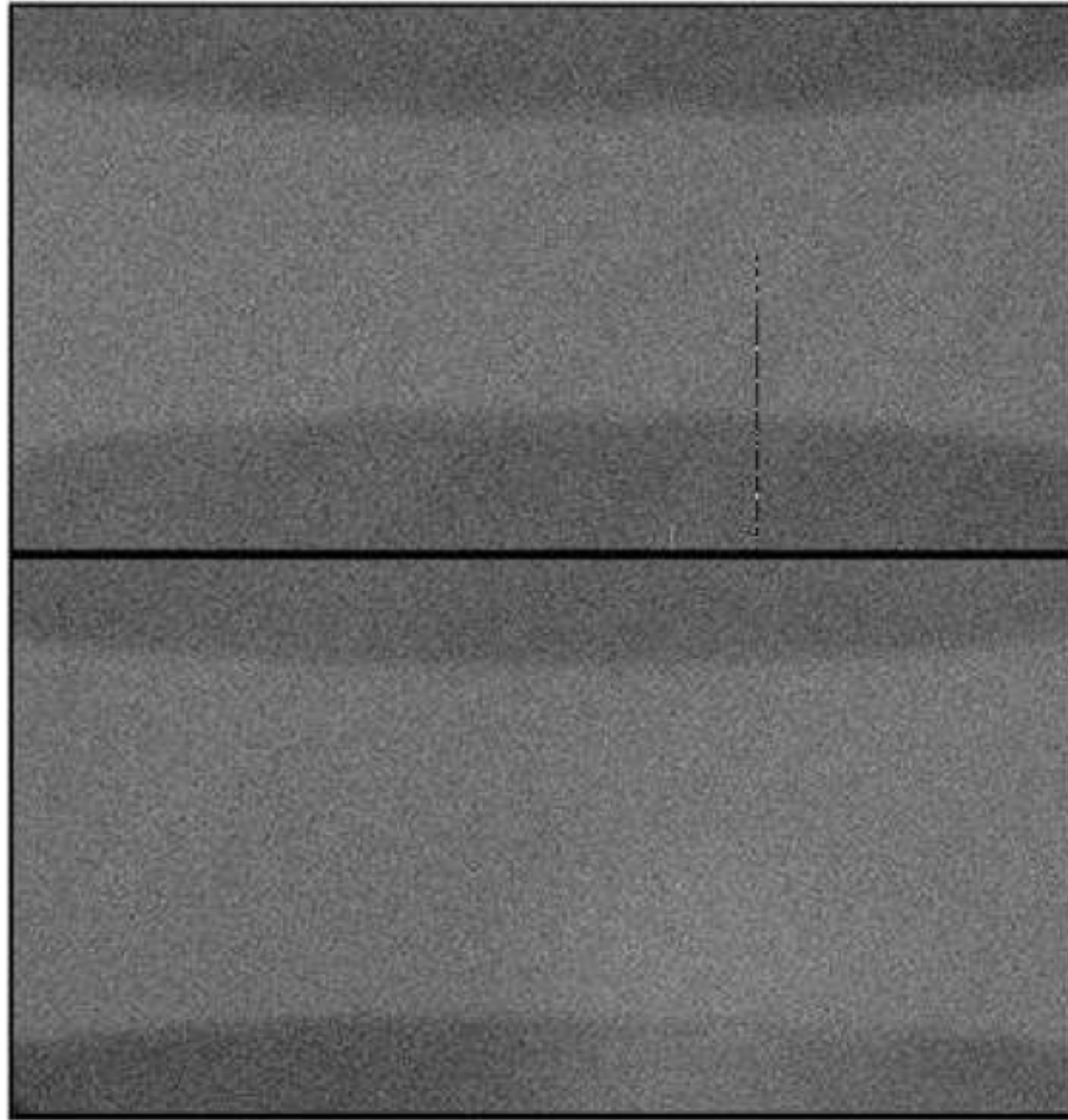
Example of UVIS hysteresis (bowtie) in both the CCDs (Baggett et al. 2010).

CY19 Cal. Plan - Sabbi, MacKenty, & WFC3 team

IR Array Monitors

To monitor the health of the IR channel we ask for 336 internal and 15 external orbits, divided as follow:

1. 235 internal orbits to obtain IR dark calibration files. The number of orbits is dictated by the observing modes requested by GOs. Because of the dark stability these calibrations can be accomplished with 45% fewer orbits than in CY18.

2. 6 external (low and high signal ramps of 47 Tuc) and 18 internal orbits (saturated internal flats) to monitor the IR non-linearity 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. 9 external orbits will be used to image ωCen at different positions and 67 internal orbits (full darks) will be used to provide a model that can remove persistence to ½ of the dark current rate. Of the 67 darks, 40 will be scheduled, on a best effort basis, after selected GO programs ("Bad actors") to quantify the persistence.

CY19 Cal. Plan - Sabbi, MacKenty, & WFC3 team

Schematic monthly profile of the Cycle 19 WFC3/IR dark monitor						
Orbit #	Obs 1	Obs 2	Obs 3	Obs 4	Obs 5	Obs 6
Orbit 1	SPARS100/FF	XX	XX	XX	XX	XX
Orbit 2	SPARS100/FF	XX	XX	XX	XX	XX
Orbit 3	SPARS100/FF	XX	XX	XX	XX	XX
Orbit 4	STEP200/FF	XX	XX	XX	XX	XX
Orbit 5	STEP200/FF	XX	XX	XX	XX	XX
Orbit 6	STEP200/FF	XX	XX	XX	XX	XX
Orbit 7	SPARS50/FF	SPARS25/FF	XX	XX	XX	XX
Orbit 8	SPARS50/FF	SPARS25/FF	XX	XX	XX	XX
Orbit 9	SPARS50/FF	SPARS25/FF	XX	XX	XX	XX
Orbit 10	STEP50/FF	STEP25/FF	RAPID/FF	XX	XX	XX
Orbit 11	STEP50/FF	STEP25/FF	RAPID/FF	XX	XX	XX
Orbit 12	STEP50/FF	STEP25/FF	RAPID/FF	XX	XX	XX
Orbit 13	STEP100/FF	SPARS10/FF	XX	XX	XX	XX
Orbit 14	STEP100/FF	SPARS10/FF	XX	XX	XX	XX
Orbit 15	SPARS200/FF	XX	XX	XX	XX	XX
Orbit 16	SPARS200/FF	XX	XX	XX	XX	XX
Orbit 17	SPARS200/FF	XX	XX	XX	XX	XX
Orbit 18	SPARS25/512	STEP25/512	STEP25/512	RAPID/512	XX	XX
Orbit 19	SPARS25/256	SPARS10/256	RAPID/256	SPARS25/256	SPARS10/256	RAPID/256

Legend:

Most popular
Popular
Least popular

NOTE: Because of the low request two modes are not shown on this table. RAPID/64 and SPARS10/128 Will be collected in 4 dedicated obits (2 per mode, one at the beginning and one at the end of the cycle).

Characterization & Correction of the UVIS CTI

25 external and 74 internal orbits are necessary to monitor, characterize and correct for CTI the UVIS data:

1. 24 internal orbits will be used for a monthly measurement of the CTI via Extended Pixel Edge Response (EPER).

2. 14 external orbits will be 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. 6 external orbits will be used expand STScI experience with CI by duplicating selected GO programs using line 17 CI. 50 internal orbits are necessary to obtain the Charge Injection correction biases.

GRISMS

WFC3 grisms are very popular in Cy19.

We request a total of 22 external orbits to:

1. Derive a flux calibration of the G102 and G141 grisms over the whole IR channel by observing the spectrophometric standards GD71/P330E in 16 different positions – 8 orbits.

2. Derive a flux calibration of the G280 grism over the whole UVIS channel by observing the spectrophotometric standard GD-71 in 10 different positions– 3 orbits.

3. Refine the wavelength calibration of the G102 and G141 grisms by placing VY-22 in 16 different positions – 8 orbits.

4. Refine the wavelength calibration of the G280 grism by observing WR14 in 10 different positions – 3 orbits.
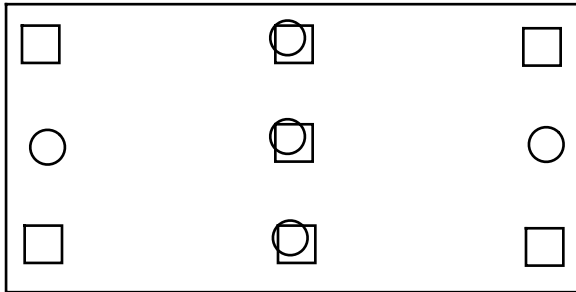
Cycle 18 □
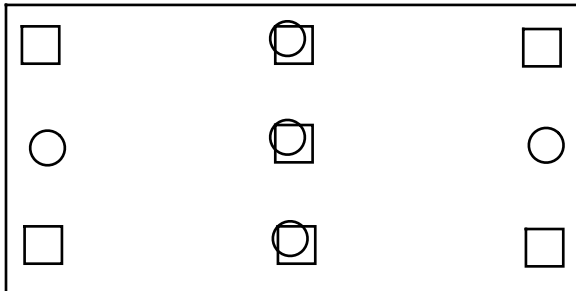
New ○

Positions of the calibration stars on the IR channel

Positions of the calibration standards on the UVIS channel

Cycle 18 □

New ○

CY19 Cal. Plan - Sabbi, MacKenty, & WFC3 team
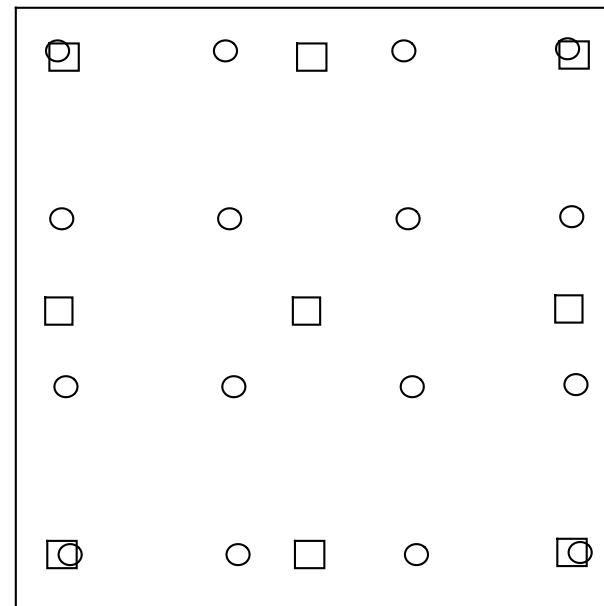
UVIS Flatfields

We request 18 external and 65 internal orbits to monitor and validate inflight flatfields of the UVIS channel:

1. 20 internal orbits to monitor the high spatial frequency variations via tungsten lamp flats;

2. 2 external orbits to characterize the wavelength dependence of the 'optical flare' by measuring the strength of the figure 8 ghosts through different filters;

3. 10 external orbits to verify the inflight correction of the flats by stepping the spectrophotometric standard G191-B2B across the detector;

4. 6 external orbits to validate the flare removal and flat inflight correction by perform spatial scanning of HD80606 in 7 different filters.

5. 20 internal orbits to observe the bright Earth and validate the Lflat correction for the UV filters. Observations will be executed on a best effort basis.

6. 25 internal obits to observe the dark side of the Earth and validate the lflat correction at the visible wavelengths. Observations will be executed on a best effort basis.

Dark earth flats have been used during Cy18 to validate both UVIS and IR LP-flats. Lflat corrections for 2 UVIS filters as derived from stellar photometry (upper panel) and earth flats (bottom panel) are shown for comparison.
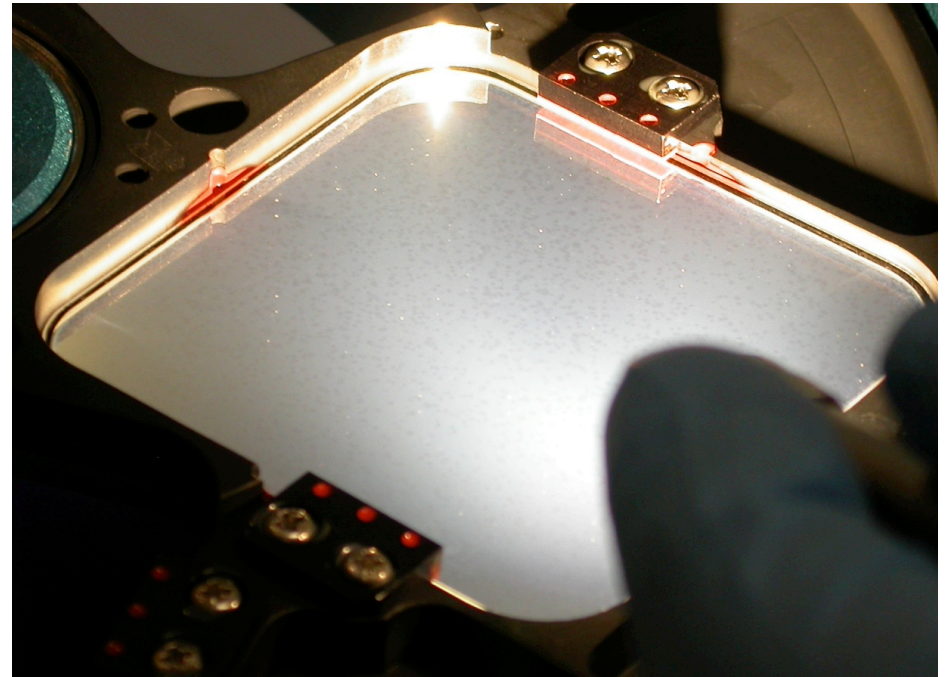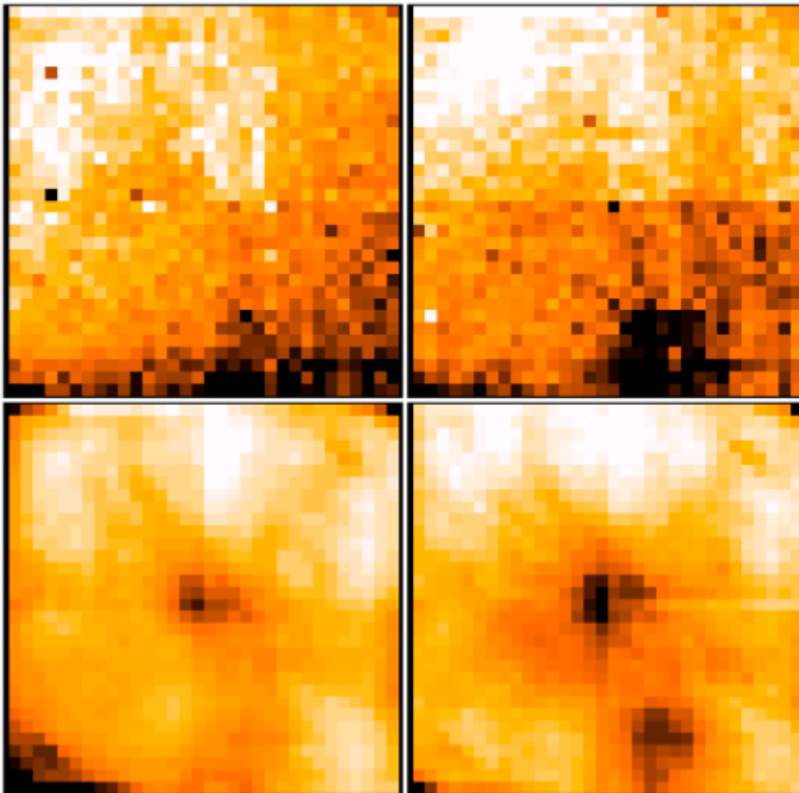

F606W   F814W

Image of the WFPC2 F343N filter, acquired during the post-SM4 laboratory inspection. P.L. Lim et al. 2010, WFPC2-ISR 2010-05 (Courtesy of J. Birretta). The filter aging is recognizable from the multitude of orange "freckles" spluttered over the entire surface.

IR Flatfields

We request 6 external and 58 internal orbits to monitor and validate inflight flatfields of the IR channel:

1. 33 internal orbits to monitor the high spatial frequency (pixel-to-pixel) variations via internal tungsten lamp flats.

2. 2 orbits to validate the flat field on-orbit correction by spatial scan imaging of the bright double star HD80606 in 2 different filters.

3. 4 external orbits to verify the flat field inflight correction by observing the spectrophotometric standard WD 1057+719 in 32 different positions across the detector in three different filters.

4. 25 internal obits to observe the dark side of the Earth and validate the L-flat correction at NIR wavelengths. Observations will be executed on a best effort basis.

WFC3 Photometric performances

54 external orbits will be used to:

- Periodically measure the photometric throughput of WFC3 in a series of key filters – 17 orbits;
- Establish the WFC3 calibration flux ladder from V~5 mag to V≥14 mag – 16 orbits;
- Obtain an independent calibration of the IR zero points and a measure of the count rate non linearity between H=14 and 17 – 4 orbits;
- Check for image stability by measuring the encircle energy of the PSF as a function of radius at 5 different locations on each detector – 5 orbits;
- Monitor the secular changes of both the UVIS and IR plate scale – 2 orbits.
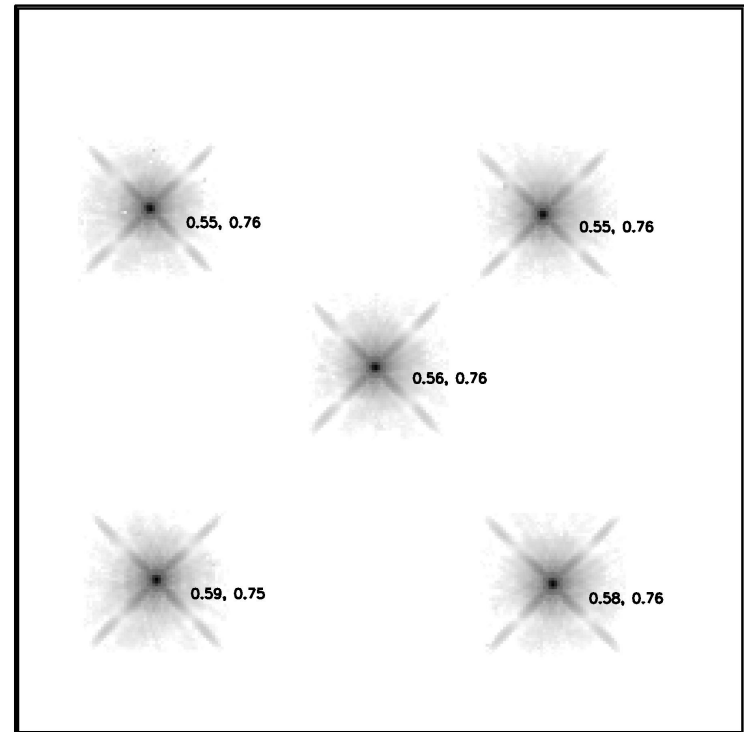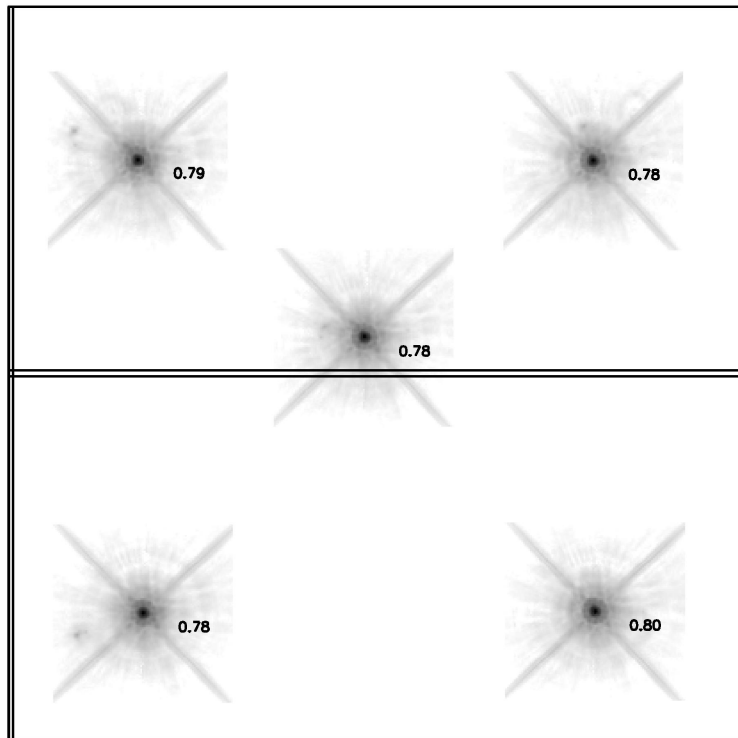
Positions of the PSF stars on the UVIS (to the left) and the IR (to the right) detectors.

WFC3 DETECTORS

CY19 Cal. Plan - Sabbi, MacKenty, & WFC3 team

1. WFC3/UVIS Anneal

Number of external orbits: 0   **Number of internal orbits**: 91

Goals: Perform regular anneals to repair hot pixels and acquire internal images to assess the procedure's effectiveness. Internal exposures are also used to generate update reference files for the calibration pipeline.

Description of the observations: Anneals are performed once a month, a cadence which optimally interleaves the WFC3 procedure with those for other instruments (one instrument per week). Internal biases, regular and charge-injected, as well as darks are taken before and after each anneal, to provide a check of bias level, read noise, global dark current, and hot pixel population. The bowtie visit provides a "fixing" image and verifies that any hysteresis has been successfully quenched after the anneal. 13 iterations will place the last Cy19 anneal in mid-Sep 2012 (the last Cy18 anneal being scheduled in mid-Sep 2011). This is a continuation of programs 11909 and 12343.

Orbits required: 91 = 13 iteration * 7 orbits (2 orbits of bias/dark before, and 2 orbits after, each anneal + 1 bowtie visit and 1 IR dark after every anneal).

2. WFC3/UVIS Bowtie Monitor

Number of external orbits: 0   **Number of internal orbits**: 130

Goals: Monitor hysteresis effect (QE offset).

Description of the observations:

- Three 3x3 binned internal calsystem flatfield (F475X)

- First flat unsaturated (initial bowtie check)

- Second flat heavily saturated (neutralizer)

- Third flat unsaturated (final check)

- Repeat every 3rd day as in Cycle 18

This is a continuation of programs 11908 and 12344

3. WFC3/UVIS CCD Daily Monitor

Number of external orbits: 0   **Number of internal orbits**: 730

Goals: Monitor the behavior of the UVIS CCDs with a daily set of bias and dark frames.

Description of the observations: We will perform 2 visits per day.

Even days (5 images/day) – 1st visit (=1 orbit): 2 biases, 1x900 sec dark
          – 2nd visit (=1 orbit): 2x900 sec darks

Odd days (4 images/day) – 1st visit (=1 orbit): 2x900 sec darks
          – 2nd visit (=1 orbit): 2x900 sec darks

Alternative plan (Number of internal orbits ~550):
    day 1, visit 1: 2 biases, 1x900 sec dark – visit 2: 2x900 sec darks
    day 2, visit 1: 2x900 sec darks   – visit 2: 2x900 sec darks
    day 3, visit 1: 2x900 sec darks
    day 4, visit 1: 2x900 sec darks   – visit 2: 2x900 sec darks

This is a continuation of programs 11905 and 12342

4. WFC3/UVIS Gain Stability

Number of external orbits: 0   **Number of internal orbits**: 13

Goals: The absolute gain of the WFC3 UVIS detector will be measured for each quadrant and compared with previous cycles to check for stability.

Description of the observations: The absolute gain of each quadrant for the nominal detector readout configuration (ABCD, gain=1.5 e$^-$/DN, bin=NONE) will be measured by taking 8 full frame pairs of internal flats fields, illuminated with the UVIS default tungsten lamp (TUNG3) through F645N, over a range of integration times to achieve exposure levels from ~500 to ~50,000 e$^-$. Full frames match the observing mode of the majority of GO programs, provide good statistics, and allow checking for gain variability across the entire detector. This is a continuation of programs 11906 and 12346. Previous measurements have been stable.

Because BIN=2 and BIN=3 have not been tested since Cycle 17, and there are over 200 instances of these modes in this cycle, we will measure the gain under these modes as well.

Data for the full frame, bin=NONE mode will be collected in 2 epochs, 6 months apart. Each epoch requires 5 internal orbits for a total of 10 internal orbits. For BIN=2 and BIN=3 mode there will be 3 orbits visit.

5. WFC3/UVIS Internal CTI Monitor (EPER measurements)

Number of external orbits: 0   **Number of internal orbits**: 24

Goals: Measure the UVIS detector Charge Transfer Inefficiency (CTI) via Extended Pixel Edge Response (EPER) method using tungsten lamp flat field exposures, and establish the CTE loss over time.

Description of the observations: We will acquire short internal flat-fields with the tungsten lamp through the filters F390M, F390W, and F438W with different illumination levels of 200, 400, 800, 1600 and 5000 e$^-$. These observations will be used to monitor UVIS CTE, by measuring the profiles into trailing over-scan region.

We will use 2 orbits every month, for a grand total of 24 orbits. This is a continuation of program 12347.

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6. WFC3/UVIS External CTE Monitor with Star Clusters

Number of external orbits: 14   **Number of internal orbits**: 0

Goals: Monitor CTE degradation as a function of epoch and source/observational parameters; calibrate photometric and astrometric corrections, provide data for Anderson's model adaptation to WFC3/UVIS.

Description of the observations: Repeat Cy 18 external CTE monitor (program 12379), continuing the observations with consistent data.

Streamlined observations, removed 2000 pxl X-dither, kept 2000 pxl Y-diher. Observe two fields of 47 Tuc and one field of NGC 6791 to cover different crowding effects. Use filters F606W and F502N to cover different backgrounds. 1 orbit x target, 3 epochs = 9 orbits.

In addition 1 orbit in CVZ to collect multiple background level sampling observation.

7. WFC3/UVIS Charge Injection

Number of external orbits: 6   **Number of internal orbits**: 50

Goals: Improve the characterization of the Cy19 CI model using the line 17, expand the parameter space for CI usage, and monitoring CTE degradation under CI.

Description of the observations: The first part of the program consist of one iteration of the standard CTE monitor but using CI. This visit should be done close in time to the CTE monitor to allow direct comparison to non-CI results. It will allow an evaluation of CI performance and in conjunction with the line 19 visit obtained in Spring 2011, an assessment of the temporal behavior of the CI. To do this we will use 1 external orbit to acquire 47 Tuc F606W/F502N Y-dithered long exposures using line 17 CI, 20 additional internal orbits will be necessary to acquire CI biases. Other 30 internal orbits will be used to acquire CI bias every ~4 months (spread over an interval of 2-4 weeks) to monitor CTE with time.

The second part of the program aims to expand STScI experience with CI, while minimizing the required number of external orbits by duplicating selected GO programs (with PI approvals) with CI. We request GO duplications up to 5 orbits.

8. WFC3/IR Persistence

Number of external orbits: 9   **Number of internal orbits**: 67*

Goals: Provide a model that can remove persistence due to previous visits to less than 0.01 e⁻/s (~1/2 the dark current rate). Quantify how the time pixels are maintained near/above full well affects persistence. Verify that persistence is not chancing with time.

Description of the observations: To quantify how the time pixels are maintained near/above full frame affect persistence we will observe ωCen 9 times, with each visit consisting of 1 or more unditherd exposures followed by a series of darks. The 9 visits will be made at 3 different positions in ωCen producing about 1000 saturated stars.

A combination of narrow, medium and broad band filters and multiple exposure will create a range of exposure histories all with about the same saturation level for stars of the same brightness. We will measure persistence as a function of exposure level and hisotry.

To measure how accurately the persistence model subtracts in real situation we will attach 2-orbit darks to "Bad Actors" in selected calibration and GO programs. Bad actors are visits after which we normally restrict use for WFC/IR for 2 orbits. We request 40 FULL orbit internal orbits through out the year.

As an alternative we can use a combination of external and internal orbits to create visits with typical dithered observing sequence, followed by FULL orbit internal darks, of one or more globular clusters.

9. WFC3/IR Dark Monitor

Number of external orbits: 0   **Number of internal orbits**: 235

Goals: Obtain IR dark calibration files necessary to support Cycle 19 observations.

Description of the observations: In order to produce the best quality and most current composite dark calibration files for Cy19 external observations, full-frame and sub-array IR dark calibration observations must be taken on a regular basis. These observations will also be used to monitor the stability of hot pixels.

This is a continuation of programs 11929 and 12349. Based on studies of the long-term trending and stability of the dark current, the above calibration goal can be accomplished with 65% orbit less than in Cy18.

Three of the internal orbits will be used to study the behavior and decay of the banding anomaly in full frame darks.

10. WFC3/IR Linearity Monitor

Number of external orbits: 6   **Number of internal orbits**: 18

Goals: Monitor the signal non-linearity of the IR channel as well as update the IR channel non-linearity calibration reference file.

Description of the observations:

Internal orbits - Each internal orbit will be used to acquire one intflat exposure up to saturation in order to provide a pixel-to-pixel map of the non-linearity of the detector. To manage persistence, each intflat is preceded and followed by a dark exposure.

External orbits - During the external orbits, low and high-signal ramps of 47 Tuc are acquired, to evaluate point source non-linearity behavior. Observation times are optimized for stars in the magnitude range V=17-22. In the low-signal ramps, stars V=17 just reach full well, while those at V=22 will have S/N~30. In the high-signal ramps, V=20 stars will be saturated, and V=22 stars will have S/N ~130. At these signal levels 47 Tuc provides many sources for the analysis of the non-linearity, from the low end at V=22, to the bright end, where some source will have signals well over full-well. This observing strategy is modeled after the non-linearity test performed on ACS (Gilliland, ACS ISR 2004-01). This program is a continuation of program 12352.

11. WFC3/IR Gain Monitor

Number of external orbits: 0   **Number of internal orbits**: 16

Goals: Measure gain in the IR channel and compare to values from previous cycles.

Description of the observations: The 16 orbits, taken within a single week about halfway through the cycle, will be used to acquire 16 internal flats for the use in computing the detector gain via the mean-variance technique. To manage persistence effects, the gain intflats are not taken back-to-back, but in their own orbits. Furthermore, each gain intflat is preceded by a dark ramp and, to ensure the internal lamp is at full output, a short low S/N narrowband exposure. The gain intflats are acquired at ~1/2 full-well to minimize non-linearity corrections. This is a continuation of programs 11930 and 12350.

This data will be used to monitor also the declining of the detector.

WFC3 PHOTOMETRY

12. WFC3 Contamination & Stability Monitor

Number of external orbits: 17   **Number of internal orbits**: 0

Goals: Periodically measure the photometric throughput of WFC3 during Cy19 in a subset of key filters in both channels. The data provide a monitor of the UVIS/IR flux stability as a function of time and wavelength as well as check for the presence of possible contaminants.

Description of the observations: The target for both channels in Cy 19 is the white dwarf spectrophotometric standard GRW+70d5824, two orbits per iteration.

The chosen cadence will be deliberately out of phase with the monthly anneal procedures in order to sample the phase space. Each iteration of the monitor will obtain sub-array observations of the standard star in a variety of filters in both UVIS and IR. The former will be done with the major UV and several visible filters, in both chips, as well as the G280 grism on chip2 for a contamination measurement. IR channel imaging will be done with the IR G102 and G141 grisms along with as many IR filters as will fit within the remaining visibility period.

Observations will be acquired every 5 weeks.

13. WFC3 Photometric Calibration & Calibration Flux Ladder

Number of external orbits: 16
Goals: .

• Increase accuracy of zeropoint measurements in key filters, monitor sensitivity trends in the UVIS and IR channels, improve characterization of photometric uncertainties at several count rates, and monitor sensitivity trends and provide high accuracy color corrections. This continues the Cycle 17 and Cycle 18 photometric programs in which we observe WD standard stars GD153, GD71, G-type P330E and M-type VB8 through the key subset of filters.

• Develop the calibration flux ladder from the brightest standard star(s) through faintest standards to improve the WFC3/IR absolute photometric calibration and cross-calibration of the observing modes now available for both grism and direct imaging, i.e. point and stare, and, spatial scanning. For the IR channel, this extends and builds upon the Cycle18 program, 12336, by observing stars fainter than 9 mag to calibrate linearity of the new modes. Program 12336 observed Vega, an absolute flux standard, as well as 5th magnitude stars with the two IR grisms in spatial scanning mode in the -1st order and the $+1^{st}$ order. Critical is wavelength and flux calibration of the -1st order, which has only been observed once, during SMOV (11522). Spatial scans are carried out at various scan rates but at constant counts per pixel

Description of the observations:

•   Direct imaging of the the 4 standard stars(UVIS and IR): 4 orbits
•   Spatial scanning of 9< V < 13 mag stars: grism and imaging (IR): 4 orbits
•   Direct imaging for V > 14 mag (IR and UVIS) : 8 orbits

At each brightness level we use two blue stars and two red(-ish) stars.

The source list consists of stars observed with STIS, ACS, NICMOS, SPITZER/IRAC, and JWST calibration standards. Brightness span the range from V ~9 mag to V=18 mag. IR and UVIS observations for the bright stars can be acquired in one orbits each, the faint stars require 2 orbits, one each for UVIS and IR observations.

Observations are paced throughout the cycle at regular intervals, roughly monthly.

Targets:
Standard suite: P330E, VB8, GD71 and GD153
A-type stars: HD165459 (A4V), 1732526 (A4V), 1740346 (A6V), 1743045 (A8II), 18032271 (A2V), 1805292 (A4V), 1812095 (A5V)
G-type stars: HD209458 (G0V), P041C (G0V), P177D, SNAP-2 (G0-5)
Other: 2M0036+18 (L3.5), 2M0559-14 (T5), KF06T2 (K1.5III),
Expected result: Minimize uncertainties due to models, drive absolute calibration to <0.5%.
Products: Synphot table updates, ETC regression suite updates, APT BOP table updates

14. Extending the Range & Precision of the Count Rate non-Linearity

Number of external orbits: 4   Number of internal orbits: 0

Goals: Determining the count rate non-linearity (CRNL) of a HgCdTe device is critical in order to extend the zeropoints measured with bright stars to the much fainter science level fluxes. We propose to observe 2 more fields of asterisms to fill in the flux range of 14<H<17, a gap between previous asterism and cluster data. We also propose to improve the precision of the cluster calibration by comparison of the CCD and near-IR data at overlapping wavelengths.

Description of the observations: We will observe 10 stars in 2 filters per orbit in 2 asterisms. The asterisms contain stars a few mag fainter than in the Cycle 18 program, yet still be well monitored in the literature to avoid known variability. The comparison between 2MASS and WFC3-IR calibrates the CRNL. For the cluster we would observe Omega Cen in a full orbit in each WFC3-UVIS F850lp and WFC3-IR F098M, bandpasses which are close enough to easily transform stellar mags. This will better measure the CRNL from 16<H<24.

15. WFC3 UVIS & IR PSF Wings

Number of external orbits: 12 (5)   **Number of internal orbits**: 0

Goals: Measure encircled energy of a PSF as a function of radius at 5 locations on each detector with an accuracy of 1% for radii r > 0.2 arcsec for UVIS and r>0.35 arcsec for IR channel. Results will be compared to SMOV and Cy17 to check for image stability.

Description of the observations: A moderately bright isolated star (GD153) will be observed at 5 locations (near the detector center and corners) in the F275W UVIS filter, and in the F098M IR filter. Deep, saturated full frame images will be obtained at each pointing to permit evaluation of the wings at radii >5 arcsec. Shorter exposures UVIS sub-array images will be obtained at each pointing with a series of increasing exposure times, to be combined with the saturated full frame images to construct very high S/N PSFs (On the IR pre-saturation reads make additional exposures unnecessary).

WFC3 GRISMS

CY19 Cal. Plan - Sabbi, MacKenty, & WFC3 team
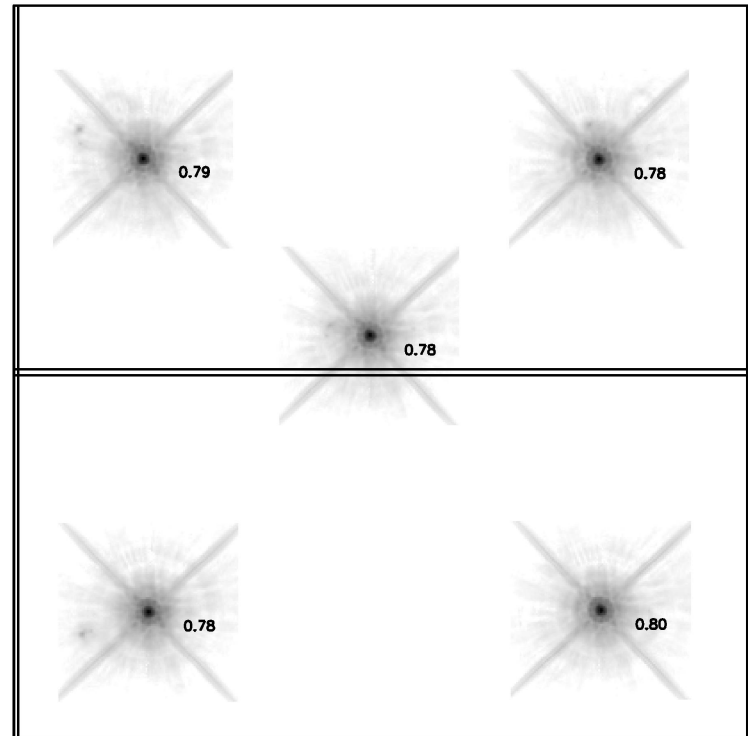
16. WFC3/IR Grisms: Flux/trace calibration and stability

Number of external orbits: 8   **Number of internal orbits**: 0

Goals: Verify and refine the flux calibration of the IR Grisms G102 and G141

Description of the observations: we will observe GD71/P330E in 16 different positions using the G102 and G141 IR Grisms. The pointings will repeat 4 previously observed positions and add 12 new positions to better sample the 2D variability wavelength dispersion relations of the 2 Grisms. This is a continuation of programs 11936, 12357, and 12358.
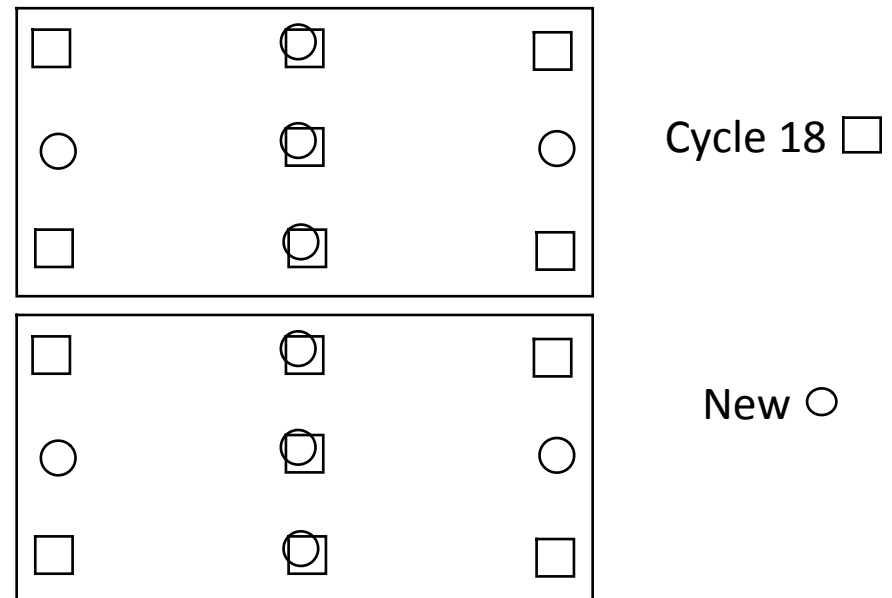

Cycle 18 ☐

New ○
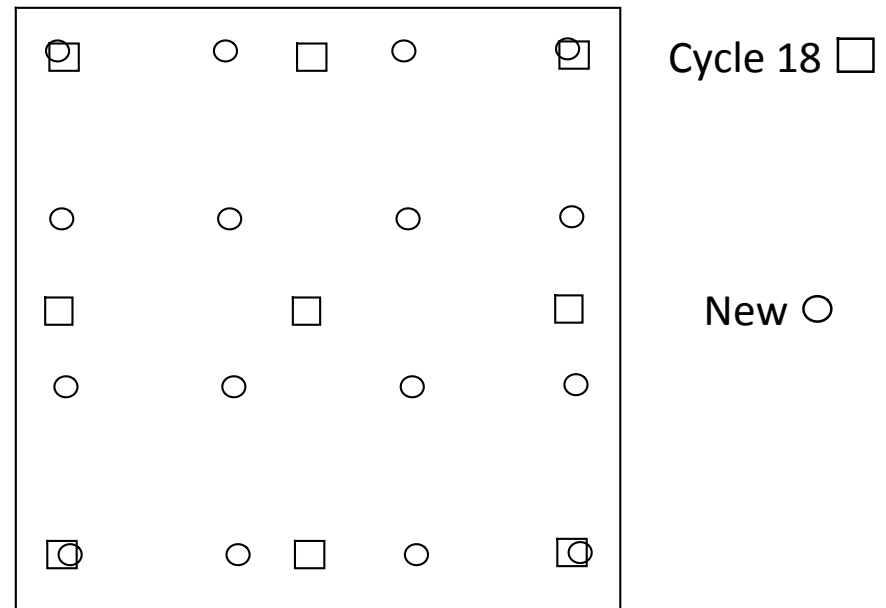
17. WFC3/IR Grisms: Wavelength & stability calibrations

Number of external orbits: 8   **Number of internal orbits**: 0

Goals: Verify and refine the wavelength calibration of the IR Grisms G102 and G141

Description of the observations: we will observe VY-22 in 16 different positions using the G102 and G141 IR Grisms. The pointings will repeat 4 previously observed positions and add 12 new positions to better sample the 2D variability wavelength dispersion relations of the 2 Grisms. This is a continuation of programs 11937, 12355 and 12356.

Cycle 18 □

New ○
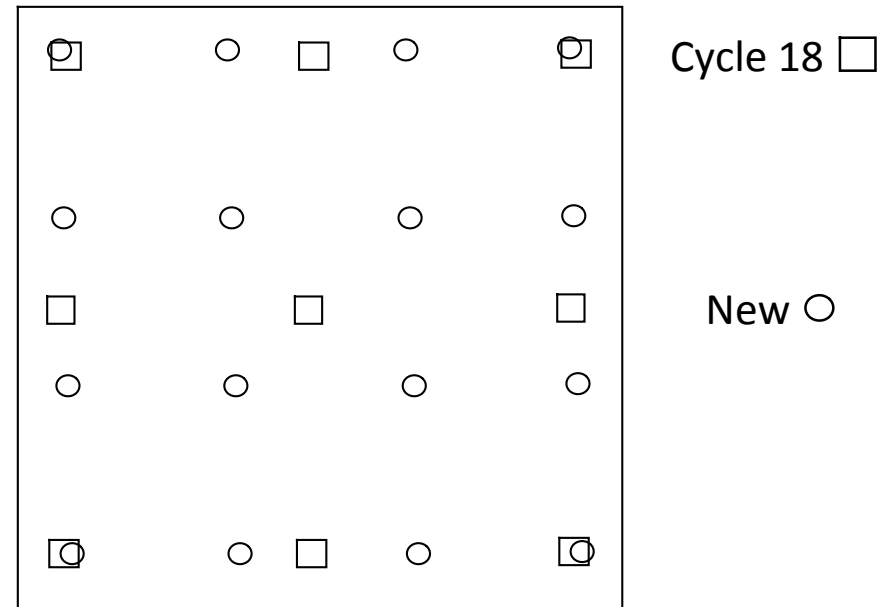
18. WFC3/UVIS Grism: Flux calibration

Number of external orbits: 3   **Number of internal orbits**: 0

Goals: Derive the flux calibration for the Grism G280 over the whole UVIS channel

Description of the observations: We will observe GD-71 in 10 different positions (5 per chip) using the G280 UVIS Grism. For each chip we will repeat 3 pointings already observed in Cycle 18. These poinitings are crucial because they show both the +1 and -1 orders. The 2 new pointings will allow us to better sample the 2D variability-wavelength dispersion relations of the Grism. The final sampling (Cycle2 18+19) will be 3x3 per CHIP.

19. WFC3/UVIS Grism: Wavelength & stability calibrations

Number of external orbits: 3   **Number of internal orbits**: 0

Goals: Verify and refine the wavelength calibration of the UVIS Grism G280

Description of the observations: We will observe WR14 in 10 different positions (5 per chip) using the G280 UVIS Grism. For each chip we will repeat 3 pointings already observed in Cycle 18. These poinitings are crucial because they show both the +1 and -1 orders. The 2 new pointings will allow us to better sample the 2D variability-wavelength dispersion relations of the Grism. The final sampling (Cycle2 18+19) will be 3x3 per CHIP. This is a continuation of program 12359.

Cycle 18 □

New ○

WFC3 FLAT FIELDS

CY19 Cal. Plan - Sabbi, MacKenty, & WFC3 team
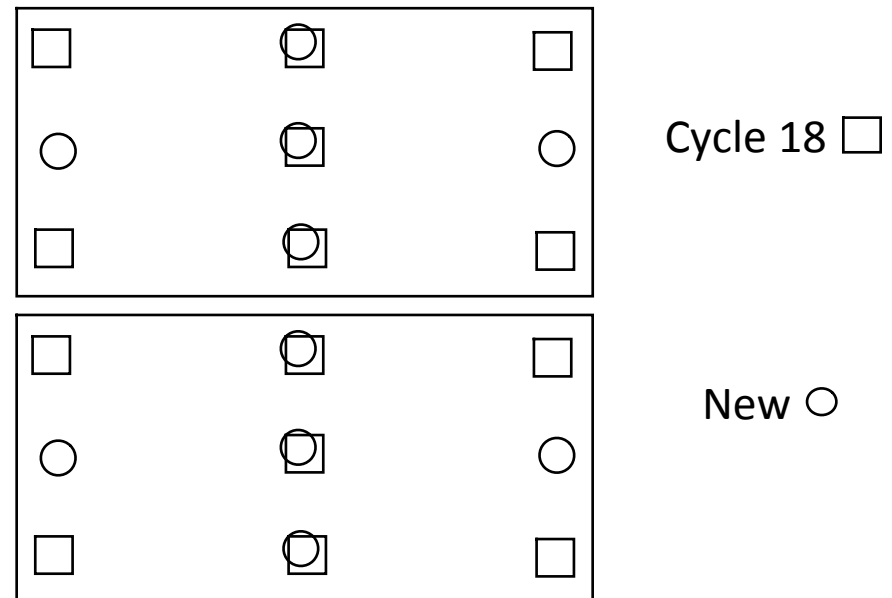
# 20. WFC3 UVIS Flare

Number of external orbits: 2   **Number of internal orbits**: 0

Goals: We will measure the relative strength of the 4 WFC3/UVIS ghost reflections with respect to the primary source as a function of wavelength.

Description of the observations: We will place a bright star in the lower left corner of amp D in a suite of filters and measure the 4 internal ghost reflections in a suite of filters to measure the wavelength dependence of the window ghosts. Full frame images are required to place all 4 ghosts on the detector, but they will be binned 3x3 to optimize observing time.

We require 10^8 e$^-$ in the primary source to give ~100 e$^-$ per pixel in the faintest ghost. To achieve this, a bright A0V star (V=8) will be observed using a short narrow band exposure plus a long broadband exposure. A two point (fine) dither will be executed at each step to reject cosmic rays. Seven narrow plus seven broadband filters will fit in a single orbit.
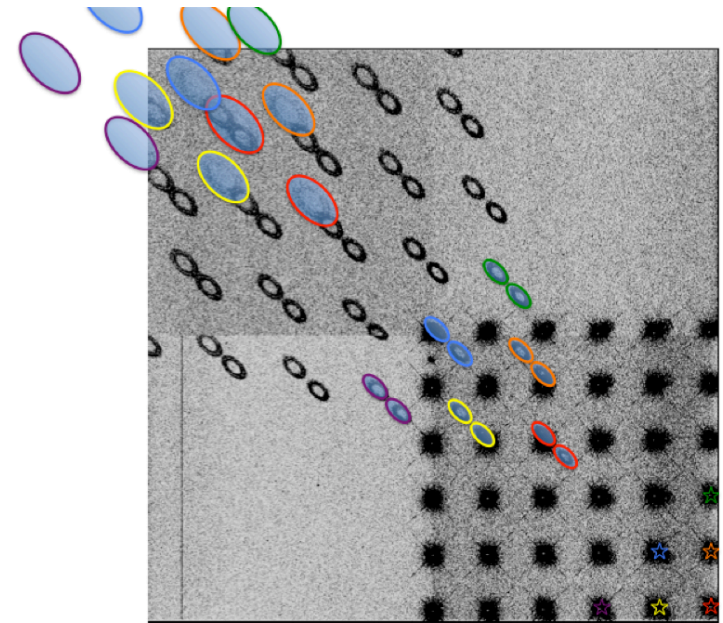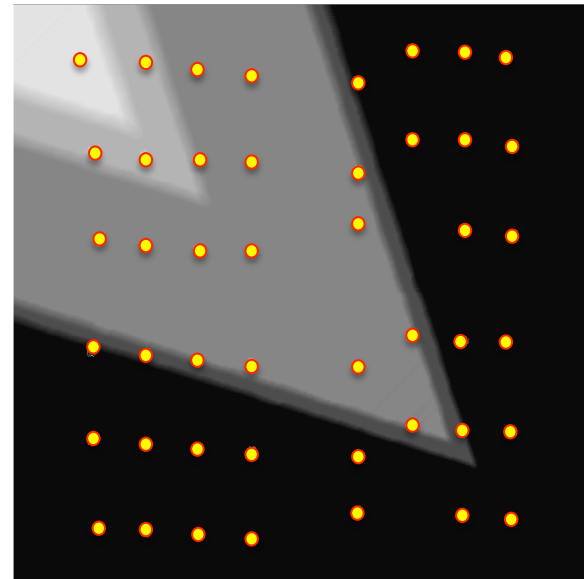
21. WFC3 UVIS Spatial Sensitivity

Number of external orbits: 10   **Number of internal orbits**: 0

Goals: We will measure the spatial stability of a standard star in a number of positions across the detector to verify the inflight corrections to the ground flats.

Description of the observations: Inflight corrections to the UVIS ground flats have proved more complex than expected, with a several large internal window reflections in the ground flats and strong spatial variations in the PSF over the detector. To to validate the accuracy of the latest flats, derived from aperture photometry of dithered stellar observations, we will move the spectrophotometric standard G191-B2B over 50 positions across the detector in 4 the broadband filters F275W, F438W, F606W, & F814W. A two point (fine) dither is executed at each position to reject cosmic rays. We will step across each of the 4 flares, across the region in amp D where the chip is 3.5 microns thinner and carefully sample the upper left corner which moves strongly in and out of focus with telescope breathing.

22. WFC3 IR Spatial Sensitivity

Number of external orbits: 4   **Number of internal orbits**: 0

Goals: We will measure the spatial stability of a standard star in a number of positions across the detector to verify the inflight corrections to the ground flats.

Description of the observations: As for the UVIS channel we will validate the accuracy of the latest flats and the stability of our flux calibration by moving the spectrophotometric standard WD 1057+719 (V=14.68 mag) across the array. In one orbit we can observe the WD 1057+719 in 3 broadband filters (F098M, F125W & F160W) in 8 different positions, for a total of 32 different positions.

23. WFC3 UVIS & IR Moonlit Flats

Number of external orbits: 0   **Number of internal orbits**: 50

Goals: Flat fields will be obtained by observing the dark side of the Earth during periods of full moon illumination.

Description of the observations: Earth flats provide a diffuse source that can be used to define on-orbit flat field corrections to the WFC3 flats. When using the sunlit Earth the wide band filters saturate at even the shortest possible exposure times and cannot be used to generate flat fields directly. Pathfinder programs 11914 and 11917 have shown the usefulness of taking moonlit earth flats and the addition of the DARK-EARTH calibration target in APT has increased the scheduling of exposures (see timeline) making the earth flats program suitable for Cycle 19. In 2 orbits (1500-s total exp time for these), we get 1E4 e/pix in F606W. Bill Januszewski. has scheduled ~4 orbits/month for dark Earth Flats and estimates that's nearly the maximum attainable (i.e. ~48/year).

The observations will consist of full-frame streaked WFC3 UVIS imagery. UVIS filters: F469N, F606W, F656N, F814W, FQ906N + F336W. IR filters: F105W, F110W, F125W, F140W, F153M, F160W, F164N, F167N.

F606W   F814W
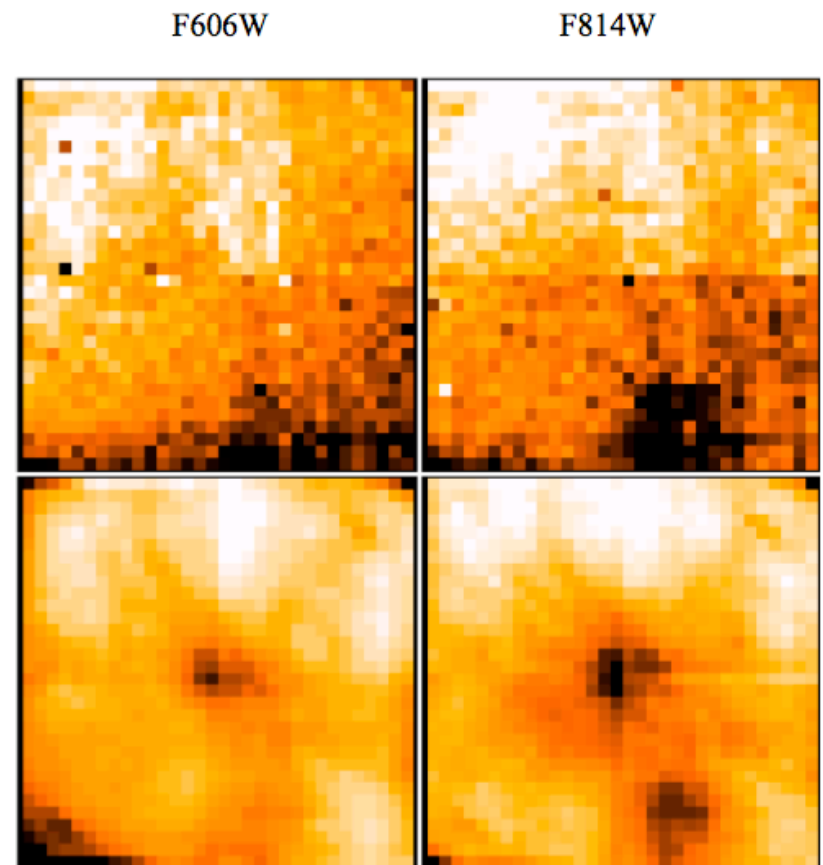
24. WFC3 UVIS Bright Earth Flats

Number of external orbits: 0   **Number of internal orbits**: 20

Goals: We will obtain sky flats in the UV using the bright Earth to fully illuminate the detector. These will allow validation of the L-flat solutions obtained from dithered stellar observations and verification that the wavelength interpolation of these solutions is accurate for filters which were not directly observed.

Description of the observations: Below ~4000Å the Earth is a uniform source of diffuse light due to the high optical depth above the cloud layer. For ACS, the HRC F344N and F330W pipeline flats were derived entirely from Earth flats (Bohlin & Mack, ISRs 2003-02 & 2005-12). For WFC3 UVIS, red leaks below ~F275W will be contaminated by out of-band light. Thus we propose to observe with the UV filters F275W, F280N, F336W, F343N, F373N, F390M.

Bright Earth flats are much easier to schedule than moonlit flats. The ACS programs were easily scheduled if kept to ~20 min. With 2 exposures each, all 6 filters will fit within a single orbit. The success rate is ~50% for ACS/HRC/F330W, so we propose 20 orbits to ensure several images with adequate illumination are obtained in each filter.

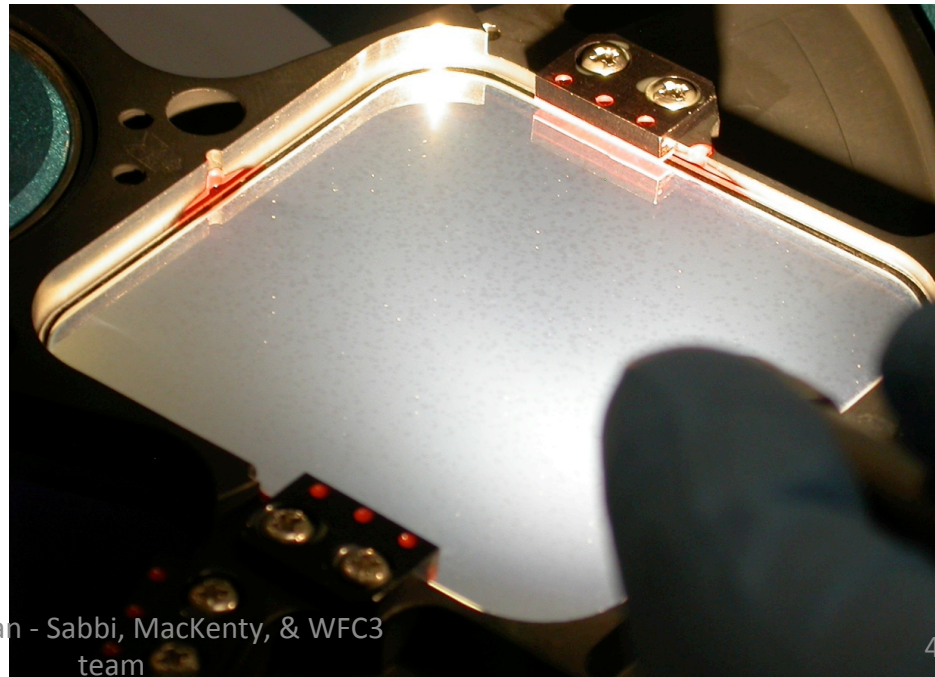# 25. WFC3 UVIS Internal Flats

Number of external orbits: 0   **Number of internal orbits**: 20

Goals: Monitor the stability of the UVIS filters.

Description of the observations: Observe internals in all the UVIS filters once early in the Cycle. We will use 3 orbits with D2 lamp for the filters F218W, F200LP, F225W, F275W, F280N, F300X, F336W, F343N, F373N, F390M, F390W, F395N, FQ232N, FQ243N, FQ378N, AND FQ387N, and 8 orbits with the Tungsten lamp to acquire the remaining 46 filters.

Observations in the 4 filters F390W, F438W, F606W, and F814W with the tungsten lamp will be repeated 6 times over the cycle for a total of 6 orbits. Late in the cycle we will repeat the 3 orbits with the D2 lamp.

Image of the WFPC2 F343N filter, acquired during the post-SM4 laboratory inspection. P.L. Lim et al. 2010, WFPC2-ISR 2010-05. (Courtesy of J. Birretta)

26. WFC3 IR Internal Flats

Number of external orbits: 0   **Number of internal orbits**:33

Goals: Monitor the stability of the IR pixel-to-pixel sensitivity.

Description of the observations:
Observe internals in all the IR filters once in the middle of Cycle (18 orbits for the Tungsten lamp).

Observations in the 5 filters F105W, F110W, F125W, F140W and F160W with the tungsten lamp will be repeated 5 times over the cycle for a total of 15 orbits.

Both internal and external observations indicate that IR flatfields are stable to the ≤1% level.
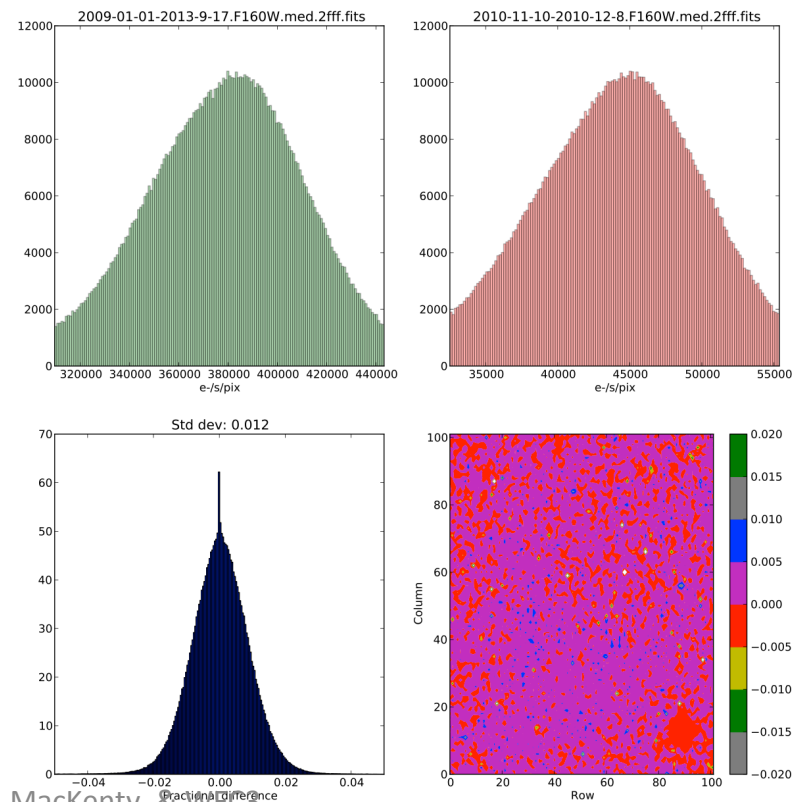
# 27. Spatial Scanned L-flat Validation Pathfinder

Number of external orbits: 8   Number of internal orbits: 0

Goals: Using spatial scans of a bright star or double star, validate L-flats generated by the standard method of observing star clusters.

Description of the observations: We will observe a bright double star, e.g. HD 80606 (V=9 each, separation = 20 arcsec) with the boustrophedonically scanned HST* in filters for which traditional L-flats using star clusters exist. We allocate six orbits for UVIS and two for IR. The advantage of a double star compared to a single star, is that the differential photometry of the one star w.r.t. the other star is independent of variations about the nominal scan rate. To take advantage of that, we plan to observe the double star first scanning fast in X with large steps in Y, then 90-degrees to that, and then combining all the differential magnitudes, binned on a regular 8x8 array, and then we will convert those from slopes to a surface much like one converts from a Hartmann wavefront sensor's slopes to a wavefront. Filters: F225W, F350LP, F475W, F656N, F606W, F850LP, F953N, F125W, F160W.

Boustrophedonically scanned HST means shaped like the ox plows, or in modern experience, like the coils on the back of a refrigerator. Each round-trip "lap" will take 1 min, and we want 8 laps per exposure, and two exp/filter, so we should be able to complete two filters per orbit.
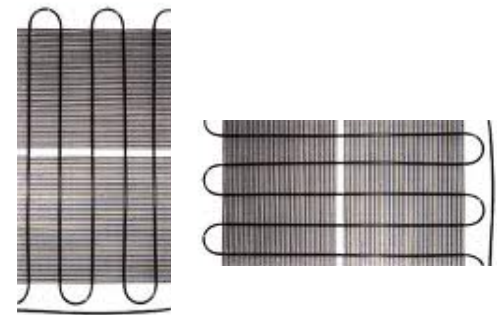
28. WFC3 UVIS and IR Channels Geometric Distortion Stability

Number of external orbits: 2   **Number of internal orbits**: 0

Goals: Establish the time dependency of UVIS and IR skews. Monitor the optical & mechanical stability of the UVIS detector and IR array. Continue the multi-cycle study of the geometric distortion time-dependency.

Description of the observations: The globular cluster ωCen will be observed in the F606W (UVIS) and F160W (IR) filters at different roll angles this winter. For both the UVIS and IR channel three exposures will be acquired in a sequence of off-nominal roll-angles with steps of +15, 0, and -15 degrees.

So far there is no evidence for a secular change in the UVIS nor IR scale over 2 years of observations.