WFC3 Cycle 25 Calibration

J. Mack, E. Sabbi, S. Baggett & the WFC3 Team 22 Sept 2017

Routine observations for 21 monitoring programs:

21 programs have the same cadence as Cycle 24 (orbit totals vary slightly due to changing cycle boundaries)

Modified observations for 4 monitoring programs:

UVIS contamination (obtain higher precision using spatial scans)
UVIS shutter monitor – reduced to 1 orbit
IR grisms (2 programs) – reduced to 1 orbit

New calibration for 2 programs:

UVIS Supplemental Photometry: Color Terms & Revisiting M512C Mitigating Persistence for Time-Series Observations

Cycle Boundaries: Nov 6, 2017 - Nov 4, 2018 http://www.stsci.edu/hst/wfc3/calibration/CY25

Orbit Request by Cycle

		External	Internal	
CY25	Monitor New Calibration*	28 31	1508 4	
	Total	59	1512	
Cy24	Monitor New Calibration*	50 19	1522 35	
	Total	69	1557	
Cy23	Monitor New Calibration*	52 46	1511 108	
	Total	98	1619	

- ❖ Shutter= 1i
- Contamination = 20e
- ❖ UVIS Photometry= 8e
- Persistence= 3e+3i

*Cycle 24 New

- **❖** CTE= 2e+15i
- ❖ GRW with STIS= 4e
- Contamination = 6e
- ❖ IR Linearity= 7e
- ❖ Sink pixels= 20i

*Cycle 23 New

- ❖ Persistence= 16e+108i
- ❖ UVIS Distortion= 30e
- ❖ -1st Grism= 2e

^{*}Cycle 25 New

^{**}Calibration from prior cycles may be found at: http://www.stsci.edu/hst/wfc3/calibration

WFC3 CY25 Calibration

- * New for Cycle 25
- + Part of Monitoring in Cycle 24

	ID	PI	Program Title	Ext	Int	ID	PI	Program Title	Ext	Int	
	14978	Baggett	UVIS anneal	0	79	14992	Deustua	WFC3 UVIS & IR photometry	11	0	
	14979	Kurtz	UVIS bowtie monitor	0	132	15398	McCullough	UVIS contamination monitor (staring and scans) *, +	20	0	<u>></u>
CCD	14980- 14982	Martlin	UVIS CCD daily monitor (darks & biases)	0	642	15397	Sahu	UVIS shutter monitoring *, +	0	1	Photometry
UVIS	14983	Khandrika	UVIS CCD un-flashed monitor	0	130	15399	Calamida	UVIS Supplemental Photometry: Color Terms & Revisiting M512C *	8	0	Phc
	14984	Martlin	UVIS post-flash monitor	0	60						
	14985	Fowler	UVIS CCD gain stability	0	18	14993	Pirzkal	WFC3 IR grisms wavelength calibration	1	0	S
	14989	Fowler	UVIS CTI monitor (EPER)	0	12	14994	Pirzkal	WFC3 IR grisms flux/trace calibration	1	0	Grisms
CTE	14990	Fowler	UVIS CTE monitor (star cluster)	8	0	14995	Brammer	WFC3 UVIS grism wavelength calibration	1	0	
	14991	Kurtz	Characterization of UVIS traps with CI	0	36	14996	МсКау	UVIS Pixel-to-Pixel QE Variations via Internal Flats	0	45	
or	14986	Sunnquist	IR dark monitor	0	97	14997	МсКау	UVIS internal flats	0	13	Flats
Detector	14987	Shanahan	IR linearity monitor	0	10	14998	Kurtz	IR internal flats	0	18	Ë
R D	14988	Shanahan	IR gain monitor	0	16	14999	Sunnquist	CSM monitor with Earth flats	0	200	
Persistence	15400	Stevenson	Mitigating Persistence for Time-Series Observations *	3	3	15000	Platais	Astrometric scale monitoring	6	0	Astrometry
Pers											Astr

WFC3 CY24 Calibration

	ID	PI	Program Title	Ext	Int	ID	PI	Program Title	Ext	Int	
	14529	Baggett	UVIS anneal	0	79	14883	Deustua	WFC3 UVIS & IR photometry	11	0	
	14530	Sunnquist	UVIS bowtie monitor	0	134	14815	Baggett	UVIS contamination monitor	14	0	
ССБ	14531 14532 14533	Bourque	UVIS CCD daily monitor (darks & biases)	0	642	14878	McCullough	UVIS contamination with spatial scans *	6	0	Photometry
UVIS C	14534	Khandrika	UVIS CCD un-flashed monitor	0	135	14882	Sahu	UVIS shutter monitoring	2	1	Phot
Ó	14535	Martlin	UVIS post-flash monitor	0	60	14870	Deustua	IR Zeropoint Linearity *	2	0	_
	14536	Martlin	UVIS CCD gain stability	0	18	14871	Deustua & Bohlin	Improving the CALSPEC model for GRW+70D5824 *	4	0	
	14879	Baggett	UVIS sink pixel map update *	0	20						
	14537	Sunnquist	IR dark monitor	0	97	14543	Pirzkal	WFC3 IR grisms wavelength calibration	4	0	ω
Detector	14538	Shanahan	IR linearity monitor	0	10	14544	Pirzkal	WFC3 IR grisms flux/trace calibration	4	0	Grisms
N Det	14539	Shanahan	IR gain monitor	0	16	14545	Brammer	WFC3 UVIS grism wavelength calibration	1	0	U
盗	14868	Riess	Improved Precision, Wavelength Dependence of the IR CRNL *	5	0	14546	Shanahan	UVIS Pixel-to-Pixel QE Variations via Internal Flats	0	51	
	14540	Khandrika	UVIS CTI monitor (EPER)	0	12	14547	Вајај	UVIS internal flats	0	13	53
	14541	Mack	UVIS CTE monitor (star cluster)	8	0	14548	Ryan	IR internal flats	0	18	Flats
CTE	14542	Martlin	Characterization of UVIS traps with CI	0	36	14549	McCullough	CSM monitor with Earth flats	0	200	
	14880	Anderson	UVIS CTE Model Re-Characterization *	0	15	14550	Platais	Astrometry monitoring	6	0	netry
	14881	Anderson	UVIS CTE Pixel-Based Model Evaluation *	2	0						Astrometry

*New in Cycle 23

WFC3 CY23 Calibration

	ID	Program Title	Ext	Int	ID	Program Title	Ext	Int	
	14366	UVIS anneal	0	79	14382	WFC3/UVIS contamination monitor	15	0	>
	14367	UVIS bowtie monitor	0	130	14383	UVIS Shutter Characterization	3	1	netr
S CCD	14368 14369 14370	UVIS CCD daily monitor (dark & bias)	0	637	14384	WFC3 UVIS & IR photometry	11	0	Photometry
UVIS	14371	UVIS CCD un-flashed monitor	0	135	14385	WFC3 IR grisms wavelength calibration	4	0	
	14372	UVIS post-flash monitor	0	60	14386	WFC3 IR grisms flux/trace calibration	4	0	ms
	14373	UVIS CCD gain stability	0	18	14387	WFC3 UVIS grism wavelength calibration	1	0	Grisms
or	14374	IR dark monitor	0	95	14388	-1st grism order calibration in IR grisms *	2	0	
Detector	14375	IR linearity monitor	0	10	14389	UVIS Pixel-to-Pixel QE Variations via Internal Flats Monitor	0	51	
프	14376	IR gain monitor	0	16	14390	UVIS internal flats	0	13	Flats
	14377	UVIS CTI monitor (EPER)	0	12	14391	IR internal flats	0	18	
CTE	14378	UVIS CTE monitor (star cluster)	8	0	14392	CSM monitor with earth flats	0	200	
	14379	Characterization of UVIS traps with CI	0	36	14393	Astrometric calibration of all remaining UVIS filters *	30	0	etry
Persistence	14380	IR persistence: Amplitude Variations*	0	60	14394	Time Dependence of X-CTE & Astrometry	4	0	Astrometry
Pers	14381	IR Persistence: Position Dependent Model *	16	48					

UVIS CCDs

Same cadence as the prior cycle

Monitor the health and stability of UVIS channel via the following calibration:

- Perform an anneal of the detector every month
 79 internal = 6 orbits/anneal * 13 anneals + 1 IR dark contingency
- Mitigate hysteresis (bowtie) by conditioning the detector via a series of unsaturated and saturated internal flats
 132 internal = 122 orbits (1 every 3 days) + 10 contingency for SIC&DH lockups
- Perform daily monitoring of the CCDs using a series of dark & biases. Provide updated darks & hot pixel maps
 642 internal = 91 four-day cycles * 7 orbits/cycle = 637 internal orbits + 5 contingency
- Assess how well post-flash is mitigating CTE with time using a series of unflashed darks
 130 internal = 10 orbits/anneal * 13 anneals
- Monitor the stability of the post-flash LED with time
 60 internal = 12 iterations * 3 orbits (pattern + brightness checks) + 12 (ref files) + 12 contingency
- Verify the gain stability in all 4 UVIS quadrants for each binning mode using internal flats over a range of exposures

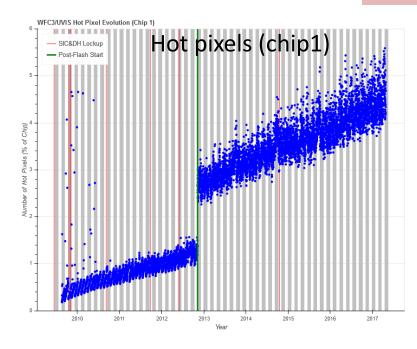
 18 internal = 9 orbits * 2 epochs

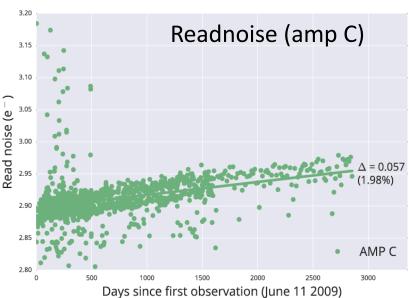
WFC3/UVIS Anneal

Orbits	External: 0 Internal: 79
PI, Co-l's	Baggett, Martlin, Bourque, Khandrika
Purpose	Perform regular anneal procedures to 1) repair hot pixels and 2) acquire internal exposures to assess the anneal's effectiveness as well as produce reference files for the calibration pipeline.
Description	WFC3 anneals are performed every 28 days, a cadence which 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. The Cycle 24 WFC3 anneals have been performed keeping the IR detector cold (IRTEMP=COLD). In Cycle 25, 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.
	79 total based on 13 * 6 + 1. The 13 iterations provide seamless continuity across the cycle boundary. Each iteration requires 6 orbits (2 before/2 after each anneal for biases/darks + 1 for the anneal itself + 1 for the attached post-anneal bowtie visit). There is 1 extra orbit included to cover one IR dark to be taken in the event an original anneal procedure (warming the IR detector) is performed during Cycle 25.
Resources: Analysis	11)arks: "11 ETE: plases: "11 15 ETE: read poise "11 15 ETE
Products	Plots, tables: read noise, dark current, hot pixels. Daily superdarks (CTE-corrected and un-CTE-corrected) and yearly superbiases for calibration pipeline. Data also currently in use for pixel history analysis.
Accuracy Goals	Readnoise to <1%; dark reference files ~2e-/hr rms; bias reference files <1e- rms
Prior Results,	Routine updates to QuickLook monitoring pages. Calibration pipeline superdarks and superbiases. Detector values for Instrument & Data Handbooks. ISR 2016-08 (Dark Calibration); ISR 2017-17, 2015-13 (Read Noise); ISR 2016-01 (Updated Calibration Pipeline for WFC3/UVIS).
Prior Cycle IDs	12343, 12687, 13071, 13554, 14000, 14366, 14529

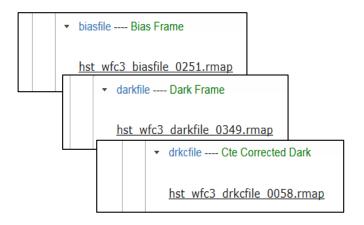
WFC3/UVIS Anneal

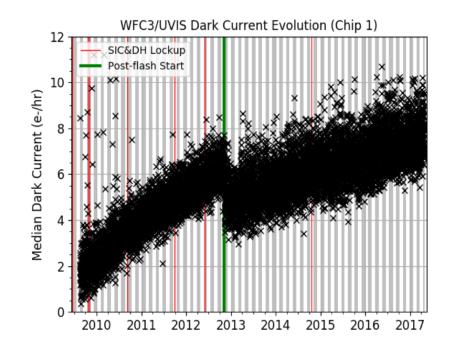
Quicklook Plots https://wfc3ql.stsci.edu/automated_outputs/cal_uvis_make_darks





Reference files for CRDS



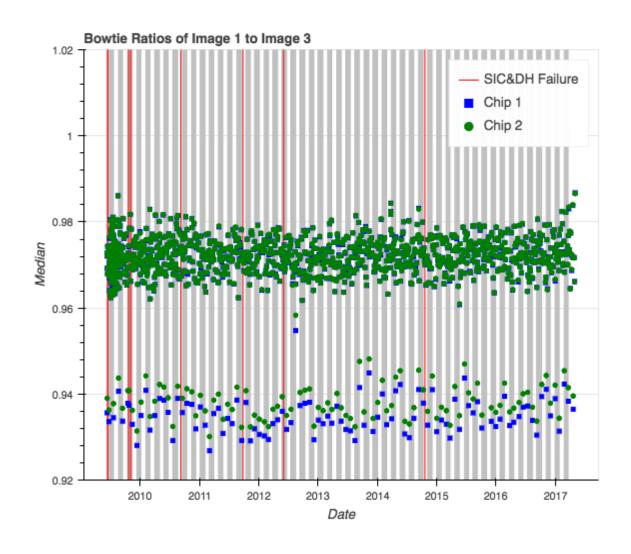


UVIS Bowtie Monitor

Orbits	External:0 Internal: 132 (Decreased from 134 in Cy24 to reflect cadence below)							
PI, Co-l's	Kurtz., Baggett, Sunnquist, Khandrika							
Purpose	uring thermal vacuum testing of internal flatfields, it was discovered that the UVIS detector exhibits casional low-level (~1%) quantum efficiency offsets (i.e. hysteresis) across both chips, an effect later bbed 'bowtie' due to its unique shape in the image ratios. The ground tests also revealed that the steresis could be negated by overexposing the detector by several times the full well amount. Thus, a ulti-cycle 'bowtie monitoring' program was developed to detect and mitigate UVIS hysteresis on orbit. The preceding programs, each visit of this program acquires a set of three 3X3 binned internal tfields. The first image is unsaturated in order to identify hysteresis, the second image is saturated to utralize any QE offsets, and the third image is unsaturated to estimate the hysteresis removal efficiency.							
Description	nternal tungsten flat field images are obtained using the F475X filter. This filter is utilized for (1) its high hroughput, (2) its bandpass (<700nm), which is known to mitigate hysteresis and (3) its status as a low-priority filter for science observations. The three images are assembled into a single visit that is to be executed every 3 days: (1) an unsaturated image used as a check for hysteresis features, (2) a saturated 'QE pinning' exposure that is used to fill traps and mitigate QE offsets, and (3) an additional unsaturated image used to assess the hysteresis removal efficiency. 122 orbits+10 extra for SIC&DH lockups							
Resources: Observations	I hree internal tungsten tlat field images are obtained using the F4/5X filter							
Resources: Analysis	Iratios over time, quantitying the etticiency of the neutralizing exposure, and investigating anomalies							
Products	Ratio of the first to the third image in a set visit. Plot to track the bowtie with time. Condition UVIS detector for science observing.							
Accuracy Goals								
Prior Results, ISRs	ISR 2009-24, ISR 2013-09, ISR 2017-08 (Relative Gain)							
Prior Cycle IDs	14530, 14367, 14001, 13555, 13072, 12688, 12344							

UVIS Bowtie Monitor

Quicklook Plots https://wfc3ql.stsci.edu/automated_outputs/cal_uvis_make_bowtie

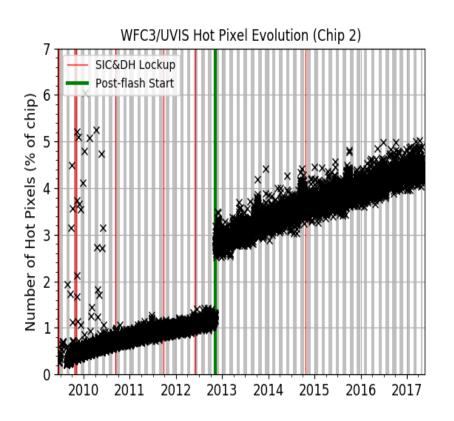


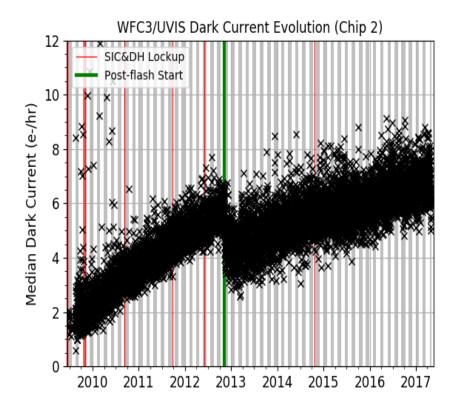
UVIS CCD Daily Monitor A,B,C

Orbits	External: 0 Internal: 642
PI, Co-l's	Martlin, McKay, Khandrika
Purpose	Continuing to 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. These reference files are used to calibrate all WFC3/UVIS images.
Description	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 are post-flashed. A small number of un-flashed internals are requested in a separate proposal. Day1 – 2 visits: one with 2 biases, one with 2 darks Day2 – 2 visits: each with 2 darks Day3 – 1 visit: 2 darks Day4 – 2 visits: each with 2 darks. All non-Day-1-Visit-darks use "no-move" darks (i.e. TARGNAME=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 to avoid overuse of any one.
Resources: Observations	91 four-day cycles * 7 orbits/cycle = 637 orbits internal orbits + 5 contingency orbits = 642
Resources: Analysis	
Products	Dark (*drk.fits, *dkc.fits) and bias (*bia.fits) reference files
Accuracy Goals	
Prior Results, ISRs	ISR 2014-04, ISR 2016-08 (darks), ISR 2015-13 (read noise)
Prior Cycle IDs	12342, 12689, 13073, 13556, 14002/03/04, 14368/69/70, 14531/32/33

UVIS CCD Daily Monitor A,B,C

Quicklook Plots https://wfc3ql.stsci.edu/automated_outputs/cal_uvis_make_darks





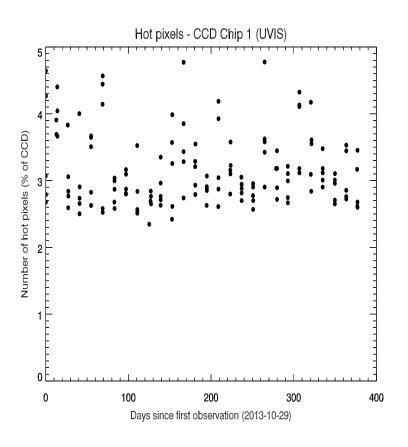
The CTE-corrected hot pixel evolution (left) and the CTE-corrected dark current evolution (right) of WFC3/UVIS chip 2 since the installation of WFC3 on HST. The gray/white regions indicate anneal cycles. The green line is the implementation of post-flashing.

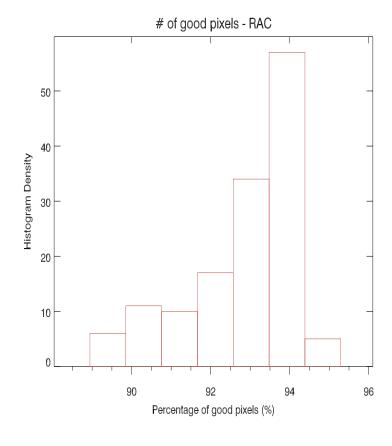
UVIS Unflashed Monitor

Orbits	External: 0 Internal: 130 (REDUCED from 135 in Cy24. Dropped 5 unneeded contingency orbits)								
PI, Co-l's	andrika, Bourque, Martlin								
Purpose	Obtain unflashed darks to monitor how well the post-flash is mitigating CTE and look at the evolution of hot pixel growth								
Description	emporal changes in CTE losses and the efficacy of the post-flash mode are monitored by a series of non-ostflashed WFC3/UVIS darks taken before and after the monthly WFC3/UVIS anneal procedures. A large lumber of internals are taken as part of a daily monitor of warm/hot pixel growth and read noise, owever they are all post-flashed. Thus, a small number of un-flashed internals are required to monitor the changes in CTE losses over with time. These un-flashed internals, in conjunction with the post-flashed ternals, will allow for an assessment of how well the post-flash is mitigating the CTE losses.								
	30 orbits = 13 anneals * 10 orbits per anneal 5 visits pre- + 5 post-anneal, where each visit consists of a single 900s dark)								
Resources: Analysis	0.2 FTE.Analysis of unflashed darks to be completed by PI and CoIs								
Products									
Accuracy Goals	Verifying the post-flash mitigation of CTE losses.								
Prior Results, ISRs									
Prior Cycle IDs	14534, 14371								

UVIS Unflashed Monitor

Results from data obtained between 2013-2015 2017 Khandrika, in prep





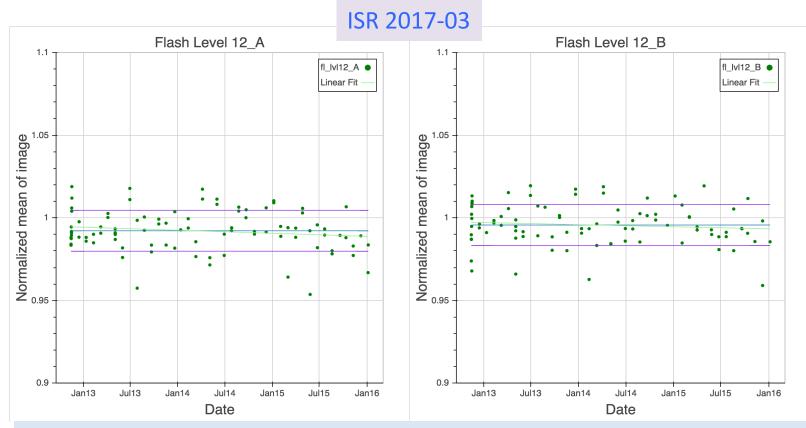
UVIS Post-Flash Monitor

Orbits	External: 0 Internal: 60
PI, Co-l's	Martlin, Khandrika, Kurtz
Purpose	The flux and illumination pattern of the post-flash LED is monitored over time. The data are used to also create a series of post-flash reference files for the calibration pipeline.
	Most observers with low-background (<12e-) data are now using the post-flash (PF) mode in WFC3/UVIS. We propose to continue the monthly monitoring of the lamp characteristics plus sufficient orbits to allow new generation of post-flash CRDS reference files to be created in the future.
Description	Each iteration of the monitor needs 3 orbits – two obtain high S/N flashed full-frames for both shutter blades to check for pattern changes. One obtains a 1kx1k subarray taken at a variety of post-flash levels to check on the brightness stability of the lamp. For the new reference files, 12 orbits are needed. Furthermore, in the event the LED illumination pattern changes more rapidly than expected 12 more orbits would be needed – if the pattern stays stable then they will not be needed.
_	60 orbits = 36+12+12 = 12 months*3 orbits/month (brightness & pattern checks) +12 (new reference file) +12 (contingency)
Resources: Analysis	
Products	Post-flash reference files (*fls.fits)
Accuracy Goals	
1	ISR 2017-13 (FLS reference files), ISR 2017-03 (lamp stability) ISR 2013-12 (flash calibration), ISR 2003-01 (flash vs charge injection to mitigate CTE)
Prior Cycle IDs	13078, 13560, 14006, 14372, 14535

UVIS Post-Flash Monitor –

Results of Post-Flash LED Lamp Stability Study:

A maximum change per year of 0.39% was found, indicating a change of less than 1 e-/pixel over the 3 years since post-flashing began. This investigation has led to the recommendation that users continue using post-flash.



Plot of normalized mean post-flash over time for flash level 12e-/pix for shutter A (left) and shutter B (right). The blue line is the mean of all data; the purple lines indicate the plus and minus one-sigma of the data; the green line is the linear fit of the data. The uncertainties are encompassed in the size of the points and are less than +/- 0.05.

UVIS Gain Stability

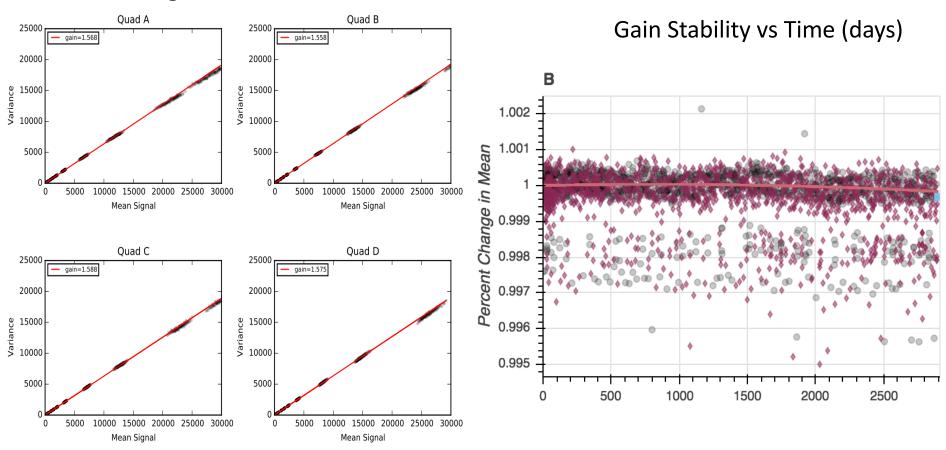
Orbits	External: 0 Internal: 18
PI, Co-l's	Fowler, Martlin, Khandrika
Purpose	Monitor the absolute gain for the nominal detector count.
Description	Observations consist of 8 pairs of full-frame binned (binned $2x2$ and $3x3$) and unbinned internal calibration subsystem flat fields at nominal gain. Two epochs, 9 orbits each, are request to be taken $^{\circ}6$ months apart. Six of these orbits will be for sampling the unbinned mode in order to increase the sampling at the lower signal levels.
1	12 full-frame internal flatfields, and 6 binned exposures ($2x2$ and $3x3$) taken in the F645N filter with the tungsten lamp, with varying exposure times. 18 orbits = 12 months, 2 epochs, 9 orbits per epoch.
	.05 FTE – Analysis to be completed by the PI using the standard mean-variance technique. Reduce any difference in the calibrated images across amplifiers for binned proposals.
Products	Improved gain coefficients for CALWF3.
Accuracy Goals	Measure gain to less than 1%
Prior Results,	ISR 2005-08, ISR 2007-11, ISR 2009-29, ISR 2011-13, ISR 2013-02, ISR 2014-05, ISR 2015-05, ISR 2016-09, ISR 2016-13 The last results in July 2016 (Cy 23) report that UVIS Gain remains constant within 1-2% of Cy 22.
Prior Cycle IDs	11906, 12346, 12690, 13168, 13561, 14007, 14373, 14536

UVIS Gain Stability

Quicklook plots:

https://wfc3ql.stsci.edu/automated_outputs/cal_uvis_make_gain https://wfc3ql.stsci.edu/automated_outputs/cal_uvis_make_bowtie

Signal vs Variance



IR Detector

Same cadence as the prior cycle

Monitor the health and stability of IR channel and verify the non-linearity correction:

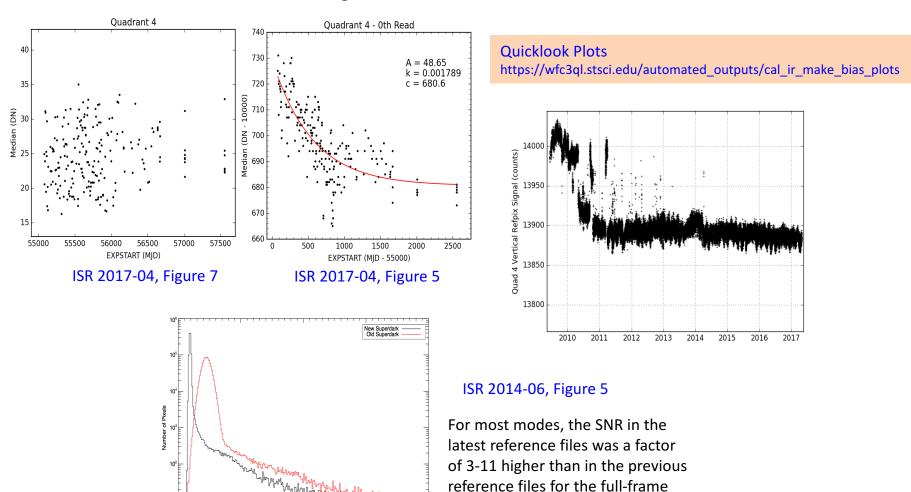
- Obtain IR darks. The number of orbits is dictated by observing modes most-requested by GOs.
 97 internal orbits = 26 orbits (SPARS200, every 2 weeks) + 71 orbits (other samp-seq/apertures)
- Monitor the IR non-linearity by obtaining saturated internal flats
 10 internal orbits = 10 orbits in F127M (half SPARS25, half SPARS10) * 1 epoch/year
- Verify the stability of the IR channel gain via a series of lamp flats
 16 internal orbits = 8 orbits * 2 epochs/year

IR Dark Monitor

Orbits	External: 0 Internal: 97
PI, Co-l's	Sunnquist, Ryan
Purpose	This program acquires a variety of WFC3/IR darks to support the removal and study of dark current. SPARS200 dark observations are periodically obtained to monitor trends in the bad pixels (hot, unstable, or dead), zeroth read level, and dark current. The remaining orbits collect dark ramps for generating stacked IR dark calibration files for use by the MAST pipeline.
Description	Full-frame and subarray dark calibration images will be collected using each sample sequence. The total number of images collected over the course of the cycle for a given mode is based on the total number of input ramps used in the current superdark for that mode and the popularity of that mode in external science observations.
Description	The IR dark current has remained nearly unchanged since launch (Sunnquist, Baggett & Long, WFC3 ISR 2017-04) which allows for more relaxed scheduling constraints compared to older WFC3/IR dark monitor programs. With the exception of the SPARS200/Full-Frame hot-pixel monitoring observations (which occur once every 2 weeks), all observations have no set scheduling parameters other than that they have to be taken sometime during Cycle 25.
Resources: Observations	Isequence/subarray combinations (weighted by usage, with each observed at least 2x /year, and up to 40x /year)
Resources: Analysis	Analysis and products to be completed by the PL Bias levels monitored by the Quicklook team
Products	Updated IR dark calibration files (DARKFILE) and IR bad pixel table (BPIXTAB)
Accuracy Goals	Improve IR dark calibration and Data Quality flags.
	ISR 2017-04 (study of dark current variation, zeroth read levels, reference pixels), ISR 2014-06 (updated dark reference files), ISR 2012-12 (dark current stability).
Prior Cycle IDs	11929, 12349, 12695, 13077, 13562, 14008, 14374, 14537

IR Dark Monitor

The darks are used to monitor the median IR dark level (left), 0th read level (middle), and vertical reference pixel signal (right) over time. The large spread in the median dark rates was studied in ISR 2017-04 using SPARS100, SPARS200 and STEP200 darks.



20 Pixel Value (edarks; the mean error values were

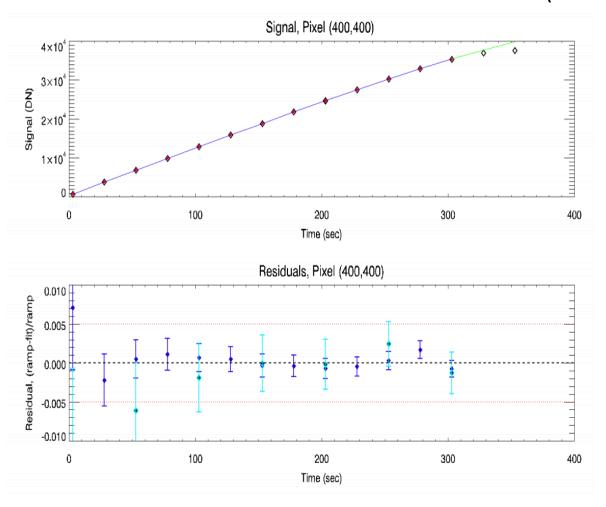
reduced by 44% - 98%.

IR Linearity Monitor

Orbits	External: Internal: 10
PI, Co-l's	Shanahan, Ryan
Purpose	To monitor the non-linearity of the WFC3/IR detector.
Description	HgCdTe detectors suffer from a non-linear response to incident flux. The calibration pipeline corrects for the effects of non-linearity. This monitor uses flat field ramps to characterize the non-linearity each detector pixel.
Resources: Observations	10 internal orbits, once per year. Visits are identical in structure and consist of a dark observation followed by two internal flats using the Tungsten lamp through F126N (half SPARS10, half SPARS50) and F127M (half SPARS25, half SPARS10). The initial narrow band flat is used to ensure that the lamp is warm and stable in preparation for the F127M exposure, but not so bright to cause persistence. A trailing dark is obtained after the F127M flat to measure the persistence decay rate.
	For each pixel, a polynomial for the full ramp vs. time. The parameters of the appropriate fit are used to define an 'ideal' linear signal rate, and subsequently a measure of fractional linearity for each read. Another curve fit to the measured linearity and signal of each read with tunable parameters is used to find a correction for the non-linear response.
Products	Characterization of the non-linearity behavior over time.
Accuracy Goals	An accurate model of the detectors non-linearity is crucial to correctly calibrating out this effect in the pipeline.
Prior Results, ISRs	ISR 2014-17, Updated non-linearity calibration method for WFC/IR
Prior Cycle IDs	12352, 12696, 13079, 13563, 14009, 14375, 14538

IR Linearity Monitor

(Hilbert, 2014)



Top panel: polynom Bottom panel: fit residu

polynomial fit to signal vs time for a single detector pixel (red points). fit residuals.

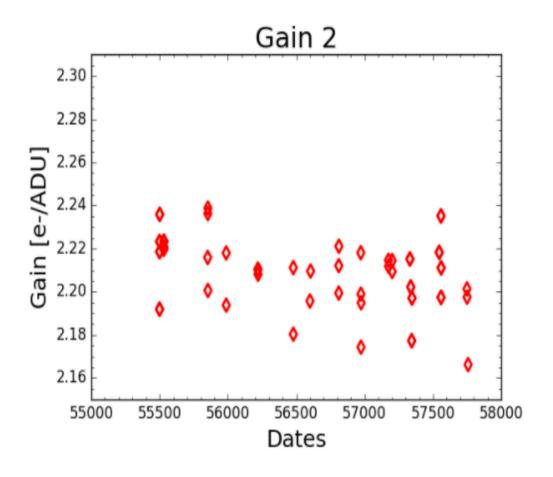
IR Gain Monitor

Orbits	External: Internal: 16
PI, Co-I's	Shanahan, Baggett, Ryan
Purpose	To measure the gain in four quadrants of the IR detector twice a year.
Description	Gain, the scaling relation between analog digital units (ADU) and photoelectrons is a fundamental detector parameter. Gain can be measured using the mean-variance method on pairs of internal flats. For each quadrant of the ramp pairs, the mean-variance method is used to calculate the gain.
	16 internal orbits, 8 in the summer and 8 in the winter. Each visit is identical and begins with a dark, allowing the BLANK to move into position before the lamp is turned on. The Tungsten lamp is turned on, and while the lamp warms a short warm up flat is taken through F126N to ensure a linear signal hits the detector for the duration of the long flat. Next, the long flat field ramp to be used in the gain measurement is taken. Finally, a trailing dark is taken to monitor persistence. Pairs of ramps are observed within 24 hours.
Resources: Analysis	Observations are processed with IDL software that calculates the gain in each detector quadrant using the mean-variance method.
Products	Measurements of the gain and scatter in gain measurements for each epoch of observations.
Accuracy Goals	The calibration pipeline depends on the gain to relate measured signal to physical units, so ensuring the pipeline value of the gain is consistent with the true detector gain is important to keep this scaling relation accurate
Prior Results, ISRs	WFC3 IR Gain from 2010 to 2015 (ISR 2015-14)
Prior Cycle IDs	12350, 12697, 13080, 13564, 14010, 14376, 14539

IR Gain Monitor

QuickLook plot

https://wfc3ql.stsci.edu/automated_outputs/cal_ir_gain

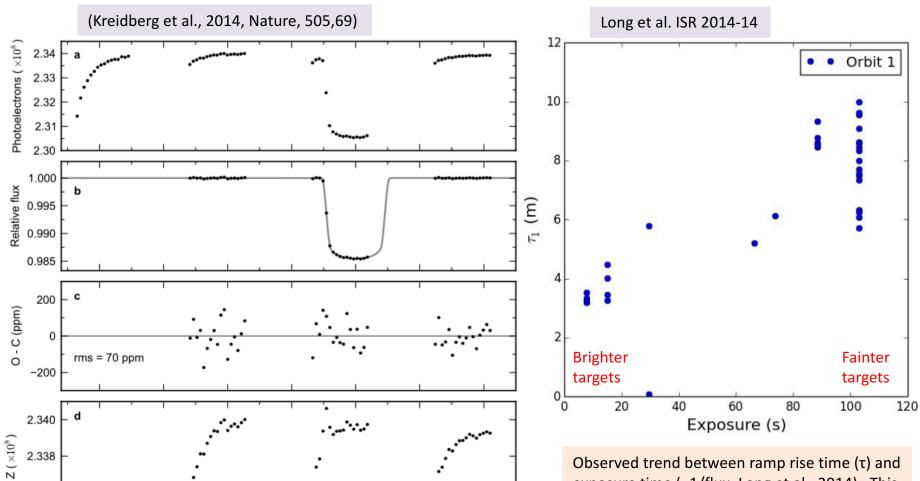


Gain is calculated via the mean-variance method for each ramp pair VS. MJD.

Characterization of IR Traps ("Persistence")

• New Program: Mitigating Persistence for Time-Series Observations
3 internal + 3 external orbits

Orbits	External: 3							
PI, Co-l's	K. Stevenson, K. Long, P. McCullough							
Purpose	The goal of this calibration program is to mitigate the effect of persistence, the dominant systematic seen in time-series observations (TSOs), and enable the use of HST's first orbit for science.							
Description	Persistence causes an increase in measured flux over time. The effect varies between the first HST orbit and subsequent orbits and is likely due to having multiple trap populations filling at different rates. Current TSOs exclude the first HST orbit from their fits, but this process could change if the detectors were preconditioned prior to the first HST orbit and during Earth occultation. The plan is to continuously illuminate the detector using the internal Tungsten lamp with F140W (1450 e ⁻ /s) during Earth occultation prior to the first exposure and between consecutive exposures. The detector read pattern during occultation would be selected to achieve the same fluence per integration with the Tungsten lamp as would be seen from the target. (Goal of 25-30 ke Fluence > 40 ke- shows systematic effects in TSO data. APT details in following slides)							
Resources: Observations	We will obtain observations of GJ 1214 (outside of transit) over 3 contiguous orbits using WFC3/IR and the G141 grism. Ten of the 15 GJ 1214 observations from GO 13021 (Pl: Bean) use the same settings as those proposed here and would serve as an ideal baseline for comparison. Note that this test is CSM movement intensive .							
	0.15 FTE over 6 months. Reduction and analysis to be completed by the PI with assistance from the Co-Is. We will use standard data reduction and light curve fitting techniques for TSOs.							
Products	Confirm Zhou et al. (2017) persistence model, Enable more science by no longer needing to discard the first HST orbit in TSO programs Enable more accurate results by reducing the amplitude of the dominant systematic for TSOs.							
Accuracy Goals	Reduce 1% ramp up amplitude to <0.1% (level required to detect exoplanet). Recover ~2% of HST's orbits by utilizing its first TSO orbit for science.							
Prior Results, ISRs	I) Long et al. ISR 2014-14: Attempts to Mitigate Trapping Effects in Scanned Grism Observations of Exoplanet Transits with WFC3/IR. They determine that preconditioning at constant fluence does not sufficiently mitigate persistence. They find a correlation between ramp rise time and exposure time (which is inversely proportional to flux). 2) Zhou et al. (2017), A Physical Model-Based Correction for Charge Traps in HST's WFC3 NIR Detector. They predict that flux (not fluence) primarily determines the shape of the persistence ramp.							
Prior Cycle IDs	13 orbits in 13573, Cycle 21							



50

100

Time-series observations of GJ 1214 over 4 orbits from scanned grisms in program 13021. Each data point is one 100 sec exposure. The ramp up is strongest in the 1st orbit, which is typically discarded. The effect resets during Earth occultation.

-100

-50

Orbital phase (minutes)

2.336

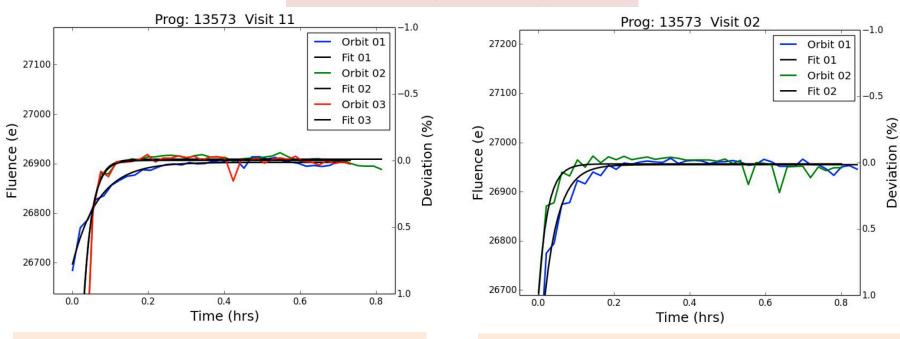
-200

-150

Observed trend between ramp rise time (τ) and exposure time (≈1/flux, Long et al., 2014). This qualitatively matches predictions of a <u>flux-dependent</u> (and not a fluence-dependent) ramp effect (Zhou et al., 2017).

Thus, continuous detector illumination during Earth occultation (without saturating) should mitigate the ramp effect.

ISR 2014-14: Tungsten white light curves

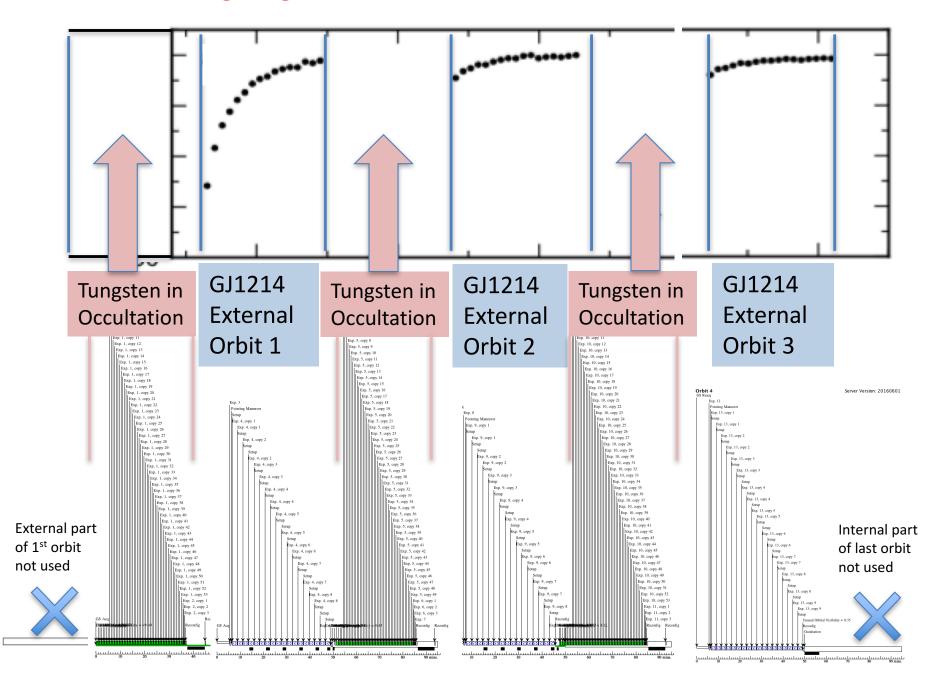


Detector not preconditioned- Noticeably different ramp rise time in orbit 01 (blue) vs orbits 02, 03 (green, red)

Preconditioned with a single 30s lamp exposure to reach a fluence 48,000 e-. The results are more consistent but not at a level to include the 1st orbit for TSO science

Instead of holding charge on the detector during preconditioning (*constant fluence*), this program will achieve *constant flux* by keeping the Tungsten lamp turned on while reading out the detector at an appropriate cadence, as determined by the target fluence.

The goal is to confirm the flux-dependent ramp effect predicted by Zhou et al. (2017) and, ultimately, mitigate the effects of persistence on TSOs.



For calculating the exposure time we have assumed a rate of 1450 e/s (Long et al, 2014) and want a level of ~30,000 e. Therefore each lamp exposure is ~22 seconds.

Exptime

								LAPTITIC
Exposure \triangle	Nu	Config	Target	Spectral El	Aperture	No. Of Iter	Optional Parameters	(seconds)
Exposure 1 (Sequence 1-2 Non-Int in Visit 11)	1	WFC3/IR		G141	GRISM256	53	[SAMP-SEQ=SPARS10, NSAMP=4]	22
Exposure 2 (Sequence 1-2 Non-Int in Visit 11)	2	WFC3/IR	TUNGSTEN	G141	GRISM256	3	[SAMP-SEQ=RAPID, NSAMP=12]	3
Exposure 3 (Sequence 3-7 Non-Int in Visit 11)	3	WFC3/IR	1 GJ-1214	F130N	GRISM256	1	[NSAMP=3, SAMP-SEQ=RAPID]	1
Exposure 4 (Sequence 3-7 Non-Int in Visit 11)	4	WFC3/IR	1 GJ-1214	G141	GRISM256	9	[NSAMP=15, SAMP-SEQ=SPARS10]	103
Exposure 5 (Sequence 3-7 Non-Int in Visit 11)	5	WFC3/IR	TUNGSTEN	G141	GRISM256	49	[SAMP-SEQ=SPARS10, NSAMP=4]	22
Exposure 6 (Sequence 3-7 Non-Int in Visit 11)	6	WFC3/IR	TUNGSTEN	G141	GRISM256	3	[SAMP-SEQ=RAPID, NSAMP=15]	4
Exposure 7 (Sequence 3-7 Non-Int in Visit 11)	7	WFC3/IR	TUNGSTEN	G141	GRISM256	1	[SAMP-SEQ=RAPID, NSAMP=8]	2
Exposure 8 (Sequence 8-11 Non-Int in Visit 11)	8	WFC3/IR	1 GJ-1214	F130N	GRISM256	1	[NSAMP=3, SAMP-SEQ=RAPID]	1
Exposure 9 (Sequence 8-11 Non-Int in Visit 11)	9	WFC3/IR	1 GJ-1214	G141	GRISM256	8	[NSAMP=15, SAMP-SEQ=SPARS10]	103
Exposure 10 (Sequence 8-11 Non-Int in Visit 11)	10	WFC3/IR	TUNGSTEN	G141	GRISM256	53	[SAMP-SEQ=SPARS10, NSAMP=4]	22
Exposure 11 (Sequence 8-11 Non-Int in Visit 11)	11	WFC3/IR	TUNGSTEN	G141	GRISM256	3	[SAMP-SEQ=RAPID, NSAMP=12]	3
Exposure 12 (Sequence 12-13 Non-Int in Visit 11)	12	WFC3/IR	1 GJ-1214	F130N	GRISM256	1	[NSAMP=3, SAMP-SEQ=RAPID]	1
Exposure 13 (Sequence 12-13 Non-Int in Visit 11)	13	WFC3/IR	1 GJ-1214	G141	GRISM256	9	[NSAMP=15, SAMP-SEQ=SPARS10]	103

Additional short Tungsten exposures in RAPID mode are placed after the SPARS10 data to fill the memory and force the buffer dump at the end of the orbit. Otherwise, the buffer dump happens in the middle of the following science orbit.

CTE Characterization and Calibration

Same cadence as the prior cycle

As in Cycles 20–25, GOs can mitigate CTI effects using post-flash. To support these efforts we request the following calibration:

Measure and monitor CTE via Extended Pixel Edge Response (EPER)

```
12 internal = 2 orbits/epoch * 6 epochs
```

• Observe stellar fields characterized by different crowding (47 Tuc and one in NGC 6791) and background (0 to 12 electrons flash) to calibrate the photometric and astrometric CTI corrections.

```
8 external = 4 orbits/epoch * 2 epochs
```

• Use charge-injected bias to monitor the length of the CTE trails. This information will be used as an input for J. Anderson's CTE algorithm.

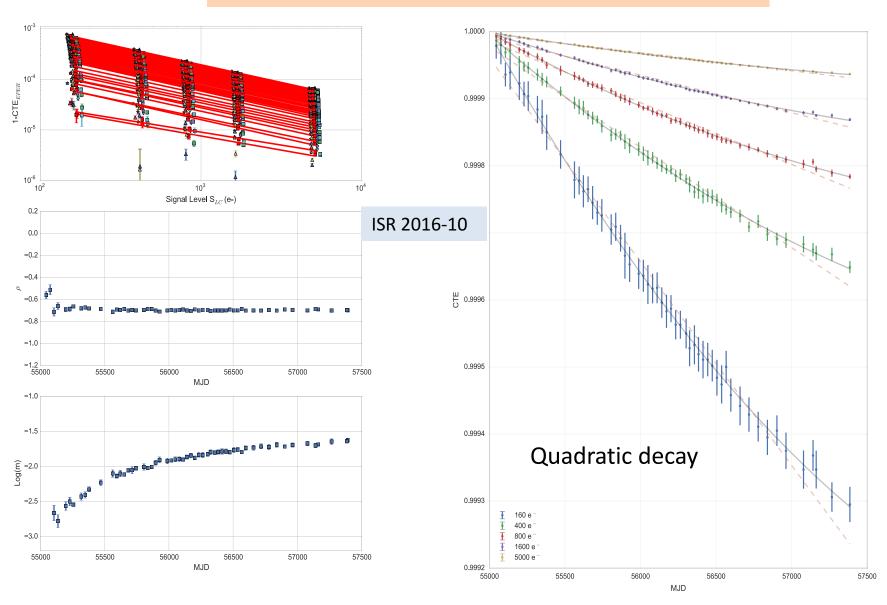
```
36 internal = 1 orbit every ~10 days
```

WFC3/UVIS CTI Monitor (EPER)

Orbits	External: 0 Internal: 12
PI, Co-l's	Fowler, Khandrika
Purpose	(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.
Description	12 internal orbits (2 every other month) are used to asses 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 flat field 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 9 weeks over the span of a year.
Resources: Observations	12 orbits = 6 epochs, each consisting of a 2 visit (orbit) pair Visit 1 = 1 dark+ 2 tungsten flats (F390M), Visit 2 = 1 dark+ 1 tungsten flats (F390W) + 2 tungsten flats (F438W).
Resources: Analysis	0.2 FTE – Analysis to be completed by the PI by analyzing the extended overscan in comparison to science pixels in the EPER readout mode. Rewriting automated monitor script and tracking changes since 2016
Products	
Accuracy Goals	Measure WFC3/UVIS CTI, and track UVIS CTE loss over time.
·	ISR 2007-13, ISR 2009-10, ISR 2011-17, ISR 2013-03, ISR 2016-10 The last results in May 2016 (Cycle 23) reports that CTE has degraded by at most 0.07% in 7 years at any illumination level. The CTE degradation is found to be quadratic, and seems to be settling with time.
Prior Cycle IDs	11924, 12347, 12691, 13082, 13565, 14011, 14377, 14540

WFC3/UVIS CTI Monitor (EPER)

Quicklook Plots here: https://wfc3ql.stsci.edu/automated_outputs/cal_uvis_make_eper



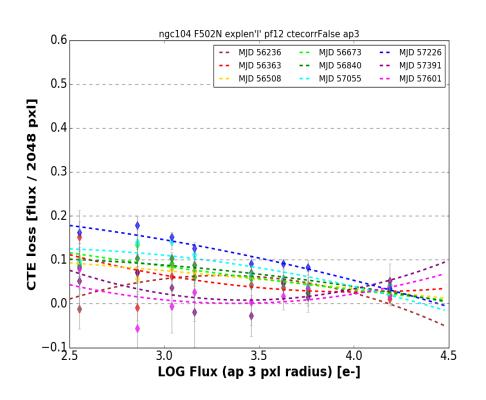
WFC3/UVIS External CTE Monitor: Star Clusters

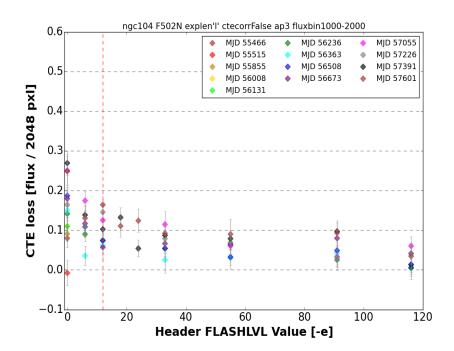
Orbits	External: 8 Internal: 0
PI, Co-l's	Fowler, Baggett
Purpose	Monitor CTE degradation as a function of epoch and source/observation parameters. Calibrate photometric corrections. Provide data to test and monitor the Anderson pixel-based CTE correction model for WFC3/UVIS.
Description	We continue, 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 47 Tuc in F502N (this filter gives approximately 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. We sample various background levels to test whether the currently recommended level of 12 e- still yields the best charge transfer. The data are also used to test the effectiveness of the pixel-based CTE correction software. In summary, there will be one orbit of NGC 6791 and three for 47 Tuc (observed in five different non-zero background level).
	8 orbits = 2 epochs * 4 orbits each Images in the F502N filter of the two star clusters NGC 104 and NGC 6791 with 0 and 12 flash level.
	0.2 FTE – Analysis to be completed by the PI by analyzing how the photometry of point sources within (dense and sparse) star clusters changes at different detector orientations.
Products	CTE coefficients. Test of efficacy of pixel-based CTE correction, test of recommended background level.
Accuracy Goals	Measure WFC3/UVIS CTE with Y distance from readout, confirm CTE correction software, test for overcorrection in flc files.
Prior Results, ISRs	ISR 2001-05, ISR 2003-01, ISR 2011-06, ISR 2014-02, ISR 2014-19, ISR 2016-17, ISR 2017-09 Results from March of 2017 noticed a 5-15% flux loss from CTE depending on source.
Prior Cycle IDs	12379, 12692, 13083, 13566, 14012, 14378, 14541

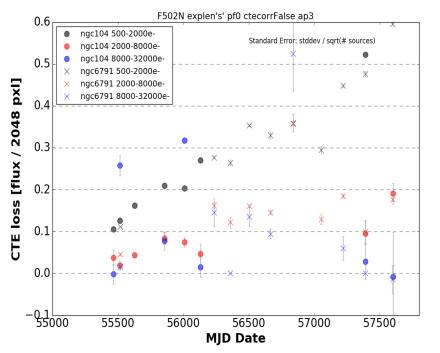
WFC3/UVIS External CTE Monitor: Star Clusters

Quicklook Plots

https://wfc3ql.stsci.edu/automated_outputs/cal_uvis_external_cte







UVIS Traps with Charge Injection

Orbits	External:0 Internal: 36
PI, Co-l's	Kurtz, Martlin, Sabbi, Khandrika
Purpose	This program is designed to monitor the UVIS trap growth via charge-injected biases
Description	The charge transfer efficiency (CTE) of the WFC3/UVIS channel continues to decline as damage from radiation accumulates. One method to mitigate the impact of CTE losses is to apply a pixel-based CTE correction algorithm the images after they are acquired. An algorithm such as this requires a detailed knowledge of the traps, which capture and release charge during the image readouts. This program will identify and characterize the traps responsible for the charge losses, map their distributions across the chips, and monitor their growth over time.
	36 orbits = 1 orbit of 'line 25' charge injected biases every 10 days. To aid the schedulers, each visit will have a 5 day window to be executed.
Resources: Analysis	PI to apply pixel history code developed by Bourque & Anderson
Products	If the LED used to post-flash data fails, CI could be used instead in order to mitigate CTE.
Accuracy Goals	
Prior Results, ISRs	ISR 2011-02. The team still needs to analyze the most recent data.
Prior Cycle IDs	12348, 12693, 13084, 13569, 14013, 14379,14542

UVIS Traps with Charge Injection

2011-02

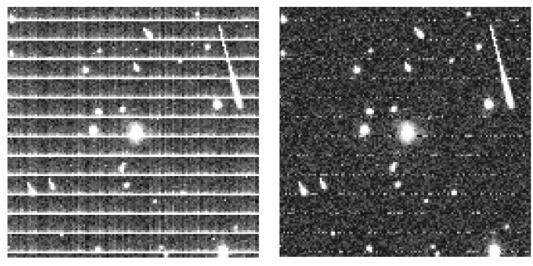


Figure 8: Portion of an NGC 104 exposure without (left) and with (right) CI subtraction. Both images are shown with a hard intensity stretch to highlight the low-level CI signal residuals.

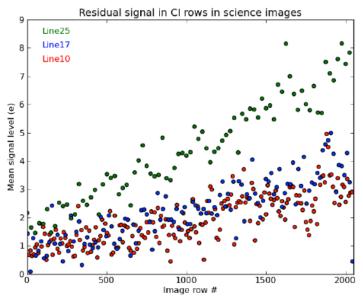


Figure 9: Mean residual signal in CI-subtracted rows of science images for each LINE mode. Only the data for CCD chip 2 is shown; chip 1 behavior is the same.

WFC3 Photometric performance

To verify the UVIS and IR photometric stability:

 Monitor the accuracy of the shutter mechanism after 8 years of operation 1 internal orbit

(reduced from last cycle; 2 external orbits dropped)

Monitor the photometric throughput with wavelength using both staring mode and scans

```
20 external orbits (10 staring + 10 spatial scans) every ~5 weeks for 2 standards (GRW+70, GD153) (same cadence ~5 weeks as last cycle but with a larger emphasis on scans) (cycle 24 used 14 orbits in staring mode + 6 in scanned mode)
```

Check temporal stability of zeropoints for a subset of UVIS and IR filters (same cadence as last cycle)

```
11 external orbits

UVIS: 8 orbits = 4 stars * 2 amps/star * 1 orbit/amp in a subset of 12 filters

IR: 3 orbits = 3 stars * 1 amp/star * 1 orbit/amp in all filters
```

New Program:

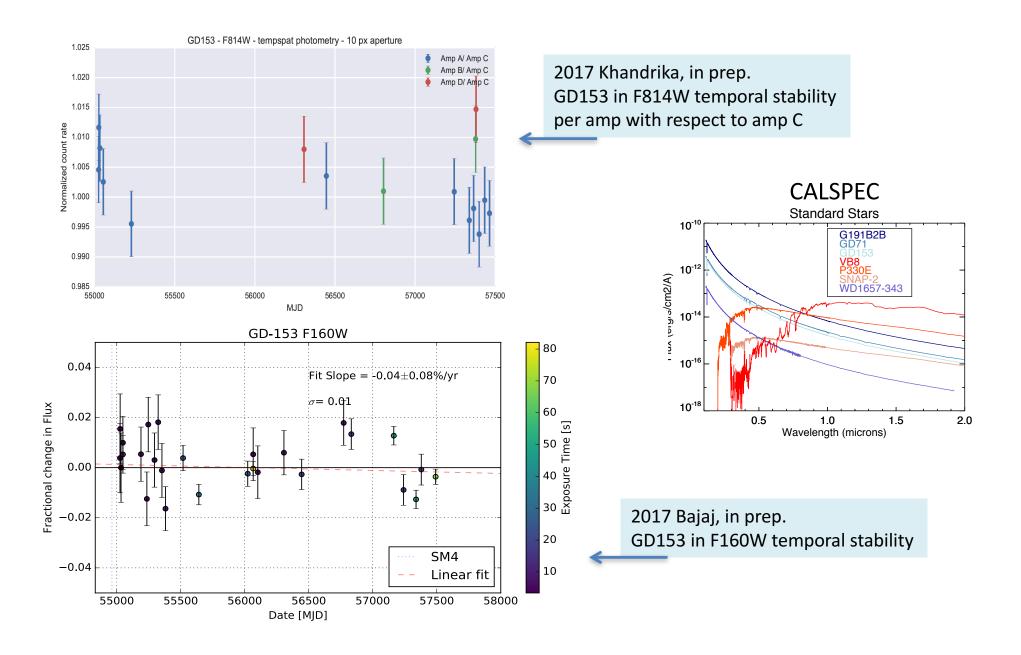
Quantify UVIS color terms in the 4 subarray corners and in the M512C subarray

```
8 external orbits=
2 orbits = A-type star * 4 corner subarrays in 5 filters
2 orbits = 1 orbit/star * 2 corner subarrays * 2 stars (GD153 & P330E)
4 orbits = M512C @ 1 orbit/star * 4 stars in 10 filters * 2 exposures each
```

WFC3 UVIS and IR Photometry

Orbits	External: 11 Internal: 0
PI, Co-l's	Deustua, Bajaj, Calamida, Khandrika, Mack
Purpose	Monitor the photometric throughput and stability, measure the inverse sensitivities and determine color term corrections for WFC3 UVIS and IR filters as a function of time, detector position, and wavelength.
Description	WFC3 UVIS: image G191B2B, GD153,GD71 and P330E in a subset of broad- and medium-band UV and VIS filters at the corners (4 amps) and using postflash. In Cycles 20 and 21 we obtained observations in all UVIS filters at all 4 corner subarrays. In Cycles 22-24 a subset of filters were observed in one UVIS1 amp and one UVIS2 amp, alternating per year. In Cycle 25, observe standards in the same filter subset in the C512B and C512D subarrays. Since the amp A focus is atypical, and since the contamination monitor already covers this region, C512A has been replaced with C512B. WFC3 IR: image GD153, GD71 and P330E in all IR filters.
	UVIS: 8 orbits = 4 stars * 2 amps/star * 1 orbit/amp in a subset of 12 filters IR: 3 orbits = 3 stars * 1 amp/star * 1 orbit/amp in all filters
Resources: Analysis	Analysis 0.2 FTE. Analysis to be completed by the PI and Co-Is Measure the photometry of the stars in each filter, compare new results to previous data, determine changes, recompute time averaged sensitivities, compute timesensitive and location-sensitive offsets from average.
Products	Improved photometric calibration in the UVIS and IR channels, synthetic photometry tables, IMPPHTAB
Accuracy Goals	Improve UVIS accuracy to 1% statistical (current: 1.4%) and 1% absolute (relative to STIS, current: ~1.5%) Improve IR photometric accuracy to 1% statistical (current: ~3%) and 1% absolute (relative to STIS, current ~2-3%). Uncertainties for UVIS and IR narrow band filters are ~5%, for UVIS LP and X filters ~5%.
Prior Results, ISRs	ISR 2017-11: WFC3/UVIS: Updates to SYNPHOT Reference Files and IMPHTTAB ISR 2017-07: WFC3 Chip Dependent Photometry with the UV filters ISR 2016-07: Updated WFC3/UVIS Chip Dependent SYNPHOT/PYSYNPHOT Files ISR 2016-03: UVIS 2.0 Chip-dependent Inverse Sensitivity Values
Prior Cycle IDs	14883, 14871, 14384,14021,13575,13089,12334,11926,11903,11451,11450

WFC3 UVIS and IR Photometry



UVIS Shutter Monitoring

Orbits	External: 0 Internal: I		
PI, Co-l's	K. Sahu, S. Baggett		
Purpose	Monitor the performance of the UVIS shutter blades. The specific objectives are: (i) compare the photometric behavior of both shutter blades, for short vs long exposures (ii) check for any shutter shading effects		
	Internal flats in each of the 4 amps will be used to monitor the repeatability and any shutter shading effects. We will continue to monitor the photometric behavior of blades A and B separately.		
Description	Two external orbits of standard star observations have been obtained in the past 3 cycles to monitor the accuracy and stability of the blades compared with prior cycles. Due to consistent results from Cycles 23 & 24 compared to SMOV, these external orbits are not required this cycle but will be resumed next cycle. In the meantime, internal flats from the bowtie monitoring program provide an additional check of the shutter repeatability.		
Resources: Observations	1 internal orbit with the tungsten lamp on each of the 4 amplifiers.		
Resources: Analysis	0.1 FTE.The analysis will be carried out by the PI. Internal tungsten lamp exposures will be used to check if count levels are consistent as expected from different exposure times and for both A and B blades.		
Products	If the shutter shading is found to be significant, or if the performance of the 2 shutters is found to be different, this would require delivery a new reference file (e.g. SHADFILE) to correct for the behavior.		
Accuracy Goals	Cross-calibrate shutters A and B to 0.2%. Monitor the stability to 0.1%		
Prior Results, ISRs	2015-12 (Sahu), 2014-09 (Sahu), 2009-25 (Hilbert)		
Prior Cycle IDs	11427 (SMOV), 14019 (Cy22), 14383 (Cy23), and 14882 (Cy24)		

UVIS Shutter Monitoring

ISR WFC3 2015-12: Internal Lamp exposures

Ratios of the counts as observed during SMOV and Cycle 23 remain constant for all 4 amplifiers, apart from an overall decline in the lamp, demonstrating that there is no change in the shutter shading compared to SMOV. The dispersion in the long set of exposures (lower-right plot) is consistent with the shutter shading reported by Hilbert (ISR 2009-25) at <0.1% rms

ISR WFC3-2015-12: Bowtie Monitor data

No measurable variation in the A/B and C/D flux ratios is found over the past 7 years, confirming the above result that shutter is stable to ~0.1%.

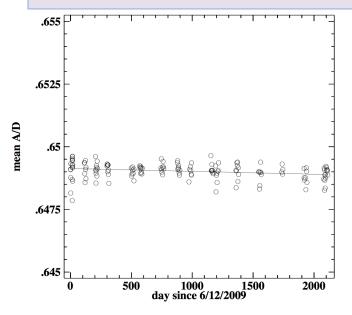
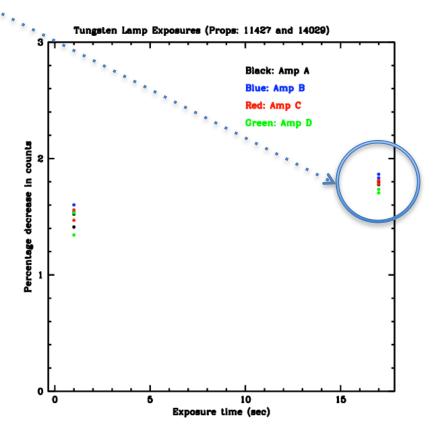


Table 1: Observed counts in different amplifiers

Filename	Shut- ter	Exp. time	Av. Counts	Av. Counts	Av. Counts	Av. Counts
		(S)	(A)	(B)	(C)	(D)
Program:						
11427						
	•	•		•	•	
iaai01rtq_flt	A	1.00	1734.6	2044.0	2013.5	2464.2
iaai01ruq flt	В	1.00	1730.2	2039.0	2008.0	2459.3
iaai01rwq flt	A	17.00	29655.4	35020.6	34679.4	42286.3
iaai01rxq_flt	В	17.00	29657.3	35022.6	34682.7	42290.5
Program						
14019:						
	•	•	•	•	•	
icr401keq_flt	В	1.00	1704.1	2006.6	1976.9	2421.8
icr401kfq flt	A	1.00	1710.3	2012.7	1984.2	2431.3
icr401khq flt	В	17.00	29127.7	34375.3	34060.1	41563.1
icr401kig flt	A	17.00	29133.6	34384.2	34067.3	41571.6



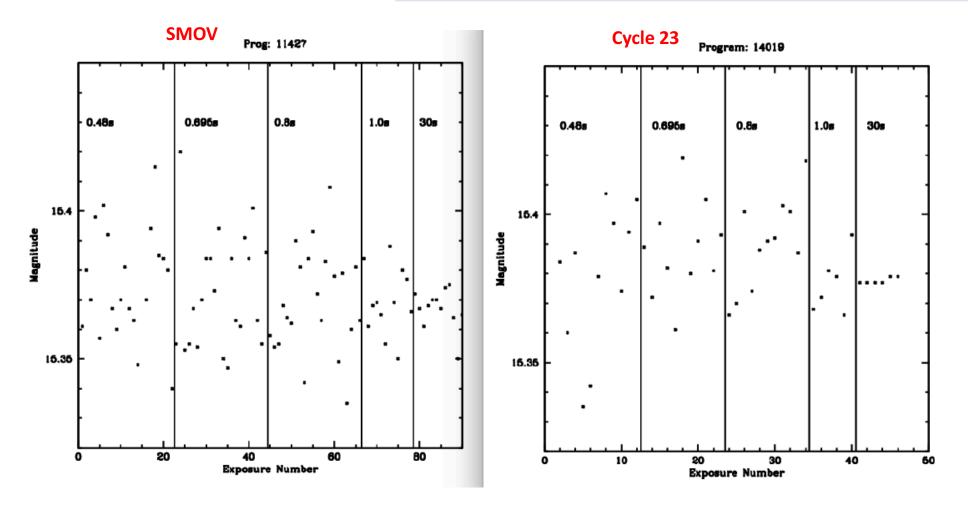
UVIS Shutter Monitoring

ISR WFC3 2015-12 External data

The standard star observations from Cycle 23 (below) & Cycle 24 (not shown) verify that there is no noticeable difference in the performance of the shutter compared to SMOV.

The 2 external orbits are therefore not requested for Cycle 25, but will be included in Cycle 26 to verify the shutter stability with exposure time.

Aside: [Scanned data from the UVIS contamination monitor cannot replace the external shutter monitoring observations since the shortest exposures are complicated by jitter and variations in scan speed, making the analysis non-trivial.]



WFC3/UVIS Contamination Monitor

Orbits	External: 20 Internal: 0				
PI, Co-l's	P. McCullough, C. Shanahan, S. Baggett				
Purpose	Periodically measure the photometric throughput of WFC3. The data monitor the presence of possible contaminants on the optics via the flux of standard stars as a function of time and wavelength.				
Description	Each visit obtains dithered or scanned subarray observations of a white dwarf standard star on both chips through a sub-sample of UVIS filters (including staring mode w/ grism G280). The white dwarf standard GRW+70D5824 has been used for past monitors but recent analyses have questioned its flux stability (Bohlin & Landolt 2015, AJ 149, 122B). As a result, we propose to include it and another white dwarf spectrophotometric standard (GD153) with equal weight. This second standard has an added benefit of being schedulable throughout the year in 1-Gyro mode. The monitor cadence is deliberately out of sync with the monthly anneals in order to sample any anneal-related phase. Given the greater precision of the scanned mode (~5x improved over staring mode, per epoch, (ISR 2017-21), we expect to gradually transition from staring mode to scanning mode, with this cycle providing validation and contemporaneous data to stitch the future scanned results to the past staring mode results.				
Resources: Observations	10 visits, spaced as evenly as possible; 2 orbits/visit, staring & scanning for GD153 and GRW+70				
Resources: Analysis	RIA 0.25 FTE, Scientist 0.2 FTE. (Staring mode data reduction is automated by quicklook software)				
Products	Annual ISR update and long-term time-dependent analytic prediction to adjust scientific results.				
Accuracy Goals	Per epoch accuracy: 0.5% staring, 0.1% scanning in 8 filters each plus G280 only in staring mode.				
Prior Results, ISRs	While no contamination of WFC3/UVIS has been detected in the past, small long-term changes are present in some filters (Gosmeyer et al., ISR 2014-20) and are not due to shutter behavior (Sahu et al., ISR 2015-12). Scanning mode has 0.1% r.m.s. repeatability (Shanahan et al. WFC3-2017-21).				
Prior Cycle IDs	Staring: I 1426, I 1907, I 2333, I 2698, I 3088, I 3574, I 4018, I 4382, I 4815 (Cy24, I 4 orbits) Scanning: I 4878 (Cy24, 6 orbits)				

WFC3/UVIS Contamination Monitor

Repeatability of scanned photometry is ~0.1% r.m.s. at all wavelengths based upon the ratios of GD153 photometry in one visit compared to another visit. (right)

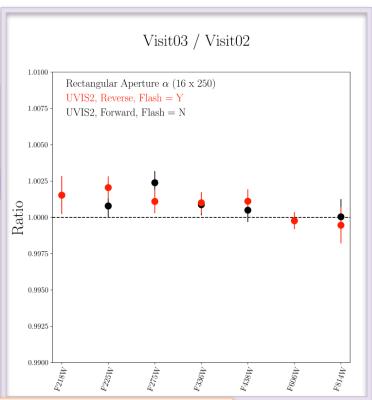
WFC3-2017-21

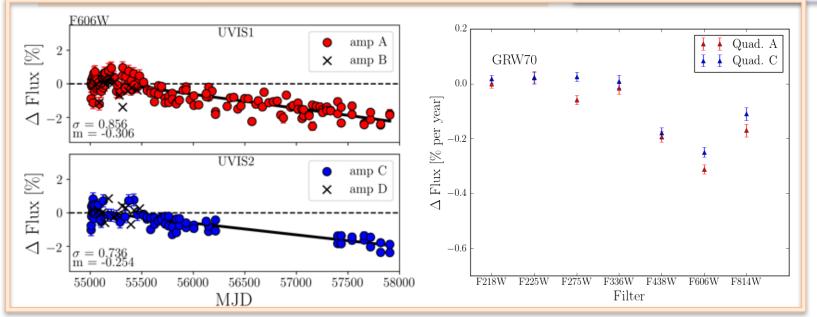
Repeatability in staring mode is ~0.5% r.m.s.

Losses for GRW+70 over 7 years are up to 0.3% per year in F606W (lower left). The flux loss per year vs.

wavelength is shown at lower right.

WFC3-2017-15





Orbits	External: 8 Internal: 0		
PI, Co-l's	A. Calamida, H. Khandrika, S. Deustua, J.Mack		
Purpose	1.) Measure the color effect of the inverse sensitivities for the UV filters (F218W, F225W, F275W) as a function of position and spectral type on the WFC3 detector 2.) Check the spatial dependence of the latest UVIS photometric calibration near the middle of the FOV where most users place their targets. This region has not been observed since 2012.		
Description	To characterize the <u>color terms any any spatial dependence</u> in measured photometry for the 3 UV filters, we plan to observe 2 white dwarfs (GD71 and GD153), an A star (1812095, CALSPEC standard) and a G star (P330E) in the <u>4 corner sub-arrays</u> for the 3 UV filters plus F606W and F814W to reach a SNR~200. Current data for GD153 and P330E in F275W shows a color term ~2% at the same position (Fig. 1) while synthetic and observed photometry show that the color effect across UVIS chips may differ by up to 3-6% according to the filter used (Figs. 2 and 3). To <u>check the photometric calibration at the center of the UVIS array</u> , we plan to observe 2 white dwarfs, the A-star 1812095, and the G star P330E in 10 filters with a SNR~500 in the M512C subarray.		
Resources: Observations	8 orbits = 4 for color terms + 4 for M512C 2 orbits for the A-type star 1812095 for the 4 sub-array corners in 5 filters. 2 orbits for GD153 & P330E in C512A and C512C. (The Cy25 monitoring program already samples C512B & C512D). 4 orbits for the M512C subarray @ 1 orbit per star (GD153, GD71, 1812095, P330E) per 10 filters per 2 exposures		
Resources: Analysis	Analysis to be completed by the PI (0.25 FTE) with assistance from co-I's (0.1 FTE). Aperture photometry will be measured for all the observed stars and combined with prior photometry calibration and contamination monitor observations for the common targets. The color terms of the inverse sensitivities for the UV filters will be measured and published together with the available WFC3 inverse sensitivity values.		
Products	Color-term corrections to the inverse sensitivity (photflam) values for the WFC3 UV filters (F218W, F225W, F275W). Spatial mapping of the inverse sensitivity for the WFC3 broad band filters.		
Accuracy Goals	Residual color effects <= 1%. Spatial characterization of the inverse sensitivity to <1%		
Prior Results, ISRs	ISR's 2015-18 & 2016-05 -> color effect measured across UVIS1 and UVIS2 for the UV filters F225W and F275W, using photometry of Omega Cen stars which span spectral ranges from the hot horizontal branch stars, Teff >= 20,000 K. to the red-giant branch stars, Teff ~ 4,000K (see Fig. 3). ISR 2016-03, ISR 2017-14-> UVIS inverse sensitivity values for chip-dependent photometry.		
Prior Cycle IDs	12699 (The last M512C observations were from 2012, Cy19: "WFC3 Photometric Calibration & Calibration Flux Ladder")		

Color terms for stars measured in the same amplifier

Synthetic / Observed count rate in F275W amp A

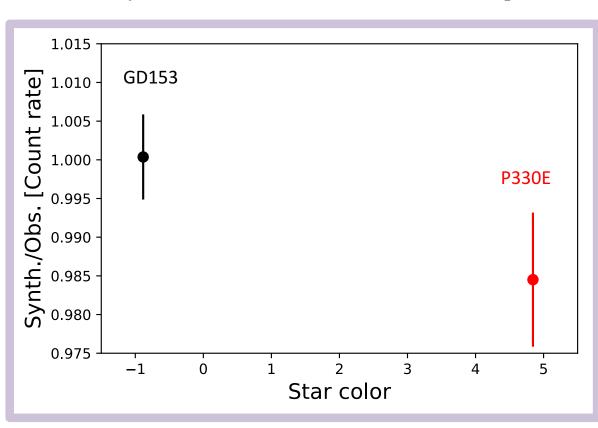


Fig. 1: Ratio of synthetic to observed count rate as a function of star color for the white dwarf GD153 and the solar analog P330E.

Photometry in the UV filters may differ up to $\sim 2\%$ in the same amplifier according to the star color.

Color terms across the two UVIS detectors: Synthetic Photometry

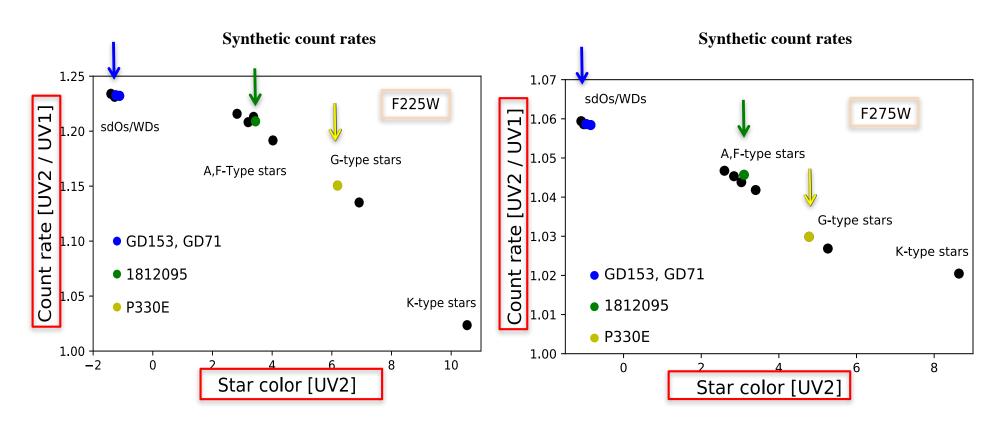


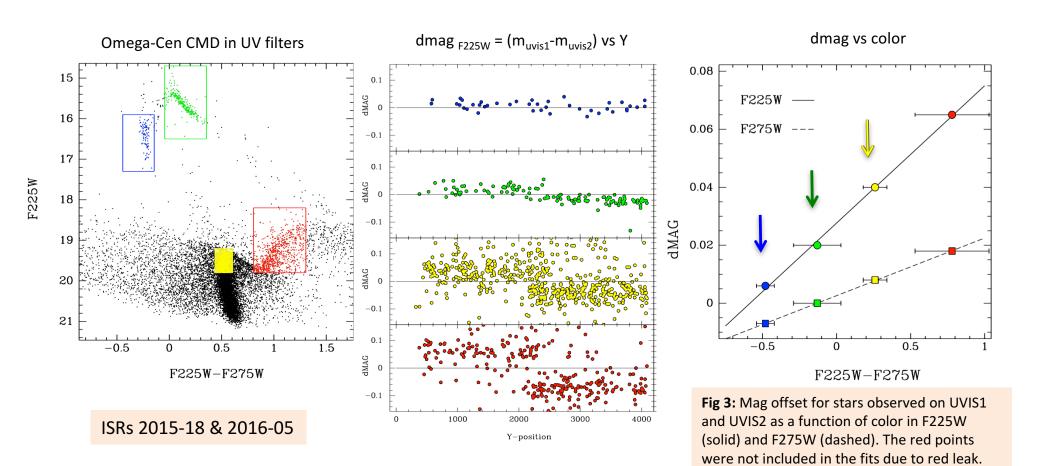
Fig. 2: Synthetic count rate ratio (UVIS2/UVIS1) as a function of star color for F225W (left) and F275W (right)

The response ratio between the two detectors in the UV filters changes with the star color, with a difference up to \sim 6% (F225W) and \sim 3% (F275W) from the hottest sdO/WD stars to cooler G-type stars.

The three stars proposed for observation, **GD153**, **1812095** and **P330E**, are marked with blue, green and yellow dots. (K-stars are excluded because of large red leaks in the UV).

Color terms across the two UVIS detectors: Omega-Cen Photometry

- ✓ For stars measured on both UVIS chips, dmag _{Filter} = (m_{uvis1} m_{uvis2}) depends on spectral type
- ✓ The change in dmag _{Filter} for a 'blue' vs a 'yellow' population is ~0.04 mag (F225W) and ~0.02 mag (F275W)



WFC3 Grism Spectroscopy

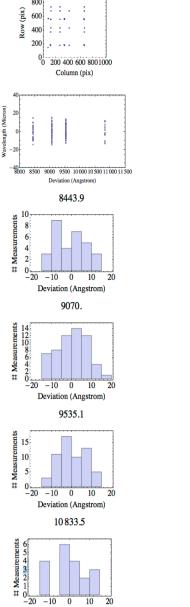
- Monitor and improve the flux calibration for both the IR grisms
 1 orbit (reduced from 4 orbits in cycle 24)
- Monitor and improve the wavelength calibration for both IR grisms
 1 orbit (reduced from 4 orbits in cycle 24)
- Monitor the wavelength stability of the UVIS grism in both chips.
 - 1 orbit Same cadence as last cycle

WFC3 IR Grism Wavelength Calibration & Stability

Orbits	External: I Internal: 0		
Orbits	(REDUCED from 4 orbits in Cy24 now that we have adequate coverage over the FOV.)		
PI, Co-l's	Pirzkal, Brammer, Ryan		
Purpose	Verify the temporal stability of the G102 and G141 grisms wavelength dispersion		
Description	Grism G102 and G141 observations of VY2-2 will be obtained and reduce to verify that the dispersion of these grisms is not changing.		
Resources: Observations	I pointing at the center of the field per grism		
Resources: Analysis	0.05 FTE		
Products	None unless change is detected		
Accuracy Goals	10A for G102, 20A for G141		
Prior Results, ISRs	ISR 2016-15		
Prior Cycle IDs	12356, 14385, 14543, 12703, 14023		

WFC3 IR Grism Wavelength Calibration & Stability

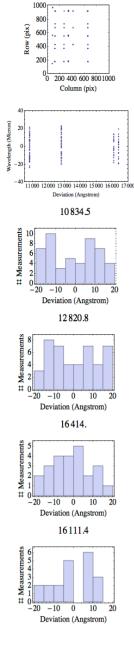




Deviation (Angstrom)

G102

G141



WFC3-ISR, 2016-15

The location at which emission lines were extracted and measured (using our new trace calibrations).

The difference between the fitted model of the wavelength dispersion and the fiducial wavelengths of the lines we detected and measured.

The following rows show histograms of these residuals, over the entire field of view, for each of the lines measured:

- G102: O I (8443.9 A), [S III] (9070.0 A),
 [S III] (9535.1 A), He I (10,833 A)
- G141: He I (12,820 A), H I (16,414 A), H I (16,413 A)

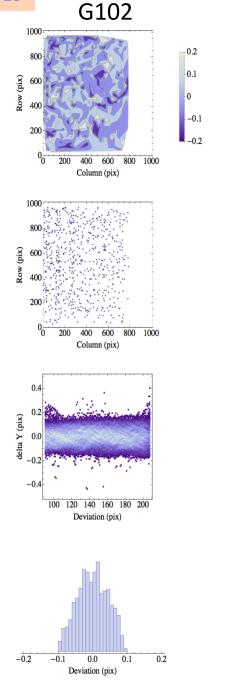
WFC3 IR Grism Flux/Trace Calibration & Stability

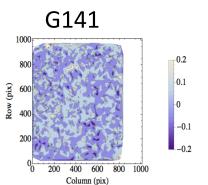
Orbits	External: I Internal: 0		
	(REDUCED from 4 orbits in Cy24 now that we have adequate coverage over the FOV.)		
PI, Co-l's	PI: Pirzkal, Co-I's: Brammer, Ryan		
Purpose	Verify the temporal stability of the G102 and G141 grisms trace solution and flux calibration		
Description	Grism G102 and G141 observations of GD-153 will be obtained and reduce to verify that he dispersed traces of these grisms are not changing and that the sensitivity remains table		
Resources: Observations	I pointing at the center of the field per grism		
Resources: Analysis	0.05 FTE		
Products	None unless change is detected		
Accuracy Goals	0.1 pixel		
Prior Results, ISRs	WFC3-2016-15		
Prior Cycle IDs	14024, 14386, 14544		

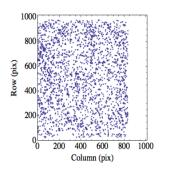
WFC3 IR Grism Flux/Trace Calibration & Stability

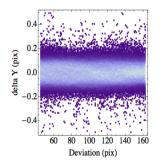
WFC3-ISR, 2016-15

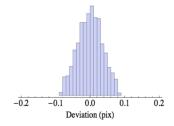












The 2D residual plots between our measurements and our trace models.

The object positions at which measurements were performed.

The residuals of all our measurements as a function of S along the trace.

The average error in the trace positions over the entire field of view.

UVIS Grism Wavelength Calibration and Stability

Orbits	External: I Internal: 0
PI, Co-l's	Brammer, Pirzkal
Purpose	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	
Resources: Observations	Heritical as they show ± 1 and ± 1 orders) proviously observed nosition and verity the stability of this l
	0.05 FTE for simple verification that no changes w.r.t. previous cycles. 0.20 FTE if recalibration is necessary.
Products	Updated configuration files, if necessary.
Accuracy Goals	Establish the stability of the UVIS wavelength calibration to ~I pixel.
1	ISRs 2009-01, 2011-18, 2017-20 (Configuration files updated Oct 2015 to replace the 2009 values) http://www.stsci.edu/hst/wfc3/analysis/grism_obs/calibrations/wfc3_g280.html
Prior Cycle IDs	12359, 12705, 13091, 13578, 14025, 14387, 14545

UVIS Grism Wavelength Calibration and Stability

ISR 2009-01

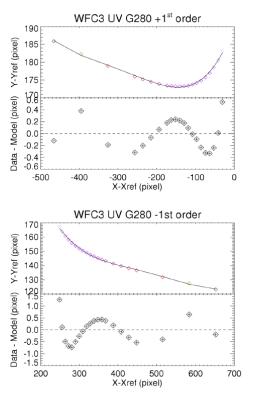


Figure 3: 4^{th} order polynomial fit to the trace of the $+1^{st}$ and -1^{st} orders on Chip 1 as determined in TV3. Monochromator steps between 200 and 815nm are fitted.

ISR 2011-18 Contamination

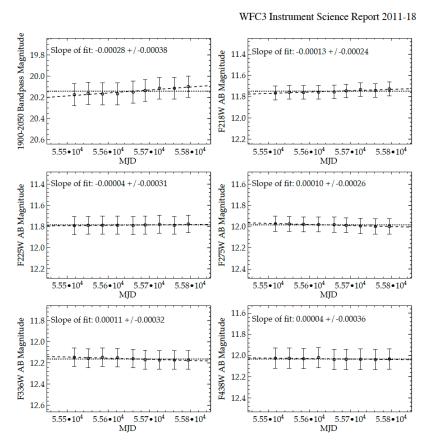


Figure 7: The G280 fluxes have been convolved with WFC3 filter transmission profiles and the appropriate PHOTPLAM values to obtain photometric magnitudes which can be directly compared with WFC3/UVIS photometry. A pseudo-filter has been created for monitoring changes as a function of time at wavelengths shorter than the bluest WFC3 imaging filter. Also shown are error-weighted least-squares fits to the data to test for evidence of change with time. Visually, the pesudo-filter appears to show an *increase* in flux with time, but not at a statistically significant level.

Flatfield Calibration

Same cadence as the prior cycle

Monitor a population of UVIS pixels with anomalous low QE values

```
45 internal orbits = 1 orbit*6 epochs (UV) + 3 orbits*13 epochs (VIS)
```

Monitor the health of the UVIS filters via int-flats

```
13 internal orbits = 3 orbits * 1 epoch (D<sub>2</sub>, all UV filters)
+ 8 orbits * 1 epoch (Tungsten, all VIS filters)
+ 1 orbit * 2 epochs (Tungsten, subset VIS filters)
```

Monitor the health of the IR filters via int-flats.

```
18 internal orbits = 6 orbits *2 exposures * 1 epoch (all filters)
+ 1 orbit *3 exposures * 2 epochs (broadband filters)
```

Monitor the health of the CSM by observing the bright earth

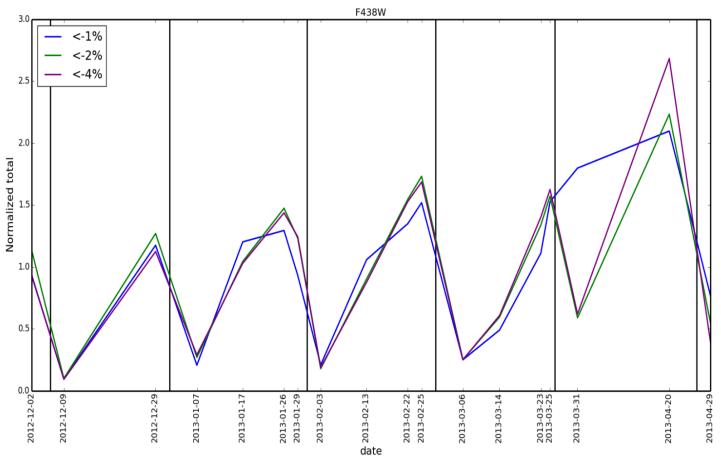
200 internal orbits = At least one flat every time the CSM is moved. (Typical cadence is 1-2x/week)

WFC3 UVIS Pixel-to-Pixel QE Variations via Internal Flats Monitor

Orbits	External: Internal: 45 (REDUCED from 51 in Cy24. Removed unneeded contingency orbits)			
PI, Co-l's	McKay, Mack, Khandrika			
Purpose	To track the population of pixels that exhibit anomalous QE variations between anneals.			
Description	This program monitors the randomly distributed population of pixels that exhibit anomalous QE variations between anneals, characterized by a sensitivity loss that is more pronounced in the blue than in the red. This population is unique for each anneal cycle and exhibits clustering in the UV. Internal flats are taken to monitor this population in the UV and Visible wavelengths.			
	45 internal orbits: UV = 1 orbit*6 epochs, VIS= 3 orbits*13 epochs For the UV, 6 orbits of internal flats with the D2 lamp are taken through F225W and F336W, 1 orbit every other month in the week before the anneal. UV orbits require non-int to minimize cycling of the D2 lamp. For the Visible filters, we will obtain 3 orbits each anneal cycle (a week before the anneal, midway between anneals, and just after the anneal) with the Tungsten lamp through F814W, F645N and F438W.			
	Gunning et al. have code that tracks the deviation of individual pixels between cycles. This needs to be adapted to analyze recent data and implemented in QuickLook for easy tracking.			
Products	A tabulated population of anomalous pixels between anneals . With this, we may be able to deliver a time dependent mask to users.			
Accuracy Goals				
Prior Results,	ISR 2014-18 "Pixel-to-Pixel Flat Field Changes in WFC3/UVIS"			
Prior Cycle IDs	13169, 13585, 14027, 14389, I 4546			

WFC3 UVIS Pixel-to-Pixel QE Variations via Internal Flats Monitor

WFC3-2014-18



Normalized low sensitivity pixel population in F438W as a function of time. Anneals are indicated by black vertical lines.

UVIS Internal Flats

Orbits	External: Internal: 13				
PI, Co-l's	McKay, Mack, Khandrika				
Purpose	Monitor the stability of the UVIS pixel-to-pixel sensitivity in all filters by obtaining internal flat fields with the sungsten and deuterium lamps				
Description	We will acquire internal flats in all UVIS filters and monitor the decay of the internal lamps				
	13 orbits = 3(D ₂) + 8(Tungsten_all) + 2(Tungsten_subset) 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.				
I	0.15 FTE. Analysis to be completed by Co-I. Check for filter stability. Search for prominent new features in each UVIS filters by comparing internal flats acquired over time.				
Products					
Accuracy Goals	Monitor the stability of the pixel-to-pixel response and track the decay of the calibration lamps.				
Prior Results, ISRs	ISR 2010-03: "WFC3 SMOV Proposal 11432: UVIS Internal Flats"				
Prior Cycle IDs	11432, 11914, 12337, 12711, 13097, 13586, 14028, 14390, 14547				

UVIS Internal Flats

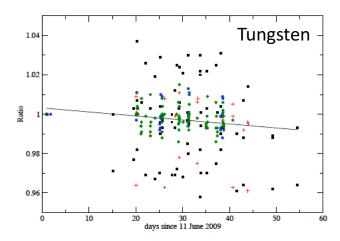


Figure 2. Ratios of the median count-rates of the flatfields (tungsten lamp) to the first flatfield observed in each filter. The figure includes all internal flats taken during SMOV (squares are wide, circles are medium, diamonds are narrow, and the plus are X and LP filters), excluding images taken to test the gain of the detector; the black line is a linear fit to the data showing a gradual drop in the lamp output of $\sim 0.5\%$ over 60 days.

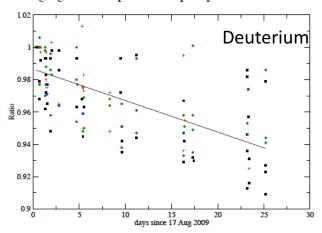
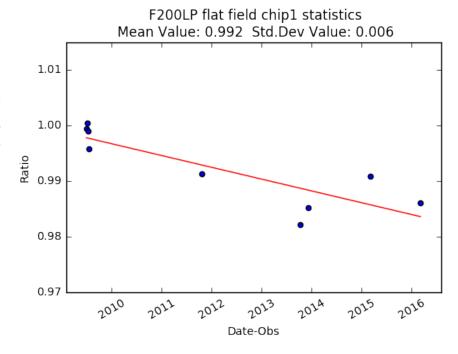


Figure 5. Ratios of the median count-rates of the flatfields (deuterium lamp) to the first flatfield observed in each filter. The figure includes all internal flats taken during SMOV (squares are wide, circles are medium, diamonds are narrow, and the plus are X and LP filters). The black line is a linear fit to the data showing a drop of \sim 5 %. The scatter seen in the data is probably caused by the variability seen in the deuterium lamp flatfields.

Latest results showing Tungsten lamp decay: 2017 McKay et al., in prep

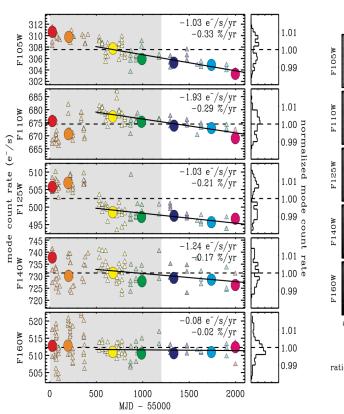


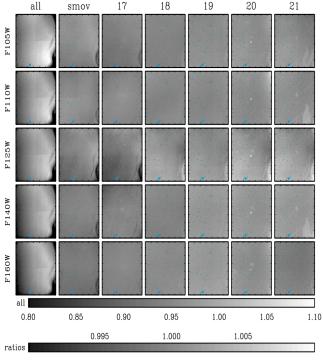
IR Internal Flats

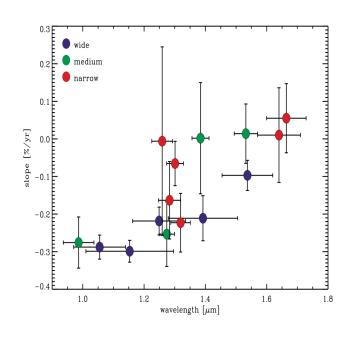
Orbits	External:0 Internal: 18			
PI, Co-l's	Kurtz, Ryan, Sabbi			
Purpose	Monitor the stability of the IR pixel-to-pixel sensitivity in all filters by obtaining internal flat fields with the sungsten lamp.			
Description	In this program, we study the stability and structure of the IR channel flat field images through all filter elements. Flats will be monitored, to capture any temporal trends in the flat fields and delta flats produced. High signal observations will provide a map of the pixel-to-pixel flat field structure, as well as identify the positions of any dust particles. This version contains a full set of IR filter exposures once in the middle of the cycle. In addition we will acquire 3 exposures in each of the 2 broadband filters F105W, F110W, F125W, F140W, and F160W twice during the cycle. This work builds on the ISR of Ryan & Baggett (2015-011).			
	18 internals = (6*2) + (3*2) We will acquire 2 exposures for the full set of IR filters once in the middle of the cycle. This requires 6 orbits* 2 exposures = 12 orbits. 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 = (2 epochs x 3 exposures). In this cycle, if time allows, we will obtain a short dark before the intflat to mitigate persistence.			
Resources: Analysis				
Products	Monitor the stability of the pixel-to-pixel response and track the decay of the calibration lamps.			
Accuracy Goals				
Prior Results, ISRs	Ryan et al (2015-11). Dahlen et al (2013-04). Hilbert et al (2009-42)			
Prior Cycle IDs	11433,11915,12338,12712,13098,13587,14029, 14391, 14548			

IR Internal Flats

Figures from WFC3-ISR 2015-11 (Ryan & Baggett)







Mode count rate as function of time for five broadband filters. Steady decline seen since cycle 18.

Median flat-field for five broadband filters for **ALL** data for SMOV-cy21 (first column). Subsequent columns show ratio of median stack (for a given cycle) to the cumulative stack (the ratio color bar is scaled +/- 1%).

Slope of mode count rate vs. wavelength (see first figure) for broadband (blue), mediumband (green), narrowband (red) filters. The trend suggests a reddening of the tungsten lamp, consistent with lamp's aging.

WFC3 CSM Monitor with Earth Flats

Orbits	External: Internal: 200
PI, Co-l's	Sunnquist, McCullough, Ryan
Purpose	Monitor the CSM angle and new blob appearances using earth flats.
Description	Take quick (~100 s) F153M exposures looking down at the dark Earth to use airglow as a uniform glowing screen. Use these images to detect new blobs and use the positions to track the CSM angle over time. Similar to the previous versions of this proposal, after this program is implemented, all 14549 visits yet to be scheduled are cancelled and this new program picks up where it left off.
Resources: Observations	200 orbits: F153M, SPARS25, NSAMP=5 Obtain at least one flat every time the CSM is moved. Typical cadence is 1-2x/week, but gaps are expected when either the CSM doesn't move or when the schedule is over-constrained.
	Monitoring to be carried out by the PI and Quicklook Team. Updates to the monitoring software/blob ISR to be completed by the PI.
Products	DQ flags (BPIXTAB), DFLTFILE (proposed)
Accuracy Goals	
1	ISR 2015-06 (impact of blobs on WFC3/IR photometry), ISR 2014-21 (time-dependent blob flags/monitoring), ISR 2012-15 (blob monitoring/color), ISR 2010-06 (blob monitoring/origin)
Prior Cycle IDs	14392,14549

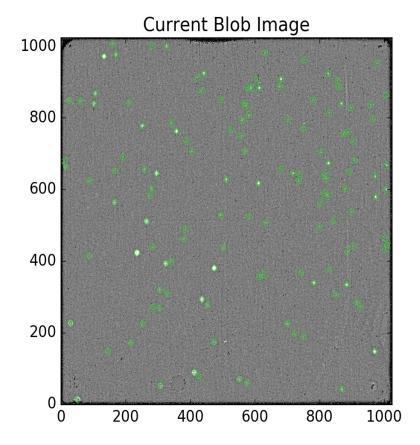
WFC3 CSM Monitor with Earth Flats

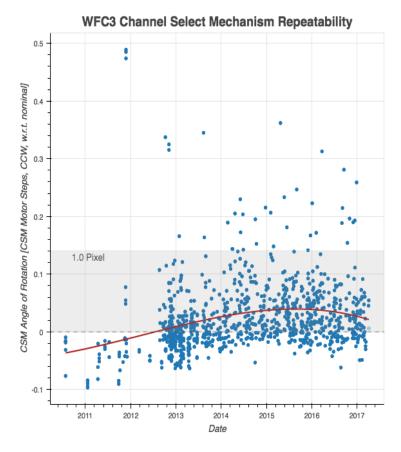
Quicklook CSM Monitor page:

https://wfc3ql.stsci.edu/automated_outputs/cal_ir_check_csm

New blobs are searched for using the most recent calibrated dark earth flat (i.e. the "blob image").

The positions of these blobs are used to measure the CSM angle of rotation – a measure that is used to ensure the CSM is operating as expected as new blobs form.





Astrometric Calibration

Same cadence as the prior cycle

• Monitor the temporal stability of the geometric distortion in both detectors

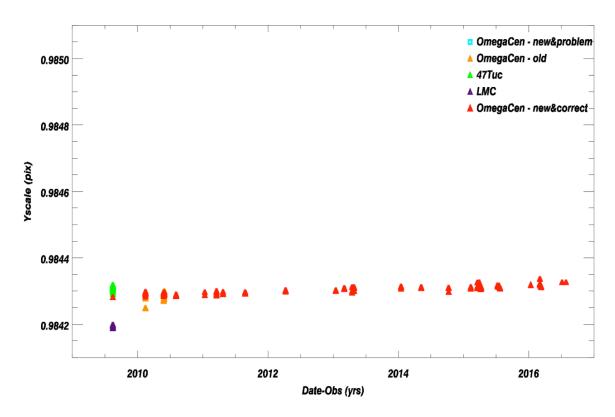
6 internal orbits = 1 exposure *3 epochs (UVIS, F606W) + 1 exposure *3 epochs (IR, F160W)

WFC3 Astrometric Scale monitoring

Orbits	External: 6 Internal: 0
PI, Co-l's	Kozhurina-Platais, Martlin, McKay
Purpose	Continue monitoring the stability of the WFC3 geometric distortion over time.
	The standard astrometric catalog in the field of globular cluster Omega Cen has been used to examine the geometric distrotion of WFC3 UVIS and IR as a function of wavelength in multi-cycle calibration programs over the last 9 years of WFC3 onboard HST. All observations from these programs have been reduced and provided the multi-wavelength geometric distortion in UVIS and IR. The derived geometric distortion coefficients implemented in the IDCTAB format are used in the HST pipeline to correct for ~7% distortion in WFC3 images down to I%.
Description	All observations of Omega Cen taken through F606W and F160W UVIS and IR filters respectively during the last 9 years (20 epochs in total) were used to look for time dependency of UVIS and IR geometric distortion and the effect of the scale change due to the thermal breathing.
	The purpose of the observations of Omega Cen through F606W and F160W is to derive the skew (non-perpendicularity of X&Y axis) and scale terms of the gemoetric distortion and look for any secular changes.
Resources: Observations	land IR will be observed with the samepointing but with 3 different OTA roll-angles per orbit over 3 epochs. December
Resources: Analysis	leach UVIS and IRdetector and solve 6-parameter transformation w.r.t Standard Astrometric Catalog or/and GAIA to
Products	Calibration geometric distortion (skew and scale parameters) via time of observations, if needed to provide empirical linear time dependency corrections for DrizzlePac. Similar to ACS/WFC time-dependent skew (see ACS-ISR-I5-06 Kozhurina-Platais, et al, 2015)
Accuracy Goals	To reduce uncertainty in the scale to 2 mas if there is time-dependent distortion.
	WFC3-ISR-2015-02 shows that the UVIS distortion is stable over 9 years on-orbit within 0.05 pixels or 2 mas. WFC3-ISR-2012-03 shows that the IR distortion is stable over 2 years on orbit within 0.1 pixel or 6mas.
Prior Cycle IDs	11911, 12094,12353,12714,13100,13570,14031,14393,14550

WFC3 Astrometric Scale monitoring

Plate-scale as function of time for WFC3/UVIS is slightly changing with time



Each point represent the calculated plate-scale from the linear solution for given single-UVIS-drizzled image. The deviation in the plate-scale over time 7-8 years is so insignificant that it can be adopted as a constant. Although we will continue to monitoring