WFC3 Cycle 22 Calibration Plan

E. Sabbi, J. MacKenty & WFC3 Team

9/9/2014

WFC3 Usage

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 continue to be very popular.

Percentage of Exposures for WFC3 Channels in the Past Cycles

	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%
Cycle 22	40%	60%	85%	15%

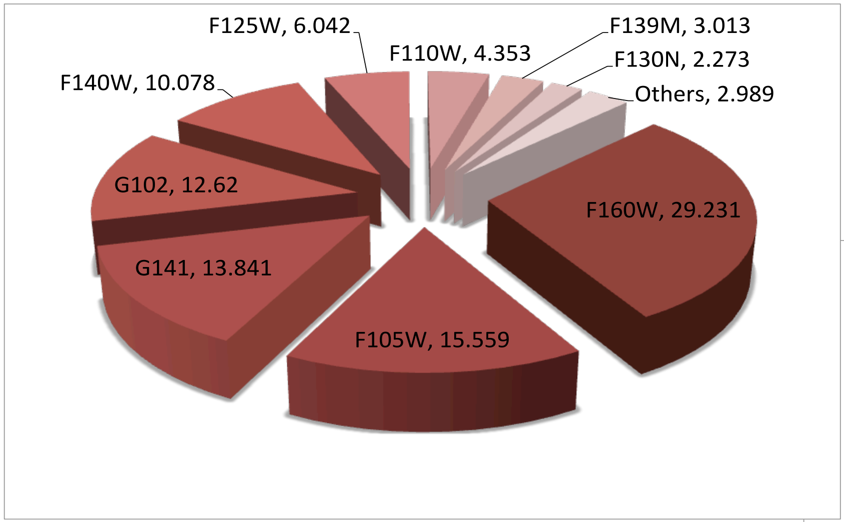
WFC3 Usage with time

HST Cycle	GO Programs* % of HST orbits	Calibration** # External orbits	Calibration** # Internal orbits
CY17	46%	256	>2000
CY18	42%	134	1719
CY19	49%	125	1497
CY20	56%	83	1833
CY21	54%	98	1907
CY22	48%	114	1620

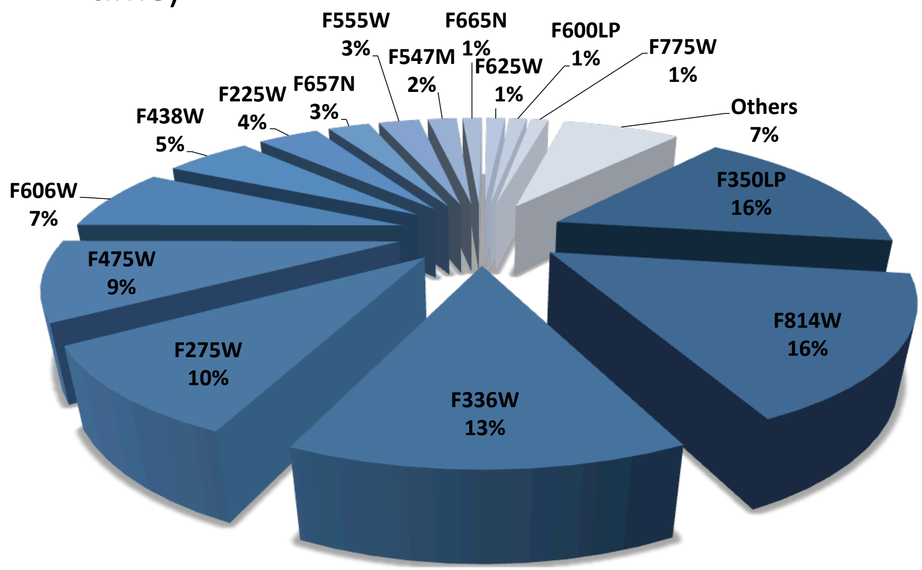
*MCT, SNAPs and Frontier Fields are not included
**Delta Calibration Programs are not included

Filter Usage

IR – Percentage of Time



- 40% of the IR exposures use GRISMS (=26% of IR time)
- **For the first time all the 15 IR filters are used in one cycle**
- 26% of the exposures uses spatial scan (=4% of IR time)

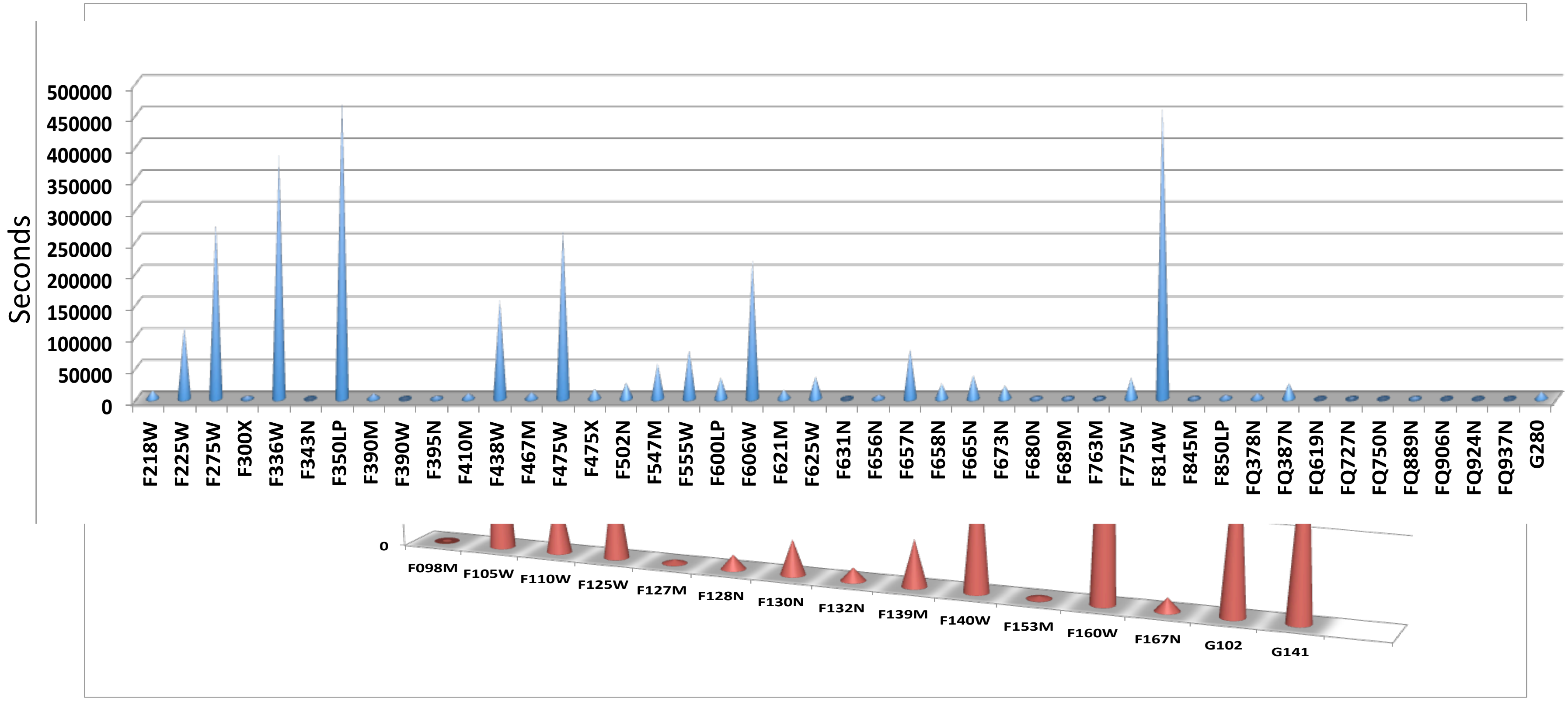


UVIS – Percentage of Time

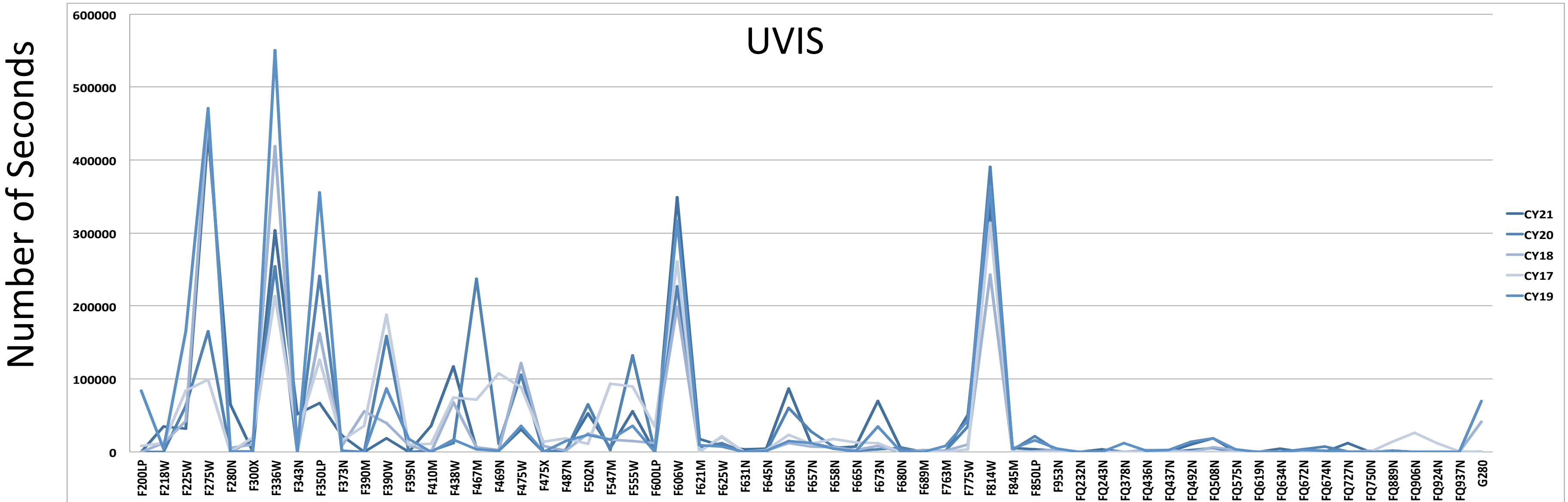
- 30% of UVIS time is used to observe in the near UV
- 67% of UVIS observations use post-flash
- 45 out of the 62 UVIS filters are used in CY22
- 2.4% of UVIS time is for spatial scan
- 0.4% of UVIS time is with G280 (10840 sec)

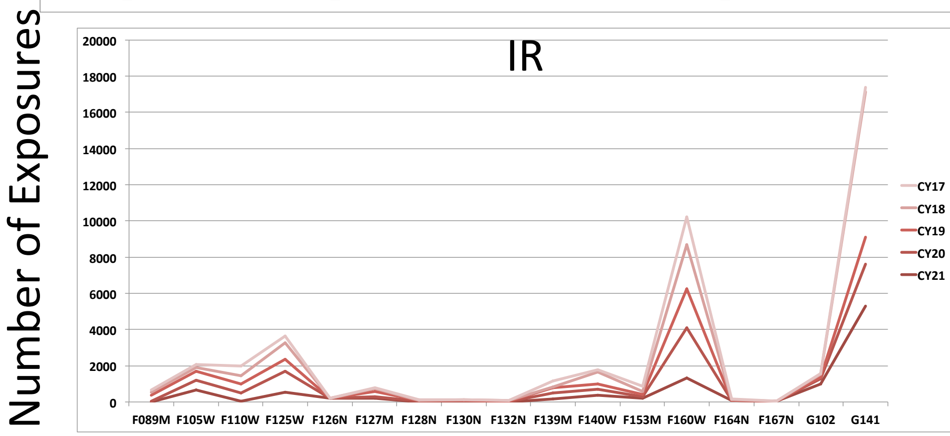
Filter Usage in Cycle 22

(Only used filters are shown)



Filter Usage Cycles 17-21





Over the past 5 Cycles, GOs asked for all but two WFC3 filters.

CY21 Approved Program

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
				CSM monitor with earth flats*	0	400

CY21 Total external orbits=98; Total internal orbits=1907,
Supplements=1 external; 100 internal orbits; 10 external orbits have been already charged to CY22

CY22 Proposed Program

Program Title	Ext. Orbits	Int. Orbits		Program Title	Ext. Orbits	Int. Orbits
UVIS anneal	0	85		WFC3/UVIS contamination monitor	18	0
UVIS bowtie monitor	0	130		UVIS Shutter Characterization	3	1
UVIS CCD daily monitor	0	637		Photometric repeatability of scanned direct imaging	4	0
UVIS CCD un-flashed monitor	0	140		WFC3 UVIS & IR photometry**	21	0
UVIS post-flash monitor	0	48		WFC3 IR observations of red CALSPEC stars**	3	0
UVIS CCD gain stability	0	18		WFC3 IR grisms wavelength calibration stability and calibration	4	0
IR dark monitor	0	95		WFC3 IR grisms flux/trace calibration stability and calibration	4	0
IR linearity monitor	0	9		WFC3 UVIS grism wavelength calibration stability and calibration	2	0
IR gain monitor	0	16		WFC3 UVIS grism flux calibration**	2	0
UVIS CTI monitor (EPER)	0	12		UVIS Pixel-to-Pixel QE Variations via Internal Flats Monitor	0	51
UVIS CTE monitor (star cluster)	6	0		UVIS internal flats	0	13
WFC3/UVIS CTE in subarrays	0	42		IR internal flats	0	18
Characterization of UVIS traps with CI**	0	36		CSM monitor with earth flats	0	200
Refining the persist. model in the IR detector	12	12		Astrometric Validation of WFC3/UVIS filters	18	0
Short term persistence	3	3		High precision calibration of WFC3/UVIS geometric distortion (CAL-13929)	10	0
Persist. after worst actors**	0	50				
Persist. after non-scanned grism obs.**	3	4				

CY22 Total external orbits=113; Total internal orbits=1620

UVIS Detectors

To monitor the health of the UVIS channel we ask for 1058 internal orbits divided as follow:

1. 85 internal orbits (the cadence has been synchronized with the other HST instruments) to perform an anneal every month – Same as last cycle
2. 130 internal orbits to mitigate the hysteresis (bowtie) effect via a series of unsaturated and saturated int-flats. – Reduced from last cycle
3. 637 internals to perform a daily monitoring of the CCDs behavior using a series of dark and biases. - Provide updated darks and hot pixel maps - Same as last cycle
4. 140 internals to assess how well post-flash is mitigating CTE with time using a series of unflashed darks - Same as last cycle
5. 48 internal orbits to monitor the stability of the post-flash LED with time. - Reduced from last cycle
6. 18 internal orbits 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. -- Same as last cycle

WFC3/UVIS Anneal

Same as CY21

Number of external orbits: 0

Number of internal orbits: 85

<u>Goals</u>: Perform regular anneal procedures in order to repair hot pixels and acquire internal images to assess the procedure's effectiveness. The internal exposures are also used to produce reference files for the calibration pipeline.

<u>Description of the Observations</u>: Anneals are performed every 28 days, a cadence which optimally interleaves the WFC3 procedure with those from other instruments, one instrument per week. Internal biases as well as darks are taken before and after each procedure to provide a check of bias level, read noise, global dark current, and hot pixel population. A bowtie visit is acquired immediately after each anneal to provide a hysteresis-neutralizing image as well as verify that any hysteresis present has been successfully quenched. During Cycle 21, the WFC3 anneals have been performed keeping the IR detector cold (IRTEMP=COLD). In Cycle 22, one iteration may be executed according to the original anneal procedure commanding which includes a partial warming of the IR detector; in that event, one post-anneal IR dark will be needed.

Orbits required: 85 total = 14 * 6 + 1
-- 14 iterations provide seamless continuation of the cadence across cycle boundaries.
-- 6 orbits are needed per iteration (2 orbits bias/dark before and 2 orbits bias/dark after each anneal, 1 orbit for the anneal itself, 1 orbit for the post-anneal bowtie visit)
-- 1 orbit for one IR dark to be taken after one iteration using the original anneal procedure which partially warms the IR detector.

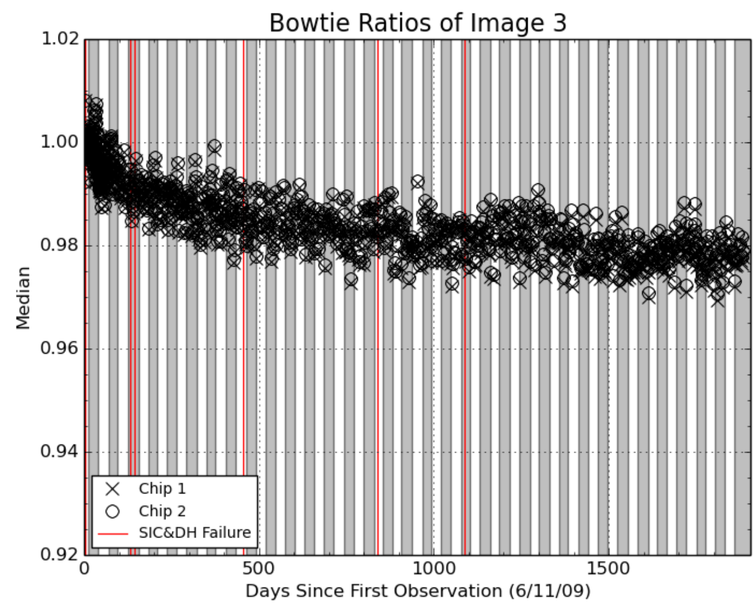
<u>Is this the continuation of previously approved program?</u> Yes -13554

WFC3/UVIS Bowtie Monitor

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

<u>Goals</u>: Monitor and neutralize hysteresis in the WFC3/UVIS detector

<u>Description of the Observations</u>: Each bowtie observation consists of a single continuous visit containing three internal flatfield exposures: (1) an unsaturated image as a check for the presence of hysteresis, (2) a saturated 'QE pinning' exposure used to neutralize QE offsets, and (3) an additional unsaturated image to provide an estimate of the QE offset removal efficiency. All images are 3X3 binned so as to minimize data volume and overhead; each visit requires ~360 seconds of telescope time. <u>The bowtie orbits are to occur every three days. Eight contingency orbits are included.</u>



(Figure, right) Median levels of the ratio between the third bowtie image and a reference bowtie image for all on-orbit bowtie visits. Each gray/white border represents a UVIS anneal. No significant outliers are seen, and thus the QE pinning exposure has always been successful at neutralizing hysteresis.

<u>Is this the continuation of previously approved program?</u> Yes - 13555

WFC3/UVIS CCD Daily Monitor

Number of external orbits: 0 **Number of internal orbits: 637**

Goals: Monitor the behavior of the UVIS CCDs with a daily set of bias and/or dark frames. These data will be used to generate bias and dark reference files for CRDS, which are used to calibrate all WFC3/UVIS images.

Description of the Observations: The internals are acquired using a pattern of single-orbit visits repeated every 4 days (see below). All darks are 900 seconds in duration and all exposures will be post-flashed. A small number of un-flashed internals are requested in a separate proposal.

Day 1 – 2 visits; one with 2 biases + 1 dark, one with 2 darks
Day 2 – 2 visits, each with 2 darks
Day 3 – 1 visit with 2 darks
Day 4 – 2 visits, each with 2 darks

Same as CY21

All non-Day-1-Visit-1 darks use "no-move" darks (i.e. DARK-NM) in which the CSM is not moved to the IR position and a narrow-band filter configuration is employed to reduce any scattered light. Since Day-1-Visit-1 Visits start with biases, and thus the CSM is in the IR position, these darks do not have to be "no-move" nor does a narrow filter have to be employed. Several different filters are used in order to distribute usage across multiple wheels thereby avoiding overuse of any particular wheel.

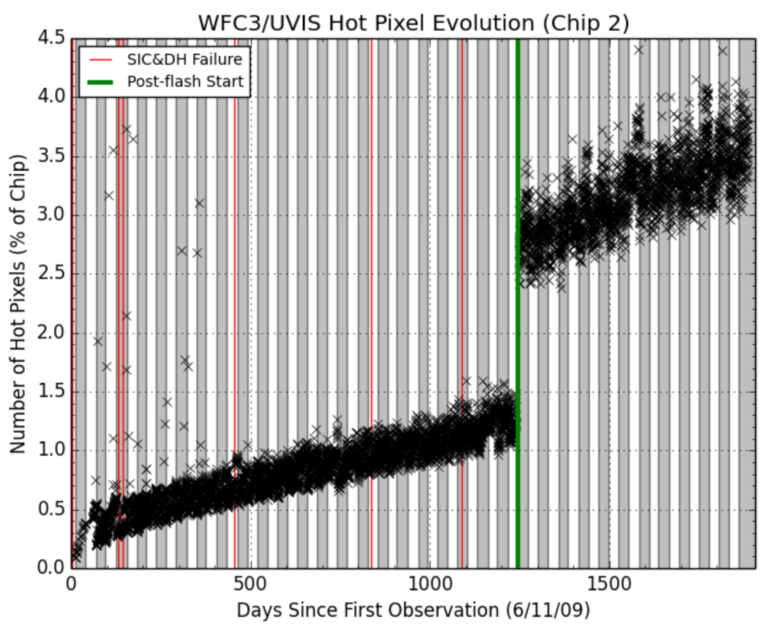
Orbits needed: 637 = 91 * 7 (= 91 iterations of the 4-day pattern)

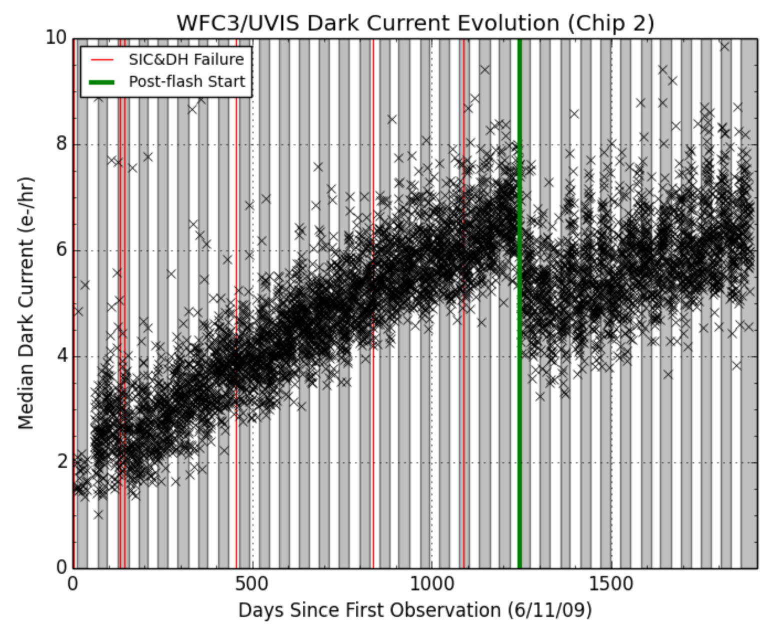
Three to four separate proposal numbers to cover this single program would facilitate APT processing.

Is this the continuation of previously approved program? Yes – 13556, 13557, 13558

WFC3/UVIS CCD Daily Monitor – cont.

<u>Goals</u>: Monitor the behavior of the UVIS CCDs with a daily set of bias and/or dark frames. These data will be used to generate bias and dark reference files for CRDS, which are used to calibrate all WFC3/UVIS images.





The hot pixel evolution (left) and the median dark current evolution (right) of WFC3/UVIS since the installation of WFC3 on HST. Each gray/white region represents anneal cycles. Note that the implementation of post-flash occurred on day 1246.

WFC3/UVIS Un-flashed dark monitor

Number of external orbits: 0 **Number of internal orbits: 140**

Goals: Monitor temporal changes in CTE losses and the efficacy of the post-flash mode in full-frame data.

Description of the Observations: The set of internals taken as part of the daily monitor are all post-flashed. However, a number of un-flashed internals are required to monitor the changes in CTE losses over time. The un-flashed internals, in conjunction with the post-flashed internals, will allow for an assessment of how well the post-flash is mitigating those losses. Ten full-frame four-amp un-flashed 900 sec darks are taken every month. To facilitate scheduling, visits contain 1 dark only (~1400 sec total time, including readout and buffer dump). The darks are grouped around the anneal iterations: 5 darks the week before and 5 darks the week after each procedure.

Orbits required: 140 (= 10 darks x 14 anneal iterations)

Same as CY21

Is this the continuation of previously approved program? Yes -13559

WFC3/UVIS Post-flash LED Monitor

Number of external orbits: 0 **Number of internal orbits: 48**

<u>Goals</u>: The flux and illumination pattern of the post-flash LED are monitored over time. The data are also used to generate post-flash reference files for the calibration pipeline.

<u>Description of the Observations</u>: Most observers with low-background (<12 e-) data are now making use of the post-flash (PF) mode in WFC3/UVIS. In this cycle, we propose monthly monitoring of the lamp characteristics plus sufficient orbits to allow a new generation of post-flash CRDS reference files to be created.

Each iteration of the monitor needs 3 orbits: two are used to obtain pairs of high S/N flashed full-frames for both shutter blades (pattern check) and one orbit for 1Kx1K subarrays taken at a variety of post-flash levels (brightness check). For new reference files, 12 orbits are needed.
Orbits needed: 48= 12x3 (pattern+ brightness check)+12(new reference)

<u>Is this the continuation of previously approved program?</u> 13078 and 13560

UVIS Gain Stability

Number of external orbits: 0

Number of internal orbits: 18

Goals: Monitor the absolute gain for the nominal detector readout.

Description of the Observations: Observations consist of 8 pairs of full-frame binned (BIN=2 and BIN=3) and unbinned internal calibration subsystem flat fields at nominal gain. Images are taken with a variety of exposure times to provide a mean-variance measurement of the gain. Two epochs, 9 orbits each, are requested, to be taken ~6 months apart. Six of these orbits will be for sampling the unbinned mode, an orbit more than previous cycles, so that we may increase the sampling at lower signal levels.

Is this the continuation of previously approved program?

11906, 12346, 12690, 13168, and 13561

Same as CY21

IR Detector

To monitor the health of the IR channel we ask for 120 internal:

1. 95 internal orbits to obtain IR dark calibration files. The number of orbits is dictated by the observing modes requested by GOs. - Same as last cycle
2. 9 internal orbits (saturated internal flats) to monitor the IR non-linearity and update the calibration reference file. - Reduced from last cycle
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. - Same as last cycle

IR Dark Monitor

Same as CY21

Number of external orbits: 0 **Number of internal orbits: 95**

Goals

- Obtain IR dark calibration observations necessary to support all observing modes used in approved Cycle 22 programs.
- Obtain IR dark observations necessary to continue regular monitoring of dark current, zeroth read level, and bad pixels (hot, unstable, or dead).

Description of the Observations Assuming that the dark current continues to remain essentially unchanged (Hilbert & Petro, WFC3 ISR 2012-11), and that the popularity of specific observing modes used in approved Cycle 22 programs is generally similar to that of the previous cycle (see Figure 1), we believe that we can accomplish the above proposal objectives using approximately the same number of orbits as last cycle's IR dark monitor program (13562). We will plan our observations accordingly as soon as information about the observing modes used by approved Cycle 22 programs is made available.

Overall, the program will be very similar in structure to previous IR dark monitor programs. The bulk of the orbits will be used to collect dark calibration observations that will be used to produce composite IR dark calibration files for use by the MAST pipeline. These observations will be collected for each observing mode at a cadence directly related to the popularity of each observing mode in approved Cycle 22 programs.
In addition, a fraction of the orbits will be used for regular collection of SPARS200/full-frame dark observations. These observations will be used to monitor trends in the dark current, zeroth read level, and bad pixels (hot, unstable, or dead).

Is this the continuation of a previously approved program? Yes. Previous IR Dark Monitors: 13562 (Cy 21), 13077 (Cy 20), 12695 (Cy 19), 12349 (Cy 18) and 11929 (Cy 17).

IR Dark Monitor –cont.

WFC3/IR Science Observations (Prime, Parallel, SNAP) Breakdown by Observing Mode

Number of Observations					
	Cycle 17	Cycle 18	Cycle 19	Cycle 20	Cycle 21
RAPID/FF	3	0	2	2	188
SPARS10/FF	40	6	110	4	2
SPARS25/FF	148	349	208	657	113
SPARS50/FF	381	1133	751	645	483
SPARS100/FF	822	2360	1509	932	1407
SPARS200/FF	87	20	3	1	0
STEP25/FF	72	0	1	23	14
STEP50/FF	419	49	490	497	51
STEP100/FF	144	246	233	230	85
STEP200/FF	150	984	903	236	371
STEP400/FF	184	9	0	0	0
RAPID/512	0	86	10	31	119
SPARS25/512	6	85	3	300	15
SPARS100/512	4	0	0	0	0
SPARS200/512	2	0	0	0	0
STEP25/512	80	34	191	261	2
RAPID/256	26	13	101	62	245
SPARS10/256	0	28	75	73	3302
SPARS25/256	4	23	68	20	22
SPARS100/256	4	0	0	0	0
SPARS200/256	8	0	0	0	0
RAPID/128	0	0	0	16	198
SPARS10/128	0	19	22	0	0
RAPID/64	0	0	0	0	442
TOTALS	2584	5444	4680	3990	7059

Percentages					
	Cycle 17	Cycle 18	Cycle 19	Cycle 20	Cycle 21
RAPID/FF	0.12	0.00	0.04	0.05	2.66
SPARS10/FF	1.55	0.11	2.35	0.10	0.03
SPARS25/FF	5.73	6.41	4.44	16.47	1.60
SPARS50/FF	14.74	20.81	16.05	16.17	6.84
SPARS100/FF	31.81	43.35	32.24	23.36	19.93
SPARS200/FF	3.37	0.37	0.06	0.03	0.00
STEP25/FF	2.79	0.00	0.02	0.58	0.20
STEP50/FF	16.22	0.90	10.47	12.46	0.72
STEP100/FF	5.57	4.52	4.98	5.76	1.20
STEP200/FF	5.80	18.07	19.29	5.91	5.26
STEP400/FF	7.12	0.17	0.00	0.00	0.00
RAPID/512	0.00	1.58	0.21	0.78	1.69
SPARS25/512	0.23	1.56	0.06	7.52	0.21
SPARS100/512	0.15	0.00	0.00	0.00	0.00
SPARS200/512	0.08	0.00	0.00	0.00	0.00
STEP25/512	3.10	0.62	4.08	6.54	0.03
RAPID/256	1.01	0.24	2.16	1.55	3.47
SPARS10/256	0.00	0.51	1.60	1.83	46.78
SPARS25/256	0.15	0.42	1.45	0.50	0.31
SPARS100/256	0.15	0.00	0.00	0.00	0.00
SPARS200/256	0.31	0.00	0.00	0.00	0.00
RAPID/128	0.00	0.00	0.00	0.40	2.80
SPARS10/128	0.00	0.35	0.47	0.00	0.00
RAPID/64	0.00	0.00	0.00	0.00	6.26

WFC3/IR Linearity Monitor

Number of external orbits: 0 **Number of internal orbits: 9**

Goals: Monitor the signal non-linearity of the IR channel and, when necessary, update the IR channel non-linearity calibration reference file.

Description of the Observations: Each internal orbit will be used to acquire one intflat exposure up to saturation level in order to provide a pixel-to-pixel map of the non-linearity of the detector. Minimizing persistence is critical for this program in order to avoid erroneous linearity results. In past cycles, persistence effects were mitigated by preceding and following each intflat with a dark current exposure. However, each transition intflat->dark and dark->intflat results in a CSM move. To reduce the number of CSM moves, and yet still protect the intflats from persistence in this cycle each visit will start with the acquisition of a dark frame and will be designated as 'worst actor'. Compared to the previous cycles this will allow us to save 9 CSM moves.

In previous Cycles we were acquiring 3 external orbits to validate the linearity measurements from 47 Tuc observations. This Cycle we will use archival data from GOs or other calibration programs, if needed.

Is this the continuation of previously approved program?

13563

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 will be used to acquire 16 internal flats for 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 a short low S/N narrowband exposure, to ensure the internal lamp is at full output. The gain intflats are acquired at ~1/2 full-well to minimize non-linearity corrections. Each dark current exposure will be collected following the rule specifying that the CSM remain in the orientation used for the preceding exposure. This will help to limit the total number of CSM moves related to this proposal.

Same as CY21

Is this the continuation of previously approved program?

13564

CTE Characterization and Calibration

This part of the calibration program requires 6 external and 90 internal orbits.
As in Cycle 20 and 21, GOs can mitigate CTI effects using post-flash. To support these efforts we ask:

1. 12 internal orbits. They will be used for a every other month measurement of the CTE via Extended Pixel Edge Response (EPER).- Same as last cycle
2. 6 external orbits. They 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. - Same as last cycle
3. 42 internal orbits of biases, short and long darks will be used to calibrate postflashed subarray observations. – New Program!
4. 36 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. – Reduced from last cycle

WFC3/UVIS CTI Monitor (EPER)

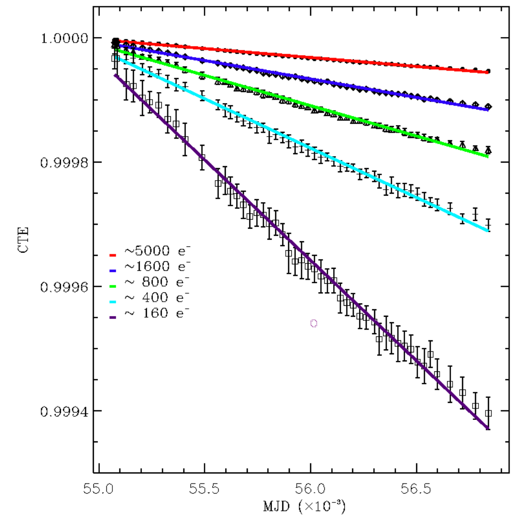
Number of external orbits: 0 **Number of internal orbits: 12**

<u>Goals</u>:

(1) Measure the WFC3/UVIS CCD Charge Transfer Inefficiency (CTI) using the Extended Pixel Edge Response (EPER) method.

(2) Assess the CTE losses over time in a continuation of the multi-cycle CTE monitor program

<u>Description of the Observations</u>: 12 internal orbits, grouped in pairs of visits, are used to assess the profiles of excess charge in the extended pixel region of the special EPER readout format and monitor the CTI of WFC3/UVIS. Each visit-pair obtains internal lamp flatfields at a variety of illumination levels as well as two short dark exposures to be used as a bias measurement. A visit-pair is taken approximately every 8 weeks over the span of a year.



CTE as a function of time for a range of signal levels spanning August 2009 through July 2014. CTE continues to decline linearly and decreases most rapidly for the lowest signal level of 160 e-. There appears to be a leveling off of CTE losses in recent data; this is still to be investigated.

<u>Is this the continuation of previously approved program?</u> Yes - 13565

Same as CY21

UVIS External CTE Monitor: Star Clusters

Number of external orbits: 6 **Number of internal orbits: 0**

<u>Goals</u>: Monitor CTE degradation as a function of epoch and source/observation parameters. Calibrate photometric corrections. Provide data to test and monitor the Anderson pixel-based CTE correction model for WFC3/UVIS.

<u>Description of the Observations</u>: The six orbits will be a smooth continuation of the previous external CTE monitoring programs. We continue, as begun in Cycle 20, using post-flash to sample background levels and monitor the efficacy of the post-flash model for CTE mitigation.
Exposures of NGC 6791 and NGC 104 (47 Tuc) in F502N (zero background) will monitor the maximum CTE in different field densities, and long exposures, dithered by 2000 pixels in detector Y, will measure absolute CTE. There will be a few short exposures as fillers at ends of orbits for long-short flux ratio tests.
We will continue to observe only two epochs per Cycle (a reduction from three, begun in Cycle 21); the low frequency is warranted by the CTE's slow and smooth evolution.
There will be one orbit for NGC 6791 and two for 47 Tuc (five non-zero background levels). Three orbits per epoch, times two epochs, to yield six orbits total.

<u>Is this the continuation of previously approved program?</u>
13566

Same as CY21

WFC3/UVIS CTE in subarrays

Number of external orbits: 0 **Number of internal orbits: 42**

Goals: Investigate the behavior of CTE in UVIS subarrays, assess the efficacy of the pixel-based CTE correction as applied to subarrays, and measure the bias levels within each subarray mode.

Description of the Observations: The current CTE algorithm has been developed and optimized for use with full-frame four-amp readouts. Subarrays do not have the same readout timing as full-frame exposures and thus CTE losses are likely to manifest differently in subarrays than in full-frames. This program acquires the data necessary to evaluate the CTE losses and to test the pixel-based CTE correction in subarrays. In addition, the biases will allow for a measure of the bias level in each subarray mode: correct bias levels are crucial for computing the appropriate CTE correction. Subarray bias levels have typically been taken to be the same as in full-frames but recent analysis has found offsets in some modes (~1-2 e-).

One 1800 sec internal orbit is sufficient to acquire a) one 900 sec post-flashed subarray dark plus 4-6 subarray biases, depending on size, or b) biases in all supported subarray modes. To obtain 1 dark plus a handful of biases in each subarray mode requires 15 type 'a' orbits. We propose one such set as early in the cycle as possible with a second iteration late in the cycle. More frequent monitoring throughout the cycle is done with the type 'b' orbits, all biases, one orbit per month, overlapping with the 'a' orbits early and late in the cycle.

Orbits required: 42 total (= 1 'a' orbit x 15 subarray modes x 2 in cycle + 1 'b' orbit per month x 12 months)

Is this the continuation of previously approved program? No

Note: darks will be taken as DARK-NM and followed by the biases in order to avoid extra CSM moves.

Characterization of UVIS traps with Charge-Injection

Number of external orbits: 0

Number of internal orbits: 36

Goals: This program is designed to monitor the UVIS trap growth via charge-injected biases

Description of the observations: We request 36 internal orbits to monitor the growth of UVIS traps. Line 25 charge-injected biases will be acquire every 10 days. Observations are designed to give the schedulers large flexibility, and therefore minimize the impact on the number of CSM moves.
The frequency has been reduced by half compared to the previous cycle.

<u>Is this the continuation of previously approved program?</u> Yes – 12784, 13084, 13569

Astrometric Calibration

We request 28 external orbits to:

1. 18 orbits will be used to verify the quality of the geometric distortion solution for all the WFC3/UVIS filters, and improve the solution for 3 filters whose current solution has residuals >0.1 pixels. - New Program!
2. 10 external orbits will be used to map and remove residual structures from the high precision geometric distortion solution derived from spatial scan. Residuals are at the level of 5 millipixels. - New Program!

Astrometric Verification of Broad, Medium, Narrow and Quad WFC3/UVIS Filters

Number of external orbits: 18 orbits

Number of internal orbits: 0

Goals:

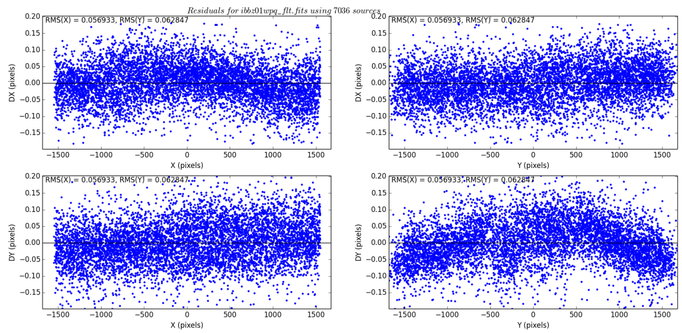
1) Improved the filter-dependent component of distortion for the 3 UVIS filters F350LP, F475W and F390M. *(Insufficient number of the observations of omega Cen through these three filters in CYC20);*
2) Verify the geometric distortion solution for Broad, Medium, Narrow and Quad UVIS filters;
3) Monitoring the optical & mechanical stability of the WFC3/UVIS, using a single F606W filter, which is continuation of the multi-cycle time-dependency geometric distortion.

Description of the observations:

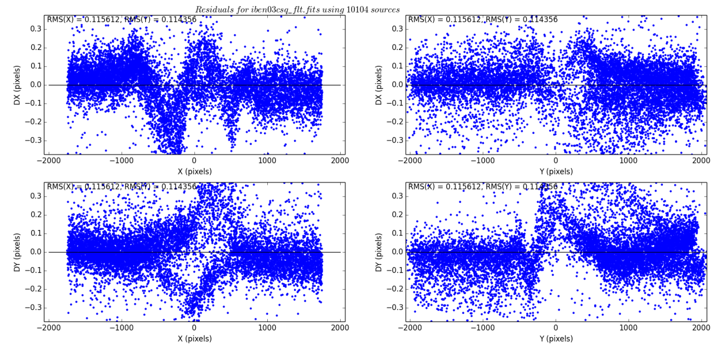
- ◆ Dither observations of the globular cluster Omega Cen (pattern +/-40") for 3 UVIS filters (F350LP, F475W and F390M) to determine the geometric solution – 9 exposures per filters ~ 5 orbits;
- ◆ Observations of globular cluster Omega Cen trough 7 Broad, 6 Medium, 12 Narrow, 16 Quad UVIS filters. Single exposure in F606W is followed by a single exposure for each of the 41 filters (on average, one orbit consists of 4 exposures: always F606W + 3 chosen filters), or a total of 13 orbits
- ◆ Observations through F606W filter will be serve as continuation of the multi-cycle time-dependency geometric distortion.

Title: Astrometric Verification of Medium, Narrow and QUAD WFC3/UVIS Filters (continue…)

- Results from DrizzlePac/TweakReg for F656N and FQ750N UVIS filters (PI M.Wong, CAL-12091) by applying standard F606W filter solution + D2IMFILE & NPOLFILE



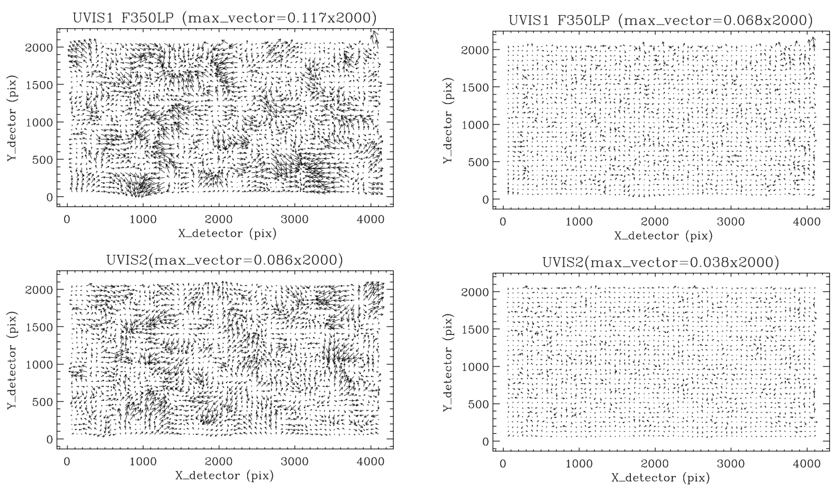
Narrow F656N Filter: XY residuals between two overlapping images. Low <0.1 pix systematics.



Quad FQ750N Filter: XY residuals between 2 overlapping images. Complicated structure & well-exceeding 0.1 pix.

Current solution in F606W and look-up table might be adequate & meeting the AstroDrizzle requirements of ~0.1 pix *only* for some Narrow filters but not for any of the Quad filters.

- Improving the filter-dependent distortion for 3 UVIS filters: F350LP, F475W and F390M (CAL-12353)



F350LP Filter.

Left: 2D-residuals map after correction for lithographic pattern but prior to F350LP filter-dependent correction.

Right: 2D-residuals map after correction for lithographic pattern *and* the existing F350LP filter-dependent distortion.

- Very noisy residuals after the correction for filter-dependent correction are due to the insufficient number of observations (only 2 – 3 exposures per each filter, Kozhurina-Platais, WFC3-ISR-14-12).
- To firmly constrain the filter-dependent distortion, 5-9 exposures are required in each filter!

High-Precision Calibration of the WFC3/UVIS Geometric Distortion – PI Riess, Approved

Number of External Orbits: 10 **Number of Internal Orbits: 0**

<u>Goals</u>: Map the residual geometric distortions found using the high precision spatial scanning technique. The residuals are measured relative to the current best geometric distortion maps and persist from year to year observations. They have a scale of roughly 5 milipixels and a correlated length of a couple of hundred pixels. Indeed, residuals of this size and scale were expected by the experience that errors and noise always exist at just below the precision of the calibration.

<u>Description of the observations</u>: We proposed to map these residuals using the back and forth spatial scanning of an open cluster where the stars are chosen to have magnitudes in the optimal range - bright enough to get measurement precision better than 5 milipixels on 10's of pixels scale but not so bright as to saturate. This requires relatively nearby open clusters so that the stars are bright, but not too close or else the stars are too far apart and we get little multiplexing. We selected some trial clusters and then ran some Monte Carlos (a million trials) to find the optimal set of dithers that will maximize the coverage of the detector field by at least one bright star (passing within 50 pixels).
For the most used filter, F606W, 4 orbits gives us 20 dithers and on the open cluster M67 we can cover 97% of the field of view with a bright line passing within at least 50 pixels. We think this is highly desirable and also allows for crosschecks with 85% of the field covered by 2 scans lines. (For comparison, 2 orbits gives 80% coverage by one which we think is not good for this most used filter).
For the other two filters used for spatial scan astrometry, F621M and F673N, we go to a brighter cluster, M48 to compensate for their lower throughput. Brighter means closer and stars are farther apart so the multiplexing is a bit less. Given these filters are used a bit less, we can deal with less coverage and we suggest going to 3 orbits per filter for 15 dithers. For M48 this will cover 76% of the field with at least one nearby scan line.

So the total would be:

Filter	Cluster	orbits/scans	available window for desired orient
F606W	M67	4 orbits = 20 scans	11/04-12/15
F621M	M48	3 orbits =15 scans	09/21-11/21
F673N	M48	3 orbits=15 scans	”

Characterization of IR Traps

18 external and 69 internal orbits will be used to:

1. We request 12 internal and 12 external orbits to improve our current model for persistence. - Increased from last cycle
2. 3 external and 3 internal orbits to determine the amount of persistence in the first 10-150 sec after an exposure. – New program!
3. 3 external and 4 internal orbits to evaluate if repeated scanned without grism observations are worst actor or not. - New program!
4. 50 internal orbits are requested to verify the amount of persistence after Worst Actors observations.- same as last cycle

Refining the model of persistence in the WFC3 IR detector

Number of External Orbits: 12 **Number of Internal Orbits: 12**

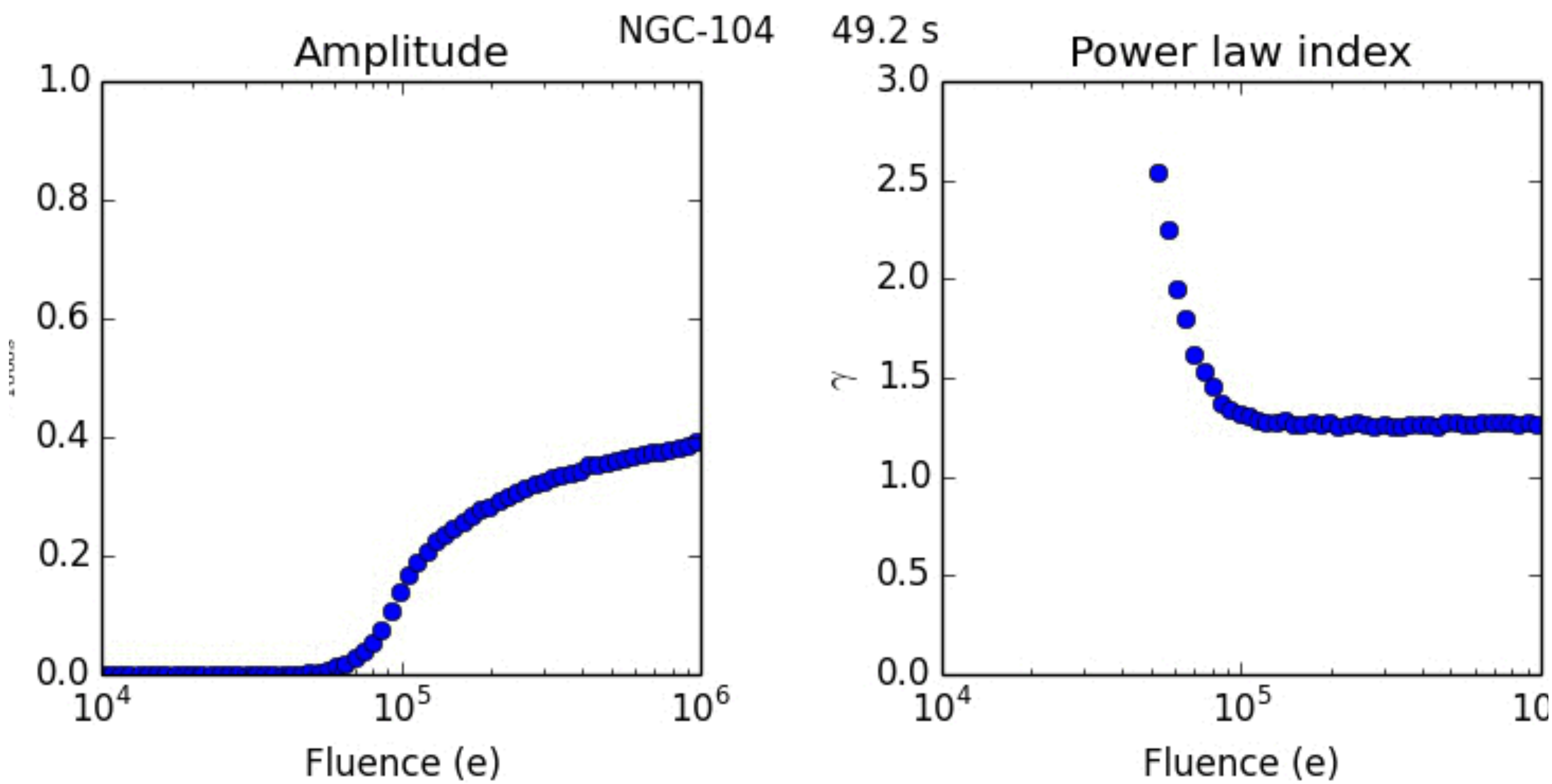
Goals: Persistence is an afterglow of one or more "stimulus" images observed in images taken later. Our original model of persistence was based solely on the fluence in the stimulus image and the time since the stimulus image was obtained. Using data from Cycle 21, we developed an improved model for persistence that includes the length of the stimulus image exposure as one of its parameters (reflecting the fact that the traps that generate persistence have finite trapping times.) This persistence model will be incorporated into the Quicklook pipeline this fall, and will be made available to HST archive users and GOs through MAST.

The purpose of this proposal is to (a) provide data for the model on a finer grid of exposure times, (b) measure more accurately the variation in persistence across the face of the detector, (c) test the repeatability of persistence with time, and (d) improve the accuracy of the model at lower fluence levels (where source crowding in our Cycle 21 observations makes determination of the persistence difficult)

Description of the Observations: Each visit will consist of multi-accum exposures of Omega Cen (or another bright extended target) followed by a series of darks that will extend through an entire orbit to measure persistence for 3000 seconds after the exposure. (A true dark, with a CSM move, will be required.) Each visit will require 2 orbits.

Four visits will duplicate exposures from the Cycle 21. Four visits will provide data for exposure times intermediate between those from the previous cycle. Four visits will be of a sparser field, most likely the halo of 47 Tuc to enable us to explore persistence at lower fluence levels. Broad filters will be used for the short observations and narrow filters for the long observations to obtain a good sampling of stars at all relevant fluence levels --> 2 orbits x 12 visits --> 24 orbits (12 external orbits; 12 internal orbits)

Variation with exposure time



$P(x)=A(x)(t/1000s)^{-\gamma(x)}$ for different exposure times

Short term persistence

Number of External Orbits: 3 **Number of Internal Orbits: 3**

<u>Goals:</u> Determine persistence from 10 – 250 seconds after an exposure

Our measurements of persistence begin typically 250 seconds after the end of external visits. For the first approximately 5000 seconds after this we know that to good approximation, persistence decays as a power law. However, persistence at very short times should show departures from this. The purpose of this proposal is to measure this persistence. This will allow a clearer understanding of how much persistence there is at short times, which will inform our physical model of persistence, and help to determine whether this persistence can actually affect the photometry, in situations where a star is observed multiple times in the detector.

<u>Description of the Observations:</u> Each visit will consist of multiple dithered exposures of a sparse, but bright field, followed by one (full) orbit of darks. A large linear dither pattern will be used to separate stars in multiple exposures. The three visits will allow for exposure times ranging from 100 to 500 seconds. Sub-arrays will be required for the shorter exposures.

(Note- this proposal could be incorporated into the "Refining the model of persistence proposal", though the observing strategy and target selection would be different).

(Note – One could consider carrying out this observation using the grism. The advantage of this is that with a single bright star one could obtain a significant number of pixels to analyze. The disadvantage is that there is considerable scattered light with the grism and this could complicate the analysis. For scanned grism observations the scattering is a major issue in similar measurements.)

(Note – Yet another possibility for carrying out this data analysis would be to use scanned observations of stars, but if one did this one would need to have multiple exposures within the scan to reset the detector, which might require this to be planned as a moving target or to use special commanding.)

Persistence after Worst Actors

Number of External Orbits: 0

Number of Internal Orbits: 50

<u>Goals:</u> Monitor the amount of persistence generated by Worst Actors. The goal of this program is simply the measure the persistence associated with all of the sources we have declared to be worst actors. This will allow us to determine whether the special observations in the Worst Actor category are well-described by our Persistence model. Furthermore, many Worst Actors are taken in a subarray mode and hence the only way to determine how much persistence there is outside the subarray is with a full frame observations. Obtaining a dark after these Worst Actors allows us to estimate the amount of persistence outside of the subarray, where the strong persistence caused by the "dwell time" peaks.

<u>Description of the Observations:</u> We will use the same strategy as for the Cycle 21 version of this program, allowing the schedulers to choose which of several types of visits to scheduled, based on what can be fit in. Standard visits are 1891 sec long and consist of 5 STEP25 NSAMP=15 full frame darks. Short visits are 1143 sec long and consist of 3 STEP25 NSAMP=15 full frame. Minimal visits consist of 1 STEP25 NSAMP=15 full frame dark. We favor standard visits, because they are long enough to measure the persistence left by spatially scanned spectra inside and outside the subarray, and to characterize its early decay characteristics, but if needed short or minimal visits can be utilized. To minimize the number of CSM moves, DARK-NM will be utilized.

Same as CY21

Persistence after non-scanned repetitive grism observations

Number of External Orbits: 3

Number of Internal Orbits: 4

Goals: Determine whether non-scanned, repetitive grism observations (such as exoplanet and faint WD binaries around bright stars) should be declared worst actors.

All exoplanet grism observations are currently categorized as Worst Actors. For scanned observations, the rationale is that a large area of the detector is impacted by persistence and so it is important to prevent any persistence from these observations affecting follow-on observations. For non-scanned observations, the area of the detector affected is considerably smaller and so the rationale for including them as bad actors is the possibility that these observations cause more than a normal amount of persistence. The purpose of the observations is to determine whether such observations do cause significantly more persistence than a standard long exposure to a similar fluence level.

Description of the Observations: Each visit will consist of a one or two orbits multi-accum exposures of a single moderately bright star matched in brightness to those typically used by GOs for similar observations followed by 2 (full orbits) of true darks. One immediately after the external observation, and one would occur about hours later.

WFC3 Photometric performance

50 external orbits and 1 internal orbit will be used to:

1. 18 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) and characterize the wavelength dependency of the throughput decrease observed at optical wavelengths (7 orbits). Increased from last cycle
2. 3 external + 1 internal orbits will be used to monitor the accuracy of the shutter mechanism after 5 year of operations. - New program!
3. 4 external orbits to check the repeatability of the photometry in scanned direct images. - New program!
4. 21 external orbits are requested to check photometric zero-points for all WFC3 UVIS and IR filters. Increased from last cycle
5. 3 external orbits are requested to enable direct calibration of Zeropoints at effective wavelengths that are closer to non-stellar sources (i.e. galaxies and SN). - New program!
6. 1 external orbit is requested to cross calibrate NICMOS count rate dependent non-linearity at blue wavelengths. - New program!

WFC3/UVIS Contamination Monitor

Number of external orbits: 18 **Number of internal orbits: 0**

Goals: Periodically measure the photometric throughput of WFC3 during the cycle in a subset of key filters in the UVIS channel. The data provide a monitor of the flux stability as a function of time and wavelength as well as check for the presence of possible contaminants on the detector windows.

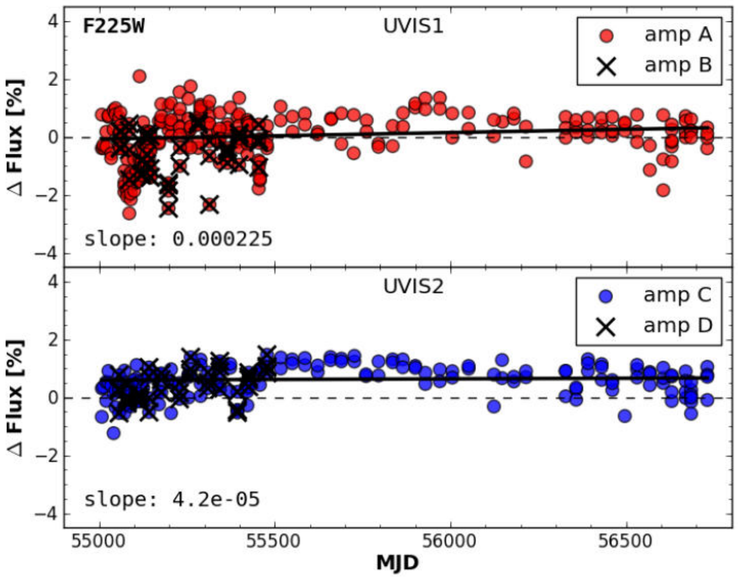
Description of the Observations: The program for this cycle has two components:

A) Continue the monitoring as done in past cycles, using the white dwarf spectrophotometric standard GRW +70d5824. Each iteration is one orbit and the observing cadence is once every 5 weeks, deliberately out of synchronization with the monthly anneals in order to sample the phase space. Each iteration obtains dithered subarray observations of the standard star in a subsample of filters in the UVIS, including the UV gris, on both UVIS detectors. The last C21 iteration is Oct 13, 2014 so 11 iterations are needed to cover C22 through Nov 2,2015.

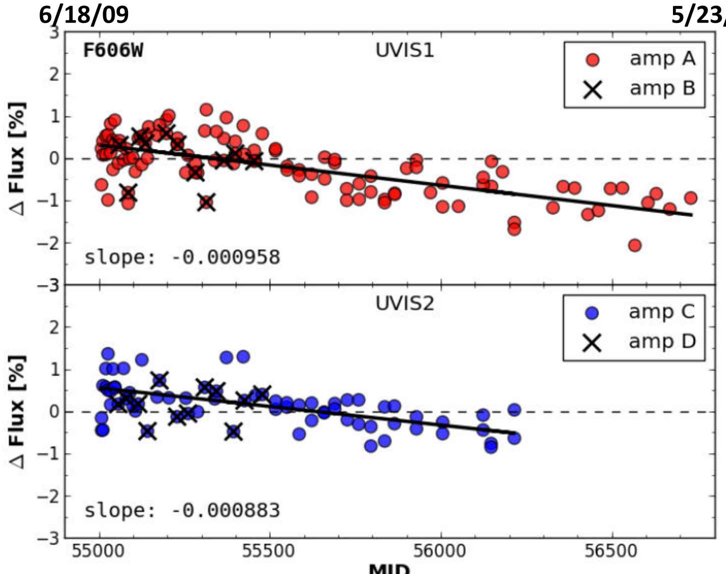
B) Due to recent analysis results which show low-level long-term throughput declines in the visible and red filters (but little decline in UV filters), 7 extra orbits are requested to expand the number of filters and stars being monitored. Specifically, 2 orbits early in the cycle will be used for supplemental GRW+70 observations using filters not observed recently but for which SMOV and C17 archival data are available, enabling additional long-term measurements. The remaining orbits will be used to acquire subarray data using the spectrophotometric standard star G191-B2B. This target was observed in 2009/2010; 5 orbits would provide 4-point dither images in all wide and medium filters in both detectors, allowing for a direct comparison to the post-launch data in order to provide a cross-check of the throughput trends seen in the GRW+70 data, as well as assess throughput stability as a function of wavelength and color.

Is this the continuation of previously approved program? Yes -13574

Results from Contamination Monitor – cont.



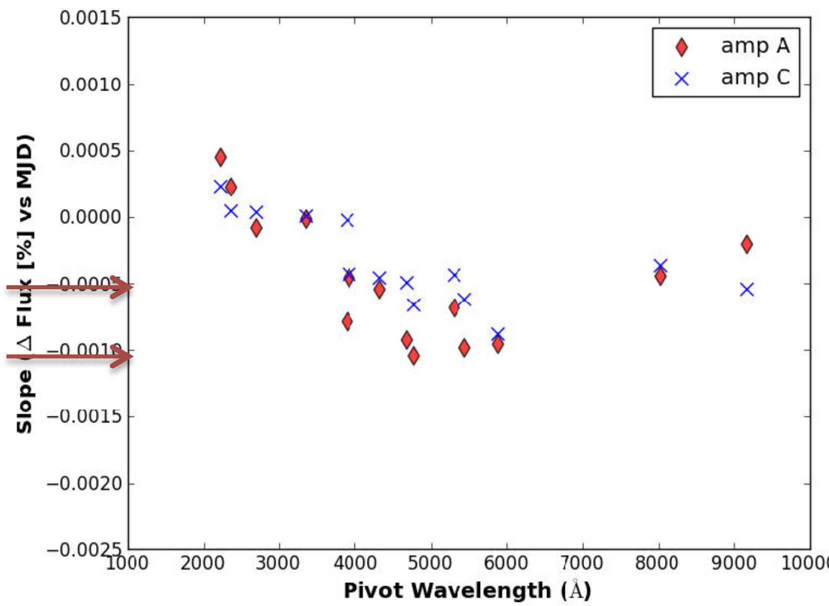
6/18/09 5/23/14



- No contamination, i.e. degradation in UV relative to visiblewavelengths, has been seen.
- However, some long-term photometric drift is evident.
- At left: change in aperture photometry relative to SMOV as a function of date for F225W (top) and F606W (bottom).
- Below: throughput change as a function of filter pivot wavelength. Largest changes are in F606W and F547M (0.3-0.4%/year). ACS exhibits a similar trend with wavelength (Bohlin et al., 2011).
- Cause of the decline in WFC3 is still under investigation using available archival data. The additional observations requested in Cycle 22 will provide the data required to characterize the behavior and produce any necessary calibrations such as time-dependent zeropoints.

-0.2%/yr

-0.4%/yr



Figures from Gosmeyer et al., ISR 2014-xx.

UVIS Shutter Characterization

Number of external orbits: 3

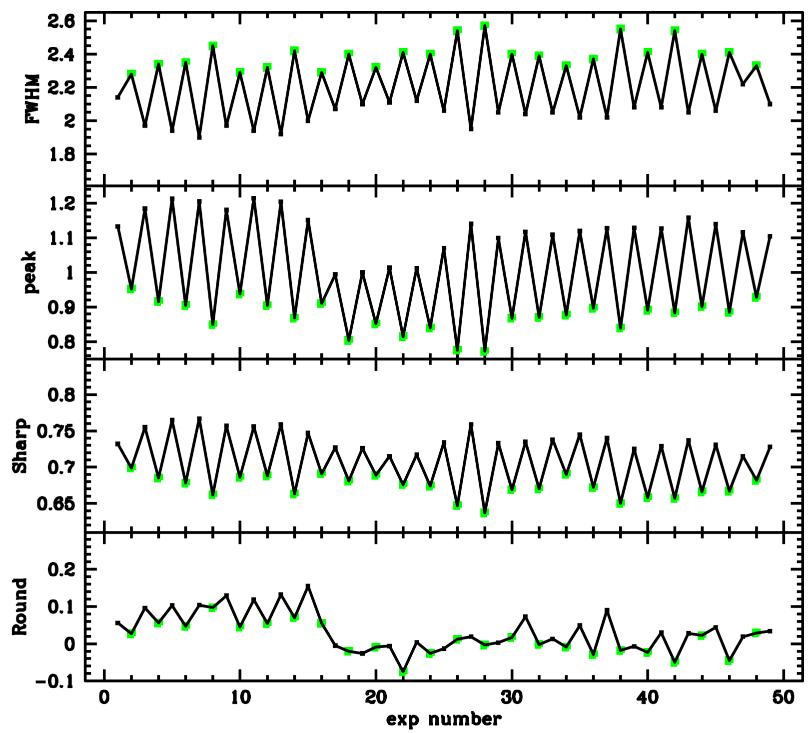
Number of internal orbits: 1

<u>Goals</u>: The goal is to characterize the performance of the shutter blades. The three specific objectives are:

(i) to check the accuracy and stability of the blades by repeating the SMOV test done 5 years ago,

(ii) to check the photometric behavior of both the shutter blades, for short vs. long exposures, and

(iii) to check for any shading effects by the shutter.



UVIS Shutter Characterization – cont.

Description of the Observations: (i) During SMOV, tests were carried out to check the accuracy and stability of the shutter. The wavelength dependence of the UVIS sensitivity variation seems consistent with the fact that the shutter speed is changing with time. So we will repeat these observations to characterize the shutter and look for any deviations (2 external orbits).

(ii) We will characterize the photometric behavior of the shutter blades A and B separately. In particular, the shortest exposures are known to be anomalous, but its possible dependence on the blade is currently unknown. Now that we are offering BLADE=A option for observations with better PSF, it is important to characterize the photometric behavior separately for the two blades (1 external orbit).

(iii) Internal flat fields will be used to quantify any shutter shading effects in the UVIS channel (1 internal orbit).

Is this the continuation of previously approved program? (SMOV test: 11427)

Photometric repeatability of scanned direct imaging

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

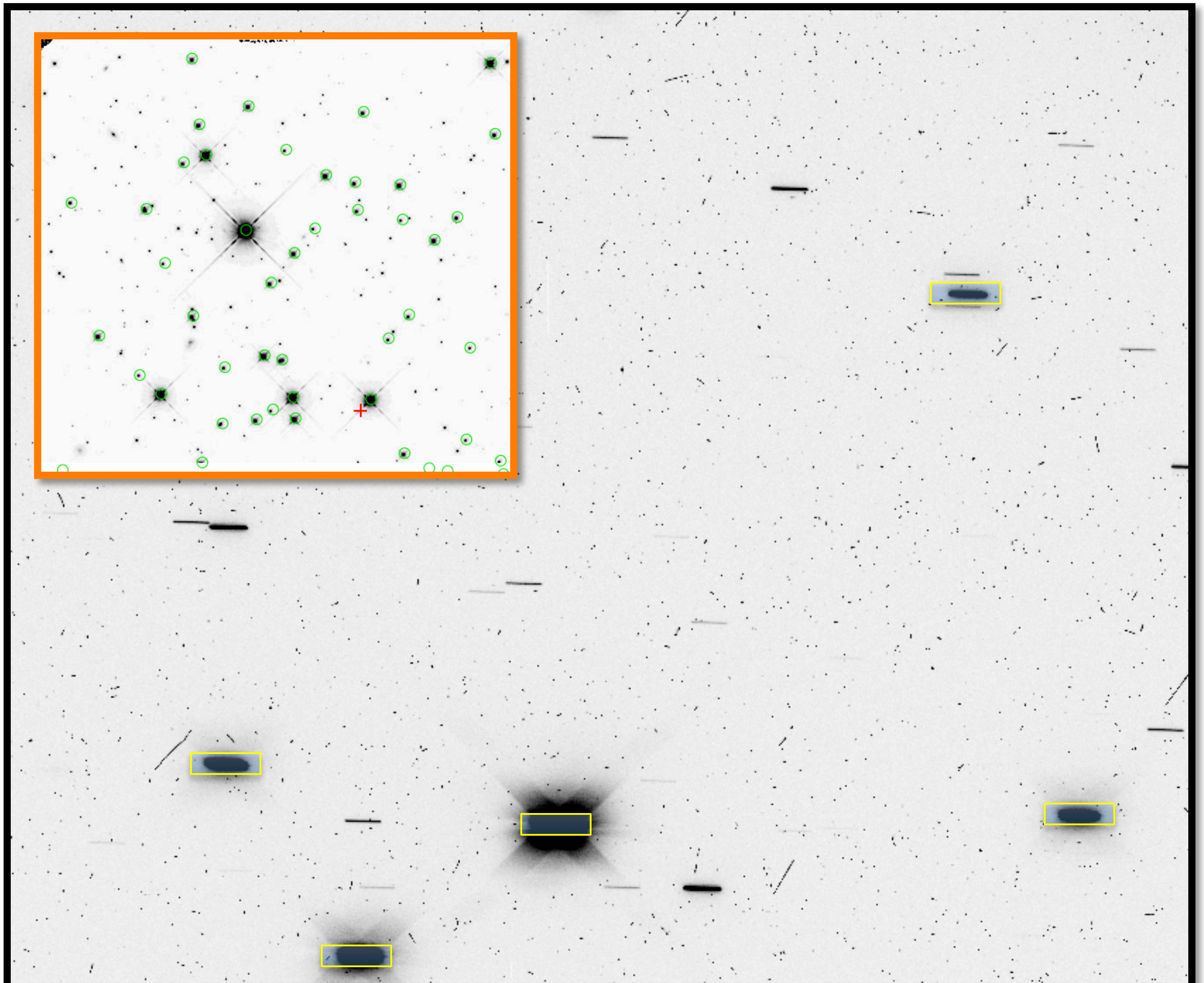
Goals: This program will measure the repeatability of photometry of scanned direct IR images in F125W. If we can demonstrate 0.1% repeatability, this would be ~10x more precise than the expected performance for staring mode photometry. Such will enable more precise synoptic monitoring programs, both for instrumental and astrophysical purposes. Examples of the latter are Kepler/K2 follow up programs. If this program succeeds, it will enable GO programs that otherwise suffer a catch-22 in which they cannot get approved because we don't know if the instrument can deliver this precision (until it's been demonstrated).

Description of the Observations: We will scan a sparse open cluster (M35 TBR) containing a dozen moderately bright stars (e.g. V ~13 mag, similar to P330E) in a single row across ~100 columns, at four epochs throughout the year. Although a pair of epochs is the absolute minimum number of epochs (2) to study repeatability, four epochs provides six unique pairs for a robust comparison. We will use one infrared filter (F125W TBR). By collecting ~40,000 e-/column, the Poisson noise of a single trail (4 million e-) will be 0.05%, and by averaging 100 pixels, we will reduce the ~1% pixel-to-pixel flat field error by ~10x. Although we will take multiple scan lines per HST orbit, we intend to dither them so as to illuminate any given pixel only once per visit to avoid the ~1% ramp-up effect known to occur in time-series of exoplanet host stars. In each orbit we also will take two sample sequences to check for consistency between RAPID and SPARS10.

Suitable UVIS data exist in MAST (Sahu's 12588/13058/13464; see next slide) but we have not found suitable data in the IR. (Riess' programs do not have more than one IR epoch suitably exposed). As a bonus, we expect to include one UVIS filter (F606W) in the proposed study in the latter half of each orbit; we will use much shorter exposures than the 500-sec ones in Sahu's programto better test the UVIS shutter's contribution to non-repeatability in scanned observations.

Is this the continuation of previously approved program? No.

Photometric repeatability of scanned direct imaging cont'd.



A section of a UVIS image showing ~50-column-wide (500-sec long) trails of stars in F606W from Sahu's program 12588/13058.

The are ~1 dozen star trails in the entire field that have 2 million electrons each and there are 6 visits in MAST.

We propose to acquire similar data in the IR F125W of a sparse star cluster.

indicates > 2 million e$^-$ in the box.

Inset: WFC3 image (F140W) of a field in M35 with 2MASS stars circled. The one near the + symbol has H=11.5 mag.

Cycle 22 WFC3 UVIS and IR Photometry (first option)

Number of external orbits: 21

Number of internal orbits: 0

Goals: Monitor the photometric throughput and stability, measure time dependent zeropoints and determine color term corrections for WFC3 UVIS and IR filters provide a check of the UVIS/IR flux stability as a function of time, wavelength and source brightness. WFC3/UVIS contamination monitor (a separate program) indicates that UVIS sensitivity is time dependent, hence zeropoints are also time dependent. **This is a continuation of Cy 17 – Cy 21 programs**.

B) Monitor throughput, sensitivity and color terms of WFC3 IR filters. **This is a continuation of Cy17-Cy20 photomtery programs.**

Description of the observations:

WFC3 UVIS: (18 orbits)

Observations of the HST spectrophotometric standard stars (G191B2B, GD153, GD71 and P330E) are used to calculate zeropoints as well as check stability of photometry as a function of time, wavelength and source brightness for both CCDs in all four amps. In Cycle 20 and Cycle 21 we obtained observations in ALL UVIS filters at all 4 corner subarrays. During Cycle 22 we will image the standard stars in a subset of broad- and medium-band UV and VIS filters at the corners, postflashed. Observations prior to Cycle 20 are unflashed.

In Cycle 22, G191B2B is observed mid-cycle, GD71, GD153 and P330e are observed close in time, in the second half of the cycle. 1 orbit/amp x 4 amps x 4 stars = 16 orbits.

Star/Cycle	SMOV+17	18	19	20	21	22
G191B2B	AC, ALL					✔ABCD, subset
GD153	ABC, subset	A, subset		AD, ALL	BC, ALL	✔ABCD, subset
GD71	AC , subset	C , subset	C, subset			✔ABCD, subset
P330E	A, subset	A, subset		AD, ALL	BC, ALL	✔ABCD, subset

Cycle 22 WFC3 UVIS and IR Photometry (alternative option)

Number of external orbits: 11

Number of internal orbits: 0

Goals: Monitor the photometric throughput and stability, measure time dependent zeropoints and determine color term corrections for WFC3 UVIS and IR filters provide a check of the UVIS/IR flux stability as a function of time, wavelength and source brightness. WFC3/UVIS contamination monitor (a separate program) indicates that UVIS sensitivity is time dependent, hence zeropoints are also time dependent. **This is a continuation of Cy 17 – Cy 21 programs**.

B) Monitor throughput, sensitivity and color terms of WFC3 IR filters**. This is a continuation of Cy17-Cy20 photomtery programs.**

Description of the observations:

WFC3 UVIS: (8 orbits)

Observations of the HST spectrophotometric standard stars (G191B2B, GD153 and P330E) are used to calculate zeropoints as well as check stability of photometry as a function of time, wavelength and source brightness for both CCDs in all four amps. In Cycle 20 and Cycle 21 we obtained observations in ALL UVIS filters at all 4 corner subarrays. we will image the standard stars in a subset of broad- and medium-band UV and VIS filters at the corners, postflashed. Observations prior to Cycle 20 are unflashed. G191B2B is observed twice – early in the cycle (in the contamination monitor) and mid-cycle in this program, complementary to the Cy17 images. In Cycle 22, G191B2B is observed mid-cycle GD153 and P330e are observed close in time, in the second half of the cycle. 1 orbit/amp x 2 amps x 3 stars = 6 orbits

Star/Cycle	SMOV+17	18	19	20	21	22
G191B2B	AC, ALL					✔AC, subset
GD153	ABC, subset	A, subset		AD, ALL	BC, ALL	✔AC, subset
GD71	AC , subset	C , subset	C, subset			
P330E	A, subset	A, subset		AD, ALL	BC, ALL	✔AC, subset

Cycle 22 WFC3 UVIS and IR Photometry (..continue)

WFC3 UVIS (continued)

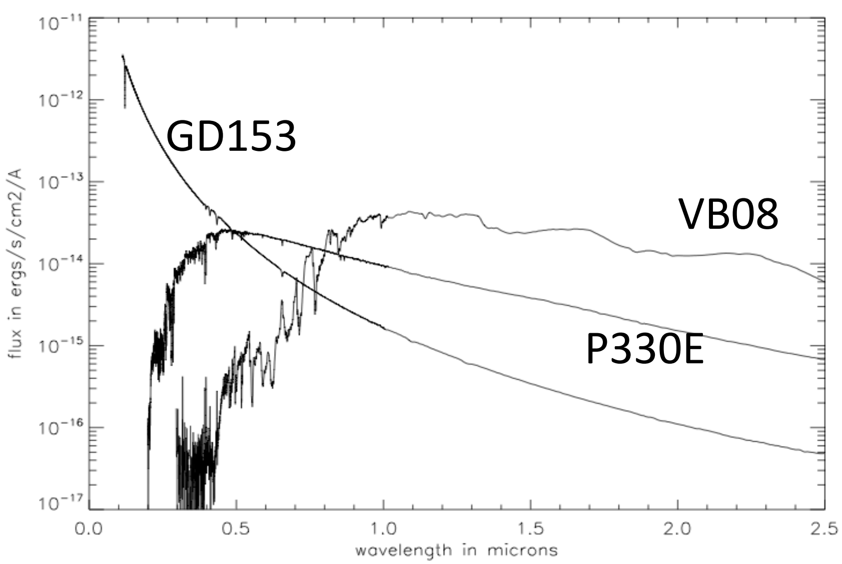
Observations of star clusters are used to check the color dependence color term effects for the red VIS filters, at two orientations. We use 47 Tuc (which was observed in Cy17) in F438W, F555W, F606W, F775W and F814W.

2 orbits

WFC3 IR: (3 orbits)

Observations of spectrophotometric standards GD153, P330E and VB08 are obtained in subarray mode for all IR filters. Stars have different brightness and color

3 stars, subarray mode, 1 orbit each, mid cycle.



Vega mags	B	V	R	I	J	H
GD153	13.17	13.40	13.8	13.3	14.012	14.2
P330E	12.972	12.9	12.56	12.212	11.76	11.45
VB08	18.7	16.7	16.61	12.24	9.776	9.2

WFC3 IR Observations of Red CALSPEC Stars

Number of External Orbits: 3 **Number of Internal Orbits**: 0

Goals: Enable direct calibration of zeropoints at effective wavelengths that are closer to non-stellar sources, e.g. faint galaxies, distant sources (similar PSFs, etc) and crosscheck WFC3 IR passbands.

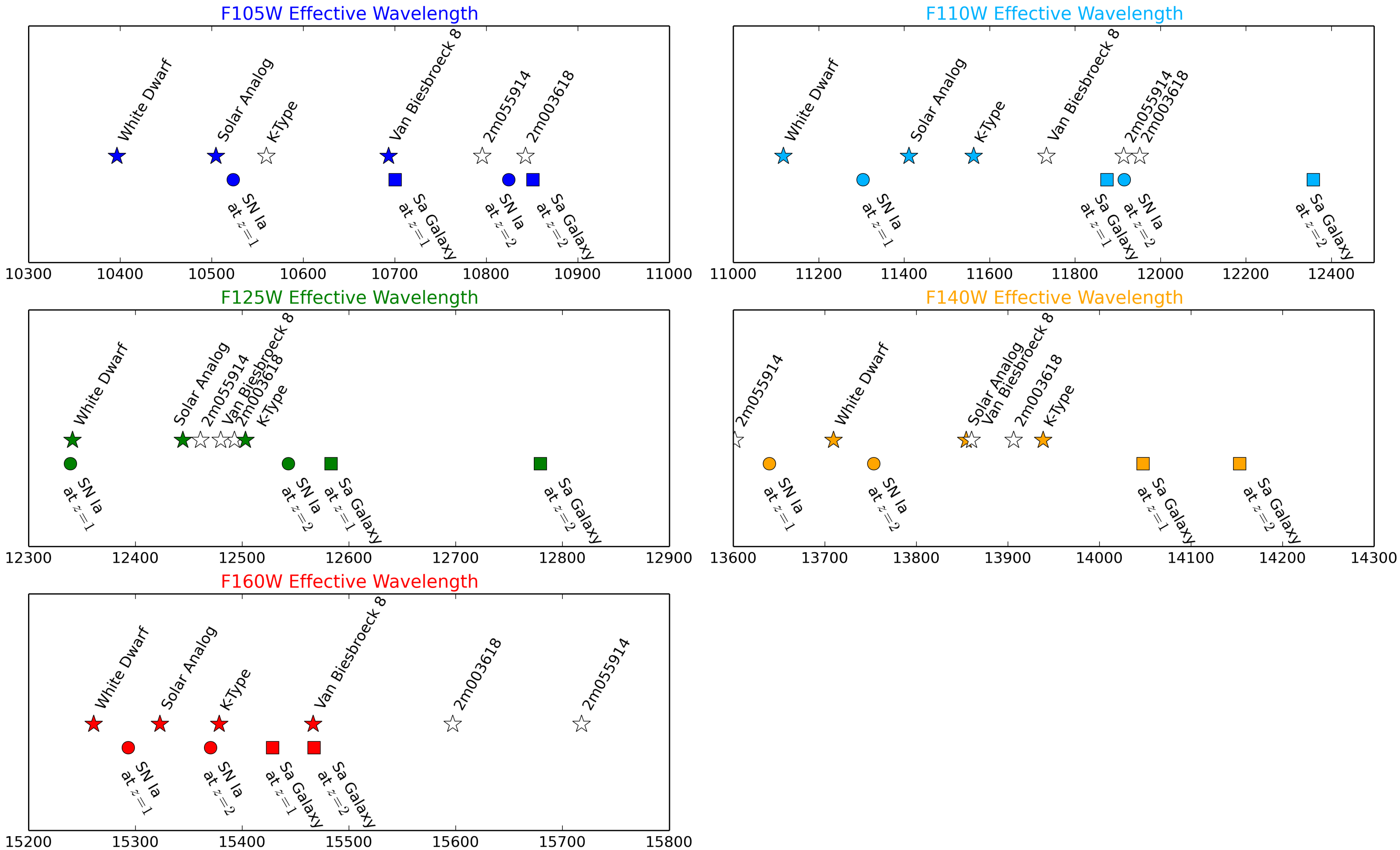
Description of Observations:

Observe 3 red CALSPEC spectrophotometric standard stars, 2M0036+18, 2M0559-14 & KF06T2, in WFC3/IR broad band filters: F105W, F110W, (F125W), F140W & F160W. KF06T2 was observed one time in the IR in 2011 (Cycle 18). VB8 is one of the standards in the regular WFC3/IR photometry program, so its properties are shown here only for completeness. The table lists spectral type, magnitudes and CALSPEC 'pedigree' (calibrated stis + nic spectra).

The graphs on the next slide indicate significant gain to be had in range of color for all broadband filters except F125W. Non-stellar objects are shown with circles and squares.

Standard Star	Sp. Type	V mag	I	J	H	K	CALSPEC Pedigree
2M0036+18	L3.5	21.34	16	12.47	11.588	11.058	stisnic_005
2M0559-14	T4.5		19.4	13.802	13.679	13.577	stisnic_005
KF06T2	K1.5 III	13.8		11.899	11.273	11.149	stisnic_002
VB8 (van Biesbroeck 8)	M7V	16.61	12.24	9.776	9.2		stisnic_005

WFC3 IR Observations of Red CALSPEC Stars (page 2)



Low Count-Rate Cross-Calibration of WFC3 F110W and NIC2 F110W

Number of External Orbits: 1 **Number of Internal Orbits: 0**

Goals: Cross calibrate NICMOS count rate dependent non-linearity at blue wavelengths. Improve calibration of existing NICMOS archival data, especially faint, deep objects.

WFC3/IR CRNL is ~ 6x smaller, and has similar F110W filters, although passbands are different. NIC2/WFC3 cross-calibrated using galaxies at sky level (Rubin et al, to be submitted), extending lamp on/lamp off testing to the count-rate of extragalactic targets. BUT NO cross-calibration of NICMOS using point sources (stars – bluer than deep galaxies) at sky level.

Description of Observations:

1 orbit of WFC3/IR F110W to match NICMOS/NIC2 depth for NGC 6558

There are 11 archival visits of NGC 6558 images in NIC2 F110W & deep (15000+ seconds) of WFPC2 F814W imaging to constrain stellar colors.

WFC3 GRISMS

12 external orbits will be used to:

1) 4 orbits are requested to improve the flux calibration for both the IR GRISMs; - same as last cycle
2) We ask 4 orbits to improve the wavelength calibration for both the IR GRISMs; - same as last cycle
3) We request 2 orbits to monitor the UVIS grism wavelengths stability in both chips; - same as last cycle
4) 2 external orbits are needed to monitor the UVIS grism flux in both chips. - same as last cycle

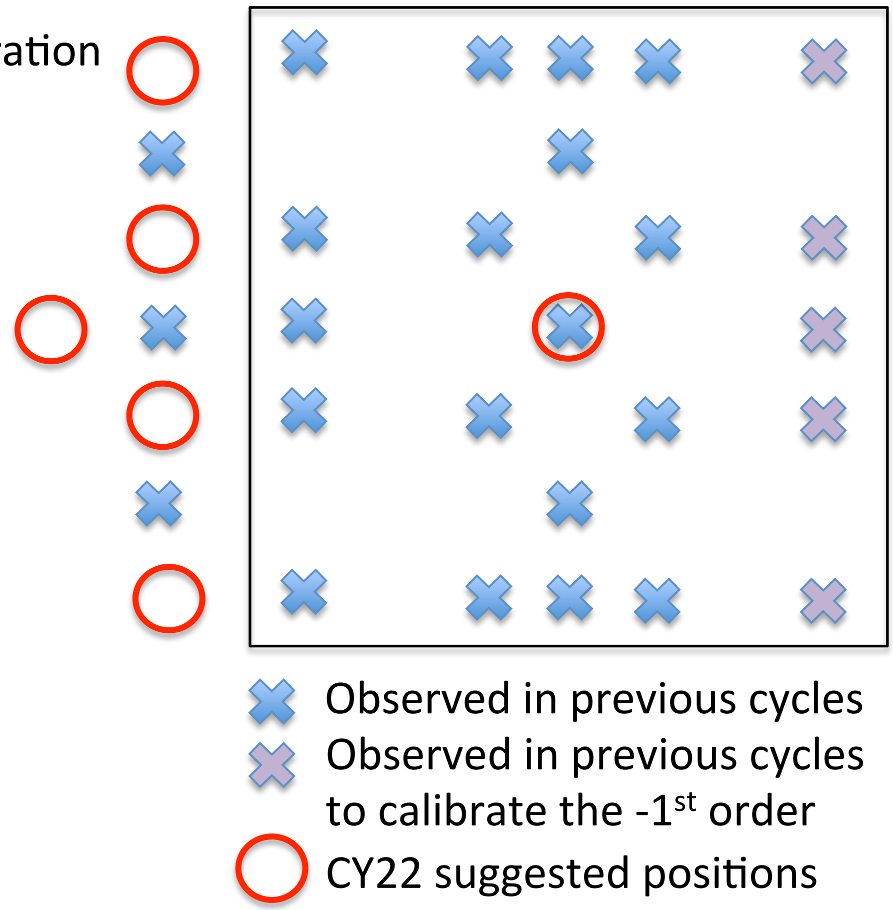
WFC3 IR grisms wavelength calibration stability and calibration

Number of external orbits: 4 (2 per filter)

Number of internal orbits: 0

Goals: Verify and refine the **wavelength** calibration

Description of the observations: 6 pointings of VY-22 using the G102 and G141 grisms. 1 previously observed positions, and add 5 new positions outside and left of the field-of-view to better test and calibrate the 2D variability of the grism wavelength dispersion relations.



Same # of orbits as CY21

WFC3 IR grisms flux/trace calibration stability and calibration

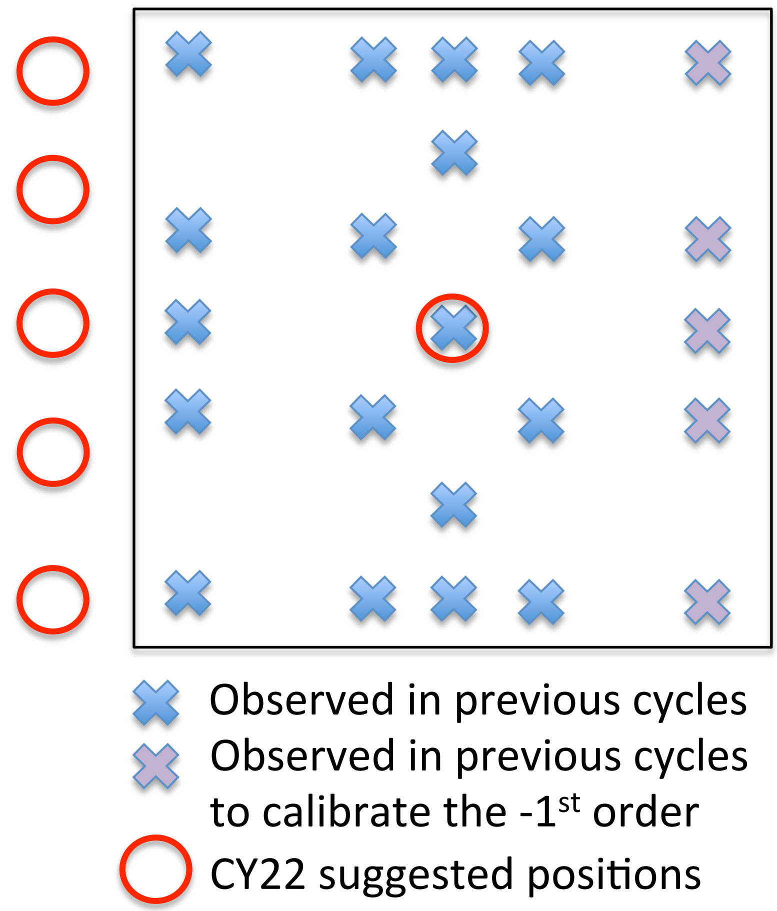
Number of external orbits: 4 (2 per filter)

Number of internal orbits: 0

<u>Goals</u>: Verify and refine the **flux** calibration

<u>Description of the observations</u>: 6 pointings of GD-153 using the G102 and G141 grisms. 1 previously observed positions and add 5 new positions, outside and left of the field-of-view to better test and calibrate the 2D variability of the grism wavelength dispersion relations.

Same # of orbits as CY21



WFC3 UVIS grism flux calibration

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

Goals: Verify and refine the UVIS **Flux** calibration. These calibration will improve our ability to process currently archived data as well as support current and future UVIS parallel observations.

Description of the observations: 8 pointings (4 per CHIP) of GD-71 using the G280 grism. Three (3) position on each CHIP will repeat (critical as they show +1 and -1 orders) previously observed position and verify the stability of this mode. The remaining five (5) positions will allow us to refine the 2D dispersion solution of this mode (by adding and by replacing failed observations from previous Cycles)

Same as CY21

WFC3 UVIS grism wavelength calibration stability and calibration

Number of external orbits: 2

Number of internal orbits: 0

Goals: Verify and refine the UVIS **wavelength** calibration. These calibration will improve our ability to process currently archived data as well as support current and future UVIS parallel observations.

Description of the observations: 8 pointings (4 per CHIP) of WR-14 using the G280 grism. Three (3) position on each CHIP will repeat (critical as they show +1 and -1 orders) previously observed position and verify the stability of this mode. The remaining five (5) positions will allow us to refine the 2D dispersion solution of this mode (by adding and by replacing failed observations from previous Cycles)

Same as CY21

Flatfield Calibrations

We request 282 internal orbits to:

1) Monitor a population of UVIS pixels with anomalous QE - 51 internal orbits Increased from last cycle
2) Monitor the health of the UVIS filters via int-flats -13 internal orbits; Same as last cycle
3) Monitor the health of the IR filters via int-flats-18 internal orbits; Same as last cycle
4) Monitor the health of the CMS mechanism by observing the bright earth – 200 internal orbits; Reduced from last Cycle

WFC3/UVIS Internal Flats

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

Goals: Monitor the stability of the UVIS pixel-to-pixel sensitivity in all filters by obtaining internal flat fields with the tungsten and deuterium lamps

Description of the Observations: We will acquire internal flats in all UVIS filters once early in the cycle. This consists of 3 orbits with the D2 lamp for the filters F218W, F200LP, F225W, F275W, F280N, F300X, F336W, F343N, F373N, F390M, F390W, F395N, FQ232N, FQ243N, FQ378N, and FQ387N. Eight orbits with the Tungsten lamp will acquire the remaining 46 filters. Observations in the 4 filters, F390W, F438W, F606W, and F814W, with the Tungsten lamp will be repeated 2 times over the cycle for a total of 2 orbits

Is this the continuation of previously approved program?
11432, 11914, 12337, 12711, 13097, and 13586

Same as CY21

WFC3/IR Internal Flats

Number of external orbits: 0

Number of internal orbits: 18

Goals: Monitor the stability of the IR pixel-to-pixel sensitivity in all filters by obtaining internal flat fields with the tungsten lamp.

Description of the Observations: We will acquire 2 exposures for the full set of IR filters once in the middle of the cycle. This requires 12 orbits (6x2). In addition we will acquire 3 exposures in each of the broad band filters, F105W, F110W, F125W, F140W, and F160W, to monitor those flats 2 times during the cycle (early and near the end). This requires another 6 orbits (2x3) for a total of 18 internal orbits

Same as CY21

Is this the continuation of previously approved program?
11433, 11915, 12338, 12712, 13098, and 13587

UVIS Pixel-to-Pixel QE Variations via Internal Flats Monitor

Number of external orbits: 0 **Number of internal orbits: 51**

<u>Goals</u>: This program continues to monitor the population of pixels exhibiting anomalous QE variations between anneals. These pixels are randomly distributed across the detector and develop lowered sensitivity during the time between anneals. The sensitivity loss is greater in the blue than in the red and the population that develops is seemingly unique per each cycle. This program will focus on constraining the maximum low-sensitivity population existing before an anneal in both the UV and Visible filters.

<u>Description of the Observations</u>: Analysis of data from previous proposals has indicated that the low-sensitivity population in the UV tends to have a grouping (of a few pixels) behavior. To better sample the UV this cycle, we will acquire 6 long orbits using the D2 lamp (to minimize lamp cycles), 1 orbit every other month in the week before the anneal – capturing the maximum number of pixels with lowered sensitivity.

For the visible filters, we will obtain 36 orbits, 3 per month, using the tungsten lamp, to obtain data the week before the anneal, where the population is largest. Nine more orbits will be acquired, 3 early cycle, 3 during the middle, and 3 near the end, to sample the population numbers immediately following an anneal, where the population is lowest. The extra orbit each month will allow additional wavelength coverage between F814W and F438W, to better sample how the population grows towards bluer wavelengths

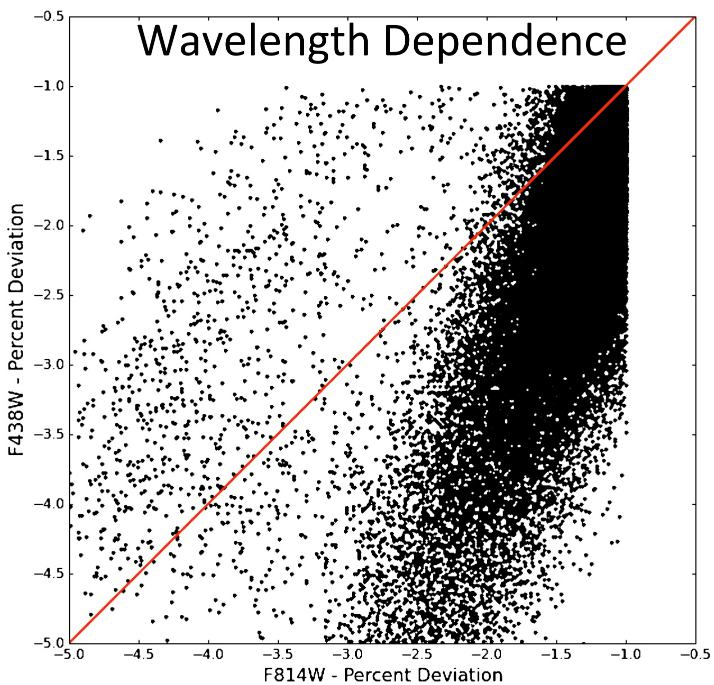
All UV orbits will require non-int to minimize cycling of the D2 lamp.

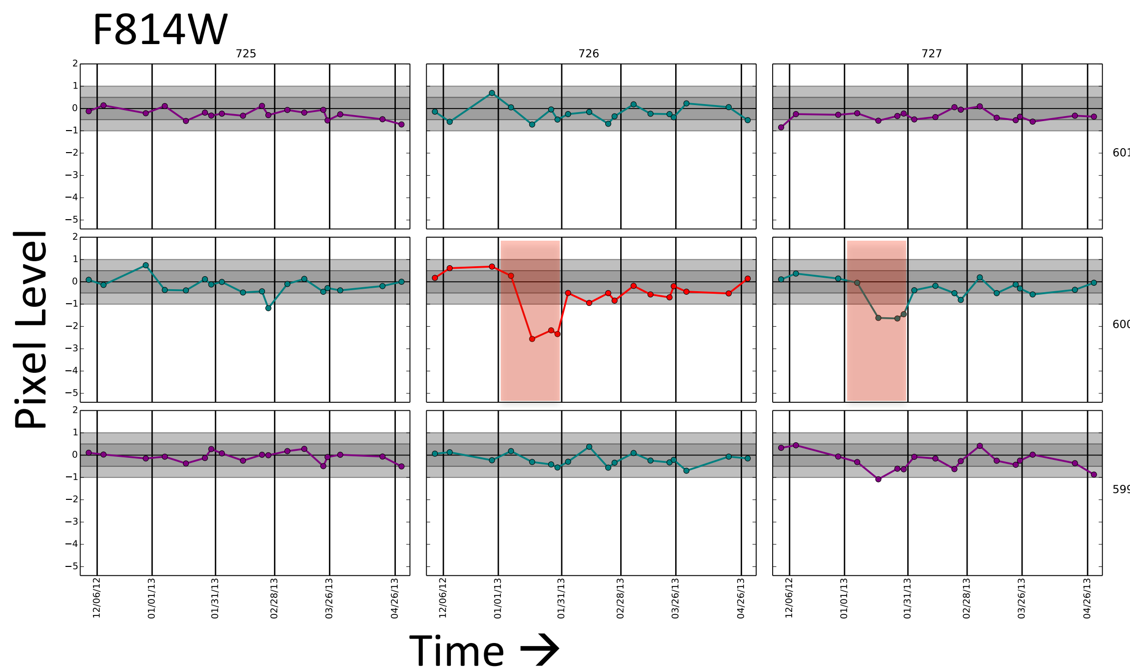
<u>Is this the continuation of previously approved program?</u>

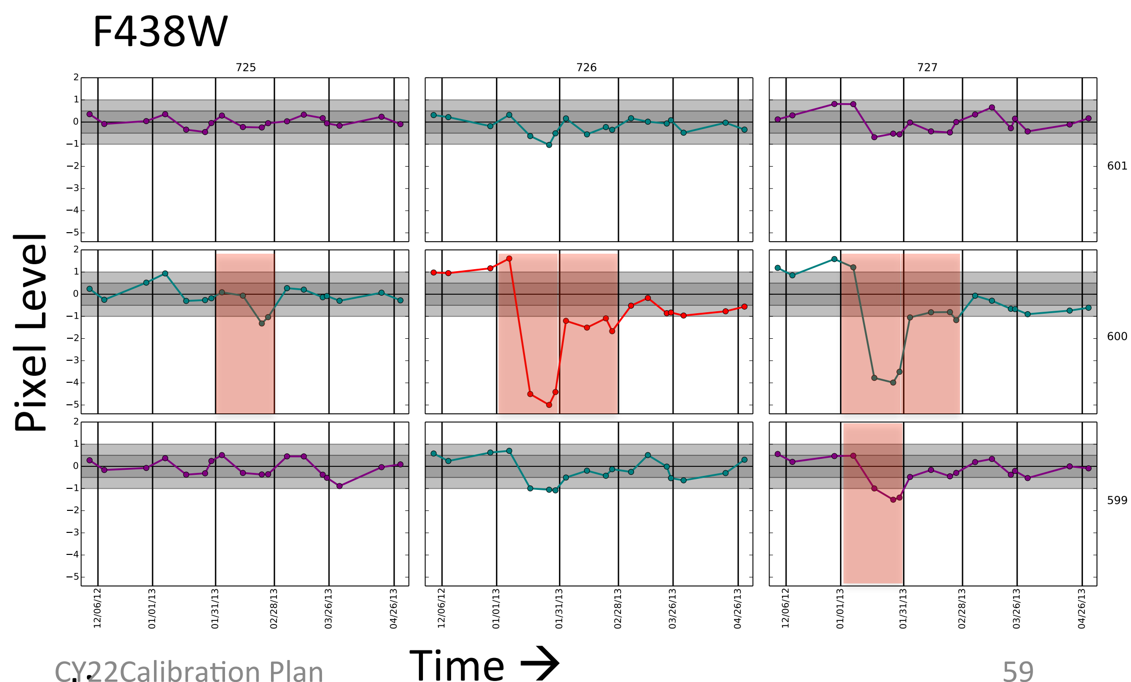
13169,13585

The timeline figures to the right show the development of grouping behavior with bluer filters. The time between anneals highlighted with the red boxes show pixels that exhibited low sensitivity at the same times.

The figure below shows the same pixel set in F814W and F438W – all with low sensitivity. Bluer filters exhibit greater sensitivity loss than redder filters.







See WFC3 ISR 2014-18 for more information

CSM Monitor

Number of external orbits: 0 **Number of internal orbits: 200**

Goals: This program will monitor, as often as practical, the position of the CSM. It is hoped that by doing so, we may detect anomalies before the CSM fails entirely, allowing us to postpone the latter.

Description of the Observations: Observe the dark Earth in F153M exactly as we have been doing for years.

Is this the continuation of previously approved program? Yes, Cycle 21's 13588.