WFC3 Cycle 29 Calibration Plan

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- **21 Routine monitoring programs** (same cadence as in Cycle 27)

- **4 Non-routine (delta) calibration programs**

Program	Description
Testing a New Method for Pinning Down CTE Losses	Explore a new method for measuring CTE losses based on long darks with flash levels the 20-50 electron background range
Supplemental Empirical CTE Calibrations for Photometry and Astrometry	Improve table-based CTE corrections for photometry and astrometry for backgrounds between 5 and 30 electrons
CTE Evaluation of Resolved Objects	Measure the impact of CTE losses on extended sources by comparing with early inflight observations
WFC3/IR Time-Dependent Sensitivity in Staring Mode (Clusters)	Test for changes in the IR sensitivity with wavelength by leveraging off of prior observations of stellar clusters

WFC3 CY29 Calibration

*** Non- monitor**

	ID	PI	Program Title	Ext	Int	ID	PI	Program Title	Ext	Int	
UVIS CCD	16564	*Baggett*	WFC3 UVIS Anneal	0	79	16578	*Sahu*	WFC3 UVIS Shutter Monitoring	0	1	Photometry
	16565	*Khandrika*	WFC3 UVIS Bowtie Monitor	0	132	16579	*Calamida*	WFC3 UVIS & IR Photometry	20	0	
	16566-16568	*Kuhn*	WFC3 UVIS CCD Daily Monitor (Darks & Biases)	0	642	16580	*Calamida*	WFC3 UVIS Time Dependent Sensitivity	12	0	
	16569	*Medina*	WFC3 UVIS CCD Unflashed (CTE) Monitor	0	130	16864	*Bajaj*	**WFC3/IR Time-Dependent Sensitivity in Staring Mode (Clusters)**	5	0	
	16570	*Martlin*	WFC3 UVIS Post-flash Monitor	0	60						
	16571	*Kuhn*	WFC3 UVIS CCD Gain Stability	0	18	16582	*Som*	WFC3 IR Grism Wavelength Calibration	1	0	Grisms
CTE	16572	*Khandrika*	WFC3 UVIS CTI Monitor (EPER)	0	12	16583	*Som*	WFC3 IR Grism Flux/Trace Calibration	3	0	
	16573	*Kuhn*	WFC3 UVIS CTE Monitor (Star Cluster)	8	0	16581	*Som*	WFC3 UVIS Grism Wavelength Calibration	1	0	
	16574	*Medina*	WFC3 Characterization of UVIS Traps with Charge Injection	0	36						
	16861	*Anderson*	**Testing a New Method for Pinning Down CTE Losses**	0	10	16584	*Martlin*	WFC3 UVIS Pixel-to-Pixel QE Variations via Internal Flats	0	45	Flats
	16862	*Anderson*	**Supp. Empirical CTE Calibrations for Photometry and Astrometry**	2	0	16585	*Khandrika*	WFC3 UVIS Internal Flats	0	13	
	16863	*Anderson*	**CTE Evaluation of Resolved Objects**	1	0	16586	*Green*	WFC3 IR Internal Flats	0	18	
IR Detector	16575	*Dauphin*	WFC3 IR Dark Monitor	0	97	16587	*Medina*	WFC3 CSM Monitor with Earth Flats	0	200	
	16576	*Green*	WFC3 IR Linearity Monitor	0	10	16588	*Platais*	WFC3 Astrometric Scale Monitoring	6	0	Astrom
	16577	*Khandrika*	WFC3 IR Gain Monitor	0	16						

WFC3 CY28 Calibration

*** Non- monitor**

Group	ID	PI	Program Title	Ext	Int	ID	PI	Program Title	Ext	Int	Group
UVIS CCD	16414	*Baggett*	WFC3 UVIS Anneal	0	79	16406	*Sahu*	WFC3 UVIS Shutter Monitoring	0	1	Photometry
UVIS CCD	16393	*Khandrika*	WFC3 UVIS Bowtie Monitor	0	132	16415	*Calamida*	WFC3 UVIS & IR Photometry	20	0	Photometry
UVIS CCD	16394-16396	*Kuhn*	WFC3 UVIS CCD Daily Monitor (Darks & Biases)	0	642	16416	*Calamida*	WFC3 UVIS Time Dependent Sensitivity	12	0	Photometry
UVIS CCD	16397	*Medina*	WFC3 UVIS CCD Unflashed (CTE) Monitor	0	130	16439	*Som*	**WFC3 IR Time Dependent Sensitivity**	2	0	Photometry
UVIS CCD	16398	*Martlin*	WFC3 UVIS Post-flash Monitor	0	60	16512	*Bajaj*	**WFC3/IR Time-Dependent Sensitivity in Staring Mode (Clusters)**	2	0	Photometry
UVIS CCD	16399	*Kuhn*	WFC3 UVIS CCD Gain Stability	0	18	16518	*Dressel*	**WFC3 Focus Cross-Calibration**	6	0	Focus
CTE	16400	*Khandrika*	WFC3 UVIS CTI Monitor (EPER)	0	12	16407	*Som*	WFC3 IR Grism Wavelength Calibration	1	0	Grisms
CTE	16401	*Kuhn*	WFC3 UVIS CTE Monitor (Star Cluster)	8	0	16408	*Som*	WFC3 IR Grism Flux/Trace Calibration	3	0	Grisms
CTE	16402	*Medina*	WFC3 Characterization of UVIS Traps with Charge Injection	0	36	N/A	*Som*	WFC3 UVIS Grism (Deferred to Cy29)	0	0	Grisms
CTE	16440	*Anderson*	**WFC3/UVIS CTE: A Direct Approach to Model Pinning**	0	24	16409	*Martlin*	WFC3 UVIS Pixel-to-Pixel QE Variations via Internal Flats	0	45	Flats
CTE	16441	*Anderson*	**Understanding How CTE Affects the Faintest Point Sources**	2	0	16410	*Khandrika*	WFC3 UVIS Internal Flats	0	13	Flats
IR Detector	16403	*Medina*	WFC3 IR Dark Monitor	0	97	16411	*Green*	WFC3 IR Internal Flats	0	18	Flats
IR Detector	16404	*Green*	WFC3 IR Linearity Monitor	0	10	16412	*Medina*	WFC3 CSM Monitor with Earth Flats	0	200	Flats
IR Detector	16405	*Khandrika*	WFC3 IR Gain Monitor	0	16	16413	*Platais*	WFC3 Astrometric Scale Monitoring	6	0	Astrom

WFC3 Calibration Orbit Request by Cycle

Cycle	Type		External (e)	Internal (i)
29	Monitor		51	1509
	Delta: Fall 2021		8	10
		Total	59	1519
28	Monitor		48	1509
	Delta: Fall 2020		6	24
	Delta : Spring 2021		9	0
		Total	63	1533
27	Monitor		48	1509
	Delta : Fall 2019		12	14
		Total	60	1523
26	Monitor		49	1512
	Delta: Fall 2018		6	2
		Total	55	1514

❖ Non-monitor (Delta) Programs

Cycle 29
- IR Time-Dep (Clusters) = 5e
- CTE Pinning = 10i
- CTE Photom/Astrom = 2e
- CTE Resolved Sources = 1e

Cycle 28
- IR Grism Flux Calibration = 2e
- IR Time-Dep (Scans) = 2e
- UVIS Background Check = 24i
- UVIS External CTE = 2e
- Photometry = 1e
- IR Time-Dep (Clusters) = 2e
- Focus = 6e

Cycle 27
- Tungsten Lamp Warmup = 4i
- UVIS Background Check = 10i
- UVIS Grism Flux Cal = 5e
- UVIS Grism Wave Cal = 4e
- IR Time-Dep Sensitivity. = 3e
- IR Color Terms (2 ACS parallels)

Cycle 26
- Persistence = 2e+2i
- Focus = 4e

http://www.stsci.edu/hst/instrumentation/wfc3/calibration-plan

UVIS CCDs

Same as the previous cycle

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

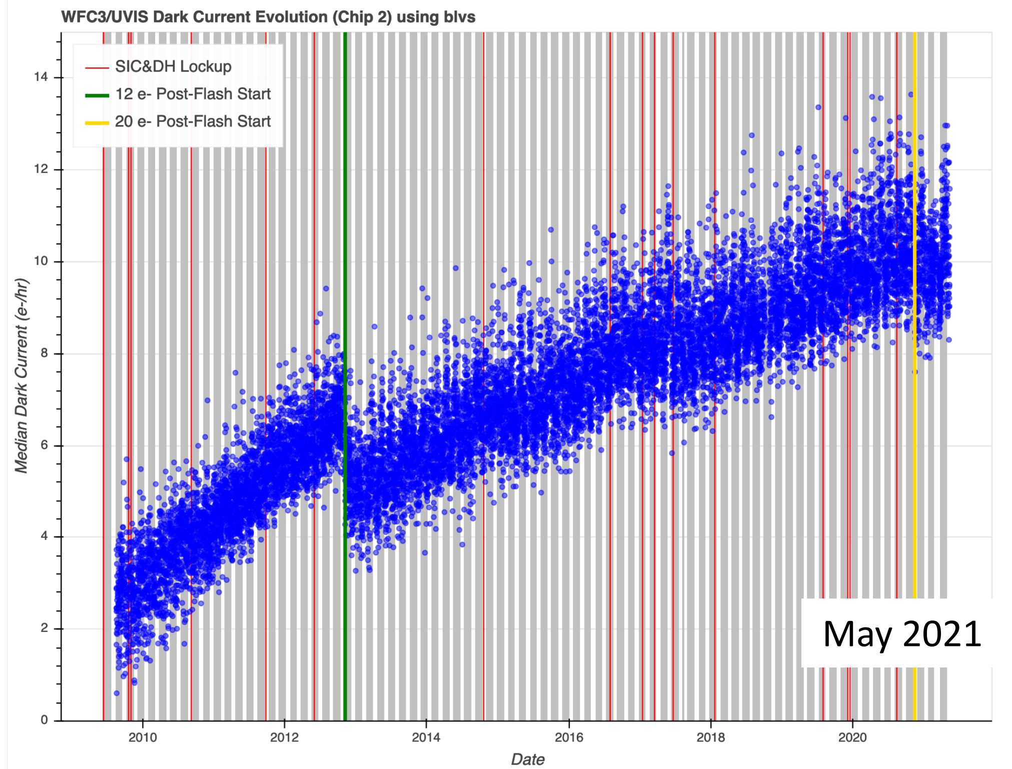
- Perform an anneal of the detector every month
  79 internal = 6 orbits/anneal * 13 anneals + 1 IR dark contingency
- Mitigate hysteresis (bowtie) by conditioning the detector via a series of unsaturated and saturated internal flats
  132 internal = 122 orbits (1 every 3 days) + 10 contingency for SIC&DH 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-I's	Baggett, Martlin, 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 prior cycle, WFC3 anneals have been performed keeping the IR detector cold (IRTEMP=COLD). This cycle, 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.
Resources: Observations	79 total = (13 iterations * 6 orbits/iteration) + 1 orbit. Each iteration requires 6 orbits (2 before/2 after each anneal for biases/darks + 1 orbit for the anneal itself + 1 orbit for the attached post-anneal bowtie visit). Seamless continuity across the cycle boundary requires 13 anneals. One orbit for 1 IR dark to be taken *only* in the event an original anneal procedure (warming the IR detector) is performed.
Resources: Analysis	Supports 100% of UVIS programs
Products	Quicklook monitoring plots, tables: read noise, dark current, hot pixels. Data used for daily superdarks (CTE-corrected and un-CTE-corrected), pixel history analysis with monthly bad pixel table deliveries as well as yearly superbiases for calibration pipeline.
Accuracy Goals	Readnoise to <1% ; dark reference files ~2e-/hr rms; bias reference files <1e- rms.
Prior Results, ISRs	ISR 2019-11: 2018 Superbias reference file; ISR 2018-15: UVIS pixel history; ISR 2017-17: Read noise
Prior Cycle IDs	12343, 12687, 13071, 13554, 14000, 14366, 14529, 14978, 15567, 15712, 16414 (cy28)

WFC3/UVIS Anneal

UVIS2 dark vs time



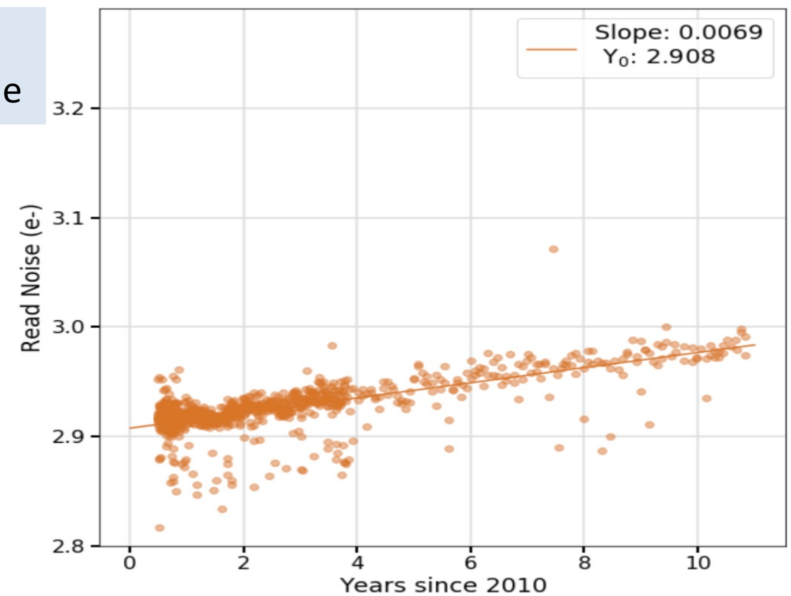
Reference files for CRDS

- BIASFILE
- DARKFILE, DRKCFILE
- BPIXTAB

Bad Pixel Table: DQ Flags

FLAG Value	Data Quality Condition	
	UVIS	IR
0	OK	OK
1	Reed-Solomon decoding error	Reed-Solomon decoding error
2	Data replaced by fill value	Data replaced by fill value
4	Bad detector pixel	Bad detector pixel
8	(unused)	Unstable in zero-read
16	Hot pixel	Hot pixel
32	Unstable pixel	Unstable pixel
64	Warm pixel	(Obsolete: Warm pixel)
128	Bad pixel in bias	Bad reference pixel
256	Full- well saturation	Full-well saturation
512	Bad or uncertain flat value	Bad or uncertain flat value
1024	Charge trap	(unused)
2048	A-to-D saturation	Signal in zero-read
4096	Cosmic ray detected by AstroDrizzle	Cosmic ray detected by AstroDrizzle
8192	Cosmic ray detected during CR-SPLIT or REPEAT-OBS combination	Cosmic ray detected during up-the-ramp fitting
16384	Pixel affected by ghost or crosstalk (not used)	Pixel affected by crosstalk (not used)

Amp C Read Noise vs time



https://wfc3ql.stsci.edu/automated_outputs/cal_uvis_make_darks
https://wfc3ql.stsci.edu/automated_outputs/cal_uvis_make_readnoise

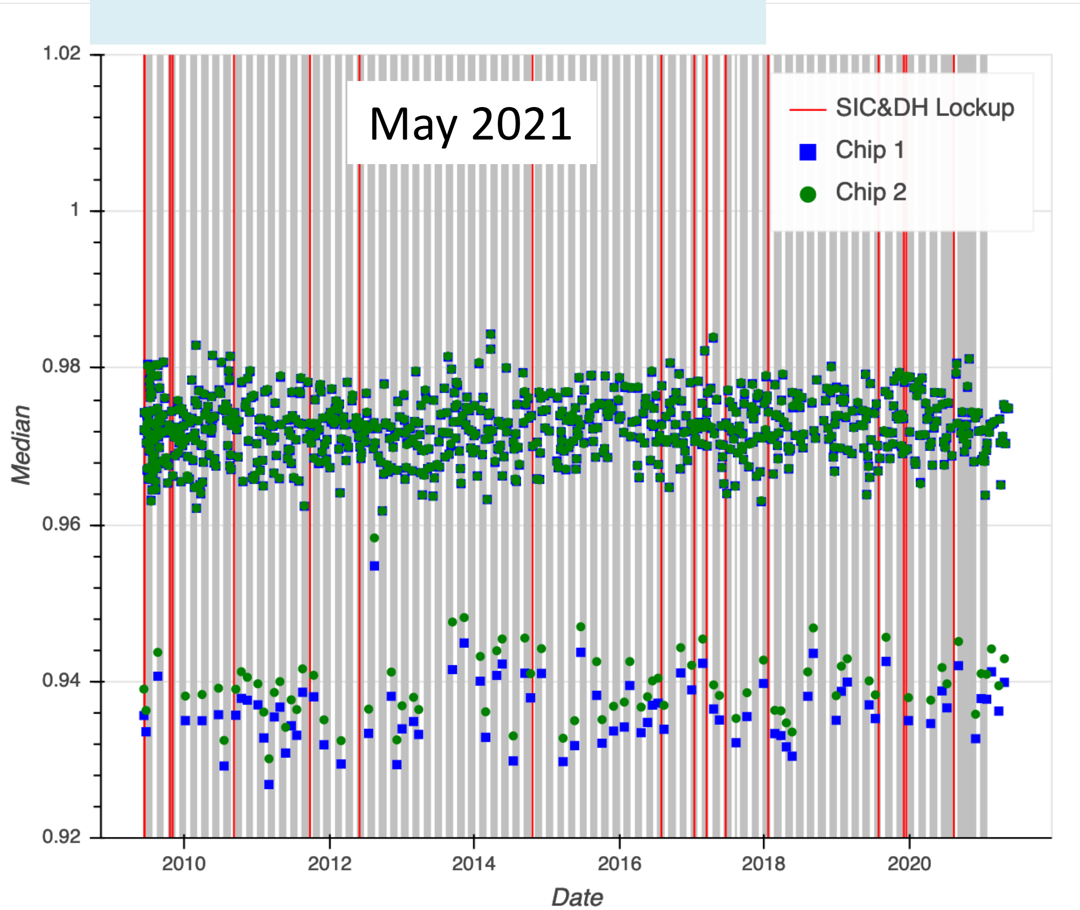
UVIS Bowtie Monitor

Orbits	External:0 Internal: 132
PI, Co-I's	Khandrika, Baggett, Pidgeon
Purpose	Condition UVIS detector for science observing. During TV internal flat testing, it was discovered that the UVIS detector exhibits occasional low-level (~1%) quantum efficiency offsets (i.e. hysteresis) across both chips, an effect dubbed 'bowtie' due to its unique shape in the image ratios. The ground tests revealed that hysteresis can be negated by overexposing the detector by several times the full well. This multi-cycle monitoring program was developed to detect and mitigate UVIS hysteresis on orbit.
Description	Each visit acquires a set of three 3X3 binned internal Tungsten flats. These include (1) an unsaturated image to check for hysteresis features, (2) a saturated 'QE pinning' exposure to fill traps and mitigate QE offsets, and (3) an additional unsaturated image to assess the hysteresis removal efficiency. The F475X filter was selected for (1) its high throughput, (2) its bandpass (<700nm), which is known to mitigate hysteresis and (3) its status as a low-priority filter for science observations.
Resources: Observations	365/3 days= 122 orbits + 10 extra for SIC&DH lockups Three internal flats every 3 days using the F475X filter.
Resources: Analysis	Supports 100% of UVIS programs; Analysis includes inspecting unsaturated frames and image ratios, identifying trends in image ratios over time, quantifying the efficiency of the neutralizing exposure, and investigating anomalies. Investigate shutter 'strobe effect.'
Products	Bowtie data is used for high-cadence monitoring of the relative gain (see slide 17) Plots for tracking the bowtie with time (ratio of the first to the third image in a set)
Accuracy Goals	Track bowtie ratio (im1/im3) versus time to 1% rms
Prior Results, ISRs	ISR 2018-11 (UVIS Shutter-induced Vibration). ISR 2017-08 (Relative Gain) ISR 2013-09 (Bowtie), ISR 2009-24 (Bowtie)
Prior Cycle IDs	12344, 12688, 13072, 13555, 14001, 14367, 14530, 14979, 15568, 15713, 16393 (cy28)

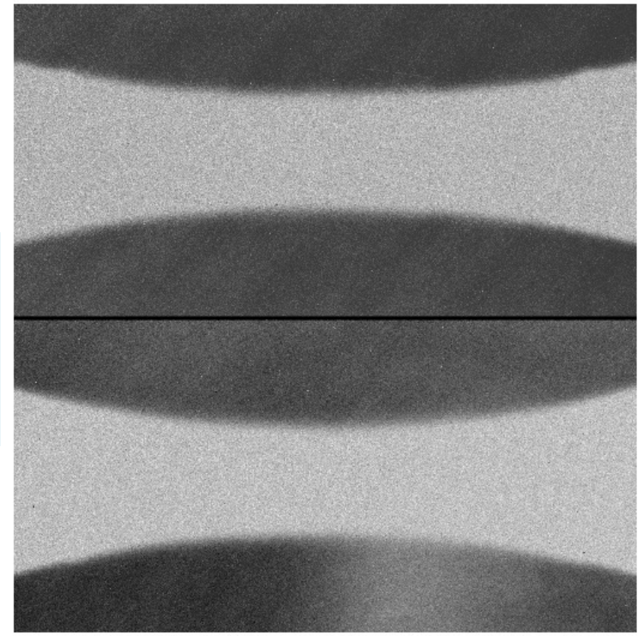
UVIS Bowtie Monitor

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

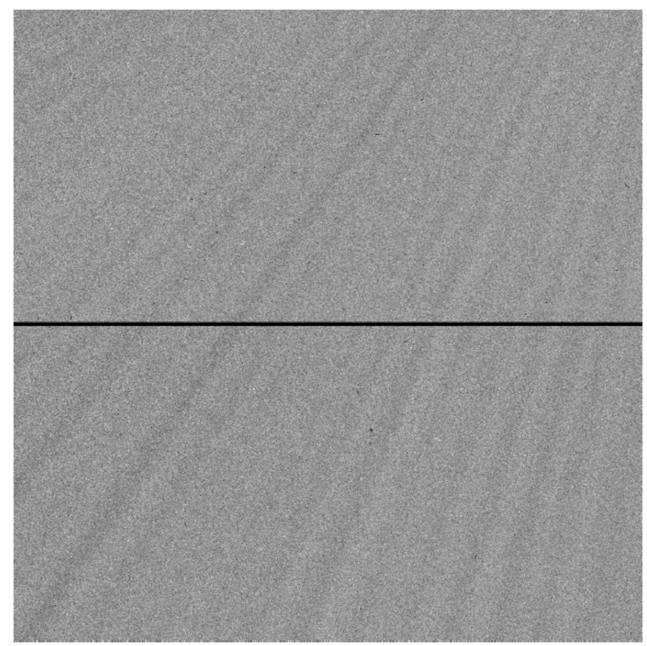
Bowtie Ratio (im1/im3) for shutter A



ISR 2013-09
Bowtie effect (im1/im3), ± 5%



ISR 2018-11
Shutter strobe effect, ± 0.25% (variation in blade speed)



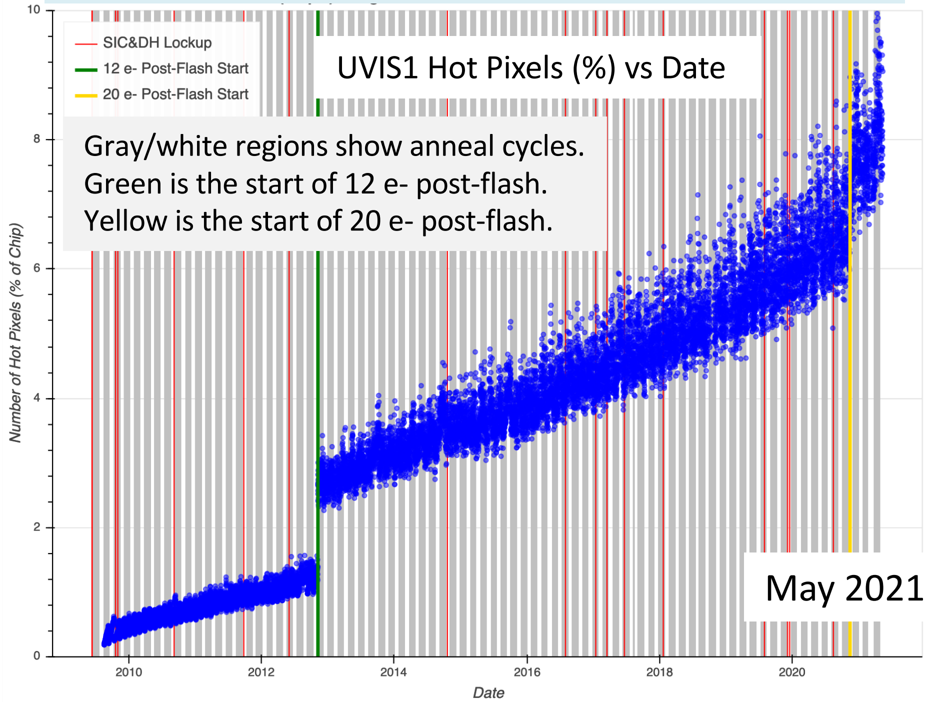
UVIS CCD Daily Monitor

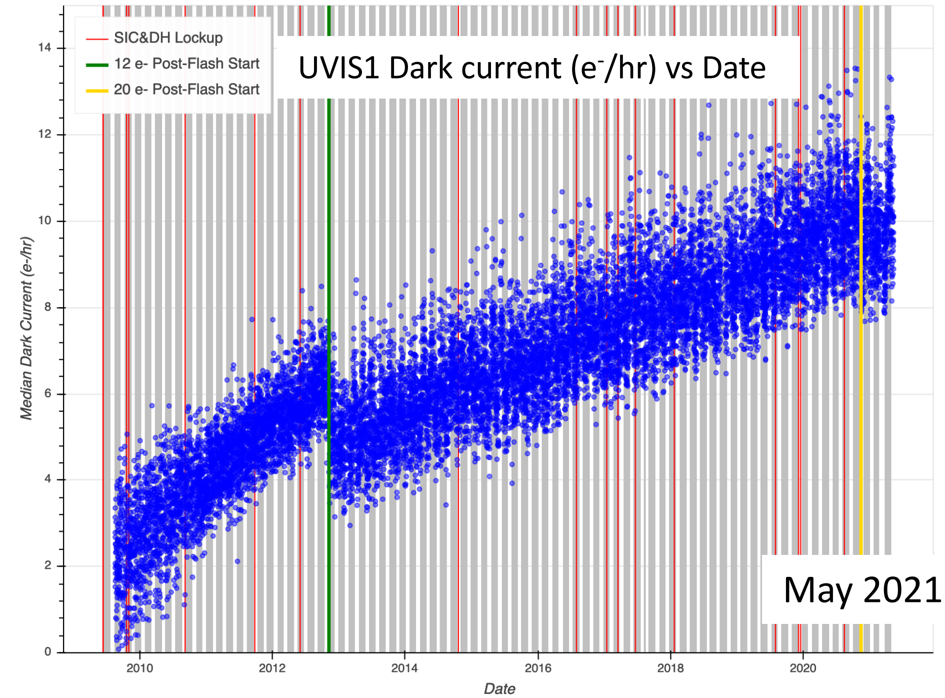
Orbits	External: 0 Internal: 642
PI, Co-I's	Kuhn, Martlin, Khandrika, Pidgeon
Purpose	Continue to monitor the behavior of the UVIS CCDs with a daily set of bias and/or dark frames. These data will be used to generate bias and dark reference files for CRDS. These reference files are used to calibrate 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 darks are requested in a separate proposal. *Day 1 = 2 visits: one with 2 biases, one with 2 darks.* *Day 2 = 2 visits: each with 2 darks* *Day 3 = 1 visit: 2 darks.* *Day 4 = 2 visits: each with 2 darks.* All non-Day1-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 Day1-Visit1 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	642 orbits = (91 four-day cycles * 7 orbits/cycle) + 5 contingency orbits
Resources: Analysis	Supports 100% of UVIS programs
Products	Reference files: Dark (*drk.fits, *dkc.fits) and bias (*bia.fits)
Accuracy Goals	Dark reference files: ~3 e-/hr rms; Bias reference files: <1 e- rms
Prior Results, ISRs	ISR 2019-11, 2018 Superbias; ISR 2019-08: Periodicity in the WFC3/UVIS Bias Overscan ISR 2018-15: UVIS pixel stability from darks; ISR 2017-23: Bias Reference Files Analysis 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, 14980/81/82, 15569/70,71, 15714/15/16, 16394/95/96

UVIS CCD Daily Monitor

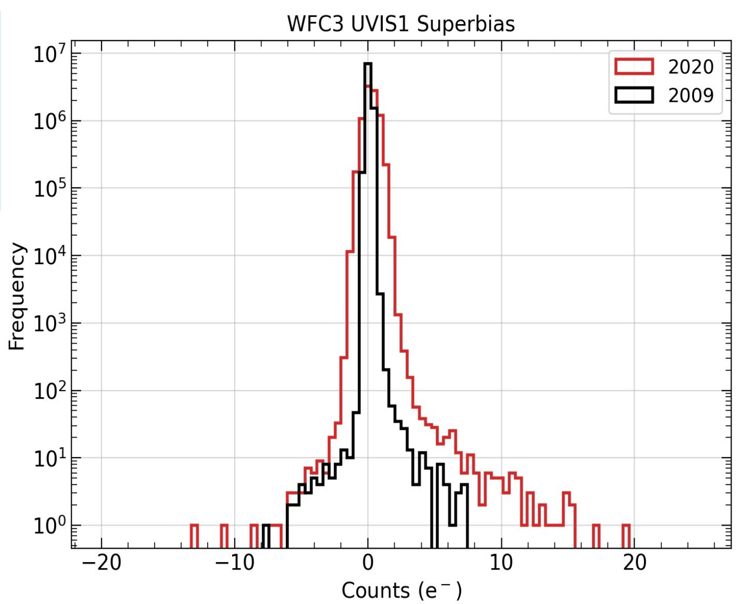
Evolution of Hot Pixels (left) and Dark current (right)

QL: https://wfc3ql.stsci.edu/automated_outputs/cal_uvis_make_darks

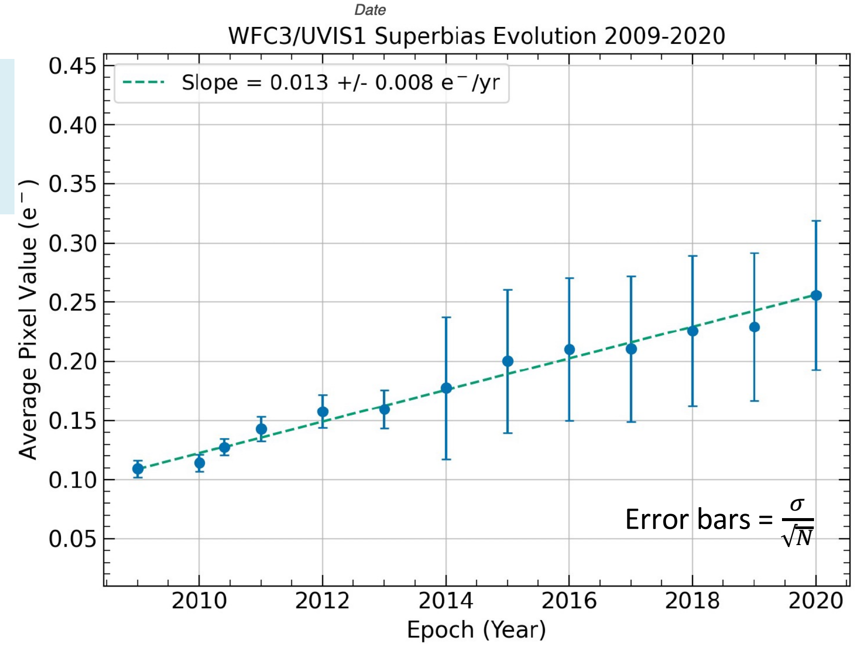




UVIS1 Superbias histograms: 2009 vs 2020



UVIS1 Mean bias vs Date

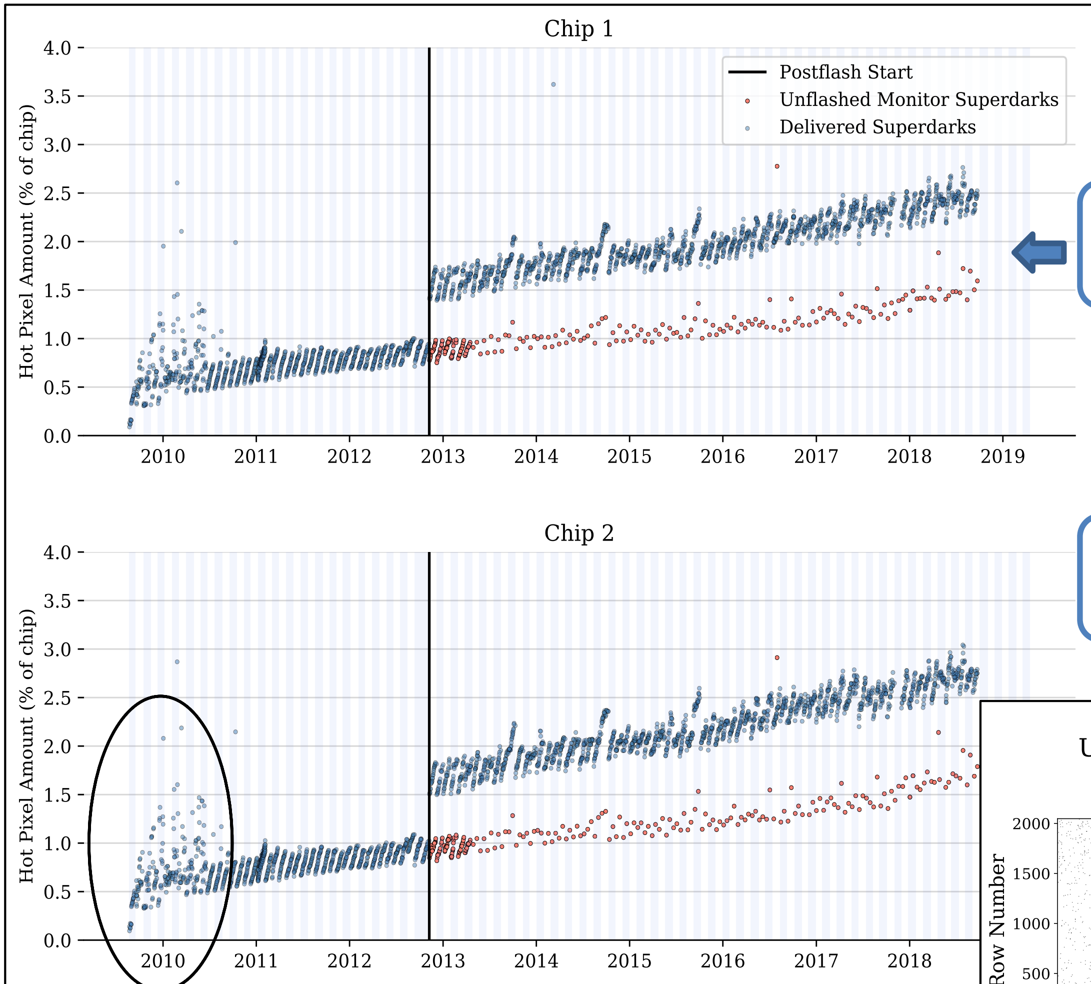


UVIS Un-flashed (CTE) Monitor

Orbits	External: 0 Internal: 130
PI, Co-I's	Medina, Khandrika, Kuhn
Purpose	Obtain un-flashed darks to monitor how well the post-flash is mitigating CTE and to measure the growth of hot pixels observed exposures with low background
Description	Temporal changes in CTE losses and the efficacy of the post-flash mode are monitored by a series of WFC3/UVIS darks (with no post-flash) taken before and after the monthly UVIS anneal. A large number of internals are taken as part of a daily monitor of warm/hot pixel growth and read noise, however 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. When used conjunction with the post-flashed internals, the un-flashed internals allow for an assessment of how well the post-flash is mitigating the CTE losses.
Resources: Observations	130 orbits = 13 anneals * 10 orbits per anneal =(5 orbits pre-anneal + 5 orbits post-anneal, where each orbit consists of a single 900s dark)
Resources: Analysis	Supports 100% of UVIS programs, but provides the most value for data taken with low backgrounds
Products	Validation that post-flash is effectively mitigating CTE losses
Accuracy Goals	Track hot pixel fraction versus time to 0.5% rms. Quantify the fractional dependence on detector position compared to those detected in flashed darks
Prior Results, ISRs	ISR 2019-10: 'Post-flashed superdarks contain at least 50% more hot pixels, and had 2 e-/hr lower dark current for each anneal cycle'
Prior Cycle IDs	13559 (cy21), 14005 (cy22), 14371 (cy23), 14534 (cy24), 14983 (cy25), 15572 (cy26), 15717 (cy27), 16397 (cy28)

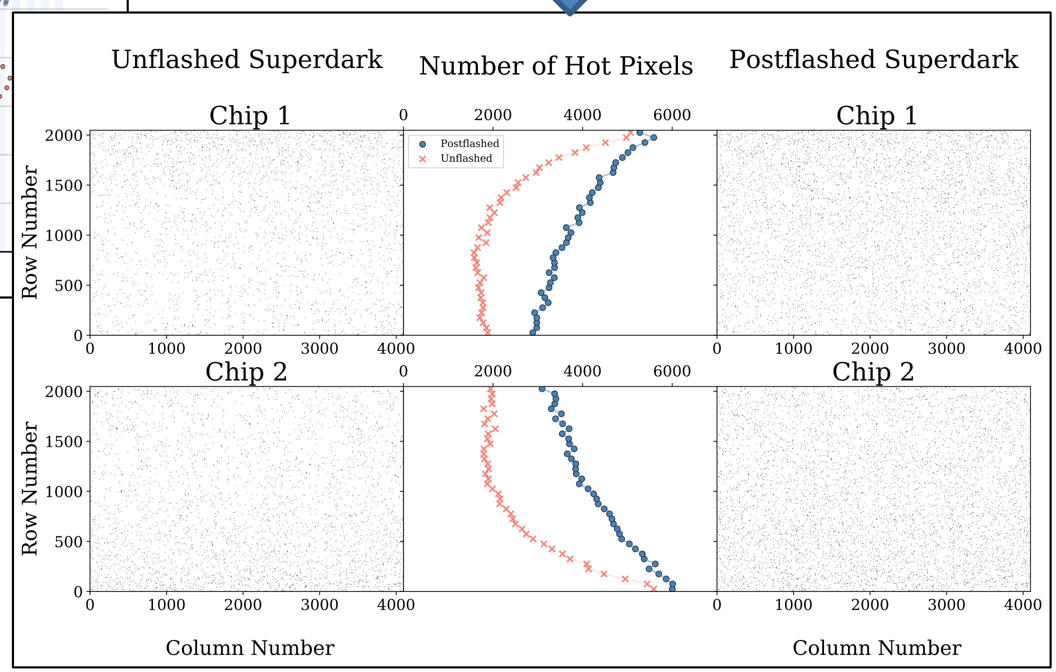
UVIS Un-flashed (CTE) Monitor

ISR 2019-10



Hot Pixel Evolution in the Post-flashed Superdarks and their Un-flashed equivalents

Hot pixel detection at each row (a comparison between Post-flashed and Un-flashed)



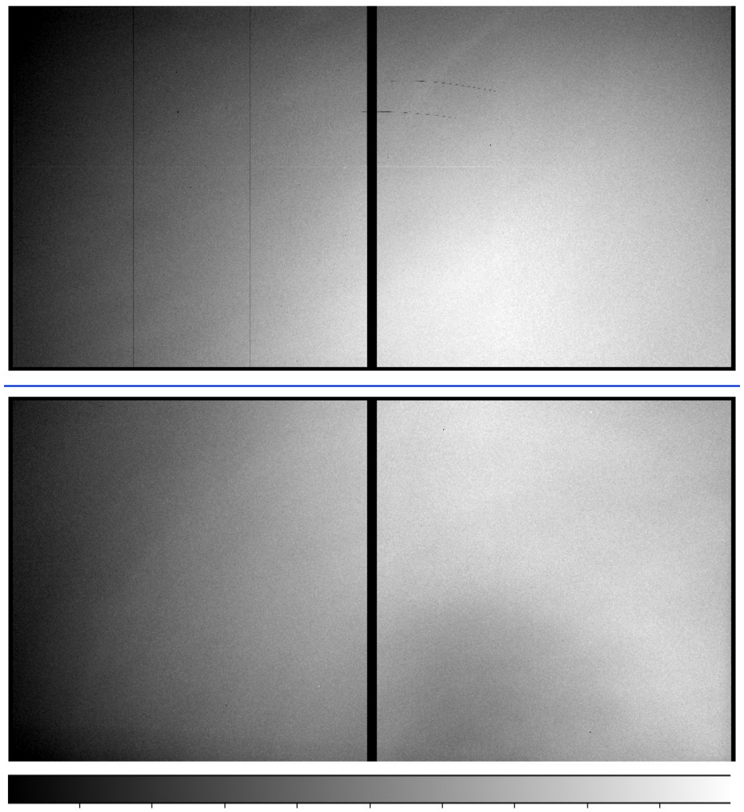
The large hot pixel % is due to scattered light in some individual exposures that were stacked to create the superdarks in this era.
These superdarks were corrected and re-delivered.

UVIS Post-Flash Monitor

Orbits	External: 0 Internal: 60
PI, Co-I's	Martlin, Khandrika, Green
Purpose	Monitor the flux and illumination pattern of the post-flash LED over time via short dark exposures. The data are used to also create a series of post-flash reference files for the calibration pipeline.
Description	Most observers with low-background (<12e-) data are now using the post-flash 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. 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.
Resources: Observations	60 orbits = 36+12+12 =3 orbits/month*12 months (brightness & pattern checks) +12 (new reference file) +12 (contingency)
Resources: Analysis	100% of UVIS programs PI to analyze subarray data @12e, Co-I to analyze long & medium current (used to make reffiles)
Products	Post-flash reference files FLSHFILE = (*fls.fits), Post-flash lookup table for APT
Accuracy Goals	Lamp stability to 0.1%/yr ± 0.5% rms. Shutter stability to 0.1%
Prior Results, ISRs	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 (shutter requirement), 14006, 14372, 14535, 14984, 15573, 15718, 16398 (cy28)

UVIS Post-Flash Monitor

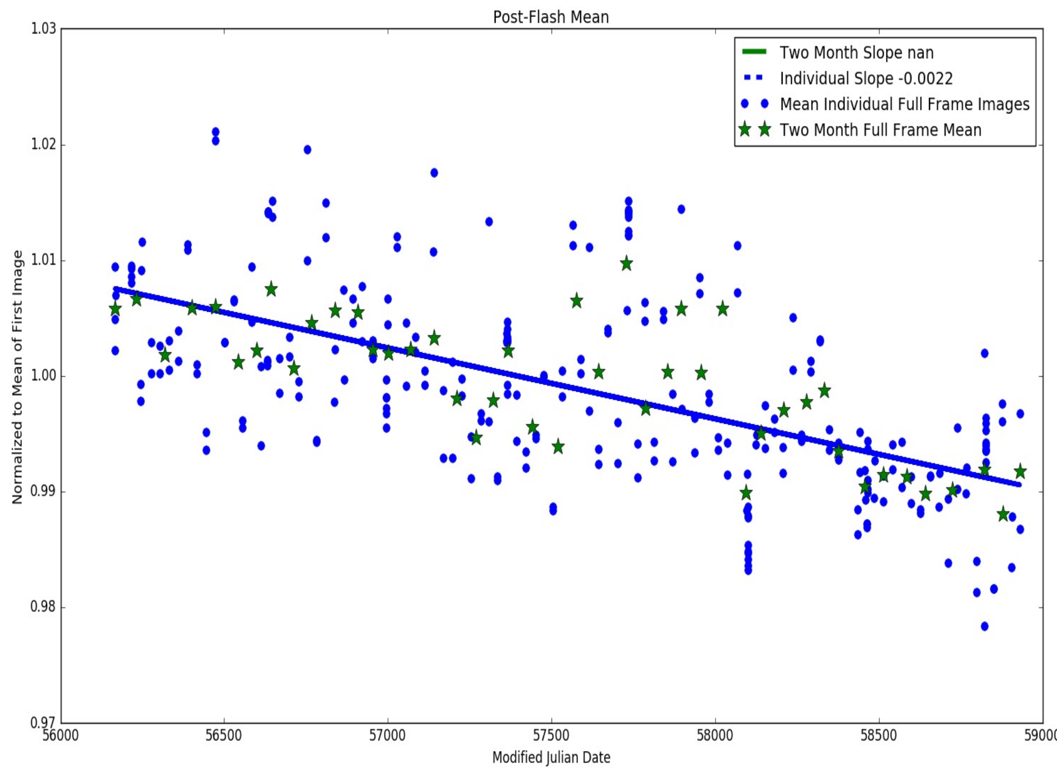
FLSHFILE Reference File:
Shutter A, Medium current



60 e-/s 90 e-/s

ISR 2017-13

Post-Flash LED Lamp Stability :
Normalized mean post-flash vs time based on high S/N PF frames. The slope is ~0.2%/year



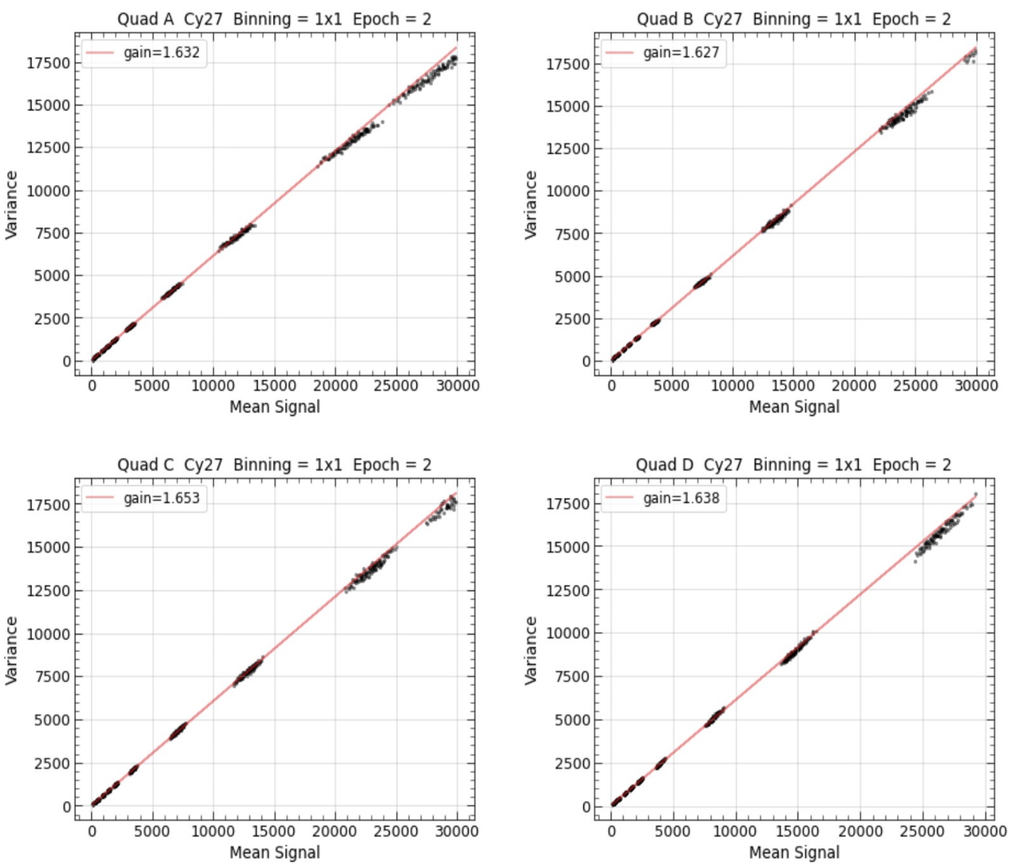
Kurtz 2020, private communication

UVIS Gain Stability

Orbits	External: 0 Internal: 18
PI, Co-I's	Kuhn, Martlin, Khandrika
Purpose	Monitor the absolute gain for the nominal detector count.
Description	Observations consist of 8 pairs of full-frame binned (2x2 and 3x3) and un-binned internal flats at nominal gain. Two epochs, 9 orbits each, are request to be taken ~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.
Resources: Observations	18 orbits = 2 epochs * 9 orbits per epoch Each epoch has 6 full-frame internal flatfields, and 3 binned exposures (2x2 and 3x3) taken in the F645N filter with the tungsten lamp, with varying exposure times.
Resources: Analysis	Supports 100% of UVIS programs Analysis using the standard mean-variance technique. Reduce any difference in the calibrated images across amplifiers for binned proposals. Reduction software requires removal of IRAF dependencies (linear fitting)
Products	Monitoring the health & safety of the instrument
Accuracy Goals	Measure gain to < 1% and track gain stability to < 0.1%
Prior Results, ISRs	ISR 2018-17: (Cy24, Cy25), 2017-08: Relative Gain ISR 2016-13: (Cy23): within ~1-2% of Cy22. ISR 2016-09, ISR 2015-05, ISR 2014-05, ISR 2013-02, ISR 2011-13, ISR 2009-29
Prior Cycle IDs	11906, 12346, 12690, 13168, 13561, 14007, 14373 (Cycle 23 ISR) 14536 (Cy24 within 1% of cy23), Cy25= 14985, Cy26=15574, Cy27=15719, Cy28=16399

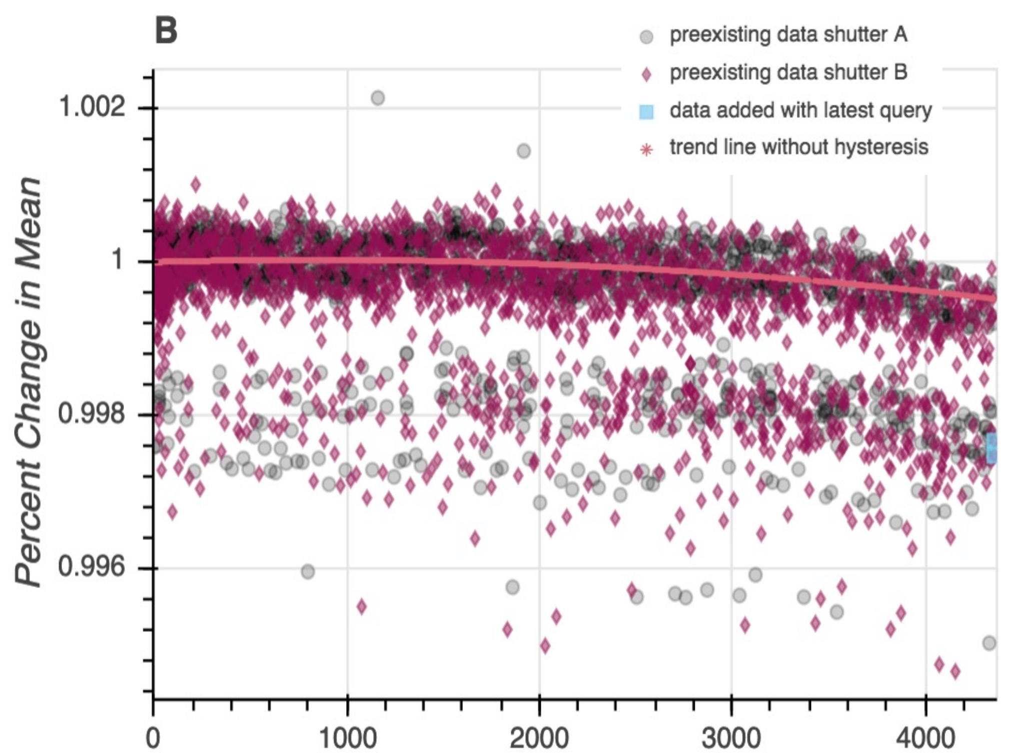
UVIS Gain Stability

Mean Signal (DN) vs Variance



Cycle 27 results (Kuhn, private comm)

Gain Ratio Stability (amp B/A) vs Time (days) derived from Bowtie frames



May 2021 Results

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

CTE Characterization and Calibration

Starting in Cycle 20, GOs can mitigate CT effects using post-flash. To support these efforts we request the following calibration monitor programs (same as the previous cycle):

- Measure and monitor CTE via Extended Pixel Edge Response (EPER)
  12 internal orbits = 2 orbits/epoch * 6 epochs

- Observe stellar fields characterized by different crowding (NGC104 and OmegaCen) with various post-flash levels to calibrate the photometric and astrometric CTI corrections.
  8 external orbits = 3 orbits/epoch * 2 epochs (NGC104) + 2 orbits/epoch * 1 epoch (OmegaCen)

- Use charge-injected bias to monitor the length of the CTE trails. This information will be used as an input for Anderson's CTE algorithm.
  36 internal orbits = 1 orbit every ~10 days

The following 'delta' calibration programs explore additional CTE effects not addressed by the monitoring data:

- Explore a new method for measuring CTE losses based on long darks with flash levels the 20-50 e- range
  10 internal orbits

- Improve table-based CTE corrections for photometry and astrometry for bkg levels between 5 and 30 e-
  2 external orbits

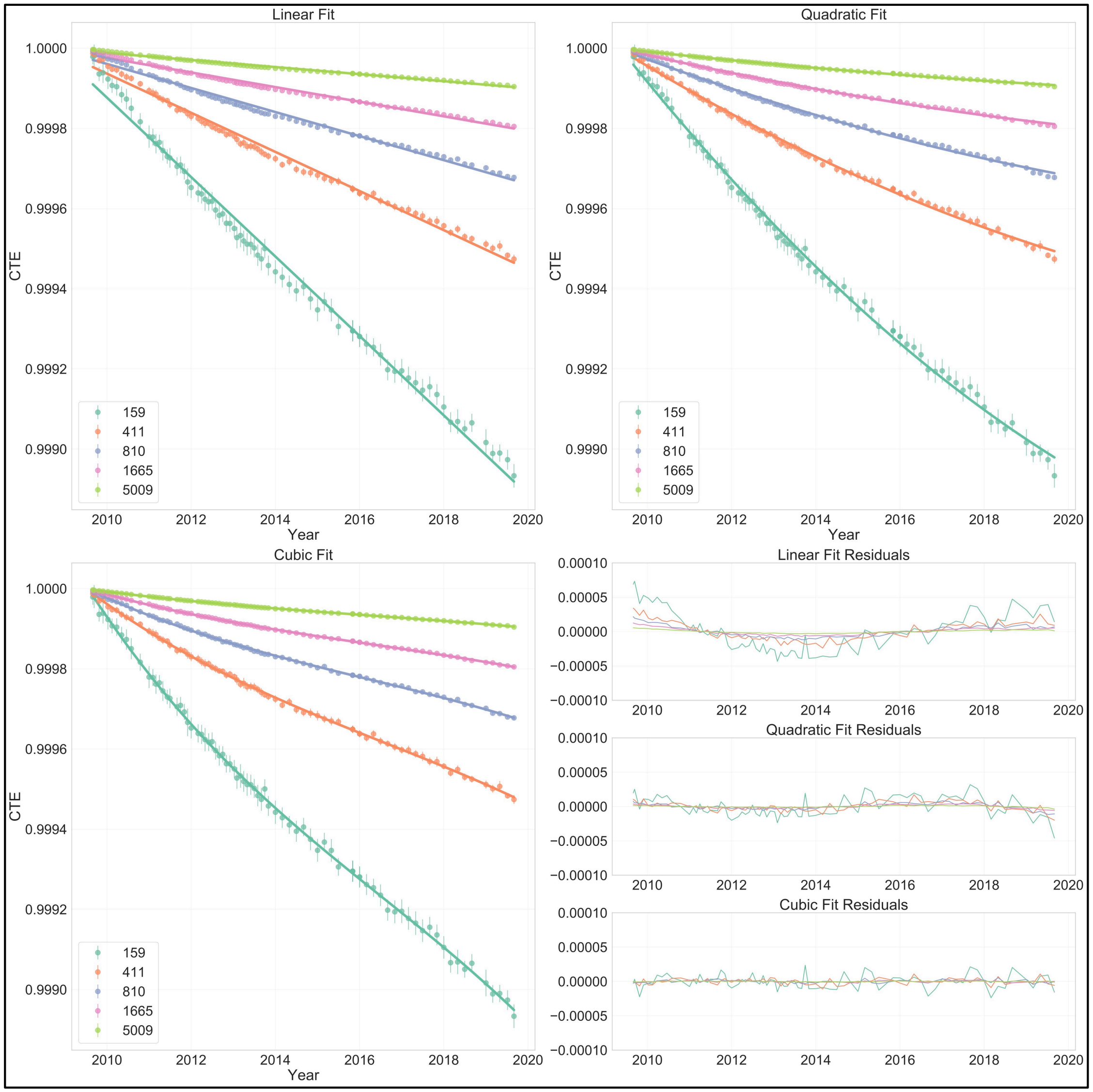
- Measure the impact of CTE losses on extended sources by comparing with early inflight data
  1 external orbit

WFC3/UVIS CTI Monitor (EPER)

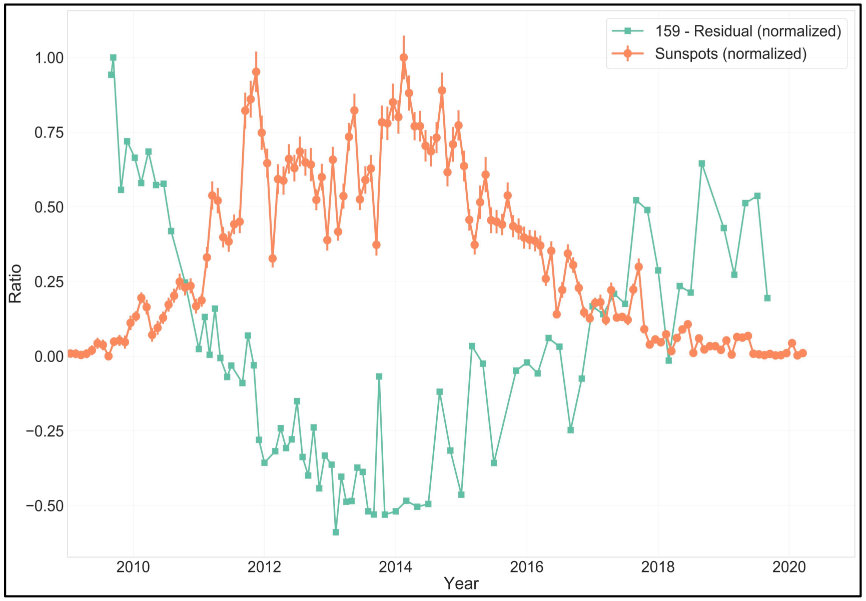
Orbits	External: 0 Internal: 12
PI, Co-I's	Khandrika, Kuhn
Purpose	(1) Measure the UVIS CCD Charge Transfer Inefficiency (CTI) using the Extended Pixel Edge Response (EPER) method. (2) Assess CTE losses over time in a continuation of the multi-cycle CTE monitor.
Description	12 internal orbits (2 every other month) are used to assess the profiles of excess charge in the extended pixel region of the special EPER readout format and monitor the CTI of WFC3/UVIS. Each visit-pair obtains internal lamp 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	Supports 100% of UVIS observations, especially faint, low background targets Analysis of the extended overscan in comparison to science pixels in the EPER readout mode. Rewriting reduction software (currently in IDL) and tracking changes since 2016
Products	Monitoring the health of the instrument; Comparison with external CTE calibration data
Accuracy Goals	Quantify decline in EPER CTE at the 4th decimal place and fit models to predict future decline
Prior Results, ISRs	ISR 2020-06: 'We observe a periodic nature in the linear fit residuals and find that it is anti-correlated to solar activity.' ISR 2016-10: "The CTE degradation appears to be quadratic and is settling with time." ISR 2013-03, ISR 2011-17, ISR 2009-10, ISR 2007-13
Prior Cycle IDs	11924, 12347, 12691, 13082, 13565, 14011, 14377 (Cy23) = in 2016 ISR 14540, 14989, 15575, 15720, 16400 (cy28)

WFC3/UVIS CTI Monitor (EPER)

ISR 2020-06



Top Left: Decline of EPER CTE as a function of illumination level (electrons) with linear fits to the data. Top right: Quadratic fit. Bottom Left: Cubic fit. Bottom Right: Residuals of each fit



Sunspot activity versus time, compared to the residuals of the 160 e– illumination level.
Both the sunspot data and the residuals are normalized to their respective maximum values

WFC3/UVIS External CTE Monitor: Star Clusters

Orbits	External: 8 Internal: 0
PI, Co-I's	Kuhn, Bajaj, Baggett, Anderson
Purpose	Monitor CTE degradation as a function of epoch and source/observation parameters. Calibrate photometric corrections. Provide data to test and monitor the pixel-based CTE model.
Description	We continue (from Cy20), using post-flash to sample background levels and monitor the efficacy of the post-flash model for CTE mitigation. Exposures of NGC104 and Omega Cen in F502N (~zero background) will monitor the maximum CTE in different field densities. (Last cycle, Omega Cen replaced NGC 6791 which is deemed too sparse. The later has more stars, particularly at the faint end, which would improve the CTE measurements). Long exposures, dithered by 2000 pixels in Y, will measure absolute CTE. We sample various background levels to test whether the currently recommended level of 20 e- still yields the best charge transfer. The data are also used to test the effectiveness of the pixel-based CTE correction.
Resources: Observations	8 orbits = 2 orbits (Omega Cen) at a single epoch + 3 orbits (NGC104) at two epochs Images are acquired in the F502N filter at eight different non-zero background levels
Resources: Analysis	Supports 100% of UVIS programs Analyze how the photometry of point sources within (dense and sparse) star clusters changes at different detector orientations. Test for overcorrection of pixel-based CTE correction in *flc files. Significant modifications required to data reduction pipeline, including IRAF dependency (e.g. centroiding)
Products	CTE coefficients. Test of efficacy of pixel-based CTE correction, test of recommended background level.
Accuracy Goals	Validate pixel-based correction to ~5% (no flash) and ~2% (with flash). Validate the recommended flash level to ± 3e-.
Prior Results, ISRs	ISR 2021-06: 'New FLC External CTE Monitoring 2009 – 2020'; ISR 2021-03: 'CTE Monitor through 2020'; ISR 2020-08: 'Strategies for Mitigation of CTE Losses' Older: ISR 2017-09, ISR 2016-17, ISR 2015-03, ISR 2012-09, ISR 2011-06
Prior Cycle IDs	12379, 12692, 13083, 13566, 14012, 14378 (ISR 2017-09), 14541, 14881 (Bulge non-monitor), 14990, 15576, 15721, 16401, 16573 (cy29)

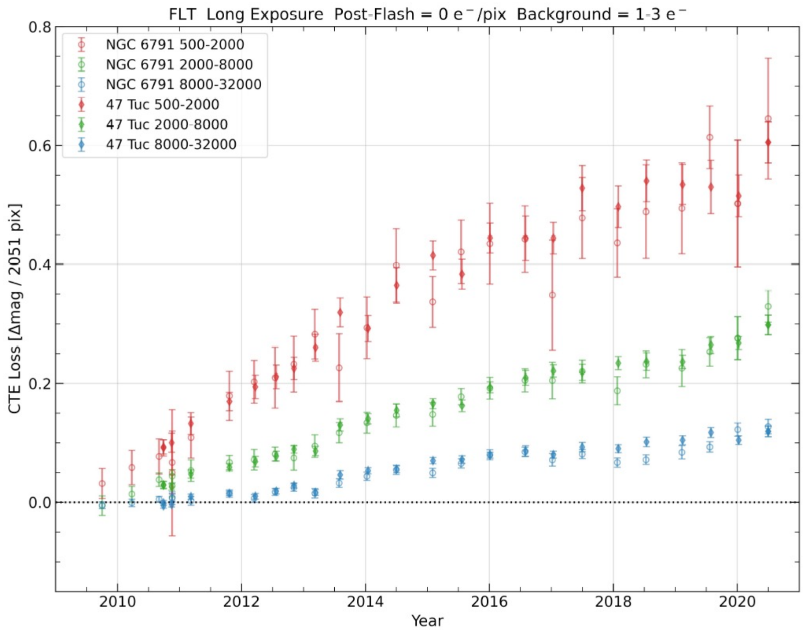
WFC3/UVIS External CTE Monitor: Star Clusters

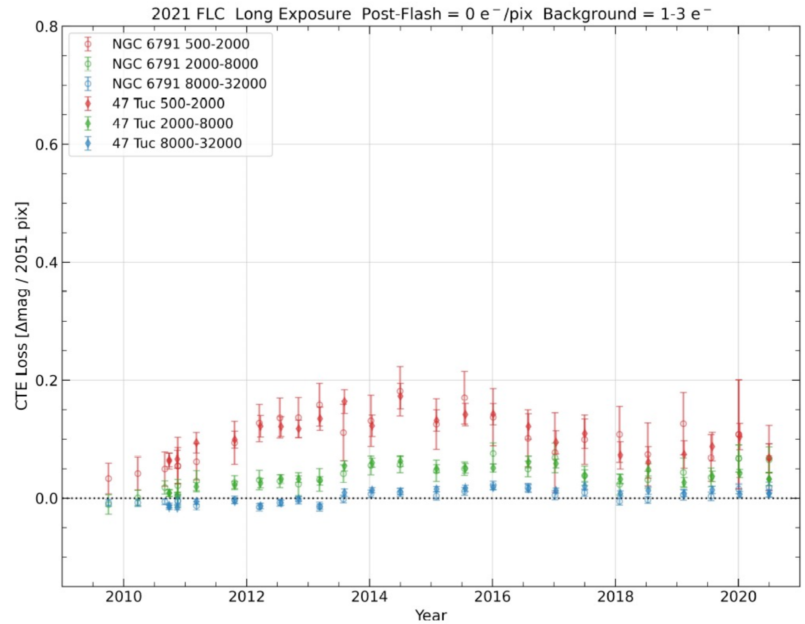
ISR 2021-06

No CTE-corr

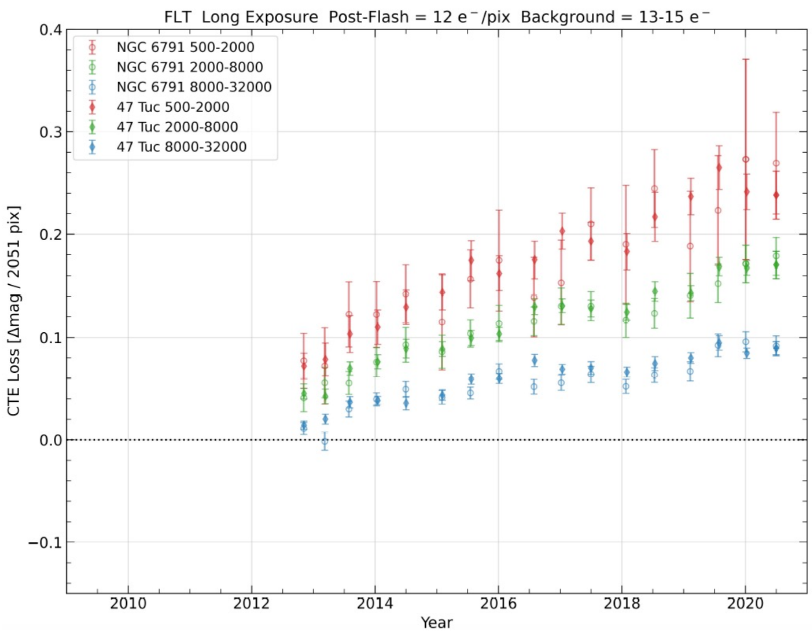
With NEW pixel-based CTE-corr

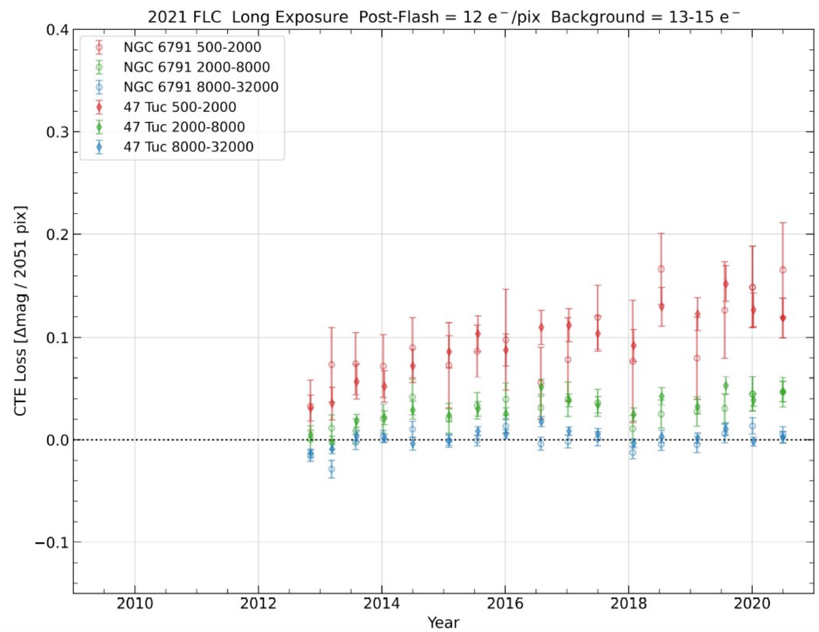
No post-flash





Post-flash: 12e-/pix





UVIS Traps with Charge Injection

Orbits	External:0 Internal: 36
PI, Co-I's	Medina, 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.
Resources: Observations	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	0% of GO programs currently use CI, but it is a useful way to monitor the CCD degradation. PI will utilize pixel history code developed by Bourque & Anderson.
Products	Alternate method of tracking the growth of charge traps across the detector.
Accuracy Goals	Mean residual signal in CI rows to ~2 e- rms
Prior Results, ISRs	ISR 2011-02: WFC3/UVIS Charge Injection Behavior: Results of an Initial Test (Bushouse) The team still needs to analyze the most recent data.
Prior Cycle IDs	Program 12348 (ISR 2011) Pending reduction: 12693, 13084, 13569, 14013, 14379,14542, 14991, 15577, 15722, 16402 (cy28)

WFC3/CTE Non-Monitor Summary

- The completed Cycle 28 programs have resulted in 2 new ISRs:
  - **ISR 2021-09**: *Updating the WFC3/UVIS CTE model and Mitigation Strategies*
  - **ISR 2021-13**: *Table-Based CTE Corrections for flt-Format WFC3/UVIS*
- The new Cycle 29 programs address remaining questions to finalize the calibration

Non-Monitor

ID	Cycle	Title	Target	Orbits	Comment
16861	29	New Pinning Method	Internal	10 Int	Long darks only to better sample 20-50 e- bkg range
16862	29	Photometry/Astrometry	Omega-Cen	2 Ext	Astrometry at all bkg levels; Photometry up to 100 e-
16863	29	Resolved Sources	Galactic Halo	1 Ext	Repeat visit from GO-12009 taken in early-2011
16441	28	Faintest Point Sources	Omega-Cen	2 Ext	Similar to 14881, with more stars than the Bulge field
16440	28	Model Re-Pinning	Internal	24 Int	Large range of PF levels; both long and short darks
16029	27	Background Check	Internal	10 Int	12 e- bkg is no longer optimal
14881	24	Model Evaluation	Bulge Field	2 Ext	Test model at range of bkg levels
14880	24	Model Pinning	Internal	15 Int	Update the 2013 empirical model

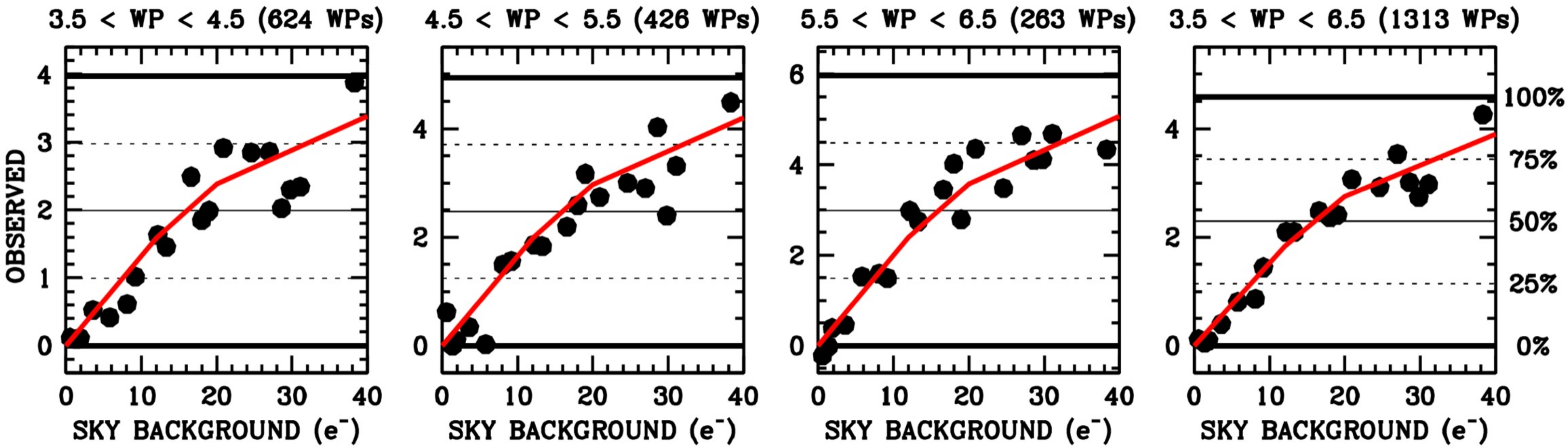
Monitor

16573 16401	29 28	CTE Monitor	NGC 104 Omega-Cen	8 Ext	Omega Cen replaced the sparse field NGC 6791. The former has more stars, particularly at the faint end
15721 15576 14990 14541	27 26 25 24	CTE Monitor	NGC 104 NGC 6791	8 Ext	Monitor CTE degradation as a function of epoch and source/observation parameters. Test and monitor the pixel-based correction model → Results in **ISRs 2020-08; 2021-03; 2021-06**

Testing a New Method for Pinning Down CTE Losses

Orbits	External: 0 Internal: 10 ***Non-monitor**
PI, Co-I's	Anderson, Kuhn, Baggett
Purpose	Evaluate a new way to measure CTE losses.
Description	Understanding CTE losses in WFC3/UVIS has very much been a learning experience. Once it was clear there were significant losses at the small-electron-packet end, WFC3 changed the strategy originally used for ACS (just measuring the trails in WPs in the long darks) to a combination of short-darks and long-darks to ***directly*** measure the losses (against the truth). That has worked well, but there are not as many WPs in the short darks as we would like. We try here a different approach: taking long darks with a variety of post-flash levels so that the relative losses-with-background can be assessed. It's not as direct as the short-long approach, but it may provide more data and it is actually more in-line with what we actually do for science. Also, the data-in-hand does not provide a lot of resolution for losses as a function of background level between 20 and 50. The data from this proposal should remedy that with more levels and much better constraints.
Resources: Observations	10 internal orbits. The standard set of UVIS dark monitor observations probes backgrounds of 0e and 20e. We will use these observations as a baseline for exploring other backgrounds. We'll explore 20 levels: 5e, 10e, 15e, 18e, 23e, 26e, 30e, 35e, 40e, 45e, 50e, 60e, 70e, 85e, 100e, 125e, 160e, 200e, 250e, and 300e. The standard dark monitor program gets 2x900s internals every orbit, so we can take two background levels in each orbit. It should thus take 10 orbits to complete this program.
Resources: Analysis	Examine the relative losses for WPs at a variety of background levels
Products	This will inform recommendations on how much background provides how much CTE-loss mitigation.
Accuracy Goals	We hope to assess CTE losses at better than the 10% level.
Prior Results, ISRs	WFC3/ISR 2021-09: Updating the WFC3/UVIS CTE model and Mitigation Strategies
Prior Cycle IDs	14880, 16440 (short+long darks)

Testing a New Method for Pinning Down CTE Losses



We reproduce **Figure 14** (above) from WFC3/ISR 2021-09 (Anderson et al), showing the surviving fraction of WPs with intensities of 4e, 5e, 6e, and the composite 4-6e as a function of background level. The data are taken from a study of the short-long darks.

The overall trends are clear, but the resolution is not great, due to the limited sampling of background and the paucity of WPs in the short dark exposures. The strategy we suggest here should provide many more WPs to study, and we probe more background levels. The study here will be indirect rather than direct, but it should help clarify the relative losses much better.

Supplemental Empirical CTE Calibrations for Photometry and Astrometry

Orbits	External: 2 Internal: 0 ***Non-monitor**
PI, Co-I's	Anderson, Kuhn
Purpose	Provide supplemental empirical photometric and astrometric CTE corrections
Description	WFC3/ISR 2021-13 provided table-based CTE corrections for photometry and astrometry for backgrounds between 5e and 30e. The astrometric corrections in that ISR were somewhat *ad hoc*, since the calibration observations were not optimized for astrometry (there were degeneracies at the bright end). In this two-orbit program, we will (1) provide photometric corrections all the way up to 100 e^- background and (2) provide explicit astrometric corrections for all background levels.
Resources: Observations	2 external orbits. We will observe the center of Omega Centauri, taking advantage of its flat spatial distribution and its bottom-heavy brightness distribution. Most observations will be taken as flashed F502N exposures, which allows efficient 339s exposures to get ~40 stars in the brightest unsaturated magnitude bin, 400 stars in the S/N~100 magnitude bin, and 8000 stars in the faint S/N~10 magnitude bin. One short exposure in F606W will give a total of 7 exposures per orbit. The chip-stepped pairs will be taken at different offsets to allow the astrometry to be calibrated as well as the photometry.
Resources: Analysis	The analysis will be straightforward, using the techniques already developed in WFC3/ISR 2021-13.
Products	A new ISR and an update to the table-based corrections for CTE.
Accuracy Goals	The goal is to get the corrections to be better than 10% with respect to Poisson errors, so that the CTE corrections will not drive systematic errors.
Prior Results, ISRs	This will build on WFC3/ISR 2021-13 (Anderson): 'Table-Based CTE Corrections for FLT images'
Prior Cycle IDs	This is a supplement to the standard CTE monitor programs. Those programs do not need to monitor the higher background levels 2x a year, but it will be good to probe them at least once in a while to pin down the model. These higher levels have never been directly probed.

Supplemental Empirical CTE Calibrations for Photometry and Astrometry

Figure 1

This shows the distribution of backgrounds observed in Cy28 GO science exposures through F606W and F814W.

It is clear that there not all of UVIS's observations have low background. It will be useful to calibrate the empirical CTE corrections above 30 electrons.

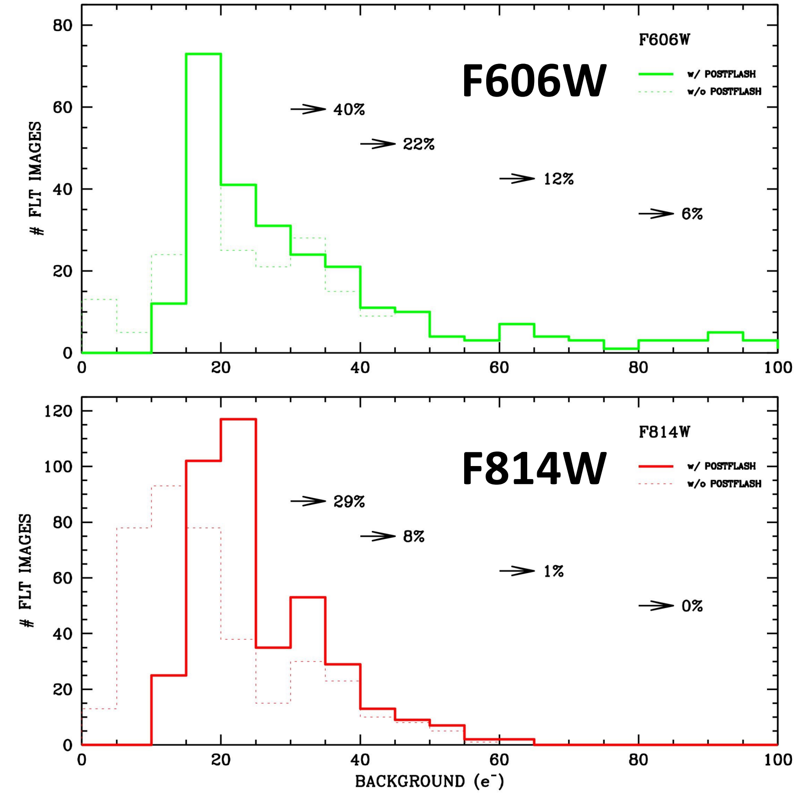
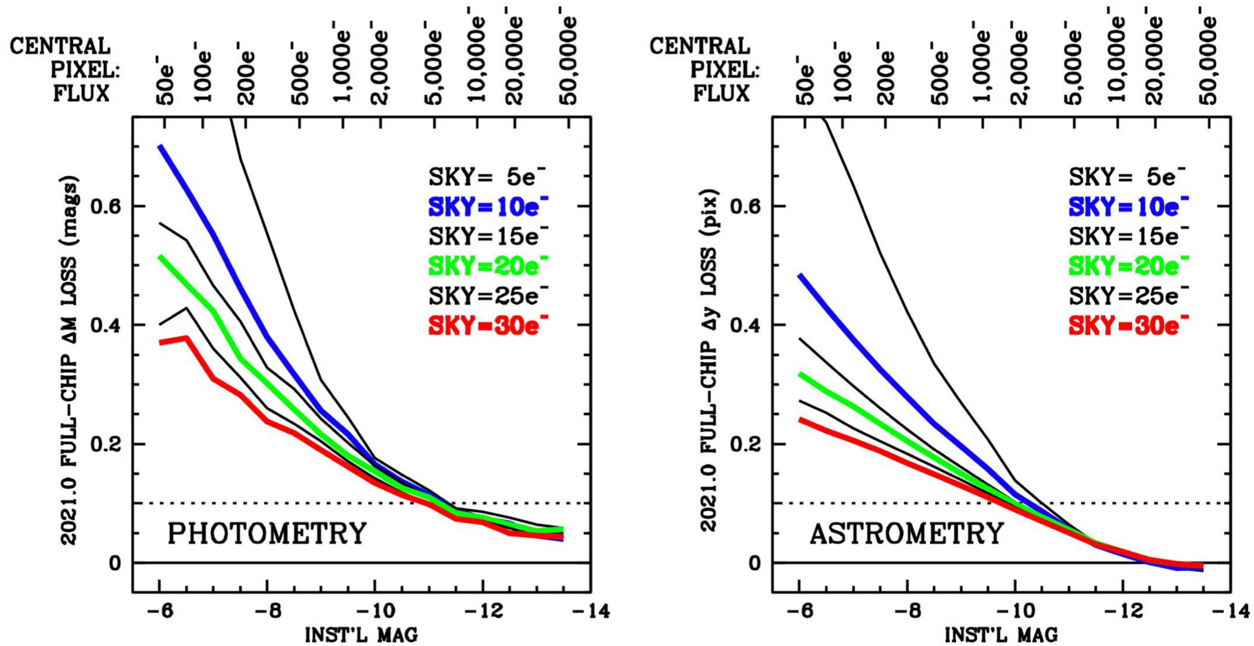


Figure 2

This shows that the standard set of CTE observations are able to probe all levels of photometric losses, but there is a degeneracy with the astrometry.

The bright stars must be used as a reference, so we cannot measure their astrometric losses. We will design this program to remove this degeneracy. (WFC3/ISR 2021-13)



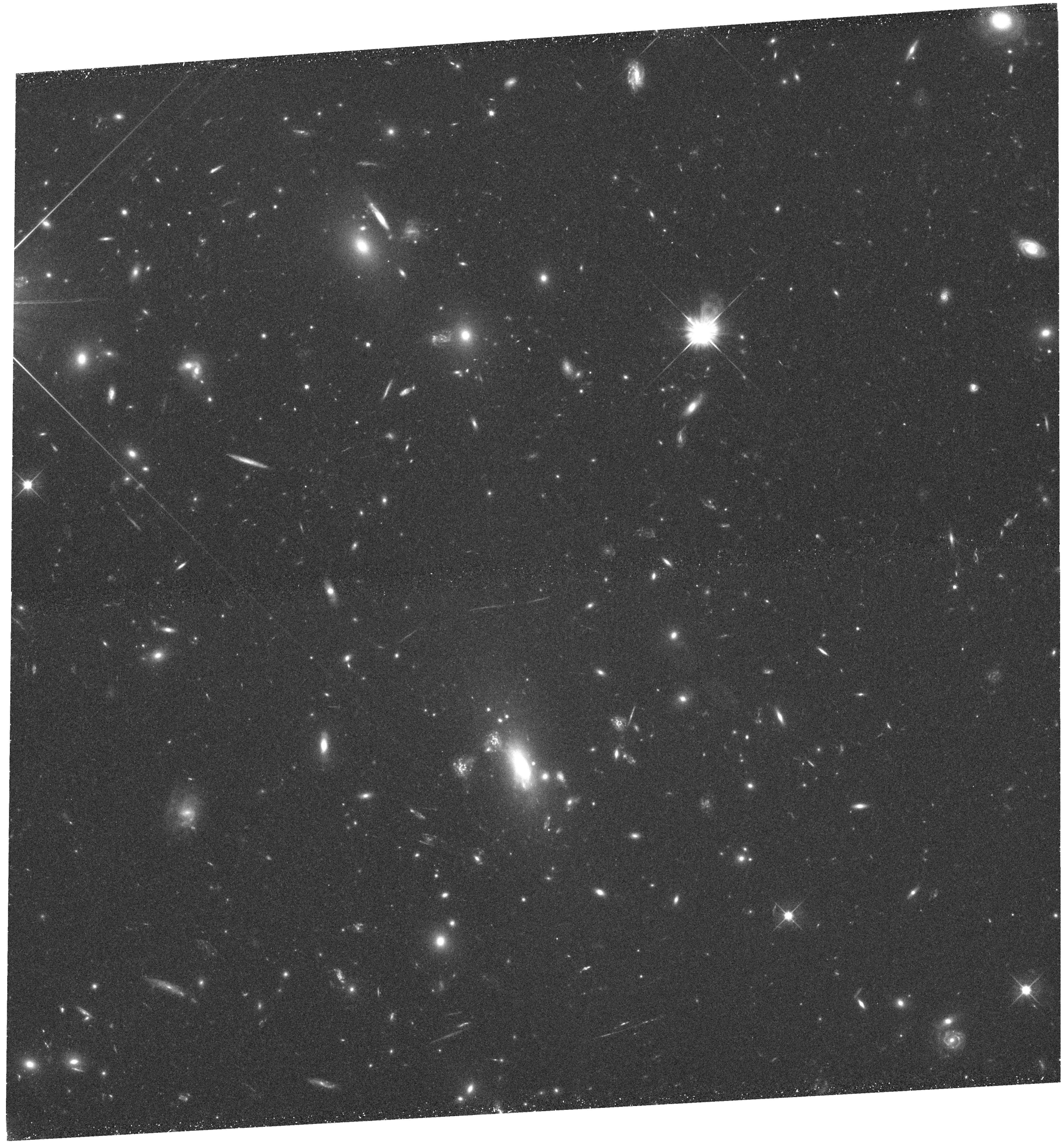
CTE Evaluation of Resolved Objects

Orbits	External: 1 Internal: 0 ***Non-monitor**
PI, Co-I's	Anderson, Mack
Purpose	Evaluate CTE losses and the pixel-based correction on extended objects.
Description	Much of the effort evaluating CTE Corrections and implications have been based on analysis of hot pixels and point sources. Many WFC3/UVIS observations focus on resolved objects, and the data from this proposal will allow for an estimate of how CTE impacts them. We will repeat a 1-orbit F606W observation taken early in WFC3's lifetime when CTE was very low, and we will use those observations as a template to study how CTE affects current observations.
Resources: Observations	One external orbit. Four dithered exposures (440 sec), using a pattern optimized for sub-pixel sampling (WFC3/ISR 2020-07) plus one additional image shifted by a whole chip relative to the others. The archival images are ~600s and have a background of 22e, which is close to the currrent recommendation. The 440s exposures should have about 15e natural background, so our aim is to supplement this up to 20e with a post-flash of 5e.
Resources: Analysis	This program requires some experience in galaxy shape analysis.
Products	An ISR that describes how CTE affects resolved objects at the recommended background of 20 e^-.
Accuracy Goals	There is no numerical metric involved, but we will provide plots to users that show how barely resolved objects survive the march to readout relative to stars.
Prior Results, ISRs	This kind of study has not been done before. It can only be done if we re-observe a field that was observed early in the life of WFC3/UVIS so that we can have a "truth" image with which to compare current CTE-degraded images.
Prior Cycle IDs	Repeat 1 orbit from GO-12009 of the target MACSJ0417.5-1154.

CTE Evaluation of Resolved Objects

MACSJ0417.5-1154

This is a one-orbit stack of a relatively dense galaxy field in F606W from GO-12090



IR Detector

Same as the previous cycle

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

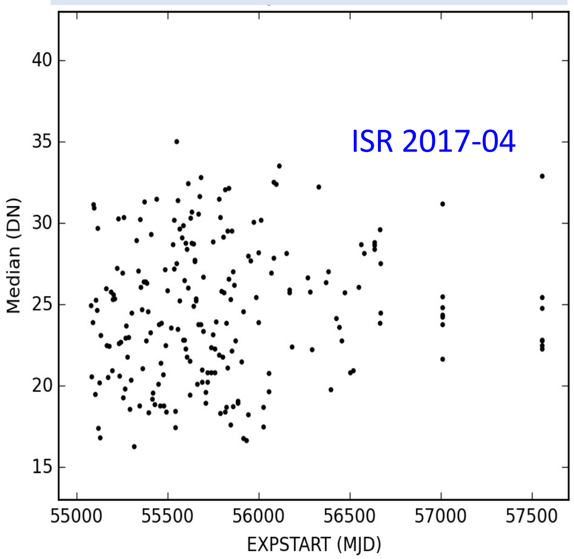
- Obtain IR darks. The number of orbits is dictated by observing modes most-requested by GOs.
  97 internal orbits = 26 orbits (SPARS200, every 2 weeks) + 71 orbits (other samp-seq/apertures)
- Monitor the IR non-linearity by obtaining saturated internal flats
  10 internal orbits = 10 orbits in F127M (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

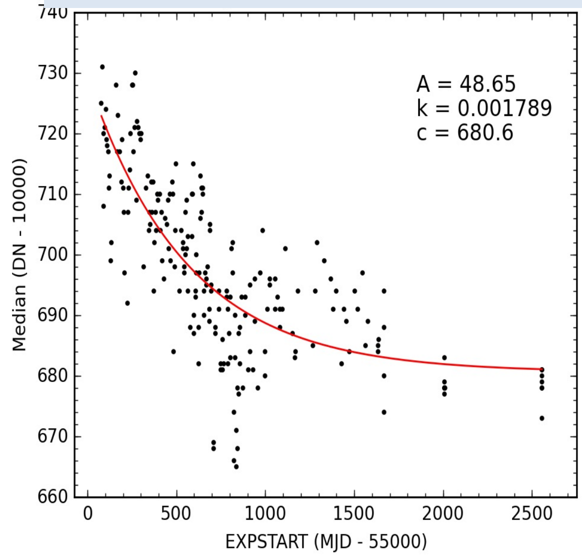
Orbits	External: 0 Internal: 97
PI, Co-I's	Dauphin, Green
Purpose	This program acquires a variety of WFC3/IR darks to support the removal and study of dark current. SPARS200 dark observations are periodically obtained to monitor trends in the bad pixels (hot, unstable, or dead), zeroth read level, and 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 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. The IR dark current has remained nearly unchanged since launch (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 (~every 2 weeks), the observations have no set scheduling parameters.
Resources: Observations	97 total orbits: 26 orbits of SPARS200 every 2 weeks + 71 orbits spread amongst the other 23 sample sequence/subarray combinations (weighted by usage, with each observed at least 2x/yr and up to 40x/yr) An 1800-sec, non-interruptible hold precedes the observations to protect from persistence.
Resources: Analysis	Supports 100% of IR programs Dark Analysis and BPIXTAB by the PI. Bias levels monitored by QL.
Products	Updated IR dark calibration files (One DARKFILE per cycle for each SAMP-SEQ) and cycle-dependent IR bad pixel table (contains flags for unstable pixels, hot pixels, bad in 0^{th} read). Updated MDRIZTAB parameter file for AstroDrizzle
Accuracy Goals	Median dark rate ~0.05 e-/s ± 0.03 e-/s rms. Reference pixel signal to ~50 DN rms
Prior Results, ISRs	ISR 2019-04: Time-dependent Superdarks, ISR 2019-03: Time-dependent Bad Pixel Tables, ISR 2017-24: A Predictive WFC3/IR Dark Current Model ISR 2017-04 (study of dark current variation, zeroth read levels, reference pixels), ISR 2014-06 (updated dark reference files), ISR 2012-11 (dark current stability).
Prior Cycle IDs	11929, 12349, 12695, 13077, 13562, 14008, 14374, 14537, 14986, 15578, 15723, 16403 (cy28)

IR Dark Monitor

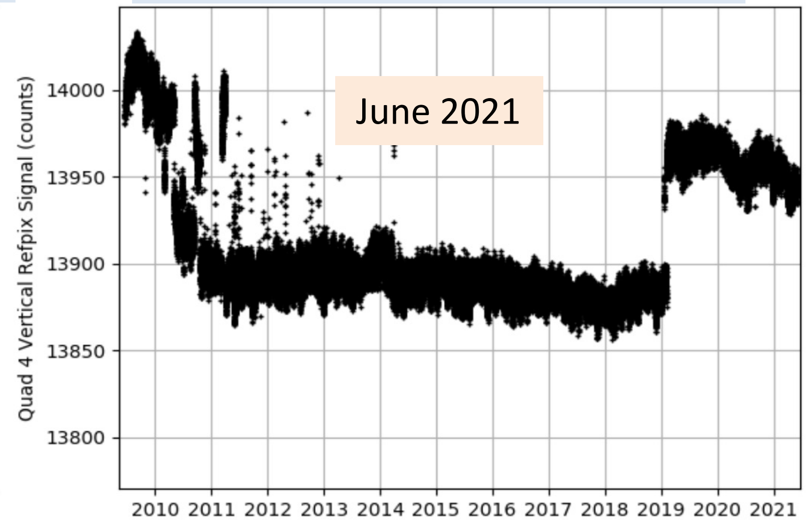
Median IR dark vs time (quad4)



The 0th read level vs time (quad4)

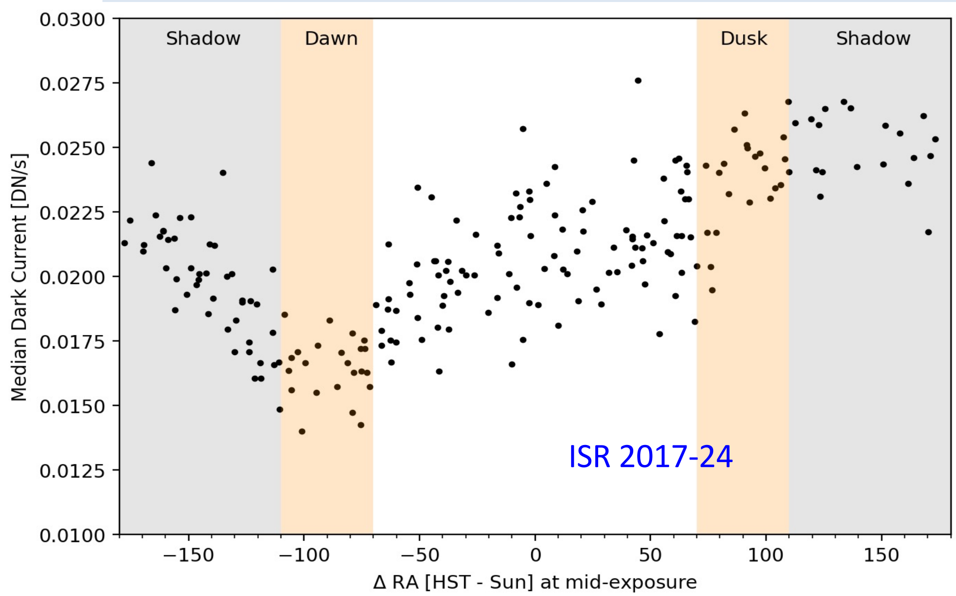


Reference pixel signal vs time (quad4)

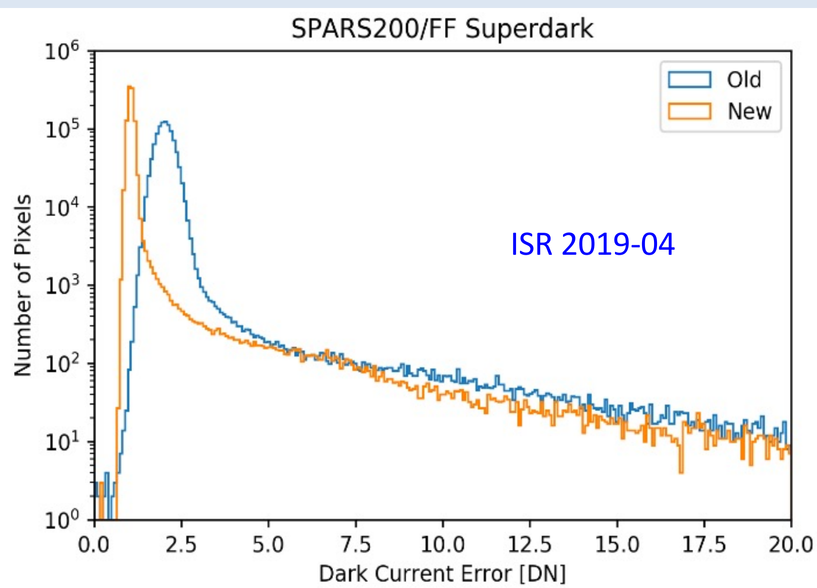


https://wfc3ql.stsci.edu/automated_outputs/cal_ir_make_bias_plots

Correlation of median dark current with the HST day/night cycle via WFC3 telemetry. Range= 0.015-0.025 DN/s



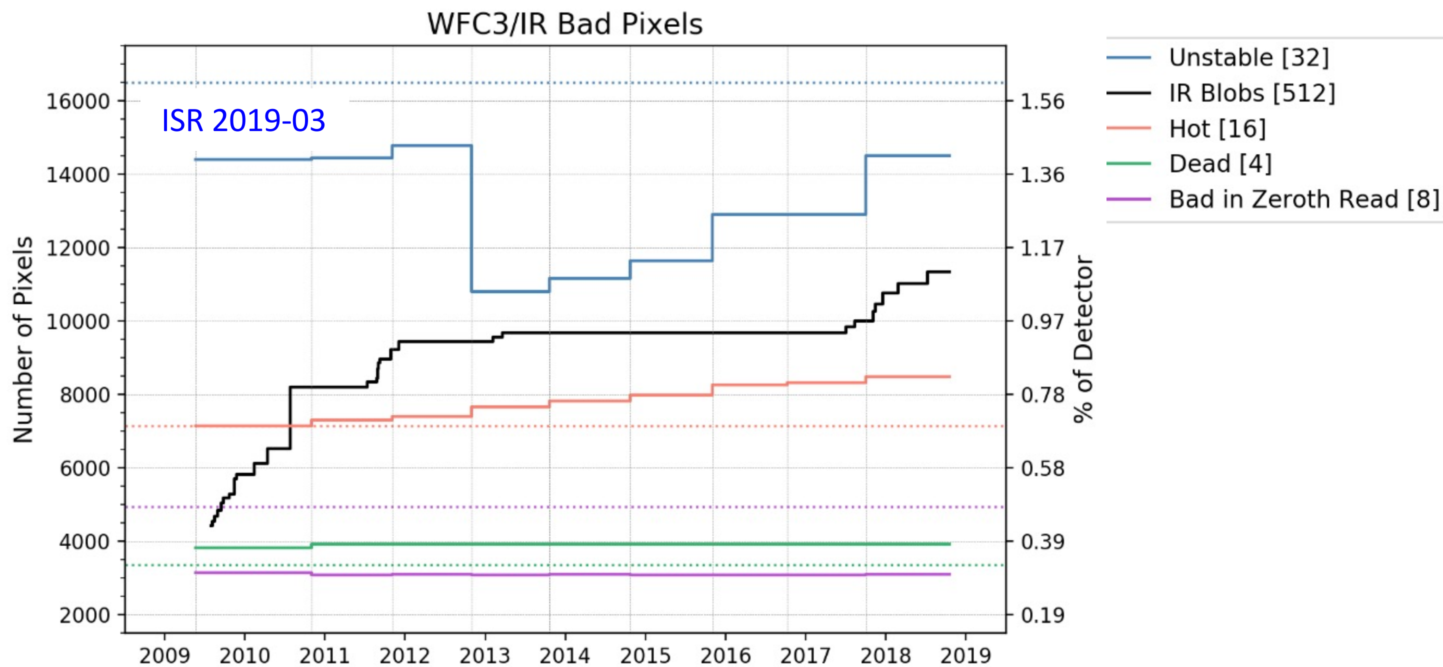
The mean dark error and its dispersion are reduced ~2-3x in the 2019 dark compared to prior (ISR 2014-06) calibration.



IR Dark Monitor

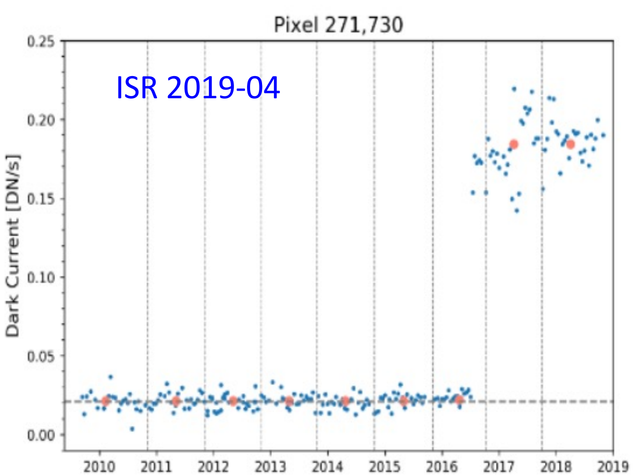
2019 Time-dependent bad pixel populations (1 per cycle)

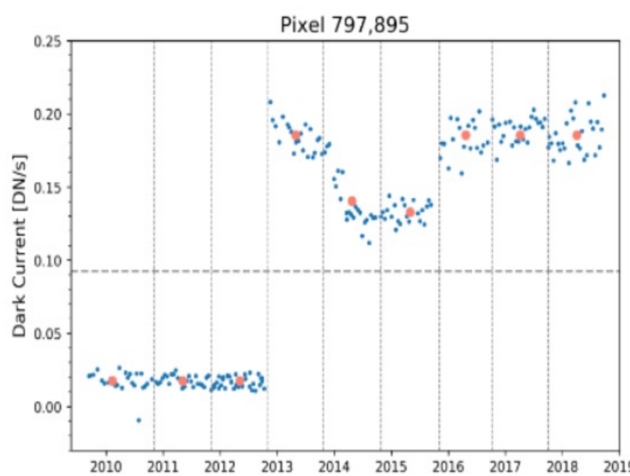
Dotted lines indicate pixel flags in the prior set of reffiles

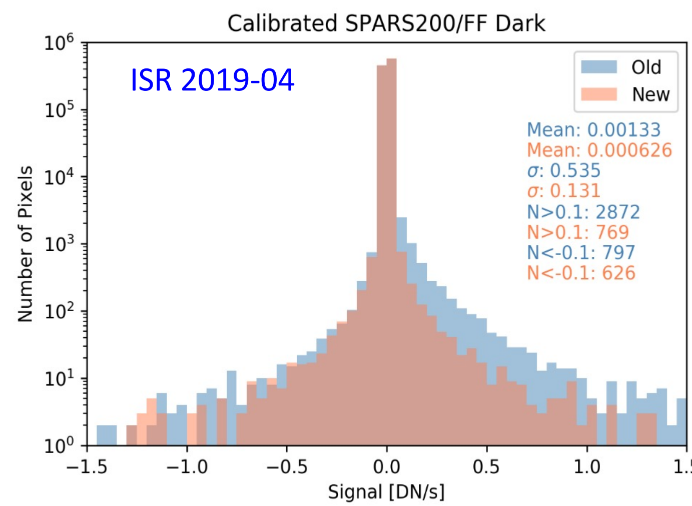


Pixel history of two pixels with superdark values determined for each cycle (orange). Dashed line compares with a simple full-stack superdark.

Single dark exposure calibrated with old vs new (Cy25) superdark







IR Linearity Monitor

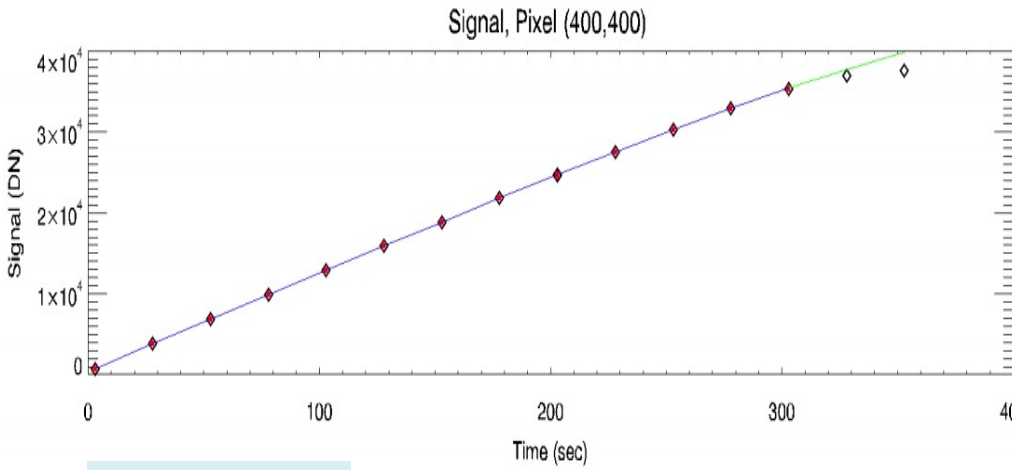
Orbits	External: Internal: 10
PI, Co-I's	Green, Bajaj
Purpose	Monitor the non-linearity of the WFC3/IR detector and track the stability over time
Description	HgCdTe detectors suffer from a non-linear response to incident flux. The calibration pipeline corrects for the effects of non-linearity. This monitor uses flat field ramps to characterize the non-linearity of 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.
Resources: Analysis	Supports 100% of IR programs. 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	NLINFILE reference file (*lin.fits)
Accuracy Goals	Photometry for long vs short exposures to <0.5% over a range of flux values
Prior Results, ISRs	ISR 2014-17, Updated non-linearity calibration method for WFC/IR These results are not yet implemented in CALWF3 (This requires simultaneous delivery of IR zpts.)
Prior Cycle IDs	(47Tuc+Internals) Programs: 11931, 12352, 12696, 13079, 13563 Internals only starting Cycle 22: 14009, 14375, 14538, 14987, 15579, 15724, 16404, 16576

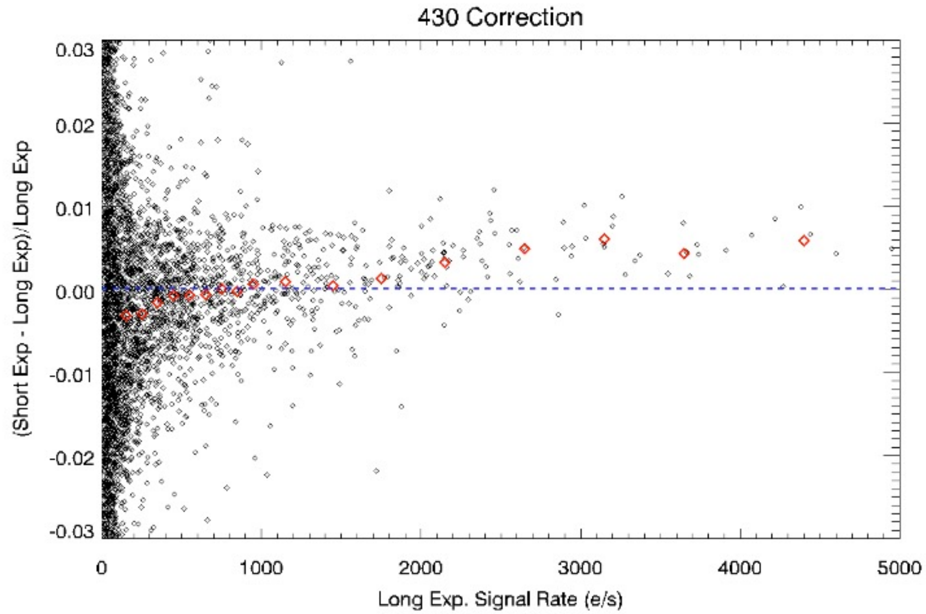
IR Linearity Monitor

Polynomial fit to signal vs time for a single detector pixel (red points)

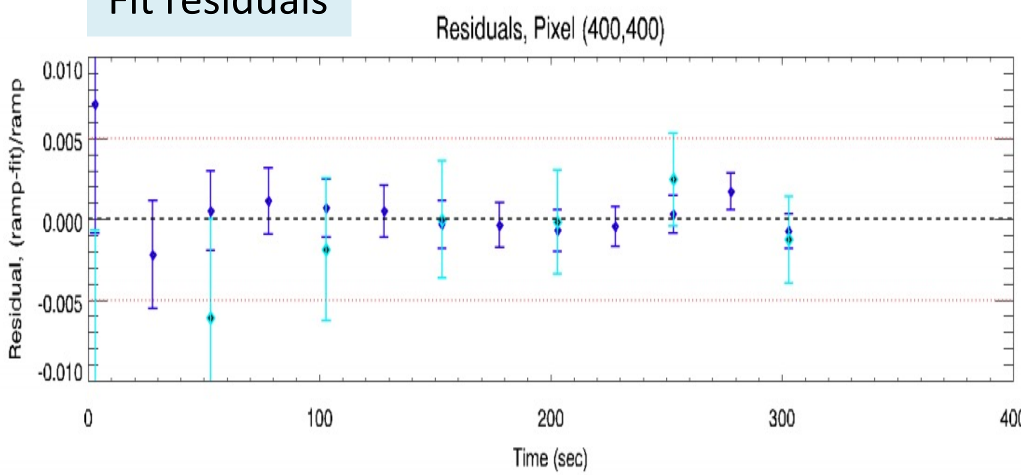
ISR 2014-17

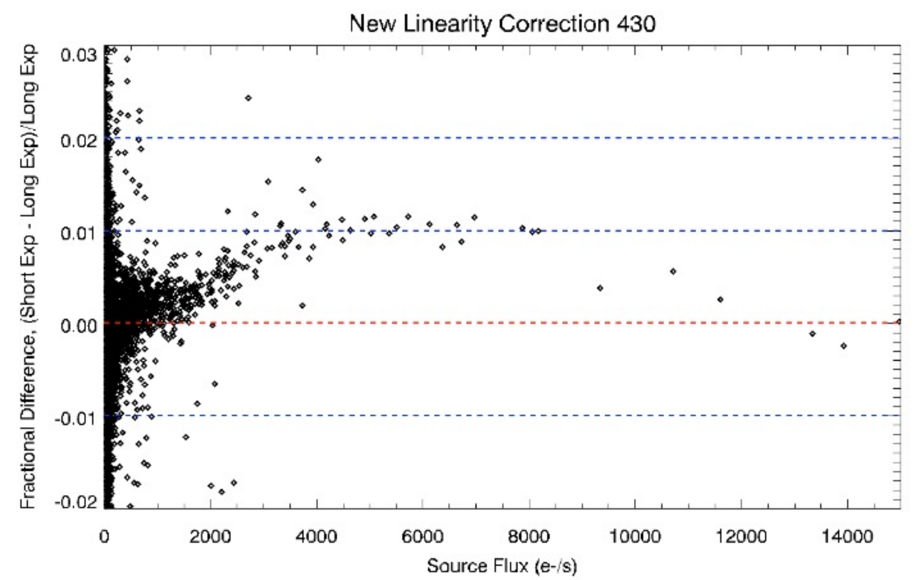
47 Tuc Validation





Fit residuals

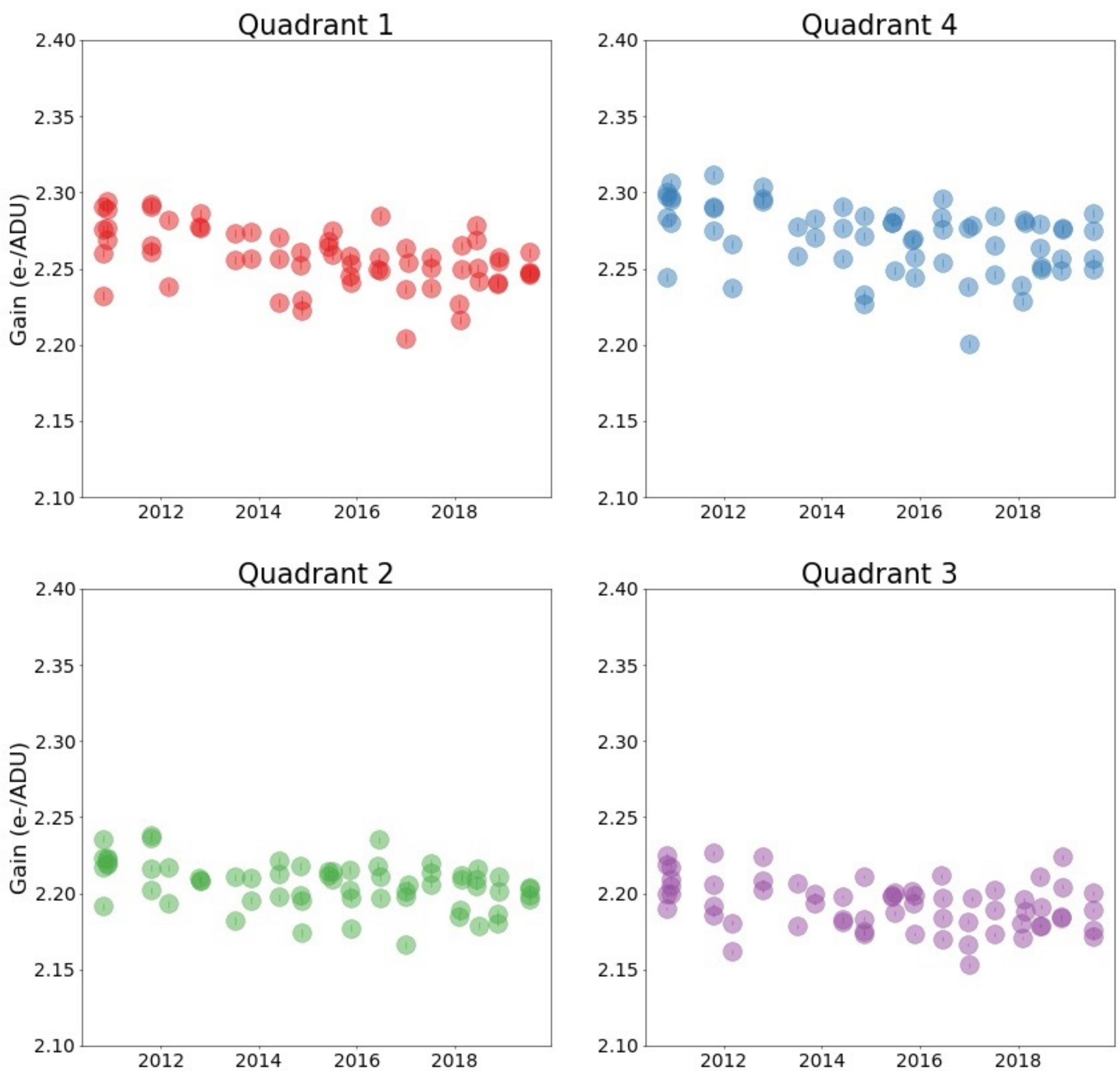




IR Gain Monitor

Orbits	External: Internal: 16
PI, Co-I's	Khandrika, Green
Purpose	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.
Resources: Observations	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	Supports 100% of IR programs. Existing IDL software calculates the gain in each quadrant using the mean-variance method. Code needs to be converted to python in order to produce QuickLook Automated Outputs.
Products	Measurements of the gain and scatter in gain measurements for each epoch of observations.
Accuracy Goals	Measure gain to < 1% and track gain stability to <0.1%
Prior Results, ISRs	ISR 2015-14: WFC3 IR Gain from 2010 to 2015 (cycles 17-22)
Prior Cycle IDs	11930, 12350, 12697, 13080, 13564, 14010 (=Cy 17-22) 14376, 14539, (Cy23,24 results in QL), 14988 (Cy25), 15580 (Cy26), 15725 (cy27), 16405 (cy28)

IR Gain Monitor



June 2020
Khandrika, private comm.

The gain is calculated via the mean-variance method for each ramp pair vs MJD.

WFC3 Photometric performance

The following calibration monitoring programs are designed to check the UVIS and IR photometric stability, (same as the previous cycle) :

- Monitor the accuracy of the shutter mechanism after 10+ years of operation
  1 internal orbit

- Monitor the UVIS throughput with wavelength using scanned observations
  12 external orbits = 2 white dwarfs (5x/yr), 1 G-star (2x/yr)

- Monitor the stability of the zeropoints for both UVIS and IR detectors
  20 external orbits=
  IR: 4 orbits = 3 white dwarfs & 1 G-star (1x/yr)
  UVIS: 16 orbits = 3 white dwarfs (1-2x/chip/yr), 1 G-star & 1 A-star (1x/chip/yr)

The following 'delta' calibration programs explore time dependence in the IR detector:

- Test for changes in sensitivity with wavelength by leveraging off of prior observations of stellar clusters
  5 external orbits = 2 orbits of M4 (6 months apart)
  1 orbit of 47Tuc
  2 orbits of Omega-Cen (one each in F110W, F160W)

UVIS Shutter Monitoring

Orbits	External: 0 Internal: 1
PI, Co-I's	Sahu, Montes Quiles, 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
Description	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. Internal flats from the bowtie monitoring program provide an additional check of the shutter repeatability. No external orbits are requested; standard star observations from Cycles 23 & 24 show no noticeable difference in the performance of the shutter compared to SMOV.
Resources: Observations	1 internal orbit with the tungsten lamp on each of the 4 amplifiers.
Resources: Analysis	Supports 100% of UVIS programs. 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	The count rate caused by the tungsten lamp is continuing to decline. The counts from A and B are consistent for 1 and 17 sec exposures. For the 0.48 sec exposures, the results are ambiguous since the lamp is still brightening during the first exposure. ISRs: 2018-11 (Shutter-induced Vibration), 2015-12 (Shutter Characterization), 2014-09 (Blade Side "A" for Short Exposures), 2009-25 (Shutter Shading)
Prior Cycle IDs	11427 (SMOV), 14019 (Cy22), 14383 (Cy23), 14882 (Cy24), 15397 (Cy25), 15584 (Cy26), 15726 (cy27), 16406 (cy28)

UVIS Shutter Monitoring

ISR WFC3 2015-12: Internal Lamp exposures

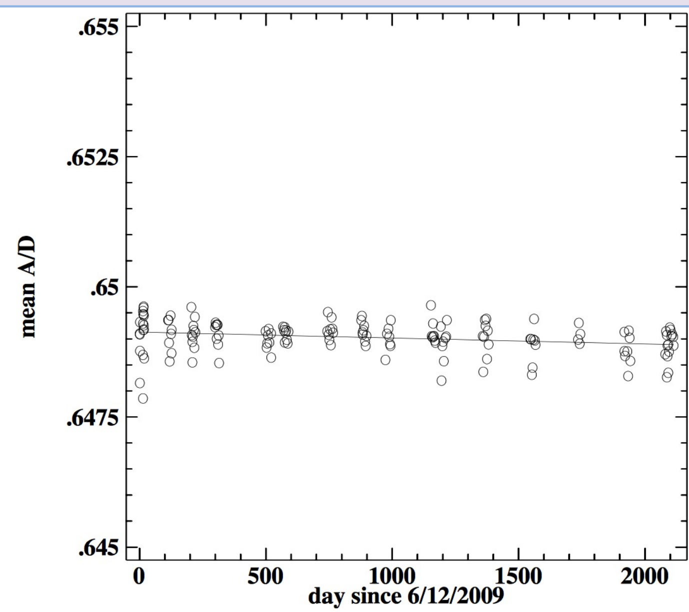
Count ratios observed in SMOV and Cycle 23 remain constant for all 4 amplifiers, apart from an overall decline in the lamp, demonstrating that there is no change in the shutter shading compared to SMOV. The dispersion in the *long set of exposures (lower-right)* is consistent with the shutter shading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

Table 1: Observed counts in different amplifiers

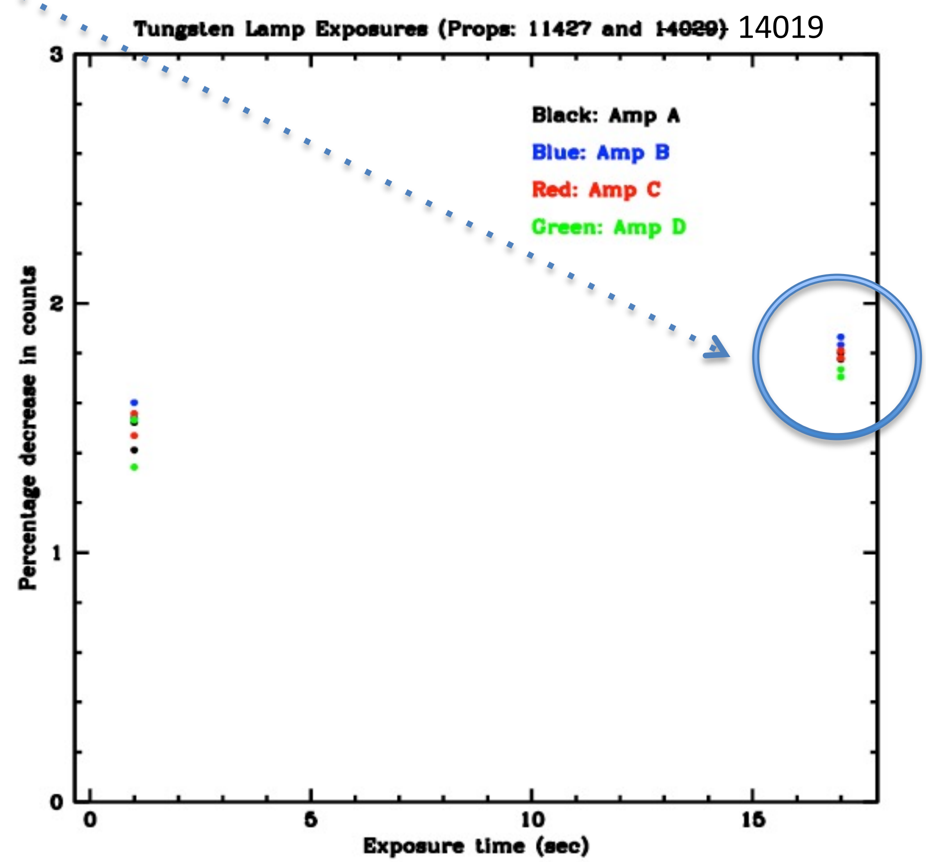
Filename	Shut-ter	Exp. time (s)	Av. Counts (A)	Av. Counts (B)	Av. Counts (C)	Av. Counts (D)
Program: 11427						
SMOV						
iaai01rtq_flt	A	1.00	1734.6	2044.0	2013.5	2464.2
iaai01ruq_flt	B	1.00	1730.2	2039.0	2008.0	2459.3
iaai01rwq_flt	A	17.00	29655.4	35020.6	34679.4	42286.3
iaai01rxq_flt	B	17.00	29657.3	35022.6	34682.7	42290.5
Program 14019:						
Cycle 23						
icr401keq_flt	B	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	B	17.00	29127.7	34375.3	34060.1	41563.1
icr401kiq_flt	A	17.00	29133.6	34384.2	34067.3	41571.6

ISR WFC3-2015-12: Bowtie Monitor

No measurable variation in the A/D and B/C flux ratios is found over the WFC3 lifetime, confirming the shutter is stable to ~0.1%.



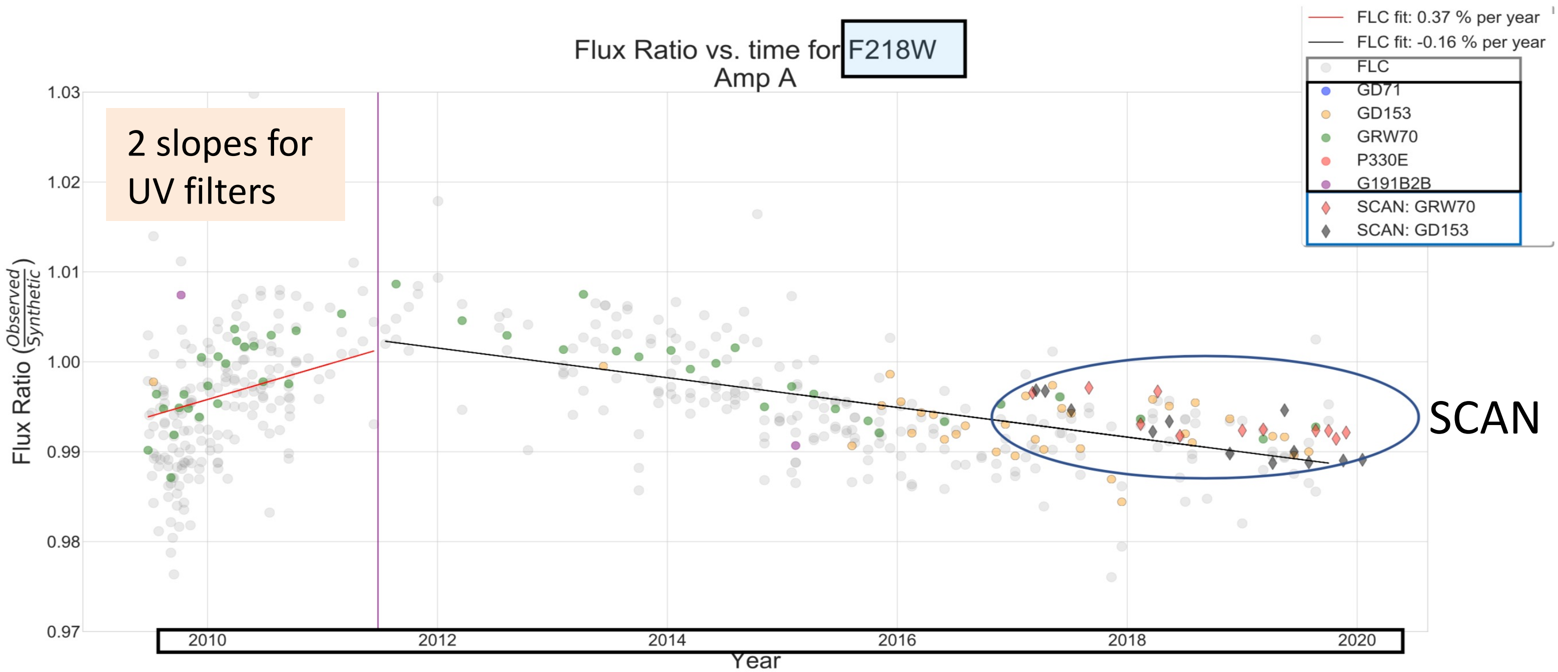
Year= 2009   2012   2015

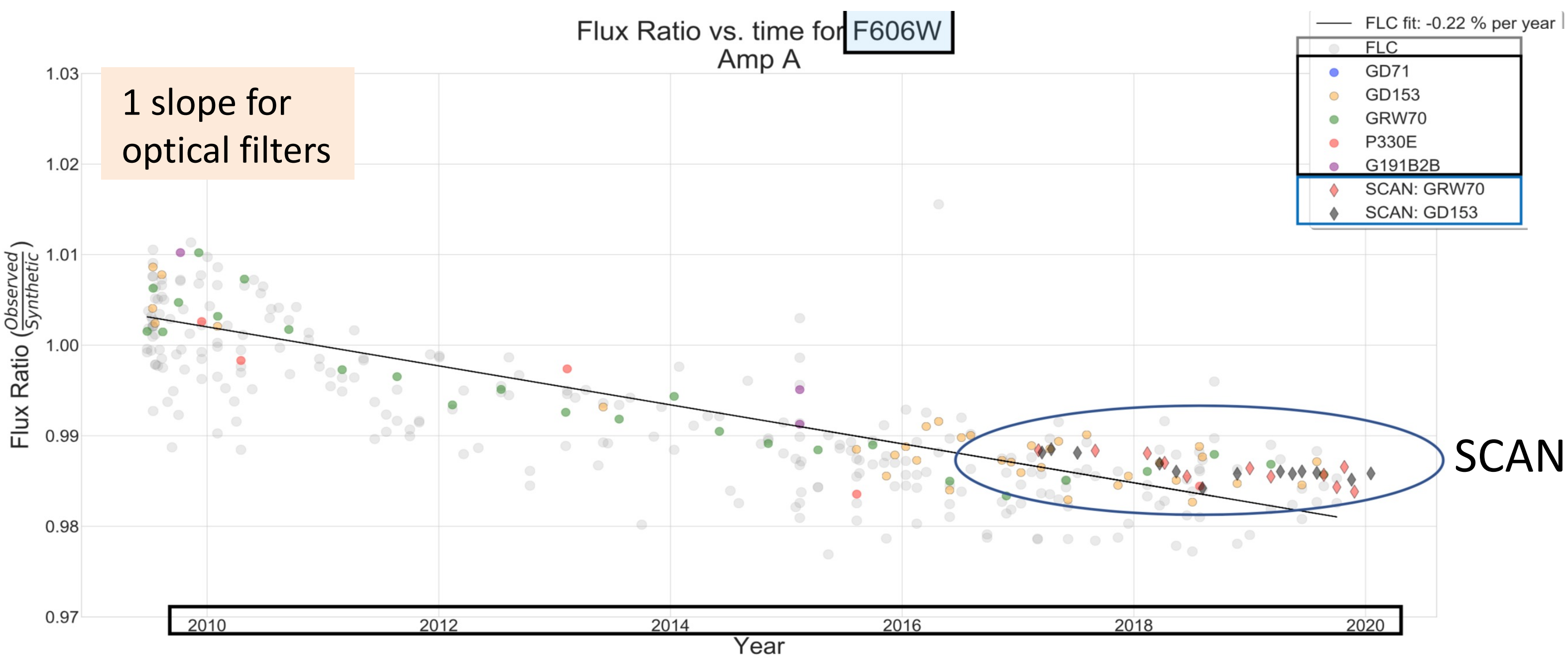


WFC3 UVIS and IR Photometry

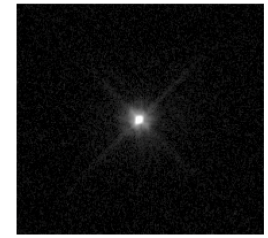
Orbits	External: 20 Internal: 0
PI, Co-I's	Calamida, Bajaj, Mack
Purpose	Monitor the photometric throughput and stability with staring mode observations. Compute the inverse sensitivities, EE, and any color terms for UVIS & IR filters as a function of time, detector position, and wavelength.
Description	***IR:*** Three white dwarf standards (**GD153, GD71, GRW+70D5824**) and a G-star (**P330E**) in all IR imaging filters. ***UVIS***: The same four flux standards (for cross-calibration) in a subset of filters in the corner subarrays. In Cy26, GRW+70 replaced G191B2B, which is too bright in many filters and which has not been used for IR calibration since Cy19. This target allows for better synergy with the UVIS scanned data, which observes GD153 and GRW+70. An A-type star (**180227**) was added in Cy27 to better constrain any color terms.
Resources: Observations	**IR**: 4 orbits = 4 stars * 1 epoch/star * 1 orbit/epoch to sample <u>all</u> filters **UVIS**: 8 orbits = 4 stars * 1 epoch/star * 2 chips * 1 orbit/chip/epoch (same as pre-Cy27 phot monitor) + 6 orbits = 2 stars * (2 epochs GRW, 1 epoch GD153) (staring subset from contam monitor) + 2 orbits= A-star * 2 epochs/star (1812095 for color terms)
Resources: Analysis	Supports 100% of UVIS & IR programs. The photometry reduction pipeline is capable of handling either FLC or DRC files.
Products	IMPHTTAB reference file which populates time-dependent photometry keywords in the image headers Synthetic photometry tables for use with the ETC and synphot
Accuracy Goals	Track stability to < ~0.1%/yr. Improve UVIS accuracy to 1% absolute w.r.t. STIS (current relative photometry is ~0.5%) Improve IR photometric accuracy to 1% absolute w.r.t. STIS (current relative photometry is ~1%.)
Prior Results, ISRs	**UVIS**: ISR 2021-04: Time-dependent Zpts; ISR 2018-16: UVIS temporal & spatial photometry, ISR 2018-08: Color terms for UV filters, ISR 2018-02: Comparing ACS/WFC & WFC3/UVIS Calibration, ISR 2017-14: Updated Chip-Dependent zpts; ISR 2017-07: UV Zpts . **IR :** ISR 2021-05: IR TDS via Scans, 2020-10: IR Zpts, ISR 2020-05: IR TDS; ISR 2019-07: IR repeatability, ISR 2019-01: Count-rate Nonlinearity, ISR 2011-08: Temporal Stability, ISR 2009-30: SMOV zpts, 2009-37: EE
Prior Cycle IDs	11450 (UVIS), 11451 (IR), 11903 (UVIS), 11926 (IR), 12334, 12699, 13089, 13575, 14021, 14384, 14870 (IR), 14871, 14883 (cy24), 14992 (cy25), 15399 (UVIS color terms), 15582 (cy26), 16030 (cy27), 16415 (cy28)

UVIS Time-Dependence (Staring + Scan)

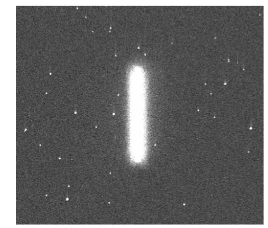




UVIS Staring 2009-2020

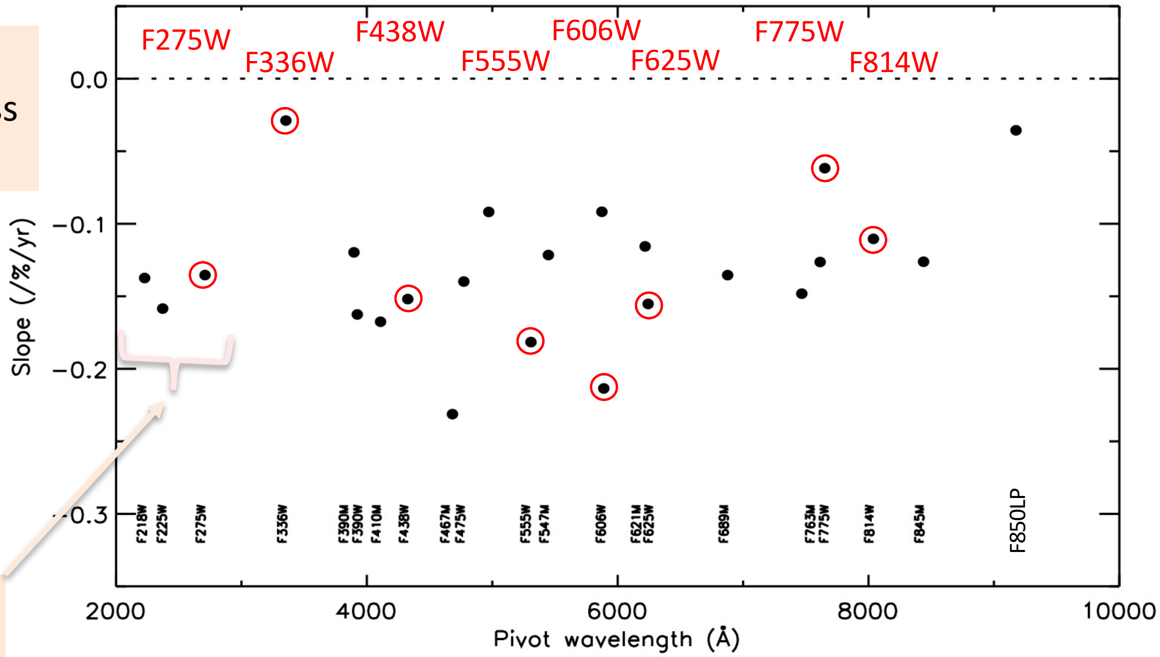


UVIS Scans 2017-2021



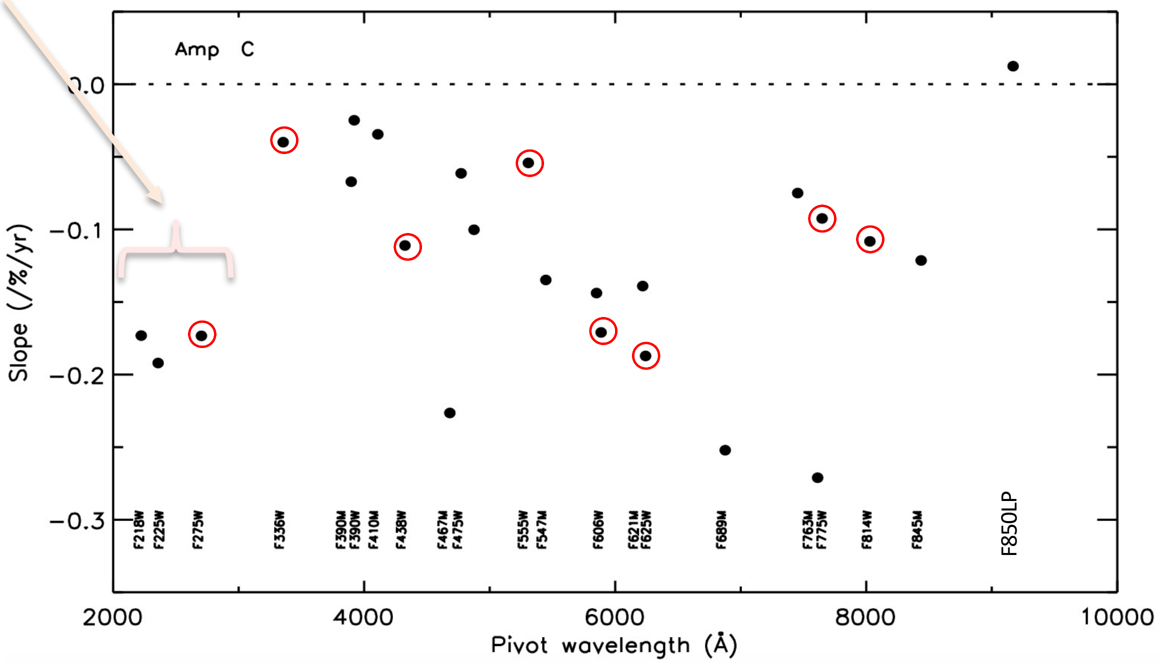
UVIS Sensitivity Loss vs Wavelength

ISR 2021-04
Mean Sensitivity Loss
~0.15% per year

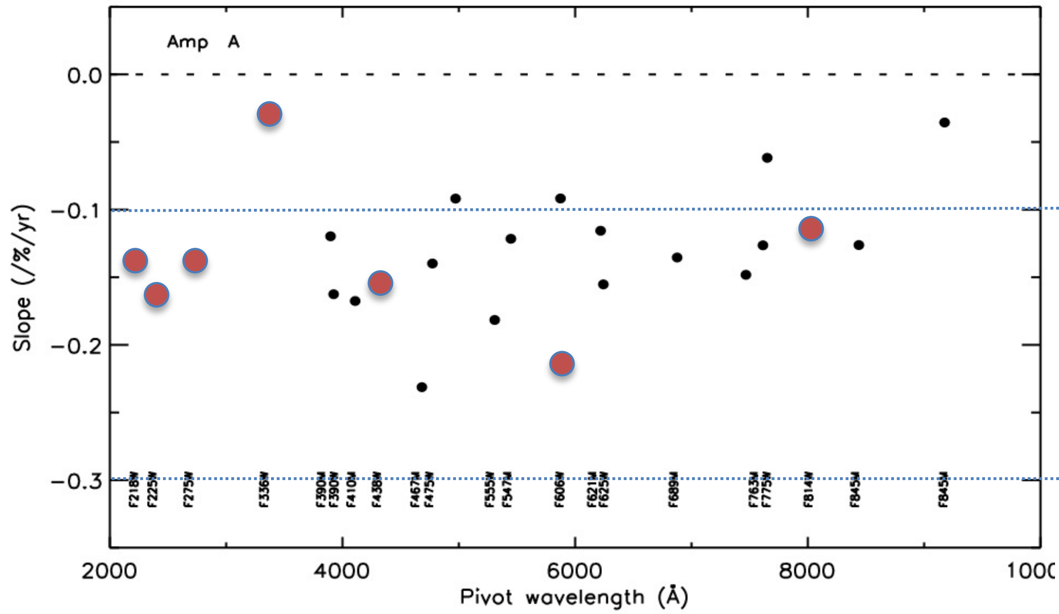


Amp A

UV filter slopes from images after 2012



Amp C



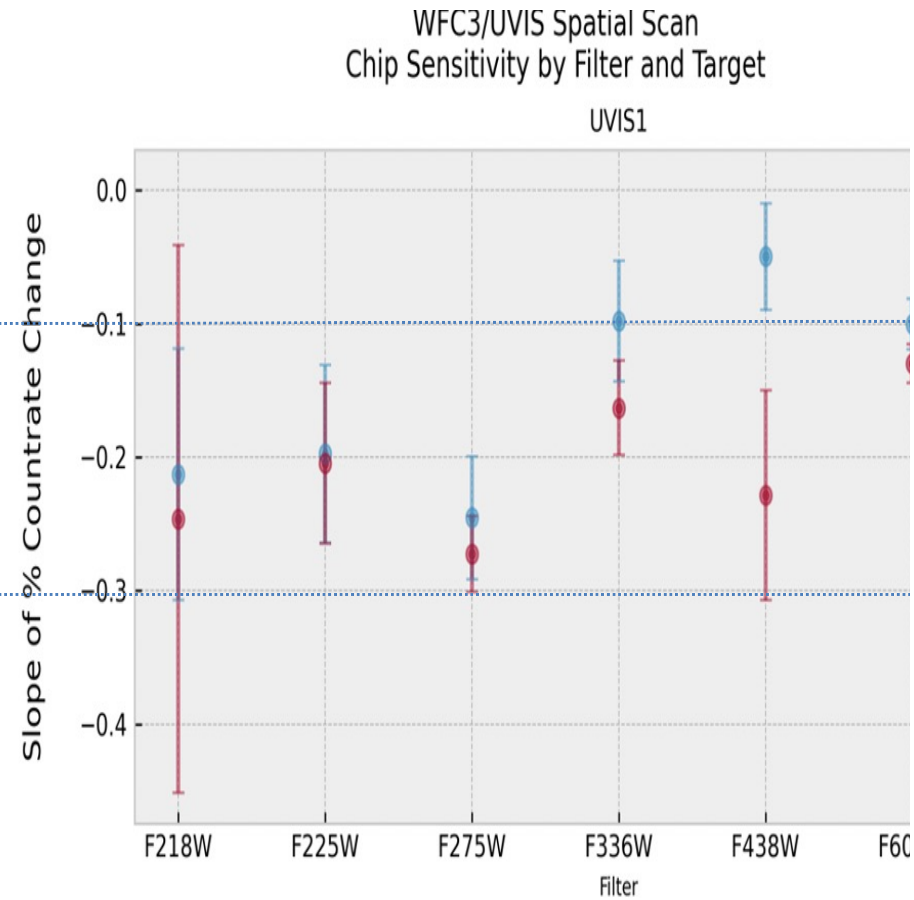
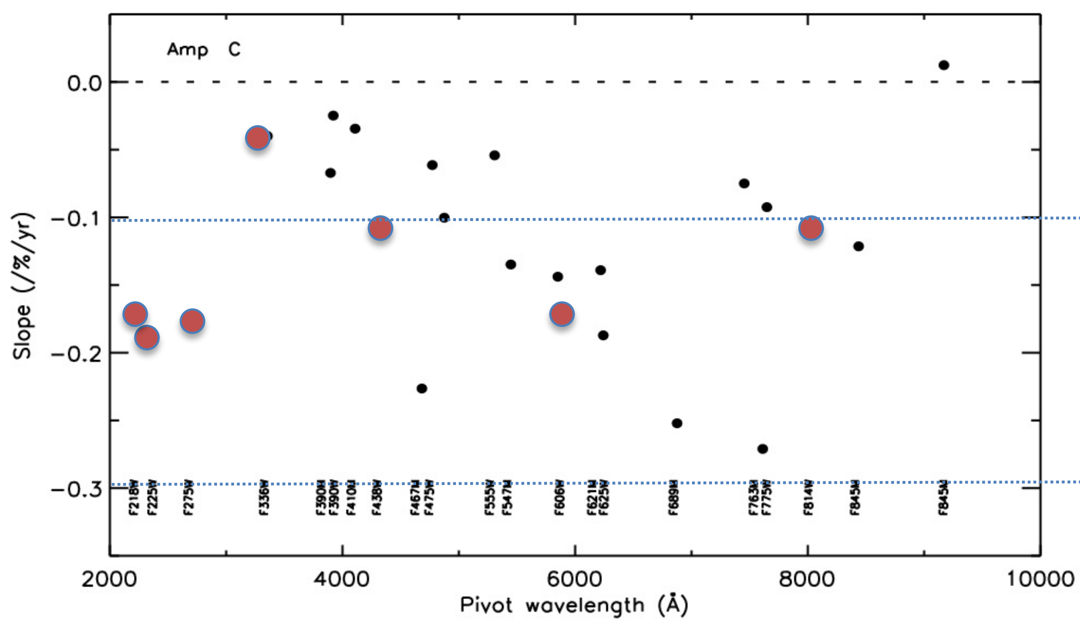


Figure 7: Measured sensitivity change slopes for the wide- and medium-band filters for the UVI detector (Amp A) as a function of pivot wavelength. Note that for the three UV filters the slope the one calculated after MJD = 55738 (see text and Table 3 for more details).



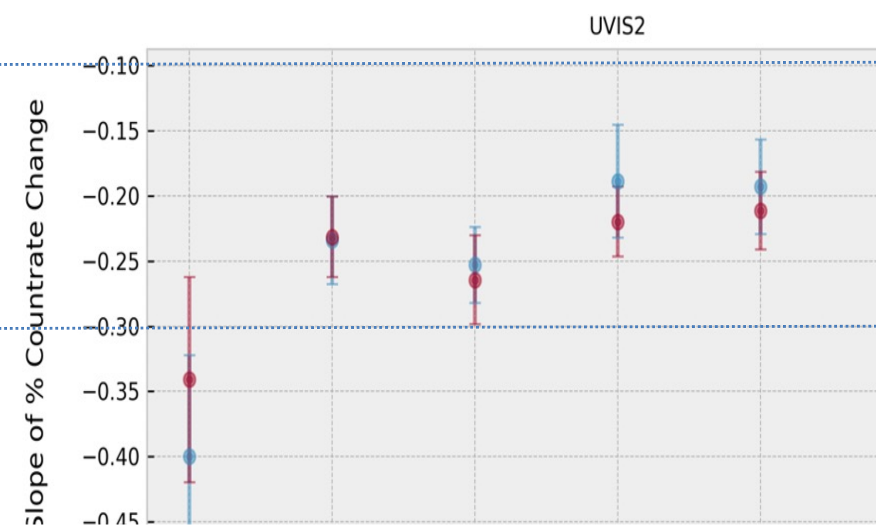
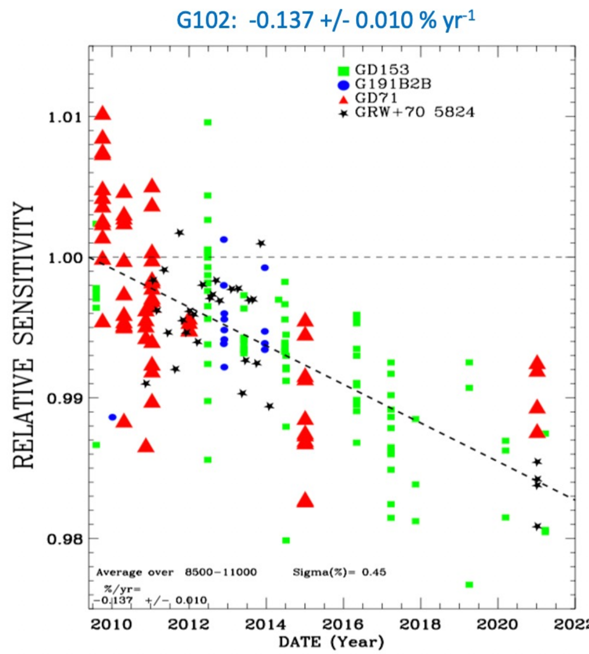
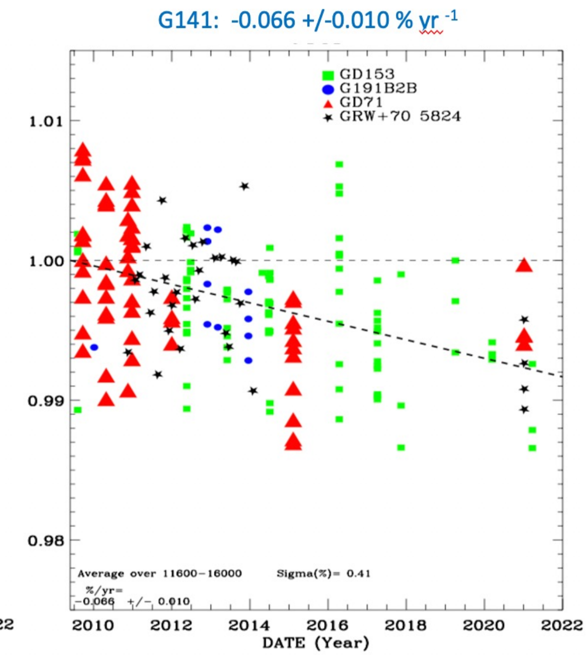


Figure 8: Same as Fig. 7 but for the UVIS2 detector (Amp C).

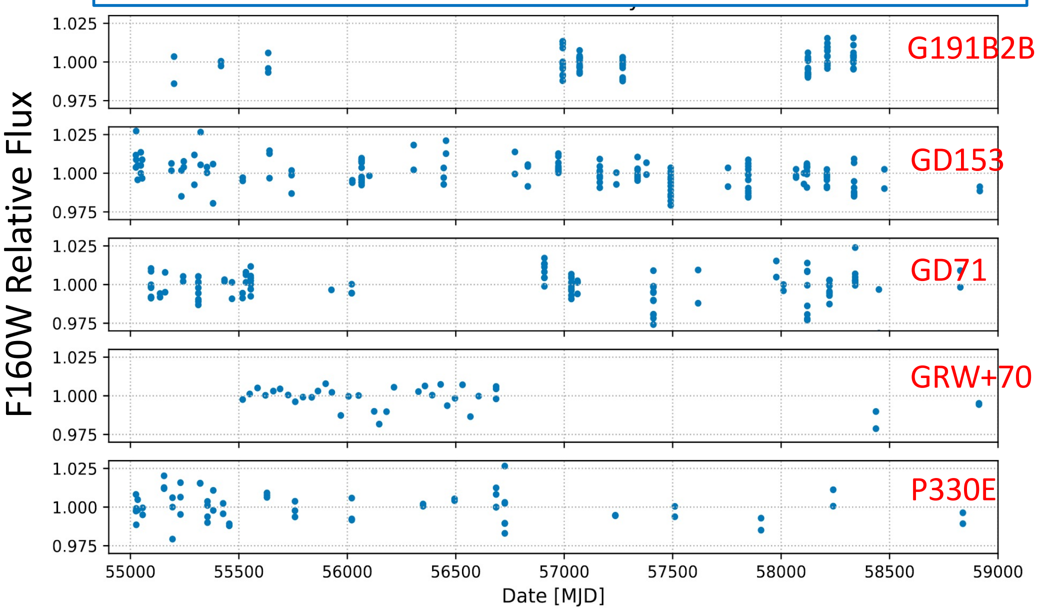
IR staring mode photometry

GRISMS
Sensitivity losses of 0.14% yr $^{-1}$ in G102 and 0.07%/yr in G141 are observed in monitoring data of HST white dwarf standards (Bohlin 2021, private comm.) These are slightly lower than the reported values by Bohlin & Deustua (2019).

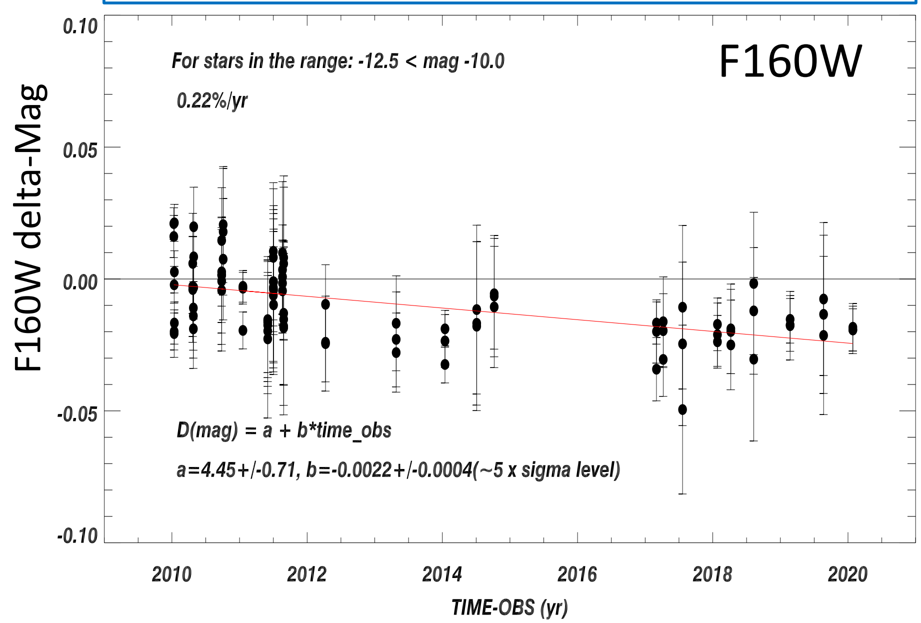




HST Standards
Monitoring of 5 flux standards over 11 years shows **no evidence** of a sensitivity loss over time, but the data limited by systematic errors with a repeatability of ± 1%. (Bajaj et al. ISR 2020-10)

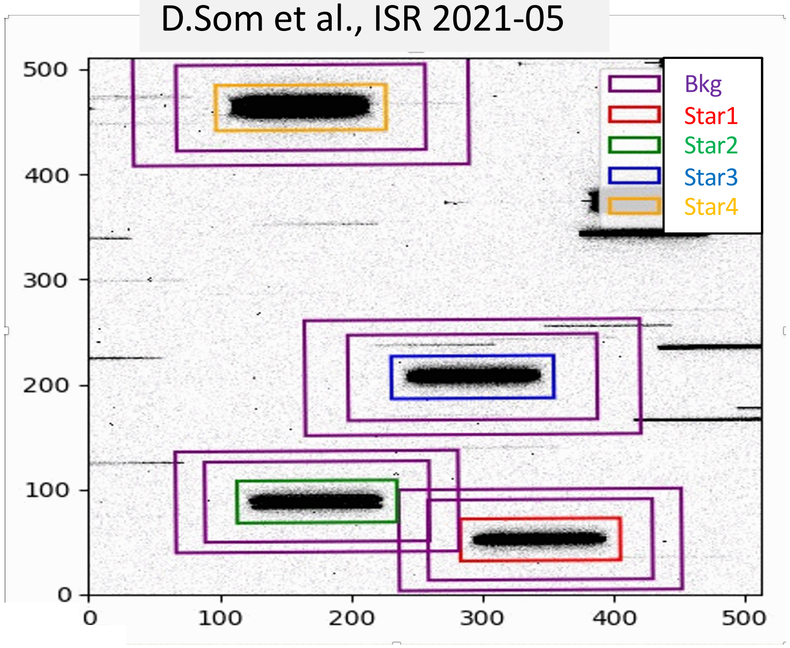


Cluster Photometry
Losses of 0.22 ± 0.04% yr $^{-1}$ are observed for the crowded stellar field in Omega-Cen used to monitor the distortion (Kozhurina-Platais et al. WFC3 ISR 2020-05)



IR scanned photometry

D.Som et al., ISR 2021-05



Non-monitor calibration programs:

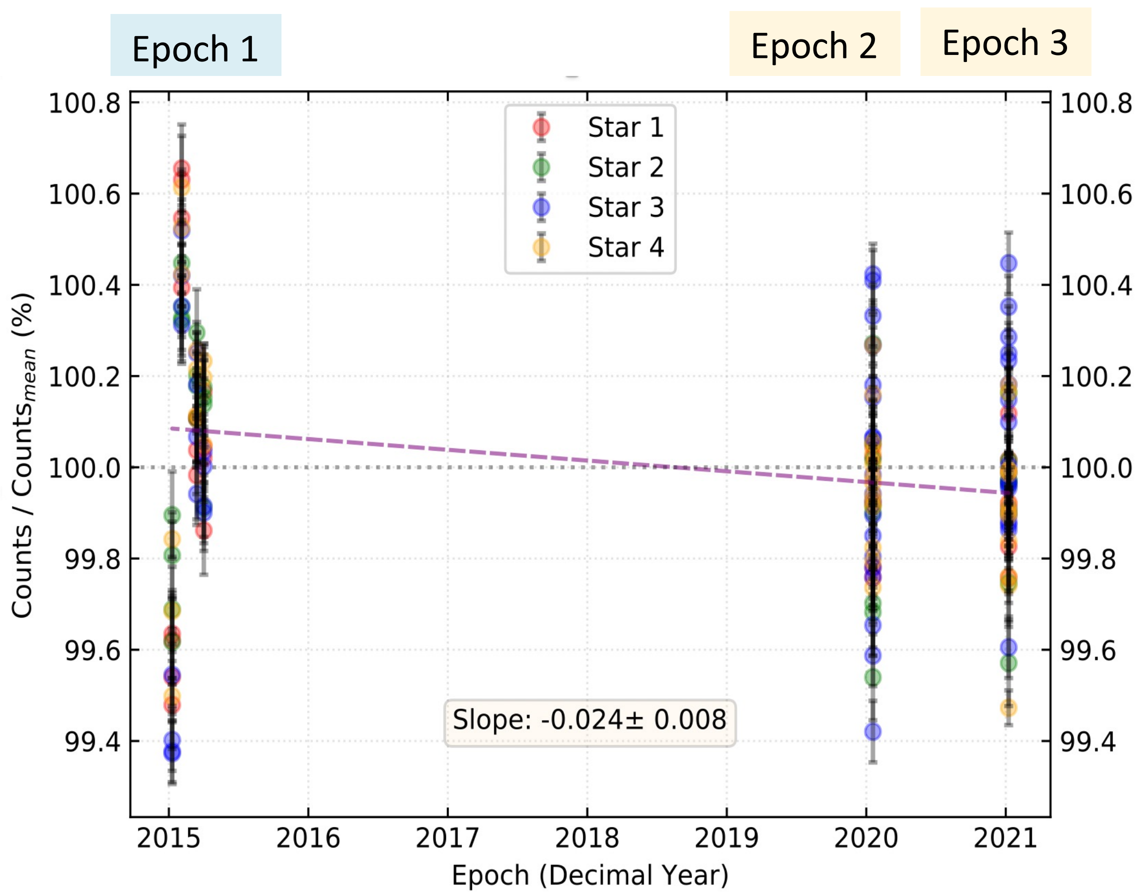
Epoch 1 : Jan 2015 (program 14020)

Epoch 2 : Jan 2020 (program 16031)
Epoch 3 : Jan 2021

Epoch 4 : Dec 2021 (program 16438, scheduling)
Epoch 5 : Apr 2022

Scans of bright (V~13) stars in **M35**

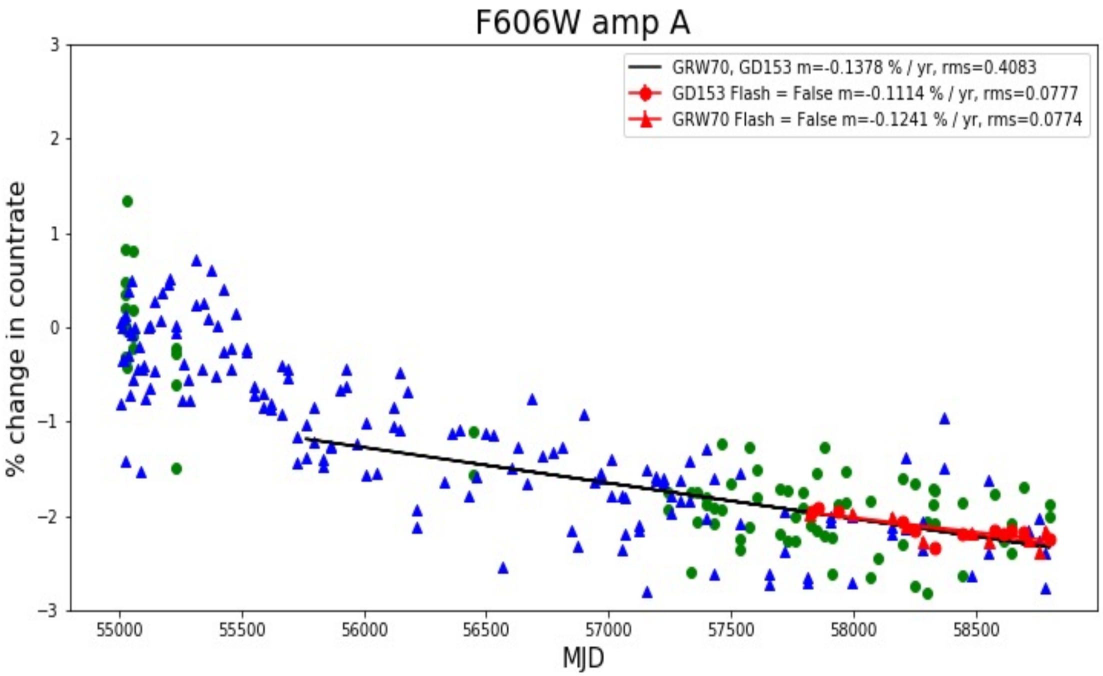
- Relative F140W photometry of 4 visits in Epoch 1 (Jan-Apr 2015) reveals variability at ~0.65% level (dominated by visits 1 & 2)
- The larger scatter in Epochs 2 & 3 is from sampling many detector positions
- We see a marginal sensitivity loss of 0.024 % yr^{-1} at the 3σ level for visits from Jan 2015 - Jan 2021

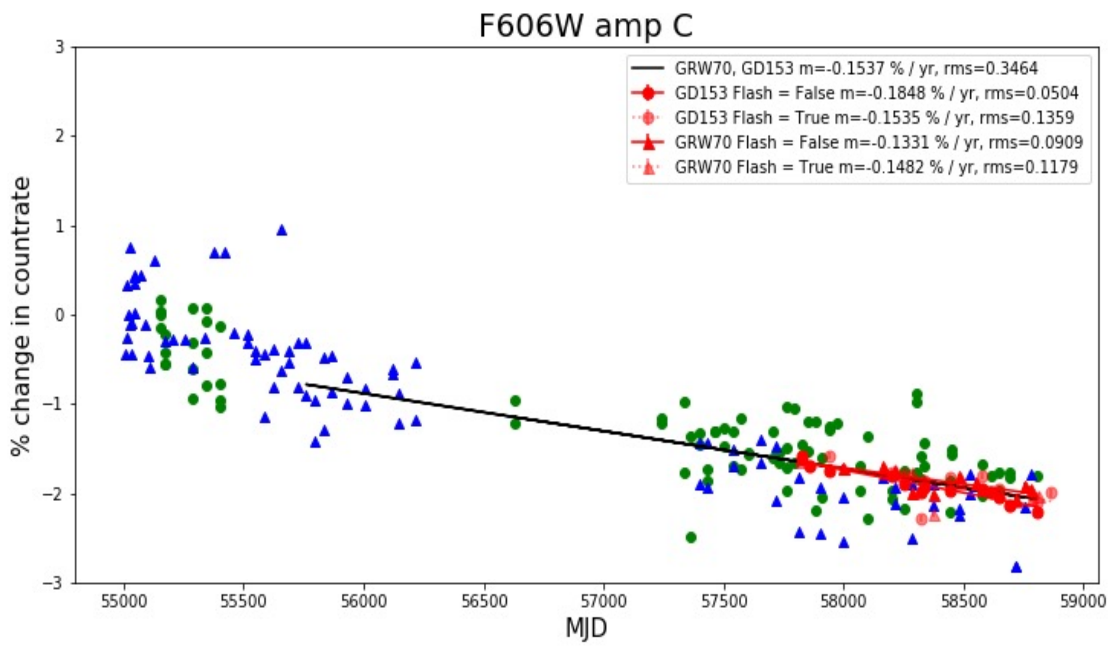


UVIS Time-Dependent Sensitivity

Orbits	External: 12 Internal: 0
PI, Co-I's	Calamida, Som, Baggett, Mack
Purpose	Monitor relative changes in the UVIS photometric throughput using scanned observations. Traditionally, this program looks for the presence of contaminants on the optics via the flux of standard stars as a function of time and wavelength. Additional filters have been added to monitor sensitivity losses at longer wavelengths. Staring mode exposures were moved to the Photometry Monitor in Cy27 for improved efficiency.
Description	Each visit obtains scanned subarray observations of HST standards in both amps A and C through a subset of filters. The white dwarf GRW+70D5824 has been used for past monitors and will be continued. A second white dwarf (GD153) was added in Cycle 23 with equal weight. This target 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. P330E was added in Cy27 to look for any color effects. Given the greater precision of the scanned mode (~3-5x improved over staring mode), we will test whether scanned data can be used for computing the photometric zeropoints or if it is better suited for quantifying relative changes.
Resources: Observations	12 orbits, scans only = 10 orbits for two white dwarfs (GRW+70, GD153) @ 5x/yr + 2 orbits for a G-star (P330E) @ 2x/yr
Resources: Analysis	Supports 100% of UVIS programs. Software developed for scanned observations from prior cycles will be used to measure relative photometry. These will be compared with the much longer baseline of staring mode data.
Products	IMPHTTAB reference file which populates time-dependent photometry keywords in the image headers
Accuracy Goals	Per epoch accuracy: 0.2%. Track temporal stability to < ~0.1%/yr
Prior Results, ISRs	While no contamination of WFC3/UVIS has been detected, long-term sensitivity losses are present in all filters (ISR 2021-04, 2017-15, 2014-20). Scanning mode has ~0.2% r.m.s. repeatability (ISR 2017-21).
Prior Cycle IDs	11426, 11907, 12333, 12698, 13088, 13574, 14018, 14382, ← (all staring mode) Cy24=14815 (staring)+14878 (scans), Cy25=15398 (staring/scans), Cy26=15583 (staring/scans), Cy27 (scans)=16021, Cy28=16416 (scans)

UVIS Time-Dependent Sensitivity





- GRW70 Staring
- GRW70 Scan
- GD153 Staring
- GD153 Scan

RESULTS:

Repeatability is ~0.2% (scans) vs ~1% (staring)

Excluding the first ~2 yrs, the slopes derived using the two methods are consistent

(Shanahan, private comm.)

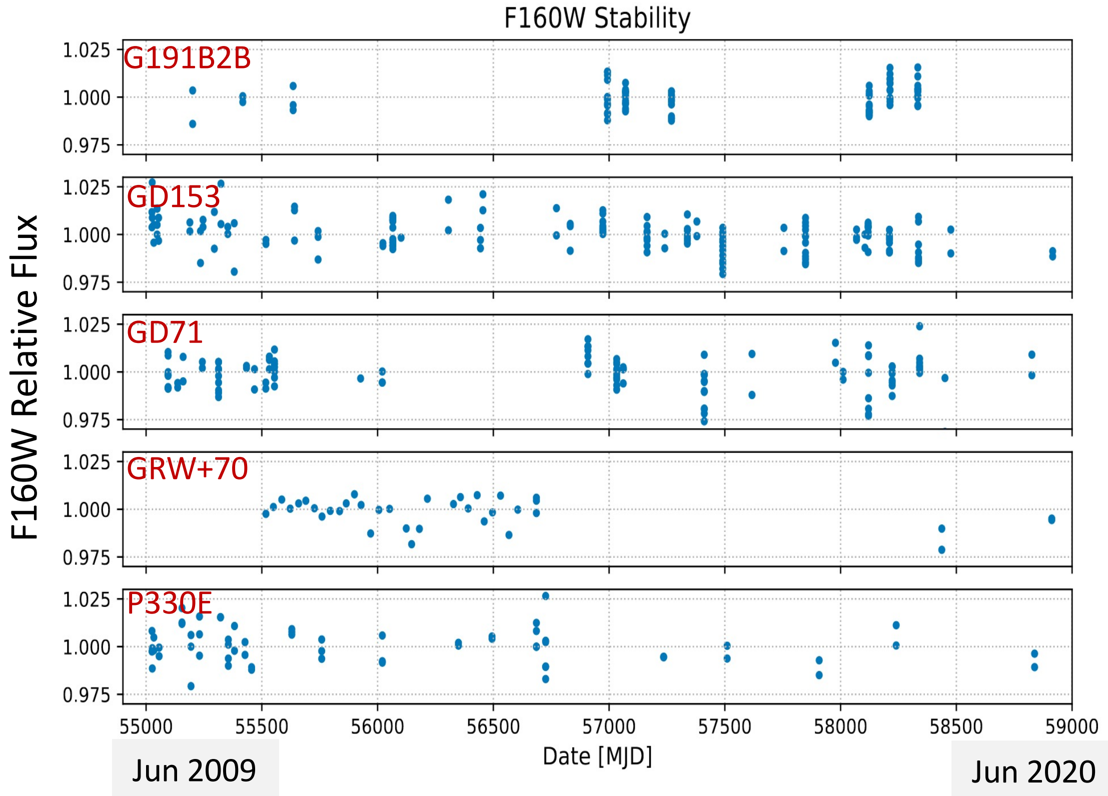
WFC3/IR Time-Dependent Sensitivity in Staring Mode (Clusters)

Orbits	External: 5 Internal: 0 ***Non-monitor**
PI, Co-I's	Bajaj, Mack, Calamida
Purpose	Test for IR sensitivity losses by leveraging off of prior observations of stellar clusters observed over a long time baseline. Investigate any dependence with wavelength and any differences in the results due to crowding.
Description	The IR grism flux monitor shows a sensitivity loss of 0.12+/-0.01 % yr^{-1} in G102 and 0.06+/-0.01 % yr^{-1} in G141. Observations of flux standards in the IR filters, however, show no evidence of any loss over time, but the repeatability is limited by systematic errors of $\pm$ 1%. Scanned observations of M35 from 2015-2020 show marginal losses of 0.024 $\pm$ 0.008% yr^{-1} in F140W, but these data show a large scatter which may be related to detector preconditioning. Cluster observations allow for the measurement of many more stars, and photometry of the core Omega-Cen used for distortion monitoring suggests losses of 0.23 $\pm$ 0.03% yr^{-1} in F160W, but crowding may play an effect on the results. Recent observations of a less dense stellar field in M4 in F110W suggest losses of 0.13 $\pm$ 0.02 % yr^{-1} (first images only) and 0.20 $\pm$ 0.03 % yr^{-1} (all images), but these consist of only 4 visits. We propose continued monitoring of M4 at a ~6 month cadence. Two additional clusters are requested: the NGC104 field 6' from the core with F160W data from 2009-2013 and an Omega-Cen field 17' from the core with F110W & F160W images from 2016-2018.
Resources: Observations	5 orbits for 3 targets; **M4**: 2 visits in F110W @ 1 orbit each, 6 months apart; **NGC104**: 1 visit in F160W to repeat the IR linearity monitor from 2009-2014. **Omega-Cen**: 1 visit each in F110W and F160W for one of the outer fields. We will repeat prior observing strategies (exposure time, dithering) to allow for accurate relative photometry and to mitigate the effects of self-persistence.
Resources: Analysis	Analysis uses software tools already developed by the PI for preliminary testing Includes IMPHTTAB reffile/synphot tables (testing, delivery, documentation)
Products	IMPHTTAB reference file to populate time-dependent photometry keywords; Synthetic photometry tables
Accuracy Goals	Characterize possible TDS losses of ~1-2% over the WFC3 lifetime to <0.5% accuracy Systematic errors across visits are up to 1%, so multiple visits/targets are required.
Prior Results	ISR 2020-10: Updated WFC3/IR Photometric Calibration; ISR 2021-05 : Scanned Photometry of M35 ISR 2020-05: WFC3 IR Sensitivity over Time; ISR 2019-07: IR photometric repeatability, 2019AJ…157…229B, 'CALSPEC: WFC3 Infrared Grism Spectrophotometry'
Prior IDs	12602, 14725, 16512 (**M4**); IR Linearity Monitor from 2009-2014 (**NGC104**); GO-14118, 14662 (**Omega Cen**)

IR Detector Monitoring

IR Flux Monitor (Staring)

Flux standards observed over 11 years show no evidence of any sensitivity loss with time, but the data are limited by systematic errors with a repeatability of ± 1%.
(Bajaj et al. ISR 2020-10)



Grism Flux Monitor

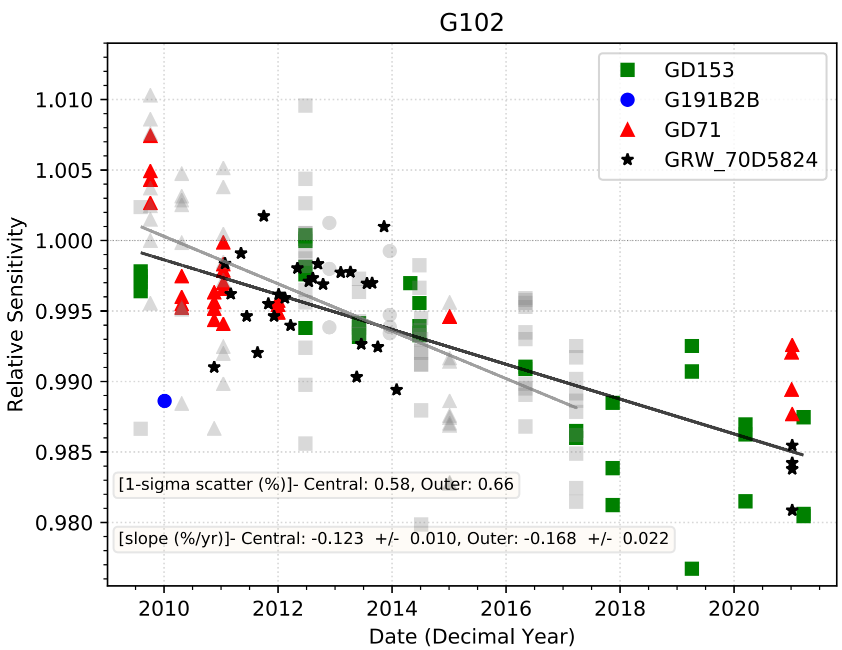
Sensitivity losses through 2021 (D. Som, private comm.) based on scans over the central region of the detector show:

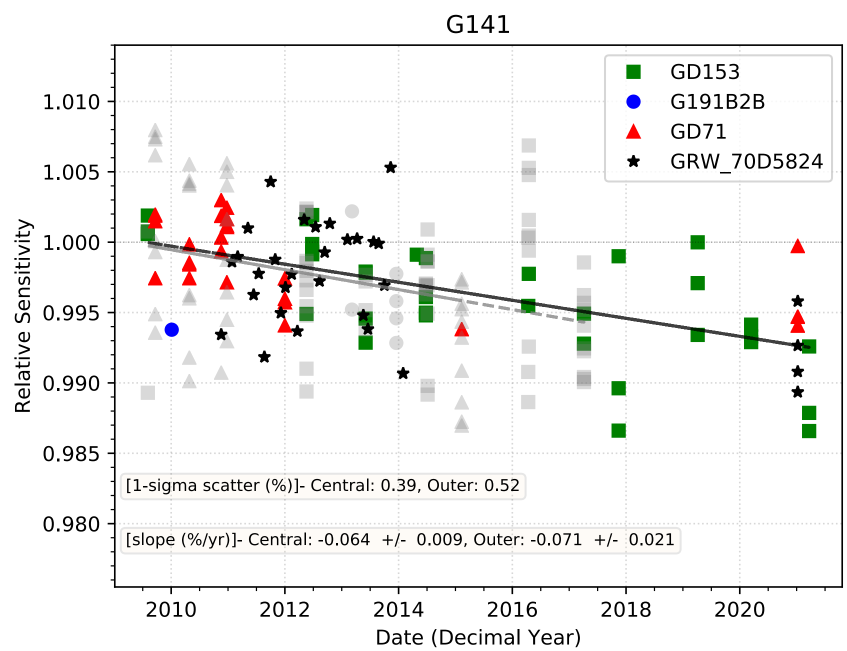
G102= -0.12+/-0.01 % per year
G141= -0.06+/-0.01 % per year

These are slightly lower than the values from Bohlin & Deustua (2019AJ…157…229B) which were based on scans through 2017 spanning the entire IR detector.

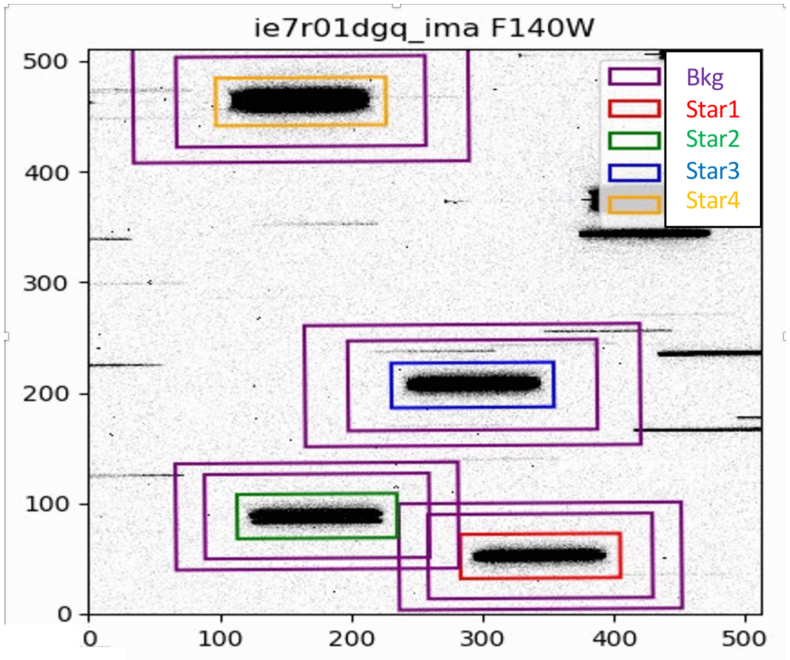
Colored points: detector center

Gray points: outer detector





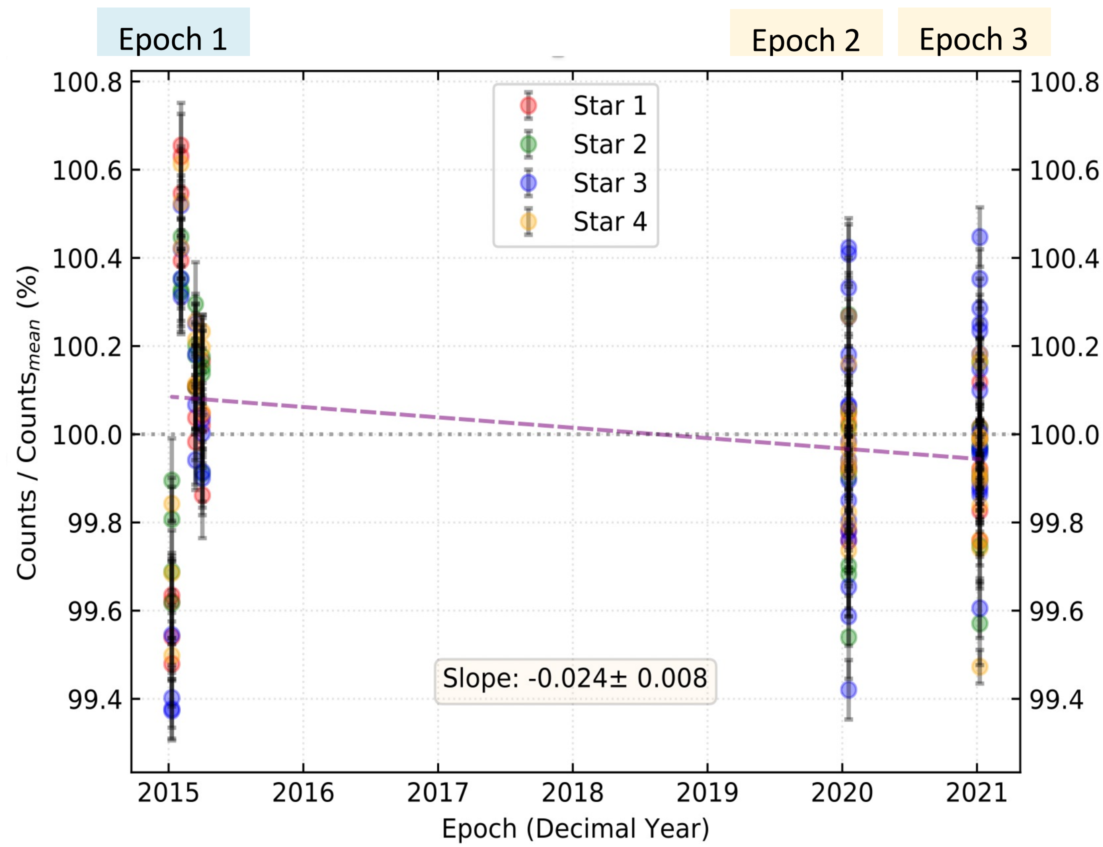
IR scanned photometry



Scans of bright (V~13) stars in **M35**

- Relative **F140W** photometry of 4 visits in Epoch 1 (Jan-Apr 2015) reveals variability at ~0.8% level (dominated by visits 1 & 2)
- Large scatter in Epochs 2 & 3 is from sampling many detector positions
- ***Marginal* sensitivity loss: -0.024 ± 0.008 % yr $^{-1}$** (3σ level)

D. Som et al. WFC3 ISR 2021-05



Observing Cadence

Epoch 1 : Cy22: Jan 2015 (program 14020)

Epoch 2 : Cy27: Jan 2020 (program 16031)
Epoch 3 : Jan 2021

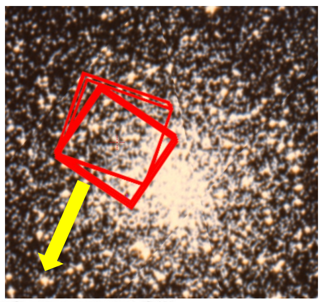
Epoch 4 : Cy28; Jan 2022 (program 16439)
Epoch 5 : Mar 2022

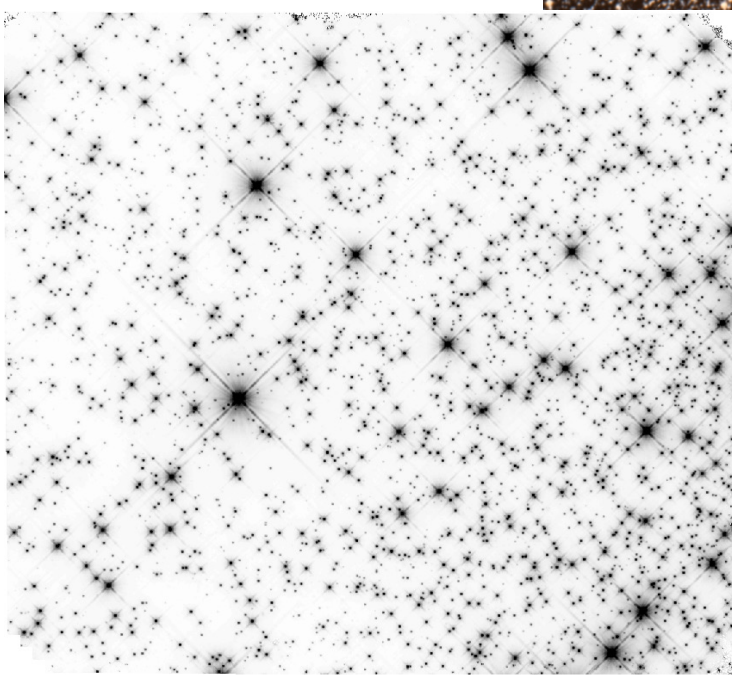
SCHEDULED

M4 Cluster – Special Calibration

- Aperture photometry; 600+ bright stars
- Large dithers to mitigate persistence

- Program 12602: Apr 2012 (2 orbits)
- Program 14725: Mar 2017, July 2017
- Program 16512: Sep 2021, **Mar 2022**
- Cy29 Proposed: **Sep 2022, Mar 2023**

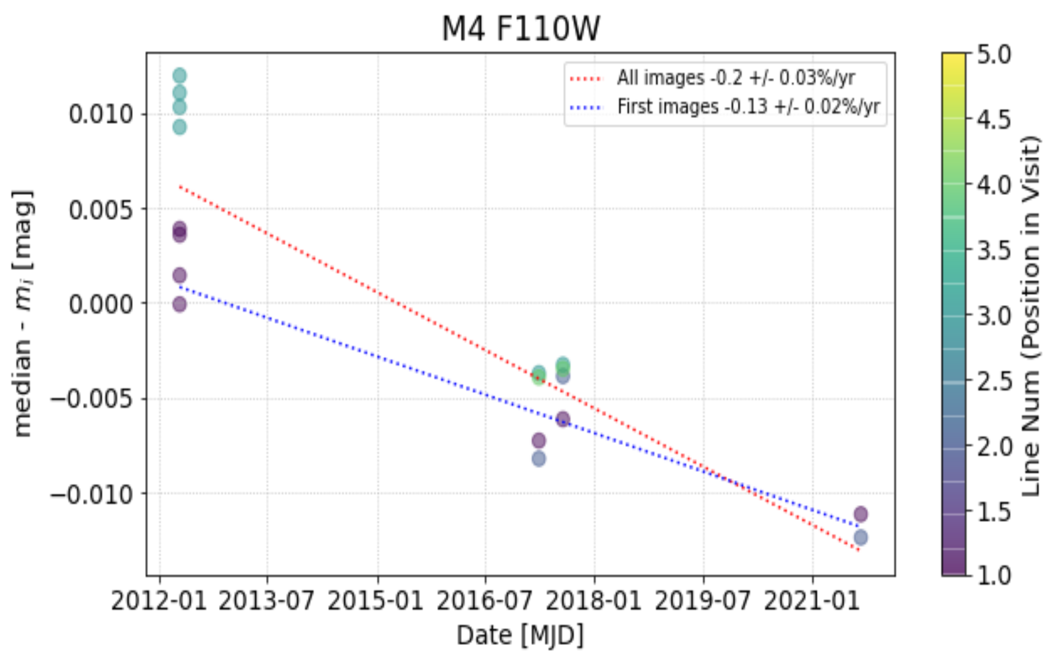




Request: 2 orbits (1 every 6 months) in F110W to continue monitoring this target

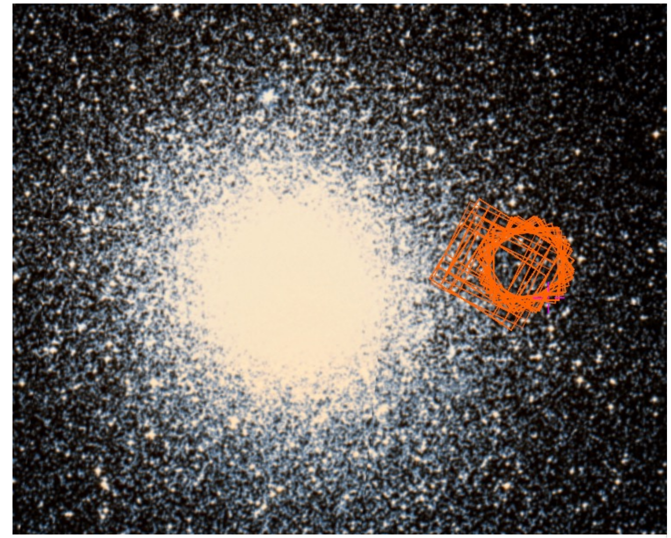
- **F110W** sensitivity loss for 'All images' in a visit is 0.20%/yr ; Using only 'First images' reduces the slope to 0.13%/yr, but the errors are large
- Delta-mag values correlate with the position in the visit, where images acquired later (i.e. those with self-persistence) have larger a D-mag
- Systematic offsets in these few visits may bias the slope, e.g. the 2017 visits differ by ~0.3%, larger than the Poisson noise from 600 stars

Using only 'first images': Slope = -0.13 ± 0.02 % yr $^{-1}$



NGC 104 – Outer Field

Request: 1 orbit in F160W to repeat the IR Linearity monitor pointing



2009:

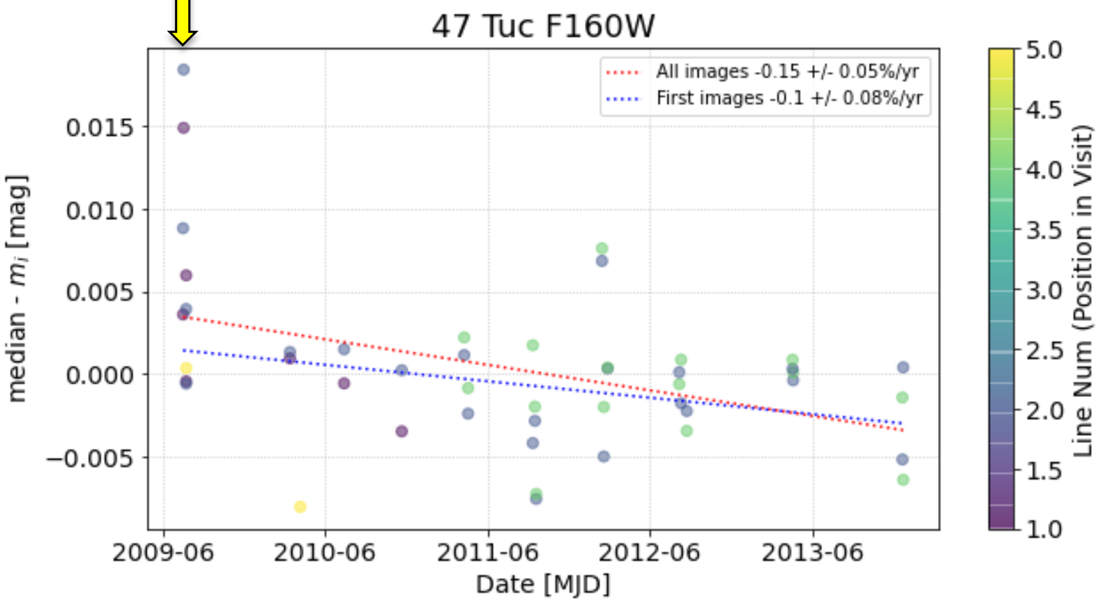
IR Plate Scale	Program 11445	(270 sec)
One 4-orbit visit with many large dithers		
IR L-flat	Program 11453	(270 sec)
Three 3-orbit visits, with repeated exposures at same dither position		

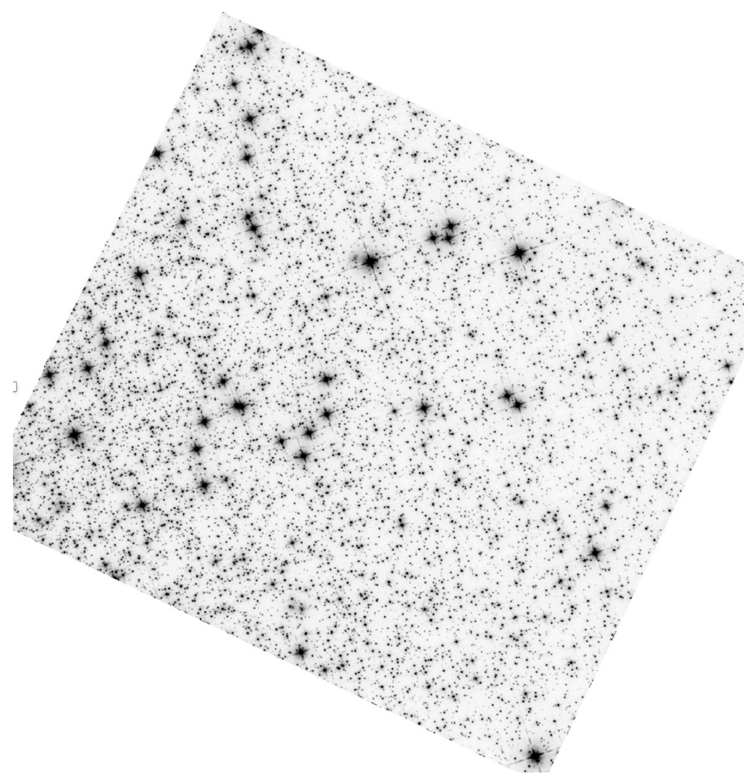
2010-2014: (90 sec + 350 sec)

IR Linearity Monitor Programs: 11931, 12352, 12696, 13079, 13563

2009: larger scatter due to self-persistence

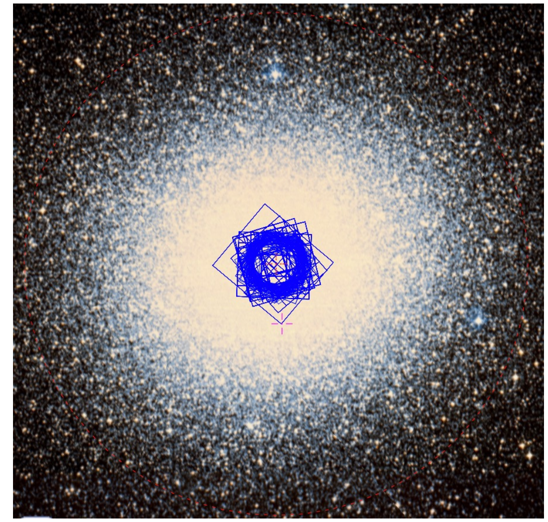
All images: Slope = -0.15 $\pm$ 0.05 % yr^{-1}
First images: Slope = -0.10 $\pm$ 0.08 % yr^{-1}





OMEGA CEN – Core

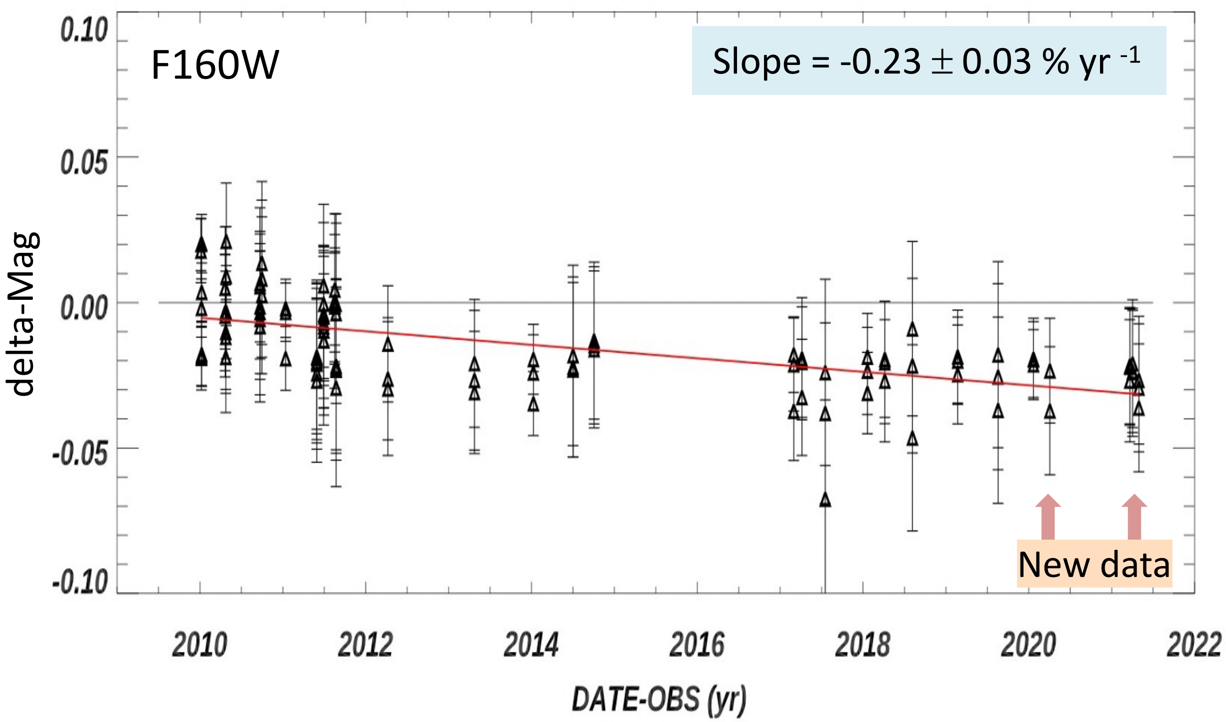
Request: No additional orbits; continue monitoring

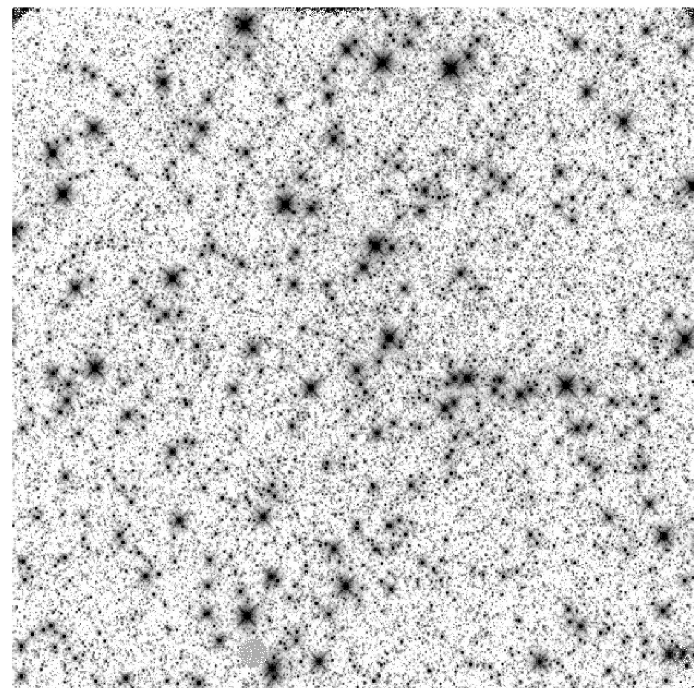


IR Distortion Monitor: 2010-2021

PSF photometry in **F160W** for the crowded region at the cluster center shows losses of 0.23 ± 0.03 % yr $^{-1}$ for all images through 2021. Fit to first images only through early 2020 show losses of of 0.25 ± 0.07 % yr $^{-1}$

(Kozhurina-Platais & Baggett: WFC3 ISR 2020-05)

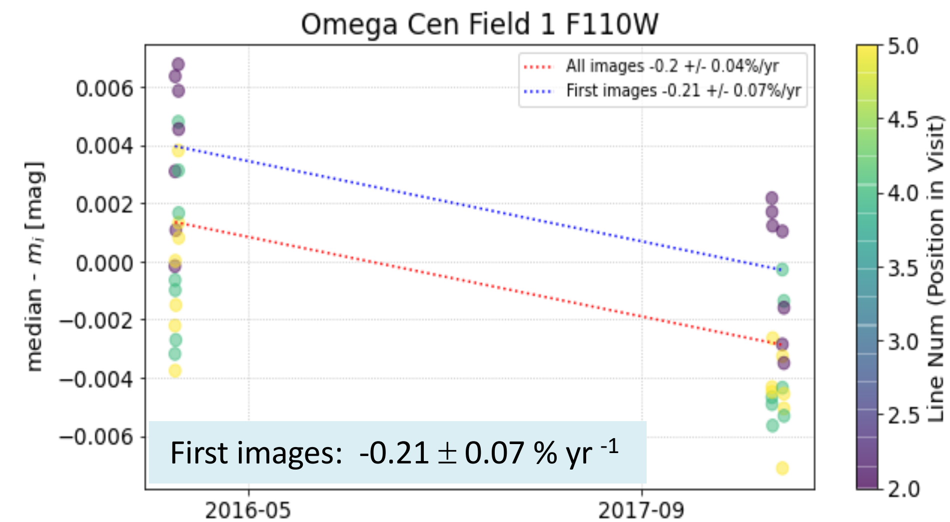


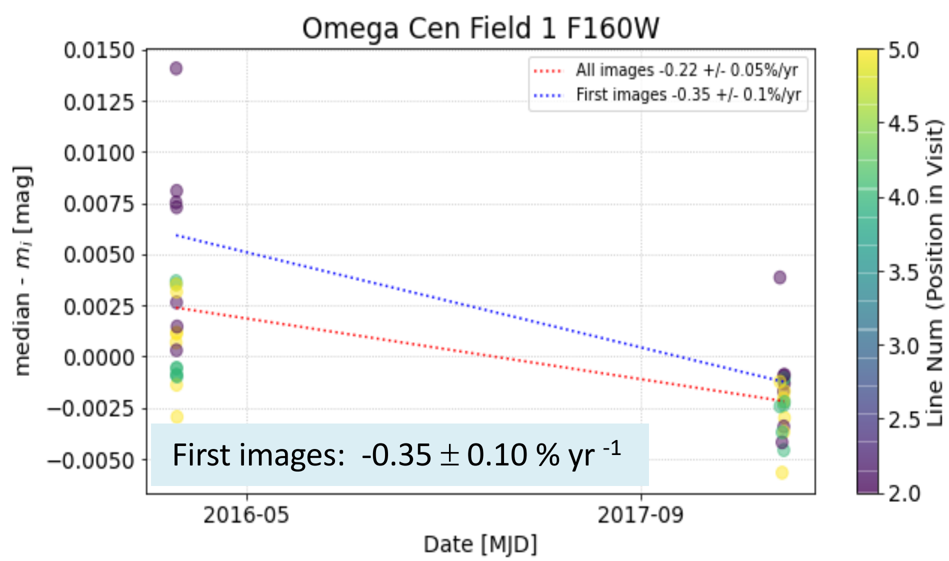


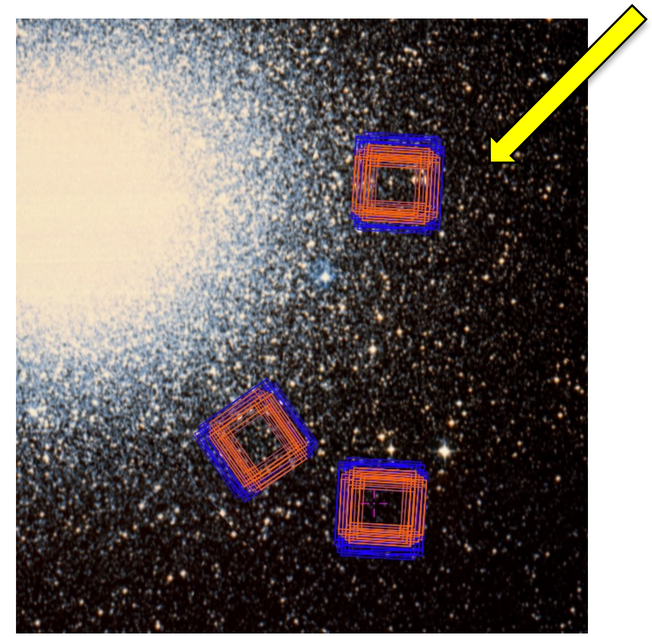
OMEGA CEN – Outer Field

Request: 2 orbits (1 each in F110W & F160W) for Field 1

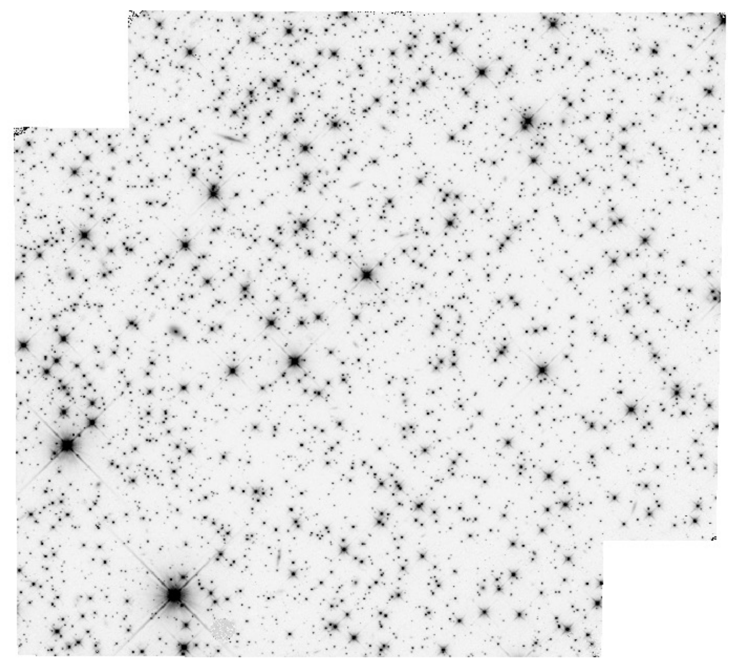
GO Programs: 14118, 14662 (Bedin, WD Cooling Sequence)
3 fields @ 17' offset from Core; Dates=2016-2018;
F110W & F160W in separate visits; large dither







id8009020_drz.fits= 150 sec + 2*1200 sec



WFC3 Grism Spectroscopy

Same as the previous cycle

- Monitor and improve the wavelength calibration for both IR grisms
  1 orbit
- Monitor and improve the flux calibration and trace for both IR grisms
  3 orbits (same as last cycle)
- Monitor the wavelength stability of the UVIS grism in both chips.
  1 orbit (performed every other cycle; skipped in cycle 28)

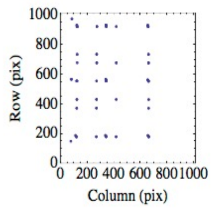
WFC3 IR Grism Wavelength Calibration & Stability

Orbits	External: 1 Internal: 0
PI, Co-I's	Som, Nikolov
Purpose	Verify the temporal stability of the wavelength dispersion for the G102 and G141 grisms
Description	Grism G102 and G141 observations of VY2-2 will be obtained and reduced to verify that the dispersion of these grisms is not changing.
Resources: Observations	1 orbit = 1 pointing at the center of the field per grism
Resources: Analysis	Supports 30% of IR programs (grisms) Automated reduction software by PI
Products	New aXe configuration files, as needed
Accuracy Goals	10 Å for G102; 20 Å for G141
Prior Results, ISRs	hstaXe Cookbook: https://github.com/spacetelescope/hstaxe ISR 2018-13: Linear Reconstruction of Grism Spectroscopy ISR 2017-01: A More Generalized Coordinate Transformation Approach for Grisms ISR 2016-15: Trace and Wavelength Calibrations of the WFC3 G102 and G141 IR Grisms ISR 2015-10: IR Grism Wavelength Solutions Using the Zero Order Image as the Reference Point
Prior Cycle IDs	12356, 12703, 13093, 13580, 14023, 14385, 14543, 14543, 14993, 15586, 15727, 16407 (cy28)

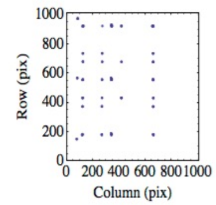
WFC3 IR Grism Wavelength Calibration & Stability

WFC3 ISR 2016-15

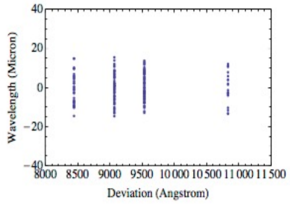
G102

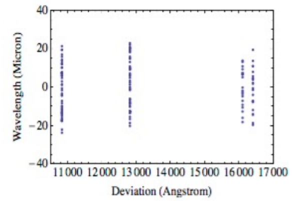


G141

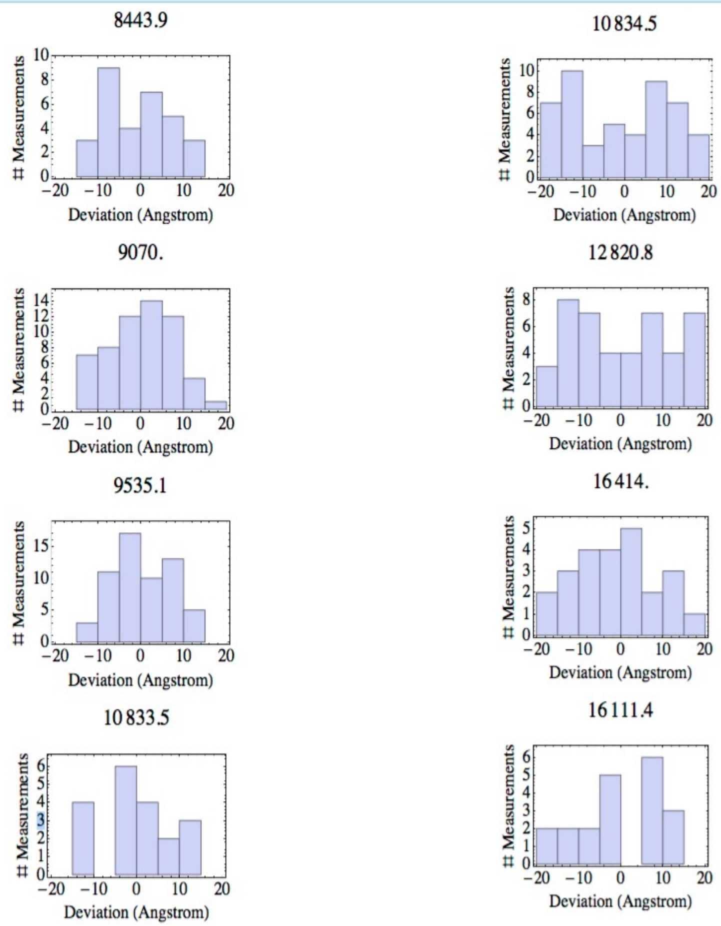


The location at which emission lines were extracted and measured (using the latest trace calibration)





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



Histogram of the fit residuals, over the entire field of view, for each emission line measured:

G102:		G141:	
O I	(8,443.9 A)	He I	(10,834.5 A)
[S III]	(9,070.0 A)	He I	(12,820.8 A)
[S III]	(9,535.1 A)	H I Br12	(16,414.0 A)
He I	(10,833.5 A)	H I Br13	(16,111.4 A)

WFC3 IR Grism Flux/Trace Calibration & Stability

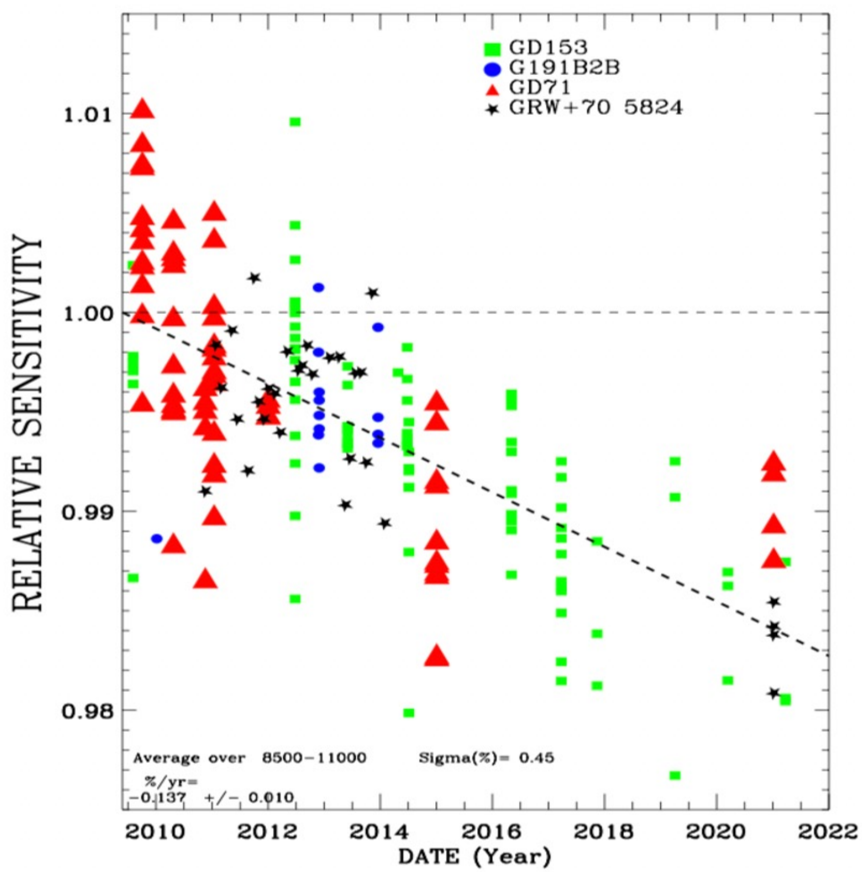
Orbits	External: 3 Internal: 0
PI, Co-I's	Som, Nikolov
Purpose	Monitor the time-dependent sensitivity (TDS) for both IR grisms via annual measurements of spectrophotometric standard white dwarf stars. Verify the temporal stability of trace solution.
Description	The original flux monitor observed GD71 and GD153 at a range of detector positions but was reduced to a single orbit of GD153 based on the stability of the initial calibration. Using a longer time baseline, a decrease in sensitivity of ~0.1% per year has been measured. In Cycle 28, we requested modifying this 1 orbit monitor to observe two additional WD standards (GD71 & GRW+70 5824) to more accurately correct for time-dependent losses, increasing the allocation to 3 orbits.
Resources: Observations	3 orbits (1 orbit/star for three WD standards in both grisms). Observations are taken at 3 positions near the center of the detector with postargs (-20, 0) (-20, +15) (-20, -15)
Resources: Analysis	ABSCAL code by Bohlin will be used by Som for analysis, TDS implementation by Nikolov
Products	Time-dependent sensitivity corrections for the GO community using grisms. Synthetic photometry tables for use with synphot and aXe
Accuracy Goals	Characterize TDS losses to accuracy <0.1%.
Prior Results, ISRs	ISR 2020-04: 'Dispersed IR background in G102, G141' (3 components= Zodi +He +Scatter) Bohlin & Deustua (2019AJ....157..229B): 'CALSPEC: WFC3 Infrared Grism Spectrophotometry' ISR 2016-15: Trace and Wavelength Calibrations of the WFC3 G102 and G141 IR Grisms
Prior Cycle IDs	11936 (GD71), 12357 (GD71), 12702 (GD71), 13092 (GD153), 13579 (GD153), 14024 (GD71), 14386 (GD153), 14544 (GD153), 14994 (GD153), 15587 (GD153), 15728 (GD153), 16408 (cy28, GD153+GD71+GRW)

WFC3 IR Grism Flux/Trace Calibration & Stability

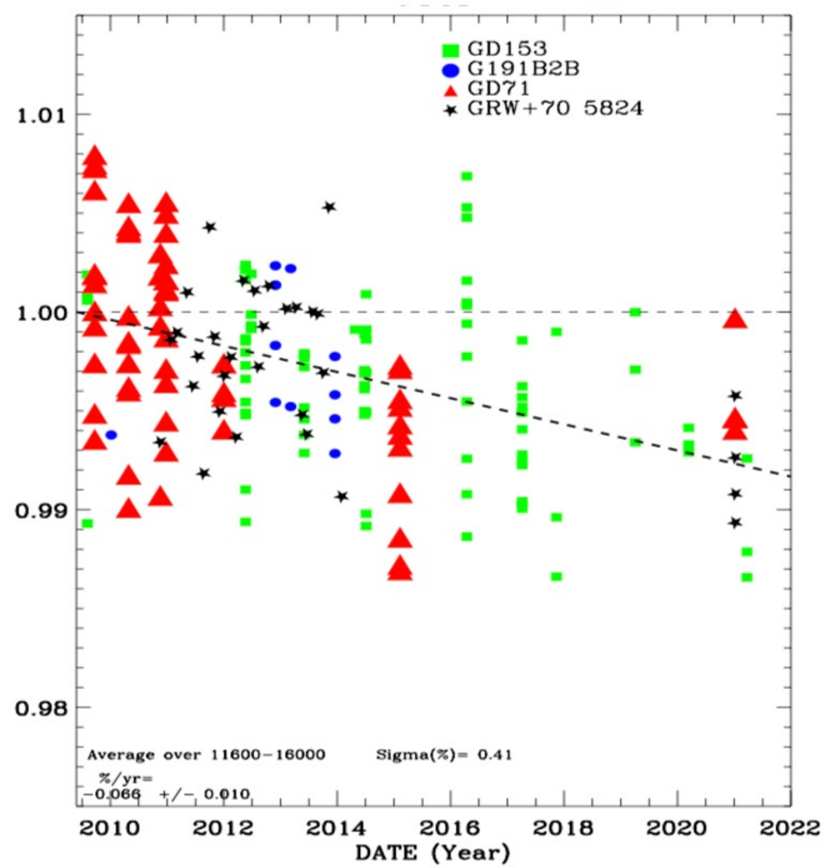
- Grisms on WFC3 are extremely popular
- Precision IR SEDs are critical for CALSPEC / support for future IR missions (JWST, Roman)
- Sensitivity losses are seen in G102, G141 archival standard star data (Bohlin 2021, private comm.)

- Grism flux monitor in Cycle 27 observed **GD153** (green), once per year
- Approval in Cycle 28 to add 1 orbit each for: **GD71** (red), **GRW+70D5824** (black)
  These three WDs are also observed using standard filters in the 'Photometry Monitor'

G102: -0.137 +/- 0.010 % yr^{-1}

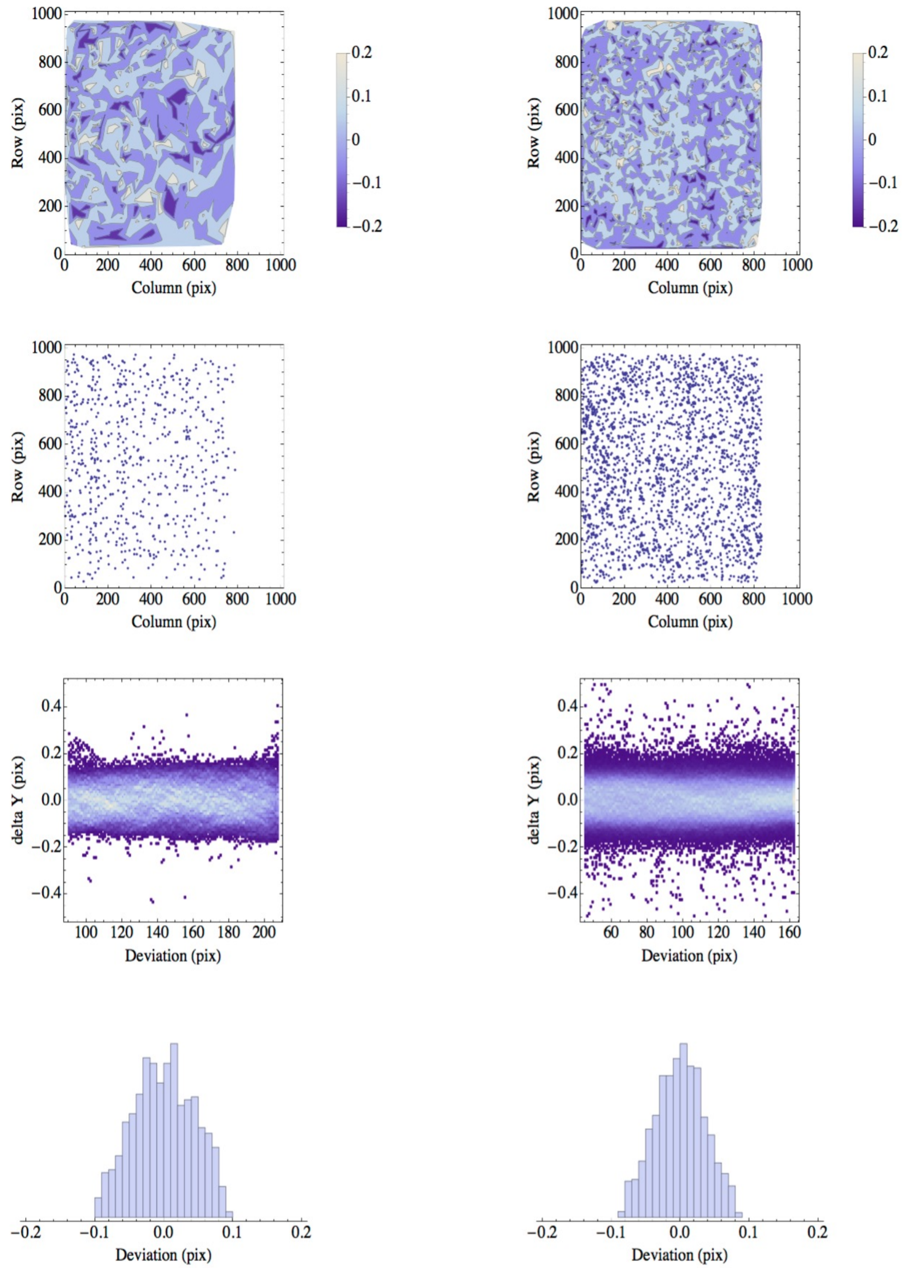


G141: -0.066 +/-0.010 % yr^{-1}



WFC3 IR Grism Flux/Trace Calibration & Stability

G102 G141



WFC3 ISR 2016-15

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

The object positions at which measurements were obtained.

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

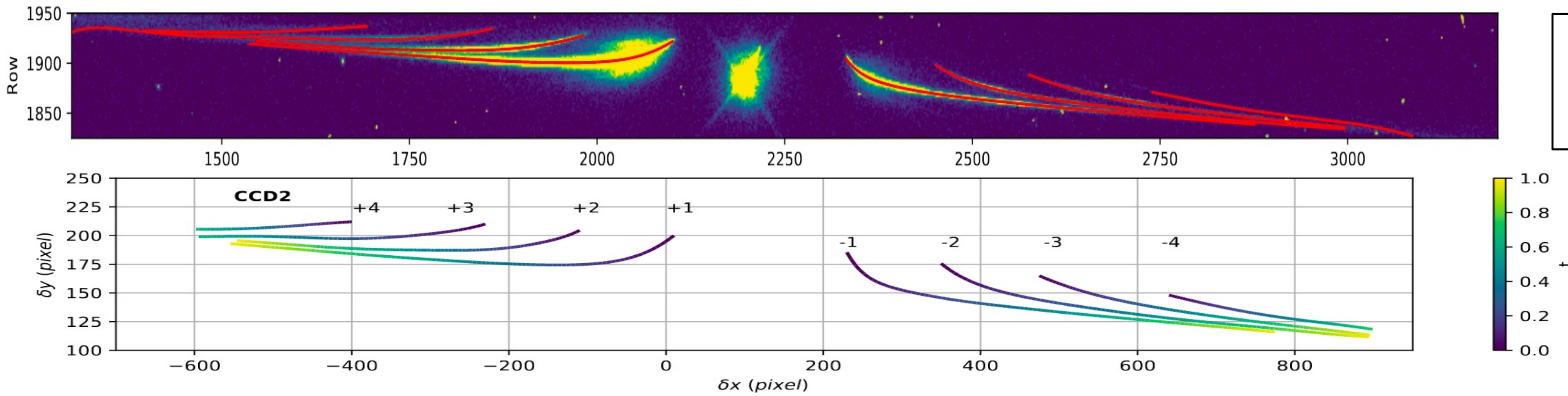
The average error in the trace positions over the entire field of view.

UVIS Grism Wavelength Calibration

Orbits	External: 1 Internal: 0
PI, Co-I's	Som, Nikolov
Purpose	Monitor and refine the UVIS wavelength calibration, as necessary. This calibration will improve our ability to process archived data as well as support current and future UVIS spectroscopic programs.
Description	Grism G280 spectra of WR-14 will be obtained to verify that the dispersion of this grism is not changing. (The flux calibration uses GD71.) One orbit is requested for monitoring every other cycle. The last observations were acquired in Cycle 27 to refine both the flux and wavelength calibration by sampling more detector positions.
Resources: Observations	1 orbit = 4 pointings (2 per CHIP). Two (2) positions on each CHIP will repeat the previously observed position (critical as they show +1 and -1 orders) and verify the stability of this mode.
Resources: Analysis	Supports 2% of UVIS programs (G280 filter)
Products	Configuration files for use with HSTaxe, recently updated in ISR 2020-09
Accuracy Goals	Establish the stability of the UVIS wavelength calibration to ~1 pixel (resolution element).
Prior Results, ISRs	ISR 2020-09: 'Updated Calibration of the G280 Grism'; ISR 2017-20: 'Trace and Wavelength Calibrations of the UVIS G280 +1/-1 Grism Orders'; ISR 2011-18: 'Contam Monitoring with G280', ISR 2009-01: 'Ground calibration'
Prior Cycle IDs	Wavelength Cal: 16022 (**cy27**, 4 orbits), 15588 (cy26, 1 orbit), 14995 (cy25, 1 orbit), 14545 (cy24, 1 orbit), 14387 (cy23, 1 orbit), 14025 (cy22, 2 orbits), 13578 (cy21, 2 orbits), 13091 (cy20, 2 orbits), 12705 (cy19, 3 orbits), 12359 (cy18, 4 orbits), 11935 (cy17, 1 orbit) Flux Calibration: 16023 (**cy27**, 5 orbits), 14026 (cy22, 2 orbits), 13577 (cy21, 2 orbits), 13090 (cy20, 20 orbits), 12704 (cy19, 4 orbits), 11934 (cy17, 1 orbit)

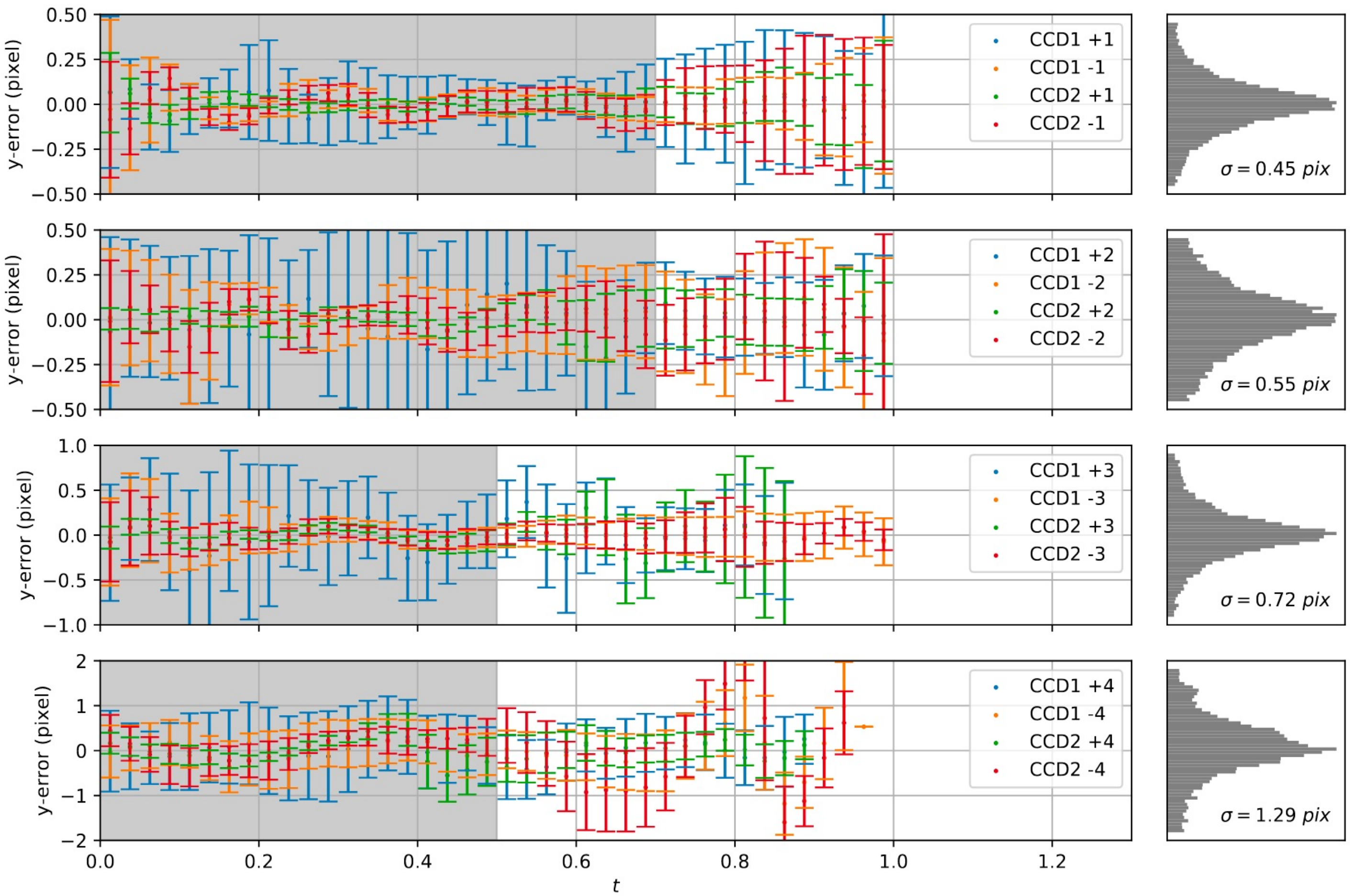
G280 Wavelength Calibration

ISR 2020-09



G280 spectrum with significant overlap in the spectral orders

Trace at the center of CCD2



Left: Fit residuals of the spectral trace for the ±1, ±2, ±3, ±4 orders vs ‘t’, a free parameter in the 2-D polynomial fits.

Shaded regions show where there is no overlap with any other spectral order.

Field dispersions for the ±1 orders are accurate to fraction of a pixel and to ~0.5 pix for the ±2 orders.

Right: Histograms of the residuals.

Flatfield Calibration

Same as the previous 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 internal flats

  13 internal orbits = 3 orbits * 1 epoch (D$_2$, 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 internal flats

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

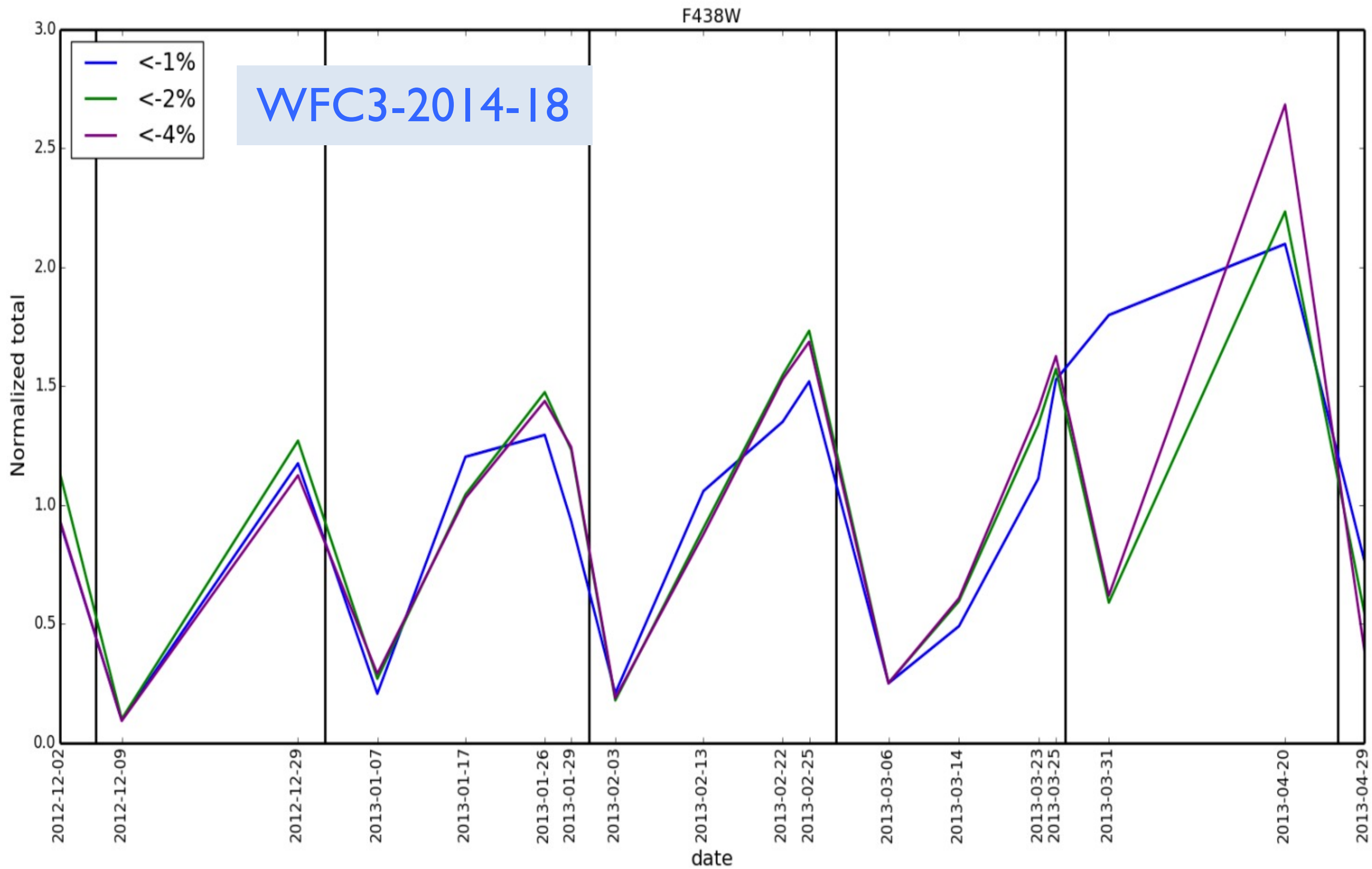
- Monitor the health of the CSM by observing the bright earth

  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: 0 Internal: 45
PI, Co-I's	Martlin, 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.
Resources: Observations	45 internal orbits: UV = 1 orbit*6 epochs, VIS= 3 orbits*13 epochs For the UV, 6 orbits with the D2 lamp are taken in F225W and F336W, 1 orbit every other month in the week before the anneal. UV orbits require non-int sequences to minimize cycling of the D2 lamp. For the Visible filters, 3 orbits each anneal cycle (a week before the anneal, midway between anneals, and just after the anneal) are taken with the Tungsten lamp in F438W, F645N and F814W.
Resources: Analysis	Supports 100% of UVIS programs (No products are delivered, but this monitor allows an assessment of QE variations over time.)
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	Track populations of low sensitivity pixels that vary by >1%, >2%, >4% for each filter
Prior Results, ISRs	ISR 2014-18 "Pixel-to-Pixel Flat Field Changes in WFC3/UVIS"
Prior Cycle IDs	13169, 13585 (ISR-2014), 14027, 14389, 14546, 14996, 15589, 15729, 16409 (cy28)

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



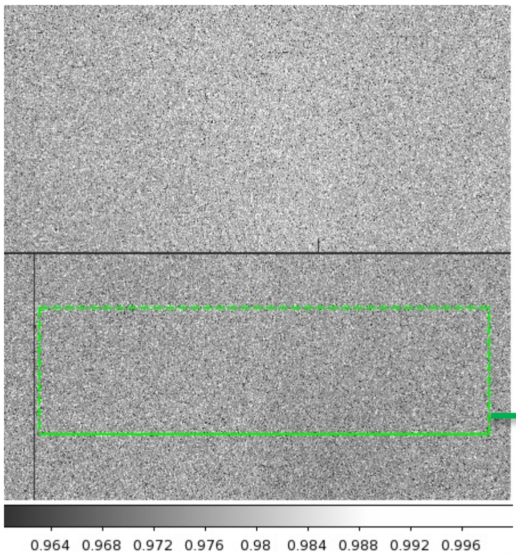
Normalized low sensitivity pixel population in F438W as a function of time. Anneals are indicated by black vertical lines.

UVIS Internal Flats

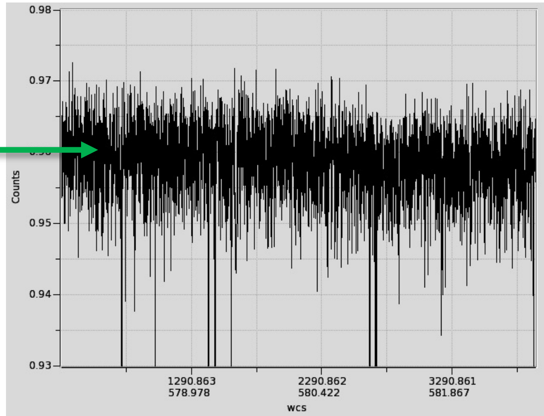
Orbits	External: 0 Internal: 13
PI, Co-I's	Khandrika, Kuhn, Mack
Purpose	Monitor the stability of the UVIS pixel-to-pixel sensitivity in all filters by obtaining internal flat fields with the tungsten and deuterium lamps
Description	We will acquire internal flats in all UVIS filters and monitor the decay of the internal lamps
Resources: Observations	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.
Resources: Analysis	Supports 100% of UVIS programs, but no products are delivered. Check for stability in the pixel-to-pixel response. Search for prominent new features in each UVIS filters by comparing internal flats acquired over time. Track the decay of the calibration lamps
Products	(No products are delivered, but this monitor allows an assessment of flat field stability over time.)
Accuracy Goals	Look for systematic changes exceeding 1%, after accounting for lamp decay
Prior Results, ISRs	ISR 2010-03: "WFC3 SMOV Proposal 11432: UVIS Internal Flats"
Prior Cycle IDs	11432 (in ISR 2010-03), Inspected, but not yet published: 11914, 12337, 12711, 13097, 13586, 14028, 14390, 14547, 14997, 15590, 15730, 16410 (cy28)

UVIS Internal Flats

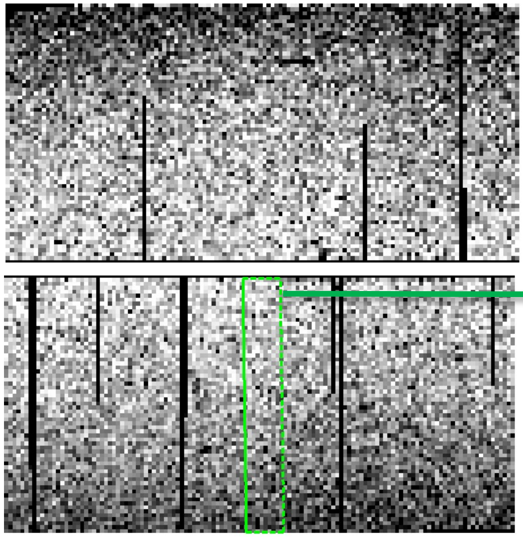
F606W 2017/ 2009 flat ratio



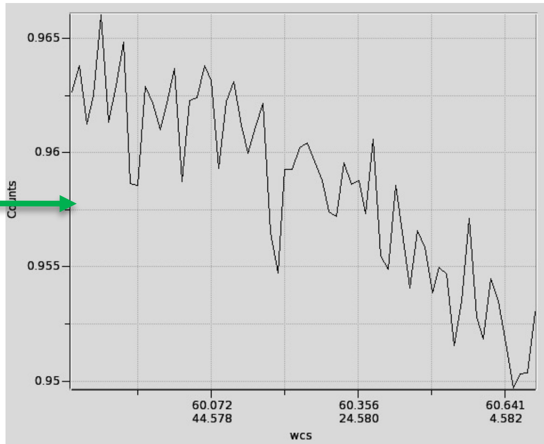
Horizontal Projection (~flat)



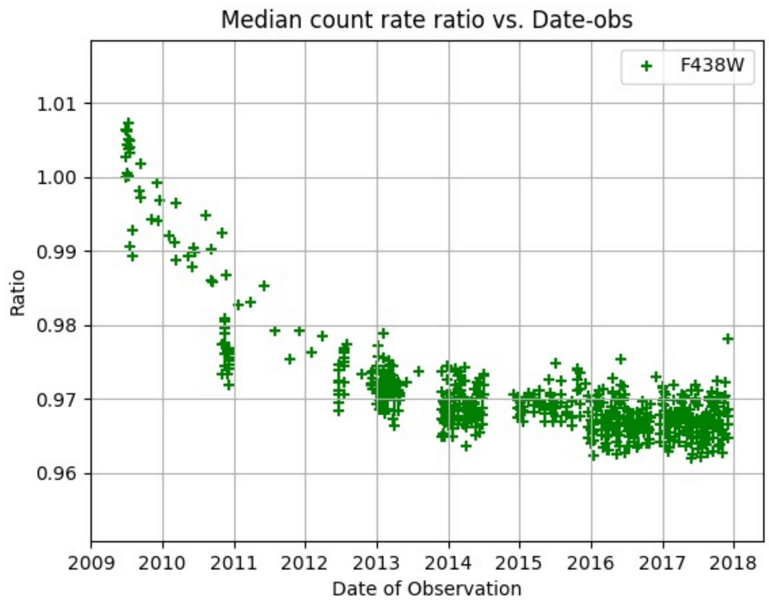
F606W 2017/ 2009 flat ratio
(Binned x 32)



Vertical Projection (~1% effect)



F438W Tungsten lamp decay



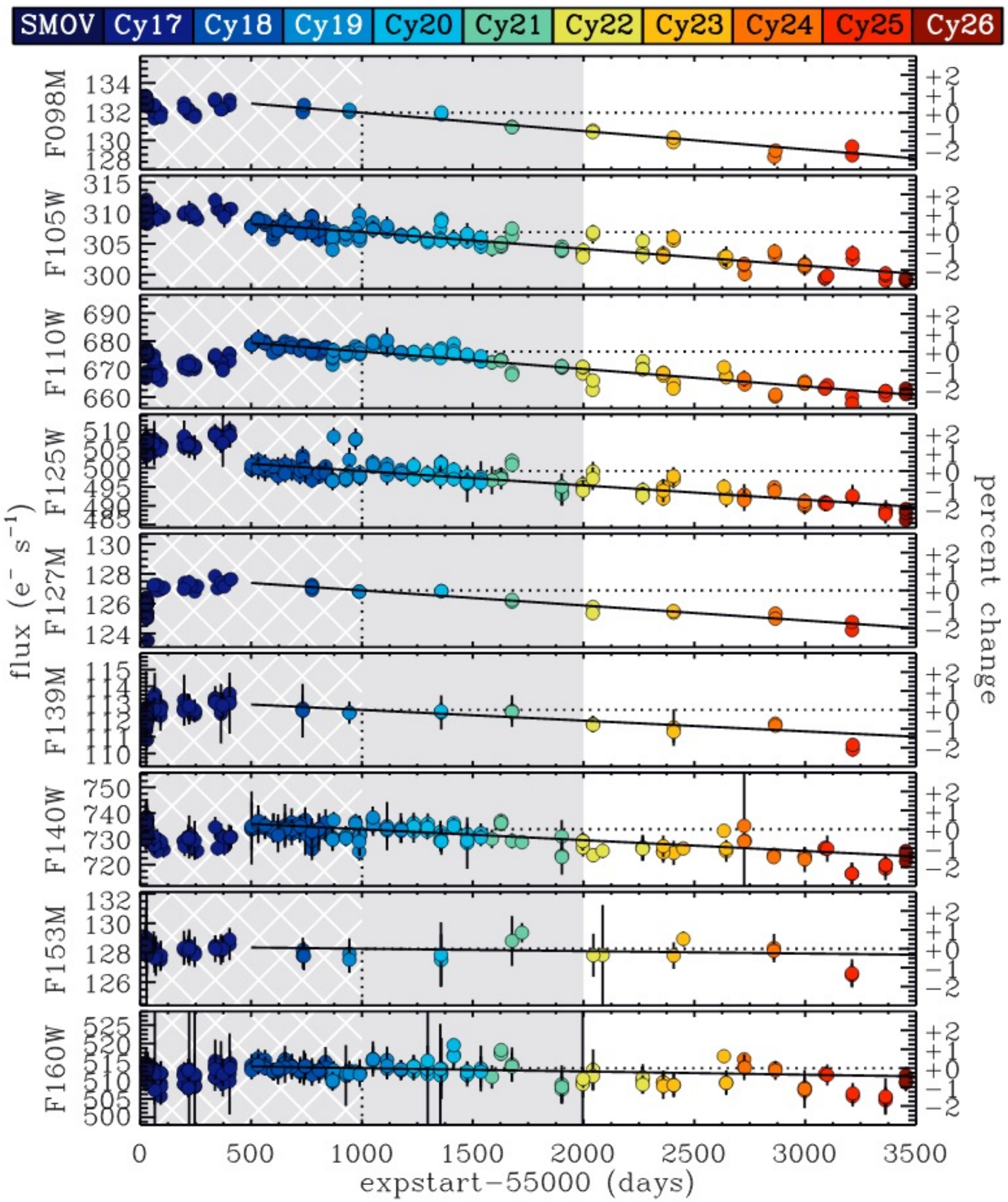
Plots courtesy of M. McKay,
2018 private communication

IR Internal Flats

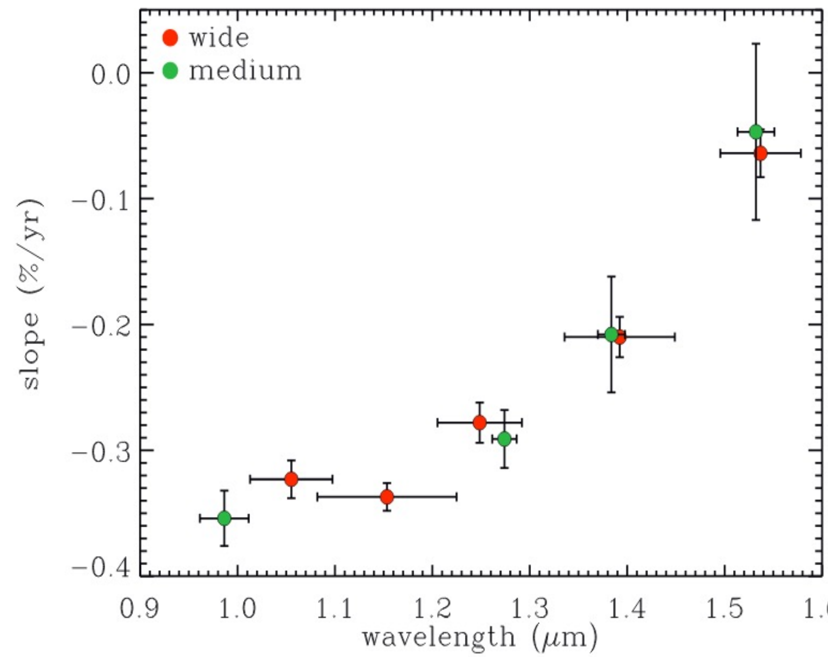
Orbits	External:0 Internal: 18
PI, Co-I's	Green, Khandrika, Kuhn
Purpose	Monitor the stability of the IR pixel-to-pixel sensitivity in all filters by obtaining internal flat fields with the tungsten lamp.
Description	In this program, we study the stability and structure of the IR channel flat field images 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.
Resources: Observations	18 internals = (6 orbits*2 exposures)_all filters + (3 orbits *2exposures) Sample the full set of IR filters once in the middle of the cycle. This requires 6 orbits* 2 exp= 12 orbits. Sample a subset of broadband 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). If time permits, obtain a short dark before the intflat to mitigate persistence.
Resources: Analysis	Supports 100% IR programs.
Products	Monitor the stability of the pixel-to-pixel response and track the decay of the calibration lamps. Use these data to update BPIXTABs (dead, unstable pixels) last modified in 2012
Accuracy Goals	Look for systematic changes exceeding 1%, after accounting for lamp decay
Prior Results, ISRs	ISR 2019-06: 'IR Internal flats; 'The tungsten lamp is becoming redder with time. We find no strong evidence for changes in the pixel-to-pixel sensitivities', ISR 2019-03: Time-dependent Bad Pixel Tables, ISR 2015-11, ISR 2013-04, ISR 2009-42
Prior Cycle IDs	11433, 11915, 12338, 12712, 13098, 13587, 14029 ← 2015 ISR includes data through Cy22. 14391, 14548, 14998, 15591 ←2019 ISR includes this more recent data. 15731 (Cy27), 16411 (cy28), 16586

IR Internal Flats

ISR 2019-06



Mode count rate vs. time. A steady decline is seen since Cy18 (MJD=56,000)



Slope of the mode count rate (%/yr) vs. wavelength. The trend suggests a reddening of the tungsten lamp as the filament vaporizes over time and coats the inner surface of the lamp.

WFC3 CSM Monitor with Earth Flats

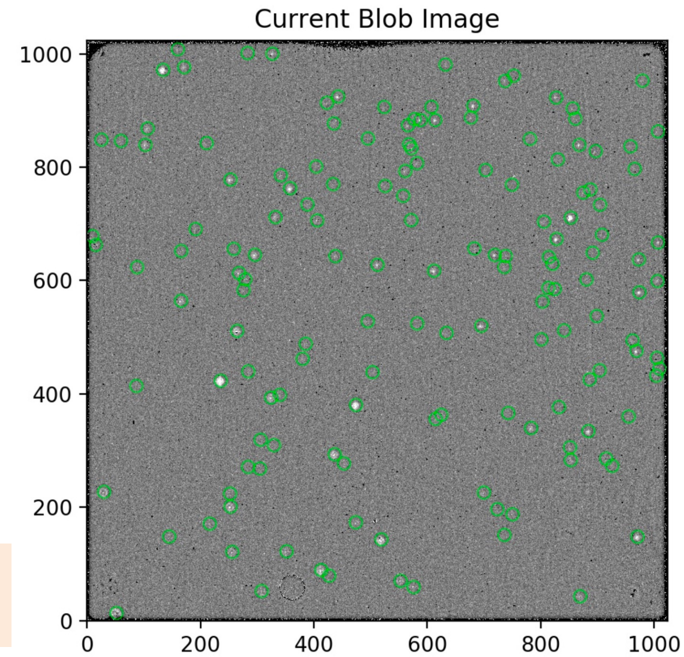
Orbits	External: 0 Internal: 200
PI, Co-I's	Medina, Green
Purpose	Monitor the CSM angle and new blob appearances using earth flats.
Description	Take quick (~100 s) F153M exposures looking down at the dark Earth to use airglow as a uniform glowing screen. Use these images to detect new blobs and use the positions to track the CSM angle over time.
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. Similar to prior cycles, after this program is implemented, all 14999 visits yet to be scheduled are cancelled and this new program picks up where it left off.
Resources: Analysis	Supports 100% of IR programs Monitoring to be carried out by the PI and Quicklook Team. Updates to the monitoring software/blob ISR to be completed by the PI. New reference files as new blobs appear.
Products	DQ flags (BPIXTAB strong blob flags), DFLTFILE (weak blob flags), "CSM offsets table" for GSFC
Accuracy Goals	Identify new blobs within 1 day of receipt of Earth flat. (Typical cadence is 1-2 flats per week)
Prior Results, ISRs	ISR 2018-06: WFC3/IR Blob Monitoring ← ISR updated regularly to include new blobs TIR 2019-01: Blob Monitoring: An End-to-End Jupyter Notebook Workflow , ISR 2017-16: Possible Overlaps Between Blobs, Grism Apertures, and Dithers 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, 14999, 15592, 15732, 16412 (cy28)

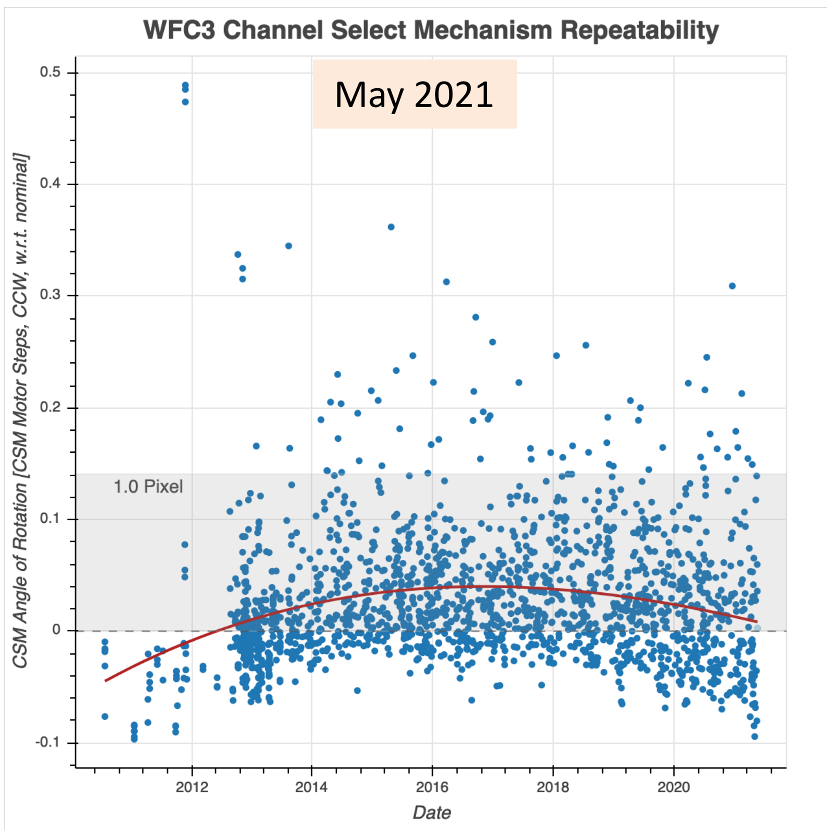
WFC3 CSM Monitor with Earth Flats

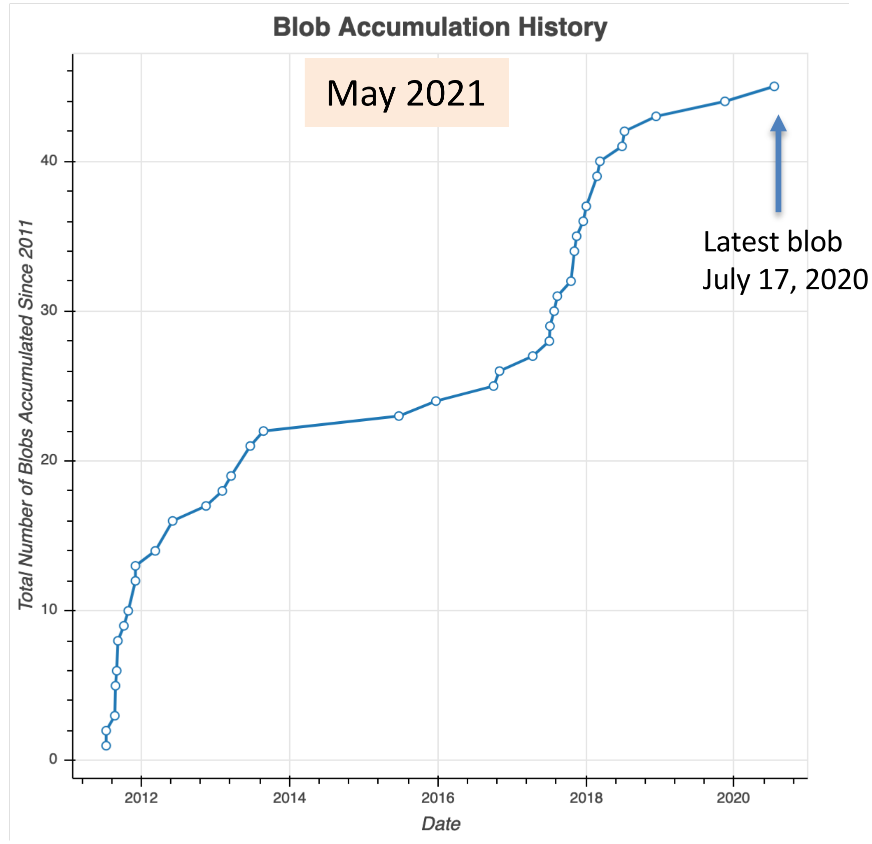
New blobs are identified using the most recent dark earth flat (i.e. the "blob image", right)

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

https://wfc3ql.stsci.edu/automated_outputs/cal_ir_check_csm
https://github.com/spacetelescope/wfc3-ir-bad-pixels/blob/master/blob_monitoring.ipynb







Astrometric Calibration

Same as the previous cycle

- Monitor the temporal stability of the plate-scale in WFC3 UVIS & IR 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-I's	Kozhurina-Platais, Martlin, Bajaj
Purpose	Continue monitoring the stability of the WFC3 UVIS and IR plate scale over time.
Description	The standard astrometric catalog in the vicinity of the Omega Cen globular cluster has been used to examine the geometric distortion of UVIS and IR as a function of wavelength in multi-cycle calibration programs over the lifetime of WFC3. All observations from these programs have been reduced and provided the multi-wavelength distortion in UVIS and IR. The geometric distortion coefficients implemented in the IDCTAB format are used in the HST pipeline to correct for ~7% distortion in WFC3 images down to <1%. Observations of Omega Cen taken in F606W (UVIS) and F160W (IR) during the last 11 years (>30 epochs in total) are used to look for any time dependency in the plate scale of the two detectors.
Resources: Observations	6 orbits: 3 epochs each in F606W UVIS and F160W IR. Observations of Omega Cen will be observed with the same pointing in each detector, but with 3 different OTA roll-angles per orbit over 3 epochs: December 2021, March 2022 and June 2022.
Resources: Analysis	Supports 100% of UVIS & IR programs; Measure accurate X & Y positions on drizzled images from each detector and solve 6-parameter transformation w.r.t. the Standard Astrometric Catalog or/and GAIA to calculate the linear terms for analysis of any time-dependency.
Products	IDCTAB, NPOLFILE, D2IMFILE reference files Calibration of the geometric distortion (skew and scale parameters) with time. If needed, provide empirical linear time dependent corrections, similar to the ACS/WFC time-dependent skew (see ACS-ISR-15-06).
Accuracy Goals	Reduce uncertainty in the scale to 2 mas if there is any time-dependent distortion.
Prior Results, ISRs	**ISR 2021-07**, Accuracy of the WFC3 Standard Astrometric Catalog w.r.t Gaia EDR3; **ISR 2019-09**: Comparison of UVIS Distortion to GAIA DR2; **ISR 2018-10**: Updates to UVIS Filter-Dependent and Geometric Distortions**; ISR 2018-09**: IR Time Dependency of Linear Geometric Distortion; **ISR 2018-01**: Accuracy of the HST Standard Astrometric Catalogs with respect to Gaia; **ISR 2014-12**: Astrometric Correction for UVIS Filter-Dependency; **ISR 2015-02**: Standard Astrometric Catalog and Stability of UVIS Distortions; **ISR 2012-07**: UVIS and IR Multi-Wavelength Distortion; **ISR 2012-03:** UVIS and IR Time Dependency of Linear Geometric Distortion
Prior Cycle IDs	11911, 11928, 12094, 12353, 12714, 13100, 13570, 14031, 14393, 14550, 15000, 15593, 15733, 16413, 16588

WFC3 Astrometric Scale monitoring

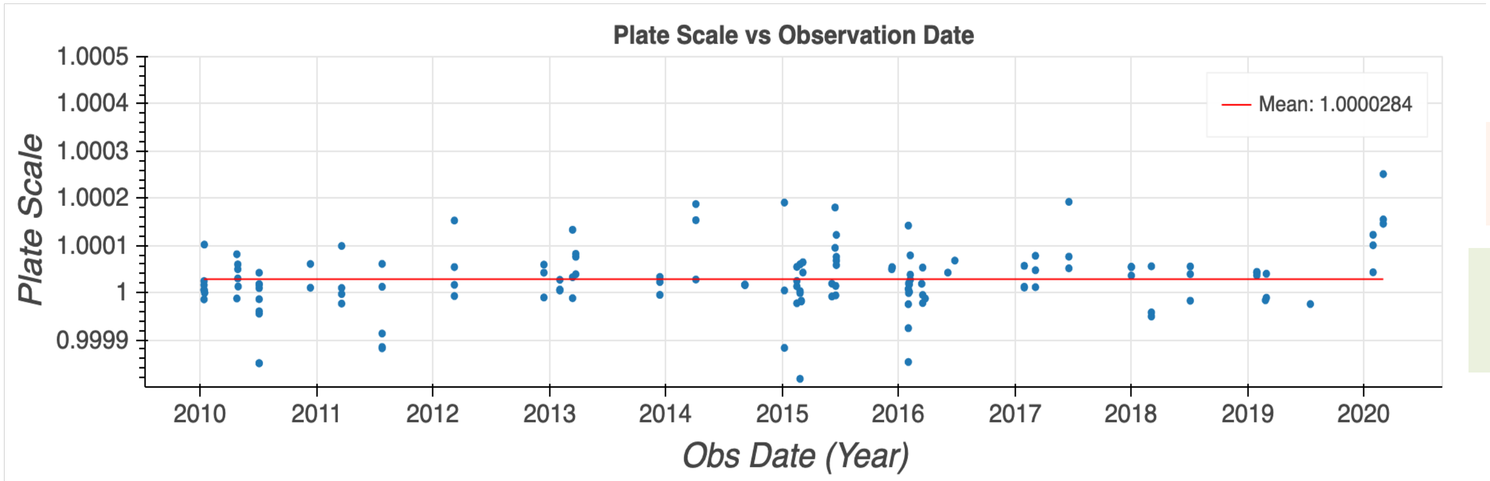
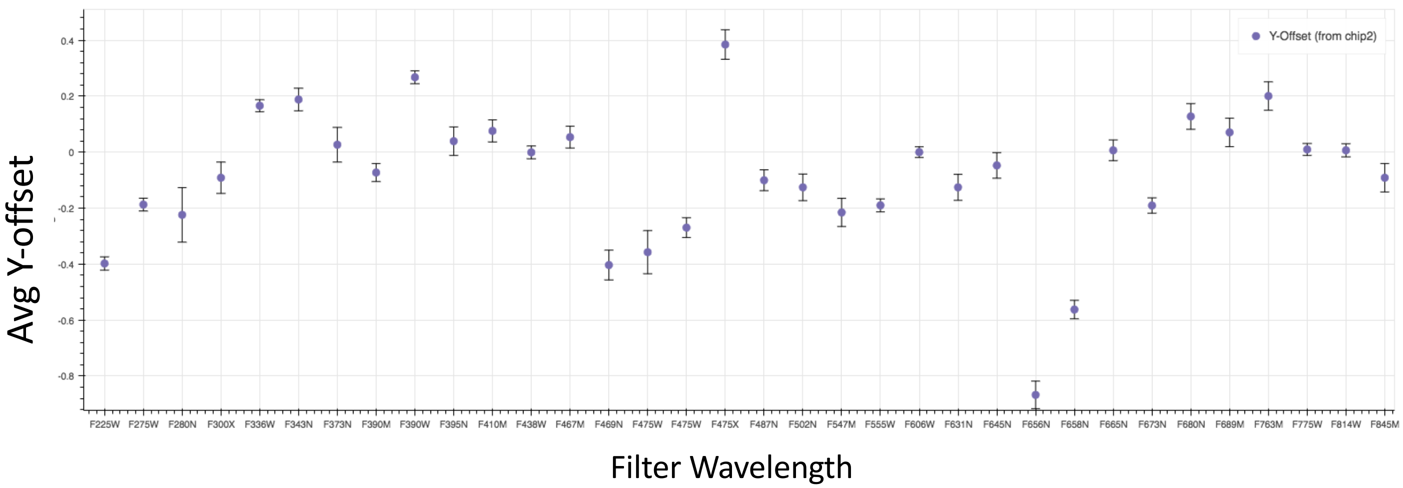
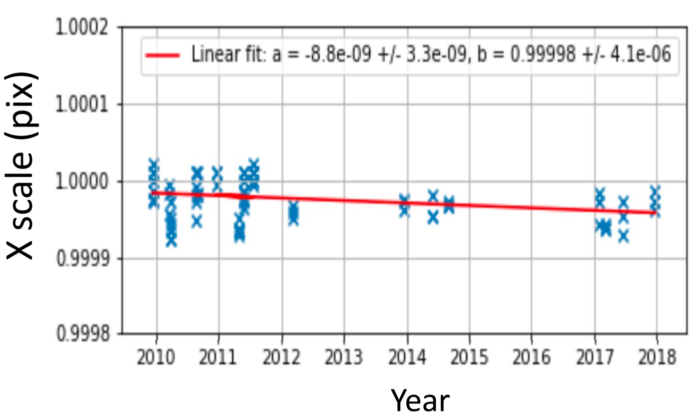


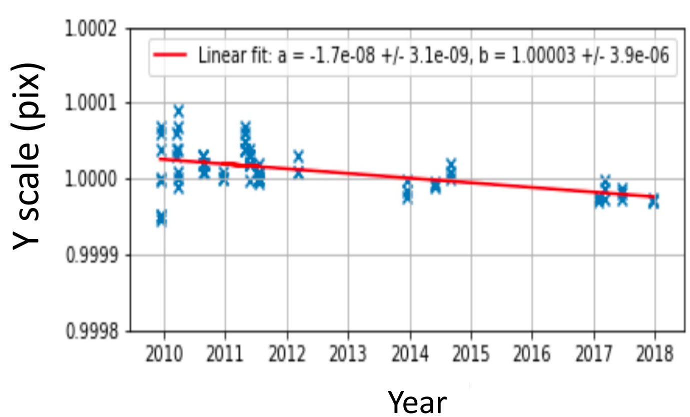
Plate Scale vs time
ISR 2021-07

UVIS plate-scale as a function of time based on the linear transformation between Gaia EDR3 and each individual UVIS image.



UVIS filter wedge offsets:
Y-offset (pix) vs Wavelength
ISR 2018-10





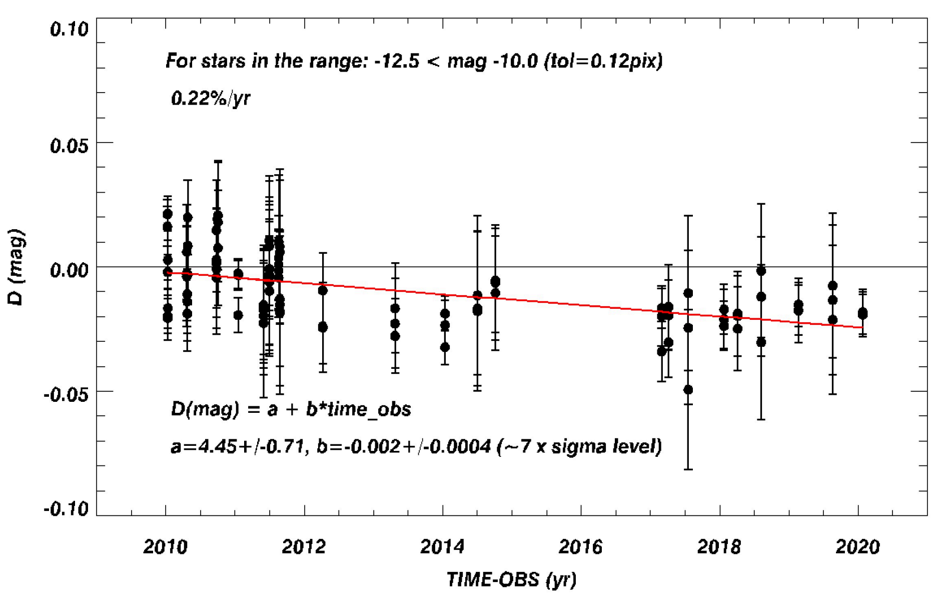
IR plate scale vs time
ISR 2018-09

WFC3 Astrometric Scale monitoring

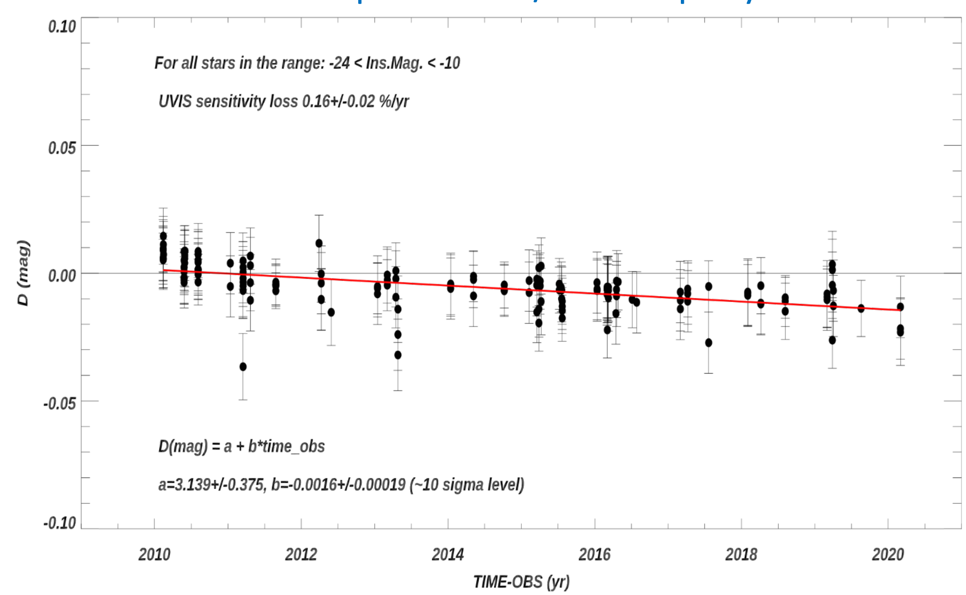
This data has also been used to measure changes in sensitivity

- The observations of Omega Cen from > 30 epochs have been used to examine the secular changes in the IR detector sensitivity (F160W) and search for any variations with time (WFC3-ISR-2020-05).
- The same approach has been used for the UVIS detector in F606W (Kozhurina-Platais, private comm.)

F160W slope = 0.22 +/-0.04 % per year



F606W slope = 0.16 +/-0.02 % per year



Average photometric offsets calculated for common stars between the first (as reference image) and the next images as function of time. The error bars are the calculated standard errors. The red solid line represents a linear fit to the averaged offsets as a function of time. The statistical coefficients and their errors are shown in the legend.