STScI | SPACE TELESCOPE SCIENCE INSTITUTE

EXPANDING THE FRONTIERS OF SPACE ASTRONOMY

Hubble Space Telescope Status

Cycle 30 TAC Presentation

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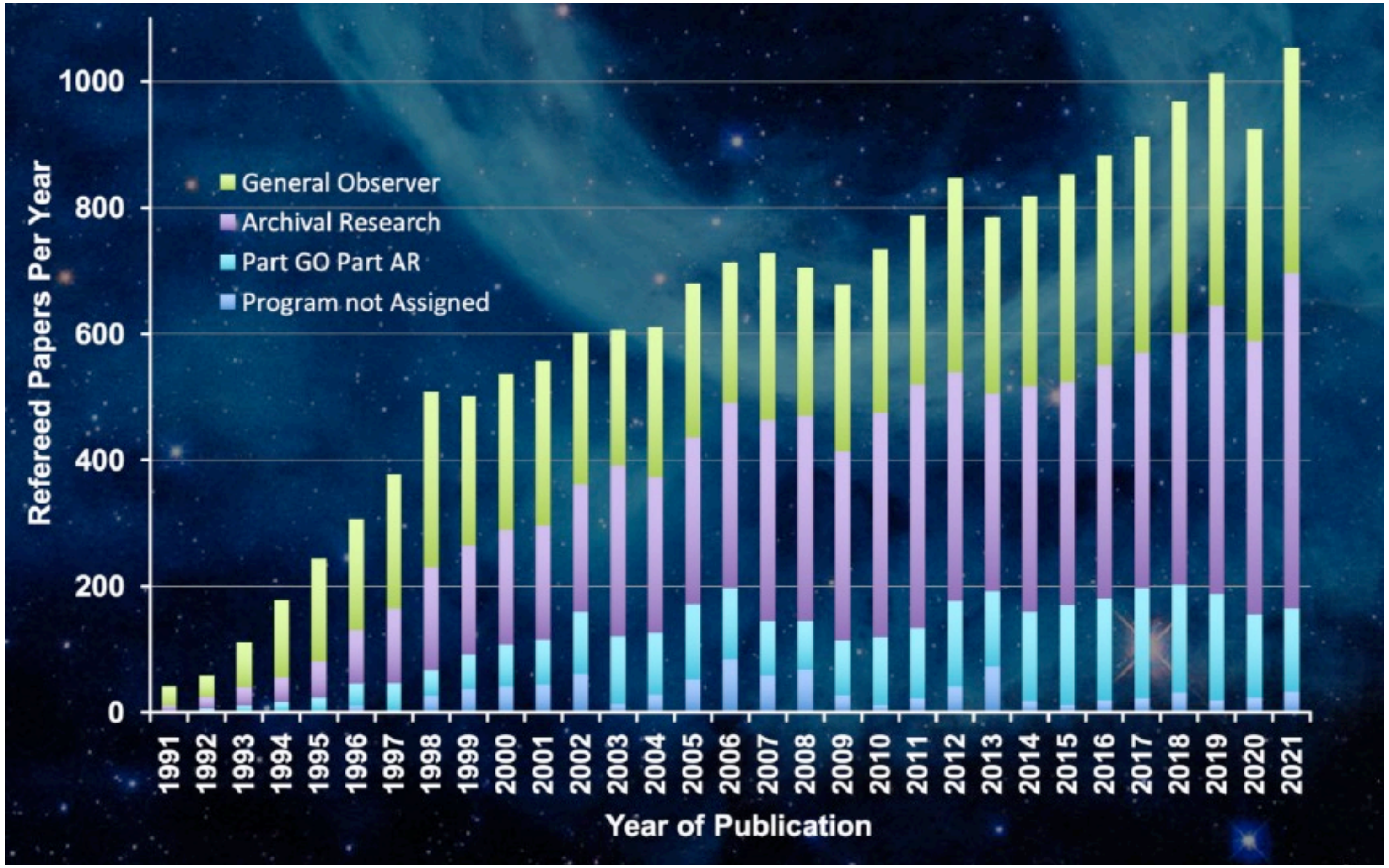
Welcome!

Thank you for serving on the Cycle 30 HST TAC

- The Hubble Space Telescope will soon complete 32 years in operation
  - We are nearly 13 years past Servicing Mission 4
    - At that time, planning was for 5 years of science operations
  - In most respects, Hubble is working now at its very best
    - There is some slight instrument performance degradation (mainly in CCD charge transfer efficiency)
    - Some degradation in the pointing control system results in more failed acquisitions than the long term average (2% has increased to about 5%)
    - Lost ~10% of 2021 due to computer problems but S/W fixes in place for one issue and effort underway to recover lost redundancy on the other issue
    - But we (GOs and STScI+GSFC) have become smarter in how we use the observatory and continue to work to mitigate these issues
- You, by serving the HST TAC process, have the privilege and responsibility of defining what Hubble does next!

Science Productivity at All Time High



- Hubble GO and AR programs produced >1000 refereed science papers in 2021
- Now 19,000+ refereed science papers to date
- >1E6 citations
- 600+ PhD theses
  - currently ~1 per week
- 1 in 6 astronomy papers influenced by Hubble

Data from the Programs You Select Will Produce Science for Years to Come

- HST archive size is >160 TB
- 6-15 TB per month retrieved
- >12,000 registered archive users (85 countries, 50 states)
- HST archive online cache delivers data within minutes to users
- Amazon Web Services became available in 2018 for archival research
  - All HST public data with very fast local processing on their servers
- Hubble Advanced Products (HAP) now available via MAST
  - Combines multiple images; from multiple visits soon
- HST processing moved to Cloud (AWS) for increased speed and reliability

2020 → 2025 Vision

Operate Hubble out to 2025 and beyond. Expect overlapping science observations with the James Webb Space Telescope, performed in a manner that maximizes the science return of both observatories by taking full advantage of Hubble's unique capabilities and the astronomical community's scientific curiosity.

How long will Hubble continue to operate?

→ As long as it remains scientifically productive

Expect at least several years of overlap between HST and JWST

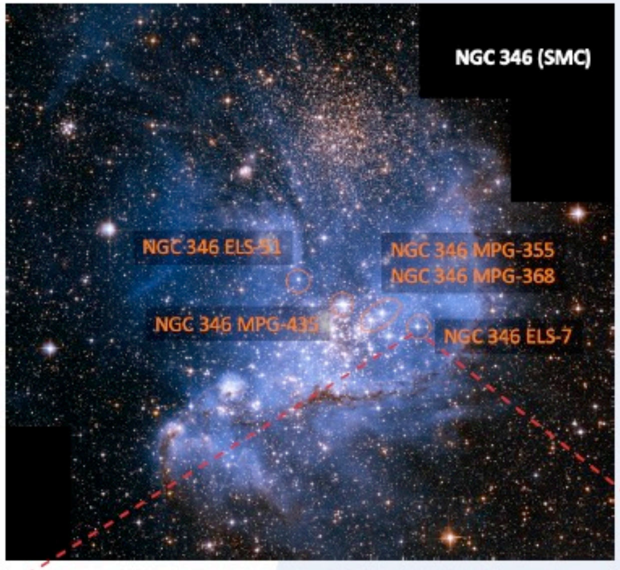
What is needed to keep Hubble scientifically productive? →

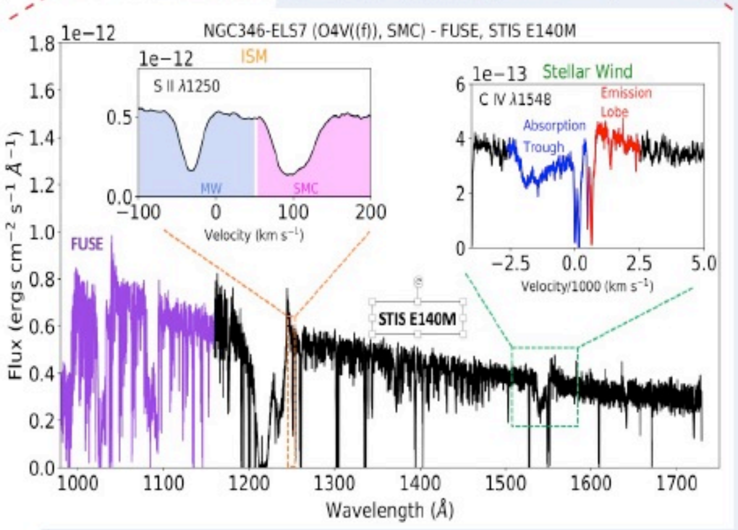
- An operating observatory
- Capable science instruments
- Scientific drivers (demand)
- Adequate staffing and user support
- Appropriate funding
- Common purpose & teamwork

ULLYSES: Ultraviolet Legacy Library of Young Stars as Essential Standards

- Ongoing ~1000 orbit Director's Discretionary program
- Ultraviolet spectroscopic library of young high- and low-mass stars
- Uniformly samples the 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
- Frequent public releases of enhanced data products

Region	Instrumental modes
LMC and SMC	COS/G130M/1096 (brightest O stars) COS/G130M/1291 + COS/G160M/1611 or STIS E140M STIS/E230M/1978 (O9 I – B9 I only) STIS/E230M/2707 or COS/G185M/1953 + 1986 (B5-9 I)
Sextans-A and NGC 3109	COS/G140L/800
Survey T Tauri stars	COS/G130M/1291 + COS/G160M/1589+1623 STIS/G230L + STIS/G430L + STIS/G750L
Monitoring T Tauri stars	COS/G160M/1589 + 1623 + COS/G230L/2635 + 2950





ULLYSES

- 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 64 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

Region	# ULLYSES targets	# AR targets	# ULLYSES orbits
LMC	98	55	225
SMC	65	65	220
Sextans-A	3	6	~37
NGC 3109	3	0	~15
Lupus	27	4	142
Cha I	12	3	98
ϵ Cha	1	1	12
η Cha	4	3	19
Orion OB1	10	0	45
∑ Ori	3	0	16
CrA	2	0	10
Monitoring CTTS	4	0	100
TOTAL	**233**	**137**	**981**

FOR MORE INFORMATION, VISIT
https://ullyses.stsci.edu

Please Share Your Science with the Public

- STScI provides support for sharing your findings with the public. Please visit
  - http://www.stsci.edu/news/scientist-resources

- Simplified email based system will initiate a process with the news team

Observatory and Instrument Update

Spacecraft Status

- High confidence in operations beyond 2025
- Current engineering efforts are extending time in 3-gyro mode
  - 3 (of 6) Gyros remain functional although one (G3) has higher drift rate
    - Has resulted in higher acquisition failure rates; operational and software mitigation efforts have improved this with additional improvements expected
  - Remaining gyros are enhanced devices with lifetimes expected to be >20 years
  - 1-Gyro mode available and tested; models predict operations into 2030s
  - <u>TAC should assume 3-gyro mode for Cycle 30</u>
- HST orbit stable well beyond 2030
- Power, thermal, communications, etc. retain significant redundancy→ 2030+ *possible!*

HST Instruments

- HST supports four science instruments
  - ACS = Advanced Camera for Surveys (installed 2002; SM3b)
  - COS = Cosmic Origins Spectrograph (installed 2009; SM4)
  - STIS = Space Telescope Imaging Spectrograph (installed 1997; SM2)
  - WFC3 = Wide Field Camera 3 (installed 2009; SM4)

- For TAC purposes, the <u>performance of these instruments has been basically stable since 2009</u>
- More information:
  - https://www.stsci.edu/files/live/sites/www/files/home/hst/_documents/HST-Booklet.pdf
  - https://hst-docs.stsci.edu/hsp/hubble-space-telescope-science-policies-group-and-peer-review-information/general-info-getting-started/hubble-and-its-instruments
  - https://www.stsci.edu/hst/instrumentation

Advanced Camera for Surveys (ACS)

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

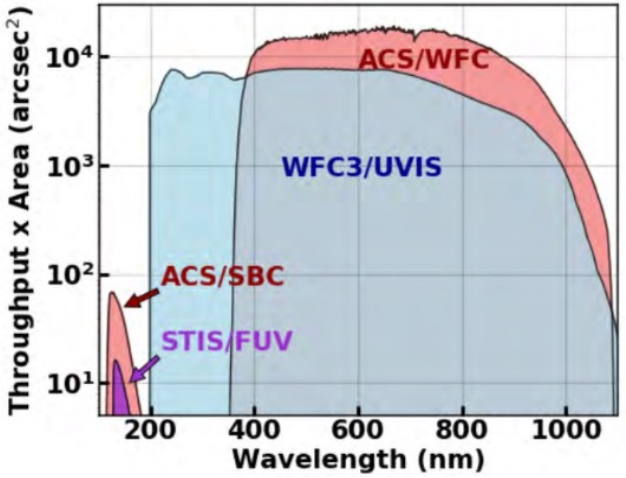
Wide Field Channel (WFC)

- 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

Please see the ACS Instrument Handbook for more detailed information on ACS capabilities.
https://hst-docs.stsci.edu/display/ACSIHB/

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



Cosmic Origins Spectrograph (COS)

- COS provides low to medium resolution spectroscopy from 800 to 3200 A.
- Has a fixed 2.5 arc second diameter aperture
- High sensitivity for observing faint sources
- Spectroscopy down to 800 A with the blue modes

COS Overview

Far Ultraviolet (FUV)

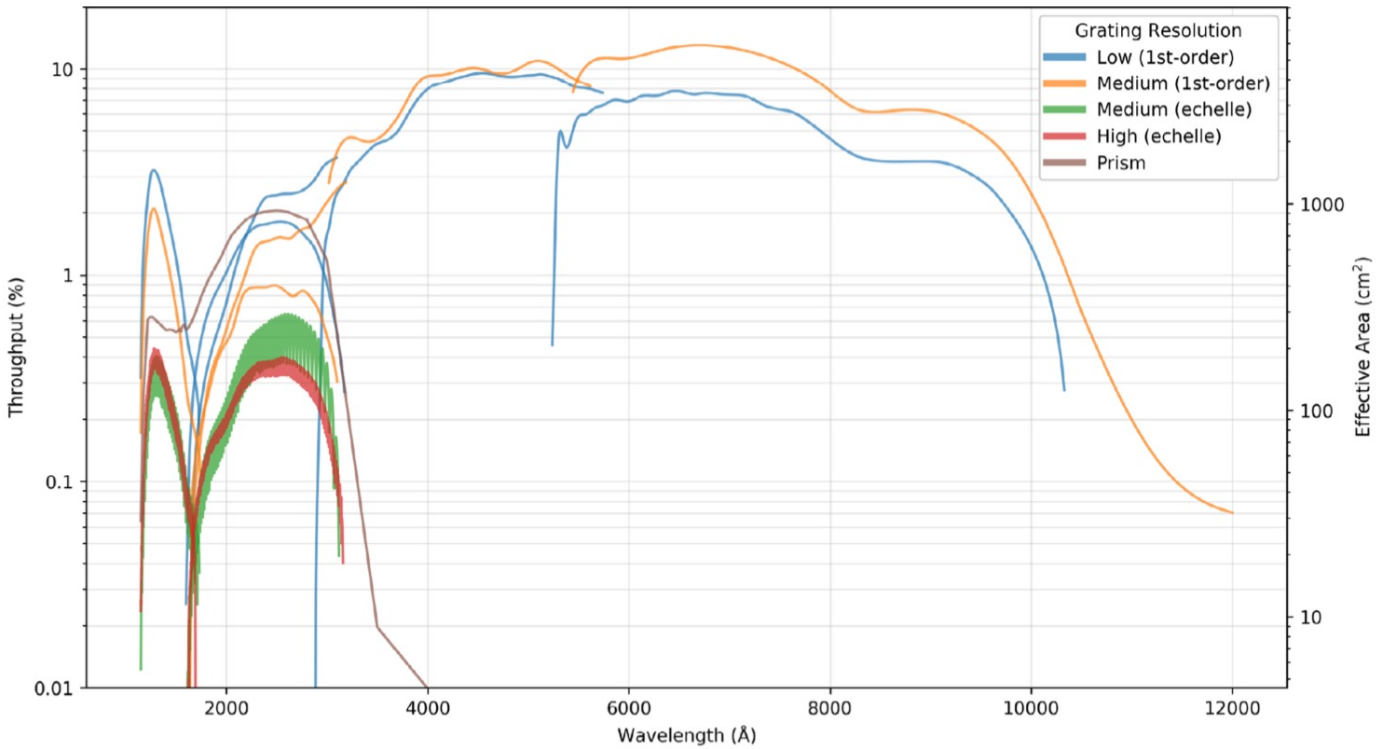
- Medium Resolution mode:
  - $R \approx$ 15,000-21,000
  - $\lambda \approx$ 900-1800 Å
- Low Resolution mode:
  - R ≈ 1,500-4,000
  - $\lambda \approx$ 800-2050 Å
- Effective area ≈ 1800-3000 cm^{-2}
- Three gratings:
  - G130M, G160M, G140L
- Pixel format: 16384 x 1024

Near Ultraviolet (NUV)

- Medium Resolution mode:
  - $R \approx$ 15,000-24,000
  - $\lambda \approx$ 1700-3200 Å
- Low Resolution mode:
  - R ≈ 2,100-2,900
  - $\lambda \approx$ 1650-3200 Å
- Effective area ≈ 600-750 cm^{-2}
- Four gratings:
  - G185M, G225M, G230L
  - G285M (available but unsupported)
- Pixel format: 1024 x 1024

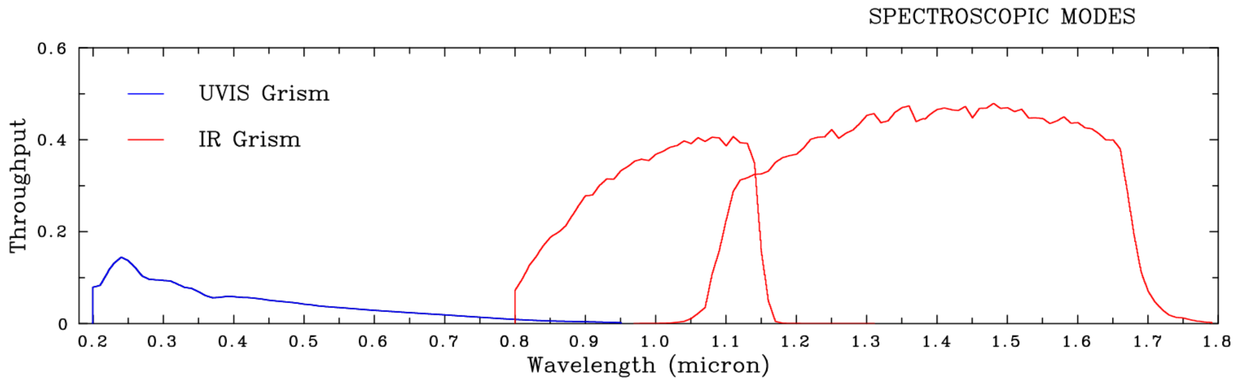
Space Telescope Imaging Spectrograph (STIS)

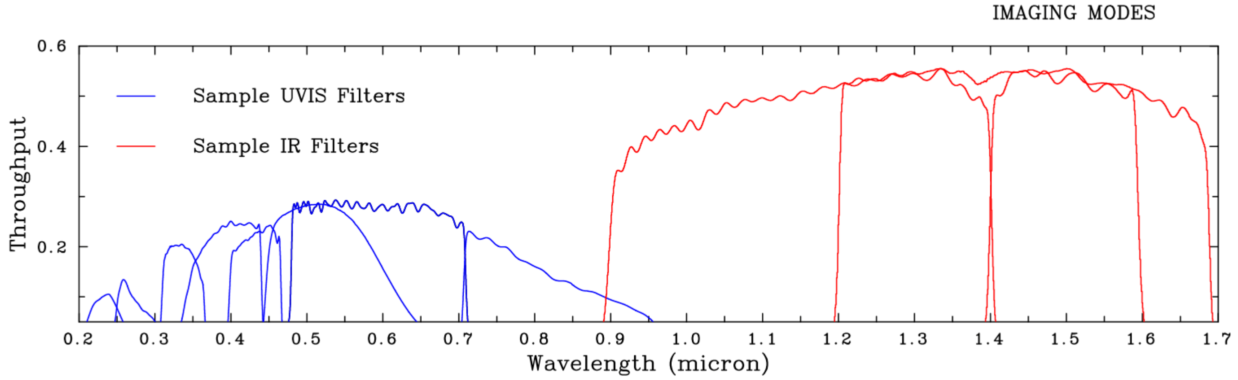
- STIS UV and visible imaging and low to high resolution spectroscopy with a variety of apertures.
- Has a coronagraphic mask and occulting bars
- Time-tag mode in the UV allows time-resolved observations
- Spatial scanning with the CCD allows high SNRs to be obtained while avoiding saturation
- High spatial resolution in the UV and visible



Wide Field Camera 3 (WFC3)

- Two channels: UVIS operating between 2000 to 10000 A, and IR operating between 0.9 to 1.7 microns.
- High resolution imaging from 2000 A to 1.7 micron with a wide complement of filters
- Grism spectroscopy providing low resolution spectra at high spatial resolution in the UV/visible and IR
- Spatial scanning by slewing during an exposure to achieve high SNR photometry while avoiding saturation with direct imaging
- Grism scanning by slewing during an exposure to provide extremely high SNR spectra





Science Instruments Status

- Engineering estimates give high confidence for long term operation beyond 2025
  - >95% COS and WFC3, >85% for ACS and STIS
- Re-designed management of COS FUV detector extends life to ~2030
- Graceful aging of CCD detectors
  - Charge transfer efficiency degradation mitigated by flashing and corrected at the pixel level with algorithms of increasing sophistication
  - Vast majority of defective pixels (warm, hot, dead) mitigated through extensive monitoring, reference files, and appropriate algorithms
- Changes in flat fields and sensitivities monitored and addressed in calibration pipelines
- Drifts in focus and alignment corrected by both mechanism motions and calibration updates

Challenges to Efficiency – Time Constrained Science Programs

- Approximately 20% of science visits in Cycles 24 and 25 had timing constraints of a few orbits or less; this has declined only slightly in Cycles 26 – 29 with the completion of two large programs having strong timing constraints
- Creates conflicts between science programs and may cause programs to have delayed execution dates
- Results in fewer flexible visits later in the plan that can be moved forward to fill schedule gaps and thus a less efficient program overall
- We ask proposers to avoid constraints and special requirements that are not scientifically required
- Starting in Cycle 26 proposers are required to justify their constraints at the Phase I stage

Please Leave the Scheduling and Technical Issues to Us

- In reviewing Cycle 30 proposals, Panels and TAC should focus on the best science

  - Constraints/Special Requirements must be scientifically justified
  - However, leave scheduling constraints to us to consider in the context of the entire Cycle 30 pool of recommended proposals
  - Also, do not concern yourselves with the suitability of observing programs if we do not remain in the nominal 3-gyro configuration
    - That is, assume current state of Hubble performance!