



STScI | SPACE TELESCOPE
SCIENCE INSTITUTE

EXPANDING THE FRONTIERS OF SPACE ASTRONOMY

The ULLYSES Director's Discretionary Program

Charting Young Stars' Ultraviolet Light with Hubble

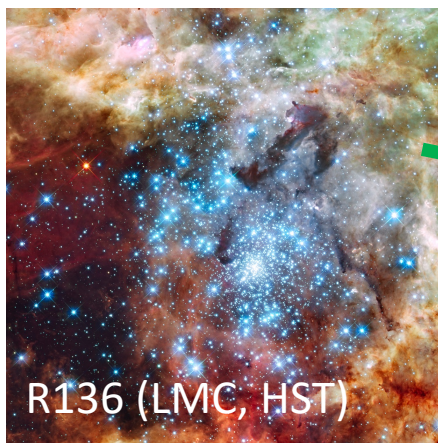
Julia Roman-Duval, Jo Taylor, Alex Fullerton, Will Fischer, Rachel Plesha
& the ULLYSES implementation team

STUC Meeting – November-December 2023



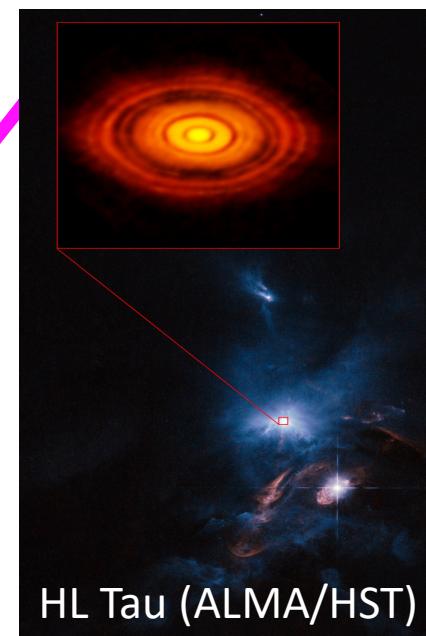
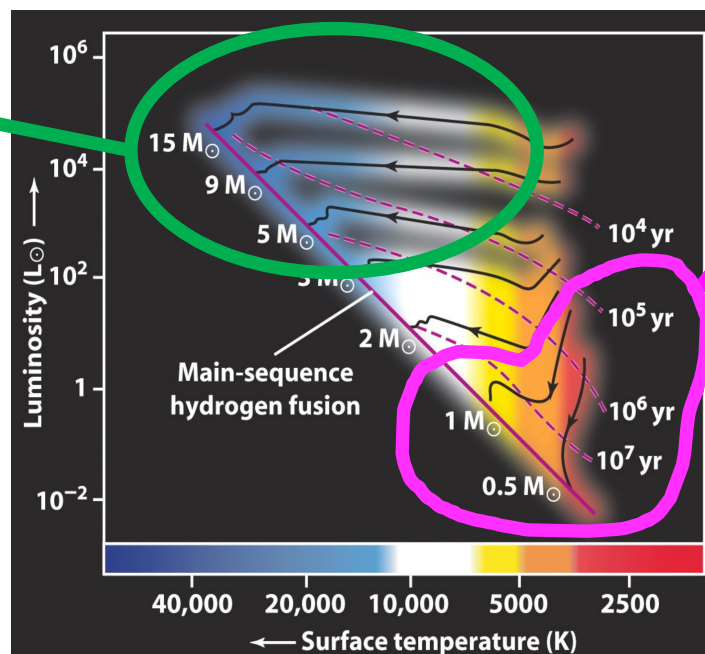
ULYSSES at a Glance

- ULYSSES = Ultraviolet Legacy Library of Young Stars as Essential Standards
- Director's Discretionary Hubble program to obtain a spectroscopic reference sample of young low and high mass stars – Largest HST program ever executed (~1000 orbits)
- The scientific framework of the program was designed by the community, via a UV Legacy Working Group and the program is being implemented by a dedicated team at STScI



R136 (LMC, HST)

~500 orbits to extend the spectroscopic library of O and B stars to low metallicity (10% - 50% solar)

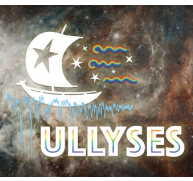


HL Tau (ALMA/HST)

~500 orbits to obtain a spectroscopic library and time monitoring of T Tauri stars (younger than 10 Myr, mass < 1 M_o)



Outline



- Program status and miscellaneous updates (Julia Roman-Duval)
- Target sample updates (Julia Roman-Duval)
- Observing updates
 - Massive stars (Alex Fullerton)
 - T Tauri stars (Will Fischer)
- Update on data products and data releases (Jo Taylor)



Program Status and Misc. Updates



Program Status



- **ULLYSES observing was COMPLETED in July 2023** (🥳😎🥳)!!!
 - **986 orbits**
 - **220 targets**
 - **86 phase IIs**
- **7 data releases**
 - ✓ **DR6** occurred on March 21, 2023
 - Advertised on Twitter, web, and by email
- **DR7/close-out planned for December 12, 2023**
 - The team has been hard at work preparing close-out since the last STUC meeting in May
 - See what's included in DR7 later in the talk (Jo Taylor for the Data Products team)



Program Status (Cont'd)



- Survey paper will be split into two papers:
 - Paper I: Goals, Design, and Initial Results
 - Paper II: Observations, Calibration, and High-Level Science Data Products
 - Both papers are advanced near the point of circulation to a larger group (including SAC)
- Several ULLYSES-focused workshops and conference sessions, e.g.,
 - AAS splinter session at AAS #241 (June 2022)
 - Lorentz workshop on massive stars organized by IAU-G2 and XSHOOTU collaboration in late 2022;
 - Protostars and Planets VII in 2023;
 - XSHOOTU workshop in Prague, September 2023



ULLYSES: Continuing the Voyage of Discovery



- [ULLYSES workshop](#) being organized at STScI
March 11-14, 2024
 - ✓ Hybrid format (but in-person participation encouraged)
 - ✓ 26 invited speakers confirmed
 - ✓ Slots for 8 contributed talks + 12 posters
 - Abstract submissions open until January 5, 2024
 - Registration open December 5 — February 12
 - ✓ 1-2 hands-on sessions + un-conference session
 - Contemplating hack session on HWO science cases
 - ✓ See event webpage in link or QR code

ULLYSES: Continuing the Voyage of Discovery

[View All Events >](#)

Workshops

MON 11 MAR 2024 - **THU 14** MAR 2024

Location

Space Telescope Science Institute (STScI)
3700 San Martin Drive
Baltimore, MD 21218

Contact Information

Have questions? Please contact [STScI](#).

Description

The observational phase of the HST Ultraviolet Legacy Library of Young Stars as Essential Standards (ULLYSES) program initiated by the STScI Director in 2019 was completed in 2023. ULLYSES provides a legacy spectroscopic UV dataset for studying star formation both locally and across the universe. The program consists of two distinct components: ultraviolet-optical-infrared spectroscopy of T Tauri stars in star-forming regions of the Milky Way, and ultraviolet spectroscopy of metal-poor OB stars in the Magellanic Clouds and other nearby low metallicity dwarf galaxies. The dataset will establish a foundation for studying the final stages of low-mass star formation, and obtaining fundamental stellar parameters as a function of metallicity for high-mass stars. Although ground-based data contain much information necessary to advance understanding of these phenomena, ultraviolet spectroscopy provides powerful diagnostic information that cannot be obtained in any other way. This ambitious, multi-faceted project used 987 HST orbits in Cycles 27-29, making it the single largest program ever executed by HST.

The ULLYSES observations are complemented by community-led, ancillary ground-based surveys that will considerably enhance the legacy value of the program. With the completion of the ULLYSES observations and ancillary programs, a variety of data products are now available, both from STScI and from the community. Initial results based on ULLYSES data are beginning to appear in the refereed literature. The time is ripe to review plans for scientific exploitation of the data, and launch new plans for research in additional areas that utilize these foundational data, e.g., interstellar medium, star and galaxy formation at high redshift, and star-planet interactions.

Consequently, this workshop is conceived as a celebration of the "end of the beginning" of ULLYSES and a forum for the community to decide next steps. Its goals are to provide:

- a review of (and an advertisement for) the data collected under the auspices of ULLYSES;
- a status update on current on-going work;
- a forum for planning a roadmap to fulfill the promised goals of ULLYSES, and for planning community involvement in the analyses, through existing collaborations or otherwise;
- a forum to discuss what other data should be collected in the near term to further enhance the legacy value of the ULLYSES dataset

By fulfilling these goals, the workshop will also serve to engage additional members of the community who are not already involved with analyses of ULLYSES data, and to engage more junior members of the community, including those who might leverage ULLYSES data in HWO (Habitable Worlds Observatory) programs.

In keeping with the workshop format, discussion of planning and practicalities will be emphasized over the dissemination of scientific results, though the latter will also have a place. Throughout, talks and discussions will emphasize the role and importance of UV spectroscopy, although the synergistic information from other wavelengths is often necessary. Of special interest will be how the advances described in the [HST Ultraviolet Legacy Science Definition WG report](#) will be realized.

[ULLYSES workshop webpage](#)





Publications by the Community (massive stars so far)



- 18 peer-reviewed publications by the community (and counting)

Massive star publications

| First author | Bibcode | Title |
|-----------------|---------------------|---|
| Daniel Pauli | 2022A&A...659A...9P | The earliest O-type eclipsing binary in the Small Magellanic Cloud, AzV 476: A comprehensive analysis reveals surprisingly low stellar masses |
| Paul Crowther | 2022arXiv220708690C | ULLYSES and Complementary Surveys of Massive Stars in the Magellanic Clouds |
| Calum Hawcroft | 2023arXiv230312165H | X-Shooting ULLYSES: Massive stars at low metallicity. III. Terminal wind speeds of ULLYSES massive stars |
| Jorick Vink | 2023A&A...675A.154V | X-Shooting ULLYSES: Massive stars at low metallicity. I. Project Description |
| Paul Crowther | 2023arXiv231107642C | Mapping the core of the Tarantula Nebula with VLT-MUSE. III. A template for metal-poor starburst regions in the visual and far-ultraviolet |
| Jiří Krtička | 2023arXiv231101257K | New mass-loss rates of Magellanic Cloud B supergiants from global wind models |
| Timothy Parsons | MNRAS, submitted | Optically-thick structures in early B type supergiant stellar winds a low metallicities |



Publications by the Community (TTS so far)



Low mass star publications

| First author | Bibcode | Title |
|---------------------|---------------------|--|
| Carlo Manara | 2021A&A...650A.196M | PENELLOPE: The ESO data legacy program to complement the Hubble UV Legacy Library of Young Stars (ULLYSES). I. Survey presentation and accretion properties of Orion OB1 and σ -Orionis |
| Antonio Frasca | 2021A&A...656A.138F | PENELLOPE. II. CVSO 104: A pre-main sequence close binary with an optical companion in Ori OB1 |
| Dirk Froebrich | 2022MNRAS.510.2883F | A survey for variable young stars with small telescopes - V. Analysis of TX Ori, V505 Ori, and V510 Ori, the HST ULLYSES targets in the σ Ori cluster |
| Catherine Espaillat | 2022AJ....163..114E | The ODYSSEUS Survey. Motivation and First Results: Accretion, Ejection, and Disk Irradiation of CVSO 109 |
| Caeley Pittman | 2022AJ....164..201P | Towards a comprehensive view of accretion, inner disks, and extinction in classical T Tauri stars: an ODYSSEUS study of the Orion OB1b association |
| Parker Hinton | 2022ApJ...939...82H | Far-ultraviolet Flares on Accreting Protostars: Weak and Classical T Tauri Stellar Pair Analysis |
| Nicole Arulanantham | 2023ApJ...944..185A | $\text{Ly}\alpha$ Scattering Models Trace Accretion and Outflow Kinematics in T Tauri Systems |
| Jerome Bouvier | 2023A&A...672A...5B | Stable accretion and episodic outflows in the young transition disk system GM Aurigae. A semester-long optical and near-infrared spectrophotometric monitoring campaign |
| Kevin France | 2023AJ....166...67F | The radial distribution and excitation of H ₂ around young stars in the HST-ULLYSES survey |
| Gangi, M | 2023A&A...675A.153G | PENELLOPE. IV. A comparison between optical forbidden lines and H ₂ UV lines in the Orion OB1b and σ -Ori associations |
| Armeni, A | 2023arXiv230910591A | PENELLOPE V. The magnetospheric structure and the accretion variability of the classical T Tauri star HM Lup |



Target and data sample updates



Archival target additions to the ULLYSES sample



- Added 29 archival T Tauri stars to the sample since DR6 (HST data and target metadata)
 - ✓ Taurus, Upper Scorpius, Lambda Orionis regions
 - ✓ Required a massive re-calibration effort for STIS/CCD data (see DP section)
- Added 52 archival massive stars in the LMC, SMC and Leo A (HST data and target metadata)

| | ULLYSES targets | Archival targets | Exposures |
|---------------|-----------------|------------------|-------------------------------|
| T Tauri stars | 60 | 80 | 2260 |
| Massive stars | 160 | 198 | 3251 |
| Total | 220 | 277 | 5511 (2252 by ULLYSES) |

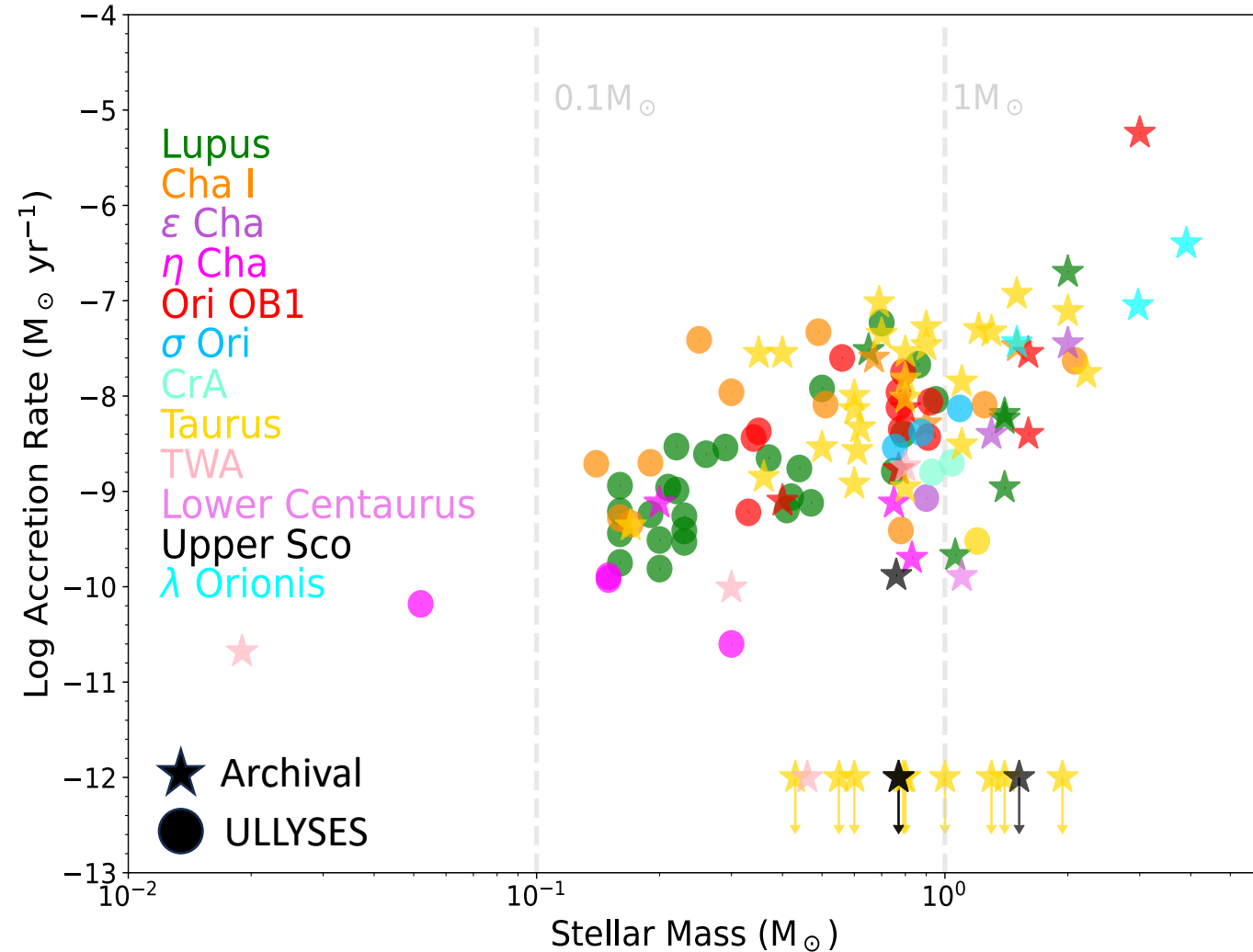


Final ULLYSES sample of T Tauri stars



ULLYSES sample (including archival targets) covers T Tauri stars parameter space:

- Age: 0.8 — 10 Myr
- Stellar mass: 0.02 — 4 M_{\odot}
- Accretion rate: $<10^{-12}$ — $10^{-5} M_{\odot} \text{ yr}^{-1}$



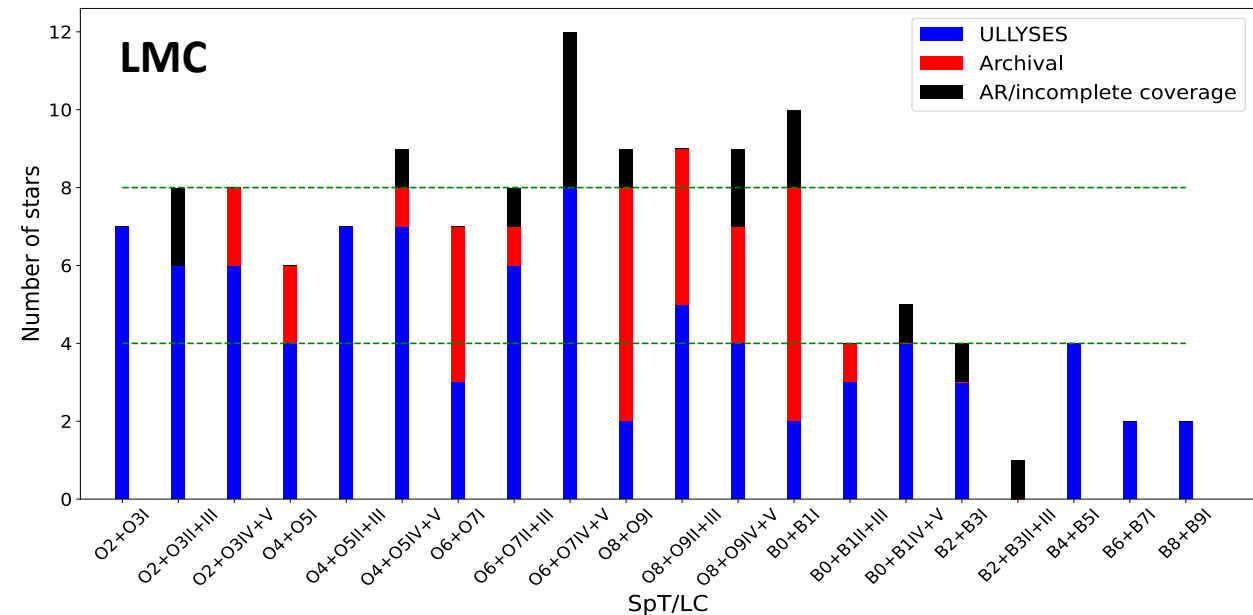
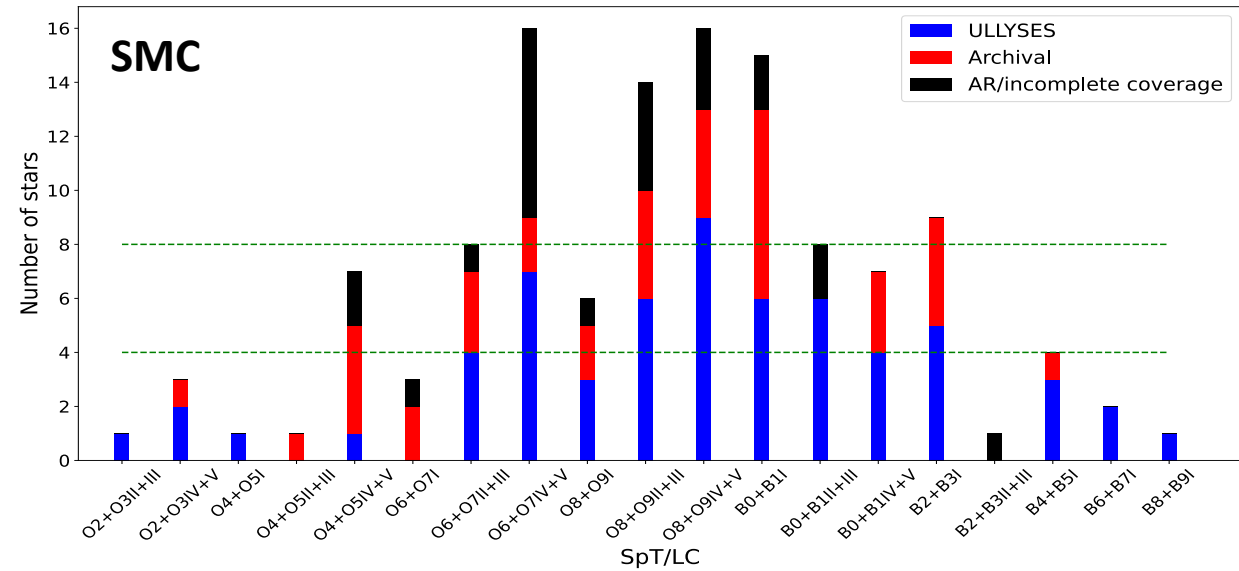


Final ULYSSES sample of massive stars



ULYSSES sample (including archival targets) covers massive star parameter space:

- At least 4 stars per bin of SpT/LC for O and early B stars
- 1-2 stars/bin for late B super-giants
- 83 “Extra” archival targets relevant to the sample found in MAST (including recent programs) with similar wavelength coverage added to ULYSSES database





Technical Observing Updates

Massive Stars



Observing Status for massive stars – 100% complete

| LMC | Number | Complete | % |
|----------|--------|--------------------------|------|
| Targets | 94 | 94 | 100% |
| Orbits | 255 | 255 | 100% |
| Programs | 32 | 32 | 100% |
| HOPRs | 16 | 27 orbits repeated (11%) | |

| SMC | Number | Complete | % |
|----------|--------|--------------------------|------|
| Targets | 60 | 60 | 100% |
| Orbits | 210 | 210 | 100% |
| Programs | 19 | 19 | 100% |
| HOPRs | 19 | 46 orbits repeated (22%) | |

- ✓ 500 orbits
- ✓ 160 targets
- ✓ 54 phase IIs

| Galaxy | Metallicity | WFC3 Pre-Imaging * | | COS G140L/800 Spectroscopy | | |
|-----------|-----------------------|--------------------|----------|----------------------------|--------|----------|
| | | Orbits | Status | Targets | Orbits | Status |
| NGC 3109 | 0.1 – 0.2 Z_{\odot} | 4 | Complete | 3 | 9 | Complete |
| Sextans A | < 0.1 Z_{\odot} | 2 | Complete | 3 | 20 | Complete |

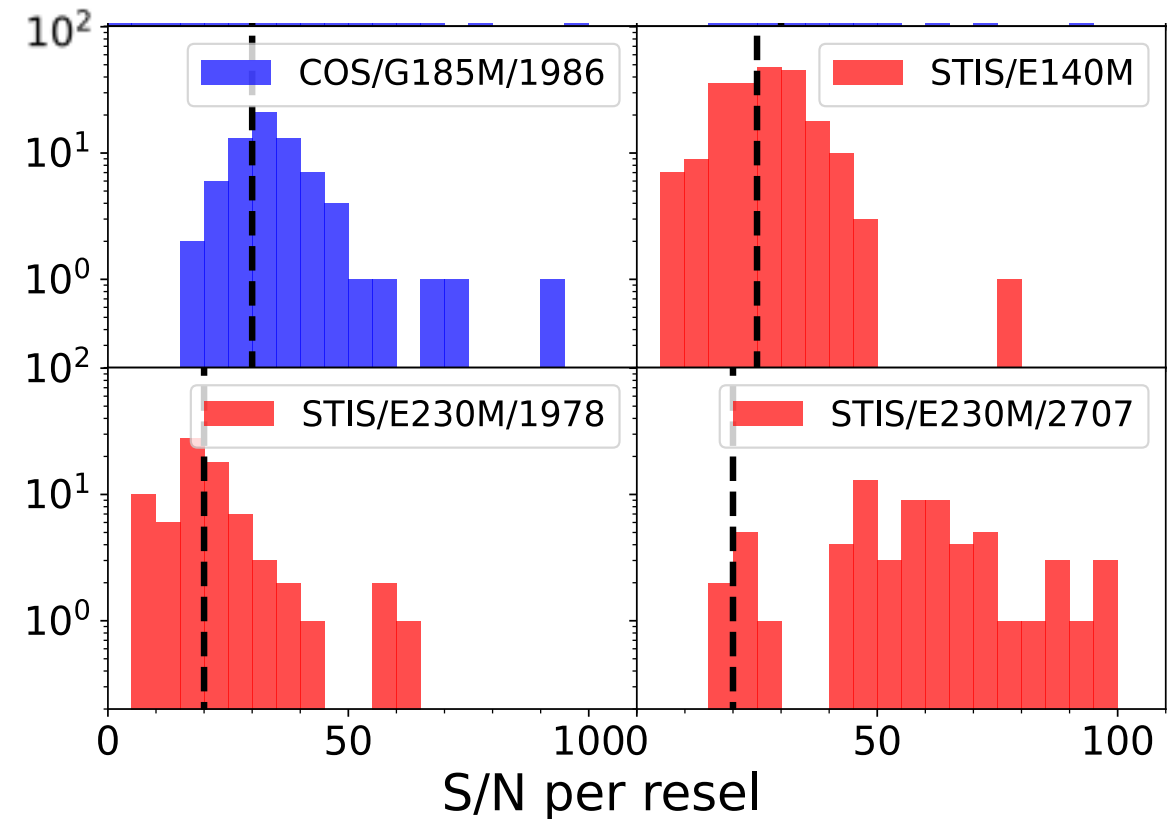
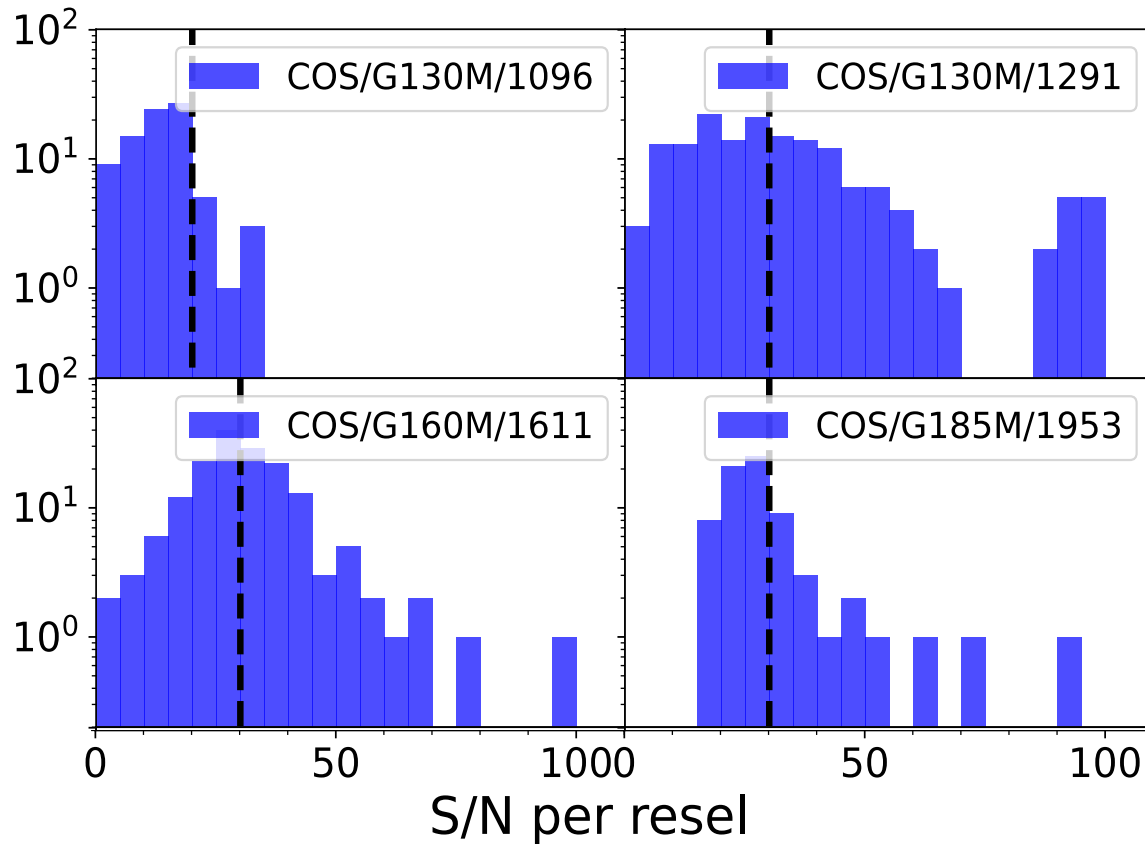
*F225W, F275W, F336W, F475W, F814W



Outcome of Massive Star Observations



- Signal-to-noise in HLSPs for DR7 (per resel) is on target
- Implemented G130M/1096 top-ups for 11 stars to raise SNR

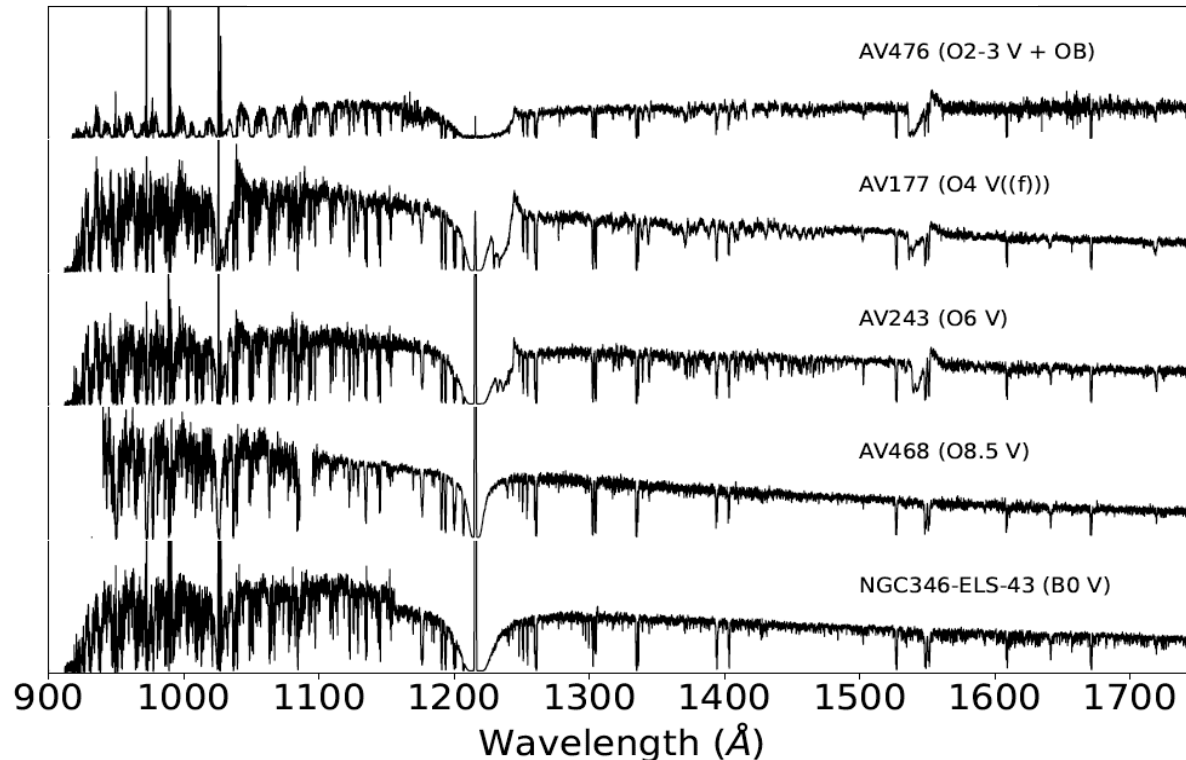




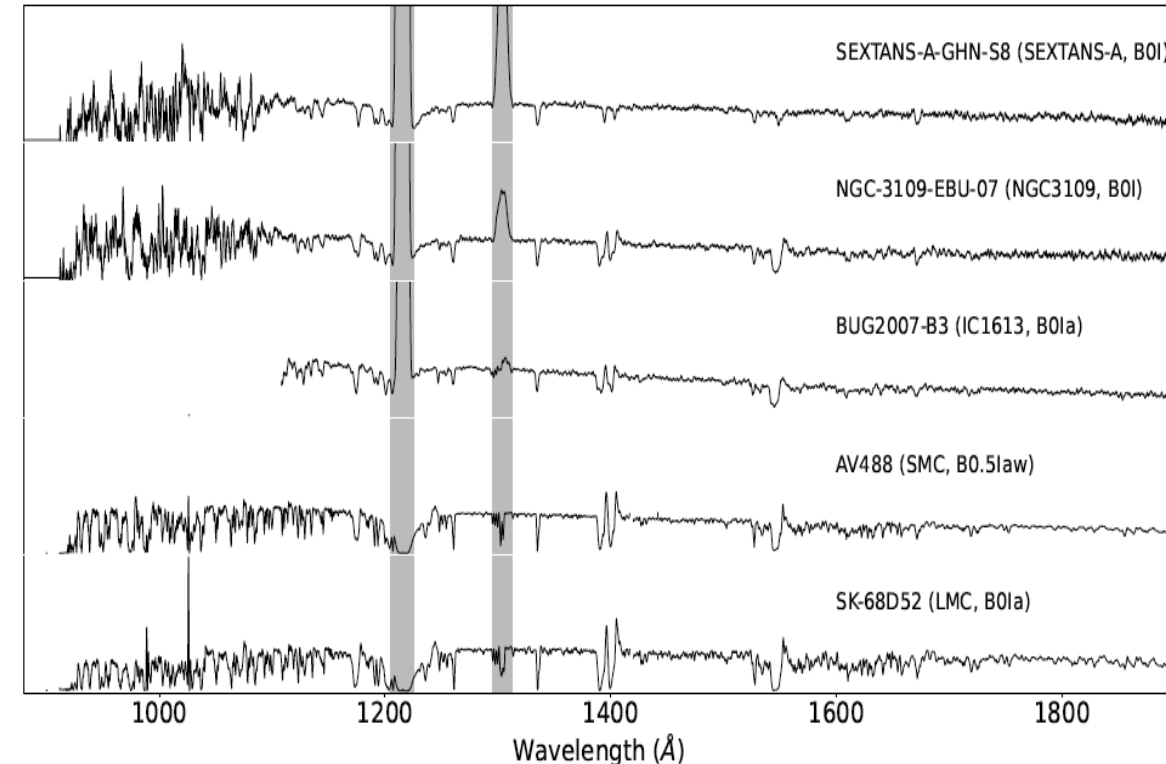
Outcome of Massive Star Observations

- Accomplished goal of uniform wavelength coverage, medium spectral resolution, uniformly excellent data quality
- Observations yield the desired spectroscopic reference sample that will help characterize the winds and photospheres of massive stars at low metallicity

Spectra vs Temperature (SMC, O stars)



Spectra vs Metallicity (B supergiants)

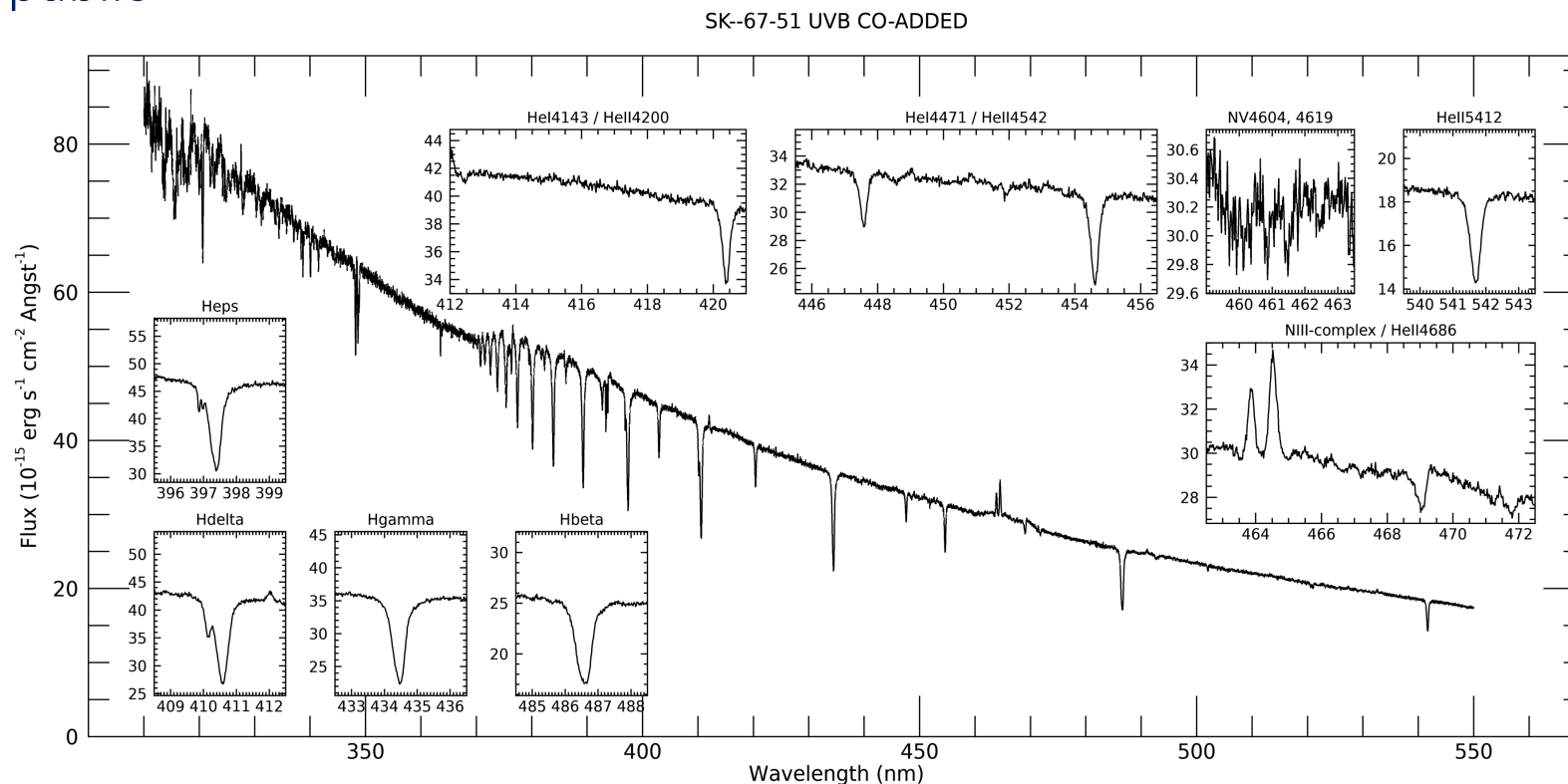




Coordinated programs for Massive Stars



- X-SHOOTU program led by IAU-G2
 - VLT X-Shooter for all ULLYSES massive stars in the “core sample”
 - Program complete; Products delivered to STScI team for formatting and ingestion
 - ULLYSES-formatted version of XSU products created; Waiting on ESO DR to ingest into MAST and release to public





Technical Observing Updates

Low Mass Stars



Observing Status for Low Mass Stars – 100% complete

| Survey TTS | Number | Complete | % |
|------------|--------|--------------------------|-----|
| Targets | 58 | 56 | 97* |
| Orbits | 390 | 390 | 100 |
| Programs | 24 | 24 | 100 |
| HOPRs | 9 | 50 orbits repeated (13%) | |

*2 targets dropped after failure

| Monitor TTS | Number | Complete | % |
|-------------|--------|------------------------|-----|
| Targets | 4x2 | 8 | 100 |
| Orbits | 96 | 96 | 100 |
| Programs | 8 | 8 | 100 |
| HOPRs | 7 | 7 orbits repeated (7%) | |

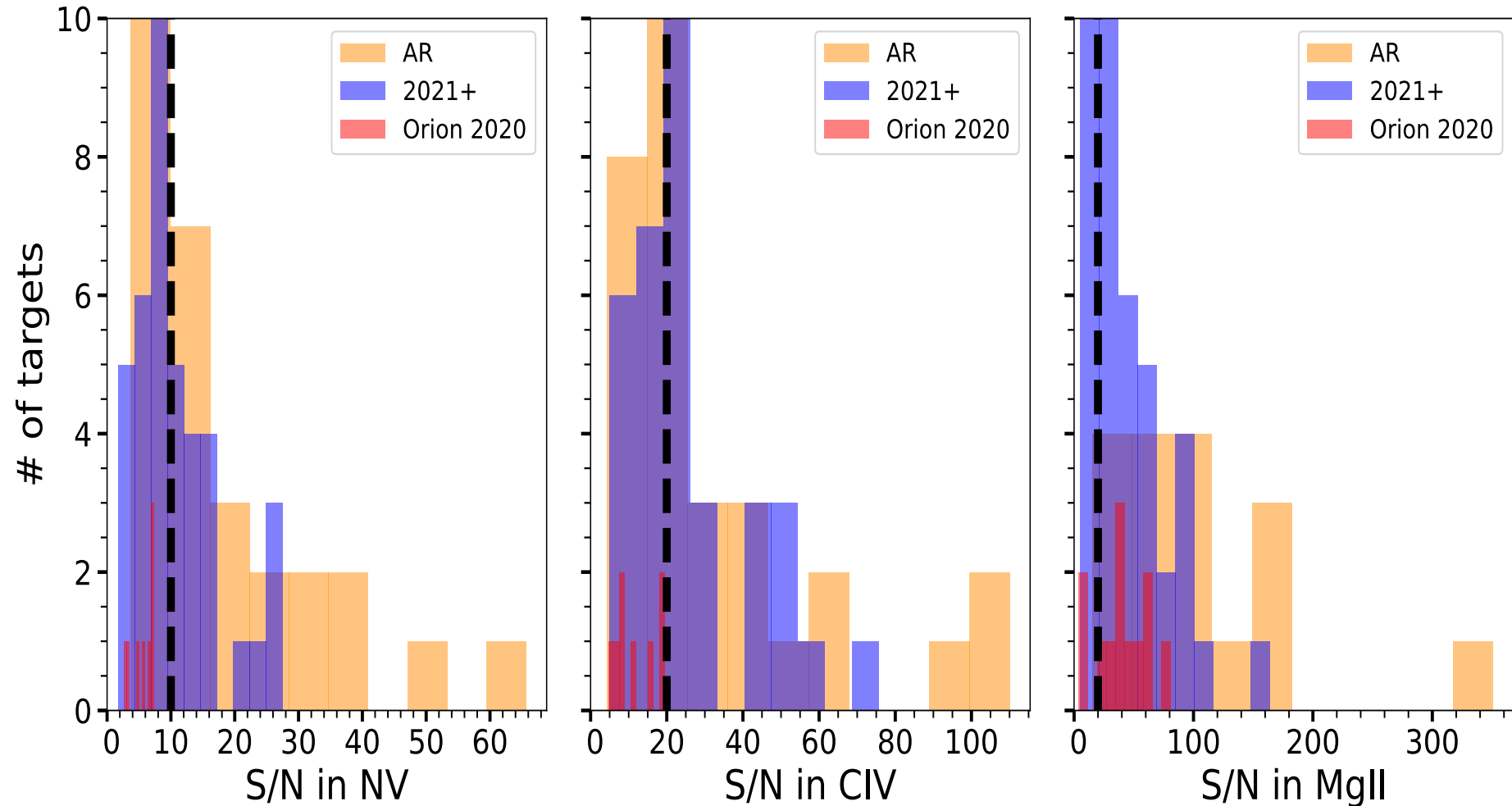
- ✓ 486 orbits
- ✓ 60 targets
- ✓ 32 phase IIs



Outcome of "Survey" T Tauri Star Observations



- S/N is on target after adjustment on extinction performed after the Orion observations in December 2020
- AR sample reaches SNR on par with ULLYSES sample



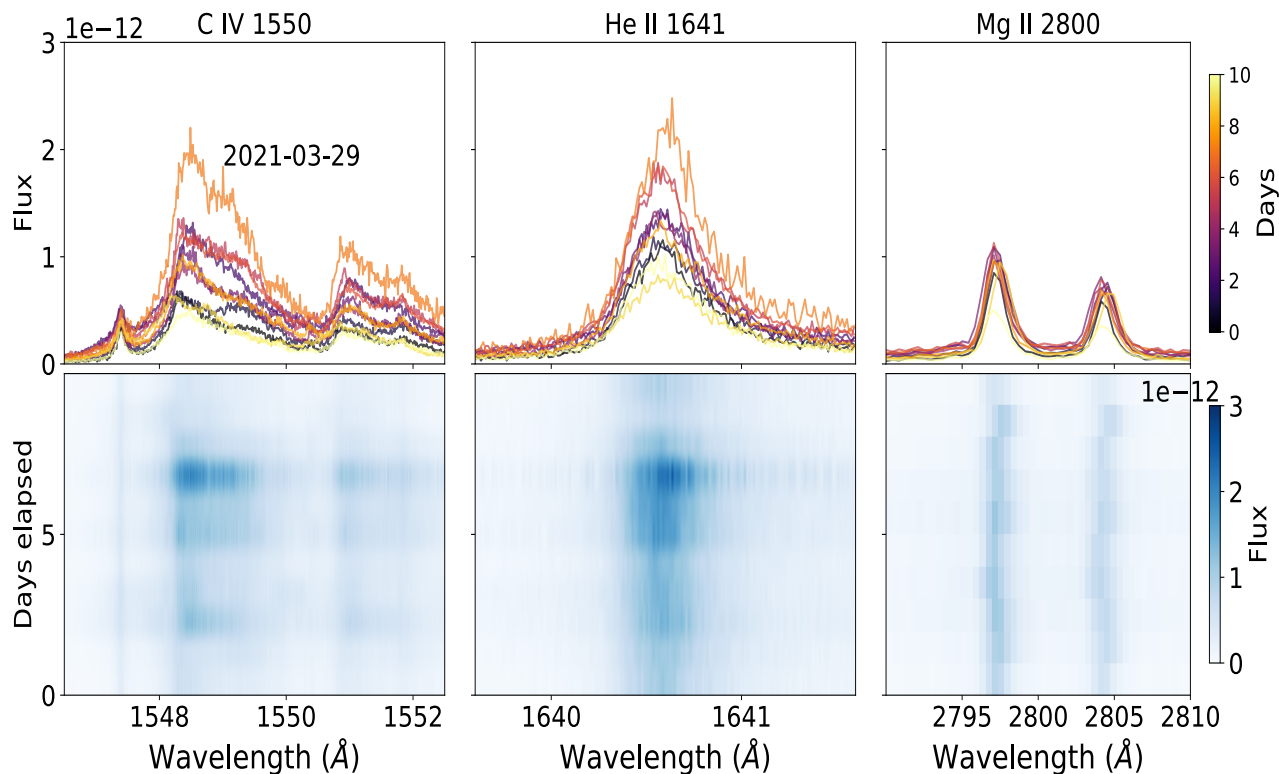


Outcome of Monitoring Observations of T Tauri Stars

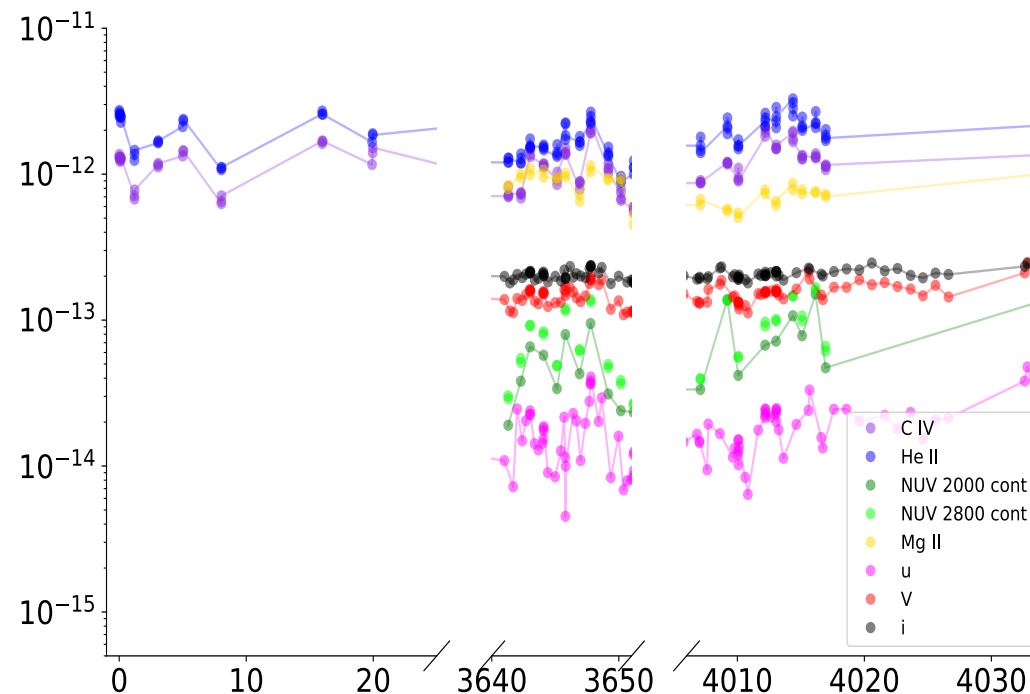


- Monitoring observations of 4 T Tauri stars achieved S/N and cadence goals to inform variability of accreting stars on timescales ranging from minutes to years

TW Hya — 2021 epoch



TW Hya — Peak line fluxes vs time





Coordinated Programs for T Tauri stars



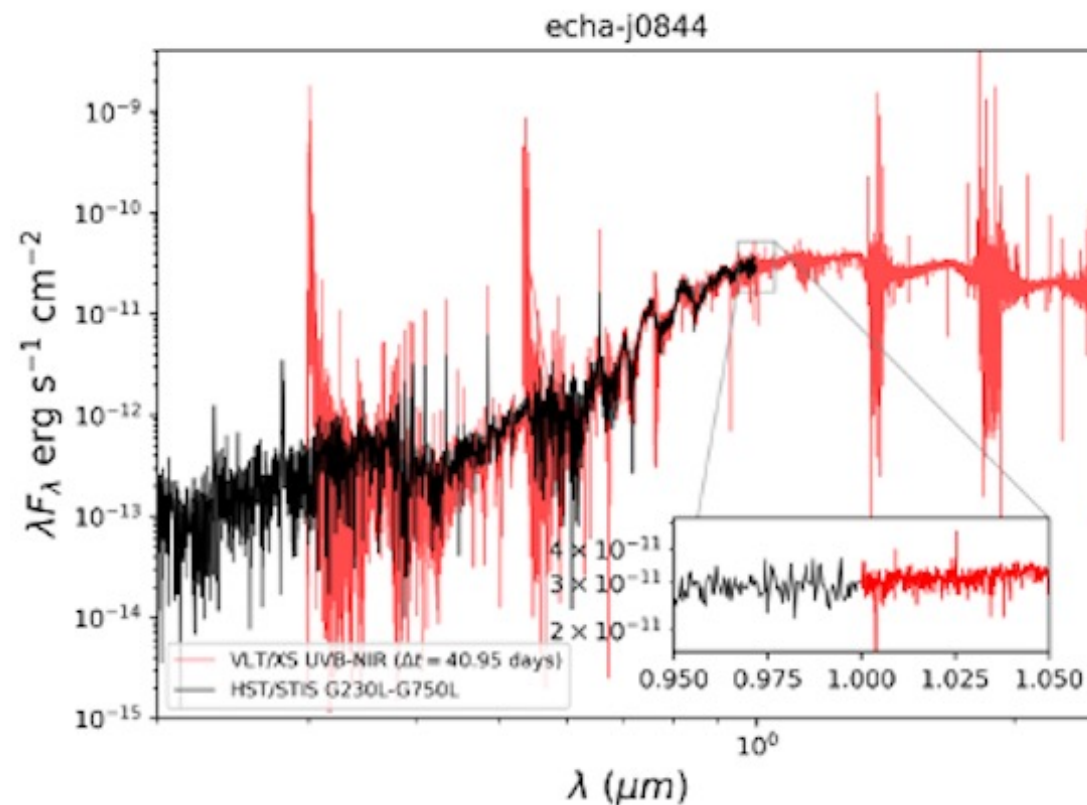
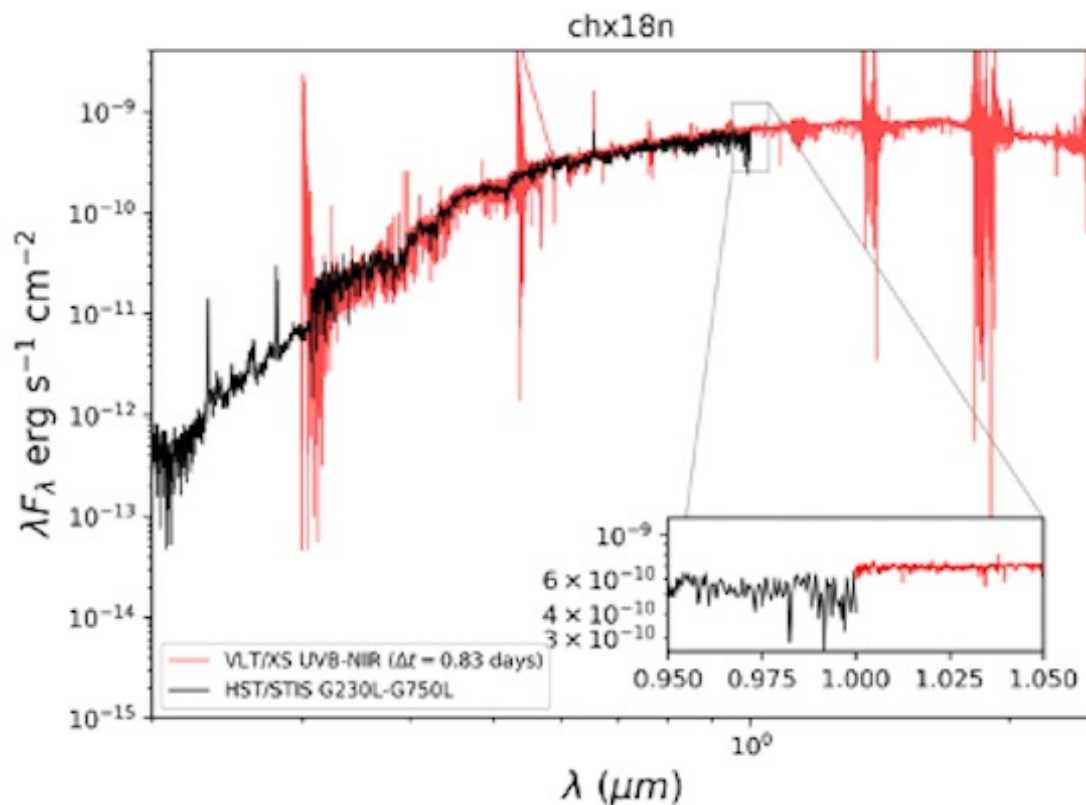
- Monitored stars only
 - Chandra/XMM-Newton (X-ray; accretion)
 - CFHT/SPIRou spectro-polarimetry (magnetic field mapping)
- Survey and monitored stars
 - PENELLOPE program on VLT: X-Shooter, ESPRESSO, UVES (accretion, extinction, stellar properties, kinematics)
 - IRTF (calibration of MIR accretion diagnostics in preparation for JWST observations of deeply embedded protostars)
 - LCO photometric monitoring (variability context + health & safety for COS and STIS)
 - ✓ LCO time-series delivered as part of ULLYSES DRs
 - TESS (high cadence variability context, March-June 2021 only)



Coordinated Programs for T Tauri stars

- PENELLOPE ESO DR on 10/26/2023

- ✓ STScI team working on formatting and ingesting the products to be hosted in MAST ULLYSES database (same timeframe as workshop: March 2024)





ULLYSES Data Products



DR7– Database, Catalog, and Website Updates

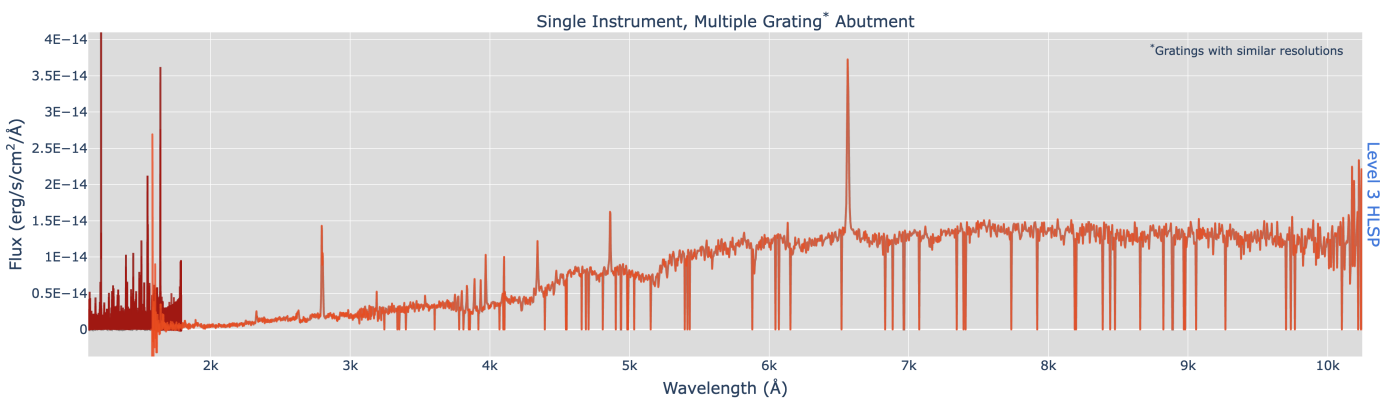
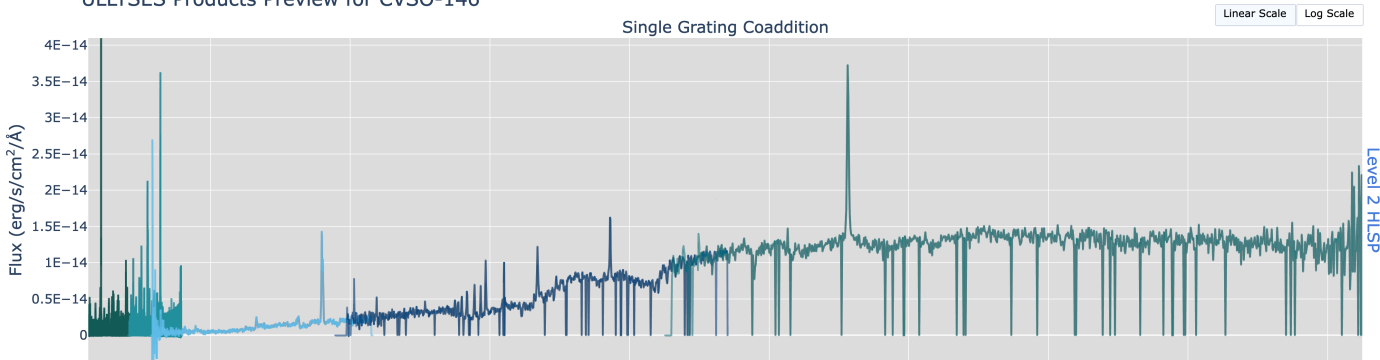
- Homogenize target naming convention; HLSP filenames will change as a result
- Add target metadata for new-to-DR7 massive stars and T Tauri stars
- Add new fields to the database/catalog
 - Intrinsic colors of massive stars
 - Gaia parameters (ID, coordinates, photometry, parallax)
 - Radial velocity
- Make interactive preview plots of our coadded products (using the python package *plotly*)
- Expand and improve documentation on website



Previews in Plotly (interactive)

Full preview spectrum

ULLYSES Products Preview for CVSO-146



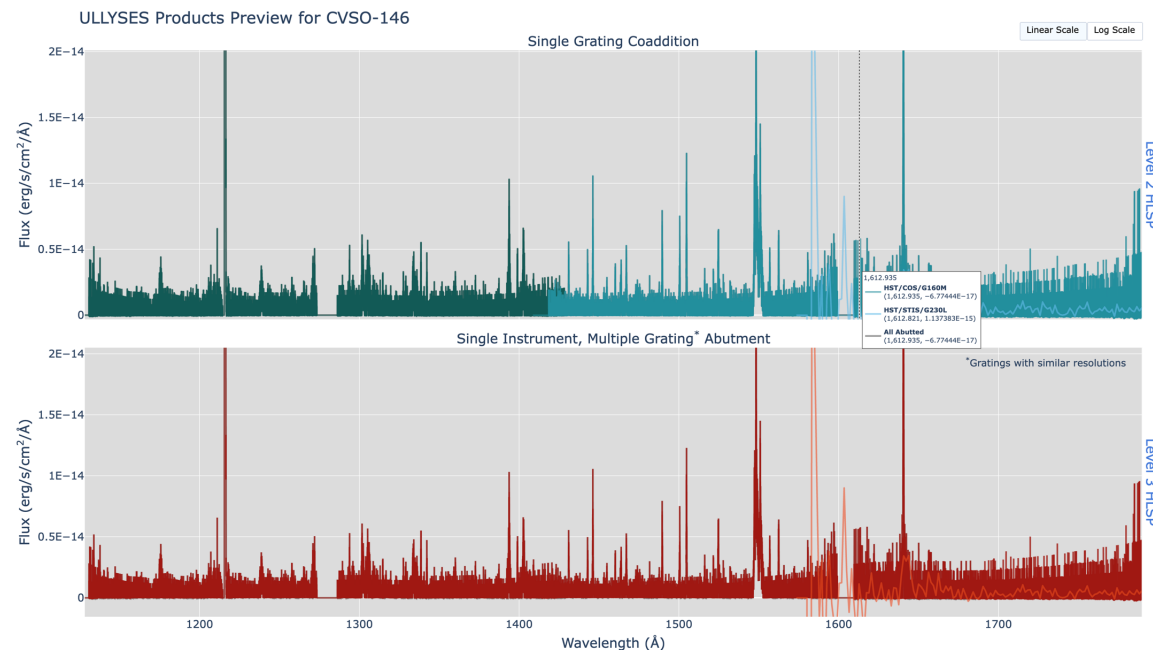
Interactively:

- Zoom in on features
- Hover for more information
- Isolate specific combined spectra
- Jump to documentation about the products
- Switch between linear and log scaling

- HST COS G130M
- HST COS G160M
- HST STIS G230L
- HST STIS G430L
- HST STIS G750L
- HST COS G130M&G160M
- HST STIS G230L&G430L&G750L
- All Abutted Spectra (Level 4 HLSP)

CVSO 146 (K6, Ori OB1)

Zoom on FUV

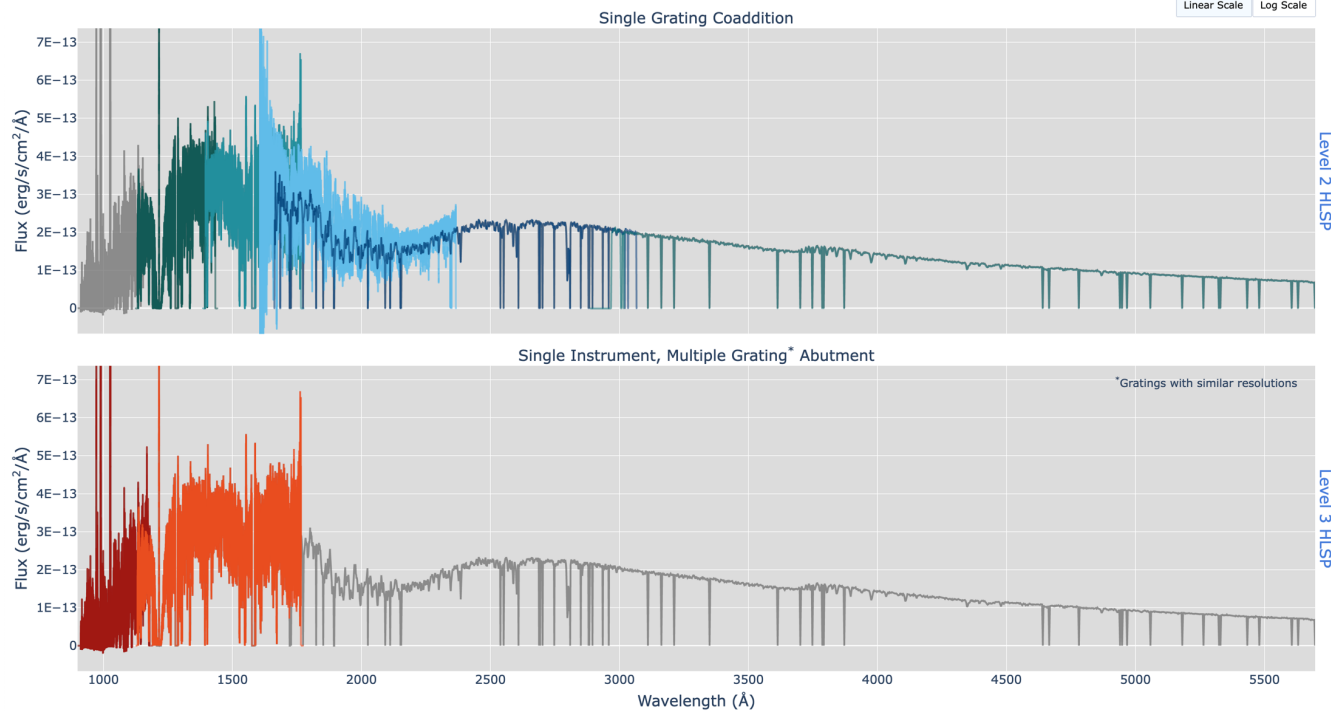




Previews in Plotly (interactive)

Full preview spectrum

ULLYSES Products Preview for SK-68D26



Interactively:

- Zoom in on features
- Hover for more information
- Isolate specific combined spectra
- Jump to documentation about the products
- Switch between linear and log scaling

SK -68 26 (LMC, BC2 Ia)

Zoom on UV





DR7– Code Updates



- Fix issue with not co-adding all data from multi-extension STIS files (documented in DR6 notes)
- Use the *stisblazefix* tool for select STIS echelle datasets
 - Will improve the flux calibration in overlaps between orders
- Fix DQ=2048 flagging for certain STIS/echelle orders
 - New orders implemented by STIS team were DQ-flagged out of co-adds by SDQ = 2048 flag. This fix will **restore the flux of interesting orders in co-added STIS spectra**
- Add COMMENT keywords to headers
 - Data quality comments, or special calibration applied to that target
- **New abutment strategy** that better prioritizes grating usage and transition points
 - Will avoid wavelength gaps for certain abutted spectra



DR7– Code Updates (Continued)



- Rename level 3 HLSPs (abutted coadded spectra of the same instrument & resolution) to “*aspec.fits*” instead of “*cspec.fits*” which is already used for level 2 HLSPs (co-adds within a single grating)
 - This resolves confusion in the community about what the *cspec* products included
- Improve the ULLYSES software packages:
 - Deploy packages on PyPI so that it can be installed with *pip*
 - **Documentation** in code and README files for easier usability
 - **Jupyter notebooks** (tutorials, walkthroughs)
 - New generic wrapper to **co-add any COS or STIS data** (with list of files as input)



DR7– Data Product Updates



- Inspect and include *sx1* spectra from SNAP program 16230
 - Extends some ULLYSES massive star spectra in the LMC and SMC with STIS/CCD NUV-optical coverage for, e.g., dust extinction studies
- Inspect and recalibrate archival STIS data for 74 TTS
 - Improves data quality of archival datasets, e.g., STIS/G750L de-fringing
- Deliver 21 new serendipitous time-series products for TTS
 - Avoids co-adding varying spectra; provides data products to study TTS variability
- Deliver last of LCOGT photometry as time-series products



DR7 – Data Product Updates (Continued)

- Flag and discard vignetted regions in COS/NUV data (first 200pix of each stripe)
 - Improves flux calibration in spectral regions where blue side of one stripe overlaps with red side of another
 - Exception for 4 monitoring TTS stars where overlapping spectra are used to scale and correct flux in vignetted regions (Mg II line)
- Prepare for ingestion of XSHOOTU and PENELLOPE community products

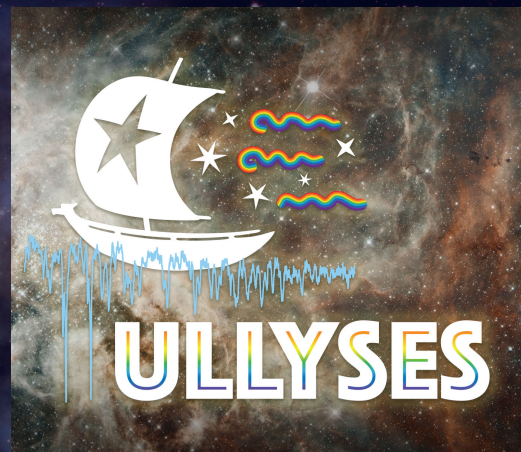


Possible Updates in 2024



- The COS team is in the process of updating the FUV geometric distortion and walk correction
- These updates affect the subsequent calibration of all data— most importantly for the wavelength calibration in ULLYSES spectra
 - With new calibration, RMS will be on order of 1-2 pixels (currently 3). Edges of spectra will improve even more
- Depending on the COS team's timeline for updating reference files, the ULLYSES team may decide to deliver HLSPs with updated COS data sometime in 2024
- This situation and timeline are still in flux, so a 2024 DR is **not** guaranteed (ULLYSES resources at ST will diminish greatly in 2024)

Questions and Feedback





Acknowledgements



ULYSSES Core Implementation Team (CIT)



Julia Roman-Duval
(CIT Lead)



Jo Taylor
(DP Lead)



Rachel Plesha
(DP Deputy Lead)



Will Fischer
TTS Observing Lead (OB star Observing Lead)



Alex Fullerton
(Pre-imaging)



Alessandra Aloisi
(Public Outreach)



Chris Britt
(DP/software)



Ivo Busko
(Observing, DP)



Travis Fischer
(DP)



Elaine Frazer
(DP)



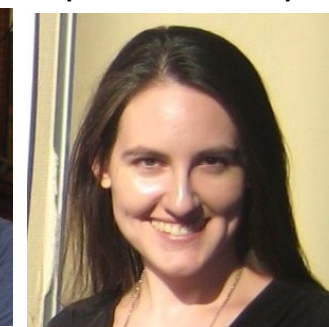
Svea Hernandez
(Observing)



Alec Hirschauer
(DP, software)



Robert Jdrzejewski
(ETC, Obs)



TalaWanda Monroe
(DP)



Charles Proffitt
(Observing)



Adric Riedel
(Targets, DP)



David Sahnou
(DP)



Richard Shaw
(Observing)



Ravi Sankrit
(Targets, Observing)



Linda Smith
(Observing)



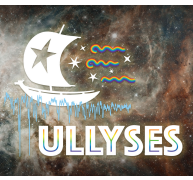
Debopam Som
(Website)



Dan Welty
(Targets, Obs, DP)

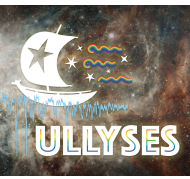


Brian York
(DP)



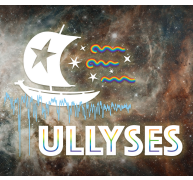
Other STScI staff involved

- Tricia Royle (Program Coordinator)
- Dave Adler and scheduling team
- Scott Fleming, Peter Forshay, David Rodriguez, Brian Erickson, Brian Charlow, and Syed Gilani (MAST)
- OPO team



Science Advisory Committee (SAC)

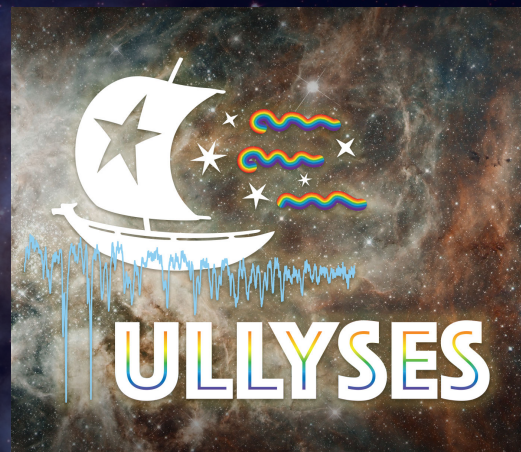
- SAC composition (Massive stars/T Tauri stars)
 - Jean-Claude Bouret (Laboratoire d'Astrophysique de Marseille)
 - Catherine Espaillat (Boston University)
 - Chris Evans (ESA@STScI, formerly UK Astronomy Technology Centre)
 - Kevin France (University of Colorado Boulder)
 - Miriam García (Instituto Nacional de Técnica Aeroespacial)
 - Chris Johns-Krull (Rice University)
 - Derck Massa (Space Science Institute)
 - Joan Najita (National Optical Astronomy Observatory)



Other community members

- Carlo Manara (ESO) for providing updated accretion rates and extinction values
- Jesus Hernandez and Javier Serna (UNAM) for providing TESS-based rotational periods
- ODYSSEUS team (led by Greg Herczeg) for interesting discussions about targets and coordination
- IAU G2 (massive stars) for useful feedback on implementation
- Derck Massa for providing vetted observations of SNAP program 16230

Thank you





Back-up Slides



ULLYSES Deliverables

WEBSITE

ullyses.stsci.edu



Program information
Observing status and schedule
Data product description
List of coordinated programs
Data release (DR) notes

PUBLIC CODEBASE

github.com/spacetelescope/ullyses
github.com/spacetelescope/ullyses-utils

Spectral coaddition and splicing
Spectral time-series
Custom calibration routines
Custom calibration configuration files
Target metadata, alias information
Automatic webpage generation
Product data quality checks



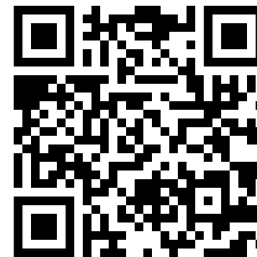
MAST DATABASE

Target metadata
Observational metadata

ULLYSES SEARCH FORM

mast.stsci.edu/search/ui/#/ullyses

Built on Missions MAST framework
Uses database and custom API



ULLYSES HLSPs

High level science data
products
See next slide



Description of Data Products

- **Flux-weighted co-added spectra** obtained with the same grating
 - E.g., different exposures with the same or different cenwaves and FP-POS
- **Spliced (abutted) spectra** between different gratings and instruments
 - E.g., FUSE + HST, COS + STIS
- **Vetted FUSE spectra** for LMC/SMC massive stars
- **Custom calibrated STIS G230L and CCD spectra of T Tauri stars**
 - In particular, **de-fringing of G750L spectra**, improved hot pixel flagging, and re-extraction of targets (as needed) and companions
- **Photometric (LCOGT) and spectroscopic (HST) time-series spectra**
 - For 4 T Tauri stars monitored over time, time-series spectra down to 10s sampling
- **Drizzled WFC3 images** of NGC 3109 and Sextans A



Data Dissemination Platforms

Data can be downloaded from 3 different platforms

ULLYSES SEARCH FORM (HLSPs only)



Built on Missions MAST framework
Uses database and custom API

MAST DISCOVERY PORTAL (HLSPs and contributing data)



See instructions at the MAST
HLSP collection

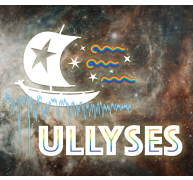
MAST ULLYSES HLSP COLLECTION (HLSPs only)



Uses MAST portal interface

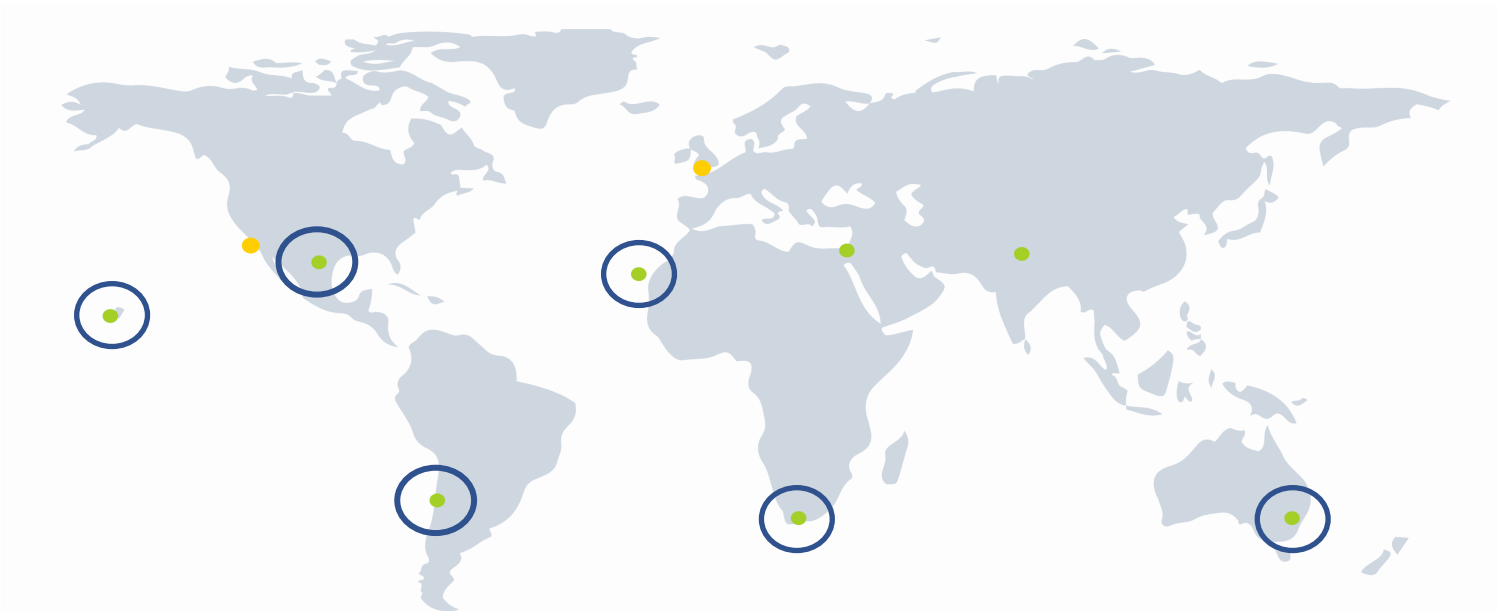
The background of the slide is a deep space image featuring a dense field of stars of various colors (blue, white, yellow) and a large, complex nebula with swirling clouds of gas and dust in shades of blue, purple, and brown. The text "Status of coordinated programs" is centered in the middle of the image.

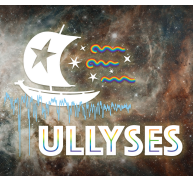
Status of coordinated programs



LCOGT Photometric Monitoring

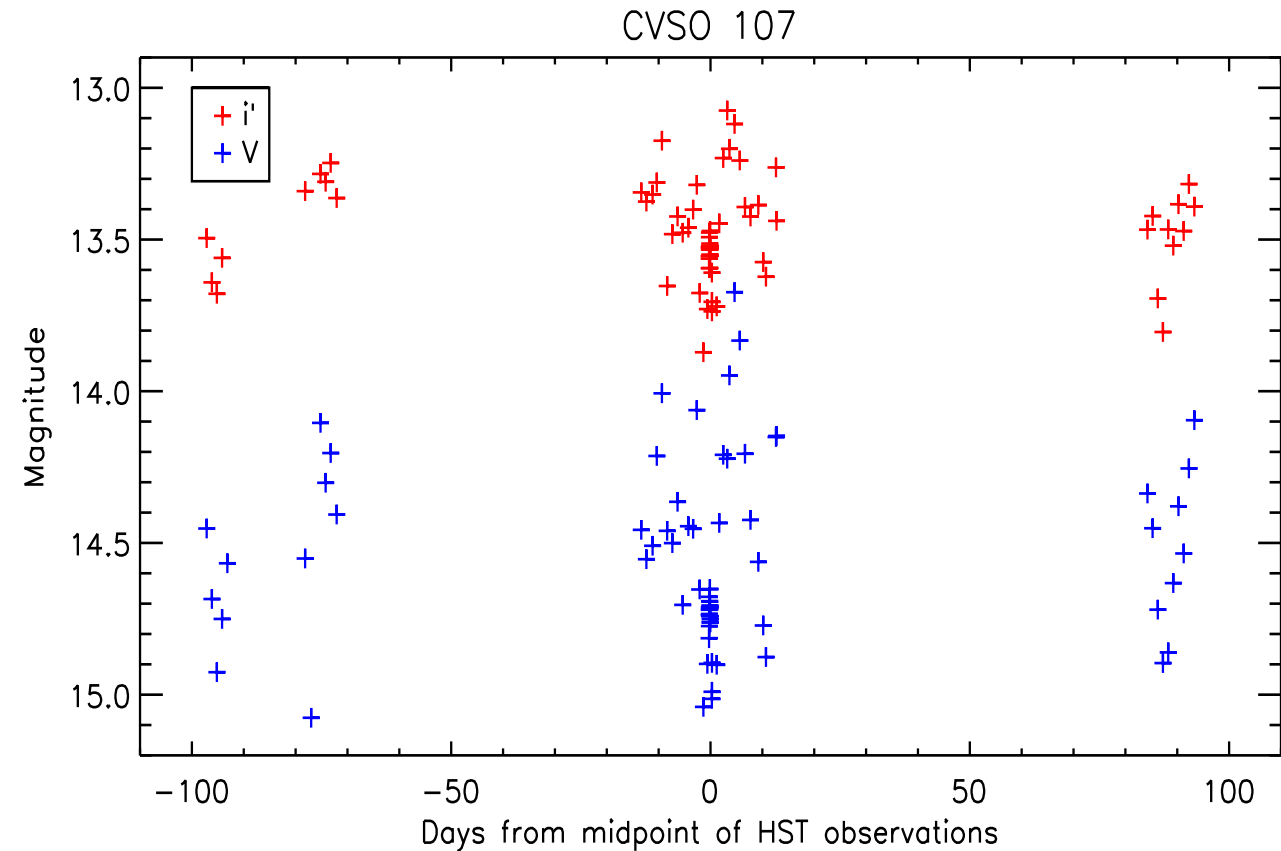
- STScI implementation team designed a large LCOGT program to perform photometric monitoring in V, i' for survey and u', V and i' for monitoring T Tauri stars
 - Program was accepted and started late August 2020
 - 545h approved in 2020B, 2021A, B, 2022A so far
- LCOGT has 0.4m robotic telescope network around the World (almost continuous longitudinal coverage)





LCOGT Photometric Monitoring

- Cadence:
 - 1x/day 3 months before/after HST epoch
 - 1x/day 10 days before/after HST epoch
 - 10x/period of the 1 (3) periods centered on the HST observations for the survey (monitored) stars
 - 15 min cadence during the HST observations
- $S/N > 10$ for all targets/bands



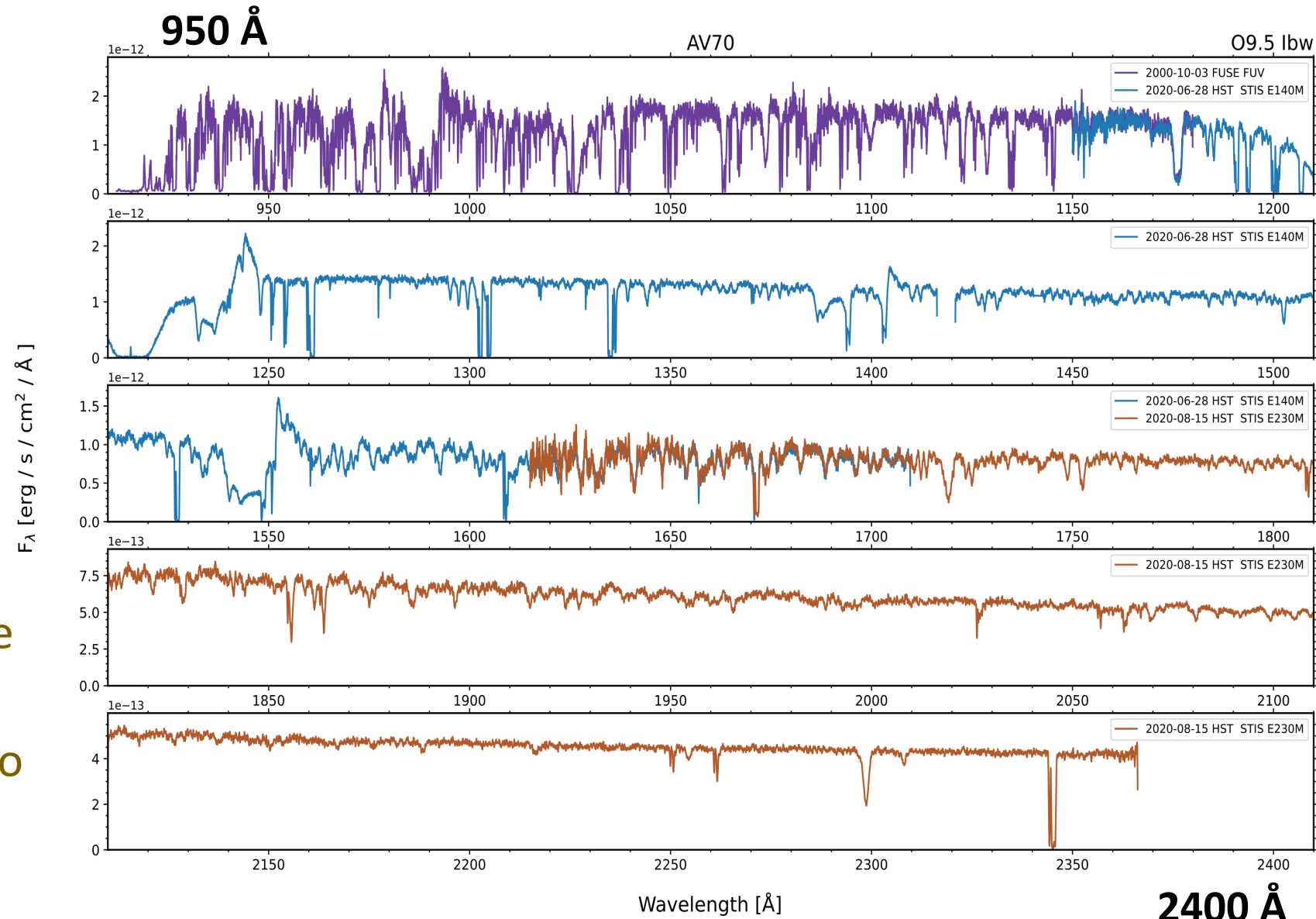


► Bright O stars only

 All stars

➤ Super-giants of temperature class O9 and later only

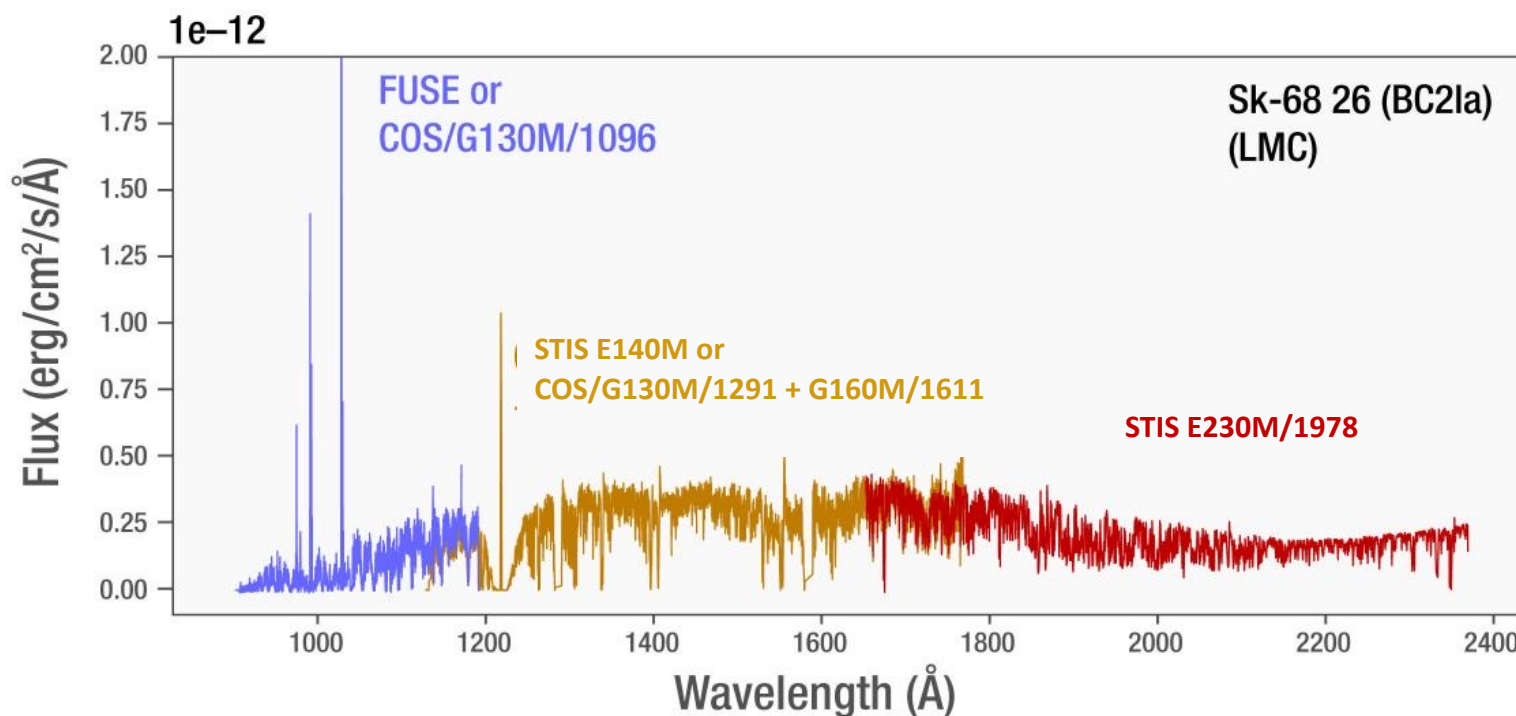
- B5 and later supergiants also get coverage up to 3100 Å with COS or STIS





Observing Strategy – LMC/SMC Massive stars

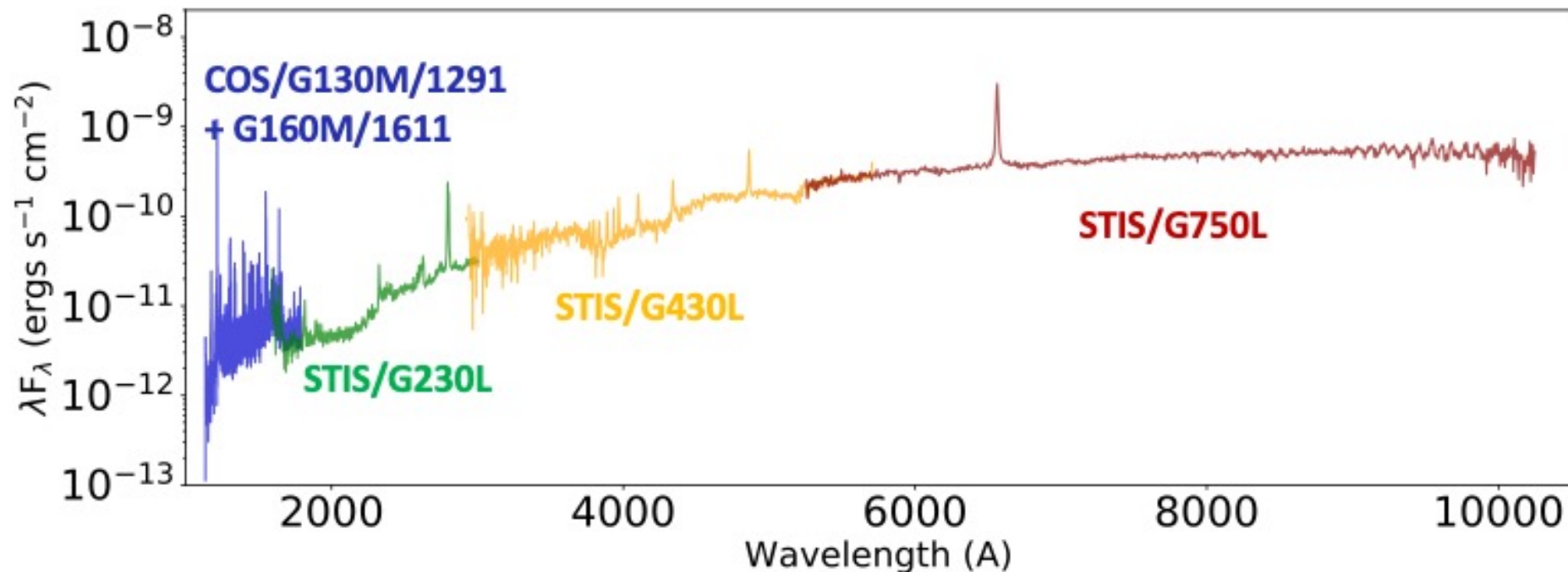
- FUV coverage from 1140 Å to 1800 Å with COS/G130M/1291 + COS/G160M/1611, or STIS/E140M for brighter stars
 - Coverage includes Ly- α
- Coverage below 1150 Å with archival **FUSE** data, or COS/G130M/1096 if cost is reasonable
- O9-B9 I stars will also be observed with the E230M/1978, extending coverage to 2400 Å (Al III, Fe III)
- B5-B9 I stars will be observed with STIS/E230M/2707 or COS/G185M/1953+1986 (Mg II)
- FUSE or COS/G130M/1096 for:
 - 70/92 O stars in LMC
 - 54/54 O stars in SMC
- Stars observable in < ~8000s with E140M offloaded to STIS (longer COS lifetime, better spectral resolution)

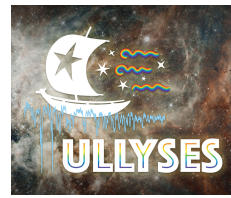




Observing Strategy – T Tauri Stars

- Survey stars:
 - Medium-resolution UV coverage 1140-1780 Å with COS/G130M/1291 + COS/G160M/1589+1623
 - NUV coverage at low resolution with STIS/G230L
 - Optical-NIR with STIS G430L and G750L
- Monitoring stars:
 - COS/G160M/1589+1623 + COS/G230L/2950





ULLYSES S/N Requirements

- **Massive SMC/LMC Stars**
 - COS/G130M/c1096: S/N = 20 / nine-pixel resel at 1080 Å continuum
 - COS/G130M/c1291: S/N = 30 / six-pixel resel at 1150 Å continuum
 - COS/G160M/c1589+1623: S/N = 30 / six-pixel resel at 1590 Å continuum
 - COS/G185M/c1953: S/N = 30 / three-pixel resel at 1860 Å continuum
 - COS/G185M/c1986: S/N = 30 / three-pixel resel at 1980 Å continuum
 - STIS/E140M/c1425: S/N = 20 / two-pixel resel at 1200 Å continuum
 - STIS/E230M/c1978: S/N = 20 / two-pixel resel at 1800 Å continuum
 - STIS/E230M/c2707: S/N = 20 / two-pixel resel at 2800 Å continuum
- **Massive Low Z Stars in Sextans A and NGC 3109**
 - COS/G140L/c800: S/N = 15 / six-pixel resel at 1600 Å continuum
- **T Tauri Stars**
 - COS G130M/c1291 S/N = 15 / six-pixel resel in peak of N V 1239 Å
 - COS G160M/c1611 S/N = 20 / six-pixel resel in peak of CIV 1549 Å
 - STIS G230L/c2376 S/N = 20 / six-pixel resel in peak of Mg II 2800 Å
 - STIS/G430L S/N=20 / two-pixel resel in continuum at 4000 Å
 - STIS/G750L S/N= / two-pixel resel in continuum at 5700 Å



Technical Implementation: BOP procedures for T Tauri stars

- Estimates for UV accretion flux based on published relations scaling emission line and continuum flux with accretion rate.
 - For Bright Object Protection (BOP) screening allow for 4X variability above baseline accretion scaling
 - Bright object magnetic flare rules for M dwarfs will also be applied to M-type T Tauri stars
 - Comparison of active T Tauri stars and main-sequence stars shows magnetic activity and flares scale with bolometric luminosity, and not with accretion. It is the nature of the underlying star that matters.
 - To apply existing flare rules, which depend on U magnitude of target, we use a U value inferred from the spectral type and V magnitude rather than the observed U flux, which is typically dominated by the accretion rather than the spectrum of the underlying star
 - Extinction is applied to the modeled flare spectrum



Community Engagement



13 AR, parallel, or complementary GO programs related to ULLYSES

| Cycle | PID | Orbits | Title | Topic |
|-------|------------------------------|--------|--|--------------------------|
| 27 | GO-15967 PI Chisholm | 49 | Constraining the Stellar Astrophysics Powering Cosmic Reionization: Spectral Templates of Extremely Low-metallicity Main-sequence O-stars | Low-Z massive stars |
| 27 | Multiple PIDs PI C Murray | 500 | Scylla (PI C. Murray, multiple PIDs) – Scylla: A pure-parallel, multi-headed attack on dust evolution and star formation in ULLYSES galaxies | Parallel to LMC/SMC |
| 28 | GO-16233 PI Schneider | 17 | Jets and disk scattering – Spatially resolved optical and FUV observations of AA Tau | CTTS |
| 28 | SNAP-16239 PI Massa | 200 | A NUV SNAP program to supplement and enhance the value of the ULLYSES OB star legacy data | LMC/SMC STIS CCD spectra |
| 28 | AR-16148 PI Senchyna | | Painting the first empirical picture of massive stars below the metallicity of the SMC with ULLYSES | Low-Z stars |
| 28 | AR-16129 PI Herczeg | | Outflows and Disks around Young Stars: Synergies for the Exploration of ULLYSES Spectra (ODYSSEUS) | CTTS |
| 28 | AR-16131 PI Hillier | | CMFGEN: A key spectroscopic tool for astrophysics | LMC/SMC/low-Z |
| 28 | AR-16133 PI Jenkins | | A comprehensive investigation of Gas-phase element abundances and extinction by dust in the LMC and SMC | ISM LMC/SMC |



13 AR, parallel, or complementary GO programs related to ULLYSES

| Cycle | PID | Title | Topic |
|-------|-----------------------------|---|----------------------|
| 29 | AR-16616 PI Howk | Interstellar tomography of highly ionized gas in the MW thick disk with ULLYSES | CGM |
| 29 | AR-16623 PI Leitherer | Feasting on the Riches of Odysseus' voyage | Population synthesis |
| 29 | AR-16640 PI Zheng | Braving the storm, quantifying the effects of Ram Pressure and Stellar Feedback in the LMC | ISM/CGM |
| 29 | AR-16602 PI Barger | The LMC's Galactic Wind through the eye of ULLYSES | ISM/CGM |
| 29 | AR-16635 PI Tchernyshyov | The first direct measurement of CO/H ₂ in subsolar environments using ULLYSES data | ISM |