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, Travis Fischer, Alex Fullerton, Will Fischer

& the ULLYSES implementation team

STUC Meeting – May 19, 2022

Outline

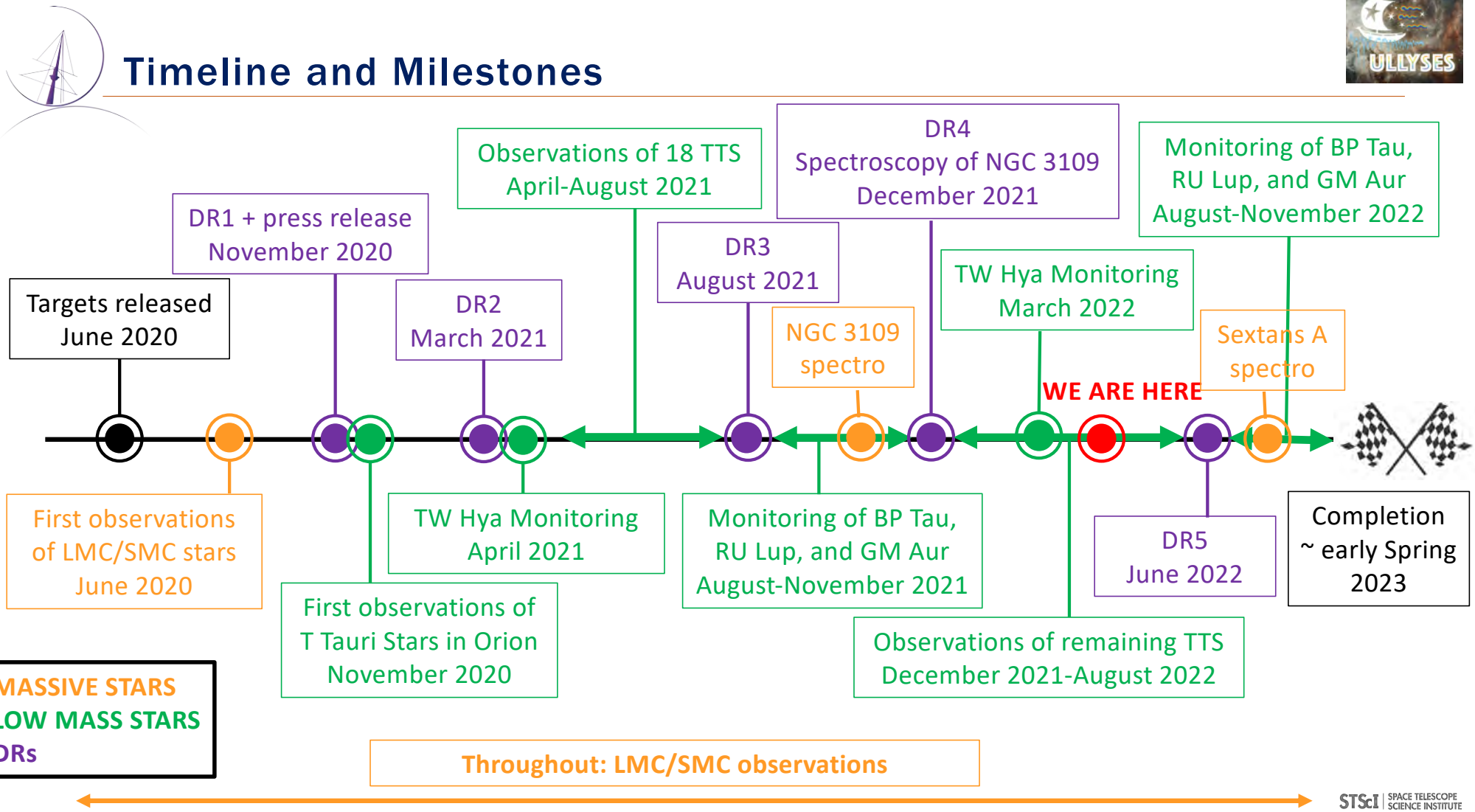
- Program status and miscellaneous updates
- Update on observing:
  - LMC/SMC massive stars
  - Low-metallicity imaging and spectroscopy
  - Survey T Tauri stars
  - T Tauri star monitoring
- Update on data products and releases
- Status of coordinated programs
- Community engagement


Program Status and Misc. Updates

Program Status

- As of May 2022, ULLYSES observing is 72% complete
- 4 data releases (latest DR4 on December 14, 2021) – see ullyses.stsci.edu
- 1 press release (https://hubblesite.org/contents/news-releases/2020/news-2020-50)
- 1 special/splinter session at AAS (#239 special session cancelled, rescheduled as splinter for AAS #240)
- 4 peer-reviewed publications by the community
  - Manara et al. 2021 (PENELOPPE X-Shooter coordinated program for T Tauri stars)
  - Pauli et al. 2022 (Study of AzV 476, the earliest O-type eclipsing binary in the SMC)
  - Froebrich et al. 2022 (analysis of the photometry for ULLYSES TTS in Orion)
  - Espaillat et al. 2022 (First paper for ODYSSEUS, the large AR program to analyze ULLYSES TTS data).

Timeline and Milestones



Upcoming events

- ULLYSES splinter session at AAS #240
- DR5 (June 2022)
- Spectroscopy of Sextans A (October-November 2022)
- Second epoch of monitoring for BP Tau, RU Lup, GM Aur (August-November 2022)
- More DRs (every 5-6 months)

ULLYSES splinter session at AAS #240

- Splinter Session for ULLYSES accepted at AAS (#240) to be held in Pasadena in June 2022
  - 60 min on June 14 (2-3 pm)
  - 6 invited speakers confirmed


Technical Observing Updates

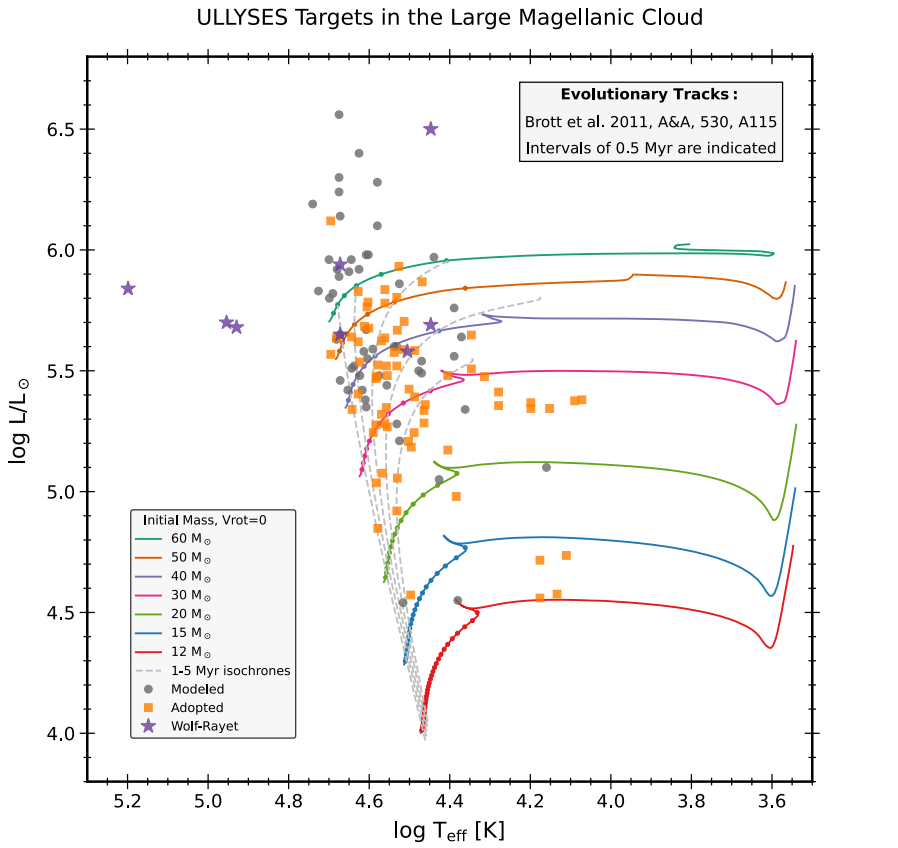
Observing: Massive Stars in the LMC

	Number	Complete	%
Targets	94	52	55.3
Orbits	238	134	56.3
HOPRs	13	23 orbits repeated (17%)	

Cycle 29 Implementation Status

41 targets, 102 orbits

Programs	17
Submitted	7
Scheduling	7



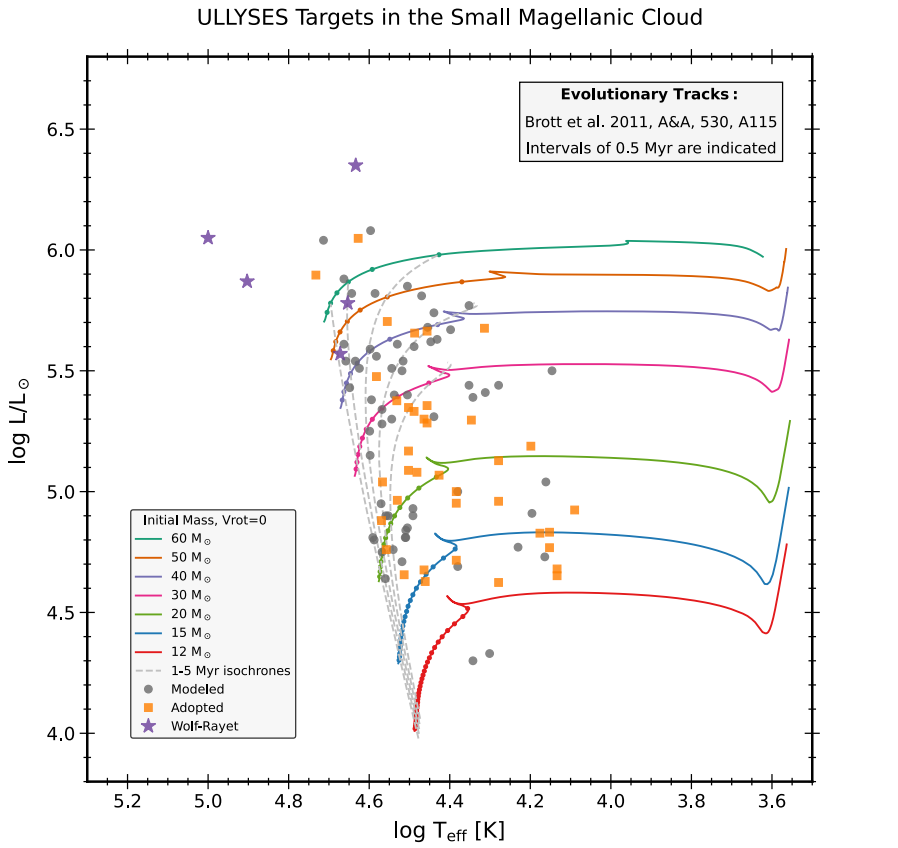
Observing: Massive Stars in the SMC

	Number	Complete	%
Targets	61	49	80.3
Orbits	207	167	80.7
HOPRs	17	40 orbits repeated (24%)	

Cycle 29 Implementation Status

11 targets, 38 orbits

Programs	7
Submitted	5
Scheduling	4



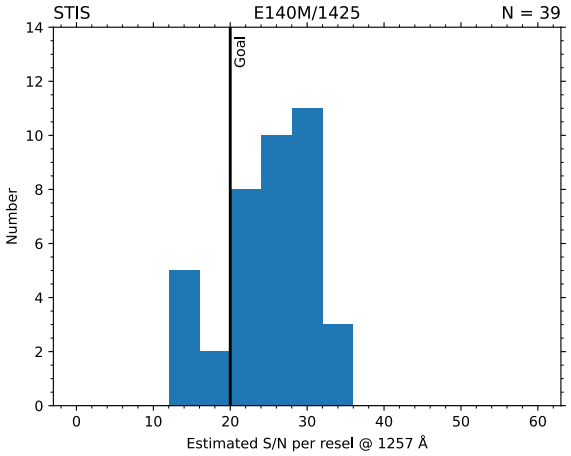
Visit-Level Data Quality: STIS configurations

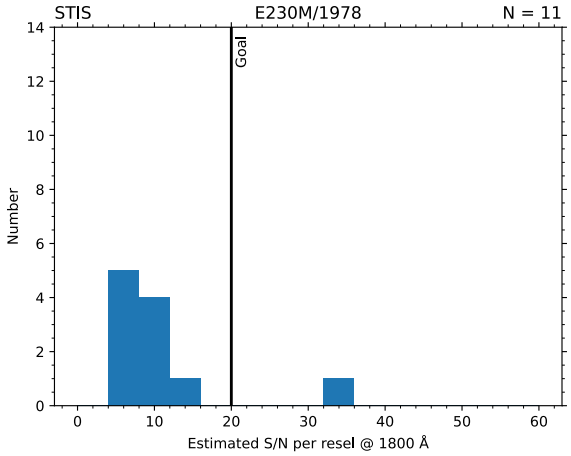
Approach to Estimating Exposure Times:

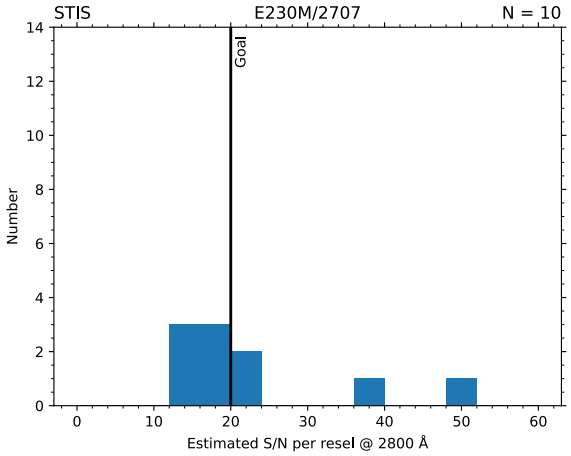
- Select model atmosphere based on Spectral Type: PoWR, WMBasic for hotter stars; C&K grid for cooler ones
- Redden the flux distribution based on measured E(B-V)
- Normalize with observed UV flux (preferred) or UBV photometry (when necessary)

Quality of the photometry and extinction is usually the limiting factor

Other factors: binarity, spectroscopic peculiarities

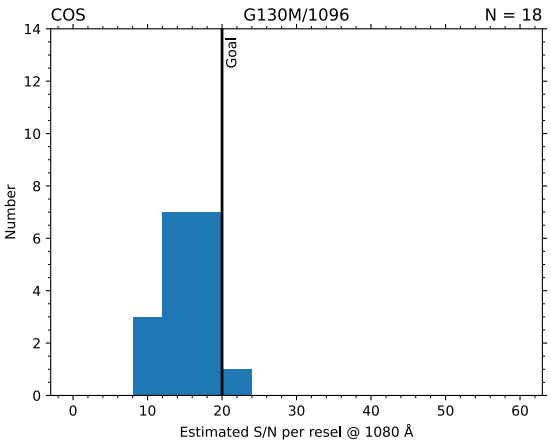


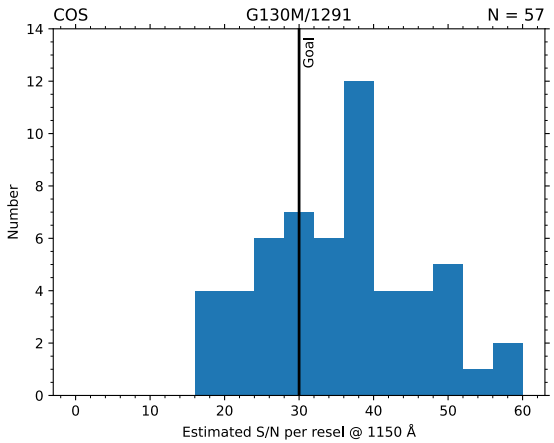


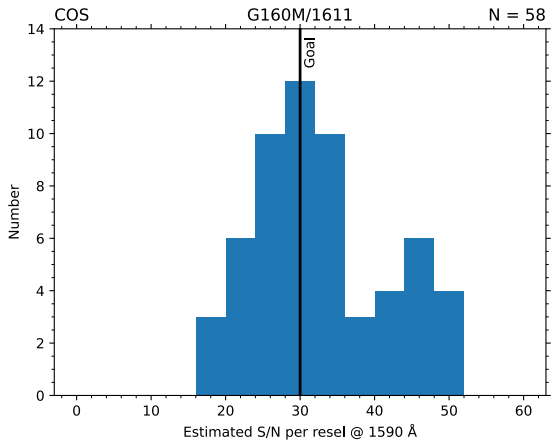


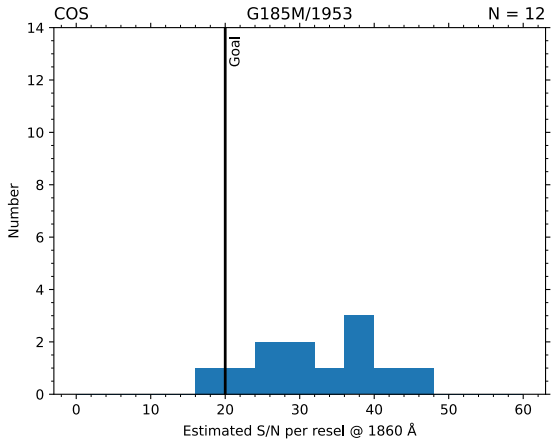
*NB: only super-giants O9 and later observed with E230M/1978, and later than B5 with E230M/2707

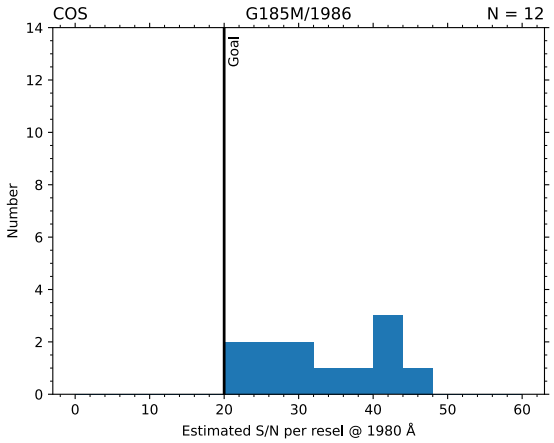
Visit-Level Data Quality: COS configurations









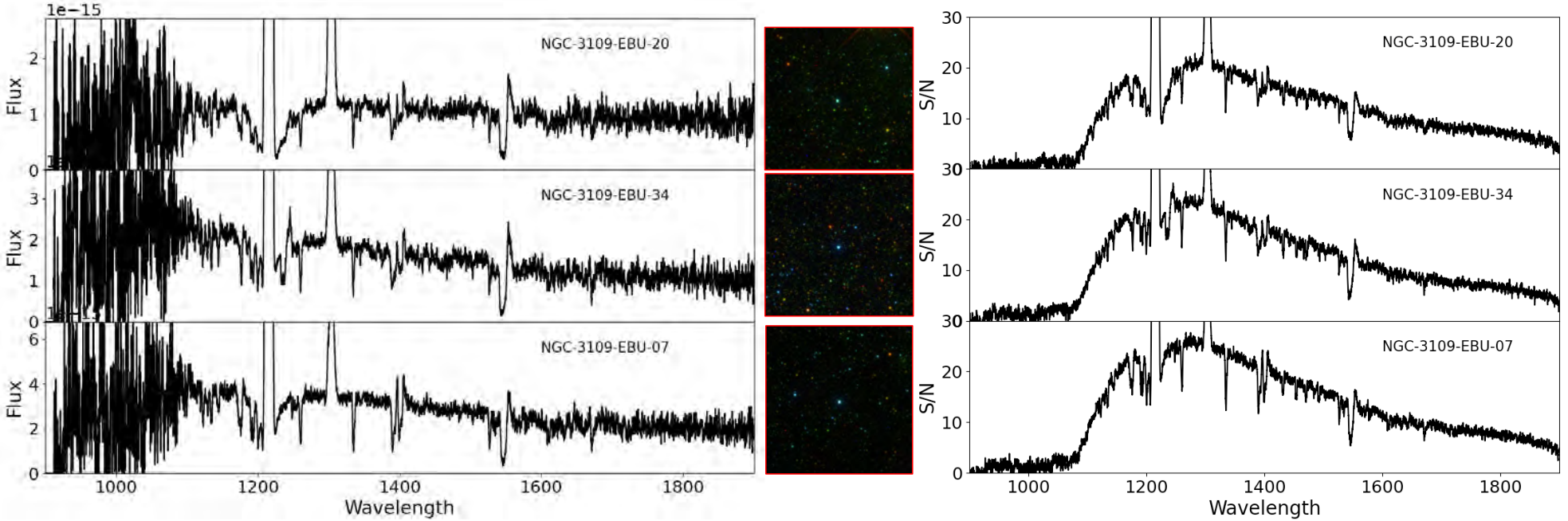


*NB: only super-giants B5 and later observed with COS/NUV (G185M)

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	Implementation

*F225W, F275W, F336W, F475W, F814W



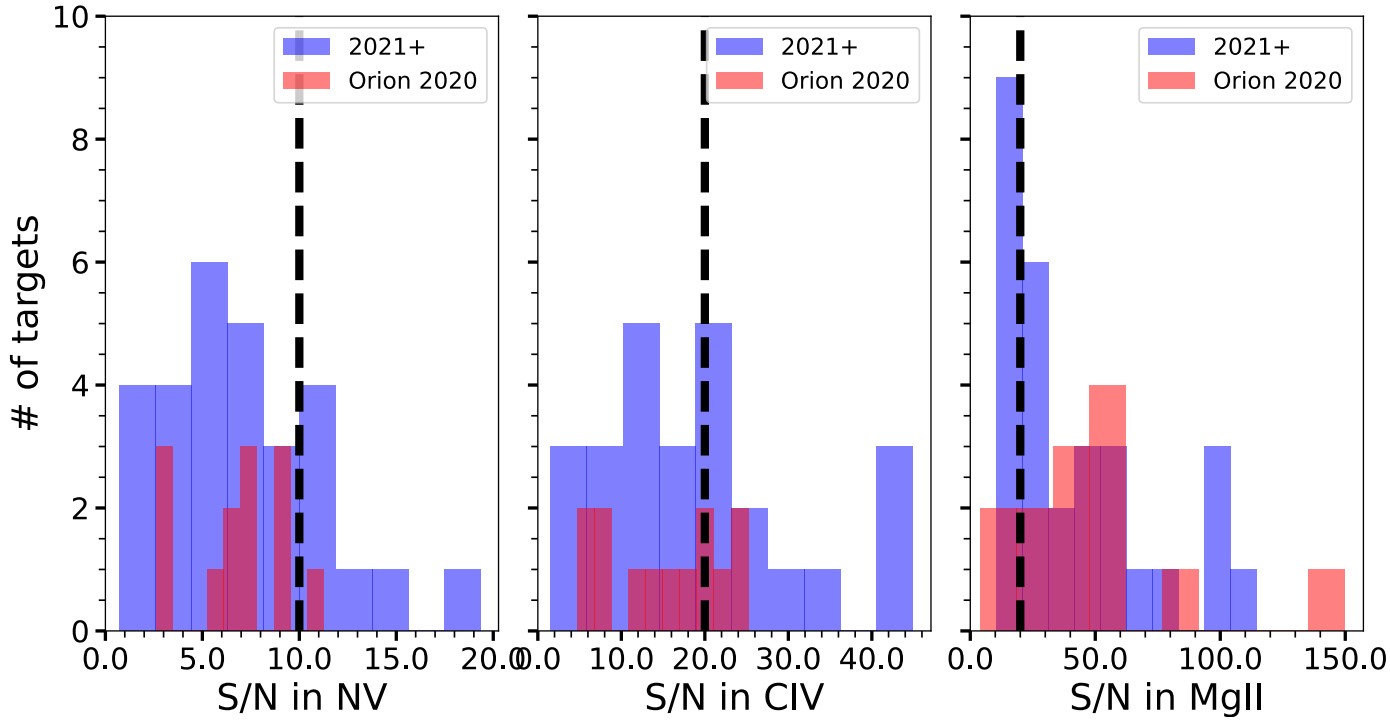
Observing: Survey T Tauri stars (58 targets/400 orbits)

- Observations complete for 47 T Tauri stars (81%)
  - 13 TTS in Orion observed in November-December 2020 during period when covered by TESS
  - 18 TTS in Lupus, Cha I, Eta Cha observed in 2021 with 16 targets in coordination with TESS
  - 16 TTS in Taurus, Lupus, Cha I, Eta Cha, Eps Cha observed in 2022
- Phase IIs submitted for 11 more survey TTS stars in Lupus, CrA (78 orbits)
  - Observations will execute before August 2022
- 7 repeats (7 targets) for 36 orbits

	Number	Complete	%
Targets	58	47	81
Orbits	390	307	79
HOPRs	7	36 orbits repeated (12%)	

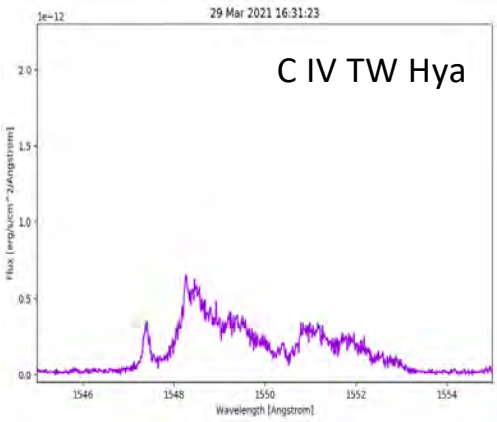
Outcome for T Tauri stars

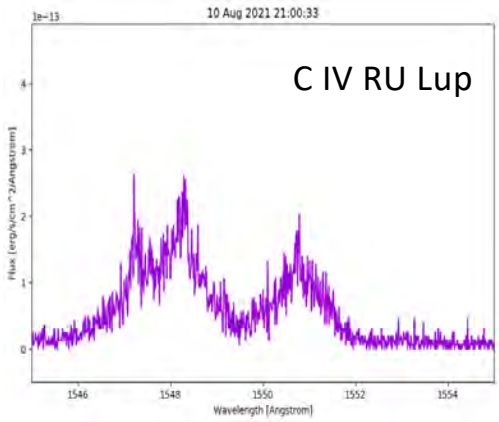
- Early observations in Orion had lower S/N than planned due to underestimated extinction
- Issue was corrected for next batch of observations
- Some objects have seen a large decrease in accretion rate, and therefore in FUV flux

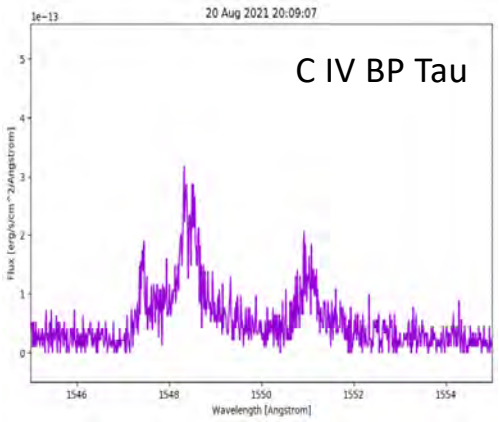


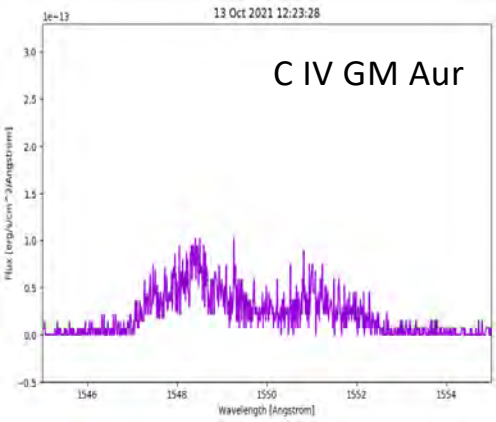
Observing: Monitoring of 4 T Tauri stars (100 orbits)

- 12 observations (4/period over 3 rotational periods) executed:
  - TW Hya (March-April 2021) – 1 failed visit (the second one)
  - BP Tau (August-September 2021) – 0 failed visits
  - RU Lup (August 2021) – 2 failed visits (repeat of first failed visit also failed)
  - GM Aur (November-December 2021) – 1 failed visit, 5 visits postponed by 6 weeks due to HST safing
- Second epoch will occur in 2022 on a similar schedule as epoch 1 (2021)
  - TW Hya completed in April 2022 with 3/12 failed visits (2/3 repeat visits also failed)









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Scheduling updates

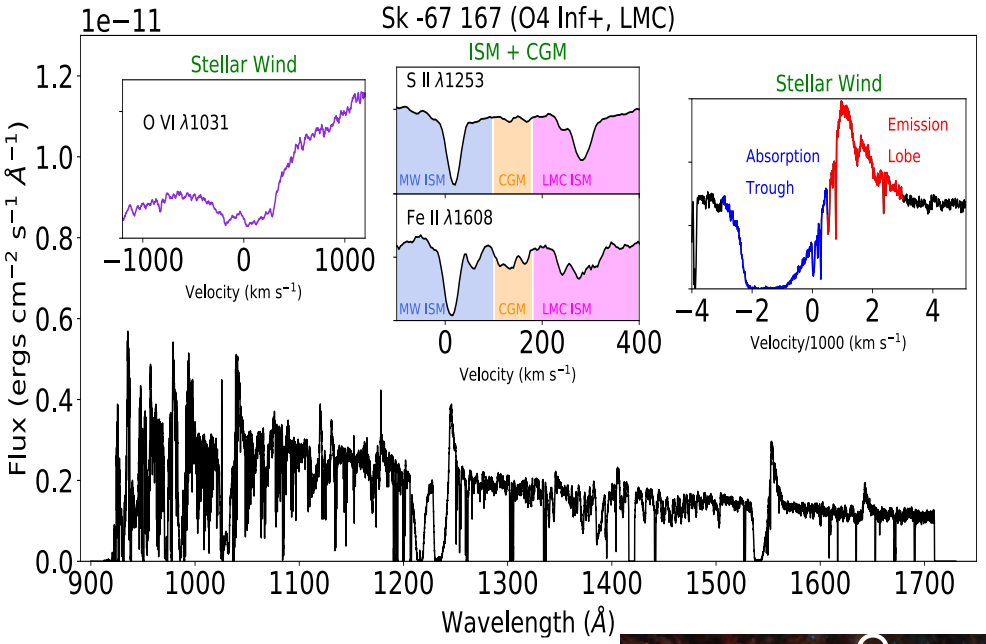
- Scheduling information is included on the ULLYSES website (https://ullyses.stsci.edu/ullyses-targets-ttauri.html)
- Scheduling updates are forwarded to a specific email distribution that includes PIs of coordinated observations (ullyses_ctts_scheduling@maillist.stsci.edu)

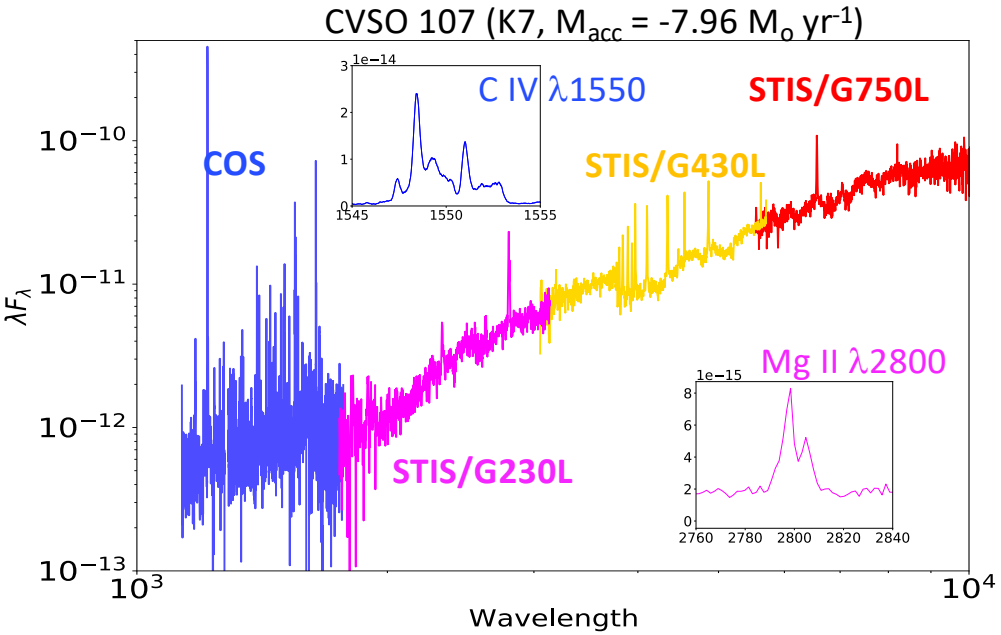

ULLYSES Data Products

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 from HST only for T Tauri stars monitored over time
- Drizzled WFC3 images of NGC 3109 and Sextans A

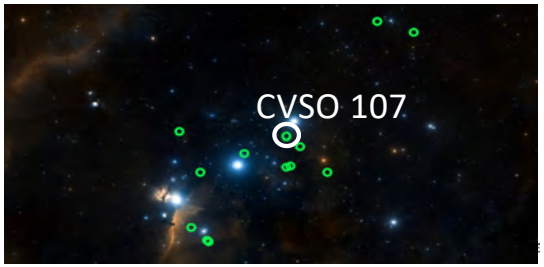
Examples of Data Products





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

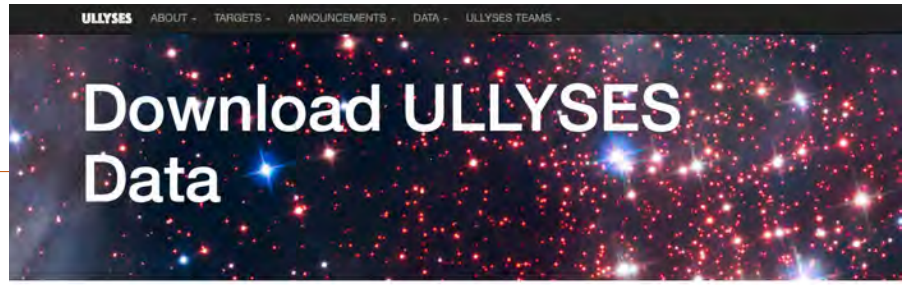
- 4 data releases (DRs) to date; DR5 planned for June 28, 2022
- Latest data release (DR4) includes:
  - COS spectra for 51 Tauri stars (31 with STIS NUV-optical-NIR)
  - COS spectroscopic time series for 4 T Tauri stars monitored with HST
  - LCOGT photometric time series for 31 T Tauri stars
  - UV spectra of 196 stars in the LMC and SMC, plus FUSE spectra of 103 of those stars
  - Drizzled WFC3 imaging of NGC 3109
  - STIS spectra of 8 non-ULLYSES targets present in STIS long-slit observations
- DRs scheduled every 5-6 months, timing optimized to deliver major increments of data
- DRs widely advertised via HST email exploder, Twitter, STScI webpage, MAST newsletters

DR5 Data Products

- DR5 will include, in addition to DR4 products:
  - COS and STIS spectra for TTS observed between November 2021 and May 2022
  - COS spectroscopic time series for the second epoch of TW Hya and extra GM Aur visits
  - LCOGT photometric time series for additional TTS completed since DR4
  - UV spectra of LMC and SMC stars observed between November 2021 and May 2022
  - FUSE spectra of ~15 stars in the LMC and SMC
  - Drizzled WFC3 imaging of Sextans A

Data Dissemination Platform

- All program information, observing schedule, and target metadata are on ullyses.stsci.edu
- Data can be downloaded from:
  - The ULLYSES website https://ullyses.stsci.edu/ullyses-download.html
  - ULLYSES search & download web application: https://ullyses.stsci.edu/search/
  - 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



In addition to the static download tables below, you may also utilize the ULLYSES interactive search and download web application here. The tables below list each target included in the latest ULLYSES data release, separated by galaxy/Milky Way region. By clicking the download link for an individual target, you will receive a tarball that includes both the HST and, if available, FUSE 1-D extracted spectra for the target as well as all High Level Science Products (HLSPs) created by the ULLYSES team. For TW Hydra, only HLSPs are available for download due to the large number of contributing 1-D spectra. You can also download all data for each region, which again includes individual 1-D spectra as well as HLSPs:

- Download all LMC targets:
  - HLSPs (164.5 MB)
  - HST/FUSE 1-D spectra (733.9 MB)
- Download all SMC targets:
  - HLSPs (189.2 MB)
  - HST/FUSE 1-D spectra (1.0 GB)
- Download all T Tauri targets:
  - HLSPs (193.8 MB)
  - HST 1-D spectra (340.1 MB)

A description of the ULLYSES data products and how they are created can be found on the data description page.

You can also download the custom DISPTAB used to calibrate monitoring stars:
Custom DISPTAB

Jump to:
- LMC
- SMC
- NGC3109
- Classical T Tauri Monitoring Stars
- Chamaeleon I Cloud
- Eta Chamaeleontis Association
- Eps Chamaeleontis Cluster
- Lupus Clous
- Taurus-Auriga Association
- Orion OB1 Association
- σ Orionis Cluster

LMC Targets

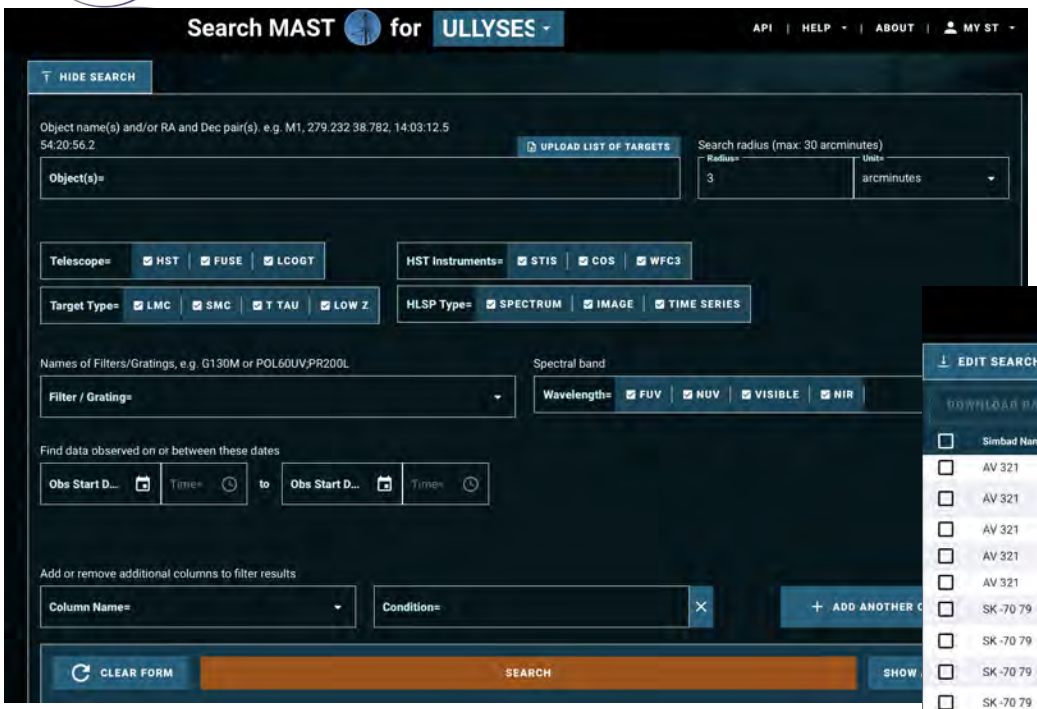
Download all LMC targets: HLSPs (164.5 MB) and HST/FUSE 1-D Spectra (733.9 MB)

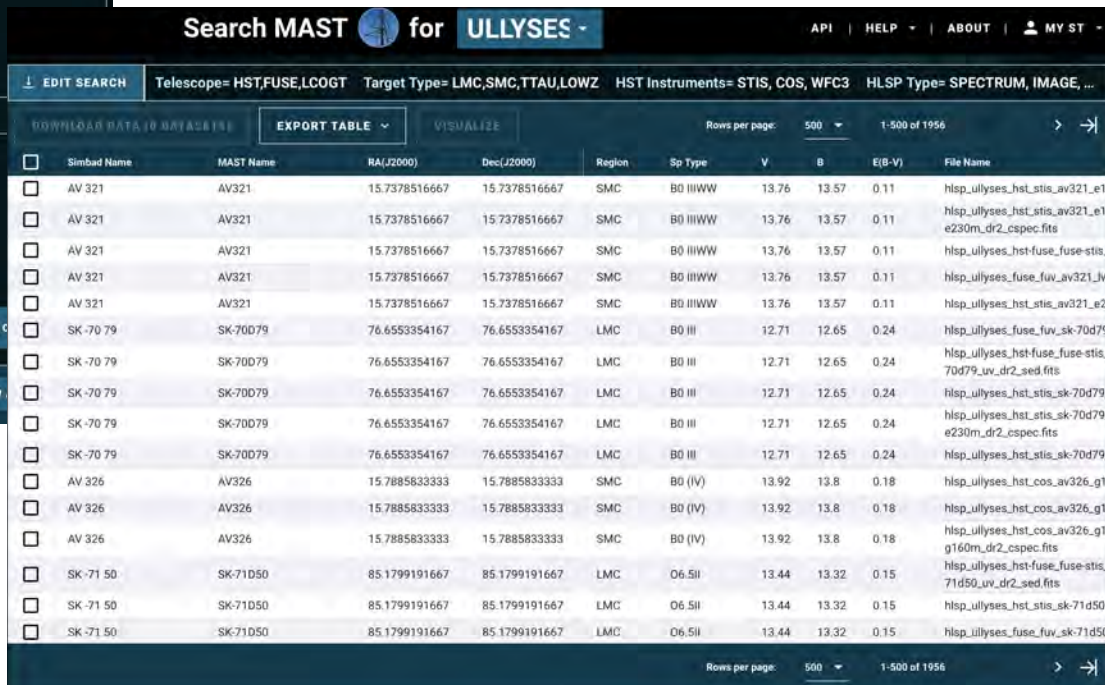
Simbad Name	MAST Target Name	RA(J2000)	DEC(J2000)	SpType	V	B	E(B-V)	Instrument(s)	Grating(s)/Filter(s)	Download Link
SK -67 2	SK-67D2	71.7686	-67.1148	B1Ia+	11.04	11.22	0.37	FUSE, STIS	E140M, E230M, FUSE/LWRS	Download Target
SK -67 5	SK-67D5	72.5789	-67.6606	O9.7 Ib	11.34	11.22	0.14	FUSE, STIS	E140H, E140M, E230H, E230M, FUSE/LWRS	Download Target
SK -68 8	SK-68D8	73.4304	-68.7148	B5 Ia+	10.99	11.04	0.14	COS, STIS	E230M, G130M, G160M	Download Target
SK -67 14	SK-67D14	73.6329	-67.2568	B1.5 Ia	11.52	11.42	0.08	FUSE, STIS	E140M, E230M, FUSE/LWRS	Download Target
SK -70 16	SK-70D16	73.739	-70.0412	B4 I	13.1	13.04	0.07	COS	G130M, G160M, G185M	Download Target
SK -67 20	SK-67D20	73.8806	-67.5007	WN4b	13.81	13.46	0.1	FUSE, STIS	E140M, FUSE/LWRS	Download Target
SK -66 19	SK-66D19	73.9748	-66.4165	O7V	14.87	14.98	0.38	COS, STIS	E230M, G130M, G160M	Download Target

Data Dissemination Platform: Future Plans

- We will be releasing new query and download platform
  - Database of targets and observations linked to user-interface via API
  - Fully integrated in MAST for long-term maintainability and impact
  - Allows for selection of targets by astrophysical parameters (e.g., SpT, LC, extinction, accretion rate etc.) and observational parameters (e.g. observatory, instrument, grating)
- As time and resources allow, UI will be enhanced to allow for visual selection of targets via plots:
  - E.g., from an HR diagram for massive stars, or a plot of mass vs accretion rate for T Tauri stars

ULLYSES Search and Download Form



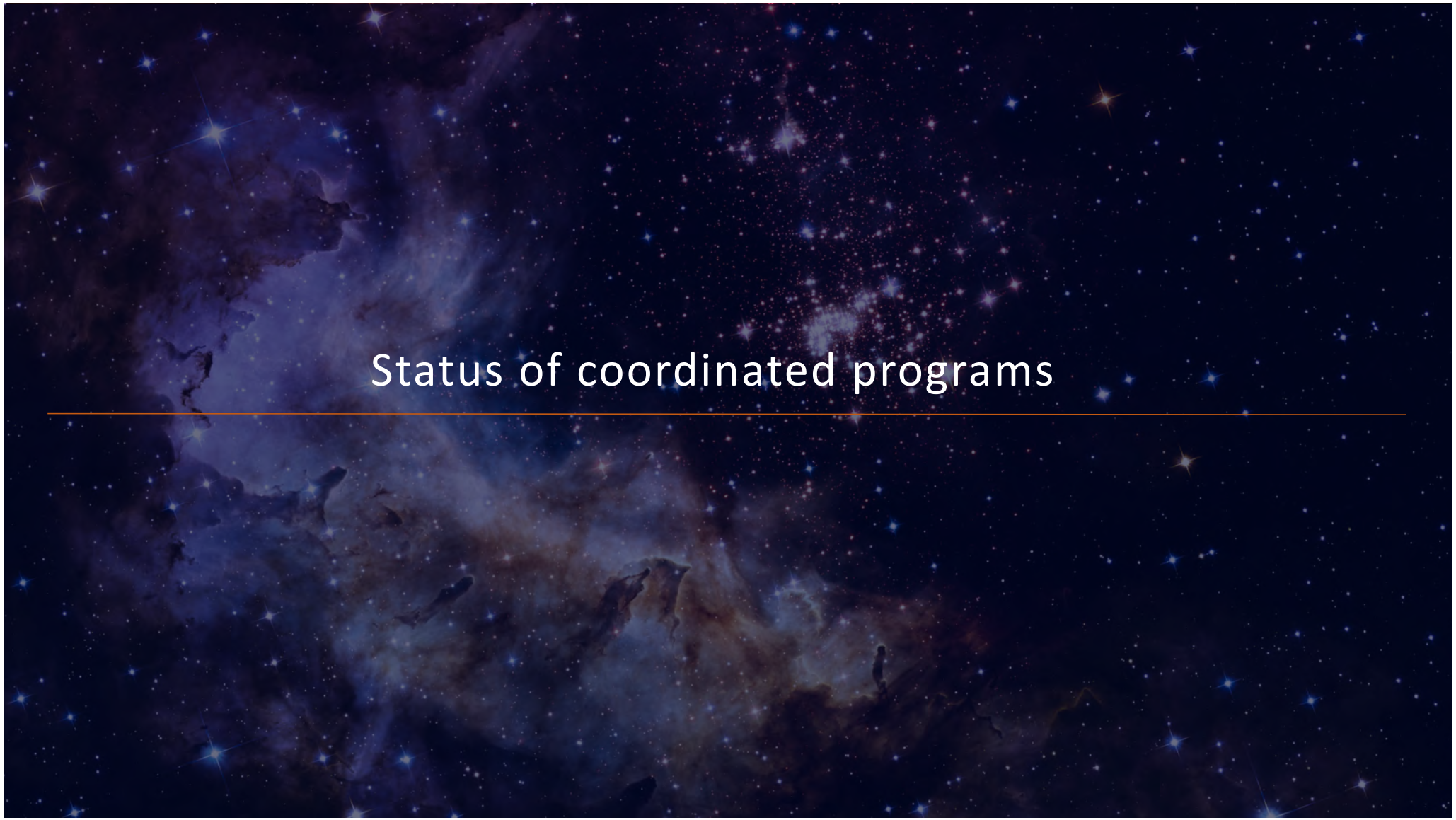


Publication of ULLYSES Code

- For DR5, we will release ULLYSES codebase and data reduction pipelines
  - Until now, all code has been restricted to internal-only github repositories
- Will be maintained in a new open-source ULLYSES python package. Package includes:
  - Code to create all of our data products
  - Supporting files with target metadata
  - Custom data processing steps for COS, STIS, and FUSE data
  - User documentation
- More improvements to come after DR5
  - Documentation will be moved to ReadTheDocs
  - Example Jupyter notebooks will be added

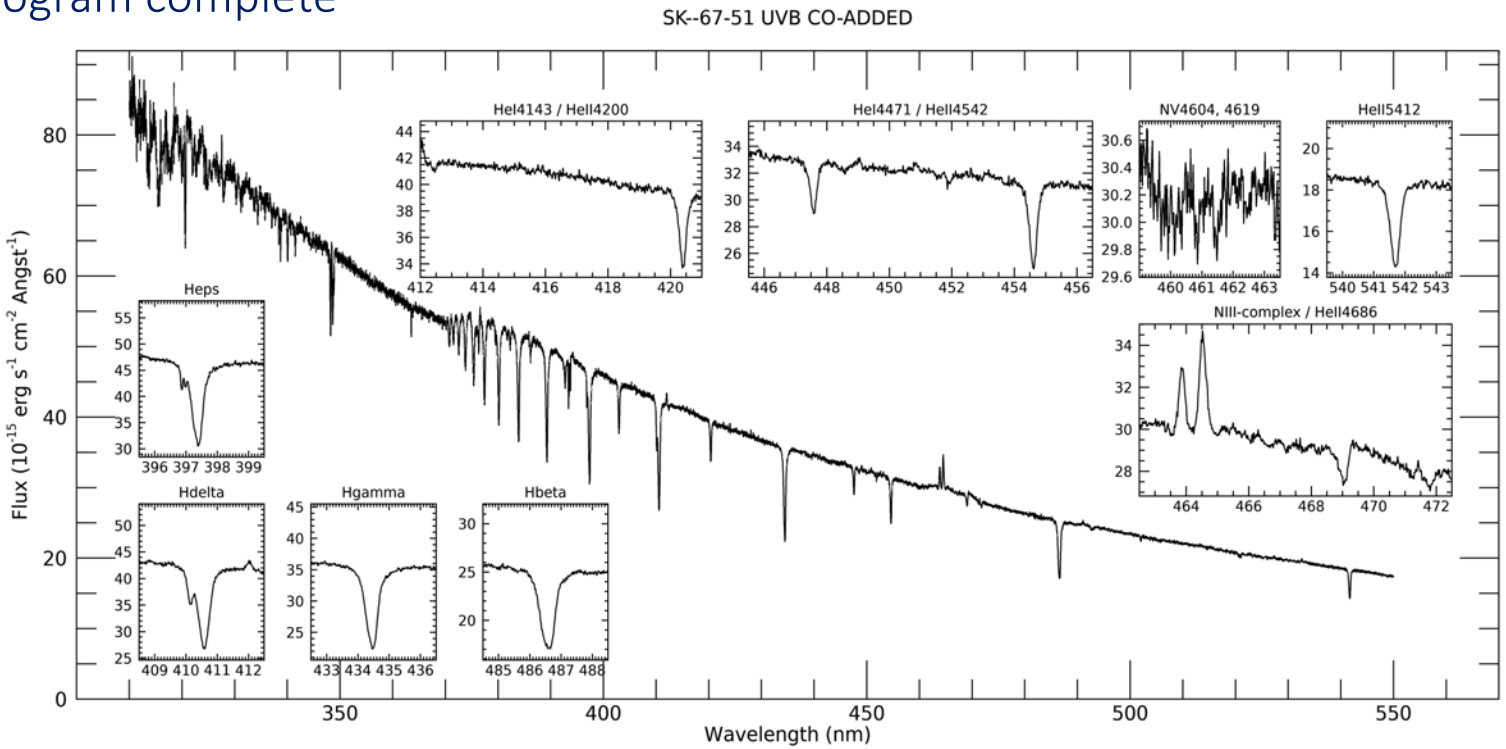
Looking Ahead

- There's still more to look forward to! Expected upcoming updates:
  - Custom-calibrated FUSE spectra for previously deferred targets
  - Serendipitous time-series products for variable (non-monitoring) stars
  - Add archival data to time-series products for TW Hydra
  - Process for submitting community products


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

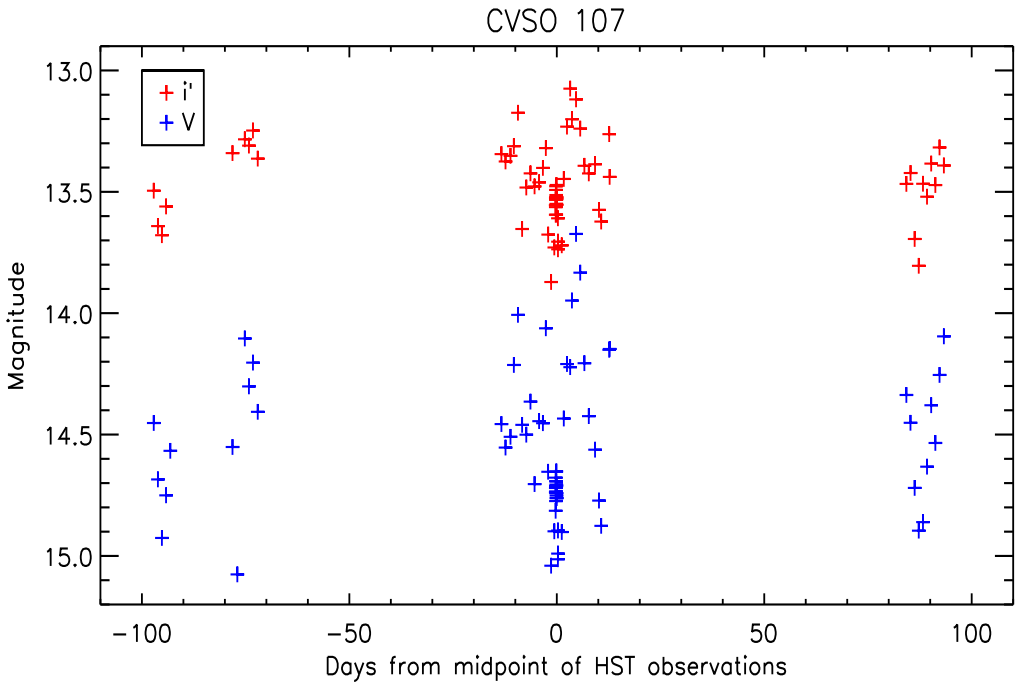
- Monitored stars only
  - Chandra/XMM-Newton (X-ray; accretion)
  - CFHT/SPIRou spectro-polarimetry (magnetic field mapping)
- Survey and monitored stars
  - VLT X-Shooter, ESPRESSO, UVES (accretion, extinction, stellar properties, kinematics)
  - IRTF (calibration of MIR accretion diagnostics in preparation 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




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 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

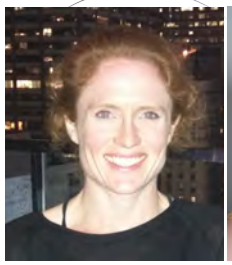
13 AR, parallel, or complementary GO programs related to ULLYSES

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/H2 in subsolar environments using ULLYSES data	ISM

Questions and Feedback

Acknowledgements

ULLYSES Core Implementation Team (CIT)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Jo Taylor
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Travis Fischer
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Will Fischer
TTS Observing Lead


Alex Fullerton
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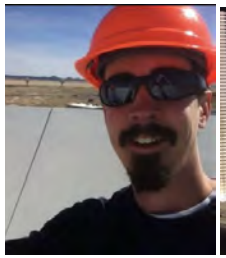
Alessandra Aloisi
(Pre-imaging)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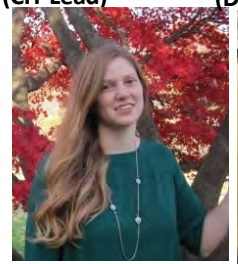
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Svea Hernandez
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(DP, software)


Sean Lockwood
(ETC, Obs)


TalaWanda Monroe
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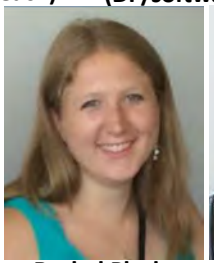
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Other STScI staff involved

- Tricia Royle (Program Coordinator)
- Dave Adler and scheduling team
- Scott Fleming, Peter Forshay, David Rodriguez (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

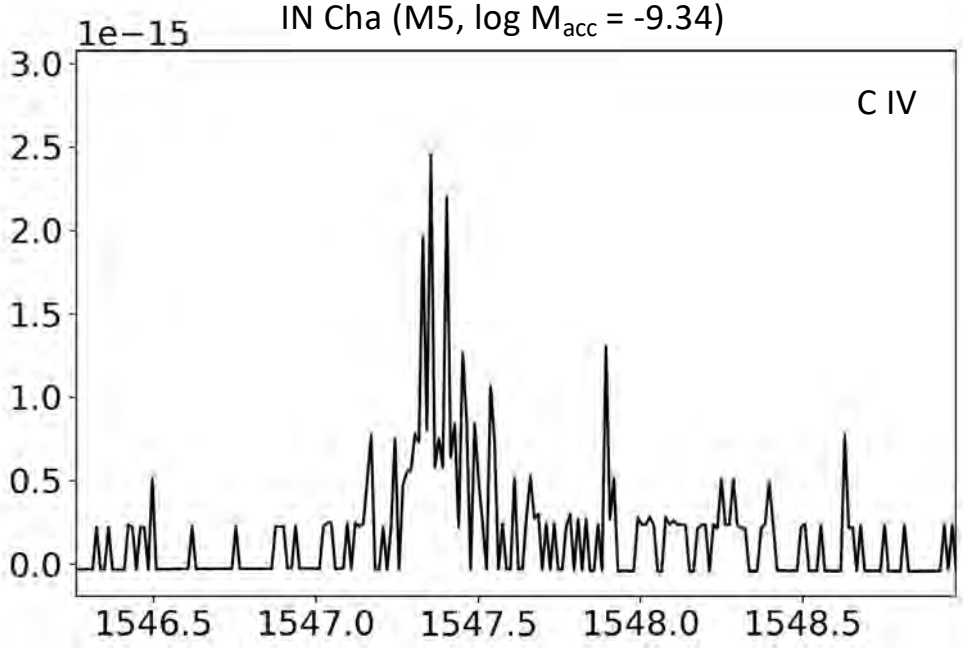
Extinction and exposure times for CTTS

- 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)

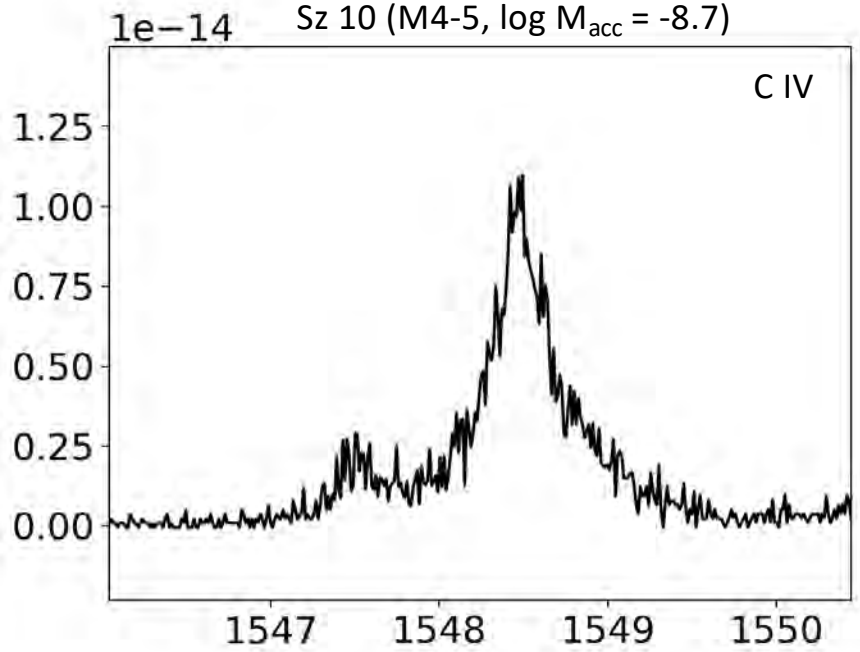
Observing outcomes for late M stars

- 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)

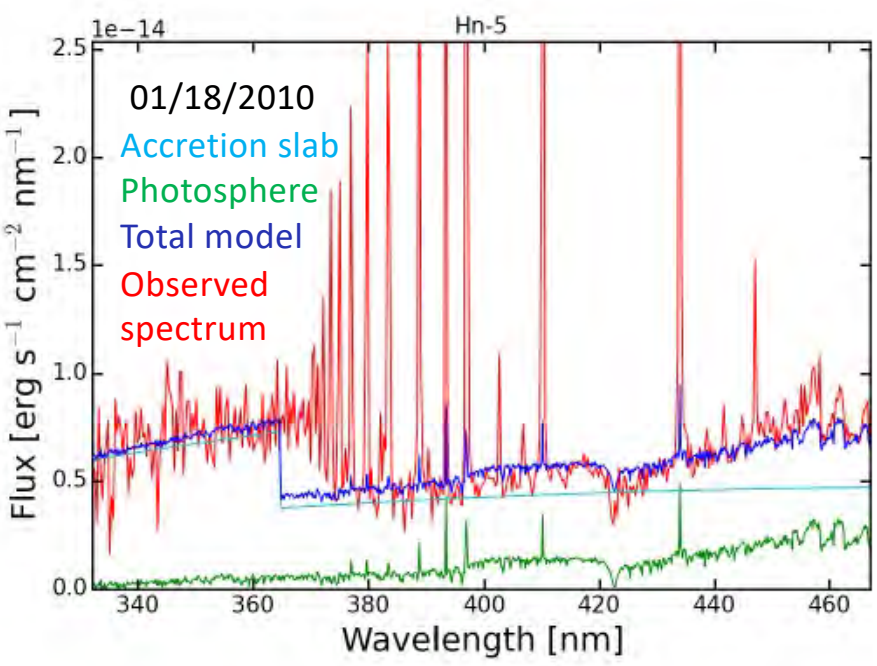


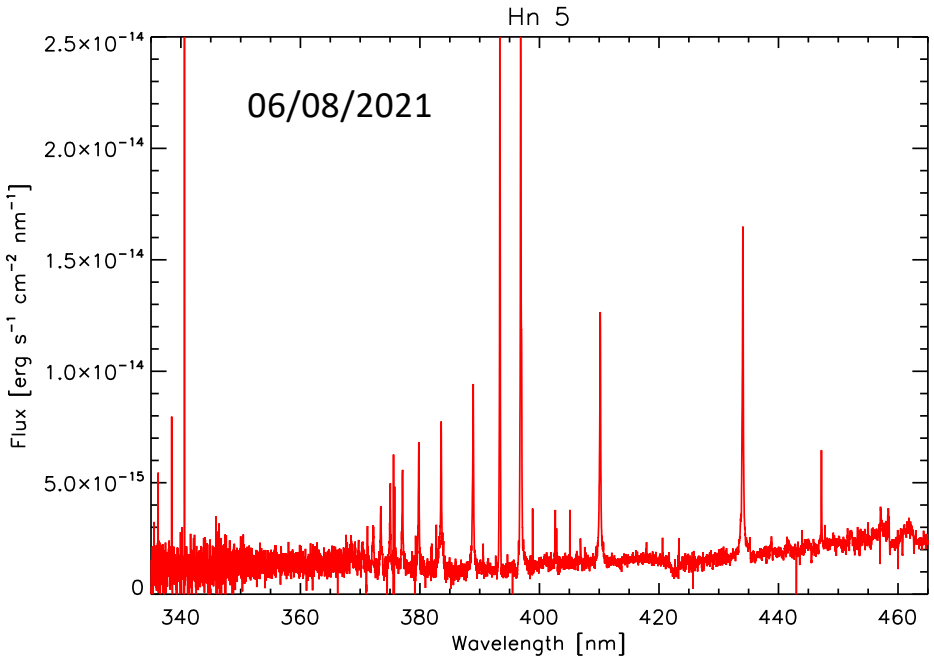
Signal-to-noise outcome

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





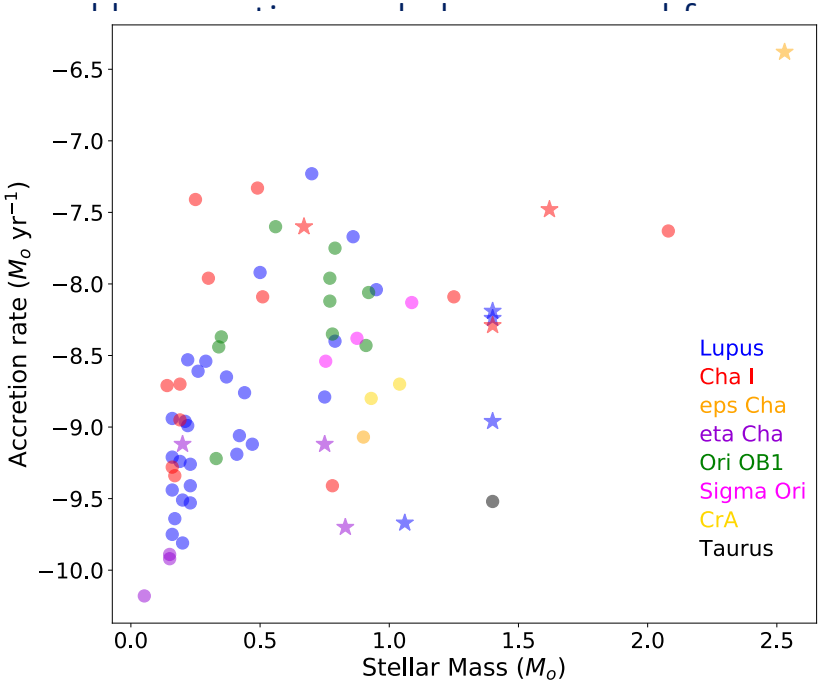
Plan adopted in Spring 2021

- 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

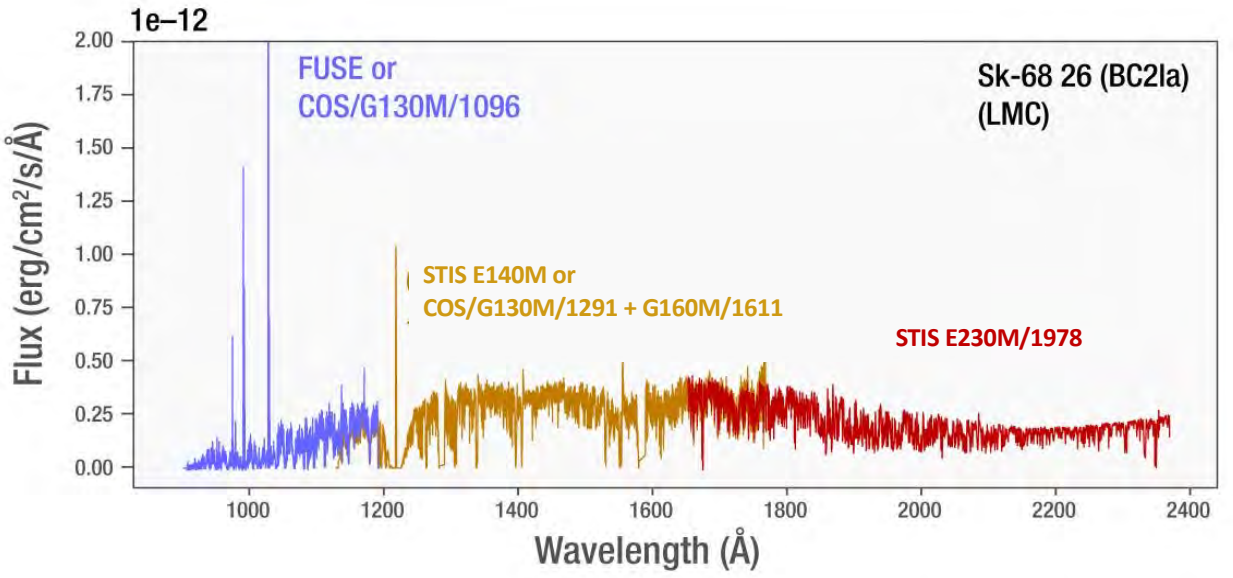
Recent T Tauri star sample updates

- 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)



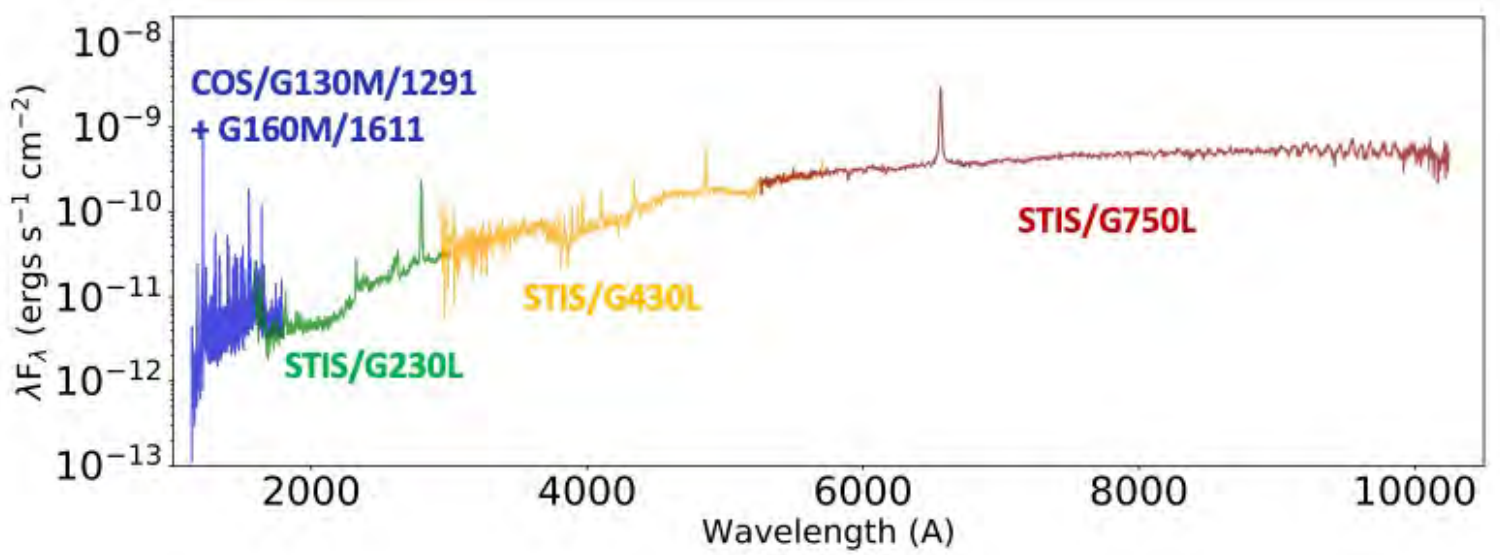
Observing Strategy – LMC/SMC Massive stars

- **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

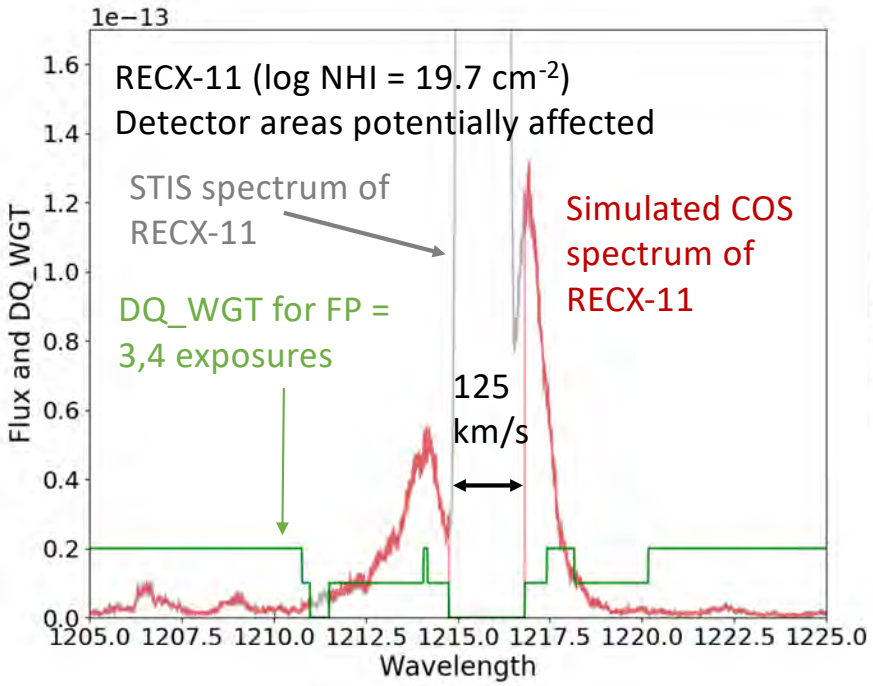


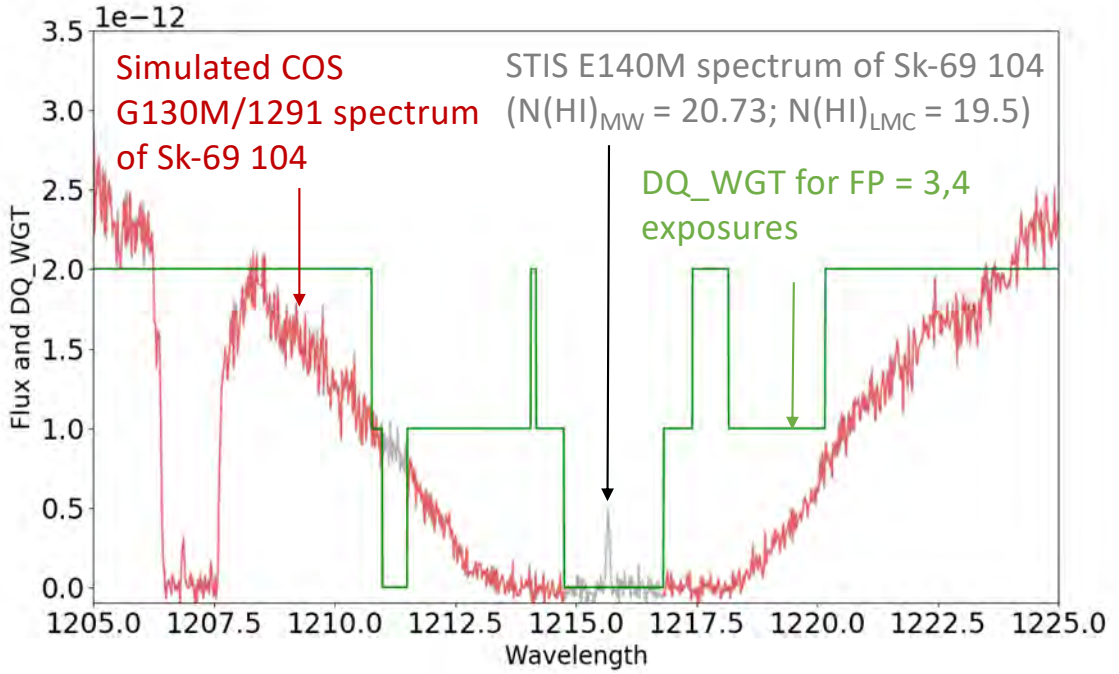
ULLYSES S/N Requirements

- 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.

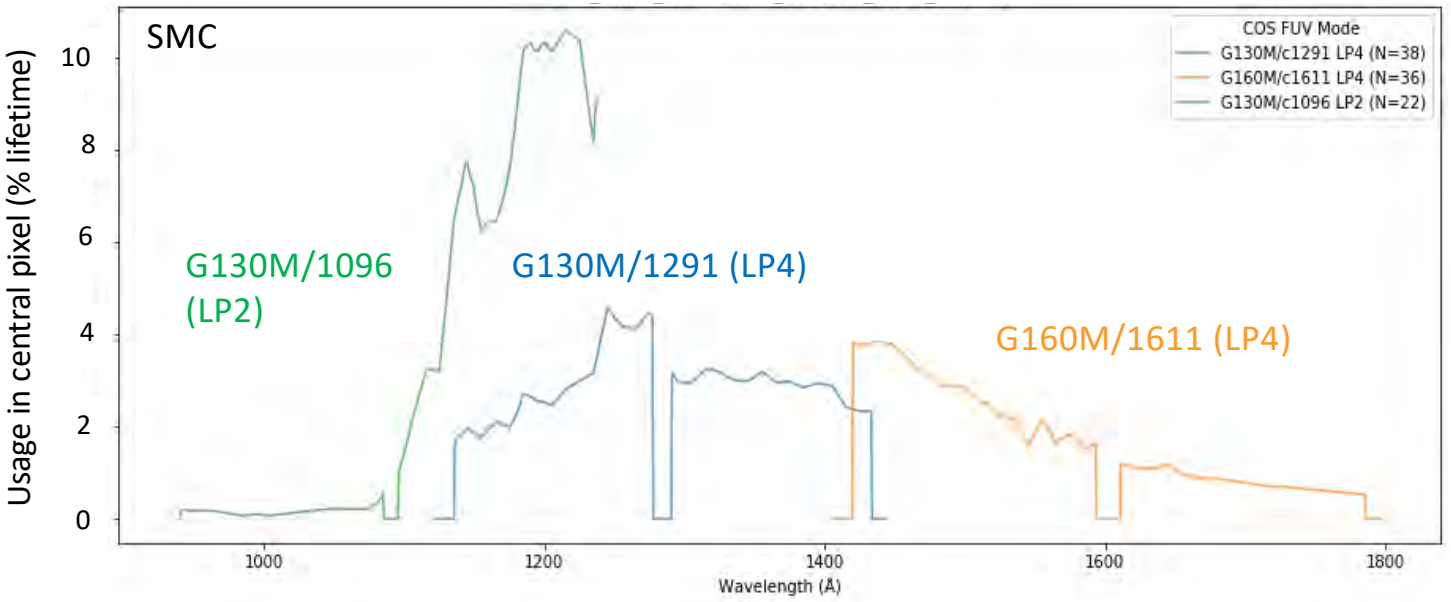




Gain-sag impact on COS – SMC

New

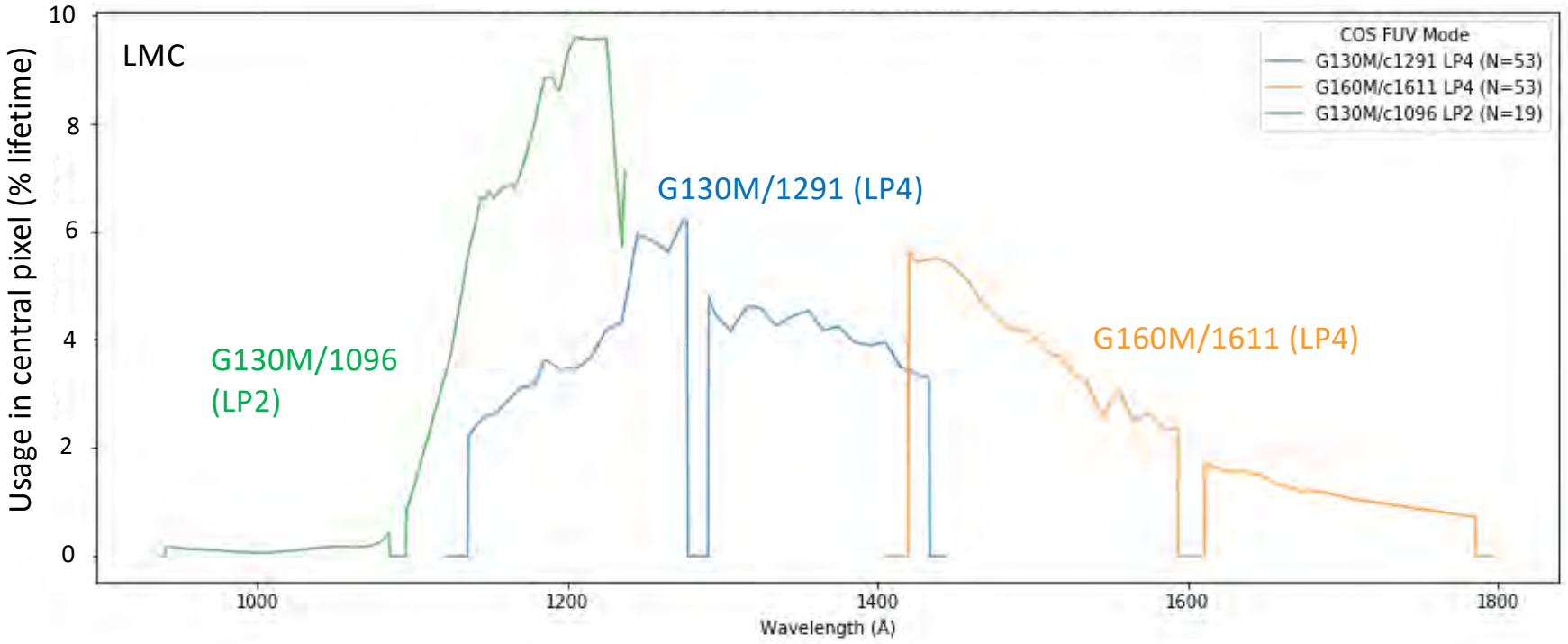
- Model SEDs and scriptable ETC used to estimate counts in the brightest pixel as a function of wavelength for each mode of observation
- Fraction of lifetime is counts/50,000
- Note: COS/G130M/1096 is operated at LP2 with high counts on FUVA



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

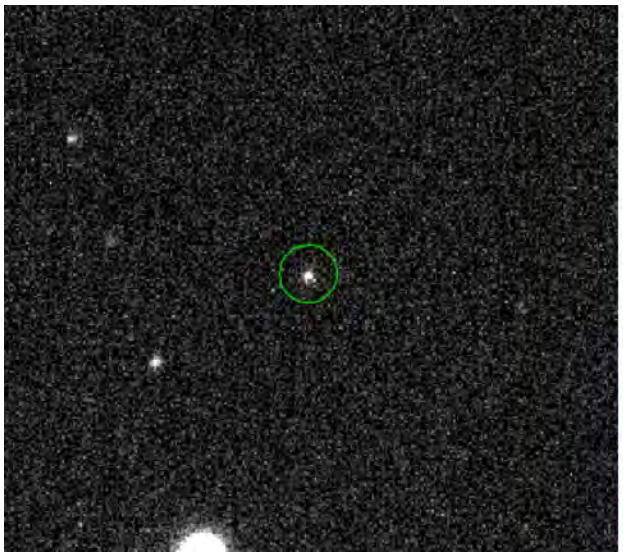
- Cadence:
  - 1x/day 3 months before/after HST epoch
  - 1x/day 10 days before/after HST epoch
  - 10x/period of the 1 (3) periods centered on the HST observations for the survey (monitoring) stars
  - 15 min cadence during the HST observations
- S/N > 10 for all targets/bands
- Flux calibration field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