



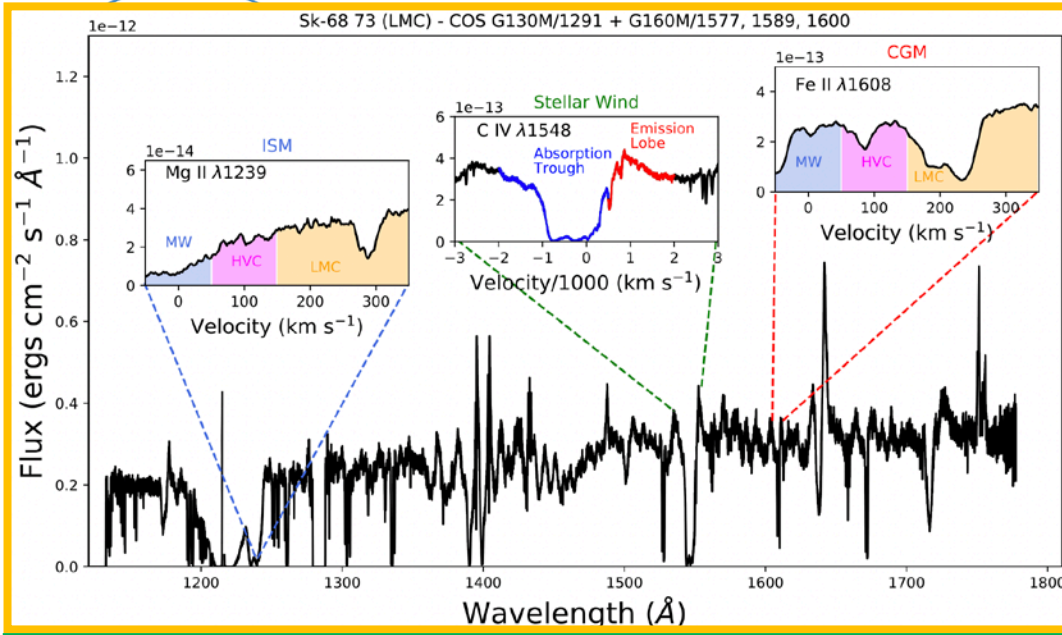
SK-67 167 (O4 Inf+)

The ULLYSES Director's Discretionary Program

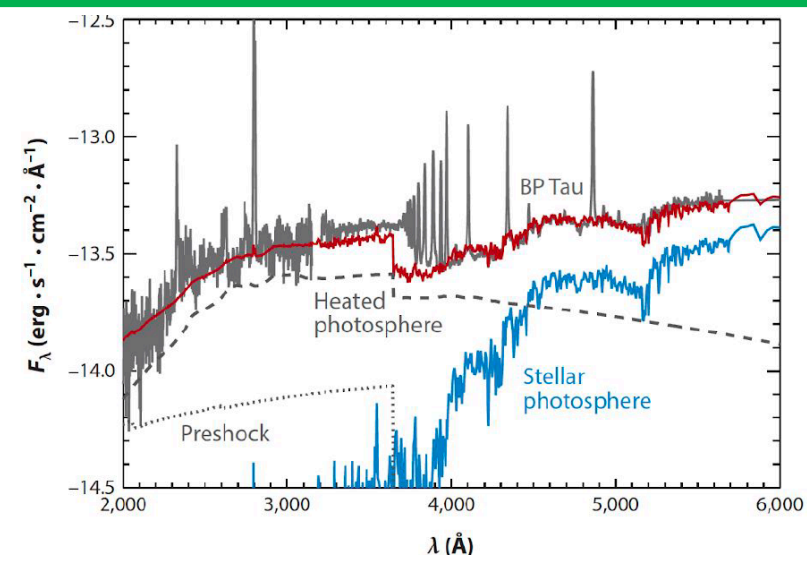
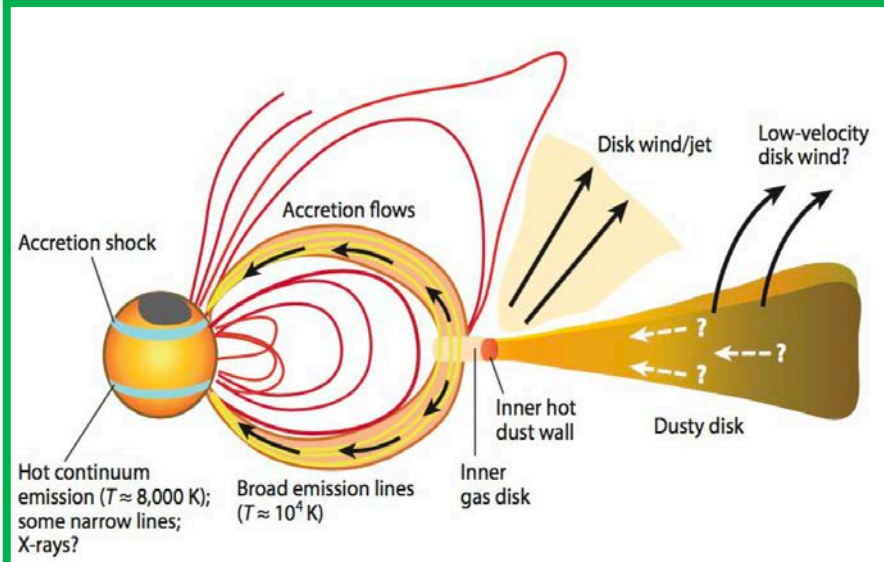
Charting Young Stars' Ultraviolet Light with Hubble



A Spectroscopic Survey of Young Low and High Mass Stars



- ~500 orbits to extend the spectroscopic library of O and B stars to low metallicity (0.08 - 0.5 Z_⊙)
- Properties of massive stars (wind velocities and clumping, mass loss rates, CNO abundances)
- Spectral templates for population synthesis and studies of LyC escape
- ISM abundances and dust depletions for studies of chemical evolution
- Kinematics, metallicity, and spatial distribution of galaxy-scale outflows in the CGM



- ~500 HST orbits to obtain a spectroscopic library and time monitoring of T Tauri stars (t < 10 Myr, M < 1 M_⊙)
- Enable transformative research in accretion and ejection physics,
- Study the evolution and dispersal of disks
- Constrain disk chemistry and planet habitability



Overview of ULLYSES target sample

- Targets released to the community in early 2020
- ~300 (including 65 archival) targets included in the ULLYSES database
- Numerous coordinated and follow-up observations planned by community:
 - *Massive stars*: VLT X-Shooter **optical/IR spectroscopy**
 - *T Tauri stars*:
 - ✓ **Optical-NIR spectroscopy**: VLT X-Shooter
 - ✓ **X-Ray**: XMM-Newton, Chandra, and ISS/NICER
 - ✓ **Magnetic mapping** with spectro-polarimetry (CFHT)
 - ✓ **IR spectroscopy** (IRTF)
 - ✓ **Photometric monitoring** with LCOGT and other ground-based observatories
 - ✓ **TESS** high-cadence monitoring in *i* band

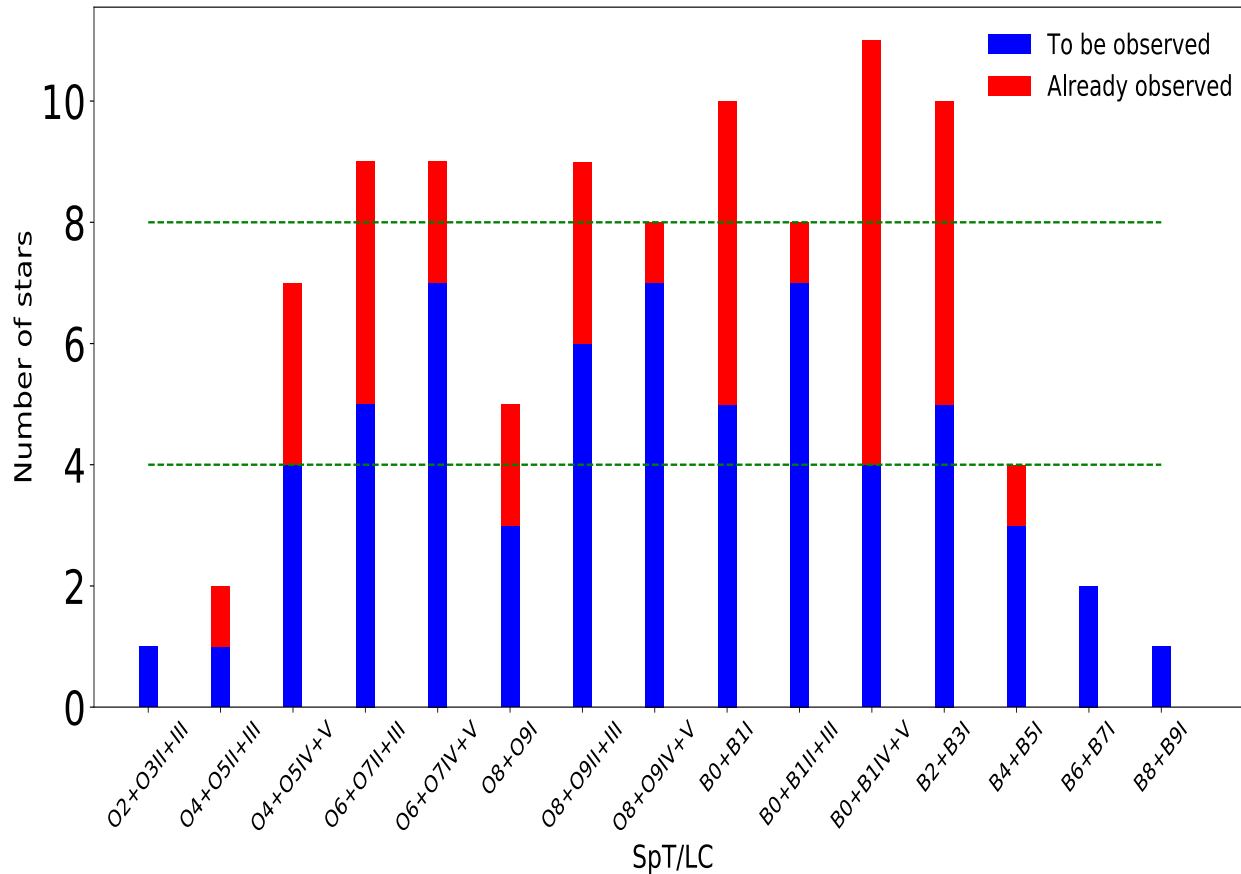
Region	# ULLYSES targets	# AR targets	# ULLYSES orbits
LMC	98	34	225
SMC	65	41	220
Sextans-A	3	6	~37
NGC 3109	3	0	~15
Lupus	27	4	142
Cha I	16	3	97
ϵ Cha	2	1	22
η Cha	5	3	20
Orion	10	0	45
σ Ori	3	0	13
CrA	2	0	10
TW Hydrae	1	0	2
Monitoring T Tauri Stars	4	0	100
TOTAL	241	92	948



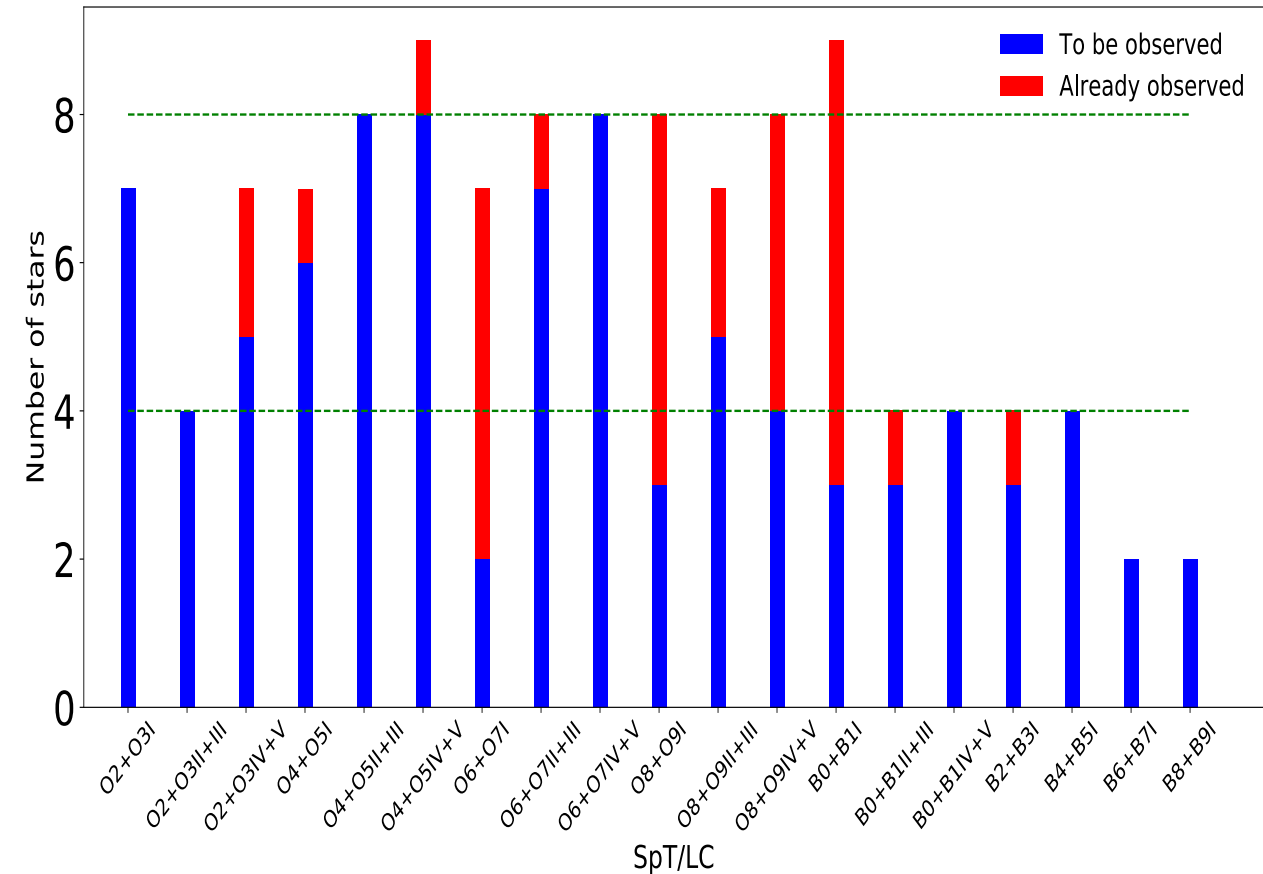
Target Selection – Sampling of spectral type in the LMC/SMC

- 4-5 O I-V per SpT/LC bin
- 2-4 B0-B4 I per bin
- 2-4 B0-B1 I-V stars per bin
- 1-2 B5-9 I per bin

SMC (20% metallicity)



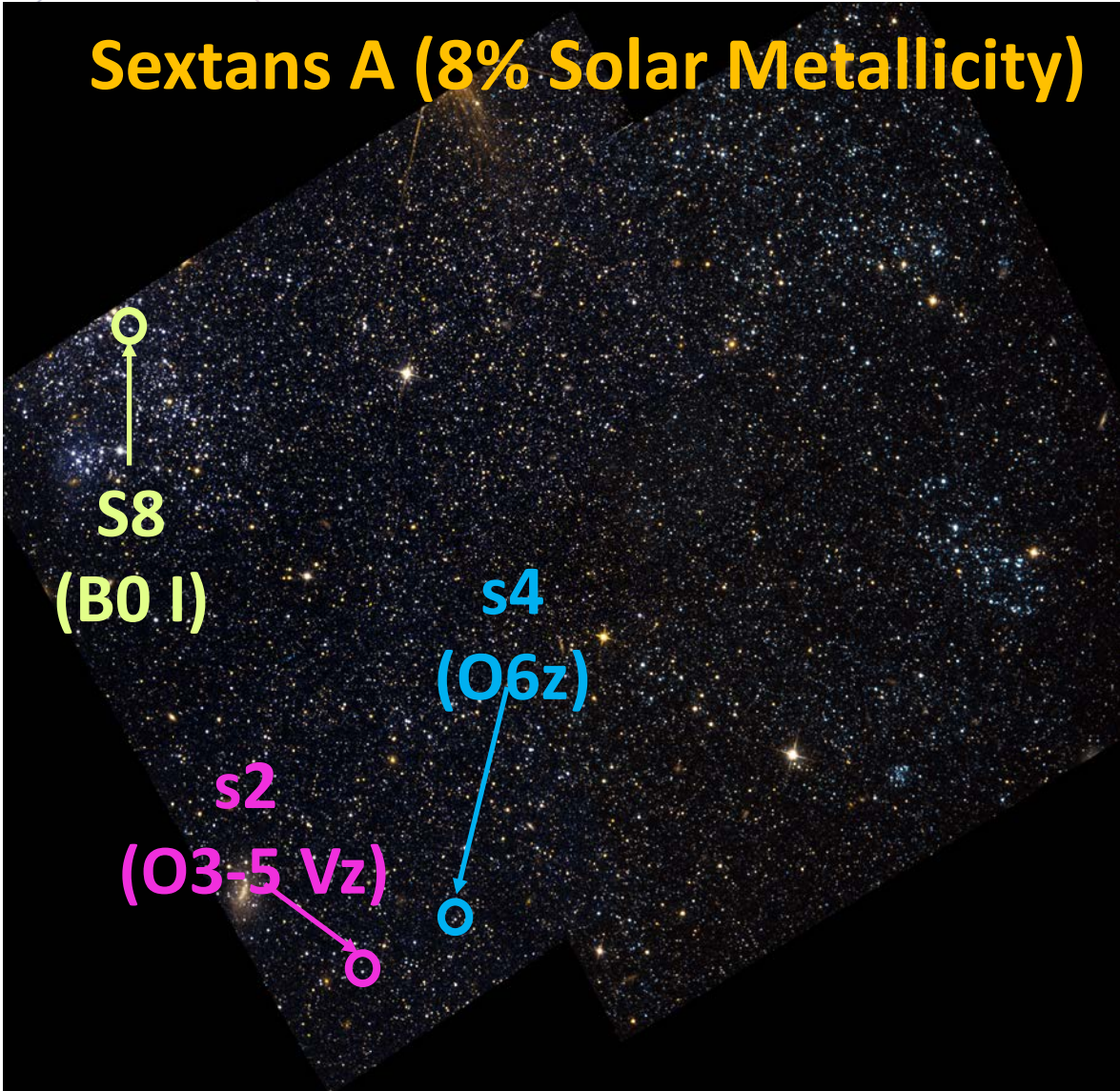
LMC (50% metallicity)





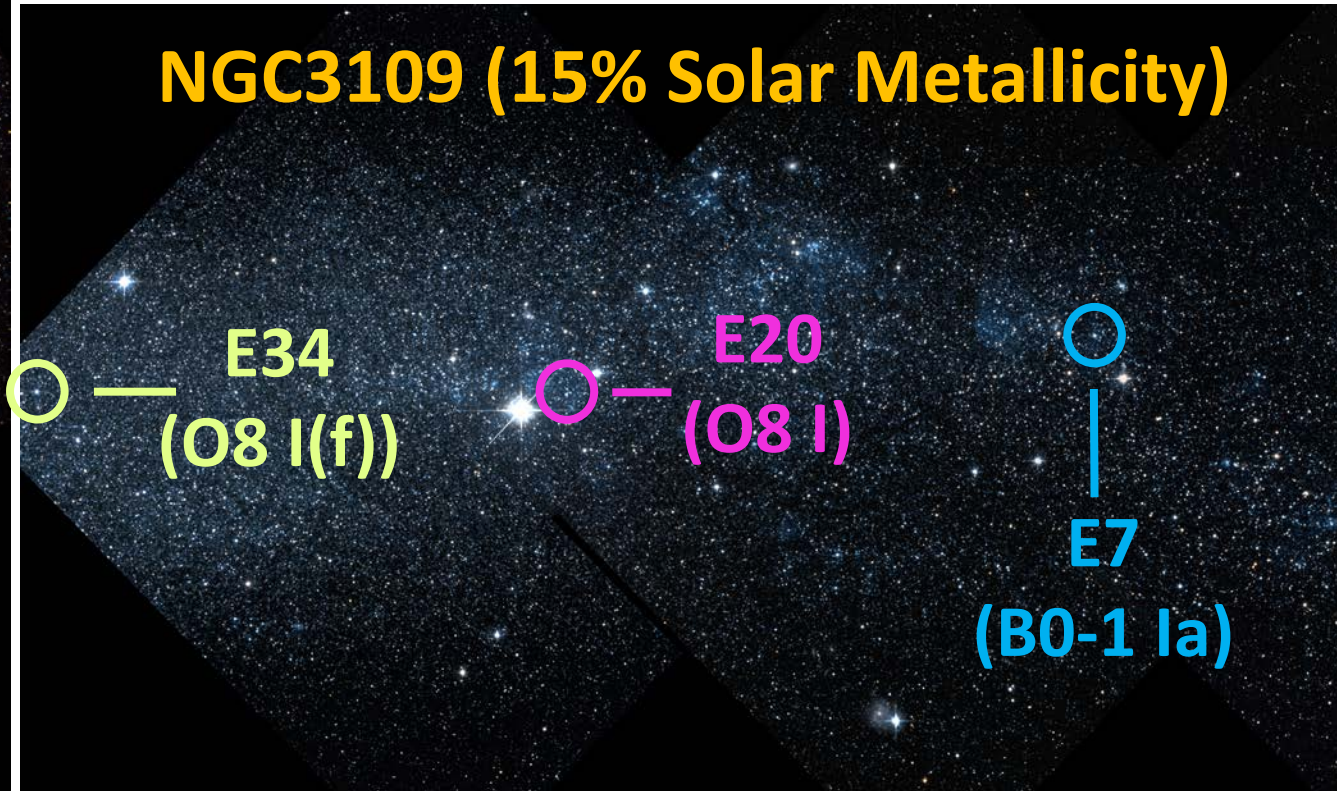
Target Selection - Low Metallicity Massive Star Sample

Sextans A (8% Solar Metallicity)



- ✓ Sextans A (8% solar metallicity)
 - 3 massive stars (O3 Vz, O6z, B0 I)
 - Also 6 more archival targets
- ✓ NGC 3109 (0.1 Z_{\odot} in O, 0.2 Z_{\odot} in Fe)
 - 3 Super-giants O8 – B0

NGC3109 (15% Solar Metallicity)

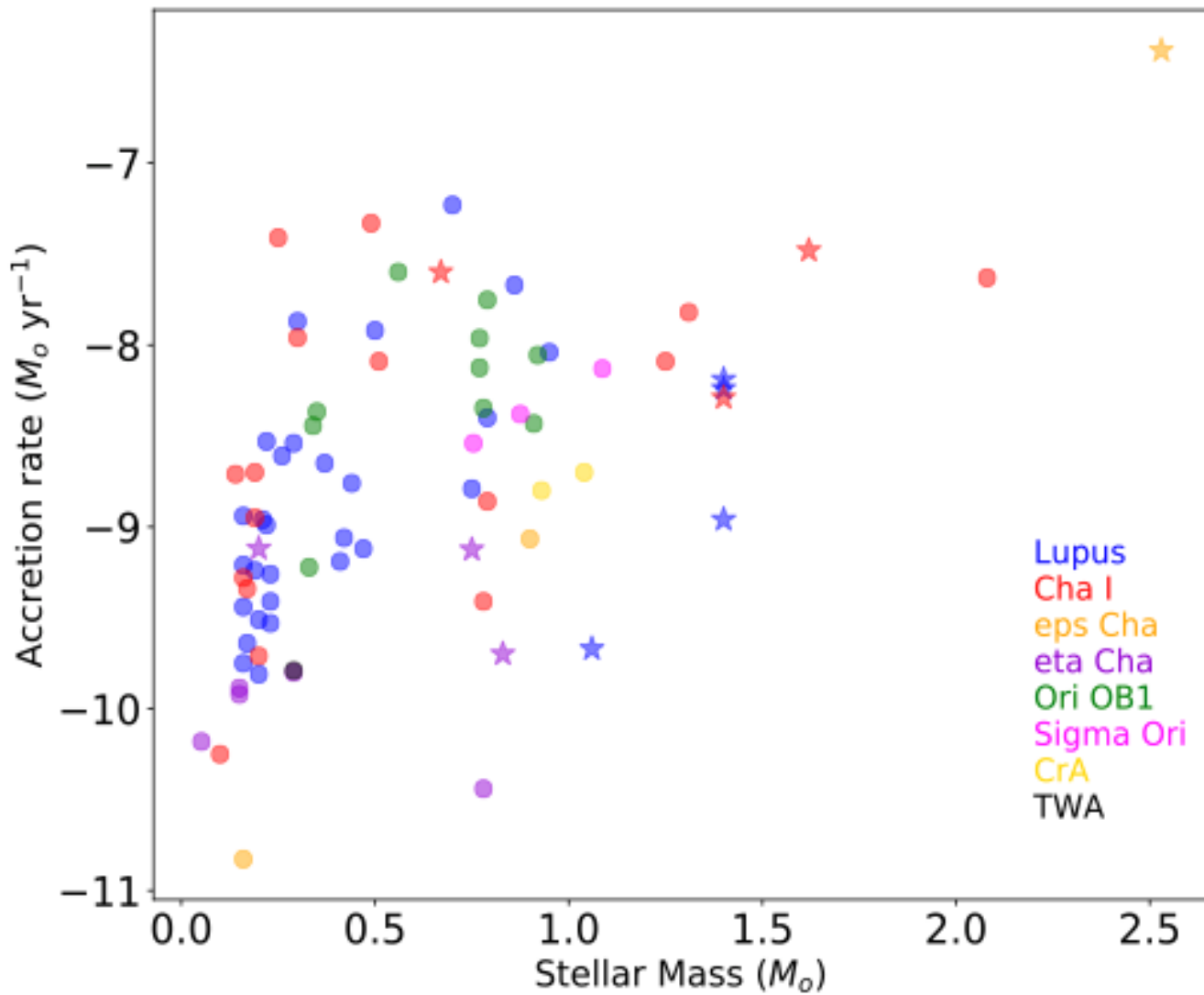




Target Selection – Sampling of mass and accretion rate for T Tauri stars

- 67 targets in 8 star-forming regions
- 355 orbits
- Complete sampling of mass and accretion rate

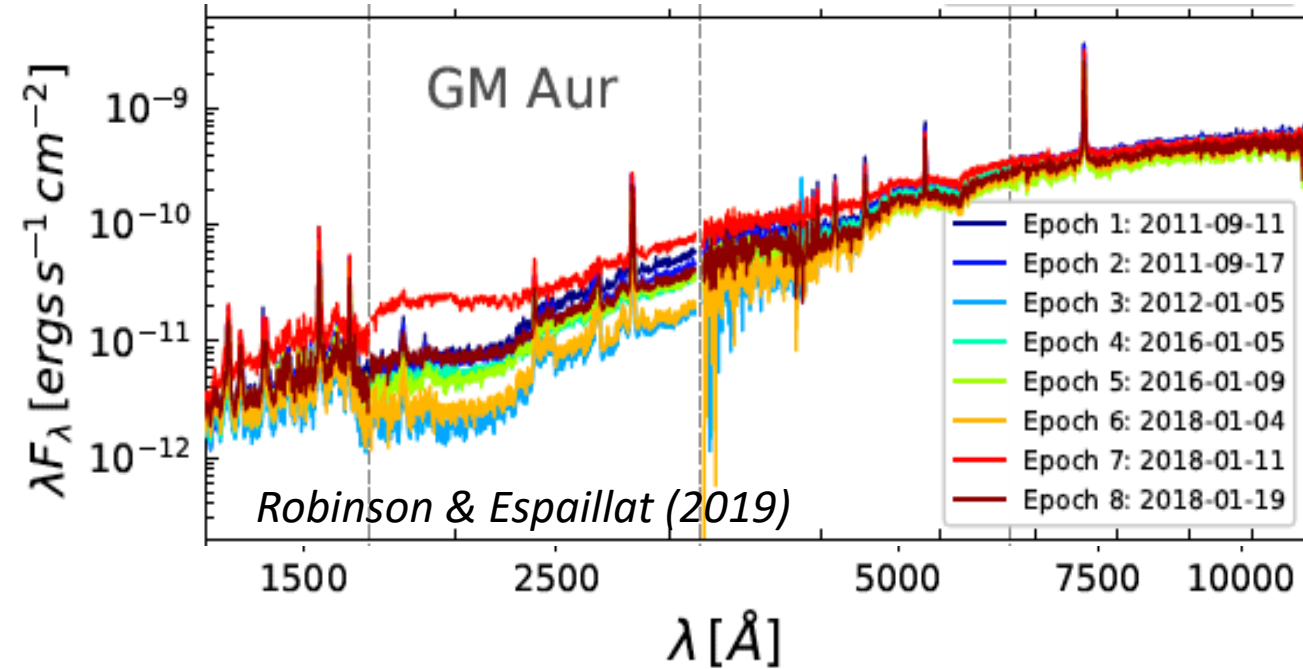
SF region	# of targets
Lupus	27
Chamaeleon I	16
ϵ Cha	2
η Cha	5
Ori OB1a, b	10
σ Ori	3
Corona Australis (CrA)	2
TWA	1





Target Selection – T Tauri Stars Monitored Over Time

- 4 T Tauri stars selected from time monitoring with HST
- Two epochs spaced out by 9-12 months, with 4 observations per rotation period for 3 periods during each epoch
- UV coverage 1400-3000 Å

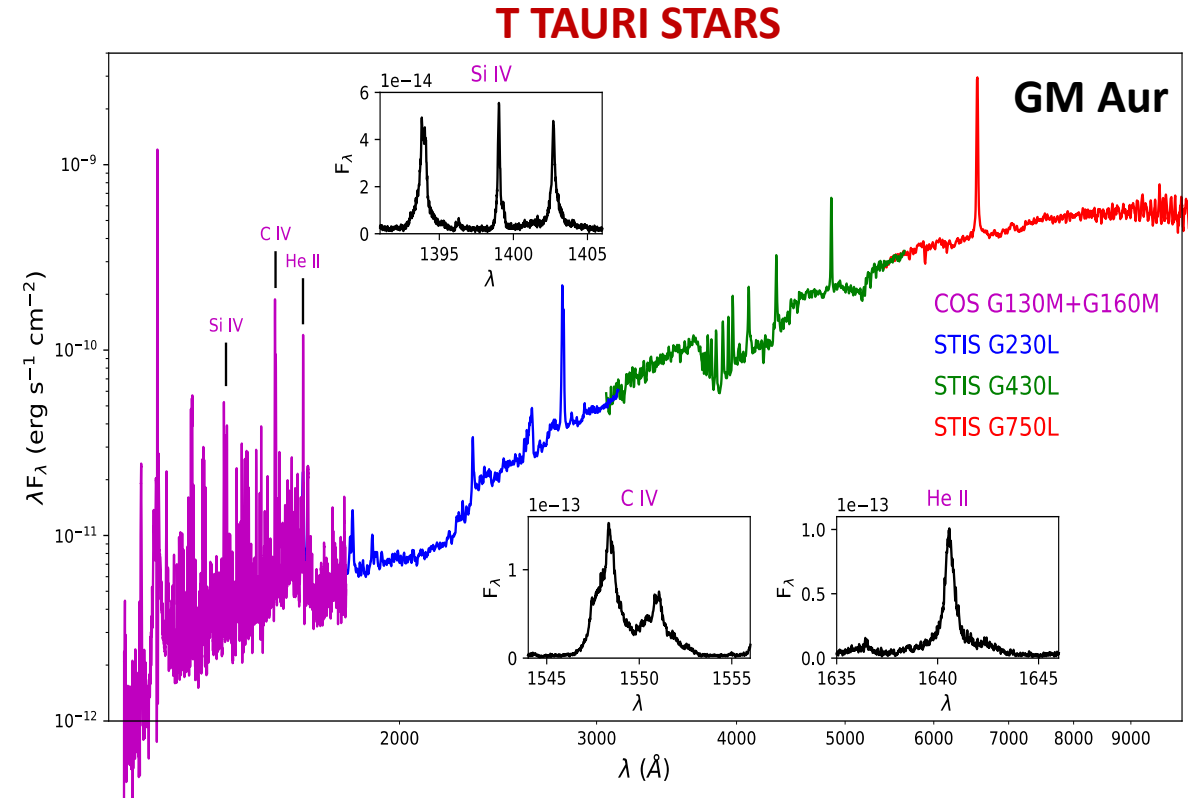
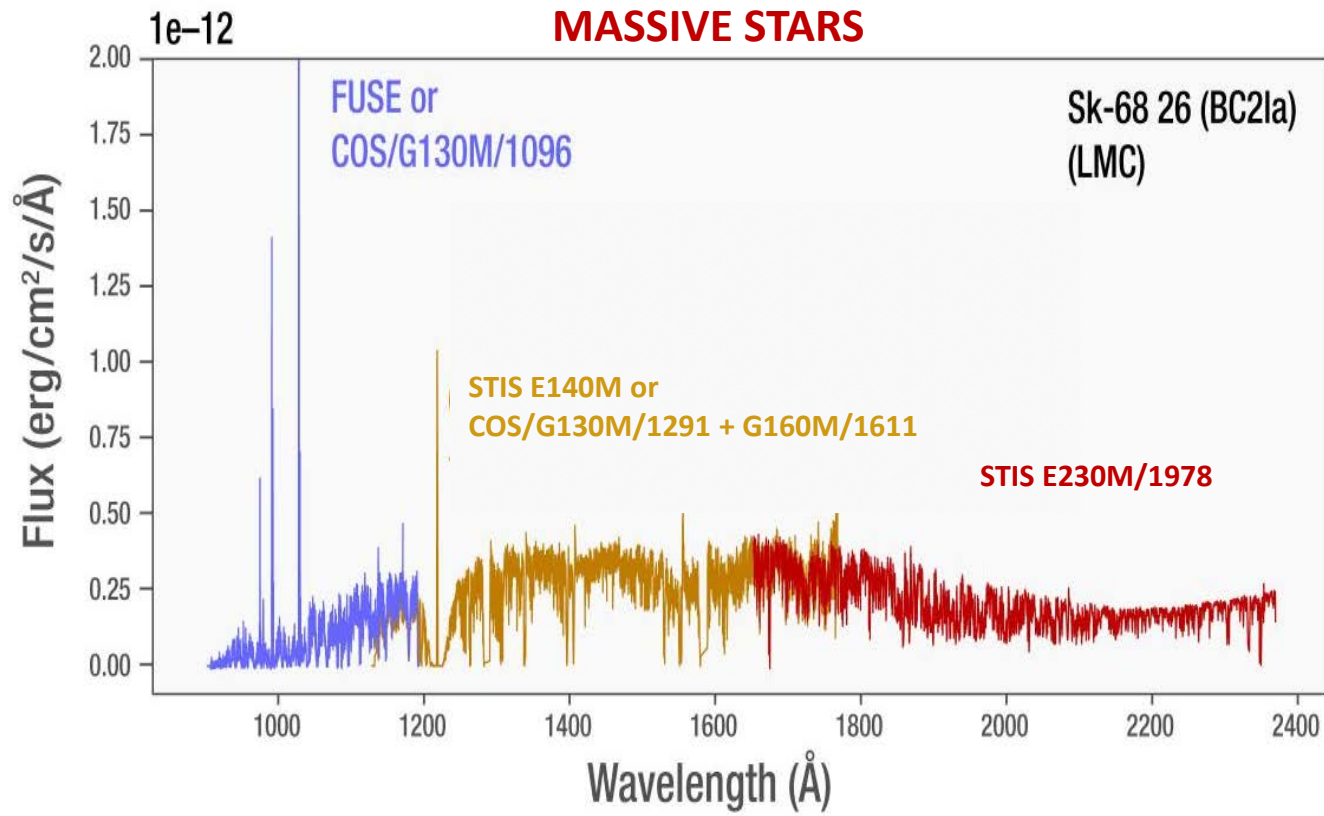


Target	RA(J2000)	DEC(J2000)	Mass (M_{sun})	Radius (R_{sun})	Mass Accretion Rate (M_{sun}/yr)	Rotational Period (days)	A_V (mag)
BP Tau	04h19m15.86s	+29d06m27.2s	0.70 ☞	2.00 ☞	2.9E-08 ☞	8.19 ☞	0.51 ☞
GM Aur	04h55m10.98s	+30d21m59.1s	1.36 ☞	1.75 ☞	5.0e-9 ☞	6.10 ☞	0.60 ☞
TW Hya	11h01m51.95s	-34d42m17.7s	0.70 ☞	1.00 ☞	2.0E-09 ☞	3.57 ☞	0.00 ☞
RU Lup	15h56m42.31s	-37d49m15.47s	0.70 ☞	1.64 ☞	5.0E-08 ☞	3.71 ☞	0.07 ☞



Observing Strategy

- FUV coverage with COS/G130M + COS/G160M, or STIS/E140M for brighter massive stars
- Coverage below 1150 Å with archival FUSE data or COS/G130M/1096 for brightest O stars
- NUV coverage with STIS/E230M for late super-giants; STIS/G230L or COS/G230L for T Tauri stars
- Optical-IR coverage with STIS G430L and STIS G750L for T Tauri stars





Observing Status



- *Massive stars:*
 - **LMC/SMC: 45 targets observed** as part of ULLYSES
 - **65 fully archival targets** in LMC+SMC combined
 - Remainder of LMC/SMC and low metallicity targets will be observed over **Cycles 28 and 29**
 - **HST/WFC3 pre-imaging of very low metallicity galaxies** with F225W, F275W, F336W, F475W, F814W
 - ✓ NGC 3109 obtained in November 2020; Sextans-A scheduled for March 2021
 - ✓ Spectroscopy with COS/G140L/800 will follow
- *T Tauri stars:*
 - **13 Orion T Tauri stars observed** in November-December 2020 in coordination with TESS
 - **19 T Tauri stars in Lupus, Chamaeleon I, and Eta Cha** will be observed in coordination with TESS in March-June 2021 (the remainder will be observed at later dates)
 - **4 monitoring T Tauri stars** will be observed in 2021 (epoch 1) and 2022 (epoch 2)
- *Observing status* and HST schedule can be checked at <https://ullyses.stsci.edu>



Community-Led Observations – T Tauri Stars Monitored Over Time

All 4 monitoring targets will be scheduled concurrently with several other facilities

T Tauri target	HST Epoch 1	Other observations
TW Hya	March 2021	Concurrent TESS, Chandra, NICER, X-Shooter, CFHT/SPIRou, LCOGT, IRTF
RU Lup	August-September 2021	Concurrent XMM, NICER, X-Shooter, LCOGT, IRTF – CFHT/SPIRou in June 2021
GM Aur	September - November 2021	Concurrent TESS, NICER, X-Shooter, LCOGT, IRTF
BP Tau	August - September 2021	Concurrent XMM, X-Shooter, CFHT/SPIRou, TESS, NICER, LCOGT, IRTF



Scheduling of Survey T Tauri Stars

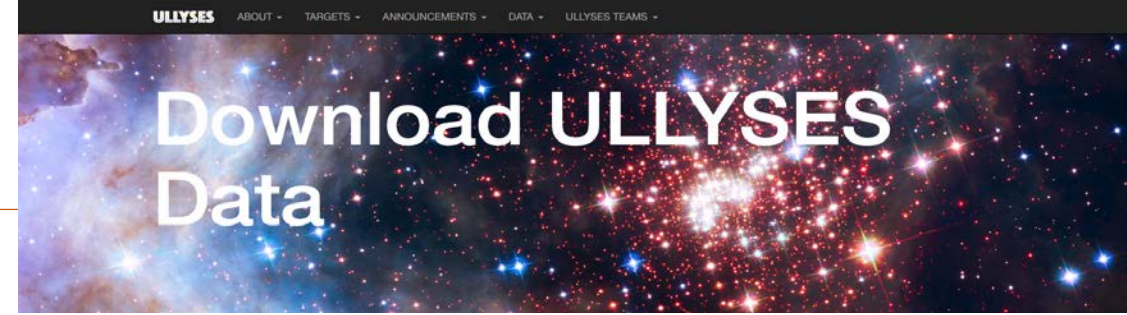
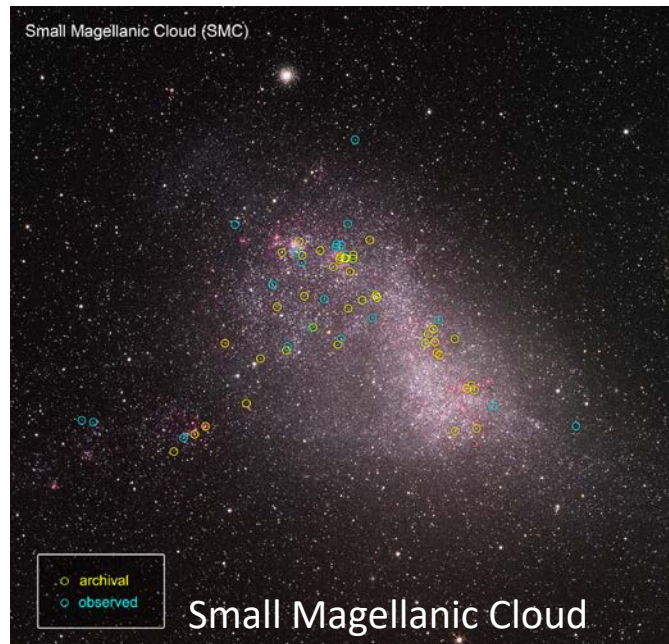
- We are coordinating the **HST scheduling** of some ULLYSES survey T Tauri stars with **TESS**
 - ✓ All 13 of the Orion targets observed in November-December 2020 along with TESS, IRTF, LCOGT, X-Shooter
 - ✓ 19 T Tauri stars being scheduled with TESS in Spring 2021 (also IRTF, LCOGT, X-Shooter)
- **LCOGT photometric monitoring** in V and i for 10 days during 5 epochs (3 months before, 10 days before, during, 10 days after, and 3 months after the HST observations)

Star-forming region	#stars scheduled with TESS/total	TESS Sector	TESS and HST windows	LCOGT windows
σ Ori	3	32	November-December 2020	August 2020 - March 2021
Ori OB1a,b	10	32	November-December 2020	August 2020 - March 2021
TWA	1	36	March - April 2021	December 2020 - July 2021
Cha I	7/16	38,39	April – June 2021	January - September 2021
Lupus	10/28	38	April – May 2021	January - August 2021
ε Cha	TBD/2	38, 39	April – June 2021	January - September 2021
η Cha	2/5	37,38, 39	April – June 2021	January - September 2021
CrA	0/2	None	2021-2022	2021-2022



ULLYSES Data Release 1

- First data release from November 5, 2020 available at <https://ullyses.stsci.edu/ullyses-download.html>
- DR1 includes LMC and SMC stars observed as part of ULLYSES during Cycle 27 and previous GO programs
- Press release at <https://www.nasa.gov/feature/goddard/2020/hubble-launches-large-ultraviolet-light-survey-of-nearby-stars>



The tables below list each target included in ULLYSES Data Release 1, separated by galaxy. By clicking the download link for an individual target, you will receive a tarball that includes both the COS and STIS 1-D extracted spectra for the target as well as all High Level Science Products (HLSPs) created by the ULLYSES team. You can also download all data for each galaxy, which again includes COS/STIS data and HLSPs:

- Download all LMC targets:
 - HLSPs (73 MB)
 - COS/STIS 1-D spectra (817 MB)
- Download all SMC targets:
 - HLSPs (102 MB)
 - COS/STIS 1-D spectra (1.7 GB)

A description of the ULLYSES data products and how they are created can be found [here](#).

LMC Targets

Download all LMC targets: [HLSPs \(73 MB\)](#) and [COS/STIS 1-D Spectra \(817 MB\)](#)

Simbad Name	MAST Target Name	RA(J2000)	DEC(J2000)	SpType	V	B	E(B-V)	Instrument(s)	Grating(s)	Download Link
SK -67 2	SK-67D2	71.7686	-67.1148	B1Ia+	11.04	11.22	0.37	STIS	E140M, E230M	Download Target
SK -67 5	SK-67D5	72.5789	-67.6606	O9.7 Ib	11.34	11.22	0.14	STIS	E140M, E230M	Download Target
SK -68 8	SK-68D8	73.4304	-68.7148	B5 Ia+	10.99	11.04	0.14	COS, STIS	G130M, G160M, E230M	Download Target
SK -67 14	SK-67D14	73.6329	-67.2568	B1.5 Ia	11.52	11.42	0.08	STIS	E140M, E230M	Download Target
SK -67 20	SK-67D20	73.8806	-67.5007	WN4b	13.81	13.46	0.1	STIS	E140M	Download Target
LH 9-89	LH9-89	74.0459	-66.4734	B0 IIIIn	13.68	13.52	0.14	COS	G130M, G160M	Download Target
N11 018	N11-ELS-018	74.171	-66.4113	O6 II(f ⁺)	13.13	13.04	0.18	COS	G130M, G160M	Download Target
N11 038	N11-ELS-038	74.1884	-66.4197	O5 III(f ⁺)	13.81	13.81	0.28	COS	G130M, G160M	Download Target
PGMW 3120	PGMW3120	74.1951	-66.4130	O5.5 V (f ⁺)	12.8	12.73	0.21	STIS	E140M, E230M	Download Target

SMC Targets

Download all SMC targets: [HLSPs \(102 MB\)](#) and [COS/STIS 1-D Spectra \(1.7 GB\)](#)

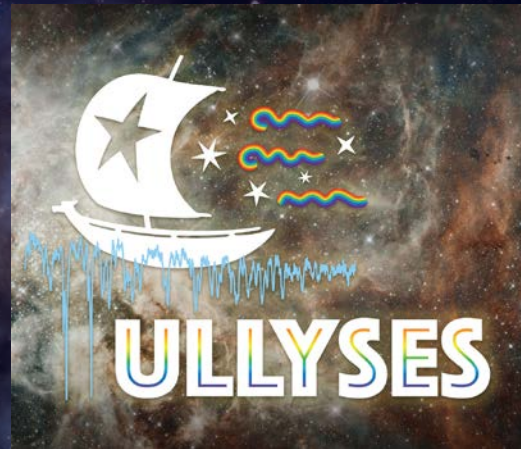
Simbad Name	MAST Target Name	RA(J2000)	DEC(J2000)	SpType	V	B	E(B-V)	Instrument(s)	Grating(s)	Download Link
2dFS 163	2DFS-163	9.2427	-73.3926	O8 Ib(f)	15.11	14.95	0.11	COS	G130M, G160M	Download Target
AV 6	AV6	11.3257	-73.2569	O9III	13.31	13.36	0.31	COS	G130M, G160M	Download Target
AV 15	AV15	11.6757	-73.4154	O6.5II(f)	13.12	12.93	0.08	STIS	E140M	Download Target
AV 16	AV16	11.7293	-73.1428	B0[e]LBV	13.03	13.15	0.42	STIS	E140M	Download Target
AV 18	AV18	11.8009	-73.1092	B2 Ia	12.44	12.47	0.2	STIS	E140M, E230M	Download Target
AV 22	AV22	11.9114	-73.1302	B5 (Ia)	12.23	12.21	0.07	STIS	E140M, E230M	Download Target
AV 43	AV43	12.1996	-72.7736	B0.2 V	13.88	13.76	0.18	COS	G130M, G160M	Download Target
AV 47	AV47	12.2145	-73.4329	O8III((f))	13.44	13.26	0.09	STIS	E140M, E230M	Download Target
AV 69	AV69	12.5717	-72.8917	OC7.5III((f))	13.27	13.09	0.09	STIS	E140M	Download Target
AV 70	AV70	12.5755	-72.6361	O9.5Iw	12.38	12.21	0.09	STIS	E140M, E230M	Download Target
AV 75	AV75	12.635	-72.8768	O5III(f ⁺)	12.7	12.55	0.13	STIS	G130M, G160M	Download Target
AV 80	AV80	12.6825	-72.7949	O7 III	13.32	13.19	0.14	STIS	E140M, E230M	Download Target
AV 83	AV83	12.7167	-72.7042	O7Iaf+	13.31	13.19	0.15	STIS	E140M	Download Target



Data Products – Overview

- **Included in DR1 (LMC/SMC spectroscopy only):**
 - ✓ STIS and COS calibrated pipeline products
 - ✓ Co-added spectra for each grating setting (multiple exposures with one setting, multiple cenwaves)
 - ✓ Spliced spectra (multiple grating settings, multiple instruments, e.g., COS + STIS)
- **Included in future DRs:**
 - ✓ T Tauri star HST spectroscopy and LCOGT photometry
 - ✓ HLSPs for LMC/SMC including archival FUSE spectra
 - ✓ Database of meta data that describes stellar parameters, instrumental configurations
 - ✓ User interfaces enabling queries
 - Search form, filtering to refine queries, visual selection from interactive plots, API
 - ✓ Quick-look tools: interactive plots of spectra with interactive S/N calculations
 - ✓ Jupyter notebooks: demonstrate data handling and analysis techniques

Thank you



ullyses.stsci.edu



ULLYSES Core Implementation Team (CIT)



Julia Roman-Duval
(CIT Lead)



Jo Taylor
(DP Lead)



Travis Fischer
(DP Deputy Lead)



Charles Proffitt
(Observing Lead)



TalaWanda Monroe
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Will Fischer
(T Tauri Star Lead Expert)



Alex Fullerton
(Massive Star Lead Expert)



Alessandra Aloisi
(Pre-imaging)



Chris Britt
(Public Outreach)



Ivo Busko
(DP/software)



Svea Hernandez
(DP)



Robert Jedrzejewski
(DP, software)



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(ETC, Obs)



Elaine Mae Frazer
(DP)



Rachel Plesha
(Targets, Obs, DP)



Adric Riedel
(Targets, DP)



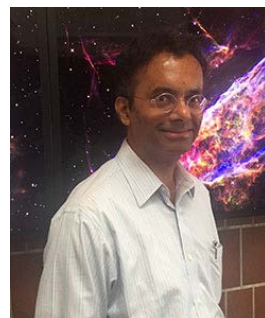
Allyssa Riley
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David Sahnou
(Observing)



Richard Shaw
(DP)



Ravi Sankrit
(Observing)



Linda Smith
(Targets)



Tony Sohn
(Observing)



Debopam Som
(Observing)



Leonardo Ubeda
(Website)



Dan Welty
(Targets, Obs, DP)

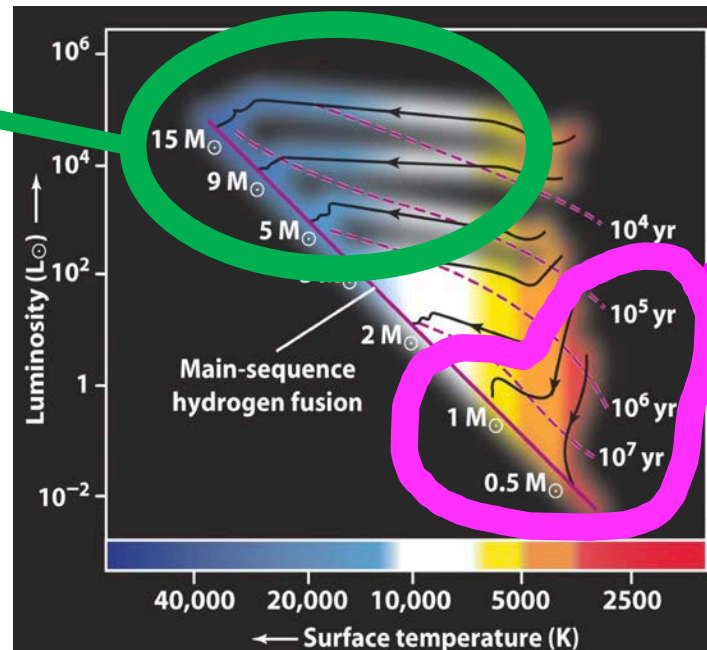


ULLYSES at a glance

- ULLYSES = 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



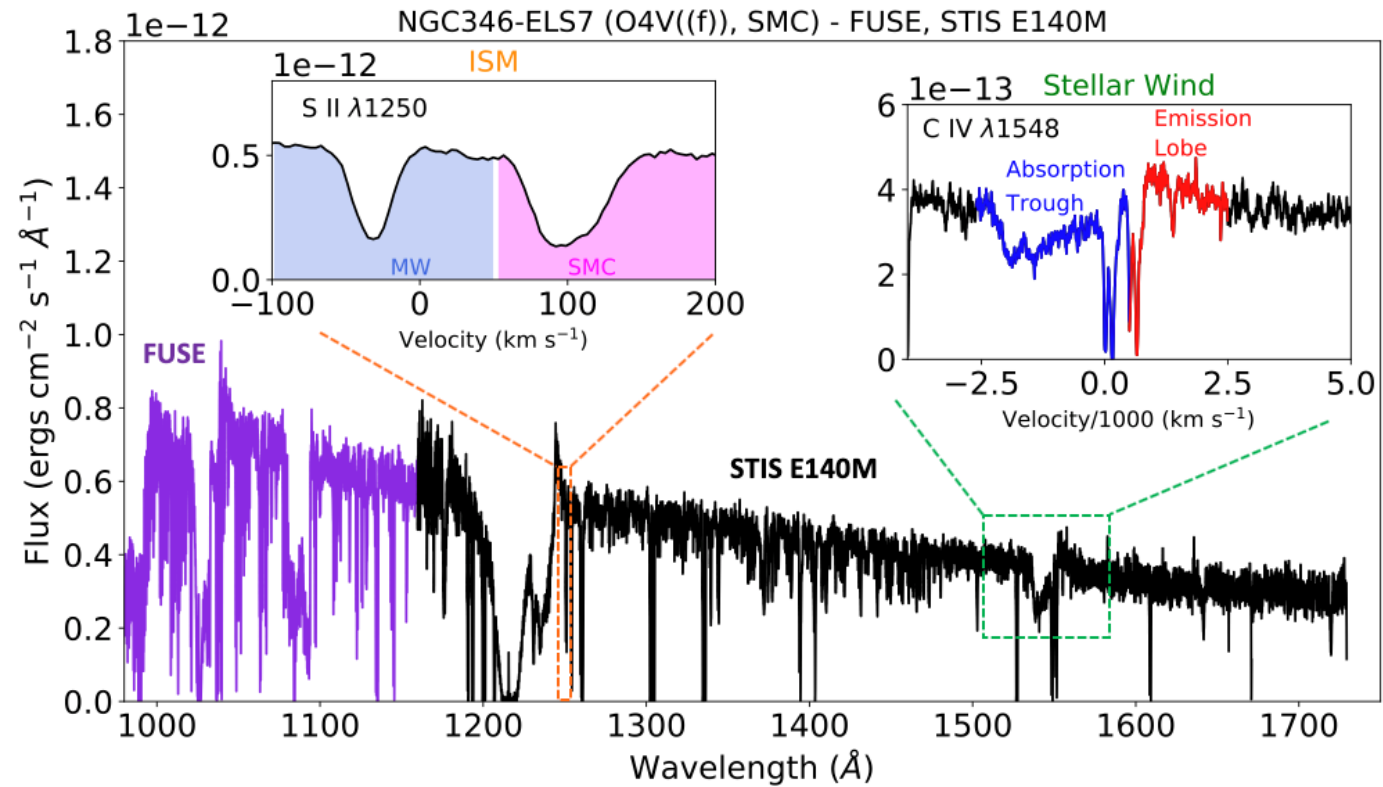
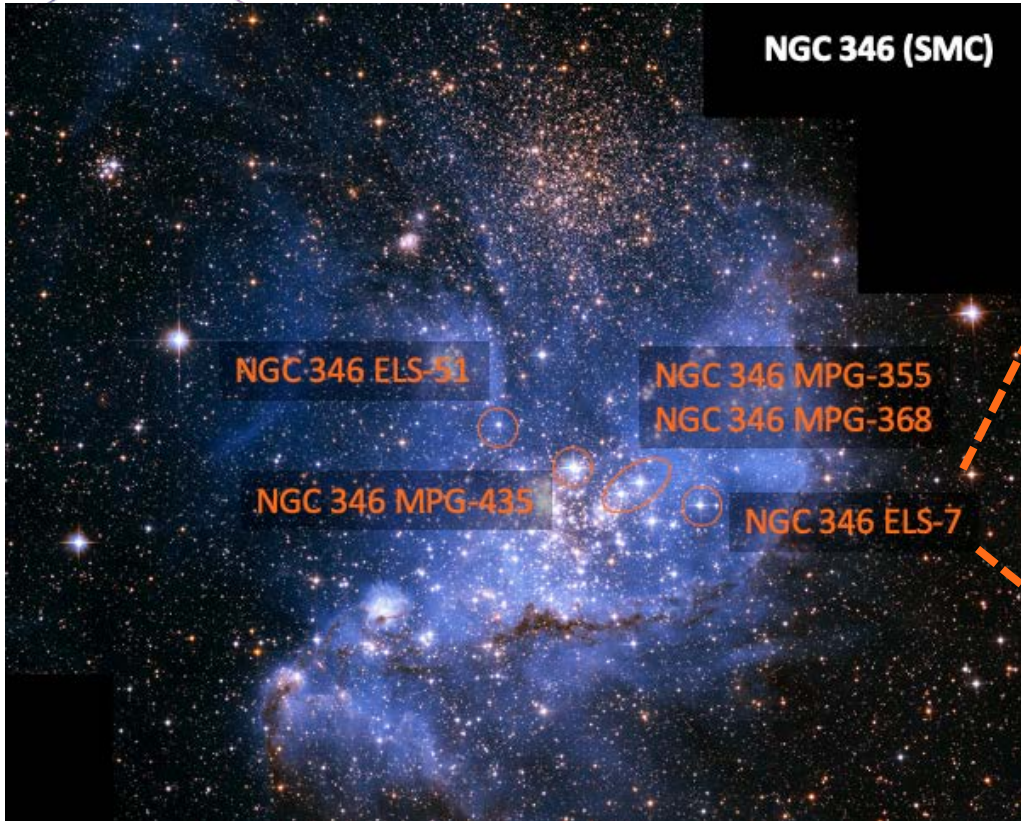
~500 orbits to extend the spectroscopic library of O and B stars to low metallicity (8-50% solar)



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



A Spectroscopic Survey of High Mass Stars



✓ Massive Stars

- Stellar winds and abundances
- Ionizing radiation
- Spectral templates for population synthesis

✓ ISM

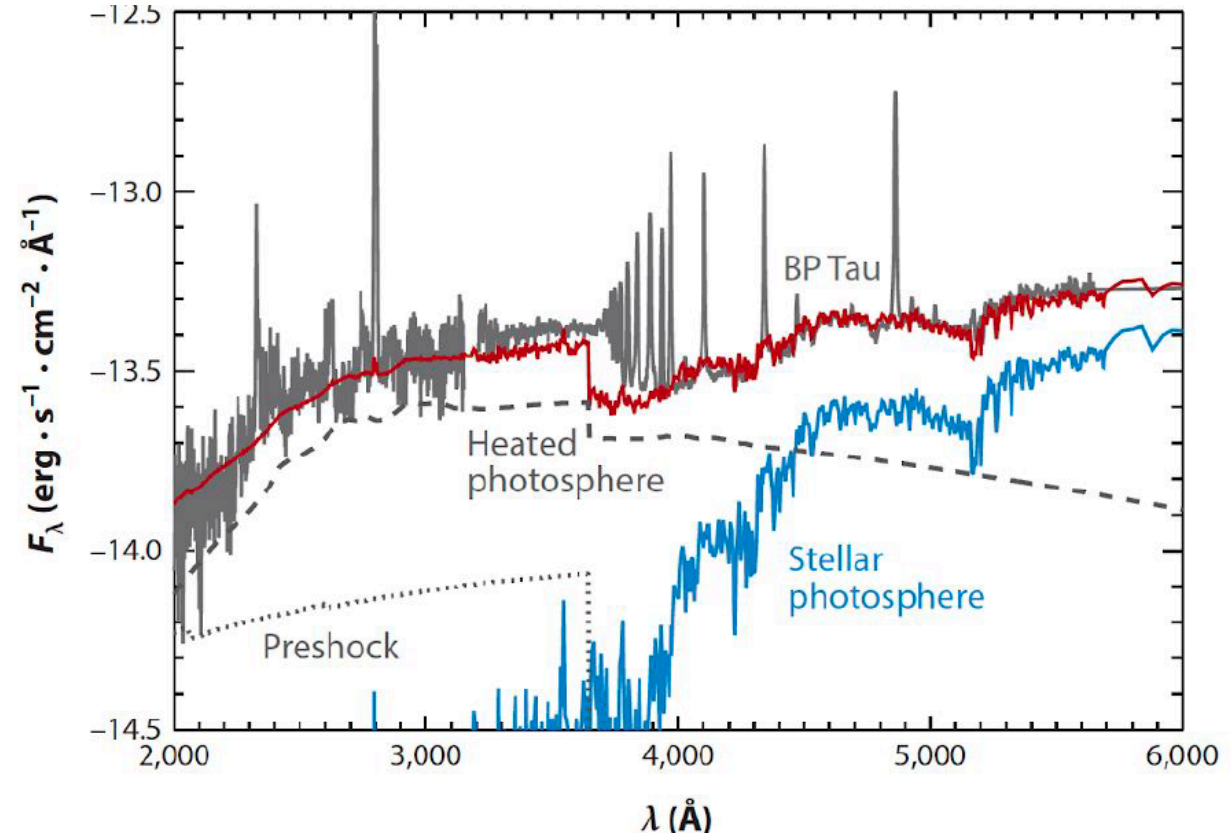
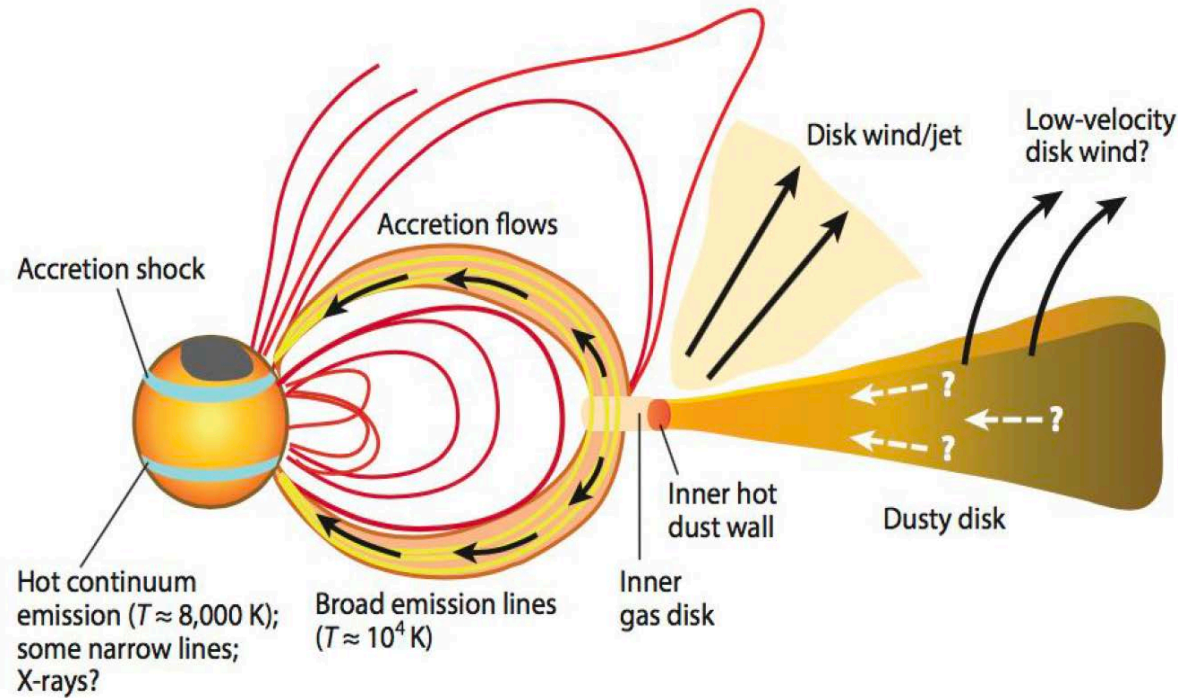
- Chemical abundances
- Depletions on dust

✓ CGM

- Kinematics
- Metallicity
- Spatial distribution



A Spectroscopic Survey of Young Low Mass Stars



✓ T Tauri Stars

- Accretion physics
- UV radiation and impact on disk evolution and planet composition and atmospheric escape
- Time monitoring component for 4 targets (100 orbits) to study accretion variability



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 (UK Astronomy Technology Centre)
 - Kevin France (University of Colorado Boulder)
 - Miriam García (Centro de Astrobiología (CSIC-INTA))
 - Chris Johns-Krull (Rice University)
 - Derck Massa (Space Science Institute)
 - Joan Najita (National Optical Astronomy Observatory)



Timeline and Milestones up to now

- June 2019: CIT and SAC assembled
- September 2019: Request for input from the community regarding target selection
- November 2019: T Tauri stars to be monitored over time and low-metallicity massive stars selected for observations released to the community
- February 18, 2020: Release of full target samples
- June 2020: First observations of LMC/SMC stars
- July 2020: Launch of website (ullyses.stsci.edu)
- August 2020: Beginning of LCOGT monitoring observations of Orion T Tauri stars

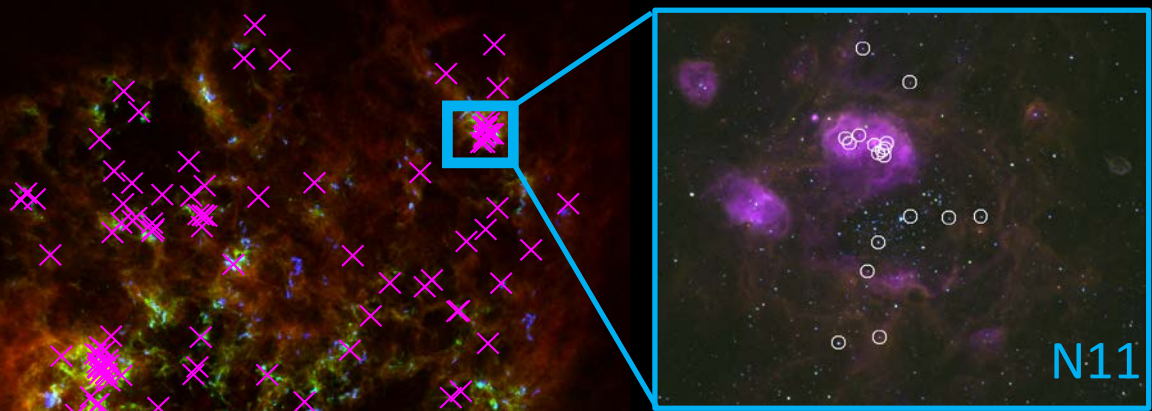


Timeline and Milestones

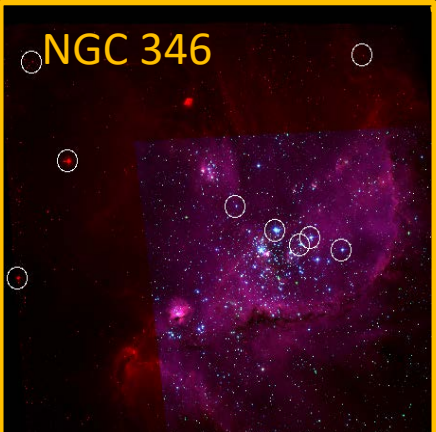
- November 5, 2020: First data release (LMC/SMC only)
- November-December 2020: HST observations of Orion T Tauri stars (with TESS, LCOGT)
- Spring 2021: DR2 (includes functional database and user interface – this is a working goal)
- Spring-fall 2021: Epoch 1 of monitoring stars, and more survey CTTS
- Quarterly data releases through the end of the program



Overview of massive stars



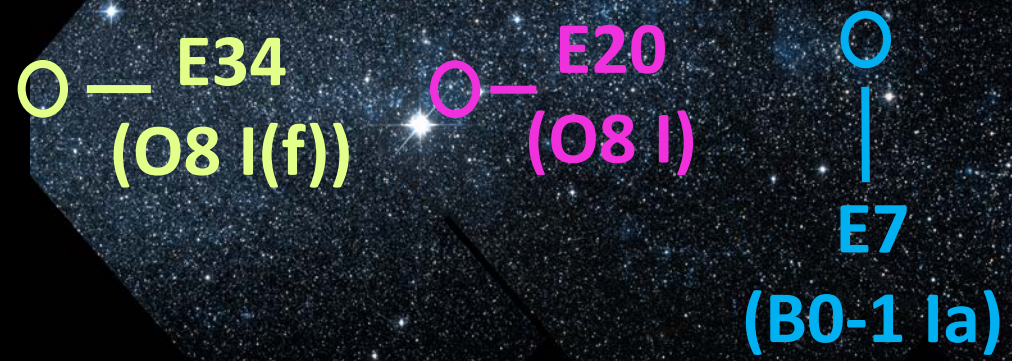
LMC
 50% Solar Metallicity
 132 targets O2-B9



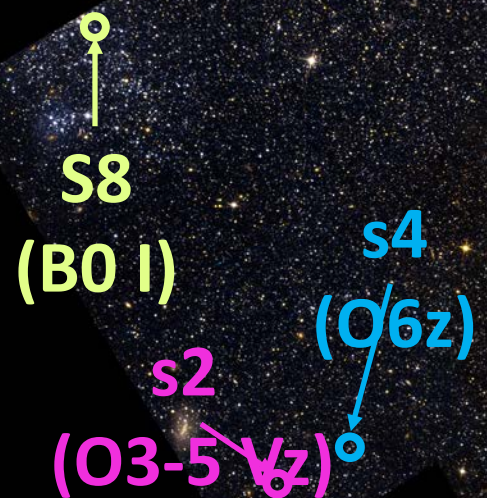
NGC 346

SMC
 20% Solar Metallicity
 106 targets O2-B9

NGC3109 (15% Solar Metallicity)



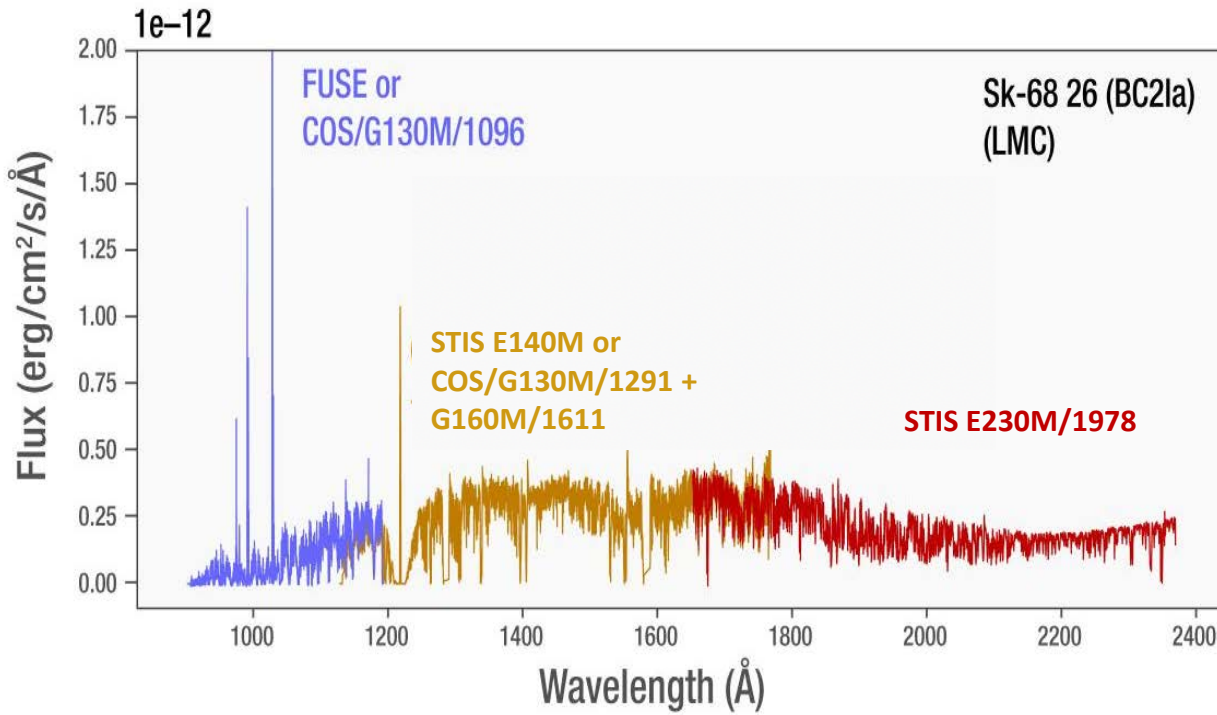
Sextans A (8% Solar Metallicity)





Observing Strategy – LMC/SMC Massive stars

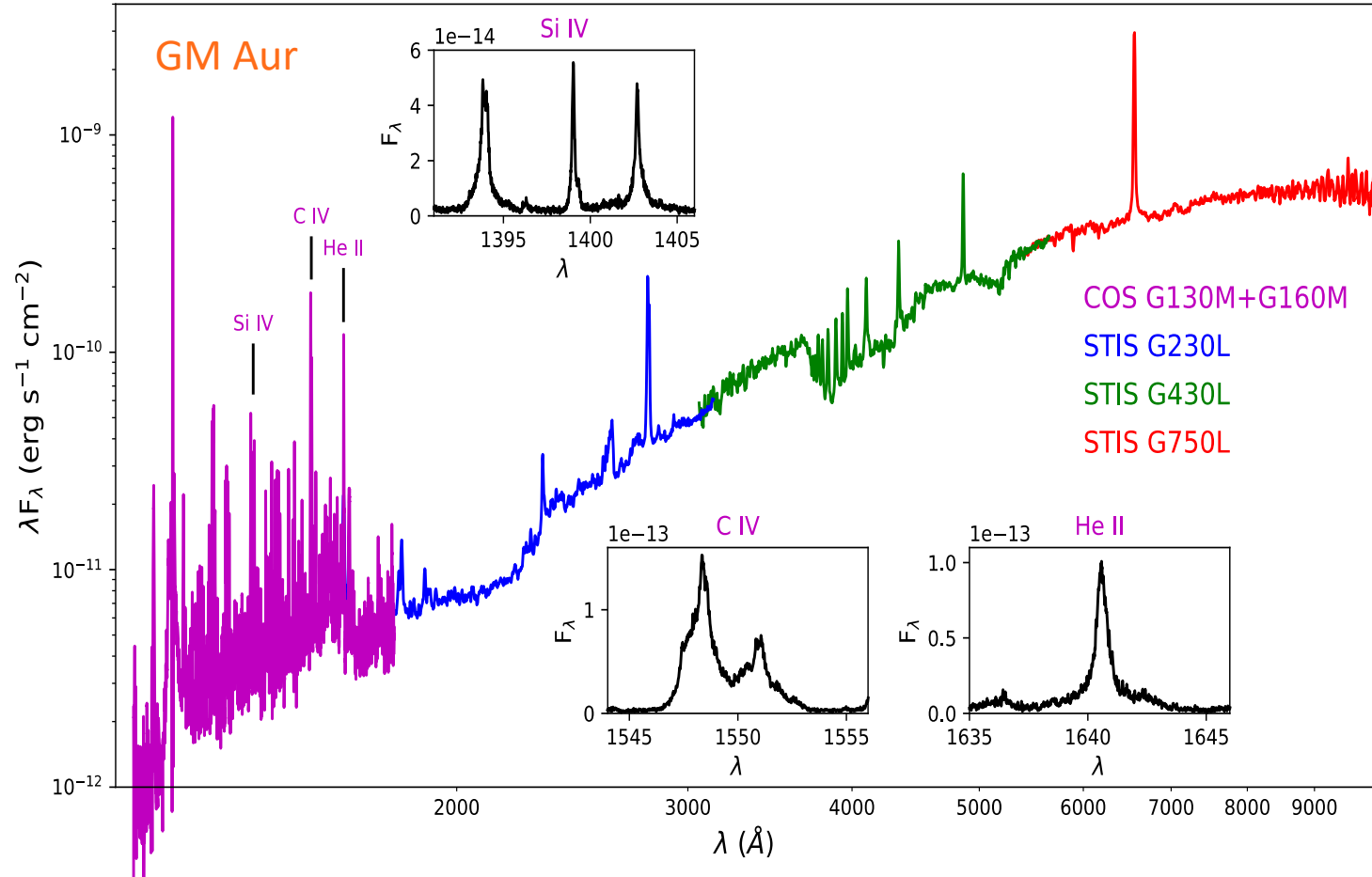
- FUV coverage from 1140 Å to 1800 Å with COS/G130M/1291 + COS/G160M/1611, or STIS/E140M for brighter stars
- Coverage below 1150 Å with archival FUSE data or COS/G130M/1096 for O stars if cost is reasonable
- STIS/E230M/1978 for O9-B9 I
- STIS/E230M/2707 or COS/G185M/1953+1986 for B5-9 I



	I	II-III	IV - V
O2-O8	<ul style="list-style-type: none"> • COS/G130M/1291 + G160M/1611 or STIS/E140M • FUSE or COS/G130M/1096 	<ul style="list-style-type: none"> • COS/G130M/1291 + G160M/1611 or STIS/E140M • FUSE or COS/G130M/1096 	<ul style="list-style-type: none"> • COS/G130M/1291 + G160M/1611 or STIS/E140M • FUSE or COS/G130M/1096
O9	<ul style="list-style-type: none"> • COS/G130M/1291 + G160M/1611 or STIS/E140M • FUSE or COS/G130M/1096 • STIS/E230M/1978 	<ul style="list-style-type: none"> • COS/G130M/1291 + G160M/1611 or E140M • FUSE or COS/G130M/1096 	<ul style="list-style-type: none"> • COS/G130M/1291 + G160M/1611 or STIS/E140M • FUSE or COS/G130M/1096
B0-B1.5	<ul style="list-style-type: none"> • COS/G130M/1291 + G160M/1611 or E140M • STIS/E230M/1978 	<ul style="list-style-type: none"> • COS/G130M/1291 + G160M/1611 or STIS/E140M 	<ul style="list-style-type: none"> • COS/G130M/1291 + G160M/1611 or STIS/E140M
B2-B4	<ul style="list-style-type: none"> • COS/G130M/1291 + G160M/1611 or STIS/E140M • STIS/E230M/1978 or COS/G185M/1921+1953+1986 	X	X
B5-B9	<ul style="list-style-type: none"> • COS/G130M/1291 + G160M/1611 or STIS/E140M • STIS/E230M/1978 or COS/G185M/1921+1953+1986 • STIS/E230M/2707 	X	X



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/2635 + 2950



LCOGT Photometric Monitoring

- STScI implementation team designed a large program with LCOGT to perform photometric monitoring V, i for survey and monitoring (also u' band) T Tauri stars – Program was accepted and started late August 2020
- LCOGT has 0.4m robotic telescope network around the World (almost continuous longitudinal coverage)
- Goals:
 - Place the HST spectroscopy in context
 - Aid in bright-object protection
 - CTTS can exhibit Fu Ori bursts over timescales of months during which their brightness can increase by several magnitudes
 - Optical monitoring a few months before the HST observations can ensure the targets are not in a burst state