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, Rachel Plesha, Alex Fullerton, Will Fischer

& the ULLYSES implementation team

STUC Meeting – October 2022

# Outline

- Program status and miscellaneous updates (Julia Roman-Duval)
- Update on observing (Alex Fullerton, Will Fischer):
  - LMC/SMC massive stars
  - Low-metallicity imaging and spectroscopy
  - Survey T Tauri stars
  - T Tauri star monitoring
- Update on data products and releases (Jo Taylor, Rachel Plesha)
- Plan for close-out (Julia Roman-Duval)


Program Status and Misc. Updates

# Program Status


- As of October 2022, ULLYSES observing is 88% Complete
  - ✓ **Observations of survey T Tauri stars are complete!**
- 5 data releases (latest DR5 on June 28, 2022) – see ullyses.stsci.edu
- 1 press release (https://hubblesite.org/contents/news-releases/2020/news-2020-50)
- 1 successful splinter session at AAS #240

# Program Status

- 6 publications by the community

| 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 |
| 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 |
| 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 | 2022arXiv220804986P | Towards a comprehensive view of accretion, inner disks, and extinction in classical T Tauri stars: an ODYSSEUS study of the Orion OB1b association |
| Paul Crowther | 2022arXiv220708690C | ULLYSES and Complementary Surveys of Massive Stars in the Magellanic Clouds |

# Misc. Updates

- Splinter session at AAS #240 was a success!
  - 6 talks (15 min each)
    - Overview of ULLYSES (JRD)
    - 2 presentations on massive stars (Grace Telford, Aida Wofford)
    - 3 presentations on T Tauri stars (Connor Robinson, Nicole Arulanantham, Thanawuth Thanathibodee)
  - About 30 people in attendance
  - Also presentation at NASA hyperwall
- ULLYSES survey paper is complete and under internal review

Draft version October 13, 2022
Typeset using LaTeX **twocolumn** style in AASTeX631

**The UV Legacy Library of Young Stars as Essential Standards (ULLYSES) Large Director's Discretionary program with Hubble: Overview and Initial Results**

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ABSTRACT

Specifically selected to leverage Hubble's unique ultraviolet capabilities, the Hubble Ultraviolet Legacy Library of Young Stars as Essential Standards (ULLYSES) is a Director's Discretionary programme of approximately 1000 orbits — the largest ever executed — that is producing a UV spectroscopic library of O and B stars in nearby low metallicity galaxies and accreting low mass stars (T Tauri stars) in the Milky Way. Observations from ULLYSES are uniformly sampling 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 ULLYSES spectral library of massive stars will provide the templates necessary for the synthesis of integrated stellar populations at high redshift that will be accessible to JWST and the next generation of Extremely Large Telescopes (ELT), and advance our understanding of Lyman-continuum escape and the re-ionization of the Universe. On the low mass end, UV spectra of T Tauri stars contain a plethora of diagnostics of disk evolution and planet habitability that will be needed to interpret the powerful probes of disk chemistry observed with ALMA, Spitzer, and JWST. Here, we provide important information related to the design of the program (observing strategy, target selection), its execution, the calibration of the data and the generation of high level science data products.

# Upcoming milestones and events

- DR5b (November 2022)
  - Only the last 17 survey T Tauri stars not released in DR5
  - Release of catalog
- Spectroscopy of Sextans A (November 2022)
- Second epoch of monitoring for BP Tau, GM Aur (December 2022 with TESS)
- DR6 (early March 2023)
  - Will include code updates, reprocessed data, new HST spectra of massive stars, FUSE recalibration of LMC/SMC massive stars, Sextans A spectroscopy, last epoch of monitoring TTS, additional archival targets (low-Z and T Tauri stars)
- DR7 (fall 2023)
  - Probably the last DR → will include re-processing of all data and complete database+catalog
- ULLYSES workshop at STScI (penciled in for fall 2023)


Technical Observing Updates

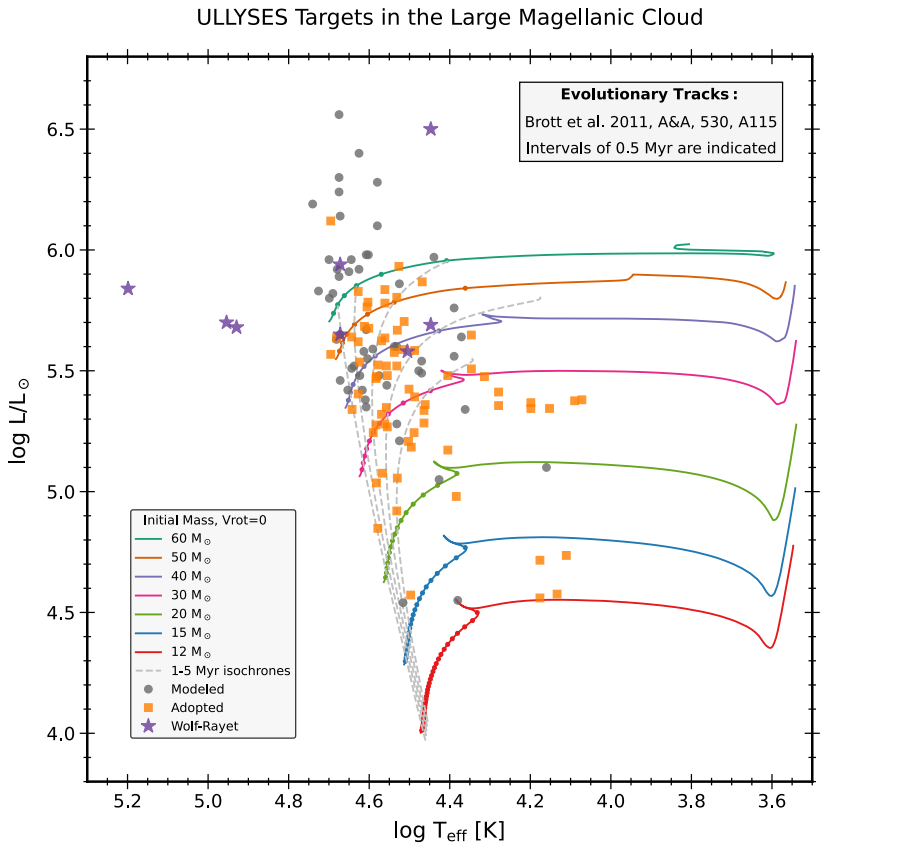
# Observing: Massive Stars in the LMC

| | Number | Complete | % |
|---|---|---|---|
| Targets | 94 | 70 | 75% |
| Orbits | 244 | 177 | 73% |
| HOPRs | 14 | 24 orbits repeated (14%) | |

**Cycle 29 Implementation Status**

41 targets, 108 orbits

| | |
|---|---|
| # Programs | 17 |
| Submitted | 14 |
| Completed | 7 |



# Observing: Massive Stars in the SMC

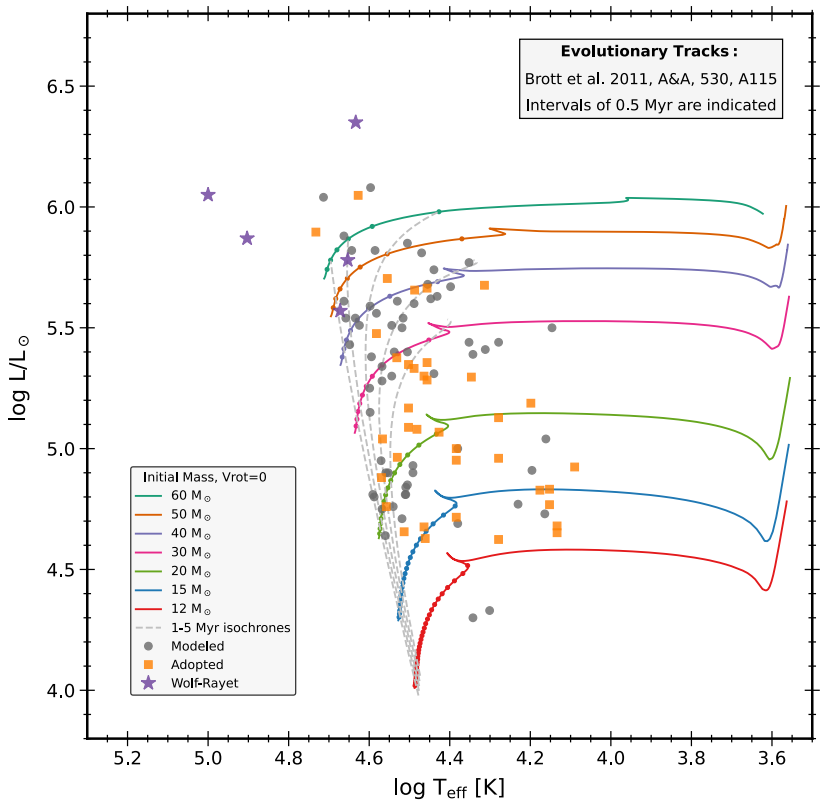
| | Number | Complete | % |
|---|---|---|---|
| Targets | 60 | 57 | 95% |
| Orbits | 205 | 193 | 94% |
| HOPRs | 19 | 42 orbits repeated (22%) | |

**Cycle 29 Implementation Status**

10 targets, 36 orbits

| | |
|---|---|
| # Programs | 6 |
| Submitted | 6 |
| Completed | 4 |

ULLYSES Targets in the Small Magellanic Cloud




ULLYSES: Charting young stars' ultraviolet light with Hubble

Version of 2022-03-28

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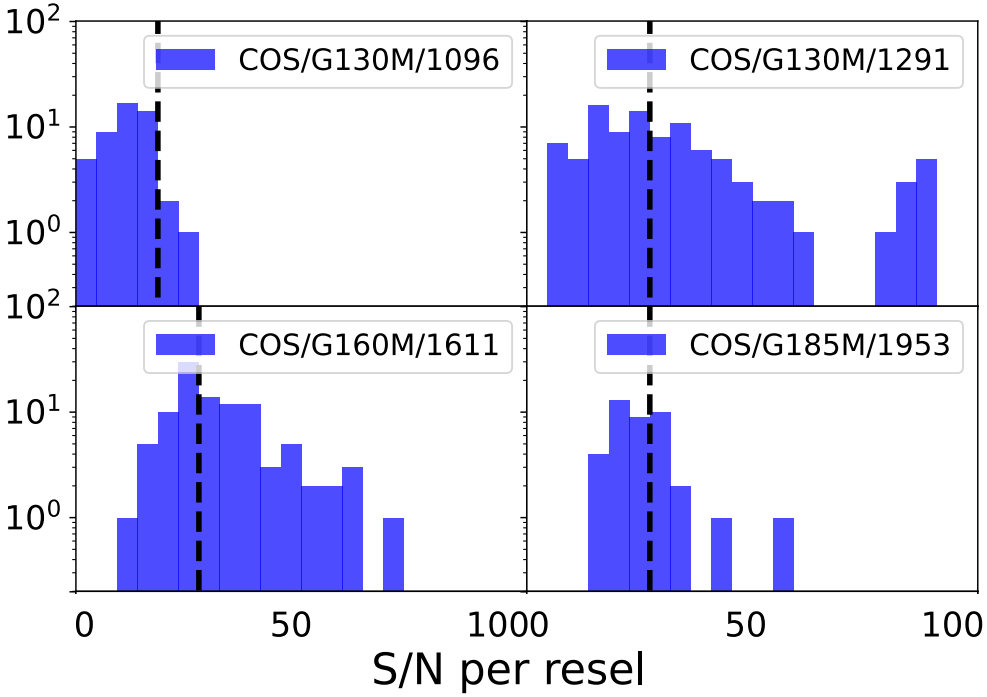
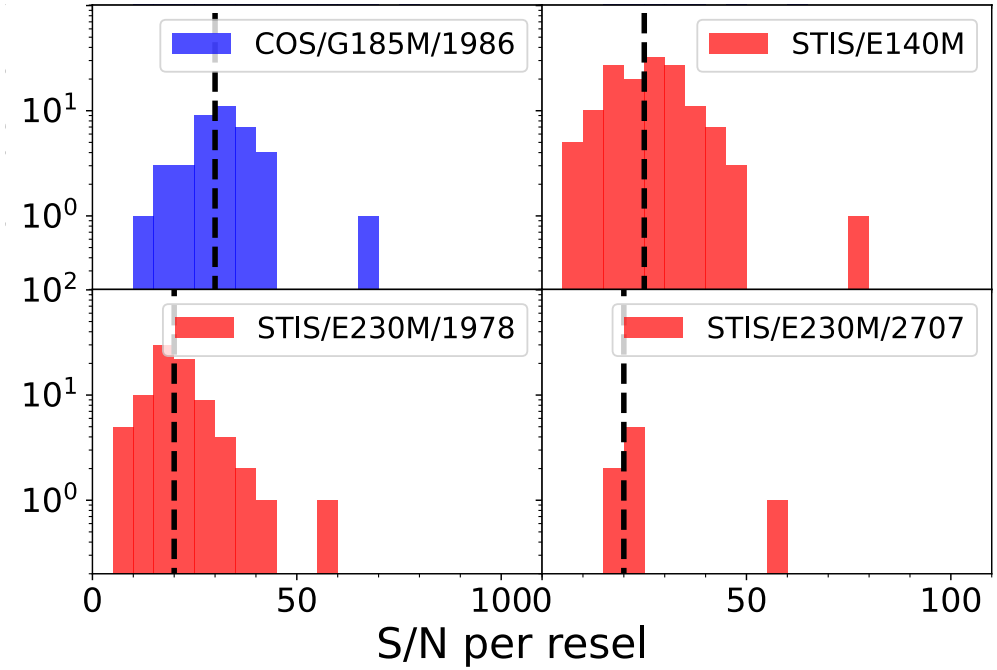
## Data Quality of COS and STIS observations of LMC/SMC stars

- Generally, the distribution of S/N is centered on the goal
- Exception of COS/G130M/1096, presumably due to estimation of exposure times based on SpT, E(B-V), and optical photometry

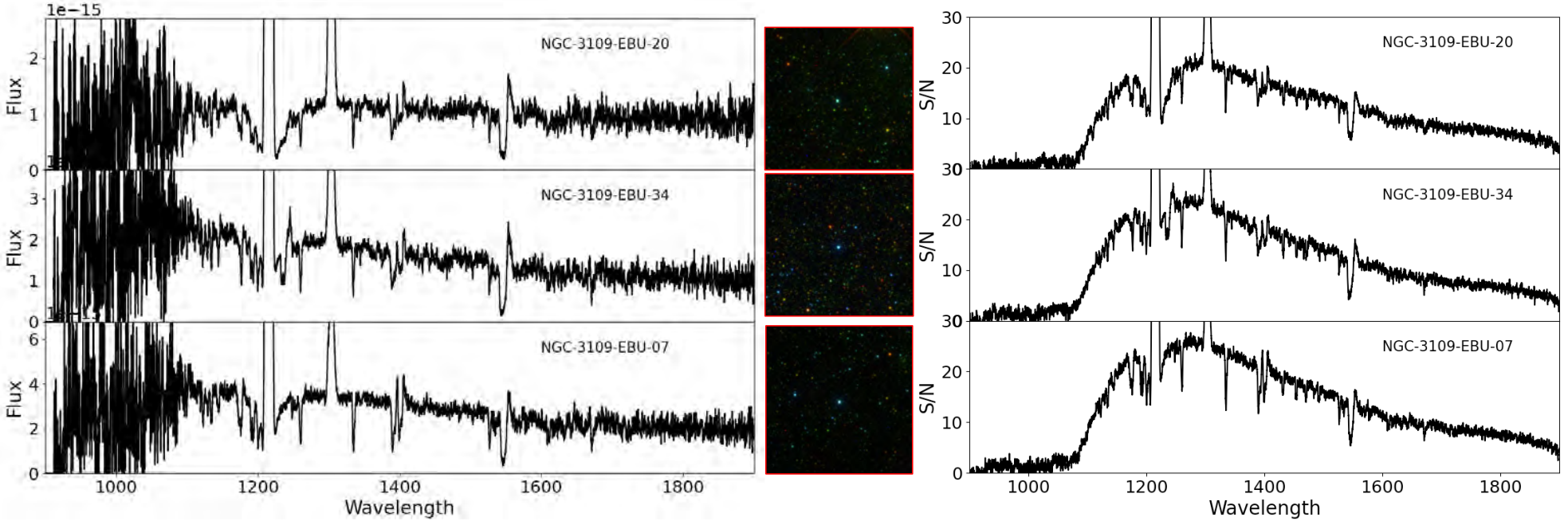


# Observing: Massive Stars in Low-Metallicity Galaxies

| 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 | Scheduling |

*F225W, F275W, F336W, F475W, F814W



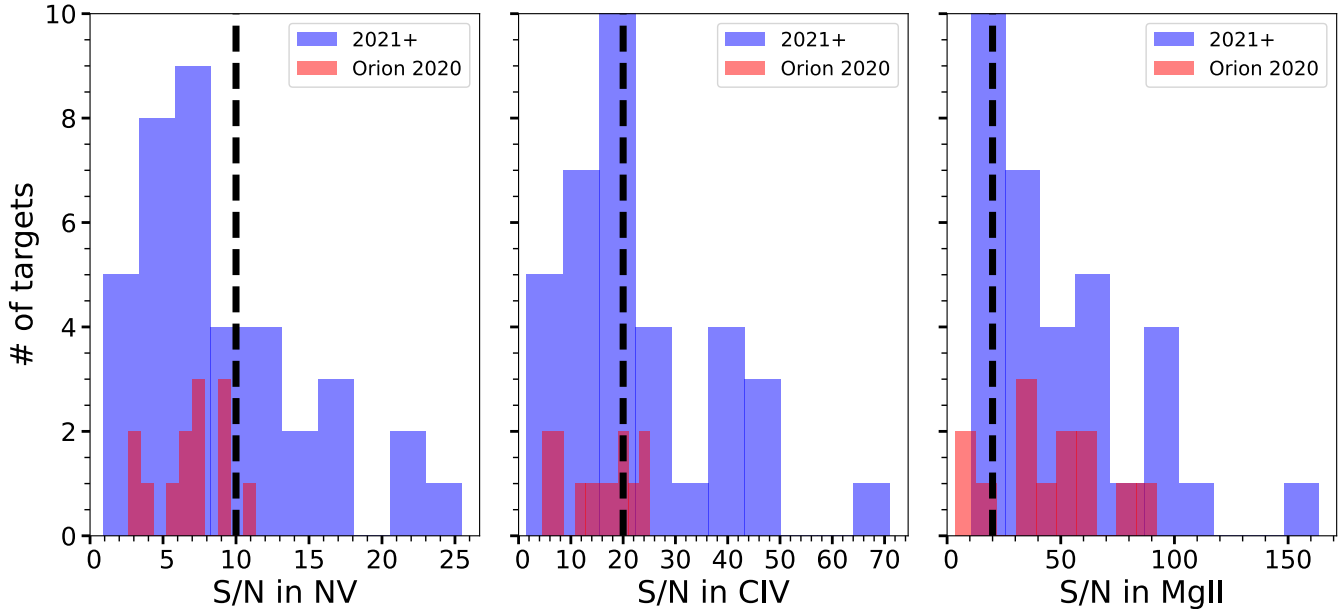
# Observing: Survey T Tauri stars (58 targets/400 orbits)

- Observations complete for all Tauri stars
  - 13 TTS in Orion observed in November-December 2020 during period when 11 covered by TESS
  - 18 TTS in Lupus, Cha I, Eta Cha observed in 2021 with 12 targets in coordination with TESS
  - 27 TTS in Taurus, Lupus, Cha I, Eta Cha, Eps Cha, CrA observed in 2022
- 9 repeats (9 targets) for 50 orbits
- 2 targets (Sz114 and Sz115) failed and were not repeated
  - Sz115 showed little accretion in X-Shooter spectrum
  - Sz114 was repeated once but repeat also failed

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

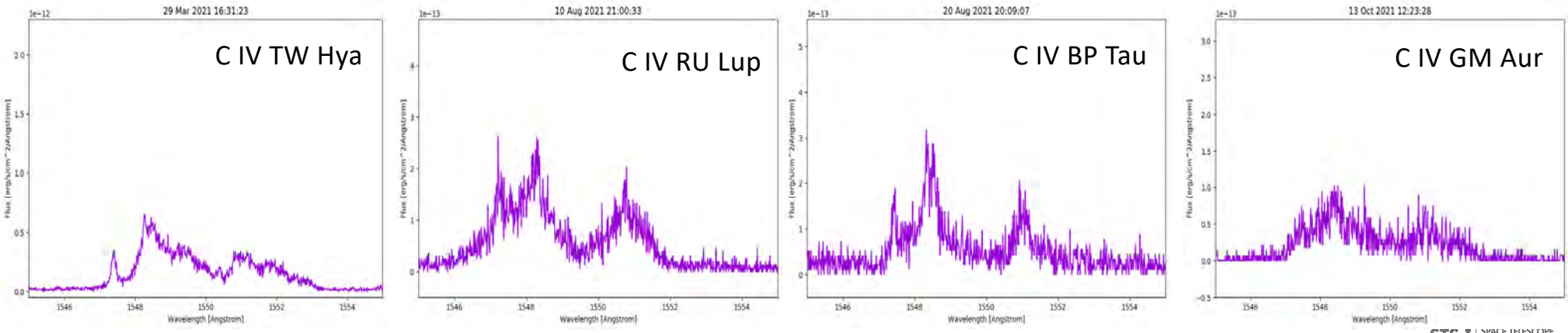
# Outcome for T Tauri stars

- Early observations in Orion had lower S/N than planned due to underestimated extinction
- Issue was corrected for next batch of observations
- Some objects have seen a large decrease in accretion rate, and therefore in FUV flux



# Observing: Monitoring of 4 T Tauri stars (100 orbits)

- 12 observations (4/period over 3 rotational periods) – Epoch 1 completed in 2021
- Epoch 2 executed for two stars:
  - TW Hya completed in April 2022 with 3/12 failed visits (2/3 repeat visits also failed)
  - RU Lup completed in August 2022 – visits 2 and 3 failed but successfully repeated at the end of the chain with only a 2 day gap
- Second epoch for BP Tau and GM Aur will execute December 2022 in coordination with TESS

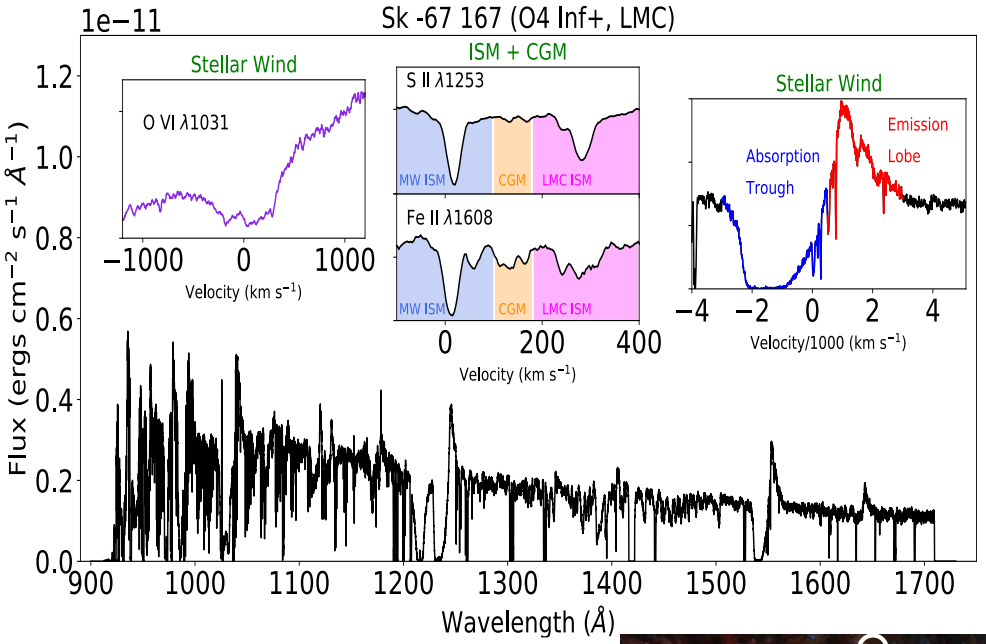


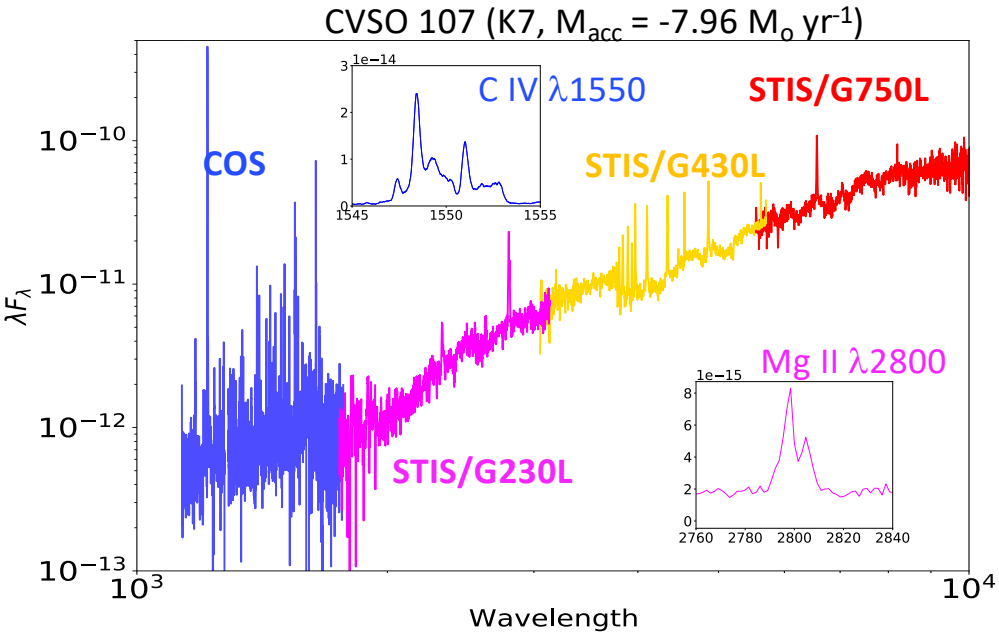

ULLYSES Data Products

## Description of data products

- Co-added spectra obtained with the same grating
  - E.g., different exposures with the same or different cenwaves and FP-POS
- 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
- Spliced (abutted) spectra between different gratings and instruments
  - E.g., FUSE + HST, COS + STIS
- Photometric (LCOGT) and spectroscopic (HST) time-series
  - Spectroscopic time-series for T Tauri monitoring stars (only HST data)
- Drizzled WFC3 images of NGC 3109 and Sextans A

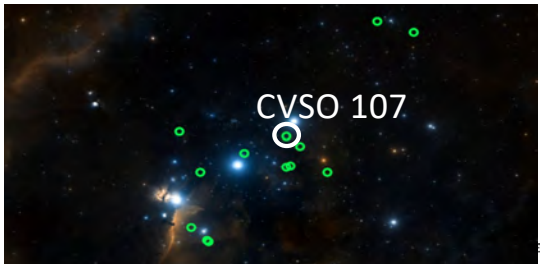
# Examples of Data Products




FUSE + STIS E140M "preview-spec" (abutted spectrum) of SK -67 167

COS + STIS "preview-spec" (abutted spectrum) of CVSO 107 (Ori OB1)



## ULLYSES Data Releases


- 5 data releases (DRs) to date
- DR5b planned for early November 2022
- DR6 planned for early March 2023
- DR7 planned for fall-winter 2023
- DRs widely advertised via HST email exploder, Twitter, STScI webpage, MAST newsletters

## DR5 contents

- Latest data release (DR5) includes:
  - COS spectra for 85 Tauri stars (41 with STIS NUV-optical-NIR)
  - COS spectroscopic time series for 4 T Tauri stars monitored with HST
    - Both epochs completed for TW Hydra!
  - LCOGT photometric time series for 40 T Tauri stars
  - UV spectra of 233 stars in the LMC and SMC, plus FUSE spectra of 122 of those stars 

  - COS/FUV/G140L/800 spectra of 3 massive stars in low metallicity galaxy NGC 3109
  - Drizzled WFC3 imaging of NGC 3109 and Sextans A
  - STIS spectra of 9 non-ULLYSES targets present in STIS long-slit observations 

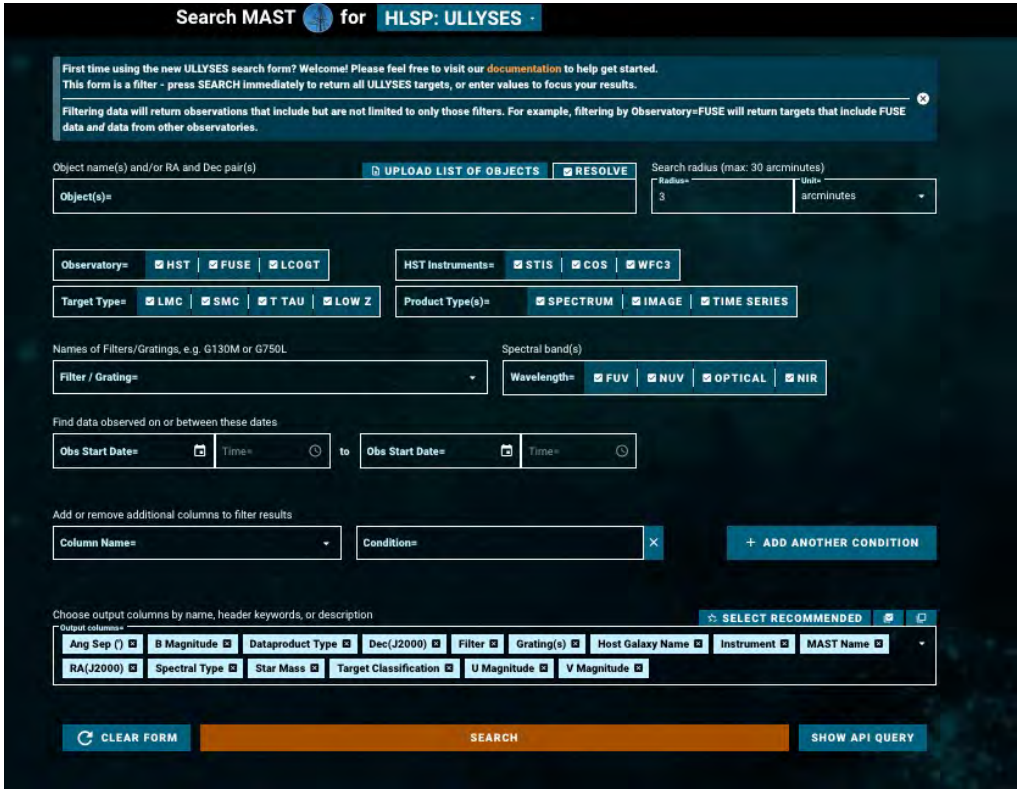
  - Publication of the HLSP-making code (including co-addition and time-series)

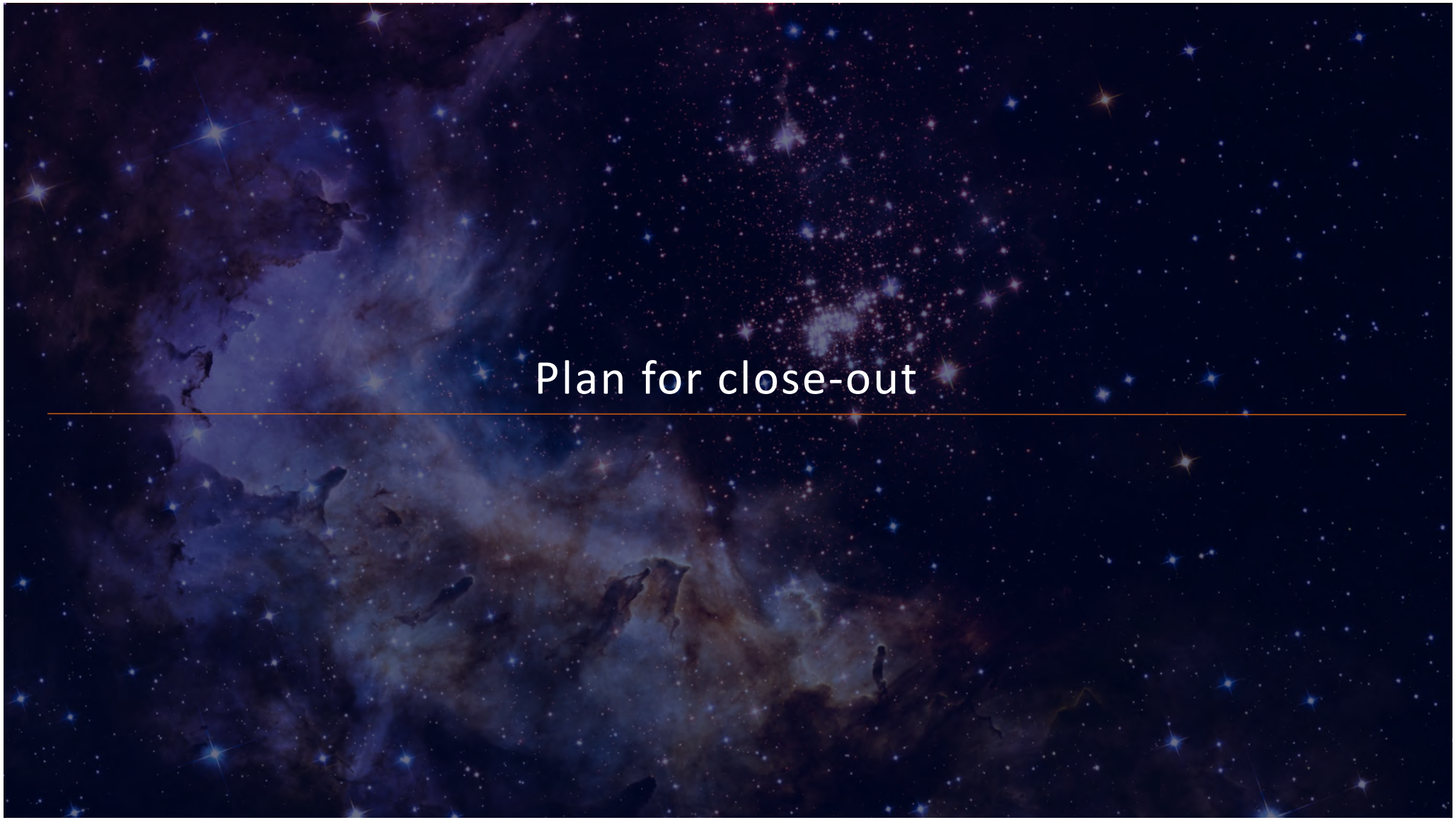
## Contents of upcoming DRs

- DR5b will **only** include HST products for 17 T Tauri stars observed since DR5
  - ➢ Custom calibrated STIS G230L, G430L, G750L spectra
  - ➢ Co-added COS/FUV G130M + G160M spectra
- DR6 will include::
  - o HLSPs for LMC and SMC stars observed since DR5 (including FUSE when available)
    - ✓ Recalibration of FUSE spectra for a subset of those stars NEW!
  - o HLSPs for Sextans A spectroscopy with COS/G140L/800 NEW!
  - o Archival COS spectra of Sextans A
  - o Second monitoring epoch for RU Lup, BP Tau, GM Aur NEW!
  - o Re-processed data for survey TTS (instrument updates)
  - o Additional archival TTS (COS FUV, possibly custom STIS calibration if time allows) NEW!
  - o LCOGT photometric time-series (including newly observed TTS)
  - o HLSP code improvements (e.g., ability to create time series for non-monitoring stars, example notebooks)

# Data Dissemination Platform

- All program information, observing schedule, and target metadata are on ullyses.stsci.edu
- Data can be downloaded from:
  - The ULLYSES catalog https://mastdev.stsci.edu/search/ui/#/ullyses/
  - MAST Data Discovery Portal (HLSPs and contributing data)
  - or directly at the MAST HLSP collection for ULLYSES (HLSPs only) https://archive.stsci.edu/hlsp/ullyses




Plan for close-out

## Plan for close-out

- Completion of the program expected between October-December 2023 (this is a working goal)
- All data products (re-processed data, website, database + catalog, HLSP code) will have their final delivery as part of DR7
    - We will time DR7 to include important instrument calibration updates (updated STIS blaze functions, updated COS walk and geometric corrections)
- We will not re-process data beyond DR7 → the products will live statically in MAST (like all other HLSP collections)

## Plan for close-out

- Items to complete during close-out phase:
  - Finalize process for ingesting community-provided HLSPs and ingest products (if not already completed)
  - Final code changes to the DB + catalog
  - Ingest all archival data and target metadata
    - ✓ Includes custom calibration of archival STIS data for TTS
  - Re-process all ULLYSES data with instrument calibration updates
  - Final updates to HLSP code
  - Provide Jupyter notebooks and tutorials for HLSP code (if not already completed)
  - Clean-up of internal code to make website target tables and DB consistent, check that all data/target meta-data is released, facilitate future ingestion of new targets/data if needed

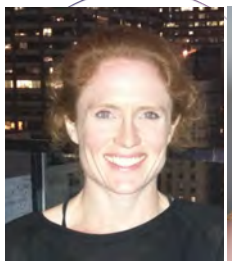
# Plan for close-out – Wishlist ("nice to have")

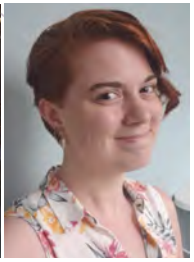
- If time and resources allow, we might:
  - Develop and provide COS and FUSE data for night-only (low airglow, important for studies of Ly-$\alpha$)
  - Implement a visual selection/query of targets (e.g., from an HR diagram)
  - Ingest STIS CCD data for LMC and SMC stars (e.g., from Derck Massa's SNAP program)
  - Ingest HST spectra and target meta-data of Milky Way massive stars to increase the range in the metallicity covered by ULLYSES (for differential comparison)
  - Consider making it possible to easily add targets/data if highly relevant GO programs are executed in the longer term future

# Questions and Feedback

# Acknowledgements

# ULLYSES Core Implementation Team (CIT)


Julia Roman-Duval
(CIT Lead)


Jo Taylor
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TTS Observing Lead


Alex Fullerton
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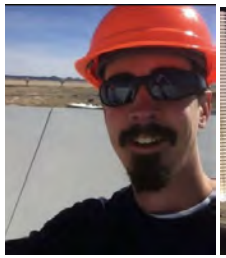
Alessandra Aloisi
(Pre-imaging)


Chris Britt
(Public Outreach)


Ivo Busko
(DP/software)

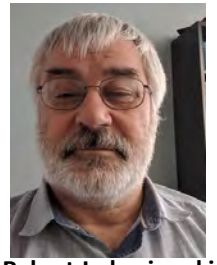

Van Dixon
(Observing, DP)


Travis Fischer
(DP)

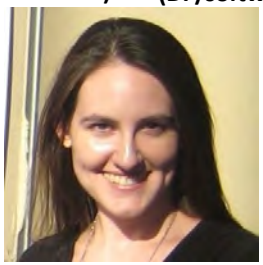

Elaine Frazer
(DP)


Svea Hernandez
(DP)


Alec Hirschauer
(Observing)


Robert Jedrzejewski
(DP, software)


Sean Lockwood
(ETC, Obs)


TalaWanda Monroe
(Observing)


Charles Proffitt
(Observing)


Adric Riedel
(Targets, DP)


David Sahnow
(Observing)


Richard Shaw
(DP)


Ravi Sankrit
(Observing)


Linda Smith
(Targets, Observing)


Debopam Som
(Observing)


Leonardo Ubeda
(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 and Brian Erickson (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)

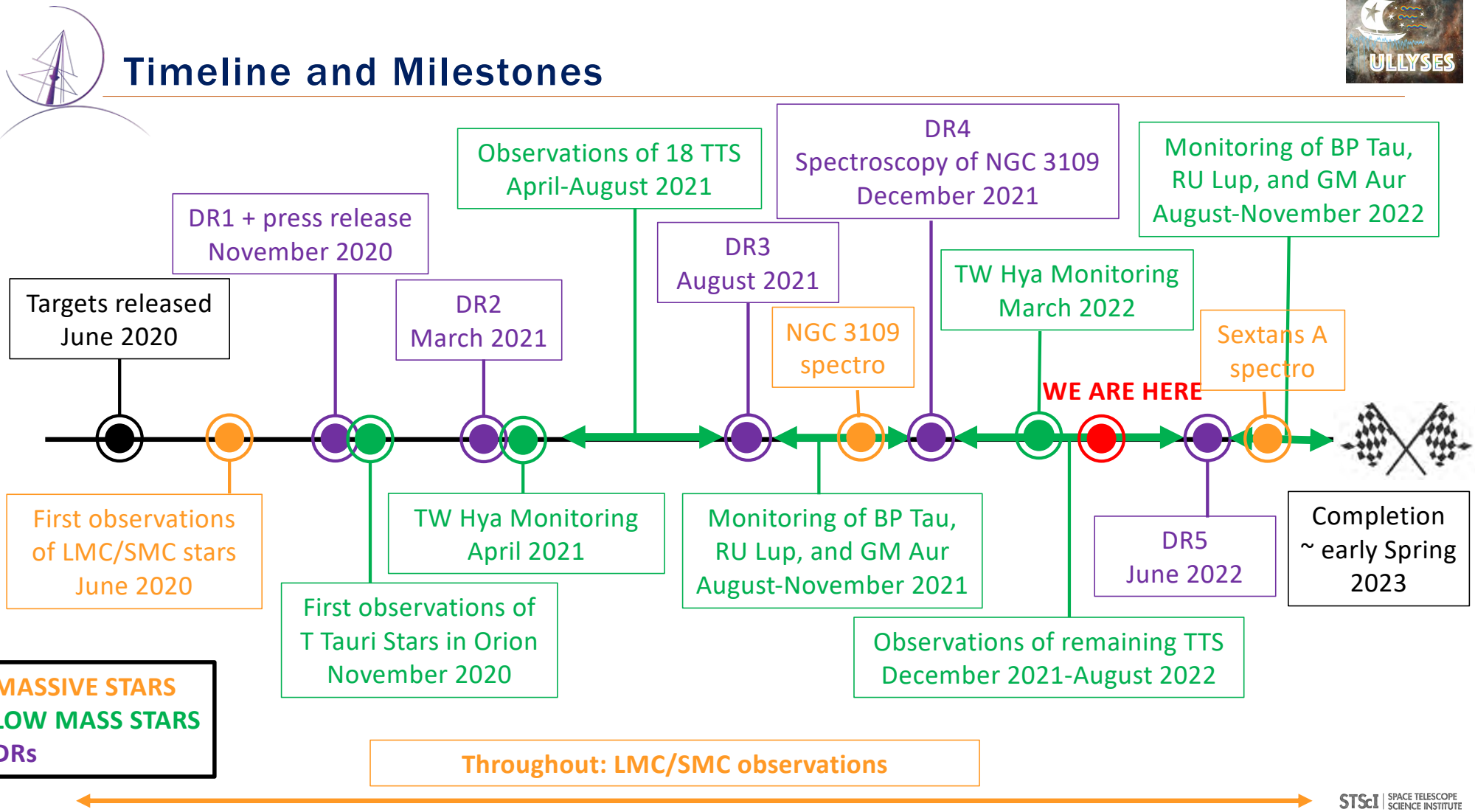
## Other community members


- 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

# Thank you

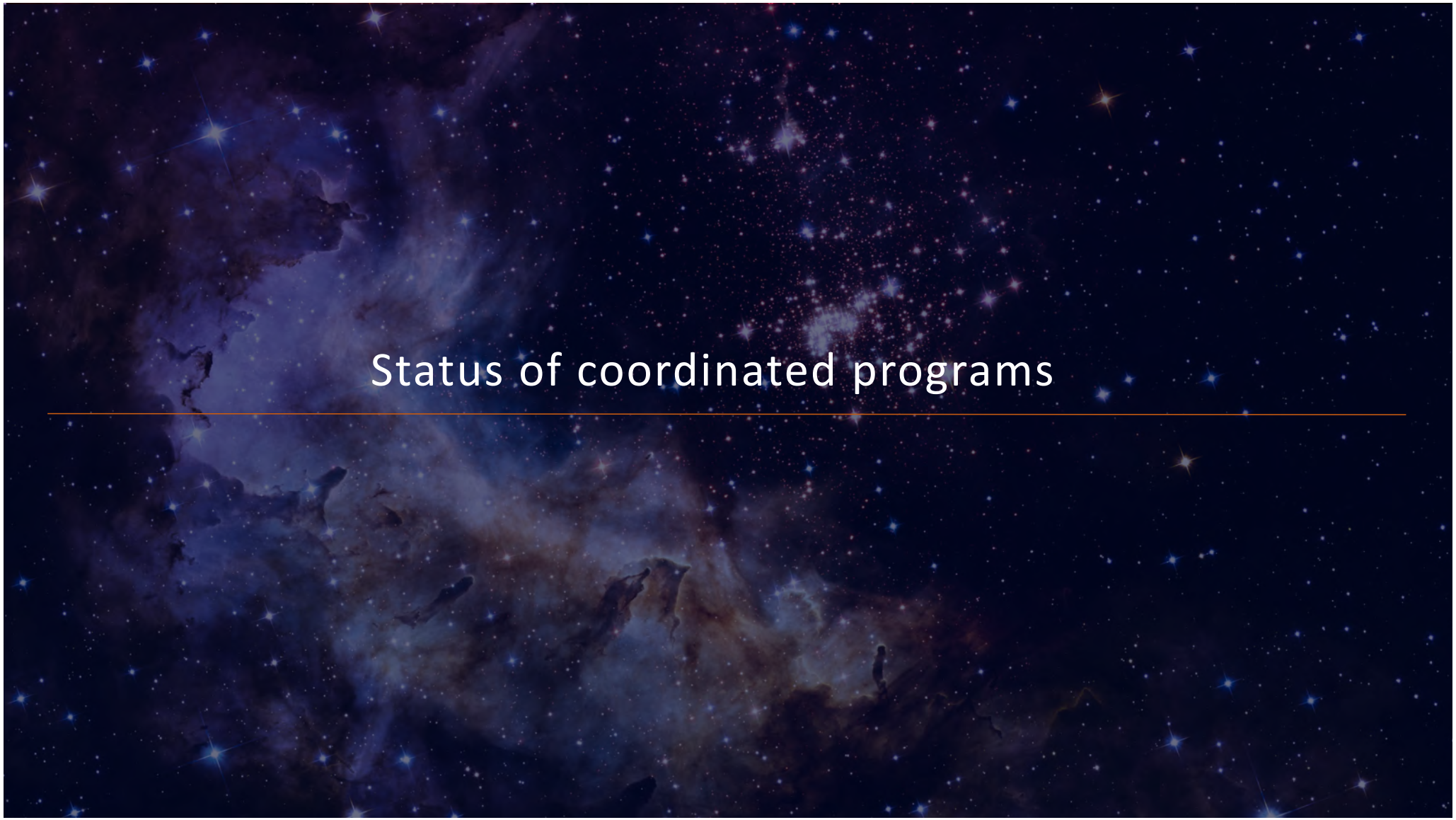
# Back-up Slides

# Timeline and Milestones



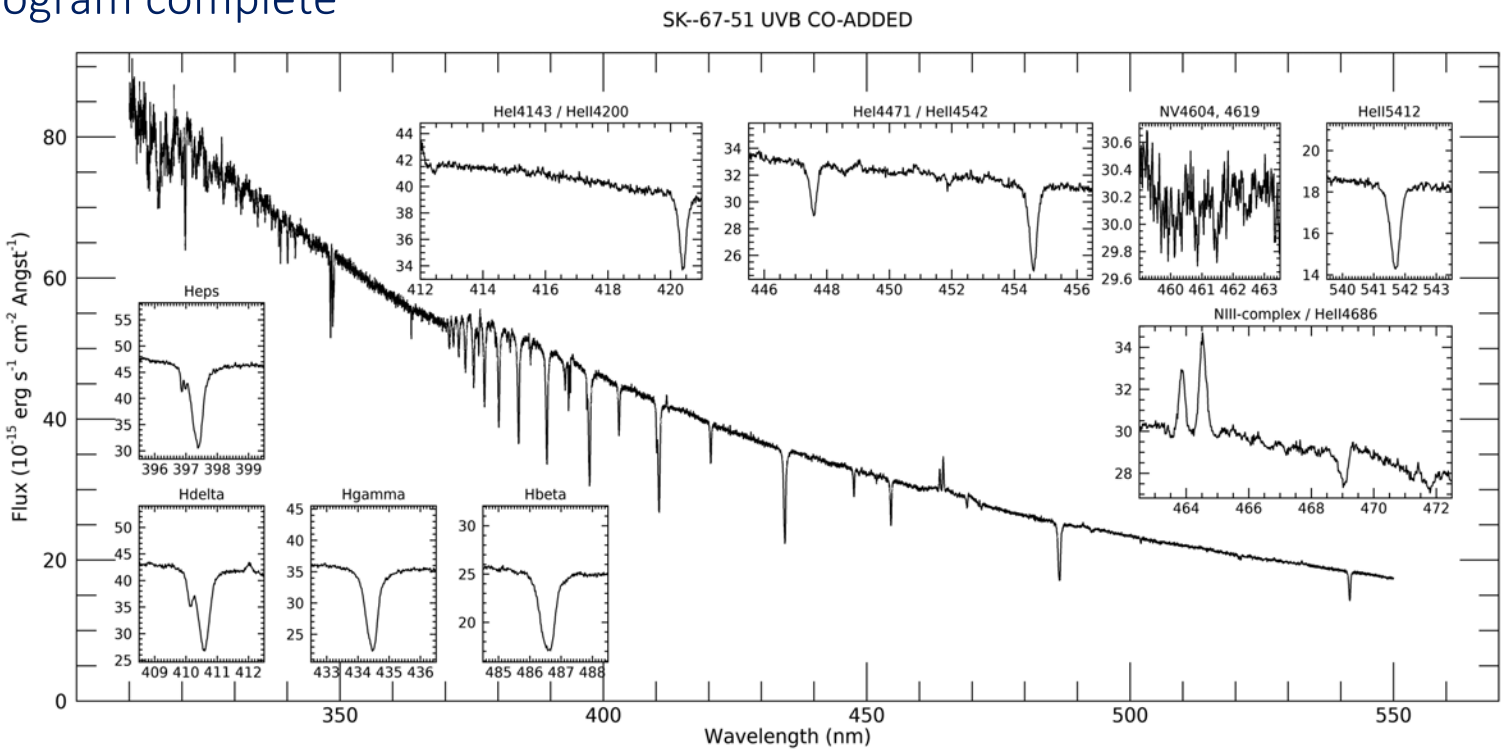
## Scheduling updates

- Scheduling information is included on the ULLYSES website (https://ullyses.stsci.edu/ullyses-targets-ttauri.html)
- Scheduling updates are forwarded to a specific email distribution that includes PIs of coordinated observations (ullyses_ctts_scheduling@maillist.stsci.edu)


Status of coordinated programs

# Coordinated programs for massive stars

- X-ShootU program led by IAU-G2
  - VLT X-Shooter for all ULLYSES targets
  - Program complete



## Coordinated programs for T Tauri stars

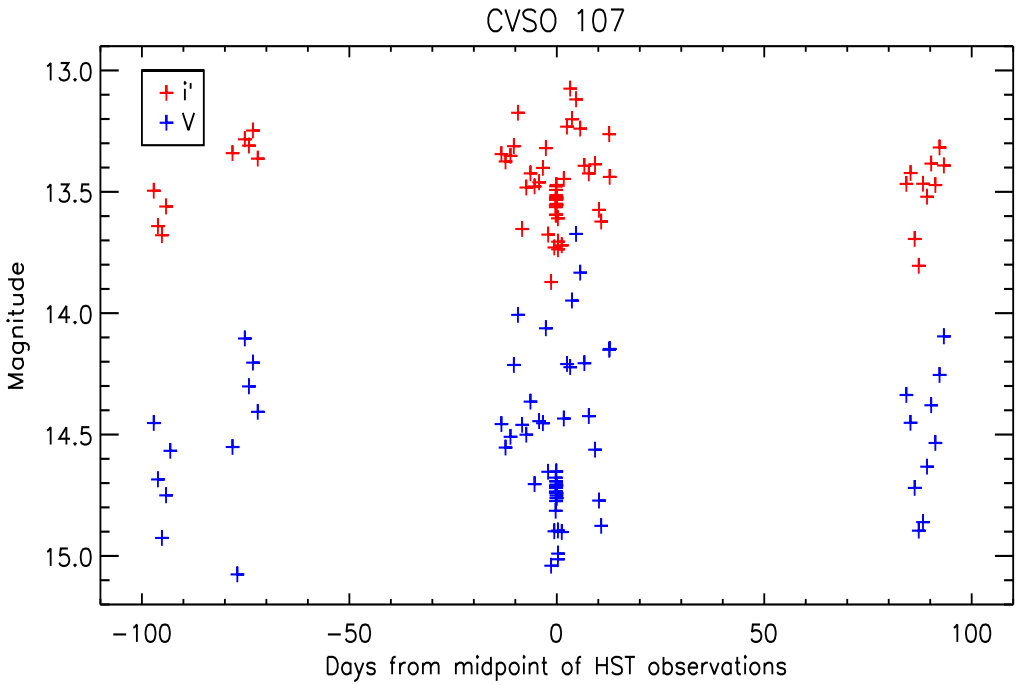
- Monitored stars only
  - Chandra/XMM-Newton (X-ray; accretion)
  - CFHT/SPIRou spectro-polarimetry (magnetic field mapping)
- Survey and monitored stars
  - VLT X-Shooter, ESPRESSO, UVES (accretion, extinction, stellar properties, kinematics)
  - IRTF (calibration of MIR accretion diagnostics in preparation for JWST observations of deeply embedded protostars)
  - LCOGT photometric monitoring (variability context)
  - TESS (high cadence variability context, March-June 2021 only)
- All programs executing successfully
  - Some coordination with TESS and LCOGT lost when programs got bumped due to July 2021 safing

# 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



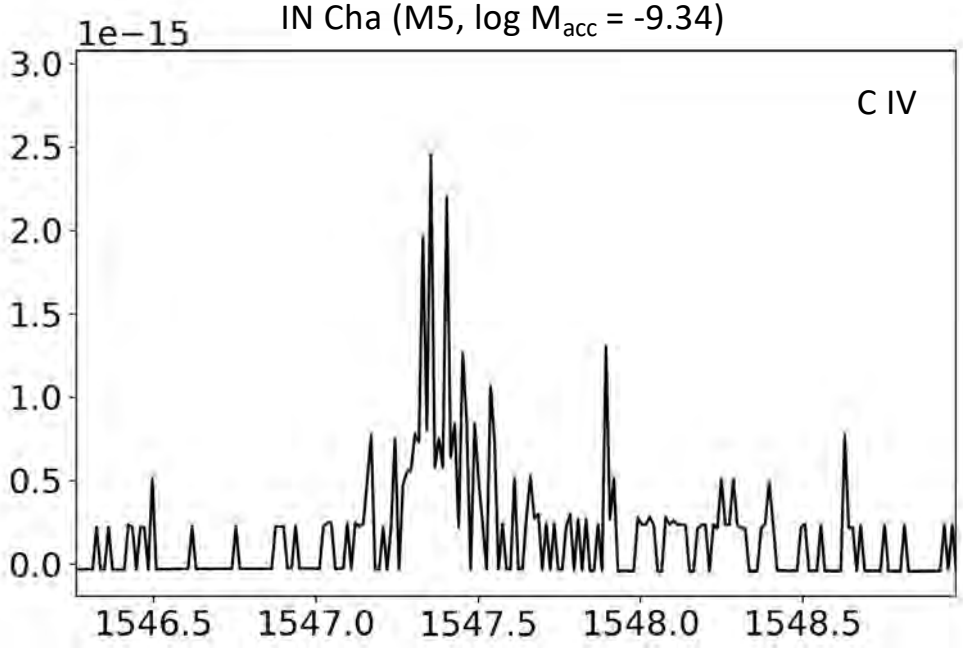
## Extinction and exposure times for CTTS

- Flux level of Orion CTTS was fainter than expected from from published accretion rates and extinction
- All T Tauri star models were scaled with an extra 0.5 of $A_V$ before ETC calculation for the sample observed in Spring 2021
  - Except for T Tauri stars in Eta Cha, for which we robustly know there is very low extinction
  - Goal S/N was decreased to S/N = 10 for N V and 20 for C IV (instead of 15 and 30 respectively)

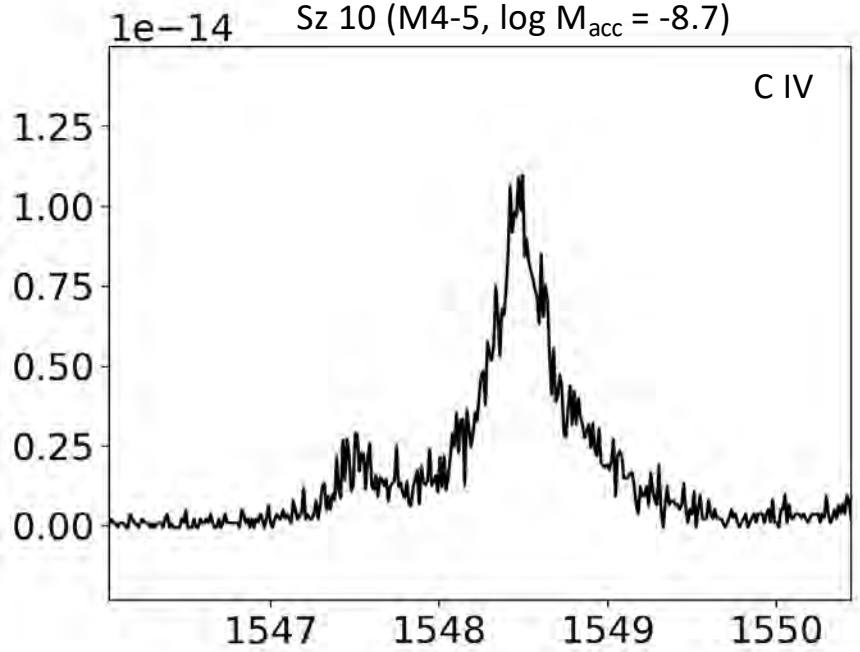
## Observing outcomes for late M stars

- Some M3-5 stars were observed to be much fainter in the FUV than expected given their published accretion rates (from X-Shooter)

IN Cha (M5, log $M_{acc}$ = -9.34)




Sz 10 (M4-5, log $M_{acc}$ = -8.7)

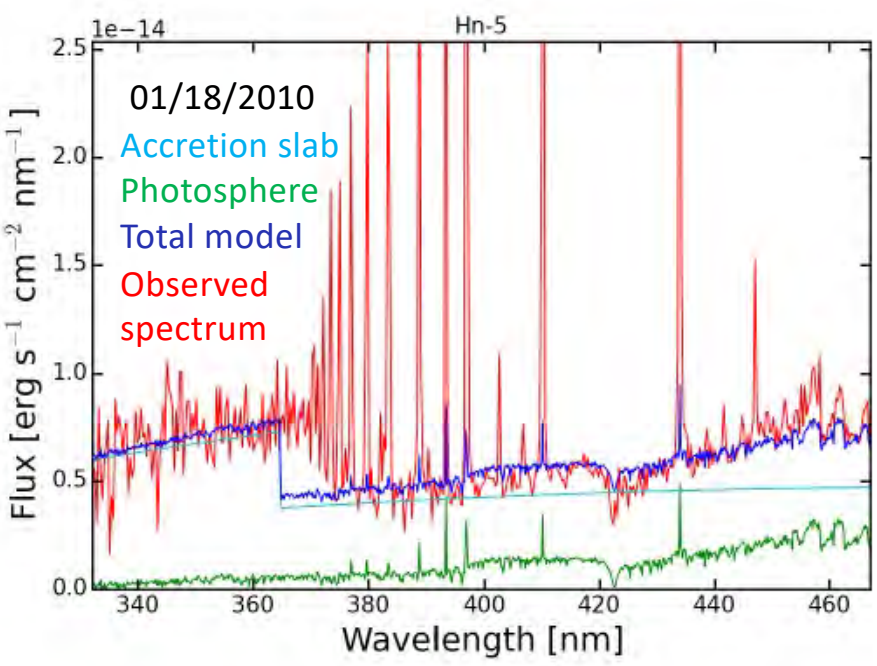


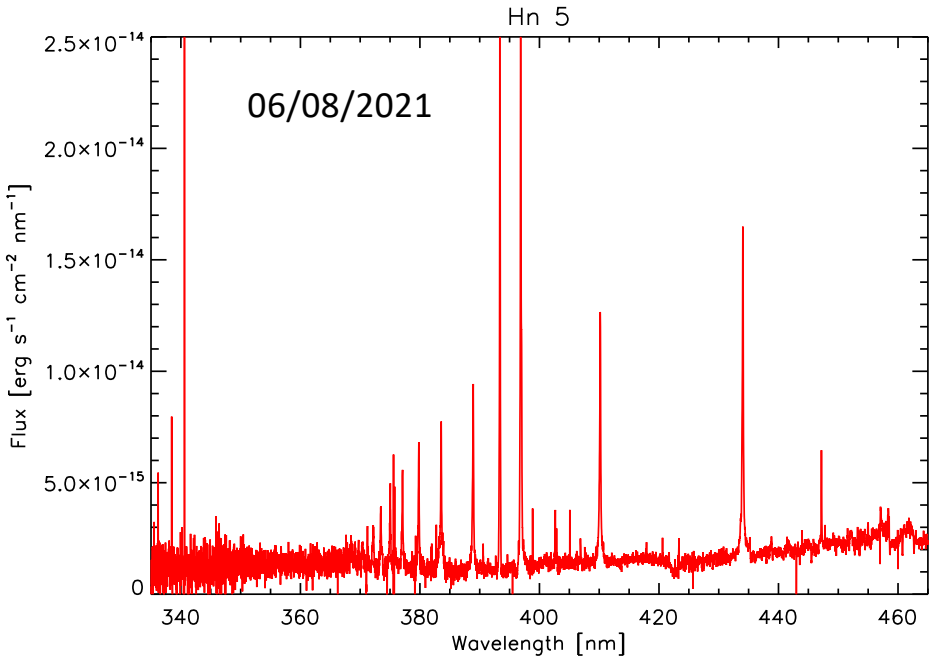
# Signal-to-noise outcome

| Target | SpT | Log dm/dt | S/N NV | S/N CIV | S/N Mg II |
|---|---|---|---|---|---|
| CHX18N | K2 | -8.09 | 8 | 16 | 44 |
| Sz75 | K6 | -7.67 | 11 | 22 | 88 |
| Sz77 | K7 | -8.79 | 5 | 14 | 34 |
| Sz45 | M0.5 | -8.09 | 8 | 22 | 75 |
| Sz111 | M1 | -9.12 | 5 | 20 | 30 |
| Sz71 | M1.5 | -9.06 | 5 | 17 | 21 |
| Sz72 | M2 | -8.65 | 7 | 24 | 88 |
| Sz130 | M2 | -9.19 | 4 | 11 | 30 |
| Sz66 | M3 | -8.54 | 0 | 0 | 20 |
| XX Cha | M3.5 | -7.41 | 9 | 30 | 30 |
| Sz76 | M4 | -9.26 | 4 | 5 | 20 |
| Sz10 | M4-5 | -8.7 | 5 | 17 | 20 |
| Sz69 | M4.5 | -9.51 | 0 | 2 | 30 |
| SSTc2dJ1600 | M4.5 | -9.81 | 2 | 3 | 12 |
| Hn5 | M5 | -9.28 | 0 | 0 | 8 |
| IN Cha | M5 | -9.34 | 0 | 0 | 8 |
| 2MASS J1143-78044 | M5.5 | -8.71 | 3 | 10 | 10 |
| ECHA-J0844.2-7833 | M6 | -10.18 | 4 | 10 | 13 |

# Variable accretion

- Carlo Manara shared X-Shooter data taken concurrently with the HST observations
- Accretion rate in IN Cha and Hn5 appears to have decreased dramatically, explaining the faint FUV flux



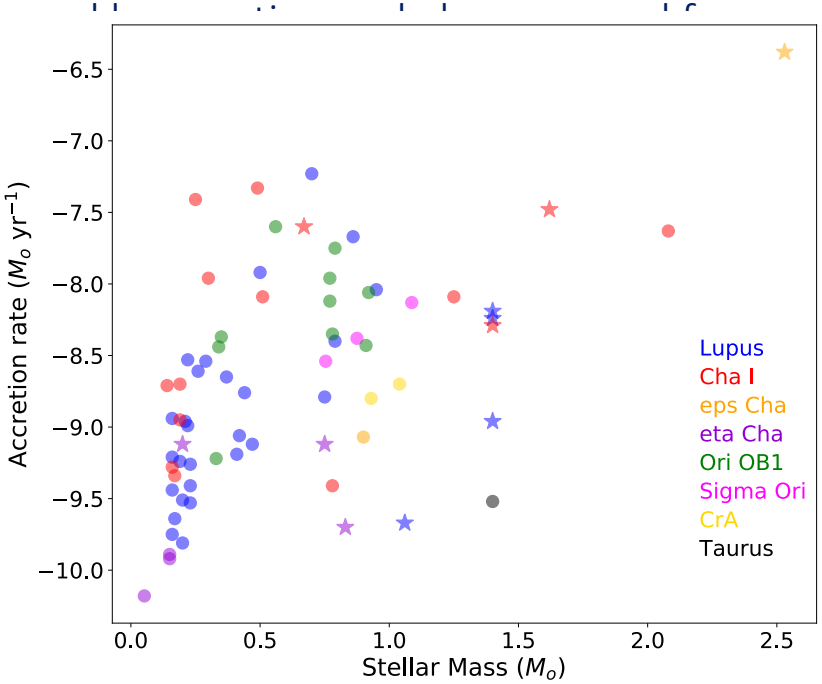
## Plan adopted in Spring 2021

- All remaining M stars left to observe show prominent Balmer jump, indicative of significant accretion
- Discussed plan for improving S/N of observations of remaining M stars with the SAC

RXJ0438.6+1546

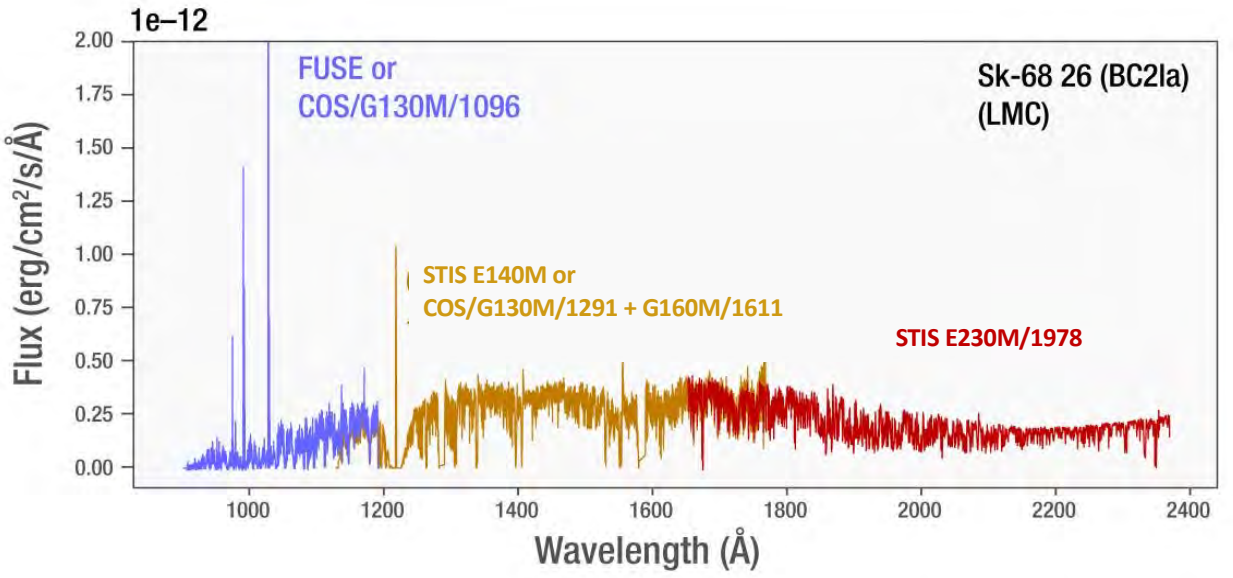
# Recent T Tauri star sample updates

- To accommodate extra exposure time, 6 expensive stars were removed from the sample in spring 2021
  - There is redundancy in M*, log(dm/dt) for all those stars, so sample is still covering parameter space
- 1 star (2MASSJ11183572-7935548) was found to be very
sample
- 3 stars (RECX 7, RECX 12, TWA 8A) did not clear the M dwarf flare BOP rules and were removed from the sample
- 2 stars (RECX 6, RXJ0438.6+1546 ) was added to the sample as M3 and K2 WTTS templates
- CTTS sample now includes 59 targets (instead of 67 targets in the original sample)



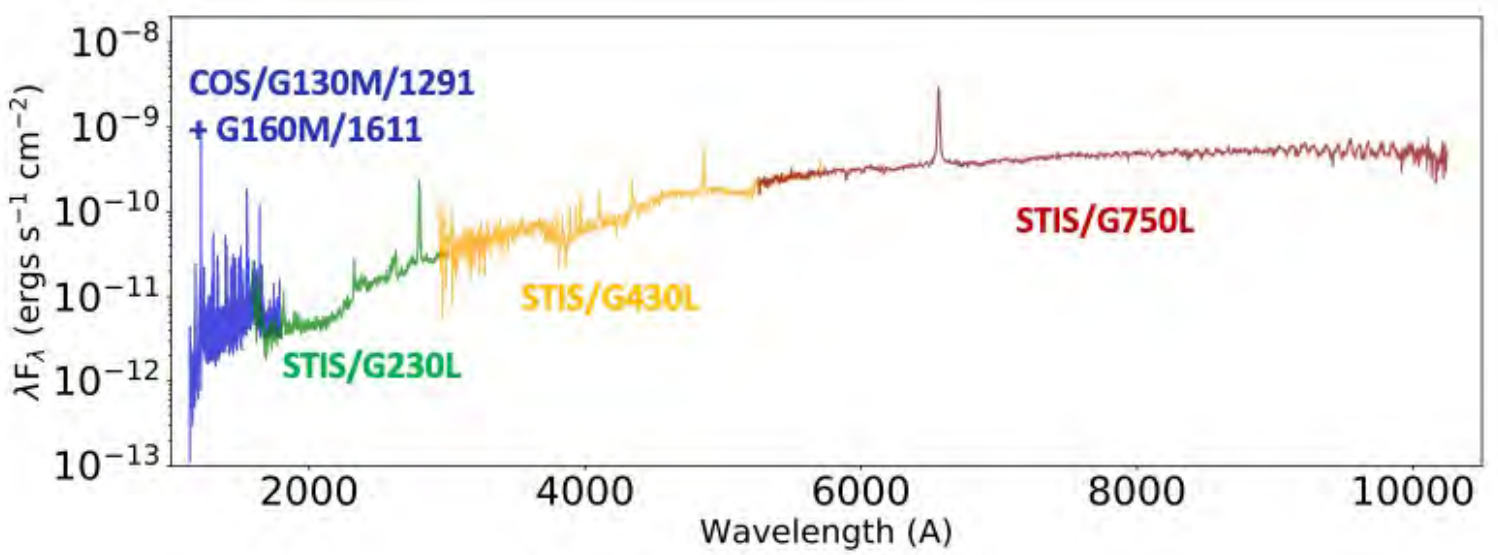
# Observing Strategy – LMC/SMC Massive stars

- **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

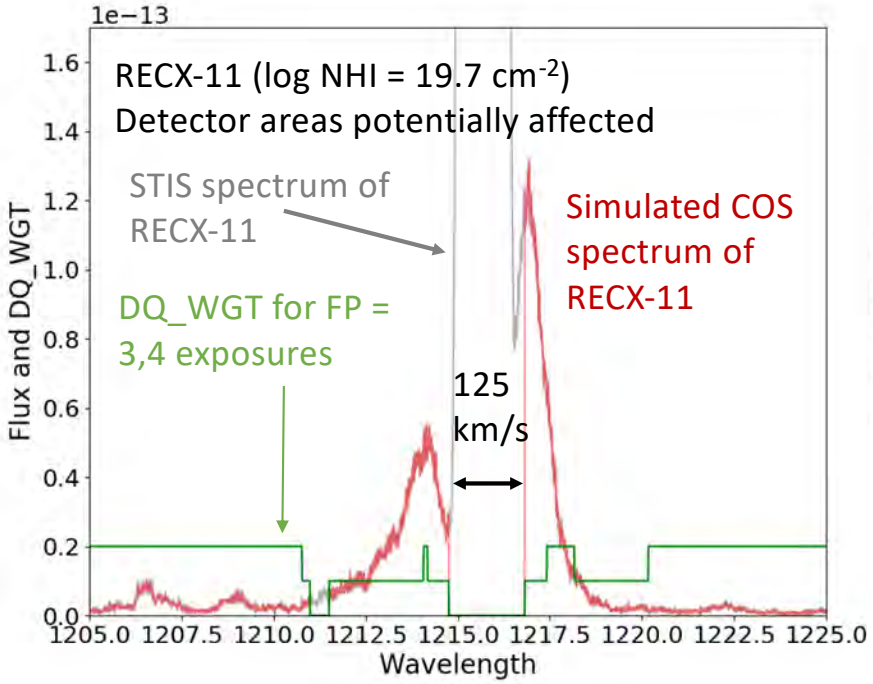


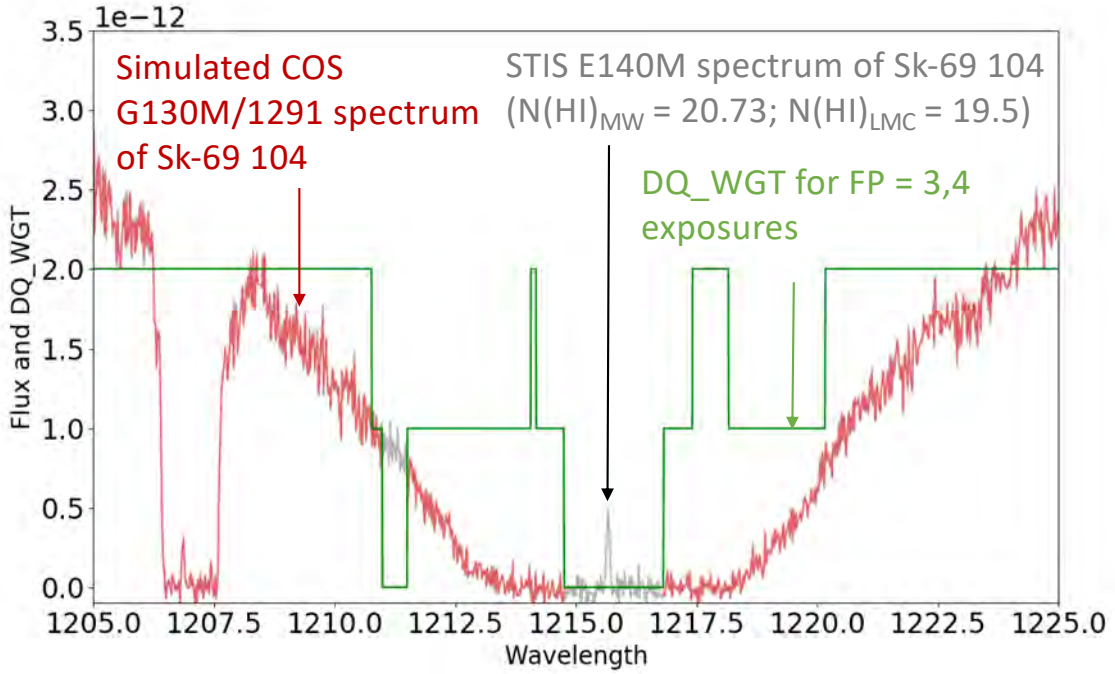
# ULLYSES S/N Requirements


- 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

# Observing Strategy – Lyman-α

- Two gain-sag holes at LP4 make Ly-α unobservable with COS/G130M/1291 within +/- 65 km/s
- The wings of an interstellar Ly-α absorption line in the LMC or SMC, and of the emission profile of an accreting star fall outside the gain-sag holes and can be observed at LP4.

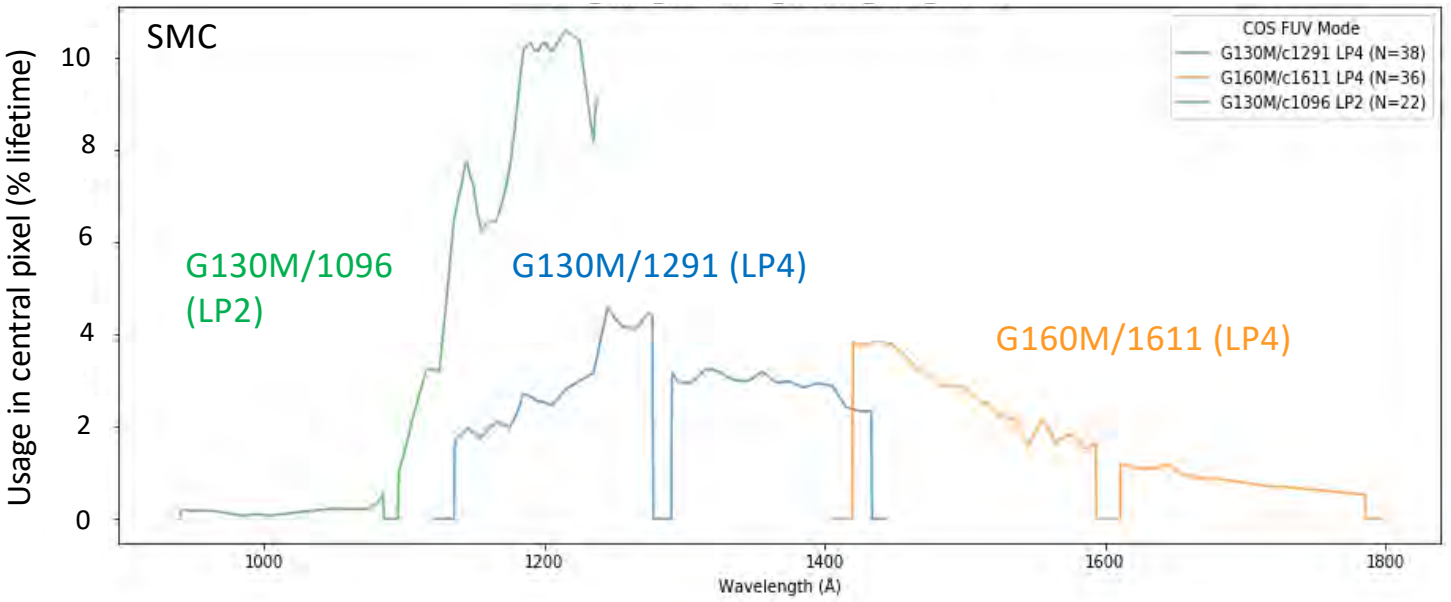


# Gain-sag impact on COS – SMC

New

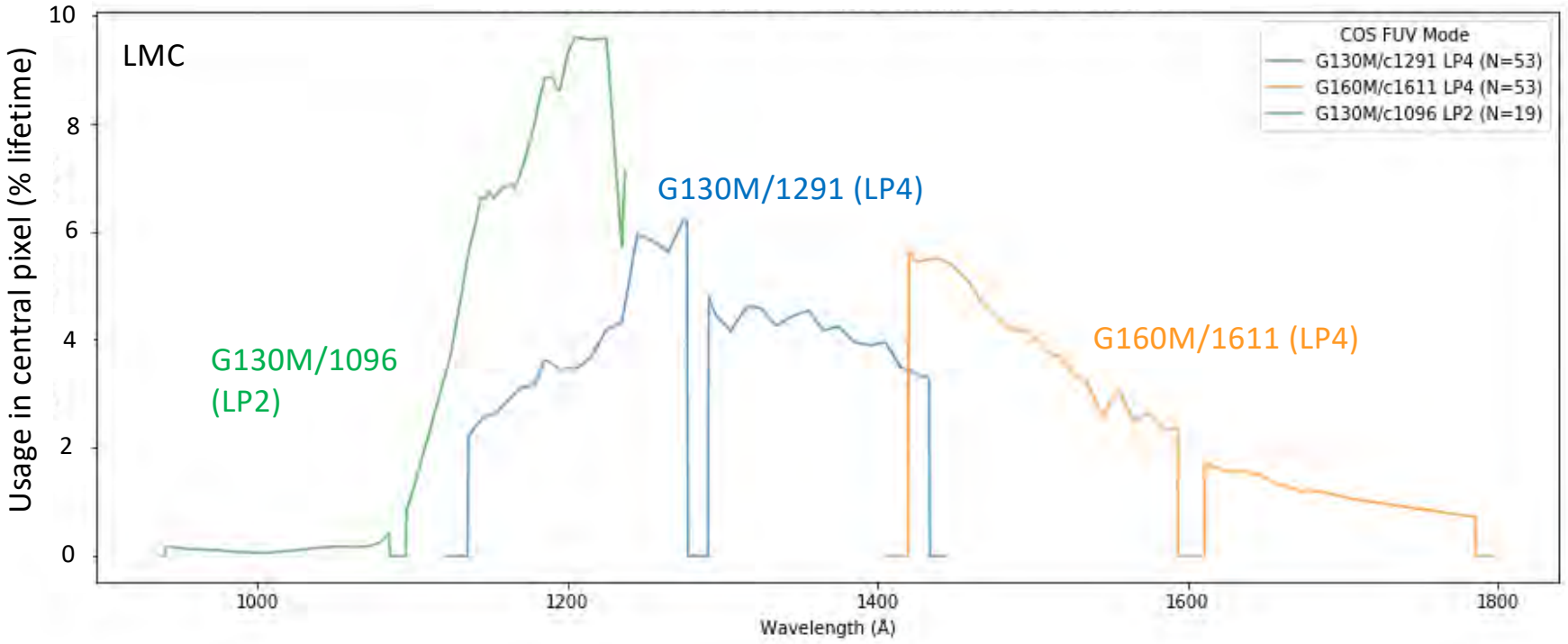
- Model SEDs and scriptable ETC used to estimate counts in the brightest pixel as a function of wavelength for each mode of observation
- Fraction of lifetime is counts/50,000
- Note: COS/G130M/1096 is operated at LP2 with high counts on FUVA



# Gain-sag impact on COS - LMC

New

- Combined LMC/SMC observations will use up about 15% (10%) of the COS LP4 FUB (FUVA) lifetime and 20% of the COS LP2 FUVA lifetime



# 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


Coordinated observations and community engagement

# LCOGT Photometric Monitoring

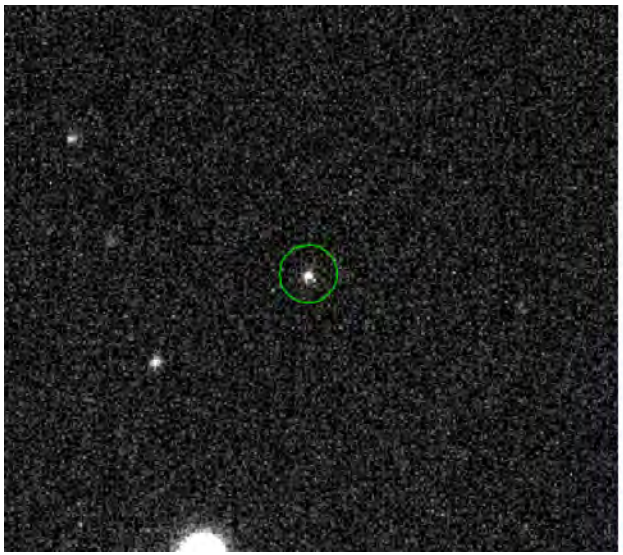
- Cadence:
  - 1x/day 3 months before/after HST epoch
  - 1x/day 10 days before/after HST epoch
  - 10x/period of the 1 (3) periods centered on the HST observations for the survey (monitoring) stars
  - 15 min cadence during the HST observations
- S/N > 10 for all targets/bands
- Flux calibration field (1x/night) for 3 targets (51 fields per target) – Use SkyMapper for other fields/targets
- u' exposure times predicted by LCOGT ETC are underestimated by a factor ~100 → u' monitoring is not feasible for the survey stars
  - We will perform u' monitoring only for the brighter 4 CTTS monitored with HST

# LCOGT Optical Photometry

- Near-simultaneous V & i' images are obtained for each star
- Exposure times typically 30 sec at V, 15 sec at i'
- Including overheads, takes about 2 min to obtain the two images
- Automated data reduction by LCOGT's BANZAI pipeline

Zoom in on CVSO 146
observed at Haleakala on 2020 Sep 19

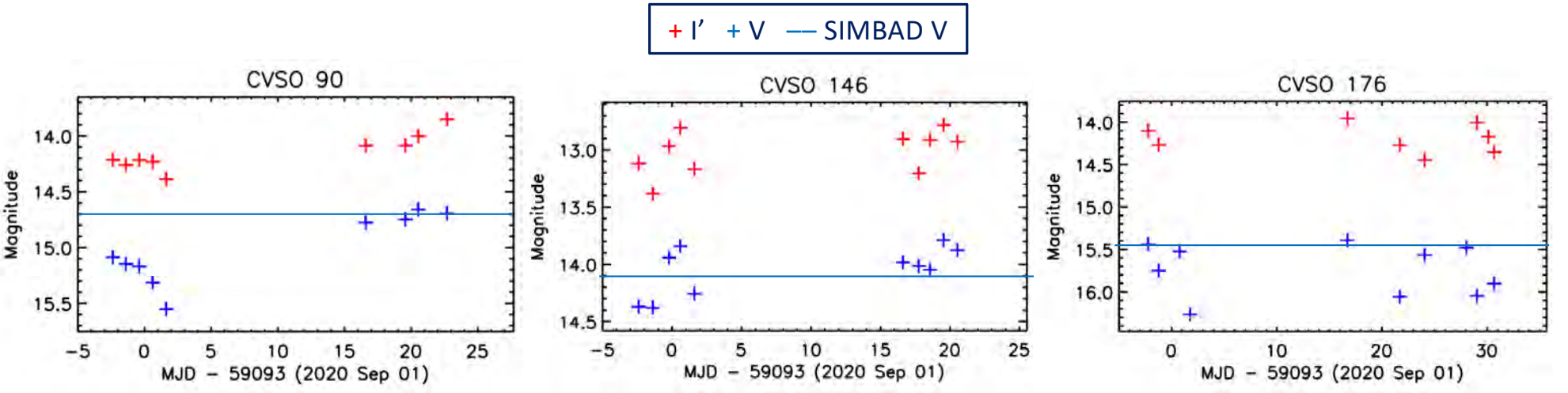
V



i'

# LCOGT Optical Photometry

- Use `aper.pro` and related routines from IDL Astronomy Users' Library (Landsman 1993) to measure counts in a 5 px (2.9") aperture, subtract sky measured in a 10–20 px annulus
- Convert counts to magnitudes by calibrating with field stars in NOMAD (V band; Zacharias et al. 2005) or SkyMapper (i' band; Australian National University)
- None of the targets observed so far are in a FU Ori burst state




Community Engagement

## Community Engagement

- Several talks/presentations to large collaborations and workshops early on in the project
  - IAU G2 (massive stars, October 2020)
  - NUVA workshop (December 2020)
  - AAS (townhall, NASA hyperwall, webinars)
  - STUC meetings
  - Princeton Bahcall lunch (March 2021)
  - Science with HST and JWST (Stockholm, summer 2022)
- Email communication with community members (ODYSSEUS, IAU-G2 teams, other community members)
- Lorentz workshop on massive stars (December 2021 – Alex Fullerton participated)
- AAS 240 splinter session
- STScI workshop or symposium in 2023
- ULLYSES survey paper (in prep)

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


| Cycle | PID | Orbits | Title | Topic |
|---|---|---|---|---|
| 27 | GO-15967<br>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<br>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<br>PI Schneider | 17 | Jets and disk scattering – Spatially resolved optical and FUV observations of AA Tau | CTTS |
| 28 | SNAP-16239<br>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<br>PI Senchyna | | Painting the first empirical picture of massive stars below the metallicity of the SMC with ULLYSES | Low-Z stars |
| 28 | AR-16129<br>PI Herczeg | | Outflows and Disks around Young Stars: Synergies for the Exploration of ULLYSES Spectra (ODYSSEUS) | CTTS |
| 28 | AR-16131<br>PI Hillier | | CMFGEN: A key spectroscopic tool for astrophysics | LMC/SMC/low-Z |
| 28 | AR-16133<br>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<br>PI Howk | Interstellar tomography of highly ionized gas in the MW thick disk with ULLYSES | CGM |
| 29 | AR-16623<br>PI Leitherer | Feasting on the Riches of Odysseus' voyage | Population synthesis |
| 29 | AR-16640<br>PI Zheng | Braving the storm, quantifying the effects of Ram Pressure and Stellar Feedback in the LMC | ISM/CGM |
| 29 | AR-16602<br>PI Barger | The LMC's Galactic Wind through the eye of ULLYSES | ISM/CGM |
| 29 | AR-16635<br>PI Tchernyshyov | The first direct measurement of CO/H2 in subsolar environments using ULLYSES data | ISM |