In 2020, the Hubble Space Telescope celebrates its 30th year as a powerful observatory for unraveling the astrophysics of the universe from Solar system studies to the high-redshift universe.

The high-resolution imaging capability of HST spanning the IR, optical, and UV, coupled with spectroscopic capability will remain invaluable through the middle of the upcoming decade. HST coupled with JWST will enable new innovative science and be will be key for multi-messenger investigations.
Key Science Threads

- Properties of the huge variety of exo-planetary systems: compositions and inventories, compositions and characteristics of their planets
- Probing the stellar and galactic evolution across the universe: pushing closer to the beginning of galaxy formation and preparing for coordinated JWST observations
- Exploring clues as to the nature 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, archive research, and mid-cycle observing proposals.


WFC3 offers high resolution imaging in many bands ranging from 2000 to 17000 Angstroms, as well as spectroscopic capability in the near ultraviolet and infrared. Many different modes are available for high precision photometry, astrometry, spectroscopy, mapping and more.

COS COS2025 initiative retains 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 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
ULLYSES CHARTING YOUNG STARS’ ULTRAVIOLET LIGHT WITH HUBBLE

The Hubble Space Telescope’s Ultraviolet Legacy Library of Young Stars as Essential Standards (ULLYSES) is a Director’s Discretionary program of approximately 1,000 orbits that will produce an ultraviolet spectroscopic library of young high- and low-mass stars in the local universe. The ULLYSES program will uniformly sample the fundamental astrophysical parameter space for each mass regime, including spectral type, luminosity class, and metallicity for massive stars, and the mass, age, and disk accretion rate in low-mass stars. The program is expected to execute over a three-year period, from Cycle 27 to Cycle 29.

PROJECT MILESTONES

<table>
<thead>
<tr>
<th>Region</th>
<th>Instrumental modes</th>
</tr>
</thead>
<tbody>
<tr>
<td>LMC and SMC</td>
<td>COS/G130M/1096 (brightest O stars) STIS/E230M/1978 (O9 I – B9 I only)</td>
</tr>
<tr>
<td></td>
<td>COS/G130M/1291 + COS/G160M/1611 or STIS/E140M</td>
</tr>
<tr>
<td>Sextans-A and NGC 3109</td>
<td>STIS/E230M/2707 or COS/G185M/1953 + 1986 (B5-9 I)</td>
</tr>
<tr>
<td>Survey T Tauri stars</td>
<td>COS/G130M/1291 + COS/G160M/1611 STIS/G230L + STIS/G430L + STIS/G750L</td>
</tr>
<tr>
<td>Monitoring T Tauri stars</td>
<td>COS/G160M/1611 + COS/G230L/2635 + COS/G230L/2950</td>
</tr>
</tbody>
</table>

For more information, visit [http://www.stsci.edu/stsci-research/research-topics-and-programs/ullyses](http://www.stsci.edu/stsci-research/research-topics-and-programs/ullyses)

Observing Strategy and Technical Specifications

The ULLYSES program is divided into two primary observational campaigns of high- and low-mass stars. The focus on high-mass stars includes observations of 65 stars in the SMC, 98 stars in the LMC, as well as 6 additional stars which are accessible in the even lower metallicity Local Group galaxies NGC 3109 and Sextans A. For low-mass stars, observations will focus on about 71 K- and M-type T Tauri stars and brown dwarfs within 8 star-forming regions in the Milky Way, including time-domain monitoring of 4 prototypical T Tauri stars with well-known rotation periods and magnetic configurations.

All targets will be observed with COS and/or STIS medium-resolution modes, as detailed in Table 2.

FOR MORE INFORMATION, VISIT
http://www.stsci.edu/stsci-research/research-topics-and-programs/ullyses
**Massive Stars**

A call for input on target selection was released to the community in the fall of 2019, leading to the prioritization of massive stars in two young clusters, N11 (LMC, 18 stars) and NGC 346 (SMC, 9 stars).

The massive star component of ULLYSES leverages on existing FUSE and HST archival data, to provide full UV coverage at medium-resolution for ~240 targets uniformly sampling spectral type and luminosity class.

The ULLYSES dataset for massive stars will enable transformative science in the field of stellar astrophysics, and enable a legacy of studies of the interstellar and circum-galactic media.

**T Tauri Stars**

The 67 T Tauri stars to be surveyed in 8 Milky Way star-forming regions uniformly sample mass and disk accretion rate. The library of UV-optical-NIR spectra from ULLYSES will enable studies of the accretion and resulting UV radiation in those objects, which affects the evolution of proto-planetary disks and the chemical composition and atmospheric escape of young planets.
Wide Field Camera 3 (WFC3) offers high resolution imaging in bands ranging from 2000 to 17000 Angstroms, as well as spectroscopic capability in the near ultraviolet and infrared. A variety of modes are available for high precision photometry, astrometry, spectroscopy, mapping and more: [http://www.stsci.edu/sites/www/home/hst/instrumentation/wfc3.html](http://www.stsci.edu/sites/www/home/hst/instrumentation/wfc3.html)
**Direct Imaging**
High resolution, wide field imaging. Large complement of filters for various photometric bands/spectral features.

**Grim Spectroscopy**
Using grisms instead of imaging filters allows low resolution spectroscopy, while maintaining high spatial resolution.

**Spatial Scanning**
Slewing during exposure (spatial scanning) places source flux on hundreds of pixels/avoids saturation, achieving extremely high SNR photometry.

**Grism Scanning**
Combining scanning and grism spectroscopy allows for extremely high SNR spectra. Useful for transit observations.

Handbook: [https://hst-docs.stsci.edu/display/WFC3IHB](https://hst-docs.stsci.edu/display/WFC3IHB)
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
  - \( \lambda = 1150 - 1740 \text{Å}, R \sim 1000 - 200,000 \sim 30 \text{ cen. wave. configurations} \)

NUV MAMA
- 1024 x 1024 CS2Te detector, TIME-TAG available
- Imaging: 25'' x 25'' FOV, 0.025'' pixels, 12 filters
- Spectroscopy: 2 first order and 2 echelle gratings
  - \( \lambda = 1650 - 3100 \text{Å}, R \sim 500 - 200,000 \sim 55 \text{ cen. wave. Configurations} \)
  - Prism Spectroscopy:
    - \( \lambda = 1150 - 3620 \text{Å}, R \sim 10 - 2500 \)

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

STIS is one of the oldest active instruments on the Hubble Space Telescope (HST).
- large fraction of total HST observing time (10-15% GO observations in recent Cycles)
- incredibly versatile and highly configurable instrument
- Numerous filters, gratings, and apertures
- large variety of unique photometric and spectroscopic modes
- high spatial resolution in the UV and optical

SPATIALLY-RESOLVED SPECTROSCOPY

ACCESS TO UV

Jupiter Aurora
Hubble Space Telescope • STIS

CORONAGRAPHY

Survey of Circumstellar Disks
Hubble Space Telescope • STIS
UNIQUE USES OF STIS

Spatial Scanning with the STIS CCD

Spatial scanning is now an available-but-unsupported mode on STIS.
- allows for more photons to be collected before reaching the CCD full-well saturation.
- better averaging over variations in the flat field,
- can lead to much better IR fringe removal than non-scanned images.
- For example, Signal-to-Noise ratios of 600-800 have been achieved in 1D extracted G750M/9336 spectra.

TIME-TAG Mode

The STIS MAMA allows time-resolved observations through TIME-TAG mode.
- tracks the collection time of each individual photon event at a time resolution of 125 microseconds.

For more information about STIS: www.stsci.edu/hst/instrumentation/stis
If you have questions about STIS/HST/STScI: https://stsci.service-now.com/hst
Dust Pillars in Carina observed with the ACS/WFC. Uses filters F502N ([O III], blue) and F658N (Hα + [N II], red).

Gravitational lensing in Abell 370 observed with ACS/WFC. Uses filters F475W (blue), F625W (green), and F814W (red).

Wide Field Channel (WFC)
- Optical imaging and slitless spectroscopy (3,500–11,000 Å)
- Highest throughput on HST in visible light
- 202'' x 202'' field of view, largest on HST
- 13 wide, medium, and narrowband filters
- 15 tunable wavelength filters
- Grism (5,500–10,500 Å); R ~ 100 at 8,000 Å
- Near-UV / visible linear polarization filters

Solar Blind Channel (SBC)
- FUV imaging and slitless spectroscopy (1,150–1,700 Å)
- High throughput, best for FUV imaging
- 35'' x 31'' field of view
- 5 longpass filters, 1 Lyman α filter
- Two prisms; R ~ 79 and 96 at 1,500 Å


Please see the ACS Instrument Handbook for more detailed information on ACS capabilities. https://hst-docs.stsci.edu/display/ACSIHB/
Crab nebula polarization with the ACS/WFC. Filters: F550M (red) and F606W plus a visible linear polarization filter (blue).

<table>
<thead>
<tr>
<th>Camera</th>
<th>Filter</th>
<th>V-band AB limit (S/N=5 in 1 hour)</th>
</tr>
</thead>
<tbody>
<tr>
<td>WFC</td>
<td>F606W</td>
<td>28.2 mag</td>
</tr>
<tr>
<td>WFC</td>
<td>F814W</td>
<td>27.7 mag</td>
</tr>
<tr>
<td>SBC</td>
<td>F125LP</td>
<td>26.0 mag</td>
</tr>
</tbody>
</table>

ACS UNIQUE AND KEY FEATURES

1. ACS/WFC has the largest field of view and highest throughput in visible light of any HST instrument
2. The ACS/WFC grism provides well-calibrated, wide-field slitless spectroscopy of visible to near-IR light
3. ACS is the only active space-based, high spatial resolution polarimeter, providing synergy with JWST dust studies
4. The ACS/SBC is especially optimized for FUV imaging, but also supports slitless spectroscopy

WHAT'S NEW FOR CYCLE 28?

The absolute photometric calibration of the SBC has been updated to remove a long-standing ~30% underestimate. Time-dependent sensitivity since launch has also been incorporated in the SBC zeropoints for improved accuracy.

New astrometric solutions based on Gaia sources have been applied to all ACS products in MAST.

For a complete list of ACS instrument science reports, please visit:
http://www.stsci.edu/hst/instrumentation/acs/documentation/instrument-science-reports-isrs
COS/FUV spectrum of hot star Sk-68 73 in the LMC

**COS Overview**

**Far Ultraviolet (FUV)**
- Medium Resolution mode:
  
  \[ R \approx 15,000-21,000 \]
  
  \[ \lambda \approx 900-1800 \text{ Å} \]

- Low Resolution mode:
  
  \[ R \approx 1,500-4,000 \]
  
  \[ \lambda \approx 800-2050 \text{ Å} \]

- Effective area \( \approx 1800-3000 \text{ cm}^2 \)
- Three gratings:
  
  G130M, G160M, G140L
- Pixel format: 16384 \times 1024

**Near Ultraviolet (NUV)**
- Medium Resolution mode:
  
  \[ R \approx 15,000-24,000 \]
  
  \[ \lambda \approx 1700-3200 \text{ Å} \]

- Low Resolution mode:
  
  \[ R \approx 2,100-2,900 \]
  
  \[ \lambda \approx 1650-3200 \text{ Å} \]

- Effective area \( \approx 600-750 \text{ cm}^2 \)
- Four gratings:
  
  G185M, G225M, G285M, G230L
- Pixel format: 1024 \times 1024

See our Handbook at
https://hst-docs.stsci.edu/display/COSIHB/

All COS spectra are on the Hubble Spectroscopic Legacy Archive (HSLA):
https://archive.stsci.edu/hst/spectral_legacy/
COS 2025: Strategy to extend the lifetime of COS

COS 2025 policies should retain the full science capability of COS out to 2025. Restrictions on G130M cenwaves allowed at Lifetime Position 4 to reduce gain sag from geocoronal Ly-alpha.

https://www.stsci.edu/hst/instrumentation/cos/proposing/cos2025-policies

WHAT’S NEW AND UPCOMING?

LP5 – investigations proceed on a new lifetime position for FUV detector: LP5.

ULLYSES – COS will be extensively used as part of ULLYSES in Cycles 28 through 30 (see information and references in this booklet)

G140L/800 – new cenwave allowing contiguous coverage of the entire spectral region 800–1950 Å on a single COS detector segment (FUVA).

G160M/1533 – new cenwave extending coverage at the short-wavelength end of G160M to overlap with the coverage of G130M/1222.

G285M use discouraged – due to declining throughput, NUV observations with the G285M grating are discouraged. Users interested in medium-resolution observations at 2500–3200 Å should consider STIS instead.