Hubble Space Telescope (HST) Mission Status

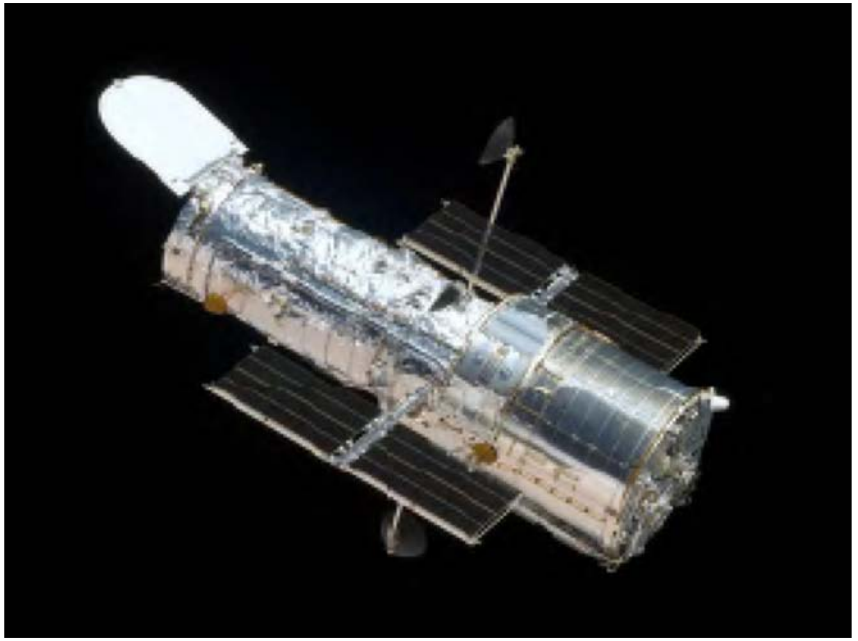
Helmut Jenkner

STUC – 19 April 2018

Summary

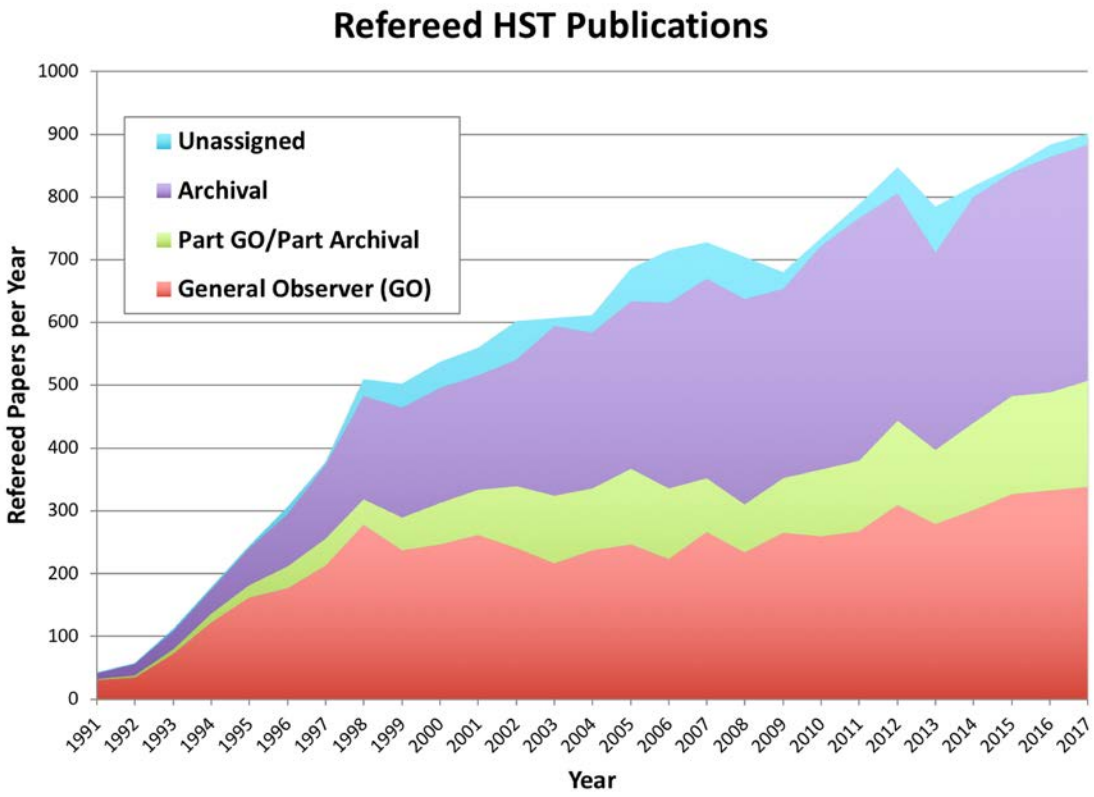
Hubble operates at the highest levels of scientific performance and productivity

- Executing Cycle 25 observing program
- Instruments performing nominally
- Monitoring Gyro 2 performance
- Few and minor anomalies over last 6 months



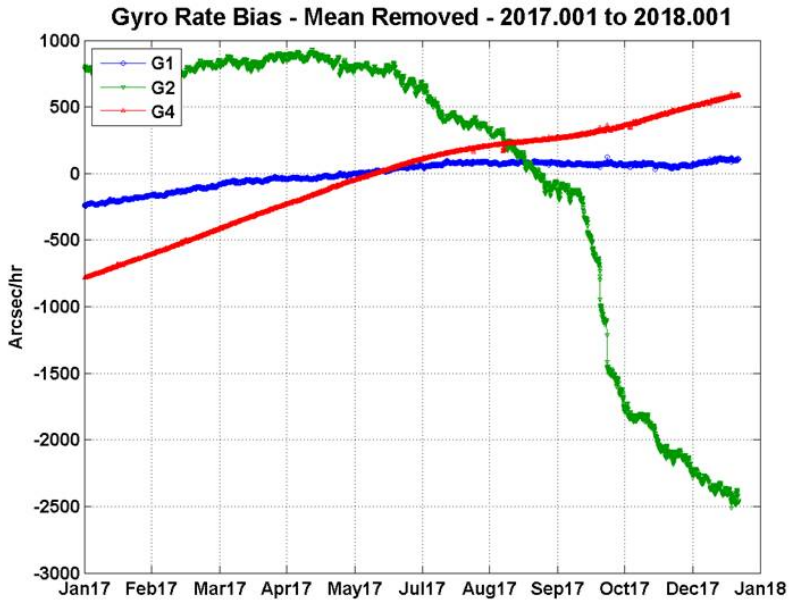
Science Productivity Sets New Record

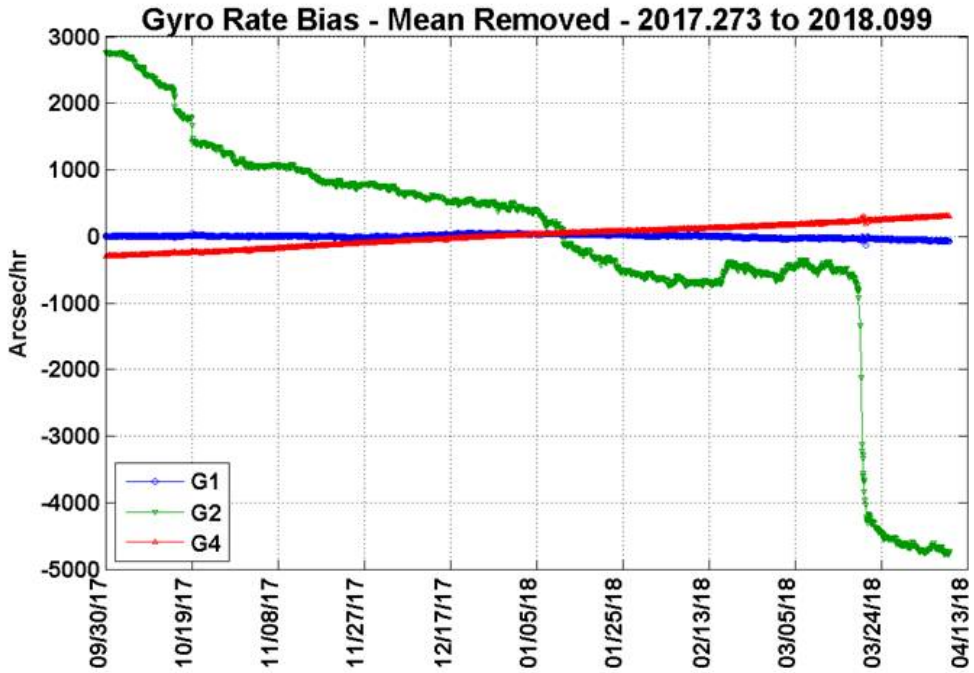
- Over 900 refereed publications based on HST data in 2017
- Over 15,500 to date



Monitoring Gyro 2 Performance

Gyro Rate Bias History (2017, 2018)

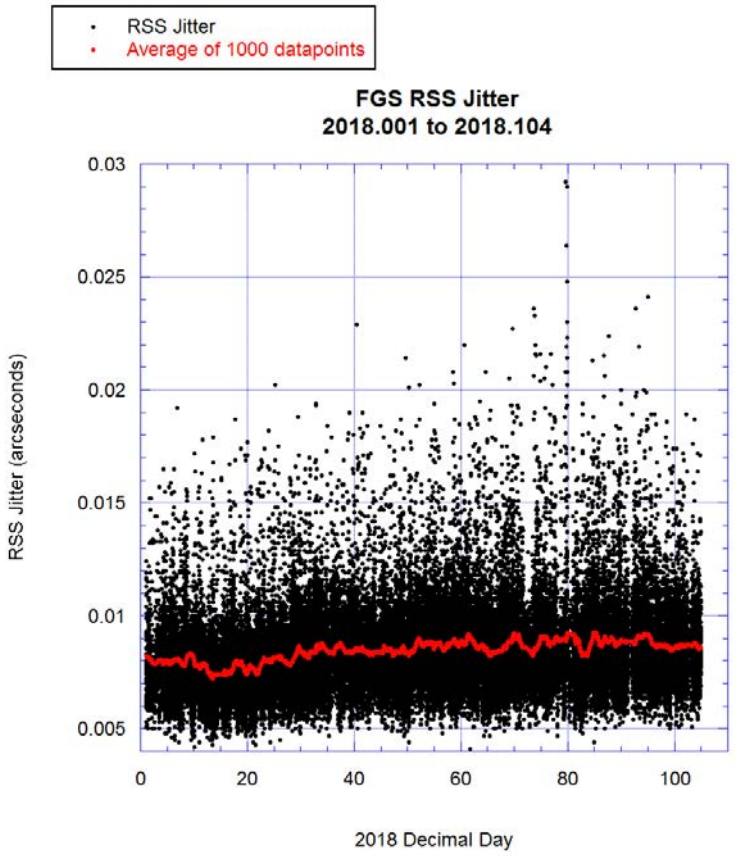




Gyro 2 (continued)

Monitoring increased jitter

- Jitter has increased slightly since last summer
- Requirement for jitter is ≤7 mas
- Little impact at current level
- Analysis shows that observations with certain (small) apertures will be affected once average jitter exceeds 10 to 15 mas



Gyro 2 (continued)

Guide Star Reacquisition Failures Mitigated

- Due to large Gyro 2 rate bias shifts, Guide Star reacquisitions tended to run long, usually by only a few seconds
- Tweaks to the flight software and to the planning and scheduling software eliminated this issue by providing ~35 seconds more time

Forward Plan

- Preserve overall gyro lifetime to the extent possible
- Once Gyro 2 fails or performance falls below well-defined levels, Gyro 6 will be switched on
  - Acquisition failures lead to ~10% losses over a two-week period
  - Jitter exceeds ~10-15 mas and leads to the postponement of too many small-aperture programs
- Stay in 3-gyro mode as long as possible to optimize observing efficiency and field of regard
- Drop into 1-gyro mode when only 2 gyros remain operational and use them sequentially

Anomalies

Solid State Recorder 3 (SSR-3)

- Stopped receiving telemetry on 01/09/2018, after an increase in uncorrectable errors over the previous weeks to months
- Recovered by power cycling the next day
- Data storage had been switched to SSR-1, so science loss was minimal

SI C&DH Lockup #12 on 01/19/2018

- Routine recovery within ~20 hours

ACS suspend on 03/16/2018

- Single-event upset during SAA passage, as has been seen before on ACS and STIS
- Recovery after ~20 hours

In all cases, the flight operations and science operations teams performed excellent joint work and responded quickly to keep HST as productive as possible

Cycle 25 Update and Long-Range Plan (Dave Adler)

Cycle 25 averaging 83.8 orbits/week over first 29 weeks

- Cycle 17-23: 84 orbits/week
- Cycle 24: 82 orbits/week (83.2 over first 29 weeks)

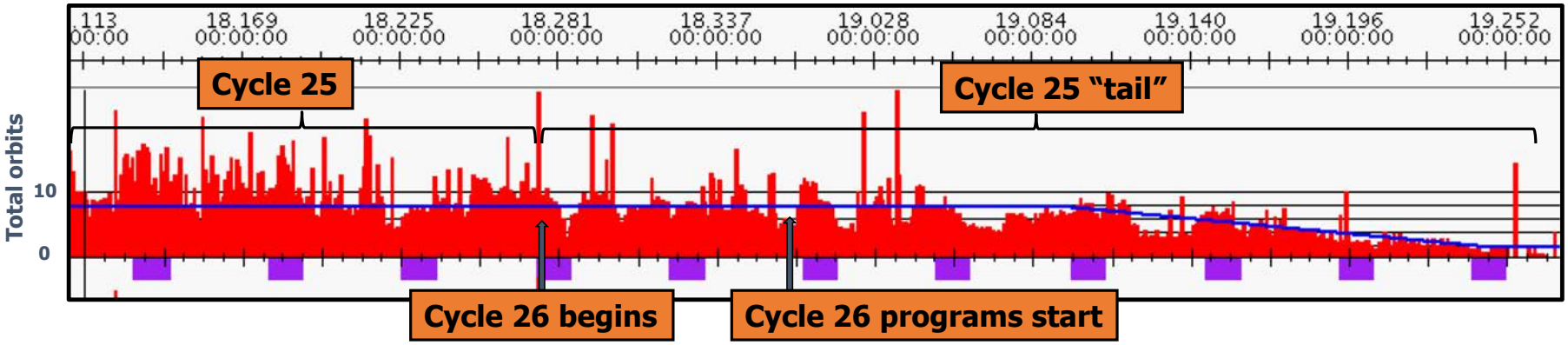
Previous Cycle Completeness

- Cycle 22: Finished in January 2018
- Cycle 23: 8 orbits remain (7 from C23 large program Apai).
- Cycle 24: ~190 orbits remain, mostly complete by mid-2018.
- Cycle 25: ~3600 orbits remain (due to 1200+ more orbits accepted in Cycle 25).

Cycle 26 starts October 1, 2018, but…

- Cycle 25 material fully subscribes plan into February 2019; tail of material into September 2019.
- Less material to be accepted in Cycle 26 (up to 2100 orbits) – medium/large/coordinated programs.
- August 17 phase I deadline; October TAC; November phase II deadline; added to LRP in December.

Long-Range Plan (LRP): Current Status



"Spikiness" in distribution mostly due to exoplanet visits waiting for plan windows.

- As before – can't plan exoplanets accurately far into future.
  - Windows beyond predictive ephemeris (>10 weeks) have unstable/unreliable plan windows.
  - Exoplanets are "stored" late in cycle; potential spots checked weekly, pulled forward as possible.

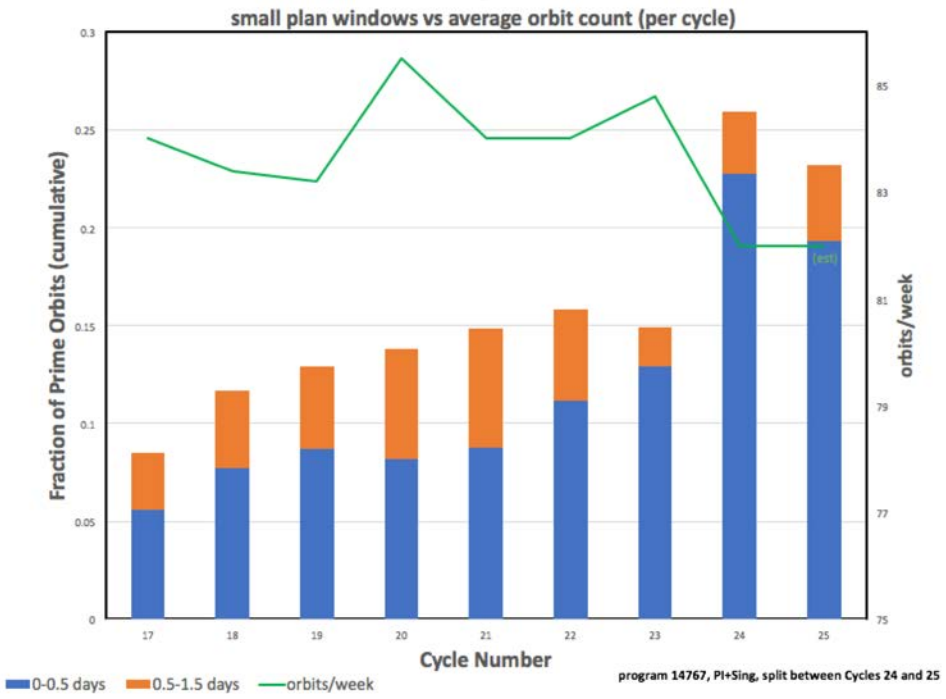
Second set of mid-cycle programs (< 100 orbits) will be added soon

- 67 programs/434 orbits requested.

LRP: Current Status

High percentage of time-constrained science limits LRP flexibility

- ~20% of science visits in cycles 24/25 have timing constraints of a few orbits or less.
- Creates conflicts between science programs.
- Results in fewer flexible visits later in the plan that can be moved forward to fill schedule gaps.
- LRP group now builds templates of constrained visits in advance to identify conflicts early in the process.



LRP: Statistics

Exoplanet Programs: Highlights

- **Sing** (Cycles 24/25 Large): 398 of 498 orbits complete.
  - 55 orbits planned for the next 10 weeks
- **Benneke** (Cycle 24 Large): 67 of 78 orbits complete.
  - One in April, other in December
- **deWit** (Cycle 25 Large): 41 of 114 complete.
- **Crossfield** (Cycle 25 Large): 13 of 127 complete

450 orbits of exoplanets with period/phase constraints remain in the plan

- Cycle 24
  - 100 orbits of Sing
  - 18 orbits from three other programs
  - Most non-Sing done by summer if windows hold.
- Cycle 25
  - 300 orbits in plan
  - 31 orbits aren't schedulable and don't have windows.

LRP: Statistics

Planetary Programs: Highlights

- Jupiter
  - Visible until late September, then in solar exclusion until late January 2019.
  - Remaining 2018 Juno perijoves: May 24, July 16, September 7.
    - **Grodent** (Cycle 24 Large): 136 of 151 orbits done.
    - **Wong** (Cycle 24 Medium): 39 of 45 orbits done.
- Europa Cycle 25 mid-cycle campaign
  - **Roth**: 8 of 55 orbits done.
  - **Sparks**: 8 of 30 orbits done.
  - **deKleer**: 5 of 10 orbits done.
- OPAL: Outer Planet Atmospheres Legacy
  - **Cycles 22-24**: 29 total orbits per cycle on Jupiter, Saturn, Uranus, Neptune.
  - **Cycle 25**: 41 total orbits
    - **Uranus**: 8 orbits in October 2017
    - **Jupiter**: 13 orbits in April
    - **Saturn**: 12 orbits in May
    - **Neptune**: 8 orbits in September.

Large/Treasury Programs

C23 Program	alloc	Exec/sched by 4/29/18	Planned before 9/30/18	Planned after 10/1/18	comment
Apai	112	105	7	0	June 2018 finish

C24 Program	alloc	Exec/sched by 4/29/18	Planned before 9/30/18	Planned after 10/1/18	comment
Benneke	78	67	5	6	December 2018 finish
Bielby	96	0	0	0	Complete
Dalcanton	108	108	0	0	Complete
Grodent	151	136	20	0	Too many planned
Kallivayalil	164	164	0	0	Complete
Roman-Duvall	101	99	0	0	Complete
Shkolnik	130	99	9	22	December 2018 finish
Sing	498	398	70	30*	Two cycles
Suzuki (ToO)	26	26	0	0	Complete

* - exoplanet visits not planned, “in the bullpen” until the LRP group can pull them forward.

Large/Treasury Programs

C25 Program	alloc	Exec/sched by 4/29/18	Planned before 9/30/18	Planned after 10/1/18	comment
Bedin	40	0	40	0	June/September epochs
Bowen	91	26	4	61	
Chen	169	7	127	35	
Crossfield	127	13	61	53*	
Froning	157	28	14	115	
Jansen	36	12	16	4	4 not in plan
Krauss	132	38	30	64	
Riess	168	137	22	8	1 not in plan
Shapley	87	33	15	39	
Steinhardt	101	0	12	89	
Suzuki (ToO)	70	1	0	21	Second cycle of SUSHI
deWit	114	41	8	56*	9 not in plan

* - exoplanet visits not planned, “in the bullpen” until the LRP group can pull them forward.

Streamlining Science Operations

- The Call for Proposals for Cycle 26 specifies that all special requirements be justified in Phase I
- Phase II deadlines will be strictly enforced to streamline budgeting process and provide a more stable LRP
- No limits for proposals with special requirements are imposed in Cycle 26
- It may be necessary to impose such limits in the future, as e.g. Chandra has already done

- See John MacKenty's presentation

In the era of flat budgets, it becomes harder and harder to maintain a stable LRP that contains lots of highly constrained programs

Hubble Spectroscopic Legacy Archive (HSLA)

Paule Sonnentrucker

HSLA Update

Paule Sonnentrucker

Next Release: May 2018 – COS Only

Ben Sunnquist

Julia Roman-Duval

- 1074 *newly* released COS FUV data & associated co-added products added in last 12 months
- FUV Blue Modes included (G130M/1055/1096/1222): New!
- FUV co-adds now include LP3, LP4 in addition to LP1 and LP2 (updated λ solutions): New!
- 248 *newly* released COS NUV data products added in last 12 months
- NUV *co-added* products now available (updated λ zero points): New!
- Redesigned Target product page with FUV & NUV co-add "Quicklooks", when relevant: New!
- Failed Visits excluded from all co-adds when relevant: New!
- HSLA naming convention matched to Hubble Source Catalog (HSC) for cross-referencing: New!
- Welcome page with updated feedback email and "Acknowledgements" & "Caveats": New!

Dan Welty

In The Works:

Joleen Carlberg

- STIS echelle E140M + E230M data & co-added products inclusion: Summer 2018
- Access points: STIS instrument page when first products delivered, Mast Portal: *under review*
- PASP paper to advertise COS FUV HSLA improvement and COS NUV expansion
- Feasibility study for HSLA inclusion in "standard" archive maintenance & update operations

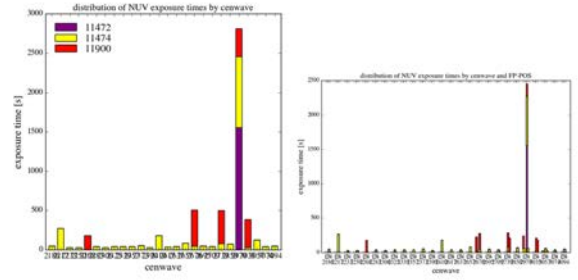
HSLA Update • Product Page: COS NUV Co-additions

Current COS/NUV HSLA: April 2017 Release

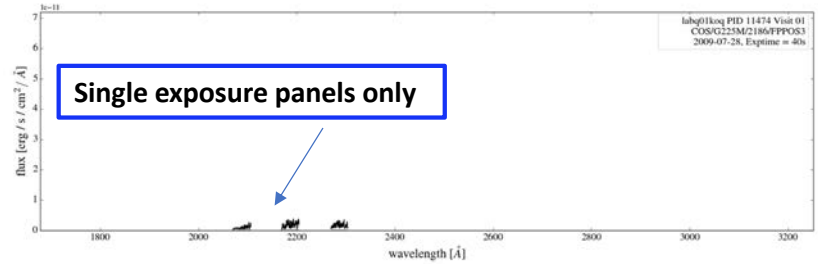
HD187691

STAR;F3-F9
α = 297.758087158, δ = 10.4150428772 (19h51m01.9409s +10d24m54.1544s)

Programs: 11472 11474 11900



Individual exposures
Legend: **flux in black**, errors in grey, both smoothed over 6 pixels (~1 resel). S/N=median(flux/error), per ~1 resel, in shaded window.



Programs ID & Info

Setting Distribution (Cenwave, FP-POS)

Single exposure panels only

New COS HSLA Release: May 2018

HD187691

STAR;F3-F9
α = 297.758087158, δ = 10.4150428772 (19h51m01.9409s +10d24m54.1544s)

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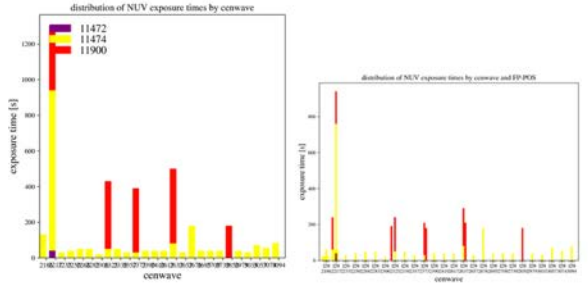
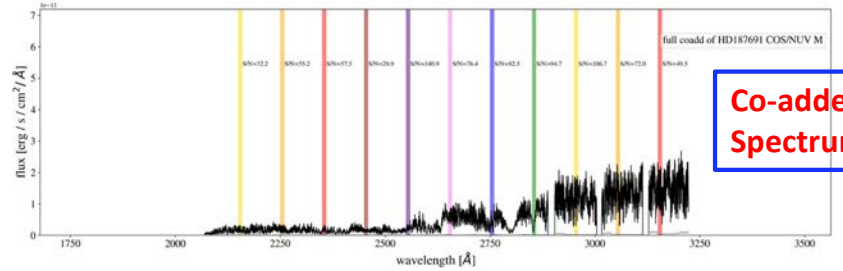


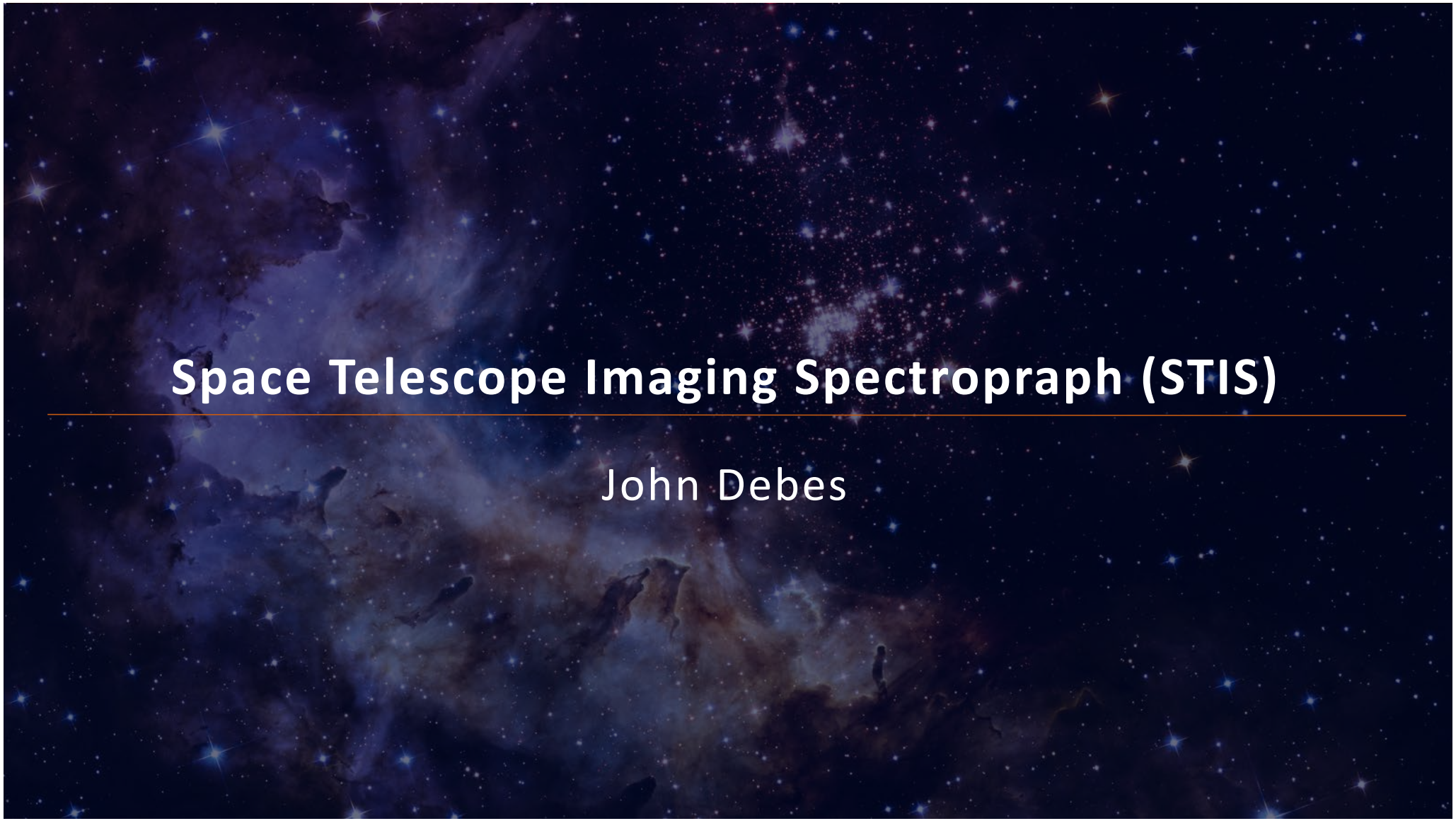
Co-added spectra. Legend: **flux in black**, errors in grey, both smoothed over ~1 resel (6 pixels for FUV, 3 pixels for NUV). S/N=median(flux/error), per ~1 resel, in shaded window.



Individual exposures
Legend: **flux in black**, errors in grey, both smoothed over ~1 resel (6 pix for FUV, 3 pix for NUV). S/N=median(flux/error), per ~1 resel, in shaded window.

NB: NUV ops remained at LP1

Co-added Spectrum



Space Telescope Imaging Spectropraph (STIS)

John Debes

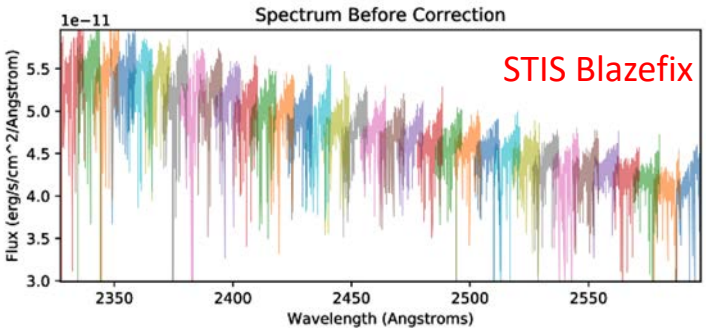
STIS Status/Completed Work

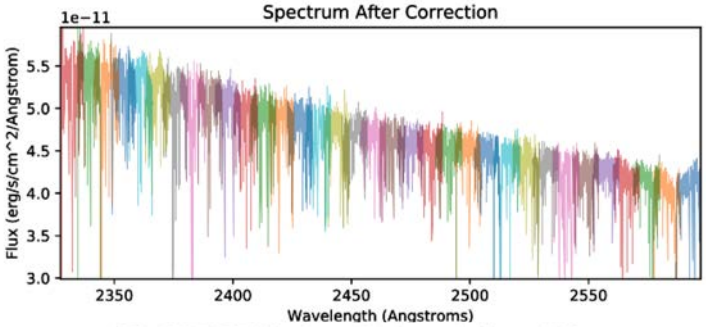
Status:

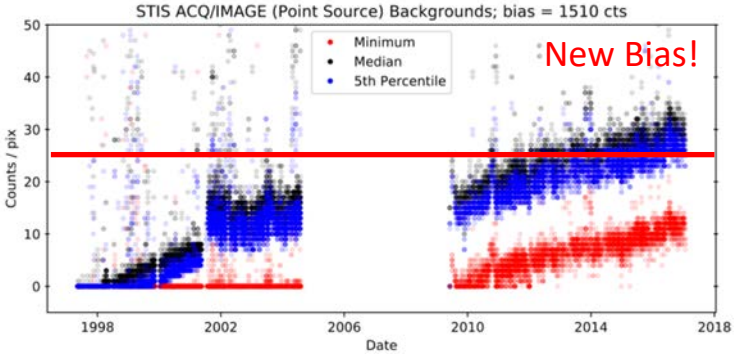
- STIS' status is relatively unchanged since last STUC Meeting
- Monitoring focus or jitter effects for any low level impacts, alerting community to areas with larger impact (i.e. small slits)

Completed Work:

- Blazefix Tool Released 1/18; Newsletter Article to be published
- Bias level increased in flight software for ACQ/IMAGEs
- NUV Flat program tweaked to protect against lamp fading

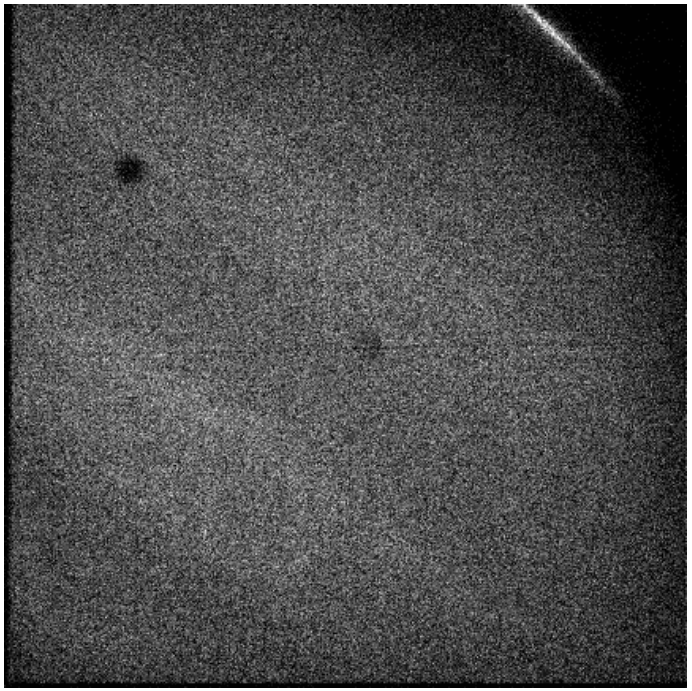






STIS Ongoing Work

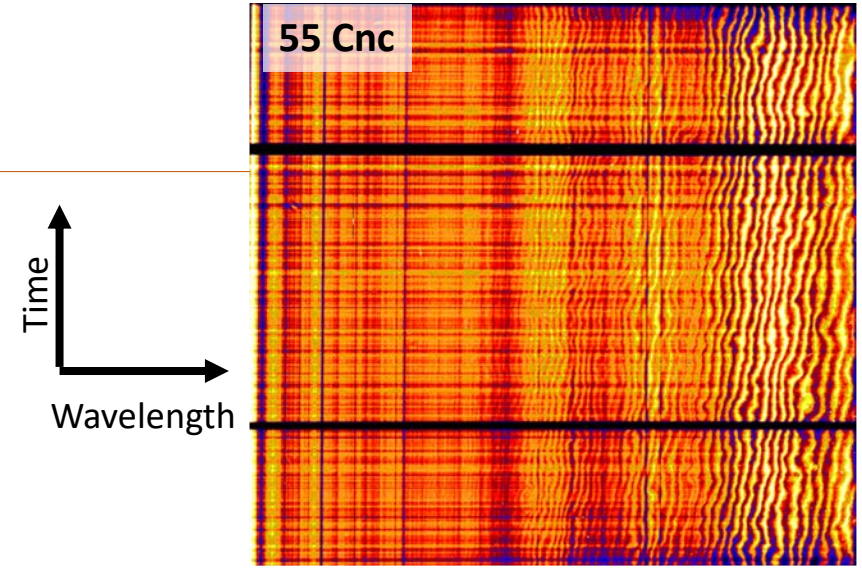
- Significant user support (Several rapid ToOs, M dwarfs, UV SNAPs, Europa)
- Cycle 26 Calibration program preparation
- IRAF Replacement Efforts-STIS Hack Day, close collaboration with Software Engineers at STScI
- Documentation in progress
  - ISR Enclosed energy Investigation of STIS spectroscopic modes
  - ISR on Binary Offset Effect (i.e., Boone et al., 2018)
  - ISR on STIS Target Acquisitions
  - ISR on Wavelength solutions for STIS modes
- Pre-SM4 data re-calibrated; final regression testing finished by May
- HSLA Support via echelle PHOTTAB updates and team feedback
- Improving Data Quality Flag support for Dithered Spectroscopy (update to CalSTIS)

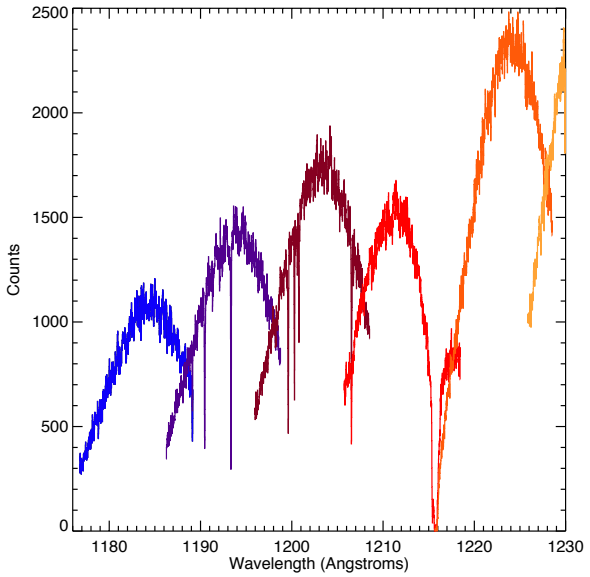


Europa transiting Jupiter
(FUV MAMA Time-Tag Movie)

Future Work

- Commissioning Transiting Exoplanet Spatial Scan spectroscopic modes
  - Observations completed
  - Initial analysis in time for Delta-26 Phase I deadline
- E140M Flux Recalibration Program
  - Observations Completed
  - Used to correct blaze function shape changes





G191-B2b

Completed STIS Documentation

- STIS ISR 2018-01 A Python Script for Aligning the STIS Echelle Blaze Function
- STIS ISR 2018-02 FUV-MAMA Geometric Distortion Solution
- STIS Instrument Handbook
- STIS Data Handbook

Cosmic Origins Spectrograph (COS)

Cristina Oliveira

COS Work – Since Last STUC Meeting

Calibration Improvements

- LP4 move in October 2018 was successful
  - All calibration reference files implemented before LP move
  - LP4-related documentation almost completed
- FUV Time Dependent Sensitivity updated
  - New breakpoint in 2015.5 : shallower slopes for all modes
  - TDS calibration accurate to +/-2%
- Gain sag reference file updated
  - Important given that observations at LP3 are continuing, concurrently with LP4 observations
- New COS/FUV LP3 + LP4 dispersion solutions have been implemented: +/3 pix residuals

Community and User Support

- Decreased S/N requirements for COS target acquisitions using Imaging mode
  - From 40 to 20 for PSA TA; from 60 to 30 for BOA TA
  - Especially useful for programs observing M-dwarfs, where both flare and quiescence states are cleared

New COS/FUV Modes: G160M/1533 and G140L/800

- G160M/1533: continuous wavelength coverage between G160M and G130M/1222
- G140L/800: continuous wavelength coverage in Segment A from 800-1800 Å, and low astigmatic height between 800 and 1100 Å
- New modes included in APT and ETC 26.1; will be fully supported for Cycle 26 observations

COS Work– Ongoing

New COS/FUV Modes: G160M/1533 and G140L/800

- Special programs executed to determine focus that optimizes resolution
- Programs to calibrate the new modes are being developed and will execute over the next few months: wavelength, flux, and spectral extraction

COS Performance Monitors

- SI monitors transitioned to Python 3
  - These include TA monitors
- New monitors are being developed
  - Hotspot
  - Post-anomaly monitor

COS Calibration

- Cycle 26 calibration plan is being developed
- Geometric distortion correction ongoing
- X-walk correction implementation (from look-up table)
- 1 Gyro mode evaluation report produced and special handover programs to follow
  - Special handover targets selected so that impact of sky visibility issues in COS calibration program can be mitigated

COS Work – Future

Evaluate Possible FUV/LP5 Position

- Evaluate feasibility of having another COS/FUV lifetime position, LP5, at ~ +5”
- Complicated by light leak

Evaluate S/N requirements for other TA strategies

- Evaluate feasibility of decreasing recommended S/N for dispersed light TA (FUV & NUV)
- Important for M-dwarfs, but also beneficial for all other programs

Implement cenwave-dependent FUV TDS

- FUV TDS depends also on cenwave (only Seg and λ dependence implemented)
- Will improve accuracy of G160M flux calibration, especially after staying at same LP for a long period of time (start diverging with each breakpoint)

Update NUV TDS reference file

- Slope of NUV TDS for G285M is shallower than currently implemented in reference file
- Slope of ~ -11% per year has lead to very low throughput

COS Documentation – Since last STUC meeting

Published

TIR 2017-01: Reconciling Modeling and Observations of the G130M 1222 and 1223 Spectral Resolution – J. Roman-Duval

ISR 2017-23: Summary of Cycle 24 Program- COS Pure Parallel Observations of Geocoronal Lyα – J. White

ISR 2018-01: Cycle 24 COS FUV Detector Gain Maps – D. Sahnow

ISR 2018-02: Cycle 24 COS/NUV Fold Distribution – T. Wheeler

ISR 2018-03: Cycle 24 COS NUV Dark Monitor Summary – M. Fix

ISR 2018-04: Cycle 24 COS FUV Dark Monitor Summary – M. Fix

ISR 2018-05: Cycle 24 COS NUV Internal/External Wavelength Scale Monitor – W. Fisher

ISR 2018-06: Cycle 24 COS FUV Internal/External Wavelength Scale Monitor – W. Fisher

ISR 2018-07: The Spectral Resolution of the COS FUV channel at Lifetime Position 4 – A. Fox

ISR 2018-08: The Spatial Resolution of the COS FUV channel at Lifetime Position 4 – A. Fox

In Preparation for release soon

COS Instrument Handbook – W. Fisher et al.

COS Data Handbook – M. Rafelski et al.

Wide-Field Camera 3 (WFC3)

Elena Sabbi

WFC3 Completed Projects

USER support

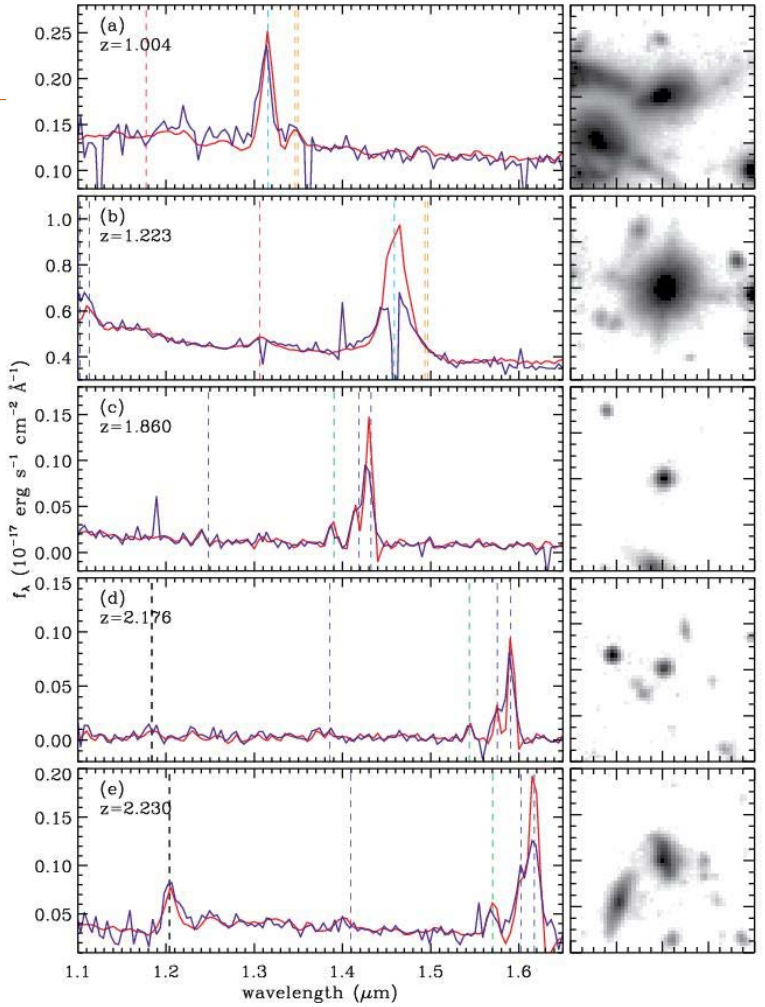
- Transition to new Help Desk
- New version of Data Handbook
- Testing of Jupyter notebooks to replace IRAF with python
- Jupyter notebook to drizzle large mosaics with Gaia

UVIS channel

- Filter-based geometric distortion solution for all the full frame broad, medium and narrow band UVIS filters

IR channel

- IR dark stability monitor and dependences
- Persistence model
- GRISM support: update of “aXe” & release of the multi-orientation spectra extraction software “LINEAR”



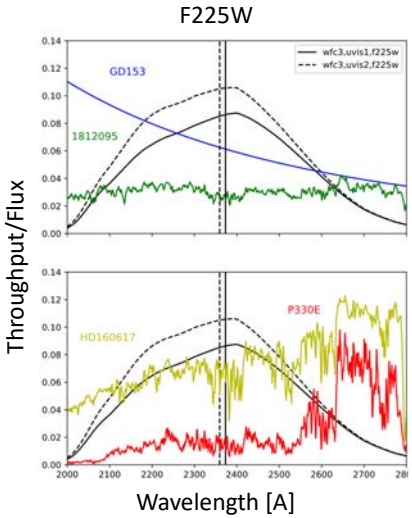
WFC3 Ongoing Projects

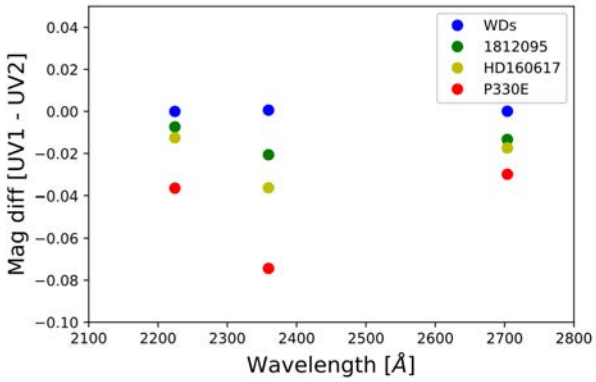
User Support

- Calibration plan for Cy 26
- Instrument Handbook (minor update)
- Primer + call for proposals

Detectors

- Detector monitor – WFC3 is performing nominally





UVIS channel	IR channel
CTE calibration update	ZP stability
UV filters color terms	Time dependent bad pixel table
Time dependent ZPs	Improved flat fields for imaging and GRISMs
PSF library – yearly update	Geometric distortion stability
Focus monitoring	Short term persistence

WFC3 Future Projects

User support

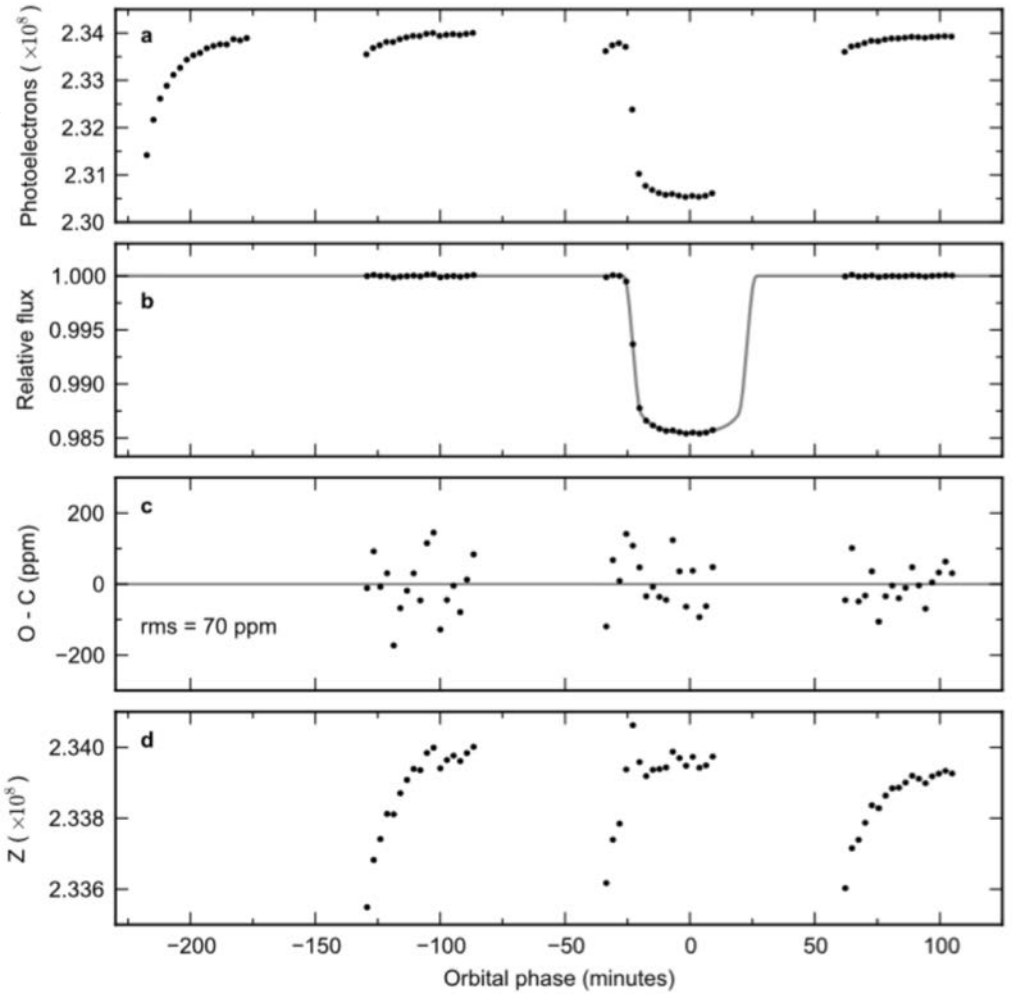
- Support for CY26 & Mid Cycles (CS reviews, Help desk)

IR channel

- Improve the Up-the-Ramp fitting for IR channel data
  - Jupyter notebook for DASH observations
- Non-linearity calibration (New data just arrived)
- IR PSF library
- Persistence characterization in exoplanet observations (Data expected in August)

UVIS channel

- L-flat interpolation validation
- Geometric distortion calibration for full frame very wide filters and Quad filters



WFC3 Publications

WFC3 Data Handbook

Gennaro et al. 2018, Version 4.0, (Baltimore: STScI)

Linear: A novel algorithm for reconstructing splitless spectroscopy from HST/WFC3

Ryan, R.E., Jr., Casertano, S., Pirzkal, N. 2018, PASP, 130c, 450

ISR 2018-03: Persistence in the WFC3 IR Detector: Intrinsic Variability
Knox S. Long, & Sylvia M. Baggett 29 Mar 2018

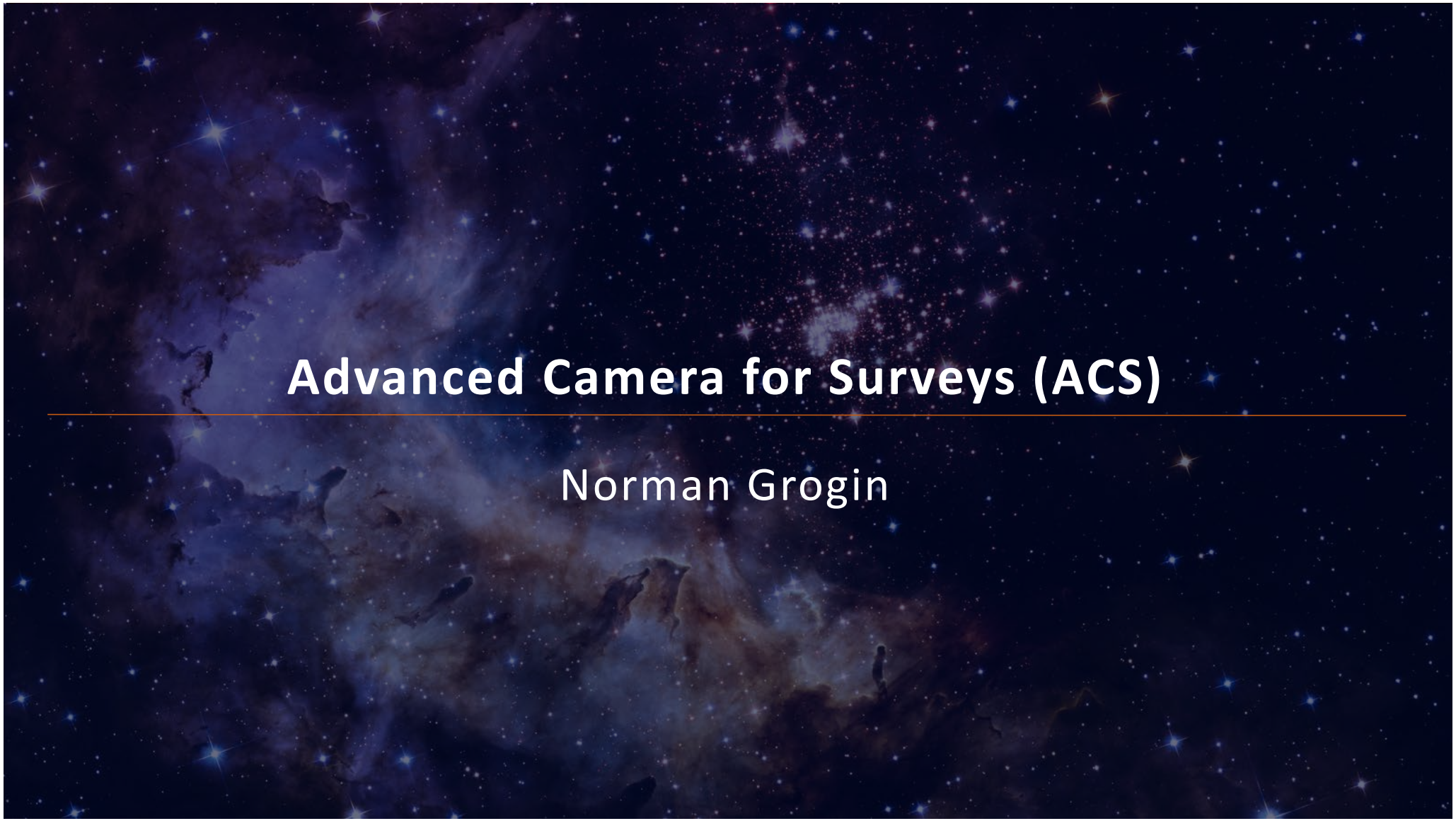
ISR 2018-02: Comparing the ACS/WFC and WFC3/UVIS Calibration and Photometry
S.E. Deustua and J. Mack 12 Mar 2018

ISR 2018-01: Accuracy of the HST Standard Astrometric Catalogs
V. Kozhurina-Platais, N. Grogin, E. Sabbi 19 Feb 2018

ISR 2017-24: A Predictive WFC3/IR Dark Current Model
wfc3_telemetry.txt
Ben Sunnquist, Sylvia Baggett & Knox S. Long 12 Dec 2017

ISR 2017-23: WFC3/UVIS: Bias Reference Files Analysis
M. McKay, S. Baggett 07 Nov 2017

ISR 2017-19: Aligning HST Images to Gaia: a Faster Mosaicking Workflow
V. Bajaj 13 Nov 2017

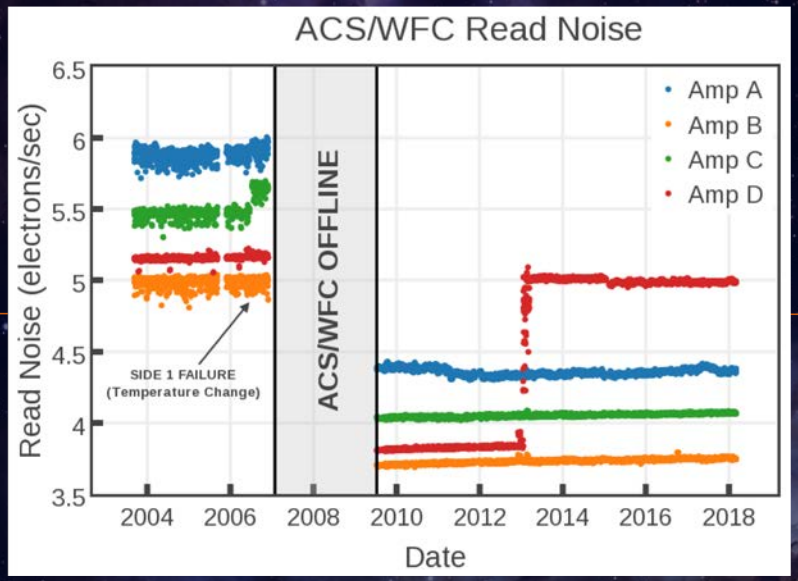


Advanced Camera for Surveys (ACS)

Norman Grogin

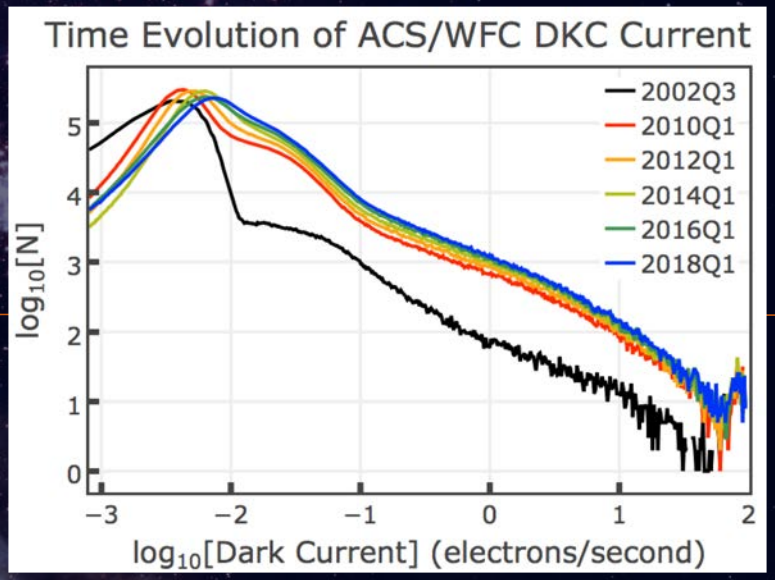
ACS: Continued Good Performance

WFC Read Noise Monitoring



Maintaining Smooth Trend-Lines

WFC Dark Current Monitoring



- Minor CCD Particle Contamination Event (May'17)
  - Two ~opaque irregular 'flecks' of 10-20pix extent; added to BPIXTAB

ACS: Recent Accomplishments

- CALACS Updates in 2018.1 Pipeline Software
  - Every anneal interval: Sink Pixel detection and DQ-array flagging
  - Inclusion of ‘readout dark’ contribution to ERR array
  - Retention of long-term-stable warm/hotpix in DQ array
  - Minor refinements to Gen2 pixel-based CTE correction

- SBC Dark Current vs Temperature
  - Warmup/Cooldown curves recently characterized with 16yrs’ data
  - Possible new best practices for scheduling, & new aper. location
- Improved LED Flash Reference File
- Transition of ‘Gap-filler’ SubSNAP to GOs

ACS: New Initiatives

- Planned Refinements to CALACS for 2018.3 Pipeline Software
  - DARKTIME fix, incorporating empirically derived commanding-overheads
  - High Dynamic-Range WFC Superdarks, leveraging 0.5sec darks since 2015
  - Gaia DR2 refinements to the WFC Geometric Distortion solution
  - Update to the WFC Bias Shift correction

- Empirical WFC PSF Estimation Tool for GOs (akin to WFC3/UVIS tool)
- Astrodrizzle worked-examples with ERR weighted WFC drizzling
- Updated webtools for WFC Zeropoints and Pixel-Area Maps
- Revised L-flats for WFC, based on 16yrs of 47 Tuc monitoring

ACS: User Documentation

- Recent ACS Additions (Nov'17-Apr'18):
  - 2018-02 : "Updates to Post-Flash Calibration for the ACS Wide Field Channel" (Miles)
  - 2018-01 : "Accuracy of the HST Standard Astrometric Catalogs w.r.t Gaia" (Platais et al.)
  - 2017-13 : "Accounting for Readout Dark in ACS/WFC Superbiases" (Ryon et al.)
  - 2017-11 : "A Flat-Field Correction for F435W" (Bohlin et al.)
  - 2017-10 : "A Comparison of the ACS/WFC and WFC3/UVIS Photometric Calibration" (Deustua et al.)
  - 2017-09 : "ACS/WFC Sky Flats from Frontier Fields Imaging" (Mack et al.)
  - 2017-07 : "Improving the Pixel-based CTE-correction Model for ACS/WFC" (Anderson)
  - ACS Data Handbook (version 9.0; Lucas et al.)
- Upcoming ACS Additions (May-Jun'18):
  - *"Mitigating Elevated Dark Rates in SBC Imaging"* (Avila et al.)
  - *"A Minor Contamination Event in May 2017 Affecting the ACS/WFC CCDs"* (Hoffman et al.)
  - *ACS Instrument Handbook for Cycle 26*