Cycle 20 Calibration Plan

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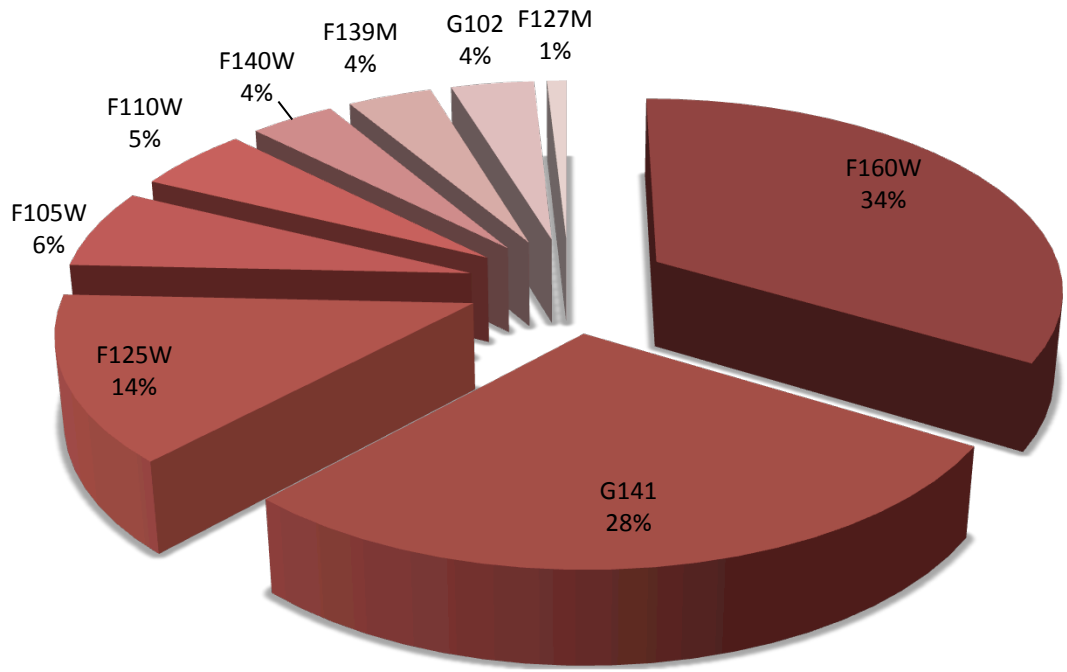
WFC3 Usage

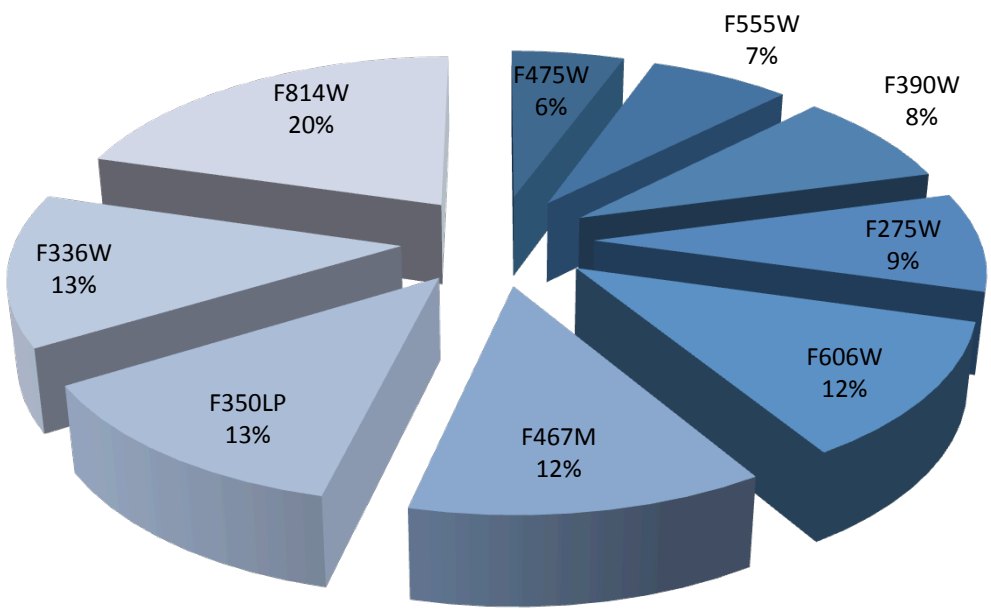
WFC3 is extremely successful because of its:

- 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 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%
Cycle 20	36%	64%	80%	20%

Summary of the Observations





- More than 30% of the IR exposures are acquired with GRISMS;
- 14 out of the 15 IR filters will be used in CY20;
- There is a request for 43 of the 62 UVIS filters;
- 43% of the UVIS exposures will be in the U and UV range.
- 44% of the UVIS exposures will use post-flash

Calibration Highlights for Cycle 20

- Improving precision
  - Photometric: CTE, IR flats, dynamic range
  - Astrometric: spatial scans for <25 micro arc second, DGEO files
  - Grism -1 order
- Enhancing UV calibrations
  - Improved flat fields, Post-Flash and CTE correction
- Understanding WFC3 better
  - IR Persistence
  - IR Blobs and CSM
  - Anomalous QE in CCD Pixels
- Monitoring the instrument
  - Throughput, gain, hysteresis, bad/hot pixels, filters transmission, blobs, Grism calibrations, CTE decline, Post-Flash stability
  - Reference files: Bias, Darks, Linearity, CTE Traps

Proposed Program

Program Title	Ext. Orbits	Int. Orbits		Program Title	Ext. Orbits	Int. Orbits
UVIS Anneal	0	107		WFC3 contamination & stability monitor	11	0
UVIS Bowtie monitor	0	130		WFC3 UVIS & IR photometry	16	0
UVIS CCD daily monitor	0	805		UVIS Grism: Flux calibration	2	0
UVIS CCD gain stability	0	10		UVIS Grism: Wavelength calibration and stability	2	0
UVIS post flash monitor	0	64		IR Grism: Flux/trace calibration and stability	2	0
IR Dark monitor	0	120		IR Grism: Wavelength calibration and stability	2	0
IR linearity monitor	3	9		IR Grism -1 Order calibration	7	0
IR gain monitor	0	16		UV L-Flats via Spatial Scans	8	0
Guard Darks for MCT Programs	0	80		UVIS Flat Field Validation	3	0
UVIS CTI monitor (EPER)	0	24		CCD Anomalous QE pixels	0	24
UVIS CTE monitor (star cluster)	9	0		UVIS Internal Flats	0	20
Characterization of UVIS traps with CI	0	122		IR Internal Flats	0	30
Line 10 CI bias to support a GO program	0	60		IR Earth Flats	0	100
IR persistence behaviors as a function of saturation time	0	72		UVIS & IR Geometric Distortion Calibration	5	0
IR persistence model tests	0	40		High Precision Astrometry	13	0

Total external orbits = 83
Total internal orbits = 1833

PART 1/2

Comparison between the executed CY19 and the proposed CY20 calibration plans.
Programs in blue were executed during CY19, but will not be executed in CY20.

Program Title	CY20 ext	CY20 int	CY19 ext	CY19 int
UVIS Anneal	0	107	0	91
UVIS Bowtie monitor	0	130	0	130
UVIS CCD daily monitor	0	805	0	730
UVIS CCD gain stability	0	10	0	13
UVIS post flash monitor	0	64	0	0
UVIS CI	0	0	4	50
Guard Darks for MCT programs**	0	80	0	150
IR Dark monitor	0	120	0	235
IR linearity monitor	3	9	6	18
IR gain monitor	0	16	0	16
UVIS CTI monitor (EPER)	0	24	0	24
UVIS CTE monitor (star cluster)	9	0	13	0
Characterization of UVIS traps with CI	0	122	0	90
Line 10 CI bias to support a GO program	0	60	0	0
IR persistence behaviors as a function of saturation time	0	72	9	67
IR persistence model tests	0	40	0	0
WFC3 contamination & stability monitor	11	0	17	0
WFC3 UVIS & IR photometry	16	0	16	0
IR asterisms & cluster	0	0	2	0
WFC3 PSF wings	0	0	6	0
Total	**83**	**1833**	**123**	**1869**

PART 2/2

Comparison between the executed CY19 and the proposed CY20 calibration plans.
Programs in blue were executed during CY19, but will not be executed in CY20.

Program Title	CY20 ext	CY20 int	CY19 ext	CY19 int
IR Grisms: Flux/trace calibration and stability	2	0	8	0
IR Grisms: Wavelength calibration and stability	2	0	8	0
IR Grisms -1st order calibration	7	0	0	0
UVIS Grism: Flux calibration	2	0	3	0
UVIS Grism: Wavelength calibration and stability	2	0	3	0
UVIS spatial sensitivity	3	0	10	0
IR spatial sensitivity	0	0	4	0
UVIS Bright Earth flats	0	0	0	20
UVIS&IR moonlit flats	0	0	0	50
UVIS internal flats	0	20	0	20
Anomalous QE pixels**	0	24	0	8
IR internal flats	0	30	0	33
UVIS flare wavelength dependence	0	0	2	0
UVIS+IR spatial scan for flats	8	0	6	0
UVIS & IR Geometric distortion	5	0	2	0
Bias, Dark and CI for binned mode	0	0	0	9
WFC3 postflash charaterization	0	0	2	15
High Precision Phot. and Astro. in Spatially Scanned UVIS Data	0	0	2	0
High Precision Astrometry	13	0	0	0
IR dark Earth flats	0	100	0	100
Total	**83**	**1833**	**123**	**1869**

UVIS Detector Monitors

To monitor the health of the UVIS channel we ask for 1161 internal orbits divided as follow:

1. 107 internal orbits (the cadence has been synchronized with the other HST instruments) to perform an anneal every month
   - Impact reduced starting Spring 2012 using UVIS only ANNEAL
   - Includes transition to Post-Flashed darks
2. 130 internal orbits to mitigate the hysteresis (bowtie) effect via a series of unsaturated and saturated int-flats.
3. 850 internals to perform a daily monitoring of the CCDs behavior using a series of dark and biases.
   - Provide updated darks and hot pixel maps
   - Cycle 20 see transition to Post-Flashed darks (increase in orbits)
4. 10 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.
5. 64 internal orbits to monitor the stability of the post-flash LED with time

WFC3/UVIS Anneal

Number of external orbits: 0 **Number of internal orbits: 107**

Goals: Perform regular anneals to repair hot pixels and acquire internal images to assess the procedure's effectiveness. Internal exposures are also used to 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 from other instruments (one instrument/week). Internal biases 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. A bowtie visit is included, performed immediately after the anneal, to provide a 'fixing' image and verify that any hysteresis has been successfully quenched.

This is a continuation of 12687 with the addition of some extra internals for the first 4 iterations in order to take both post-flashed and un-flashed darks. Once the methodology can be confirmed, the program would transition to post-flashed darks only.

Orbits required: 107 = 13 iterations * 7 nominal orbits (2 orbits bias/dark before, and 7 orbits after each anneal, + anneal itself [counted as 1 orbit] + 1 bowtie visit + 1 IR dark after every anneal)
+ 4 iterations * 4 extra orbits (2 orbits darks before, and 2 orbits after each anneal)

WFC3/UVIS Bowtie Monitor

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

Goals: Assess and quench any hysteresis, or QE offset, in the UVIS detector.

Description of the observations: Three 3x3 binned internal calibration subsystem flafields are taken every three days: an unsaturated, saturated, and unsaturated exposure, in that order. The images in each visit provide a check for hysteresis before and after the QE is pinned or neutralized by the saturated flatfield. The total visit length, including image readout, is about 500 sec.

Orbits needed: 1 orbit every 3 days for the duration of the cycle requires 122 orbits plus 8 orbits to serve as on-hold contingency visits (e.g., for recovery from a saving event).

WFC3/UVIS CCD Daily Monitor

Number of external orbits: 0 **Number of internal orbits: 805**

Goals: Monitor the behavior of the UVIS CCDs with a daily set of bias and dark frames. These data will be used to generate bias and dark reference files for CDBS, which are used to calibrate all WFC3/UVIS images. Transition from the present un-flashed mode to the new post-flashed mode, which should give better removal of hot pixels as CTE continues to increase.

Description of the observations: We will normally perform either 1 or 2 visits per day, with a 4-day rotation:
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

During a 3 month period we will transition from the present un-flashed exposures to exposures using the new post-flash capability. During this transition we will double the number of visits per day, and obtain duplicate sets of un-flashed and post-flashed exposures. This will allow us to optimize flashing of the calibration files, and gain experience generating reference files from the post-flashed exposures, while minimizing the risk to calibration of GO observations. It will also allow observers time to test and respond to the new calibration methods.

This is a continuation of programs 11905, 12342, and 12689.

UVIS Gain Stability

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

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

Description of the observations: Observations consist of 8 pairs of full-frame, unbinned, nominal gain internal calibration subsystem flatfields. Images are taken at a variety of exposure levels to provide a mean-variance measurement of the gain. Two epochs, 5 orbits each, are requested, to be taken ~6 months apart.

UVIS post-flash monitor

Number of external orbits: 0 **Number of internal orbits: 64**

Goals: The primary goal of this program is to monitor the post-flash LED's output and illumination pattern over time. An initial baseline sample to confirm linearity and stability of levels is obtained early in the cycle followed by regular monitoring of a small subset of those modes.

Description of the observations: More than 90% of the flash levels available to outside observers require the use of low current (the rest are at medium) so the emphasis will be on low current plus some medium. Nevertheless, in order to have an effective baseline for future cycles, a small number of high current exposures are required as well. After these initial exposures, acquired over the first ~month of the cycle, monitoring is done at a cadence of every week, tapering to every other week.

Orbits needed: total of 64 internal orbits

30 for baseline in first month (22 orbits low current + 5 medium + 3 high)
24 one orbit per week for 6 months of monitoring
10 one orbit every other week for 5 months of monitoring

IR Detector Monitors

To monitor the health of the IR channel we ask for 216 internal and 3 external orbits, divided as follow:

1. 120 internal orbits to obtain IR dark calibration files. The number of orbits is dictated by the observing modes requested by GOs. This program has been reduced by half compared to previous cycles because of the stability of the IR darks.
2. 3 external (low and high signal ramps of 47 Tuc) and 9 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. 80 internal orbits will be used to collect guard darks for MCT programs

IR Dark Monitor

Number of external orbits: 0 **Number of internal orbits: 120**

Goals:

- Obtain IR dark calibration files necessary to support Cycle 20 Observations
- Obtain IR dark calibration files necessary to continue the monitoring of dark current and hot pixels

Description of the observations: In order to produce the best quality and most current composite dark calibration files for cycle 20 external observations, Full-frame and subarray IR dark calibration observations must be taken on a regular basis. These observations will also be used to monitor the overall stability of the dark current. In addition, the longest observations will also be used to monitor the stability of hot pixels.

As found by Hilbert and Petro (2012) in WFC3 ISR 2012-11, the dark current has remained basically unchanged since launch. The stability of the dark current has allowed us to reduce the number of requested internal orbits by 51% compared to the cycle 19 IR dark monitor. The dark current of course, should still be monitored across all aperture size/sample sequence combinations used by Cycle 20 observers, just at a reduced cadence.

WFC3/IR Linearity Monitor

Number of external orbits: 3 **Number of internal orbits: 9**

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 current exposure. A short, low S/N flat also precedes each intflat, to ensure the tungsten lamp has reached a steady state for the linearity observation.

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 12696.

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 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 program 12697.

WFC3/IR Guard Darks in support of MCT Programs

Number of external orbits: 0 **Number of internal orbits: 80**

Goals: Continuation of existing practice to obtain darks prior to MCT visits.

Description of the observations: Although the IR persistence calibration should now be sufficient for essentially all GO observations, we propose to continue the practice of obtaining guard darks prior to MCT deep survey visits which use the IR channel. At this point, the primary motivation is consistency over this multi-cycle program.

CTE Characterization and Calibration

This part of the calibration program requires 9 external and 206 internal orbits.

In Cycle 20, GOs will have 2 way to mitigate CTI effects: post-flash and Anderson's correction algorithm. In order to do this we need:

1. 24 internal orbits will be used for a monthly measurement of the CTI via Extended Pixel Edge Response (EPER) continuing existing trending.
2. 9 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. 122 internal orbits with charge-injected bias to monitor the length of the CTI trails. This information will be used as an input for the Anderson's algorithm.
4. 60 internal orbits with charge injected bias to support the single remaining GO program using CI.

Title:WFC3/UVIS Internal CTI Monitor (EPER measurements)

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

Goals:

1) Measurement of the WFC3/UVIS CCD detector Charge Transfer Inefficiency (CTI) via the EPER (Extended Pixel Edge Response) method using tungsten lamp flat field exposures;
2) Establishment of CTE losses over time;
3) Continuation of the multi-cycle CTE monitor program

Description of the observations:

The program consists of internal tungsten lamp flat field observations with short exposures through three filters F390M, F390W and F438W with different illumination levels of 200, 400, 800, 1600 and 5000 electrons. These observations will be used to monitor the CTE detector over time, by measuring the profiles into trailing over-scan region (EPER - extended pixel edge response), as described by Kozhurina-Platais (ISR-WFC3-2009-10; 2010, and in "HST Calibration Workshop"; ISR–WFC3-2011). This program is a continuation of the EPER monitor carried out during cycles 17, 18, and 19. Orbits required: 24 (= 2 orbits every 3 months).

UVIS External CTE Monitor: Star Clusters

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

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

Description of the observations: Continuation of the CTE monitoring programs, with modifications to sample background levels and test the new post-flash mode as an instrument for CTE mitigation.

Exposures of NGC 6791 and NGC 104 (47 Tuc) in F502N (zero background) to continue monitoring of maximum CTE in different field densities. Long exposures, dithered by 2000 pixels in detector Y, to measure absolute CTE. Few short exposures as fillers at ends of orbits for long-short flux ratio tests.

The F606W exposures from previous programs are dropped; instead, we will obtain different background levels through post flash mode, with finer and well controlled steps in background level.

Orbit use: 1 orbit for NGC 6791, 2 for 47 Tuc (5 non-zero background levels), -> 3 orbits per epoch, times 3 epochs: 9 orbits total.

Additional, special calibrations taken in Cycle 19 (CAL/WFC3 12692) were exploratory and will not be repeated in the current Cycle 20.

Characterization of UVIS traps with Charge-Injection

Number of external orbits: 0 **Number of internal orbits: 122**

Goals: The program will identify and monitor the UVIS trap growth via charge-injected biases (Anderson model).

Description of the observations: We request 122 internal orbits to monitor the growth of UVIS traps. Charge-injected biases will be acquire every 3 days. We will alternate between line 17 and line 25 charge-injected mode.

This is a continuation of CY19 program 12784

Line 10 CI bias to support a GO program

Number of external orbits: 0 **Number of internal orbits: 60**

Goals: The program supports the Cycle 19 GO science program using charge injection (CI).

Description of the observations: Line 10 CI biases will be acquired to support Cycle 19 GO program which is using charge injection and has already completed 10 visits. The remaining 6 visits will be acquired between Nov 2012 and Feb 2013. We ask to modify the phase 2 of this proposal so that the calibration data will be acquired with the GO program. We estimate ~60 orbits to support this program.

Characterization of IR Persistence

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

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

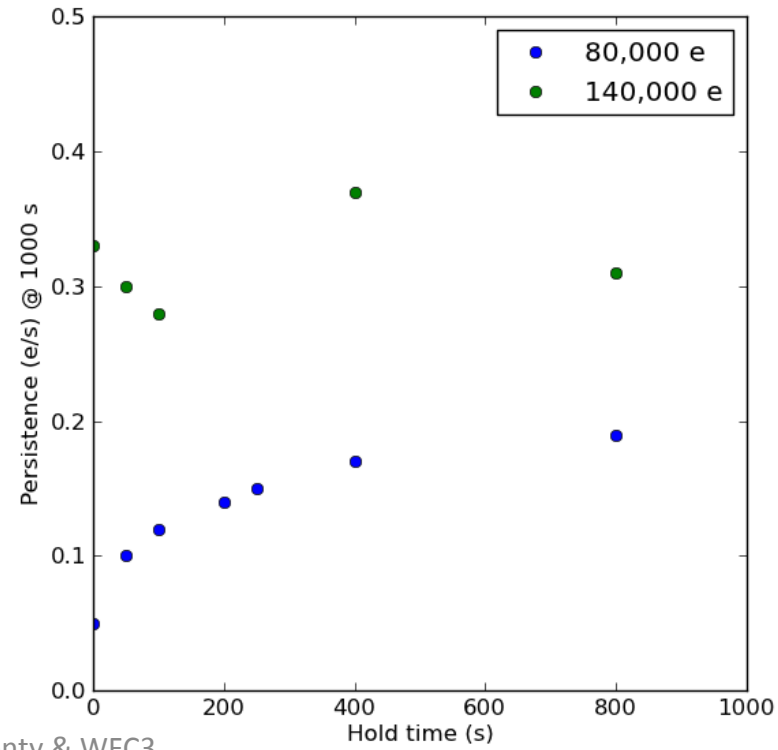
Persistence behavior as a function of saturation time

Number of external orbits: 0 **Number of internal orbits: 72**

Goals: Persistence is a function not only of the maximum value to which an IR pixels is saturation, but also the time it is saturated. We want to better characterize how the time a pixels is saturated affects persistence, so that this can be incorporated into the persistence model

Description of the observations:

- This program is an expanded version of a portion of the Cycle 18 Calibration program. We will use special commanding to turn off the calibration lamp at the appropriate time within a multiaccum. This effective holds the pixels at a certain saturation level from lamp turnoff to the end of the exposure. We will follow each tungsten lamp exposure for a series of darks lasting 2000 seconds after the tungsten lamp exposure. We propose to observe 6 levels and 6 delays, so the program would require 36 visits. The internals are each 2 orbits long → 72 orbits



Persistence model tests

Number of external orbits: 0 **Number of internal orbits: 40**

Goals: Obtain darks after GO observations to test the persistence model in practical situations

Description of the observations:

- Darks will be attached to GO visits of selected GO programs that will cause persistence. We were unable to execute a similar program in cycle 19 because we attempted to attach the parallels late in the planning process. We propose here to modify the Phase IIs of selected GO programs (with STScI PIs) so that the darks are scheduled with the program. We would like to attach follow-on darks to 20 visits and follow the decay in persistence for 2 orbits → 40 visits

WFC3 Photometric performance

27 external orbits will be used to:

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

WFC3 Contamination and Stability Monitor

Number of external orbits: 11 **Number of internal orbits: 0**

Goals: Periodically measure the photometric throughput of WFC3 during the cycle 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 is the white dwarf spectrophotometric standard GRW+70d5824, one orbit per iteration. The chosen cadence is deliberately out of phase with the monthly anneals in order to sample the phase space. Each iteration of the monitor will obtain subarray observations of the standard star in a subsample of filters in both UVIS and IR. A single orbit allows sampling of ~5 filters in each of amp A and C, plus several IR filters, along with the IR & UVIS grisms and the necessary reference images.

Orbits required: 11 = 1 orbits every 5 weeks for the duration of the cycle, reduced from the 17 orbits used during the previous cycle.

WFC3 UVIS and IR Photometry

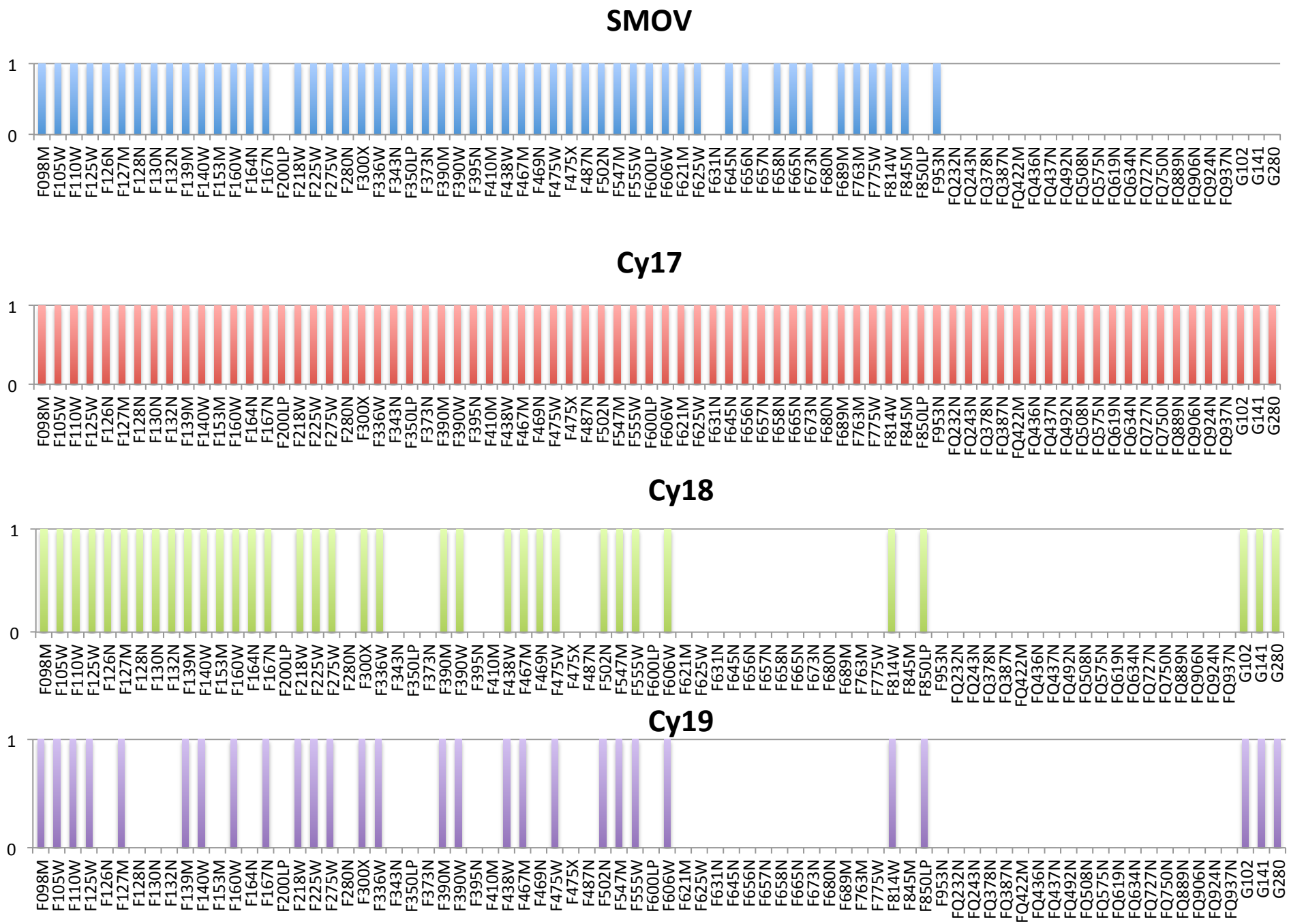
Number of external orbits: 16 **Number of internal orbits: 0**

Goals: This program monitor changes in filter transmission over the area of the detectors. This program builds and extends Cycle 19 Programs 12698 and 12699, Cycle 18 Programs 12334 and Cycle 17 Programs 11903 and 11926. The last time all the filters were checked was Cycle 17 (see plot next slide)

Description of the observations:

WFC3 UVIS and IR:

Observations of stars GD153 and P330E are obtained in subarrays in two UVIS amplifiers and two quadrants of the IR detector to monitor changes in the filter transmission in all the UVIS and IR filters. It is expected that is program will be repeated in Cycle 21 on the other two quadrants of the detectors. This monitors spatial variations in the performance of the filters, changes in bandpass (via the use of stars of different colors), and changes in total transmission. In addition, over two Cycles this will repeat the Cycle 17 calibration of all of the Quad Filters.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GRISM Calibration

We request a total of 15 external orbits to:

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

Programs 1-4 monitor the calibrations already achieved in Cycle 17-19; Program 5 is required to complete the precision calibration of Vega and enable the -1 order for science observations.

UVIS Grism flux stability monitor

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

Goals: Verify the stability of the flux calibration in both the UVIS chips

Description of the observations: The wavelength calibrator GD153 will be used to verify the stability of the wavelength calibration in both the UVIS chips. Three pointings per chip are required.

UVIS Grism wavelength stability monitor

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

Goals: Verify the stability of the wavelength calibration in both the UVIS chips

Description of the observations: The wavelength calibrator VR14 will be used to verify the stability of the wavelength calibration in both the UVIS chips. Three pointings per chip are required.

IR Grisms flux stability Monitor

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

Goals: Verify the stability of the flux calibration for both G102 and G141

Description of the observations: The flux calibrator GD153 will be used to verify the stability of the flux calibration for both the IR grisms in three positions over the detector.

IR Grisms wavelength stability monitor

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

Goals: Verify the stability of the wavelength calibration for both G102 and G141

Description of the observations: The wavelength calibrator VY-22 will be used to verify the stability of the wavelength calibration for both the IR grisms in three positions over the detector.

Wavelength and Flux Calibration of the -1st orders of the WFC3 IR Grisms

Number of external orbits: 7 **Number of internal orbits: 0**

Goals: To provide accurate flux and wavelength calibration for the -1st order of both WFC3/IR grisms, G102 and G141, across the IR array.

Description of the observations:

Flux Calibration and Sensitivity Function: During Cycle 19 we discovered through Program 12336 and two additional GO programs that the sensitivity functions determined for the -1st orders are incorrect. The sensitivity function of the -1st orders were determined during SMOV, as a by-product of the effort to determine the flux calibration in the +1st order. We used one orbit of 12336 with standard star P330E to map the -1st order sensitivity function at several positions along one trace (corresponding to T2 on the figure). These data are just now available and will also enable a cross check between the +1st and -1st orders. We propose to map the sensitivity function in the three tracks with a white dwarf, G191B2B at 12 positions to measure the sensitivity as a function of position on the detector, and a cross check with the +1st orders for tracks T1 and T2. T3 places the +st orders off the detector. For T2 the data from P330E will be combined with that of G191B2B to ensure that the sensitivity function has both high accuracy and high precision.

Wavelength Calibration: Current wavelength calibration of the -1st orders were determined during SMOV, as a by-product of the program to characterize the grisms' +1st order. Also during Cycle 19, as a consequence of analyzing the 12336 Vega data, we found that the wavelength solution differs from that of the +1st order by ~100 Angstrom (or about 2 pixels). This Cycle 20 program will determine the wavelength calibration specifically for the -1st order at the same 12 positions as for the flux calibration program using a standard wavelength calibrator, a PN. We will also provide a cross-check with the +1st order.

Flatfield Calibrations

We request 11 external and 174 internal orbits to monitor and validate WFC3 flatfields divided as follow:

1. 8 external orbits to validate the UV inflight flatfield via spatial scan.
2. 3 external orbits to monitor the UVIS spatial sensitivity and validate the accuracy of the UVIS flats by stepping a spectrophotometric calibration standard across the detector.
3. 24 internal orbits to monitor a population of UVIS pixels with anomalous QE.
4. 20 internal orbits to monitor the high spatial frequency variations via tungsten lamp in UVIS flats.
5. 30 internal orbits to monitor the high spatial frequency variations via tungsten lamp in IR flats.
6. 100 internal orbits to observe the bright Earth and improve the IR inflight flats. The program also monitors the IR blobs.

WFC3 UV L-flat by Spatial Scans

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

Goals: Obtain a low-frequency flat field in each of two UV filters, F225W and F275W.

Description of the observations: We will observe a UV bright double star with boustrophedonic spatial scans. This program was originally planned as part of program 12713, but we learned in that program that the scans require two orbits instead of the one that we had initially estimated, due to overheads of scanning. Because UV-bright stars are few and far between, even in clusters, the traditional method of obtaining an L-flat, namely taking many large-dithered staring-mode exposures is ineffective in the UV. Using the scanning technique and one double star, we should be able to determine the L-flat in the UV filters F225W and F275W. For each filter, we require two HST orbits for each visit that scans multiple times in X and in Y, and we require two visits with a relative orient difference of 90 degrees. Hence 8 orbits total.

WFC3 UVIS Flat Field Validation

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

Goals: We will step a photometric standard across the detector to measure the spatial stability and verify the accuracy of the new UVIS flat fields. This program will supplement observations obtained in Cycles 17 and 19 in F275W, F336W, F438W, F606W, & F814W. We request 1 additional UV filter (F225W) and a repeat of 1 filter (F606W) to close out the calibration program.

Description of the observations: Initial results indicate that the UVIS flats are accurate to +/- 1% in F336W, F438W, & F814W. The F606W photometry shows variations of +/- 2%, likely due to uncertainties in the shutter repeatability for the short 0.7 sec exposures. To verify the expected 1% accuracy, we propose 1 orbit to repeat the test using a fainter standard (GRW+70 @ 1.5s) to sample a subset of the original detector positions.

The F275W photometry shows a residual 3% QE offset between chips which is not corrected by the flats. Since the QE offset increases with decreasing wavelength, we also expect to find a residual offset in F225W. Additionally, the UV ground flats (F225W & F275W) were obtained warm. A strong 'fish-scale' pattern is evident in both UV flats and is not corrected by the dithered stellar data, which can only model low-frequency structure. The F275W results show spatial variations of +/-2%, likely due to this pattern. We propose 2 orbits to step a different standard star (G191-B2B @ 1.3s) across the detector in F225W to further constrain the amplitude of the 'fish scale' pattern at the inflight operating temperature.

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

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

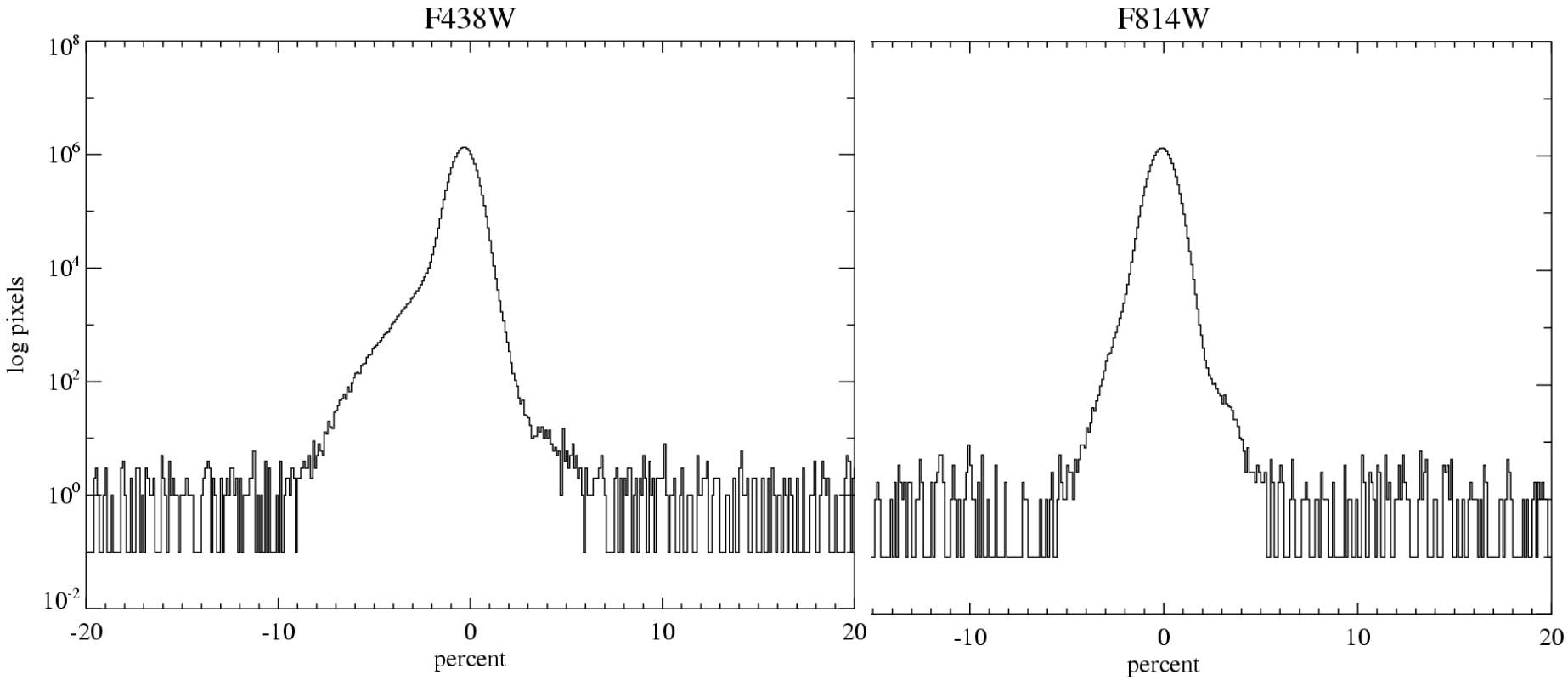
Goals: This program will monitor the population of pixels showing anomalous QE variations between anneals. During each period between anneals, a population of pixels with lowered sensitivity develops which is largely reset by the next anneal, with the effect being larger in the blue than in the red. The pixels of lowered sensitivity appear to be a unique set each cycle, not a subset that turns on and off with the anneal, and are randomly distributed across the detector.

Description of the observations: Over a period of 6 month we will take 4 internal orbits of data each month using the F438W and F814W filters and the Tungsten lamp. These orbits will bracket the monthly anneal. A subarray will be taken at the beginning of each orbit to warm-up the lamp.

All orbits will be non-interrupt to minimize cycling of the limited-lifetime lamp. Exposure times will be chosen to achieve a mean of ~37,000 counts per pixel.

Observations will allow us to track down when the population of anomalous pixels develops in the cycle.

Deviant QE pixels



- Flats in F438W & F814W before & after anneal procedure
- Above plots show histogram of ratio before & after
- Check for pixels showing variability (QE response) arising from radiation damage that anneals out
- Preliminary results show ~3000 pixels in F438W, less in F814W, which are low before anneal and normal after
- No significant overlap with hot pixels, appears to be QE variability

C. Pavlovsky

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 internal flats in all UVIS filters once early in Cycle. We will use 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, 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.

This is a continuation of program 12711.

WFC3 IR internal flats

Number of external orbits: **Number of internal orbits: 30**

Goals: Monitor the stability of the IR pixel-to-pixel sensitivity in all filter elements by taking internal flat fields using the Tungsten lamp.

Description of the observations: We will do bi-monthly monitoring of broad band filters F105W, F110W, F125W, F140W, and F160W. This requires six times three orbits for a sum of 18 orbits. In addition, one full set of all filters are obtained once in the middle of the cycle. This requires 12 orbits for a total of 30 internal orbits. In Cy 19 we used an additional 3 internal orbits to test alternative sampling sequences. This test is not repeated in Cy 20.

WFC3 IR medium band flats with the Dark-Earth

Number of external orbits: 0 **Number of internal orbits: 100**

Goals: Obtain flat fields of superior quality to existing ones for WFC3 IR in selected filters.

Description of the observations: We will observe the dark-Earth when regularly-scheduled science observations are in occultation. The night-sky airglow, primarily from OH molecules, is bright in the IR, e.g. we observed ~100 e-/s/pixel in F153M and half that in F164N or F167N, all without moonlight. Thus, flat fields can be obtained without scheduling around full moon, which limited the number of exposures we obtained in the previous HST cycles under similar programs 11917 and 12709. We estimate approximately five times as many scheduling opportunities without the constraint of observing within +- 3 days of full moon. This suggests that we can obtain this year as many total counts/pixel through all four medium band filters as we had obtained through the wideband filters in a year. We propose to observe the four medium band IR filters with pairs of SPARS25-6 (100-sec) exposures, each of which typically will produce Poisson noise per pixel of 1% rms. If we can obtain 100 visits in the Cycle 20, then we can obtain a Poisson limit of 0.14% (1-sigma, per pixel) flat fields in each of the 4 medium band filters.

Notes: **A)** If the ongoing analysis of the previous programs' wideband IR flats indicates we should re-observe the wideband filters, we can substitute them into this program. **B)** This program could leave persistence on the IR detector in two ways: 1) inadvertently observing twilight-Earth, or 2) observing city lights. We estimate there is a very small probability of city lights creating bright trails. In 62 similar exposures with wideband filters, the single worst case city-light trail had a peak of 30% full well, and a few had 6% full well. With medium or narrow band filters, the risk is even less. **C)** this program has the auxiliary benefit of monitoring blobs from dust accumulation on the CSM mirror. **D)** we refer to these as "internal" orbits because they are external targets observed for only a few minutes per visit, during Earth occultation of science targets.

Astrometric Calibration

We request 18 external orbits to:

1. Monitor the stability of the geometric distortion for both the UVIS and IR channels and add F621M to the set of calibrated filters (the first relatively narrow band in this set) - 5 orbits.
2. Use spatial scans to increase our knowledge of the internal distortions of WFC3/UVIS, better understand and measure the WFC3-FGS calibration, and to quantify the potential of this technique– 13 orbits.

WFC3/UVIS and IR Geometric Distortion Calibration

Number of external orbits: 5 **Number of internal orbits:**

Goals: In the previous cycles studies of the WFC3 geometric distortion have show that the WFC3 geometric distortion is stable and with no evidence for secular changes. However, during each interval of the orbital target visibility, there is a linear trend of the UVIS and IR X & Y axes skew at the level of +/-2 and +/-7 mas, respectively (Kozhurina-Platais et.al 2012, WFC3-ISR-2012-03). Observations of Omega Cen through UVIS F606W and F160W IR filters will be used to derive the skew and scale terms of the geometric distortion and look for any secular change over time and/or during the orbital time of target visibility. Omega Cen will be also observed through the uncalibrated UVIS filter F621M. F621M filter is one of the best available filter for high precision astrometry due to its small wave front errors, negligible fringing, and narrower wavelength range to suppress color dependence. This filter will be used for astrometric spatial scanning program in Cycle 20.

Description of the observations: The observation of Omega Cen through F606W and F160W as a standard filters in UVIS and IR will be observed with the same pointing but with different roll-angle of the OTA in around March 2013.
The set of 8 exposures in F606W and F160W filters are sampled in the allowed full range of roll-angles at the ecliptic latitude of Omega Cen, and ranged approximately from 300 to 360 degree. Four UVIS exposures in 1 orbit will be observed in the following sequence of off-nominal (~360 degree) roll-angles: Orbit #1 - 0,+10,+15,-5 degree. Four IR exposures in 1 orbit will be observed in the following sequence of off-nominal (~360 degree) roll-angles: Orbit #2 - 0,+10,+15,-5 degree. In order to improve the schedule, a small range of roll is allowed at each specific roll angle. The order of the exposures in each orbit is specified by a SEQUENTIAL Special Requirement and the order of the orbits is specified by AFTER Special Requirements. To maintain accurate pointing control, 2-guide star acquisitions are used. If suitable guide stars can be found, the same pair of guide stars are used for all 8 exposures.
In addition a sequence of 9 short F606W and 9 long F621M exposures will be distributed in 3 orbits. Each orbits will have a different orientation. In each orbit a 700 pixel dither pattern will be executed.

Note: Programs 13044, 13049 and 12915 are measuring proper motions using the IR channel, hence the need for the IR astrometric solution monitoring.

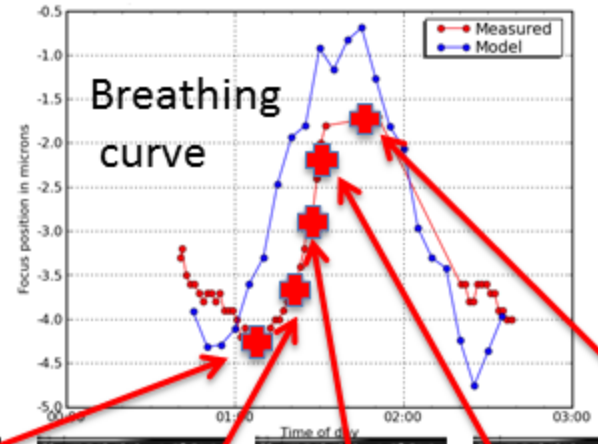
High Precision Astrometry with Spatial Scanning

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

Goals: This program uses the enhanced astrometric precision enabled by spatial scanning to calibrate remaining obstacles to reaching <<40 micro-arc second astrometry (<1 milli-pixel) with WFC3/UVIS by 1) improving geometric distortion 2) calibrating the effect of breathing on astrometry 3) calibrating the effect of CTE on astrometry, 4) characterizing the boundaries and orientations of the WFC3 lithograph cells.

Description of the observations: We will observe an open cluster, M35, which has multiple stars with 11<V<16 mag, the optimal brightness range for high S/N spatial scanning calibration. The position of M35 allows for observations separated by a few days with a 180 degree roll, and a greater leverage on geometric distortion. We obtain 5 sequential 350 second scans (in the Y direction) per orbit in F606W, designed to measure the variation in astrometry due to orbital breathing (typically a 3 micron, monotonic change during the orbit) followed by another such orbit to measure the repeatability at similar breathing positions. These 2 orbits are repeated at few days later for the same field but with a 180 degree orientation change to calibrate static, residual errors in the present geometric distortion maps. The fields are selected to contain ~25 stars with 11<V<16 with positions that would scan over the lithograph cell boundaries to measure the X-position cell discontinuities. The total cost is 4 orbits. The observations are repeated for a second filter (TBD for filter choice), to distinguish the origin of the previous calibrated astrometric terms, from the detector plane and/or filter substrate. One orbit obtain spatial scans in the X-direction with and without a postflash to measure 1) the effect of CTE on the Y-position and to measure the lithograph cell boundaries to measure the Y-position cell discontinuities. We include in the M35 observations a re-calibration of the WFC3-FGS alignment and validate this over a significant variation in breathing and other possible orbital disturbances (4 orbits).

Scheme



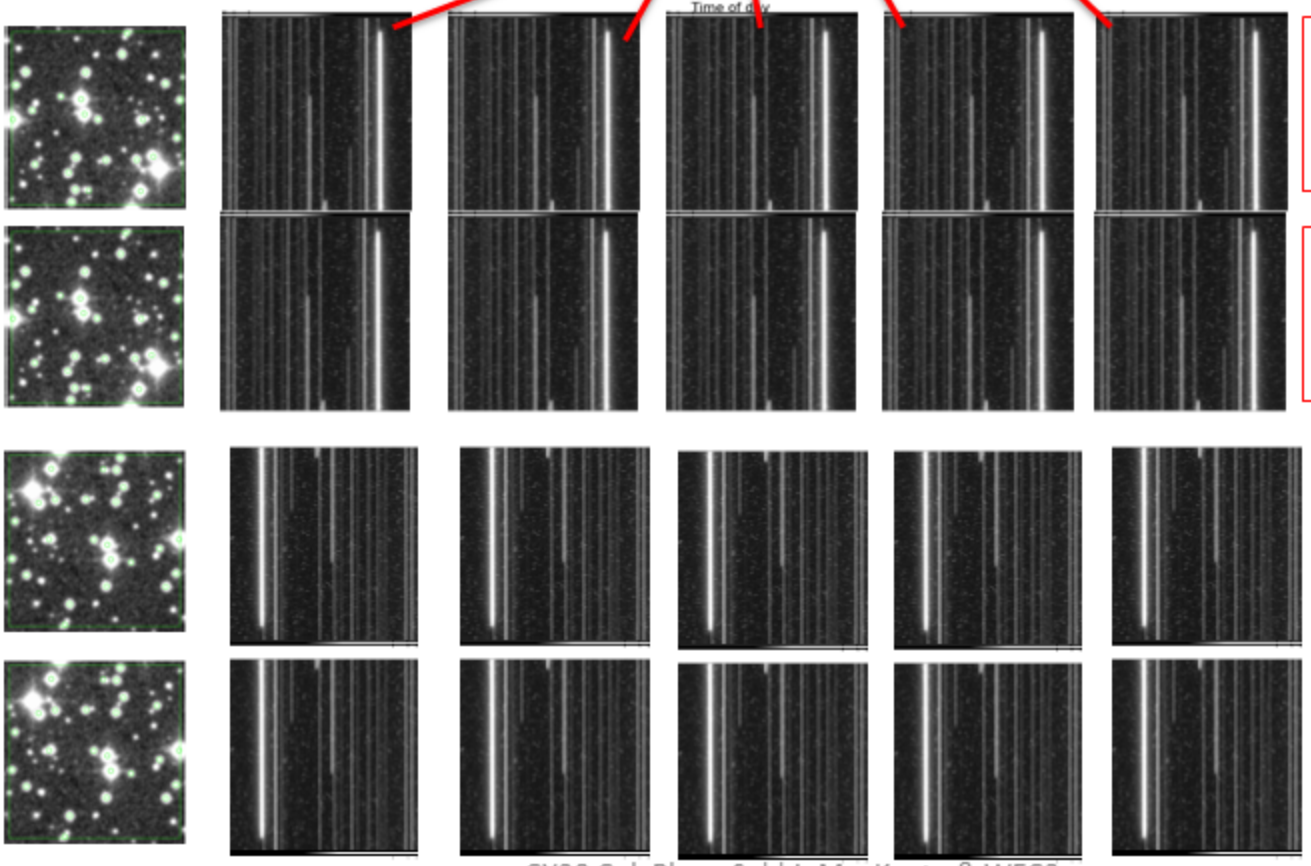
Orbit

1

2

3

4



Purpose

X-position vs. breathing, lithograph cells, σ~1 milipix

X-position astrometry Vs. breathing, repeatability

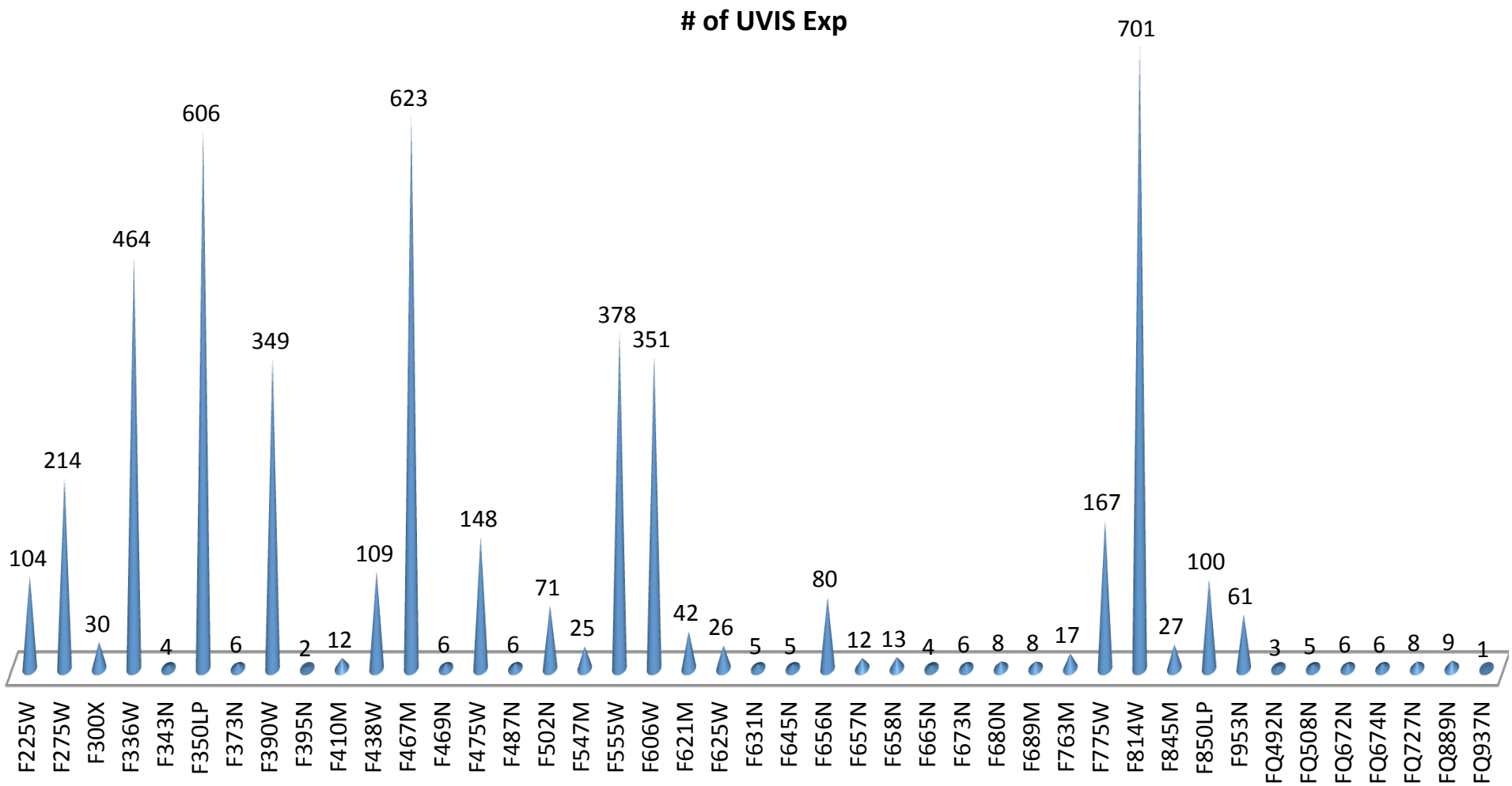
Geometric distortion independent of breathing

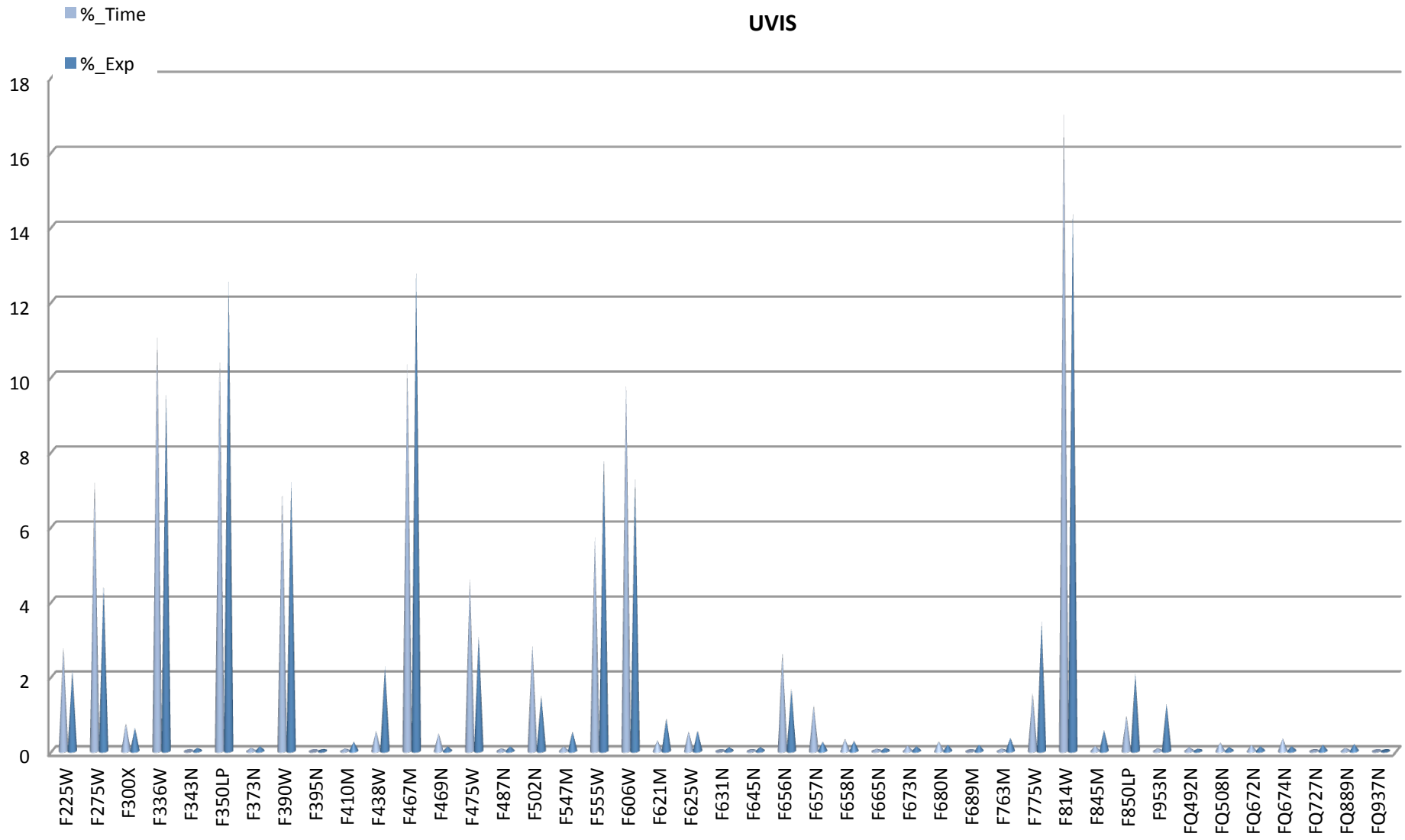
Geometric distortion independent of breathing, repeatability

First iteration with F606W, second with TBD filter, separates filter vs detector distortion

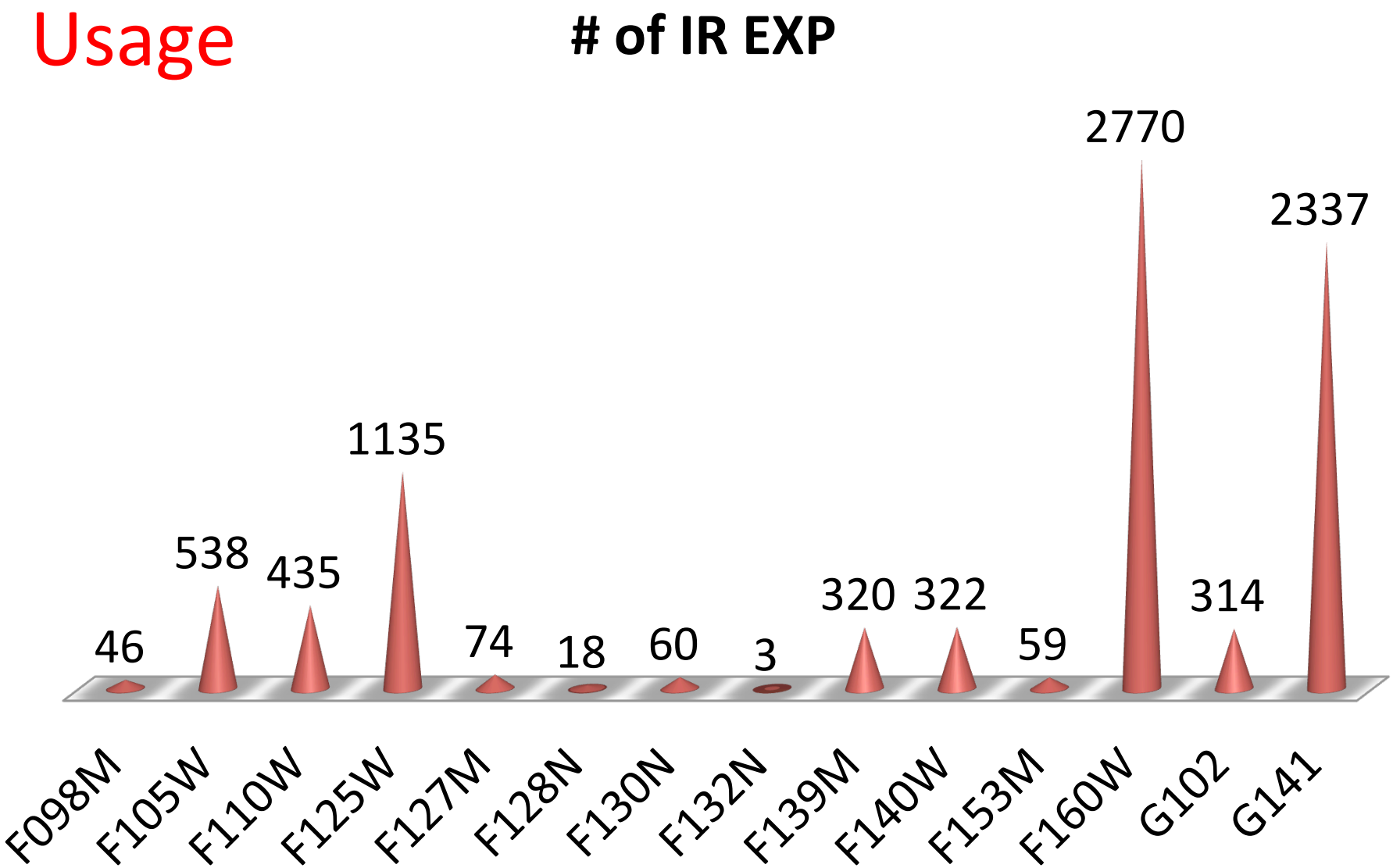
SUPPORTING MATERIAL

CY20 UVIS Filter Usage




UVIS
%_Time
%_Exp
18
16
14
12
10
8
6
4
2
0
F225W
F275W
F300X
F336W
F343N
F350LP
F373N
F390W
F395N
F410M
F438W
F467M
F469N
F475W
F487N
F502N
F547M
F555W
F606W
F621M
F625W
F631N
F645N
F656N
F657N
F658N
F665N
F673N
F680N
F689M
F763M
F775W
F814W
F845M
F850LP
F953N
FQ492N
FQ508N
FQ672N
FQ674N
FQ727N
FQ889N
FQ937N

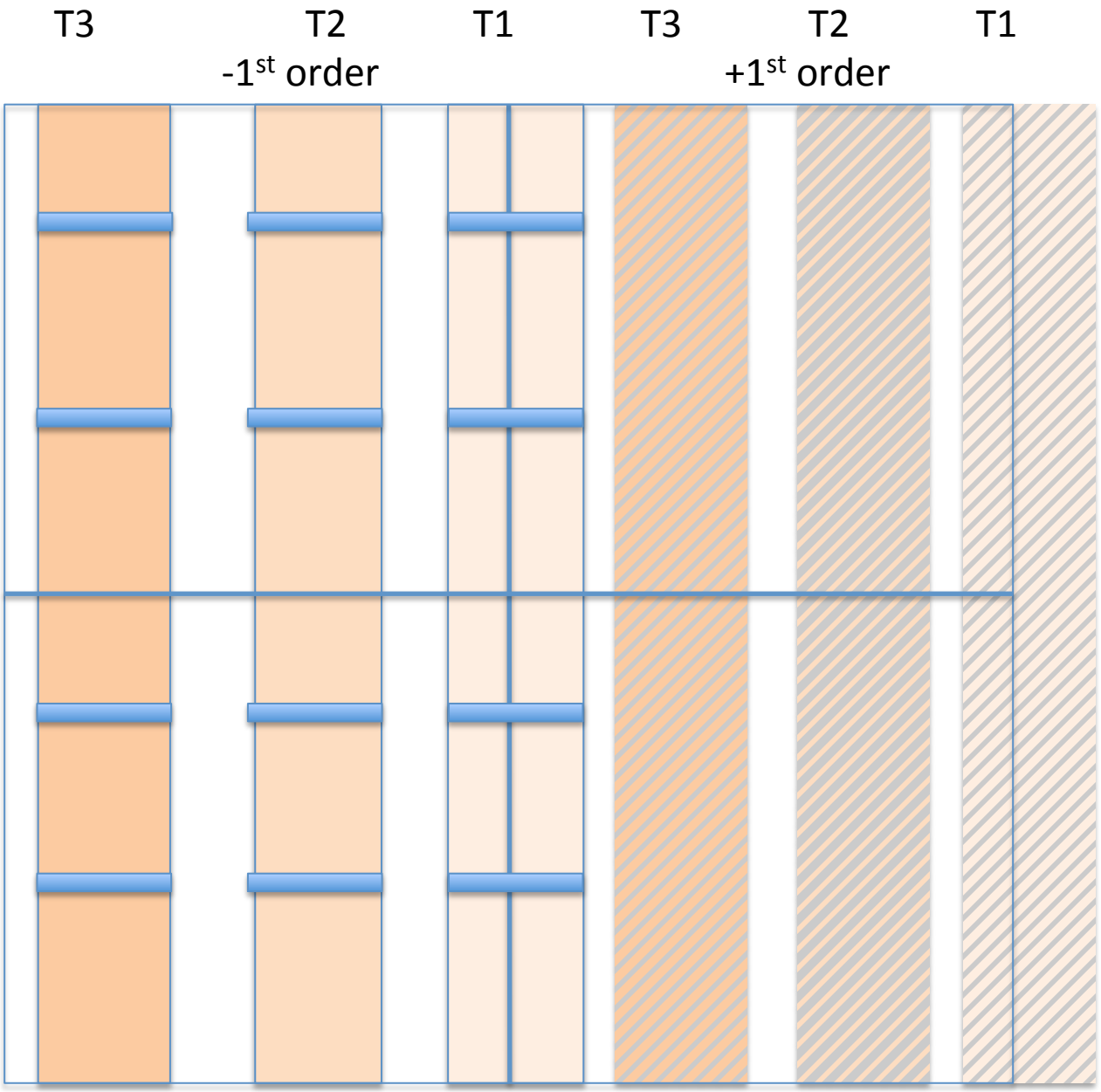
CY20 IR Filter Usage



DETAILS OF -1 ORDER GRISM CALIBRATION

Description of the observations: We will obtain SNR=100 spectra of G191B2b in the -1st orders at 12 positions on the IR array. These positions are chosen to match the location of -1st order spectra in Cycle 19 GO programs and for the Cycle 19 "Vega" calibration program.
G191B2B brightness: V=11.6mag
Average exposure time to obtain SNR=100 per resolution element = 600 seconds
Number of positions =12
Number of Grisms = 2
Total number of spectra = 24
➔ 14,400 seconds + readout overheads
Number of direct images = 2
Exposure time per image = 5 seconds
➔ 10 seconds+readout overheads
Total number of external orbits = 5.

We will obtain high signal to noise spectra of a planetary nebula in the -1st orders at 12 positions with the IR G141 grism, and 10 positions with the IR G102 grism. G102 is less often used. These positions are chosen to match the location of -1st order spectra in Cycle 19 GO programs and for the Cycle 19 "Vega" calibration program.
PN Vy 2-2 or PN IC 5117:
Average exposure time to obtain ~10 to 1000 e- at line peak = 203 seconds
Number of positions =12
Number of Grisms = 2
Total number of spectra = 22
➔ 5791 seconds including readout and acq. overhead
Number of direct images = 12
Exposure time per image = 3 seconds
➔ 24 seconds+readout overheads
Total number of external orbits = 2



Dark blue rectangles mark the 12 positions of G191B2B. Vertical rectangles show Vega's driftscan spectral tracks in the -1st order. Hashed boxes are the positions of the corresponding +1st order tracks. T1 is rightmost possible position for the -1st order.

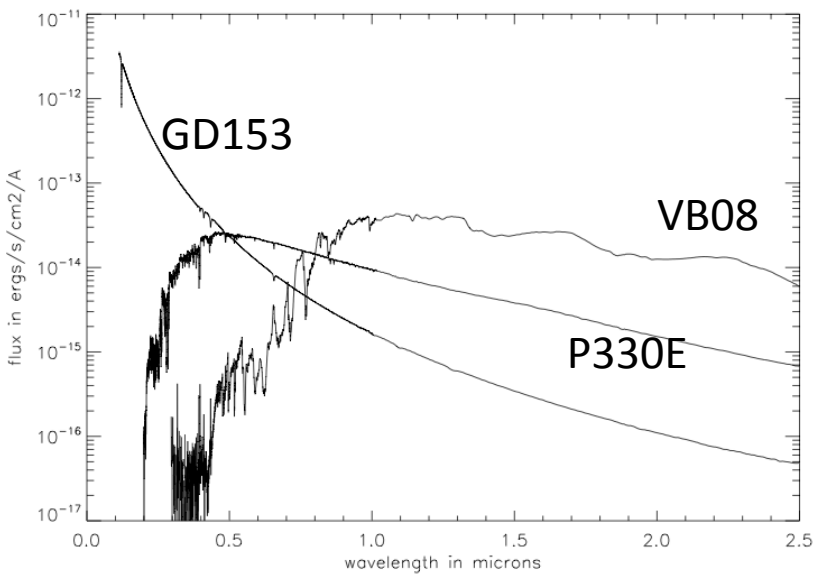
Positions

- POSTARG 1: x position in arcseconds
- POSTARG2: y position in arcseconds

T1		T2		T3	
POSTARG1	POSTARG2	POSTARG1	POSTARG2	POSTARG1	POSTARG2
+62	+50	+42	+50	+15	+50
+62	+20	+42	+20	+15	+20
+62	-20	+42	-20	+15	-20
+62	-50	+42	-50	+15	-50

Amp	A (42 + 5)	B (42 + 5)	C (42 + 5)	D (42 + 5)
GD153	3 / 1835	3 / 2100	3 / 1996	3 / 2155
P330E	3 / 2517	3 /2455	3 / 2737	3 / 2800

Number of orbits / on-target time in seconds
Orbit includes overheads, on-target time does not
2 point dither, SNR=200, minimum exptime = 1 sec



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