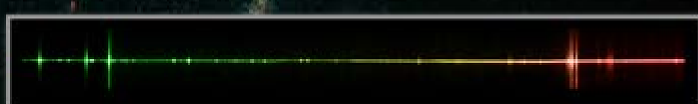
Hubble Space Telescope

2020 and Beyond



More than 29 years since launch, the Hubble Space Telescope continues its role at the forefront of astronomy, ranging from our own Solar System to the high-redshift universe.

Through the middle of the next decade, HST will remain the only space-based telescope providing spectroscopy and high-resolution imaging at UV, optical, and near-infrared wavelengths. With the launch of JWST, the bold science questions pursued with HST will be bolstered by the complementary capabilities of the two observatories.

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Key Science Threads

- Properties of the huge variety of exo-planetary systems: compositions and characteristics of the parent stars and their planets
- Probing the stellar and galactic evolution across the universe: pushing closer to the beginning of galaxy formation and preparing for JWST deep observations
- Exploring traces of dark energy
- Probing the effect of dark matter on the evolution of galaxies
- Quantifying the types and astrophysics of black holes of over 7 orders of magnitude in size
- Tracing the distribution of chemicals of life in the universe
- Investigating phenomena and possible sites for robotic and human exploration within our Solar System

Observing opportunities include preparation for JWST observations, the UV initiative, and mid-cycle observing proposals.

Highlights

ACS Cycle 25 (CALACS) broadly updated for pixel-level corrections: "Putting the electrons back where they belong"
http://www.stsci.edu/hst/acs/performance/calacs_cte/calacs_cte.html

WFC3 calibration (calwf3) updated for pixel-level corrections in UVIS and IR (ISR 2018-15 and ISR 2019-02) LINEAR, software for reconstructing WFC3 slitless spectroscopy, now available (ISR 2018-03) Extensive PSF library available via MAST Portal (under Select a Collection)

COS COS2025 initiative put in place in Cycle 25 aims to retain full science capability of COS/FUV out to 2025 (http://www.stsci.edu/hst/cos/cos2025). Also, new G140L/800 and G160M/1533 cenwaves have been commissioned and are available starting in Cycle 27.

STIS Updates for CALSTIS include geometric distortion, time sensitivity and blaze shift.
See stisblazefix, a tool for blaze fixing:
https://github.com/spacetelescope/stisblazefix

Wide Field Camera 3 (WFC3)

WFC3 In Brief

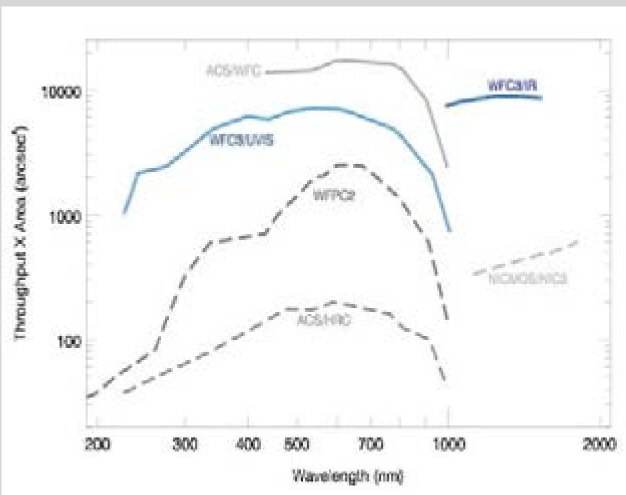
Ultraviolet-Visible Chanel (UVIS)

- 162'' x 162'' field of view
- 62 filters: 200 - 1000 nm coverage
- 1 grism: 200-400 nm
- 0.039''/pixel

Infrared Chanel (IR)

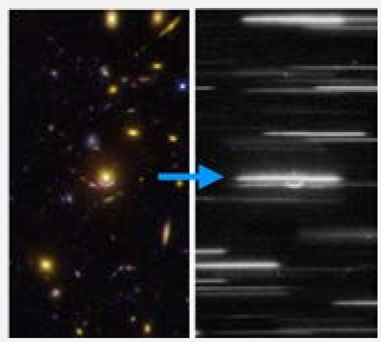
- 123'' x 136'' field of view
- 15 filters: 800 - 1700 nm coverage
- 2 grisms: 800 - 1150 nm, 1075-1700 nm
- 0.13''/pixel

Basic Modes



Direct Imaging

- high resolution imaging over the full optical and infrared wavelength range
- wide field of view in both channels
- range of broad, medium and narrow filters



Grism Spectroscopy

- low resolution slitless spectroscopy in UV & IR
- zJ & JH continuous coverage in IR
- high multiplexing
- spatially-resolved emission lines
- 10x increase in redshift accuracy over photometry

Spatial Scan Imaging

- measure changes in source position to a precision of 20-40 µas
- enables parallax distance measurements up to 5 kpc.
- Riess et al. 2014, ApJ, 785, 161

Dash Observing Strategy

- Enables multiple pointings per orbit in gyro guiding without re-acquiring the guide stars
- Momcheva et al. 2017, PASP, 129, 15004

Spatial Scan Spectroscopy

- best suited for stellar spectra
- high precision spectrophotometry
- spectrum perpendicular to the dispersion direction, = more photon collection
- longer exposures saturation free
- transit spectroscopy
- McCullough & MacKenty 2012, ISR WFC3 2012-08
- Casertano et al., 2016, ApJ 825, 11

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All WFC3 Instrument Science Reports are available at **http://bit.ly/2eoHlwt**
For further information about WFC3, visit our website: **www.stsci.edu/hst/wfc3**
For more information about STScI: **help@stsci.edu**
For proposal information: **https://hst-docs.stsci.edu/display/HSP/HST+Proposal+Opportunities+and+Science+Policies**

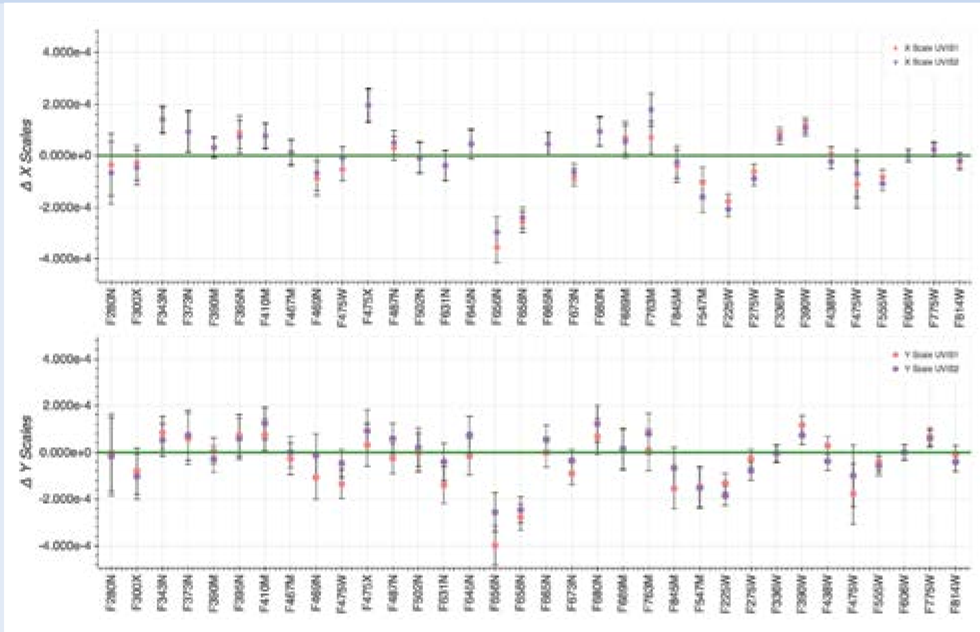
Wide Field Camera 3 (WFC3) *continued*

What's new?

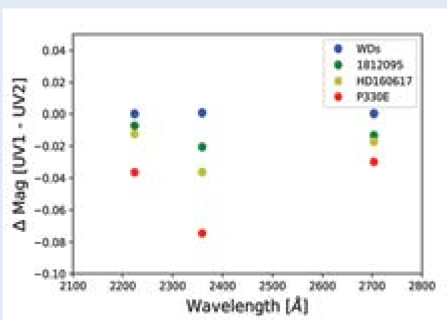
UVIS geometric distortion update

Geometric and fine-scale distortion solutions are now available for 34 narrow, medium and wide band UVIS filters.

Martlin et al. WFC3-ISR 2018-09



Difference along the X (top panel) and the Y (bottom panel) axis between the plate scale values for every UVIS filter and the reference filter F606W, for both Chip1 (in orange) and Chip2 (in purple).



Color term transformations for WFC3 UV filters

Color term transformations for magnitudes measured on the Chip2 relative to Chip1 are now available for the UV filters F218W, F225W, and F275W. The color terms are provided as magnitude offsets as a function of spectral types.

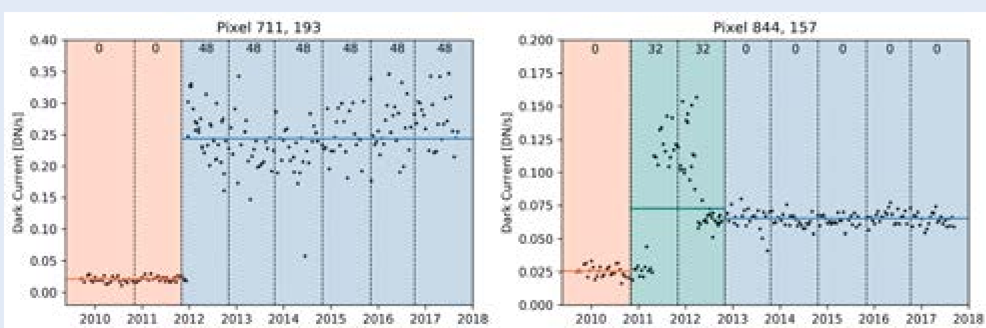
Calamida et al. WFC3-ISR 2018-14

Synthetic ST magnitude s difference for a sample of CALSPEC stars of different spectral type

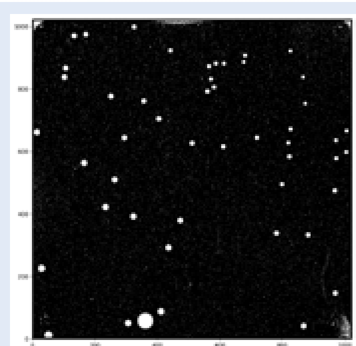
Time dependent IR bad pixels and dark calibration

The analysis of the bad pixels in the IR channel shows that a pixel can remain cold and stable for several years, become unstable for few years and then become again cold and stable, or warm and stable. New bad pixel tables for each of operation have been released. Pixels are flagged as cold and stable (0), unstable (32) or warm and stable (48).

New high S/N dark for each year of operation are also available.



Temporal behavior of two of the IR channel pixels. Pixel 711, 193 (left panel) remained cold and stable for the first three years of operation and the become warm and stable. Pixel 844,157 was cold and stable the first two years of operation, was unstable from 2011 to 2013, and has been cold and stable for the past 5 years.



Bad pixel table for 2016.The table includes blobs, the death star, and pixels that were either bad and unstable, or warm and stable.

Advanced Camera for Surveys (ACS)

Orion nebula

(F435W + F555W + F658N + F775W + F850LP)

Abell 370

(Frontier Fields: F435W + F606W + F814W)

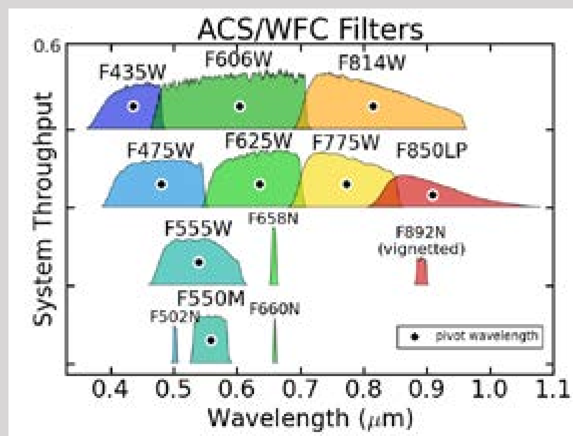
Wide Field Channel (WFC) images shown above

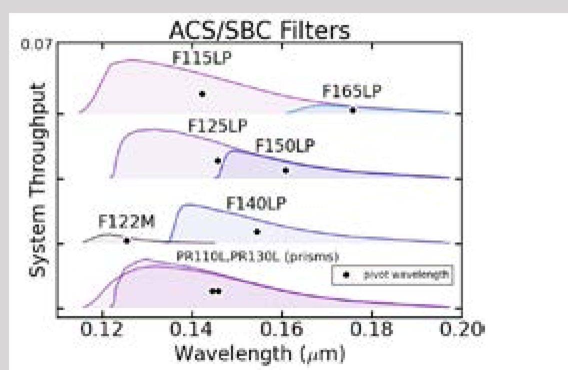
- Optical imaging and spectroscopy (3,500–11,000 Å)
- 202'' x 202'' field of view, largest on HST
- Two 2,048 × 4,096 25 μm/pixel CCDs
- 0.05'' pixels; critically sampled at 8,000 Å
- 3 mirror design, overcoated silver on mirrors
- 13 wide, medium, and narrowband filters
- 15 ramp filters with selectable central wavelengths
- G800L grism (3,500–10,500 Å) R ~ 100 at 8,000Å
- Polarizers optimized for UV and visible wavelengths with relative position angles 0°, 60°, and 120°

Solar Blind Channel (SBC)

- FUV imaging and spectroscopy (1150 –1700 Å)
- 35'' x 31'' field of view, 0.032'' pixels
- 1024 x 1024 CsI 25 μm/pixel MAMA
- 2 mirror design, MgF_2 on Al
- 5 longpass filters, 1 Lyman α filter, 2 prisms
- PR110L, PR130L prisms R ~ 79, 96 at 1500 Å

High Resolution Channel (HRC) inoperative





http://www.stsci.edu/hst/acs/analysis/throughputs

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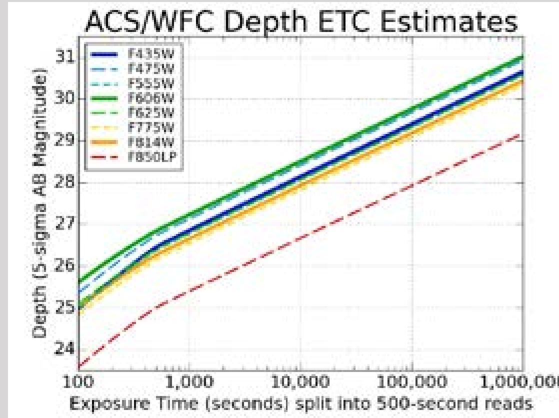
More information on ACS can be found at **http://www.stsci.edu/hst/acs**
For more information about STScI: **help@stsci.edu**
For proposal information: **https://hst-docs.stsci.edu/display/HSP/HST+Proposal+Opportunities+and+Science+Policies**

Advanced Camera for Surveys (ACS) *-continued*

V-band detection limits for WFC, HRC, and SBC				
Camera	Filter	V limit (S/N = 5 in one hour)		
		O5 V (Kurucz model)	A0 V (Vega)	G2 V (Sun)
WFC	F606W	27.8	27.8	28.0
WFC	F814W	26.7	27.0	27.7
HRC	F330W	26.8	24.8	24.1
HRC	F606W	27.3	27.3	27.5
SBC	F125LP	27.8	23.2	13.5

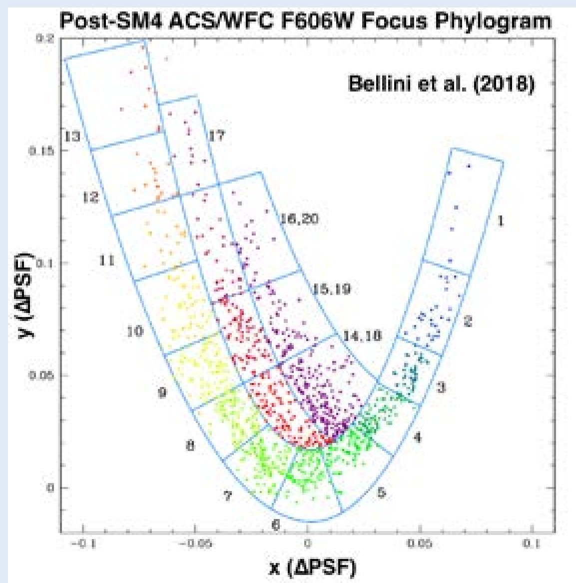


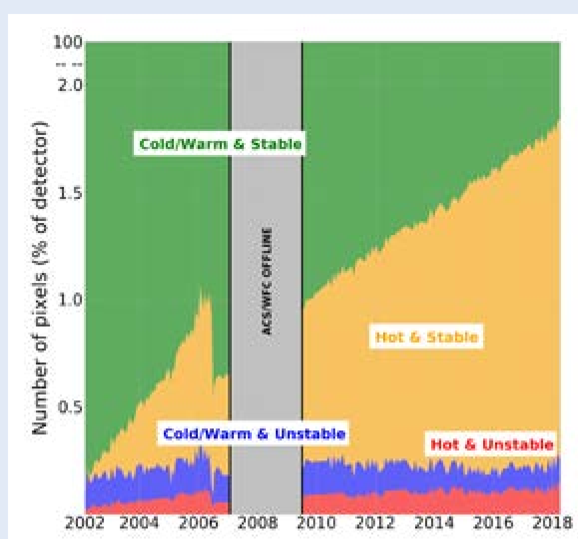
What's new?

ACS Calibration Pipeline (CALACS) broadly updated for Cycle 27: New CTE forward model available; pixel-based CTE correction now uses amp-dependent read noise values; bias drift correction applied to select subarray modes; improved cosmic-ray rejection algorithm ACSREJ.

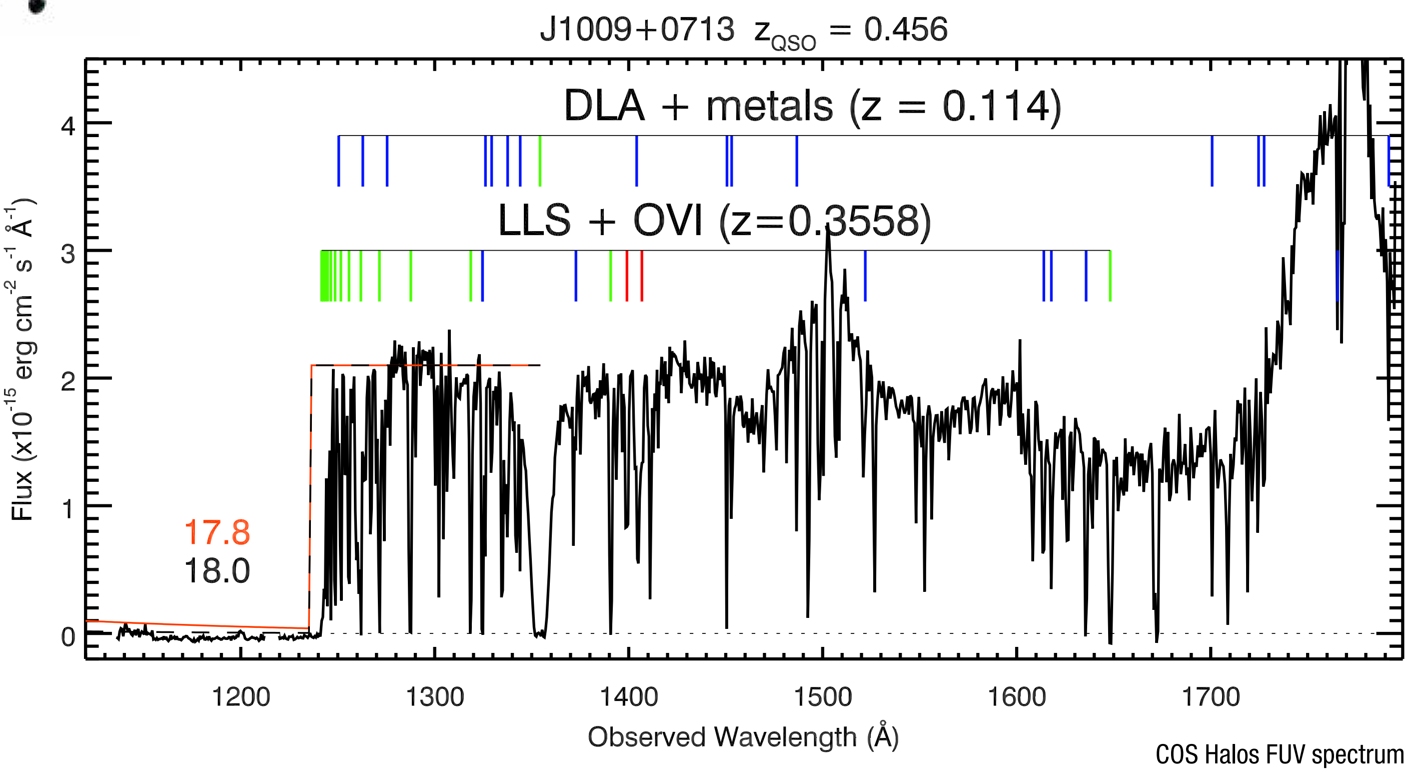
Recent ACS Instrument Science Reports (ISRs) http://www.stsci.edu/hst/acs/documents/isrs

- 2018-01: "Accuracy of the HST Standard Astrometric Catalogs w.r.t. Gaia" (Kozhurina-Platais et al.)
- 2018-02: "Updates to Post-Flash Calibration for the Advanced Camera for Surveys Wide Field Channel" (Miles)
- 2018-03: "A Minor Contamination Event in May 2017 Affecting the ACS/WFC CCDs" (Hoffman et al.)
- 2018-04: "Improving the Pixel-Based CTE-Correction Model for ACS/WFC" (Anderson & Ryon)
- 2018-05: "Updates to the CALACS Cosmic Ray Rejection Routine: ACSREJ" (Miles et al.)
- 2018-06: "Remeasuring the ACS/WFC Absolute Gains" (Desjardins & Grogin)
- 2018-07: "Mitigating Elevated Dark Rates in SBC Imaging" (Avila et al.)
- 2018-08: "Focus-Diverse, Empirical PSF Models for the ACS/WFC" (Bellini et al.)
- 2018-09: "ACS/WFC Parallel CTE from EPER Tests (Ryon et al.)
- 2019-01: "The ACS/WFC G800L Grism: I. Long-term Stability" (Hathi et al.)
- 2019-02: "Post-SM4 ACS/WFC Bias I: The Read Noise History" (Desjardins)
- 2019-03: "Assessing the Accuracy of Relative Photometry on Saturated Sources with ACS/WFC" (Olaes)





Cosmic Origins Spectrograph (COS)



COS Halos FUV spectrum
(Tumlinson et al. 2011)

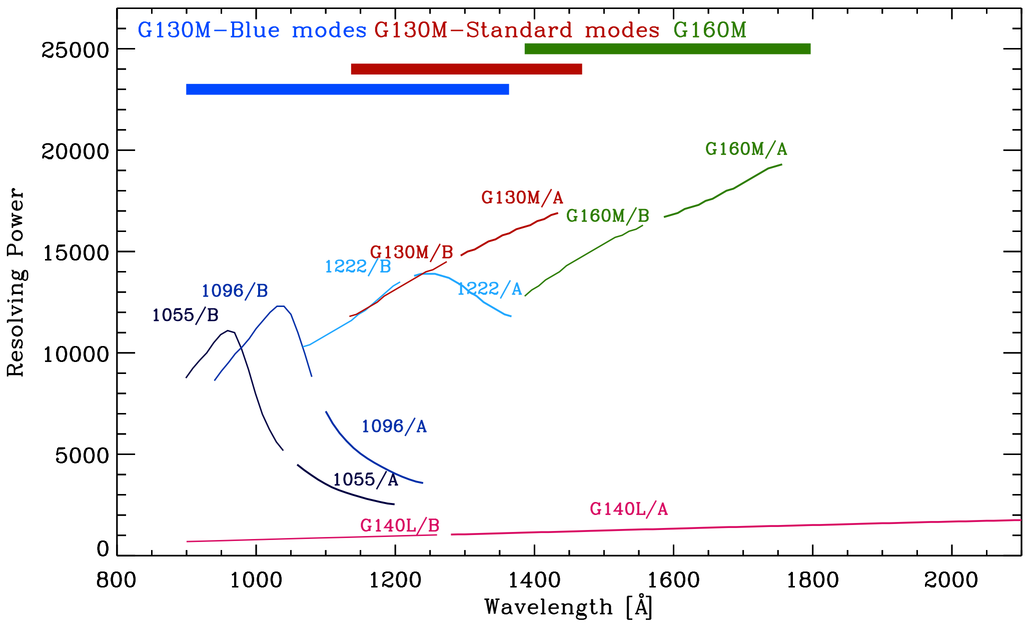
COS Overview

Far Ultraviolet (FUV):

- Medium Resolution mode:
  R (λ / Δ λ) ≈ 15,000-21,000
  λ ≈ 900-1800 Å
  λ per exposure ≈ 292-360 Å
- Low Resolution mode:
  R (λ / Δ λ) ≈ 1,500-4,000
  λ ≈ 800-2050 Å
  λ per exposure ≈ >1150 Å
- Effective area ≈ 1800-3000 cm^{-2}
- Background ≈ 1.1 x 10^{-4} cts s^{-1} $resel^{-1}$
- Blue modes:
  unique access to λ < 1150 Å, but lower resolution and throughput than standard M grating modes.
- New G140L/800 mode offers lower astigmatic height in range [800, 1150] Å

Near Ultraviolet (NUV):

- Medium Resolution mode:
  R (λ / Δ λ) ≈ 15,000-24,000
  λ ≈ 1700-3200Å
  λ per exposure ≈ 3 x 35-41 Å
- Low Resolution mode:
  R (λ / Δ λ) ≈ 2,100-2,900
  λ ≈ 1650-3200 Å
  λ per exposure ≈ 2 x 398 Å
- Effective area ≈ 600-750 cm^{-2}
- Background ≈ 7.4 x 10^{-3} cts s^{-1} $resel^{-1}$
- NUV imaging mode:
  FOV area (arcsec2) ≈ 4.9 (un-vignetted) or 12.5 (full) Pixel Scale (arcsec) ≈ 0.024



COS/FUV resolution as function of wavelength for Cycle 25+

COS 2025: New strategy to extend the lifetime of COS

The goal of COS 2025 is to retain full science capability of COS/FUV out to 2025. It places restrictions on the G130M cenwaves allowed at Lifetime Position 4 to reduce gain sag from Ly-alpha. It was put in place starting with Cycle 25.

For more information visit: **http://www.stsci.edu/hst/cos/cos2025**

What's New?

G140L/800 – New cenwave setting that allows for contiguous coverage of the entire spectral region 800 - 1950 Å on a single COS detector segment (FUVA) with a low spectral height below 1150 Å, allowing higher S/N for background-limited observations. Flux calibration accuracy is ~10 – 15% in the [900, 1100] Å range, while the wavelength calibration is accurate to ~+/-3 pix.

G160M/1533 – New cenwave setting that extends coverage at the short-wavelength end of G160M by 44 Å to overlap with the longest wavelengths covered by G130M/1222. Has similar properties to the existing G160M/1577 cenwave but with the key advantage of allowing a broad range of FUV wavelengths to be covered by just two central wavelength settings (1222+1533). For full details, see the COS Instrument Handbook: **http://www.stsci.edu/hst/cos/documents/handbooks/current/cos_cover.html**

FUV wavelength calibration – The effort to rederive dispersion solutions for the M gratings, for all COS/FUV lifetime positions, has been completed. All M-grating dispersion solutions are now accurate to +/-0.5 resolution element, or +/-3 pix.

G285M use discouraged – Because of declining throughput, NUV observations with G285M grating are discouraged. Users interested in medium-resolution spectroscopic coverage of the 2500 – 3200 Å wavelength region are encouraged to use STIS instead.

Cosmic Origins Spectrograph (COS) *– continued*

The Hubble Spectroscopic Legacy Archive

Solar System and Exoplanets

Sample	Targets	Files (tar.gz)
All Solar System (N = 32)	Targets	Download (153 MB)
Extrasolar Planets (N = 14)	Targets	Download (206 MB)

Galaxies and Clusters

Sample	Targets	Files (tar.gz)
All Galaxies (N = 250)	Targets	Download (1.9 GB)
Starbursts (N = 95)	Targets	Download (1.2 GB)
Spirals (N = 18)	Targets	Download (107 MB)
Star Forming (N = 36)	Targets	Download (132 MB)
Dwarf Compact (N = 44)	Targets	Download (351 MB)
Emission Line (N = 25)	Targets	Download (136 MB)
Irregular (N = 8)	Targets	Download (59 MB)
Galaxy Clusters (N = 24)	Targets	Download (218 MB)

Stars

Sample	Targets	Files (tar.gz)
All Stars (N = 521)	Targets	Download (7.5 GB)
Early Type Stars (N = 112)	Targets	Download (1.9 GB)
Late Type Stars (N = 82)	Targets	Download (1.2 GB)
White Dwarfs (N = 169)	Targets	Download (2.3 GB)
T Tauri Stars (N = 34)	Targets	Download (708 MB)
Novae and Cataclysmic Variables (N = 49)	Targets	Download (265 MB)
Post-AGB (N = 27)	Targets	Download (426 MB)
Low-Mass X-Ray Binaries (N = 7)	Targets	Download (91 MB)
Other (N = 41)	Targets	Download (834 MB)

QSOs, AGN, and Seyferts

Sample	Targets	Files (tar.gz)
QSOs, AGN, and Seyferts (N = 628)	Targets	Download (8.8 GB)

Supernovae and SNRs

Sample	Targets	Files (tar.gz)
Supernovae and SNRs (N = 11)	Targets	Download (304 MB)

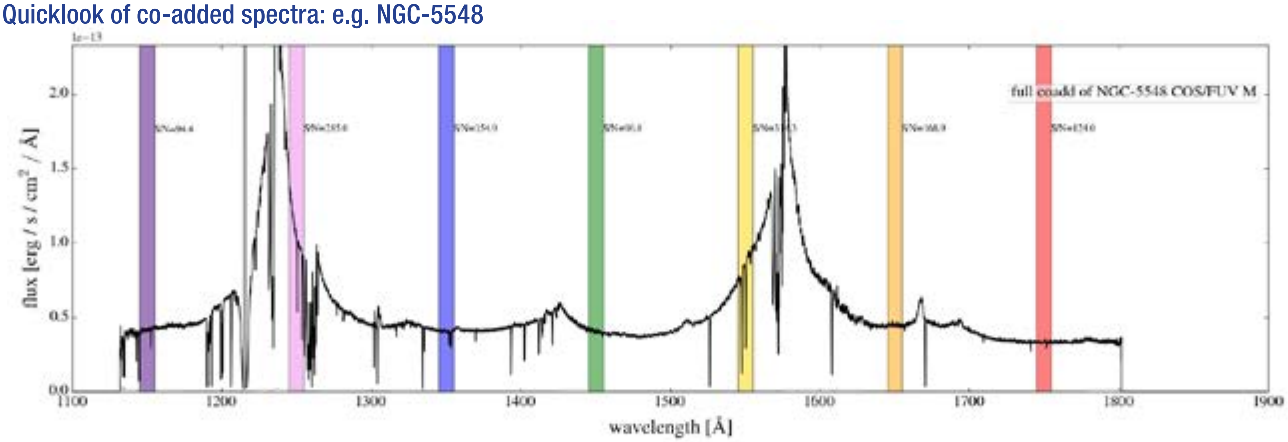
- Archive contains science-grade combined spectra of COS data organized by target type and scientific purpose
- Download all the data associated with a target or type of target with a single click

https://archive.stsci.edu/hst/spectral_legacy/

Searchable, and can be sorted by many attributes

Number	Target Name	RA	DEC	Nexp	Target Description	AltName	AltClass	Redshift	MAST	Median S/N	FUV M	FUV L	Download
256	NGC-5548	214.498	25.1368	764	GALAXY;SEYFERT	NGC 5548	G	0.017	MAST	165.306		...	ALL
30	3C273	187.278	2.05241	7	GALAXY;JET;QSO;QUASA	3C 273	QSO	0.158	MAST	105.659		...	ALL
233	MRK-509	311.041	-10.7235	28	GALAXY;NUCLEUS;SEYFE	MRK 0509	G	0.034	MAST	103.741			ALL
97	IRAS-F04250-5718	66.5032	-57.2003	14	GALAXY;LYMAN ALPHA C	GALEXASC J042600.66-571200.9	G	0.104	MAST	83.1052		...	ALL
299	PKS0405-123	61.9518	-12.1935	38	GALAXY;QSO;SEYFERT	[HB89] 0405-123	QSO	0.572	MAST	78.1699		...	ALL
230	MRK421	166.114	38.2086	12	GALAXY;BL LAC	MRK 0421	G	0.030	MAST	75.4871		...	ALL

Quicklook of co-added spectra: e.g. NGC-5548



Space Telescope Imaging Spectrograph (STIS)

FUV MAMA (Multi Anode Microchannel Array)

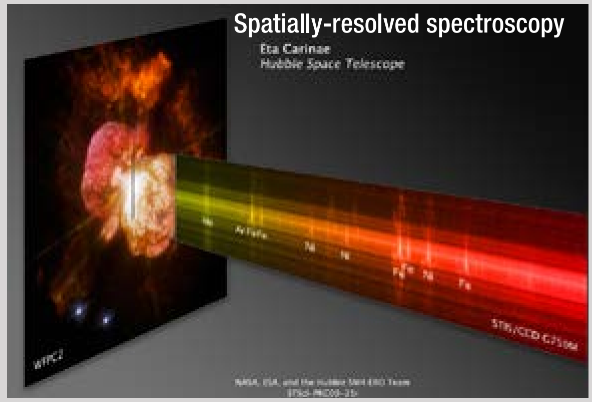
- 1024 x 1024 CsI detector, TIME-TAG available
- Imaging: 25'' x 25'' FOV, 0.025'' pixels, 9 filters
- Spectroscopy: 2 first order and 2 echelle gratings
  λ = 1150 – 1740Å, R ~ 1000 - 200,000
  ~30 cen. wave. configurations

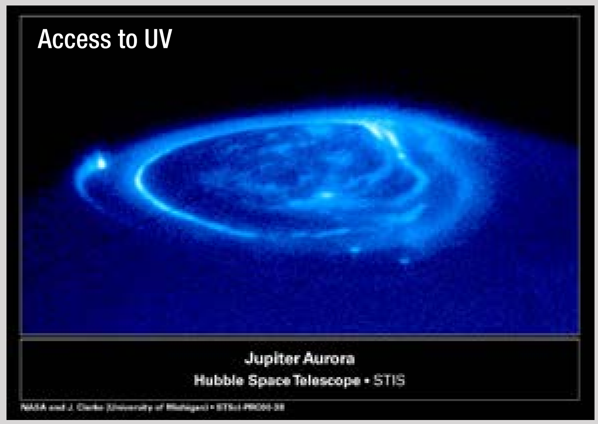
NUV MAMA

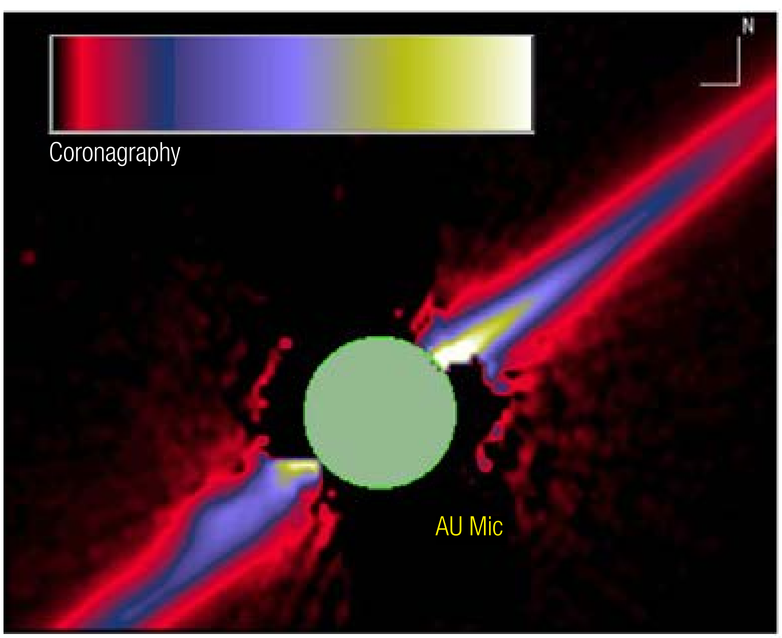
- 1024 x 1024 Cs_2Te detector, TIME-TAG available
- Imaging: 25'' x 25'' FOV, 0.025'' pixels, 12 filters
- Spectroscopy: 2 first order and 2 echelle gratings
  λ = 1650 – 3100 Å, R ~ 500 - 200,000
  ~55 cen. wave. configurations
- Prism spectroscopy
  λ = 1150 - 3620 Å, R ~ 10 – 2500

CCD

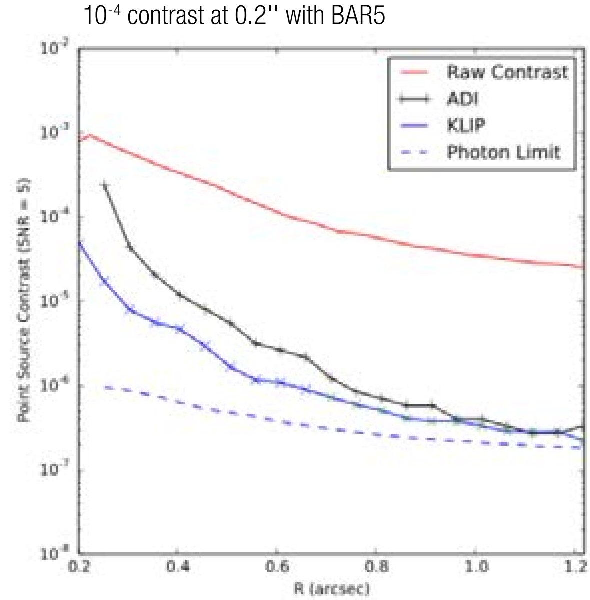
- 1024 x 1024 SITE CCD detector
- Imaging: 52'' x 52'' FOV, 0.051'' pixels, 9 filters
- Spectroscopy: 6 first order gratings
  λ = 1650 – 11,000 Å, R ~ 500 - 10,000
  ~40 cen. wave. configurations
- Usable with coronagraphic mask and occulting bars
  Broadband imaging (2000 - 10,300 Å)
  Bar-occulted spectroscopy (2000 - 10,300 Å)







10^{-4} contrast at 0.2'' with BAR5



STIS offers visible and UV imaging and spectroscopy **http://www.stsci.edu/hst/stis**
For more information about **STScI: help@stsci.edu**
For proposal information: **https://hst-docs.stsci.edu/display/HSP/HST+Proposal+Opportunities+and+Science+Policies**

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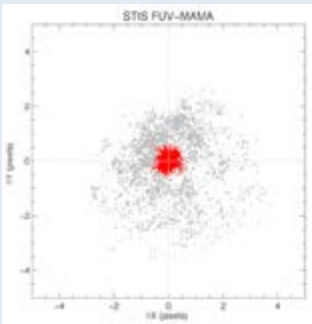
Space Telescope Imaging Spectrograph (STIS) *– continued*

What's new?

Reference File Updates for CALSTIS

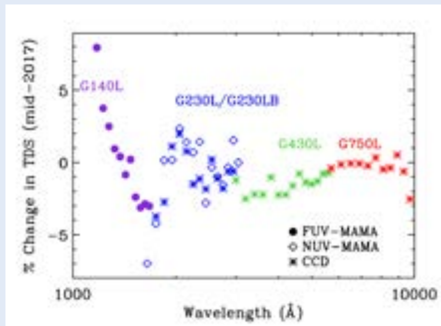
Geometric Distortion

- Geometric distortion correction for FUV-MAMA imaging
- Astrometric precision reduced from ~30 to ~4 mas



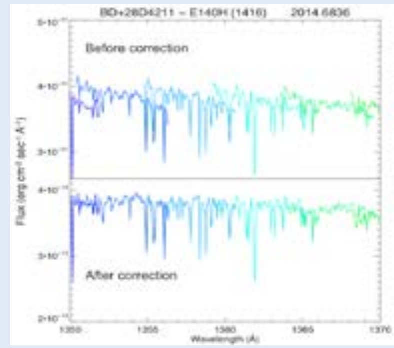
Time Dependent Sensitivity

- Updated corrections to the time dependent sensitivity of all spectral modes
- Improved flux calibrations up to ~8%



Blaze Shift

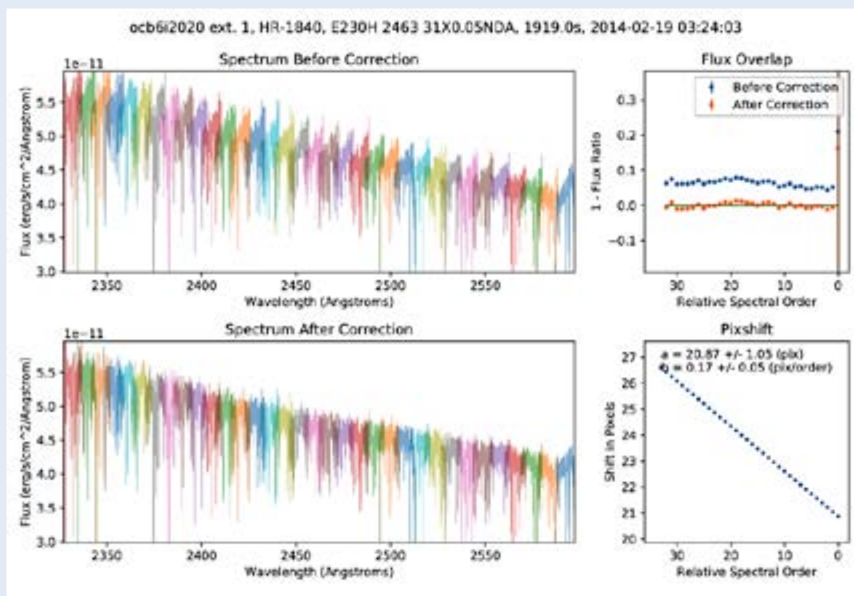
- Updated blaze shift for FUV E140H
- Reduces "flux mismatch" in overlapping regions from 5-10% to < 5%



Blaze fix tool: stisblazefix

- Python tool for finding empirical correction to blaze shift
- Improves correction on individual spectra over CALSTIS results

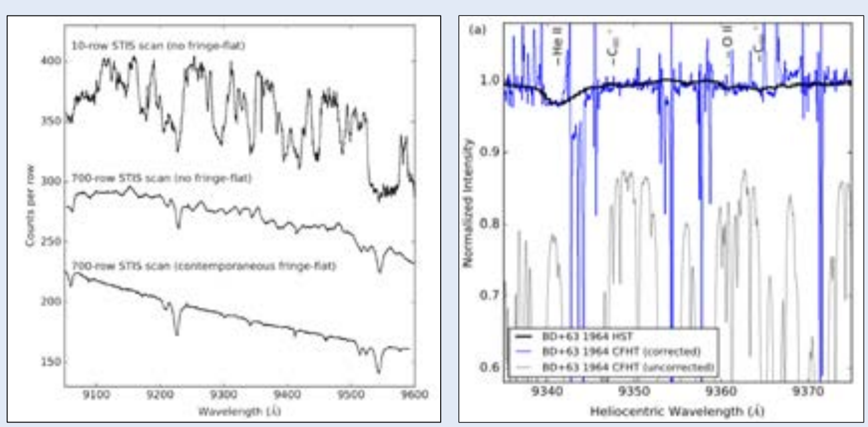
More info: https://stisblazefix.readthedocs.io/



New CCD Spatial Scanning

- Overcome fringing limitations in the red to achieve high S/N (>500)
- Mode is currently "available but unsuported" – STIS team is investigating more support for Cycle 27

More info: goo.gl/p48U9S



Weak DIBs detected with STIS spatial scanning (Cordiner et al. 2017, ApJL, 843, L2)

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