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, Charles Proffitt, TalaWanda Monroe, Joleen Carlberg, Jo Taylor

Space Telescope Science Institute

STUC Meeting – April 14, 2020

ULLYSES at a Glance

- ULLYSES = **Ultraviolet Legacy Library of Young Stars as Essential Standards**
- Large (~1000 orbits) **Director's Discretionary** Hubble program to obtain a **spectroscopic reference sample of young low and high mass stars**
  - The survey will sample **spectral type, luminosity class, and metallicity for massive stars**
  - ULLYSES will sample **mass and accretion rate for T Tauri stars**
- The scientific framework of the program was designed by the community, via a UV Legacy Working Group (report was released to the community in early 2019)
- The **Core Implementation Team (CIT)** at STScI is leading the implementation of the program (target selection, observing strategy, technical implementation, data products and website)
  - CIT is working with a **Science Advisory Committee (SAC)**, composed of experts from the community
- For more information, see http://www.stsci.edu/stsci-research/research-topics-and-programs/ullyses

Timeline and Milestones

- 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
- November 2019: Fall STUC meeting
- **February 18, 2020: Release of full target samples**
- March 6, 2020: HST proposal deadline
- **March 25, 2020: First ULLYSES program flight-ready (PID 16103)**
- May 2020: JWST proposal deadline
- **Late spring 2020: First light for massive stars (LMC/SMC)**
- **Summer 2020: Launch of website and first data release (DR1)**
- **October 2020: Beginning of the T Tauri star observations**
- Quarterly data releases beyond fall 2020

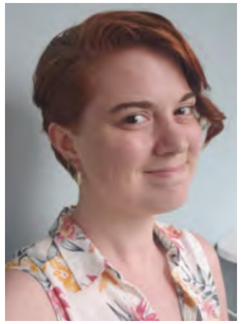
Labeled as *New*

in this presentation

ULLYSES Core Implementation Team (CIT)


Julia Roman-Duval
(CIT Lead)

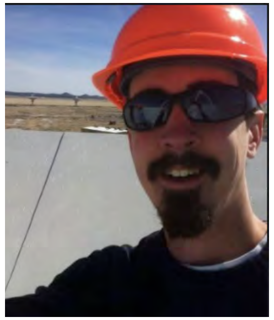

Joleen Carlberg
(Data products Lead)


Jo Taylor
(DP Deputy Lead)


Charles Proffitt
(Observing Lead)


TalaWanda Monroe
(Observing Deputy Lead)


Alessandra Aloisi
(Pre-imaging)


Chris Britt
(Public Outreach)


Ivo Busko
(DP/software)


Will Fischer
(Targets, Obs, DP)


Alex Fullerton
(Targets, Obs, DP)


Robert Jedrzejewski
(DP, software)


Sean Lockwood
(ETC, Obs)


Elaine Mae Frazer
(DP)


Rachel Plesha
(Targets, Obs, DP)


Adric Riedel
(Targets, DP)


Allyssa Riley
(DP)


David Sahnow
(Observing)


Richard Shaw
(DP)


Ravi Sankrit
(Observing)


Linda Smith
(Targets)


Tony Sohn
(Observing)


Leonardo Ubeda
(Website)

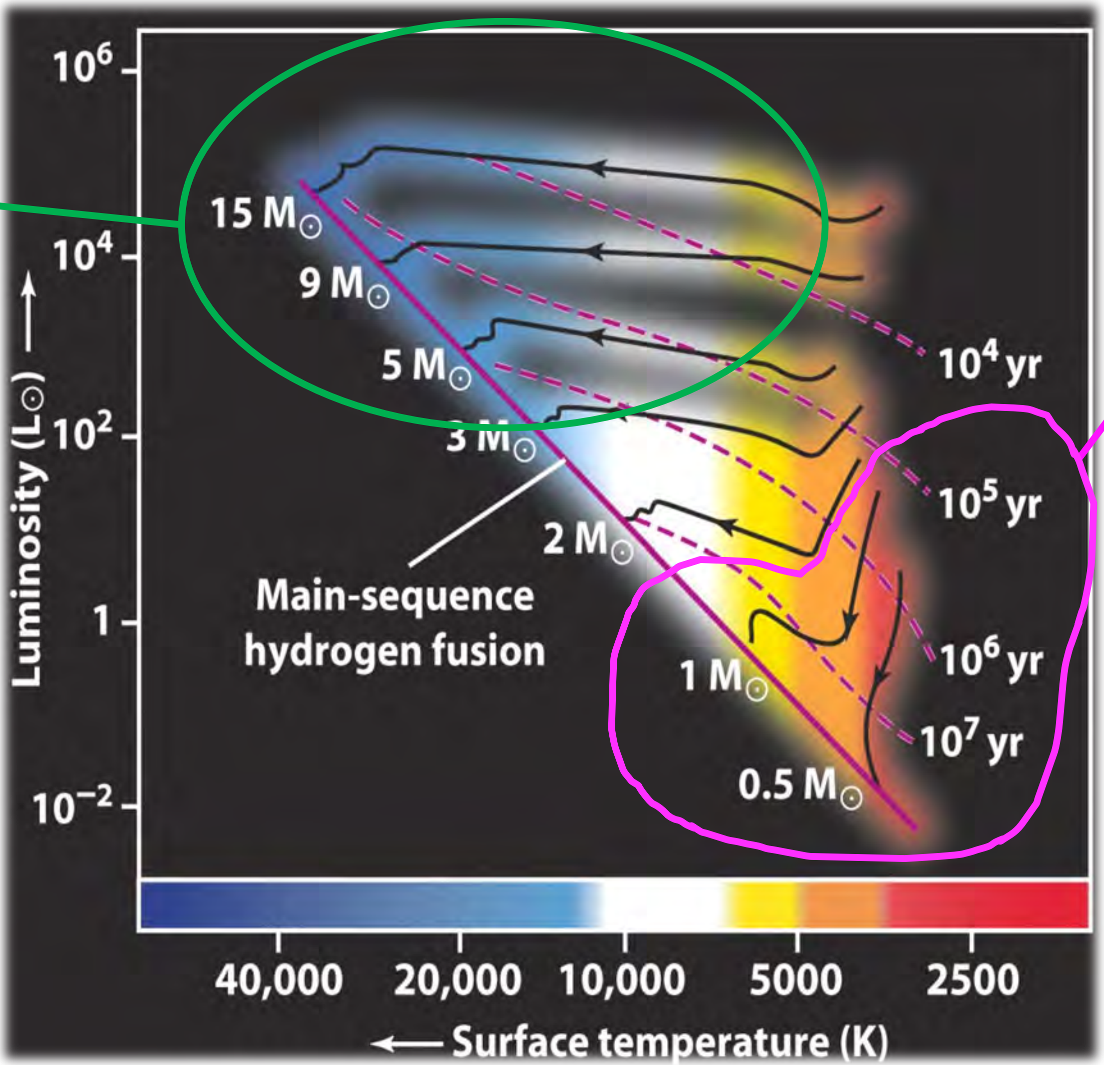

Dan Welty
(Targets, Obs, DP)

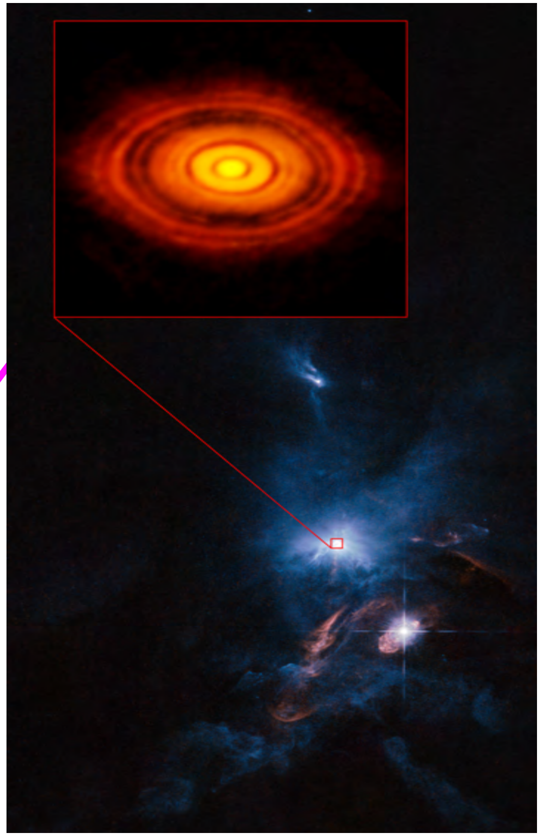
Science Advisory Committee (SAC)

- 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 (Instituto Nacional de Técnica Aeroespacial)
  - Chris Johns-Krull (Rice University)
  - Derck Massa (Space Science Institute)
  - Joan Najita (National Optical Astronomy Observatory)

Overview of the ULLYSES Scientific Objectives

A Spectroscopic Survey of Young Low and High Mass Stars



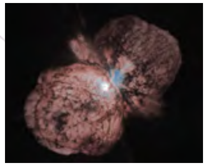


~500 orbits to extend the spectroscopic library of O and B stars to low metallicity (0.08 - 0.5 Z_o)

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

Scientific Goals of the Massive Star Component

✓ Stellar Astrophysics



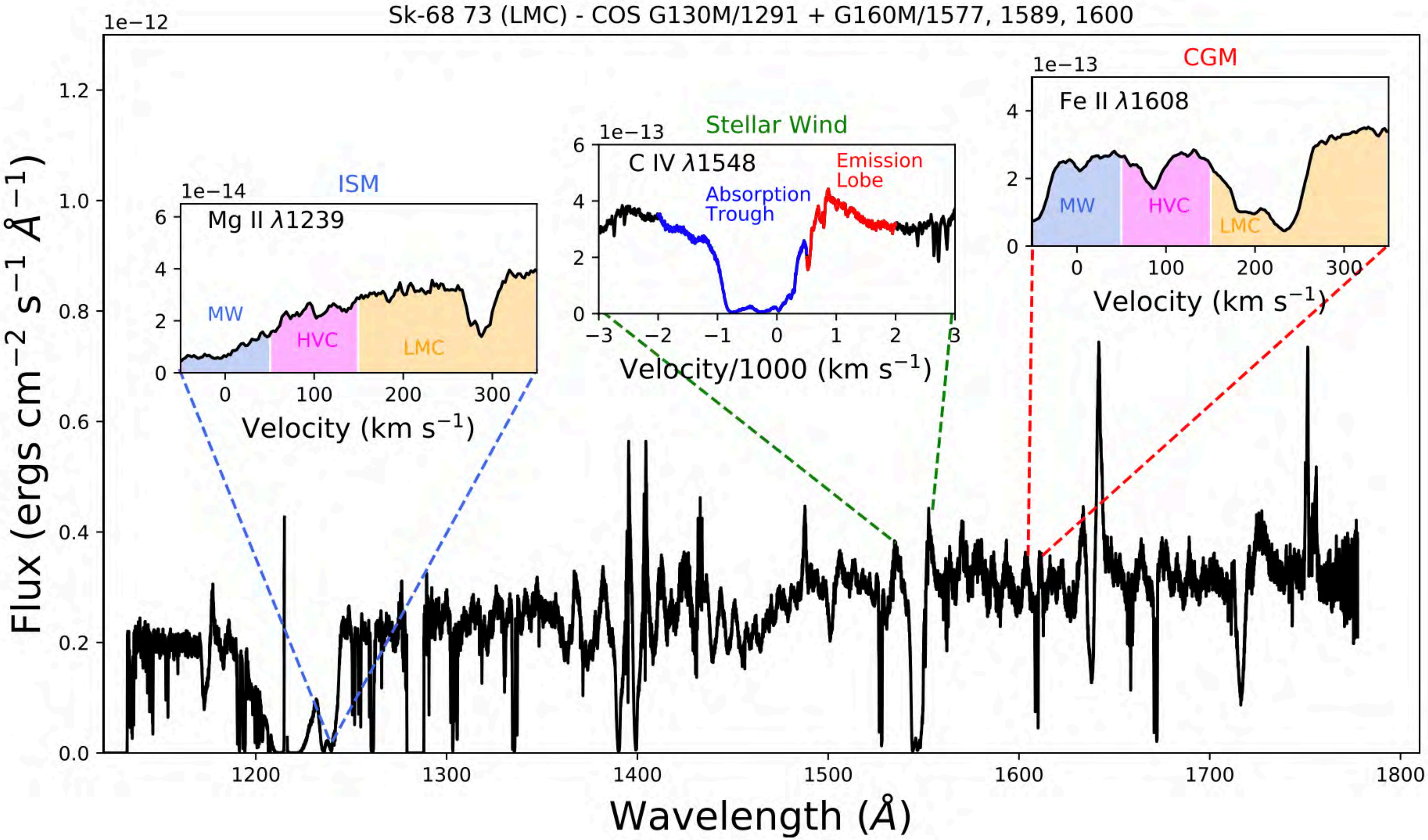
- Stellar winds and abundances
- Ionizing radiation
- Spectral templates for population synthesis

✓ ISM

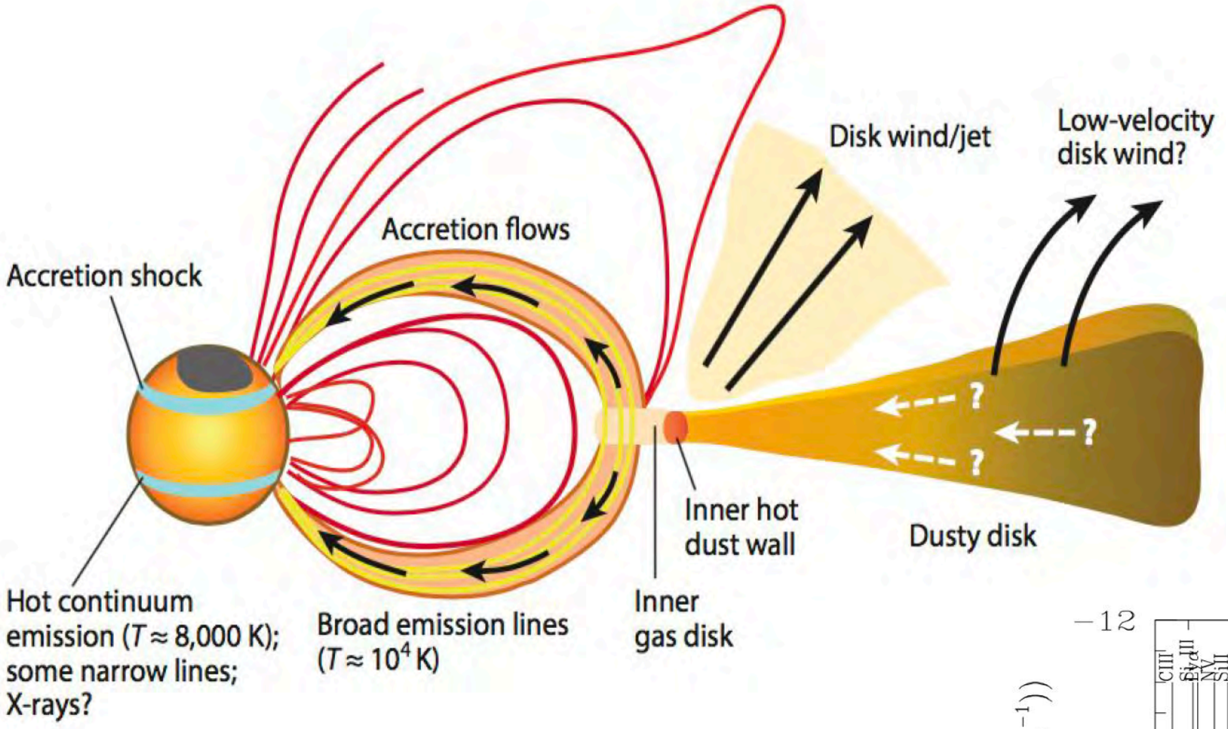
- Chemical abundances
- Depletions on dust

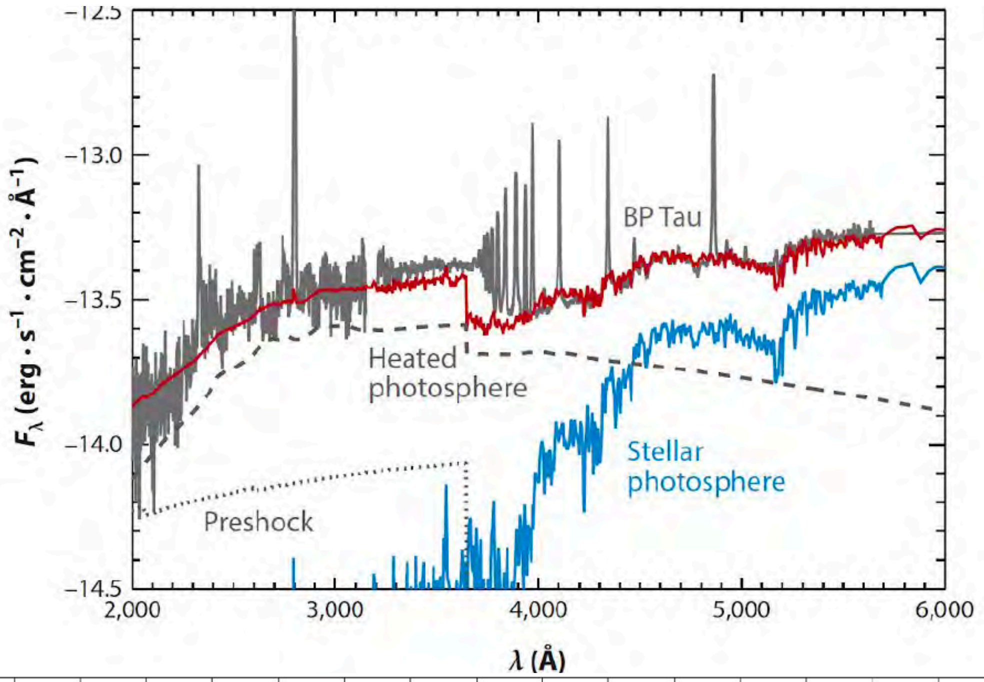
✓ CGM

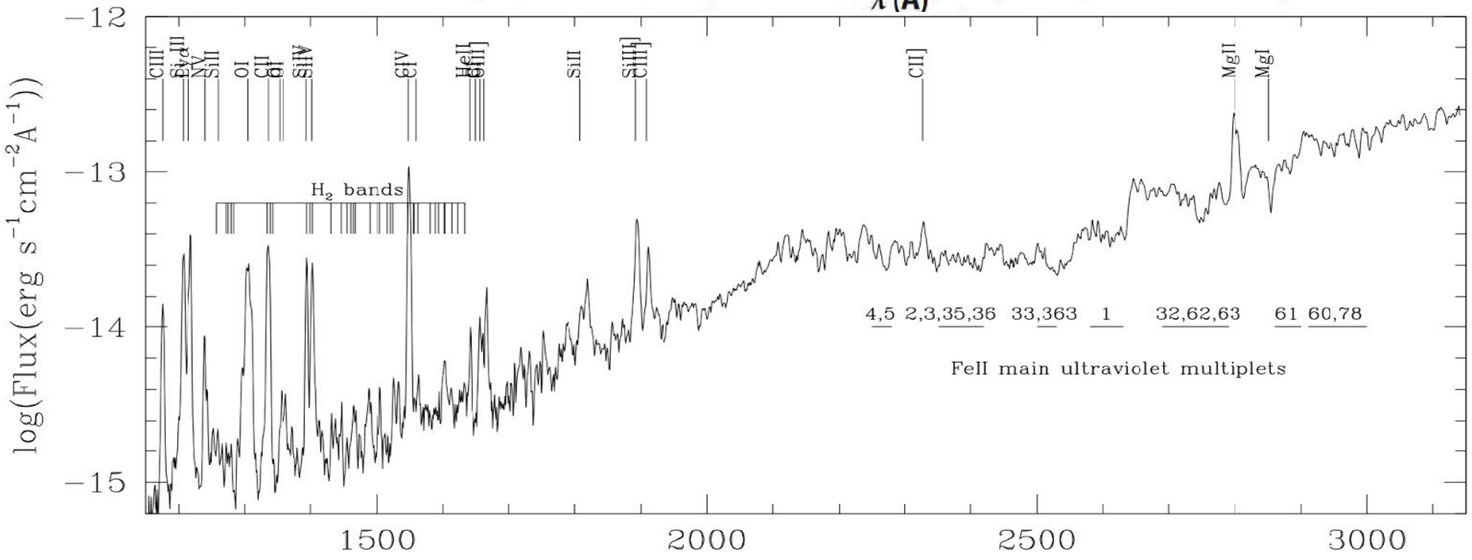
- Kinematics
- Spatial distribution
- Metallicity (with GASKAP)



Scientific Goals of the Low Mass Star Component







- ✓ Accretion physics in T Tauri Stars
  - Emphasis on low mass (<0.5 M_o)
  - Accretion shocks, flows, disks, and jets in UV-NIR
  - Time monitoring component (100 orbits)

Target Selection

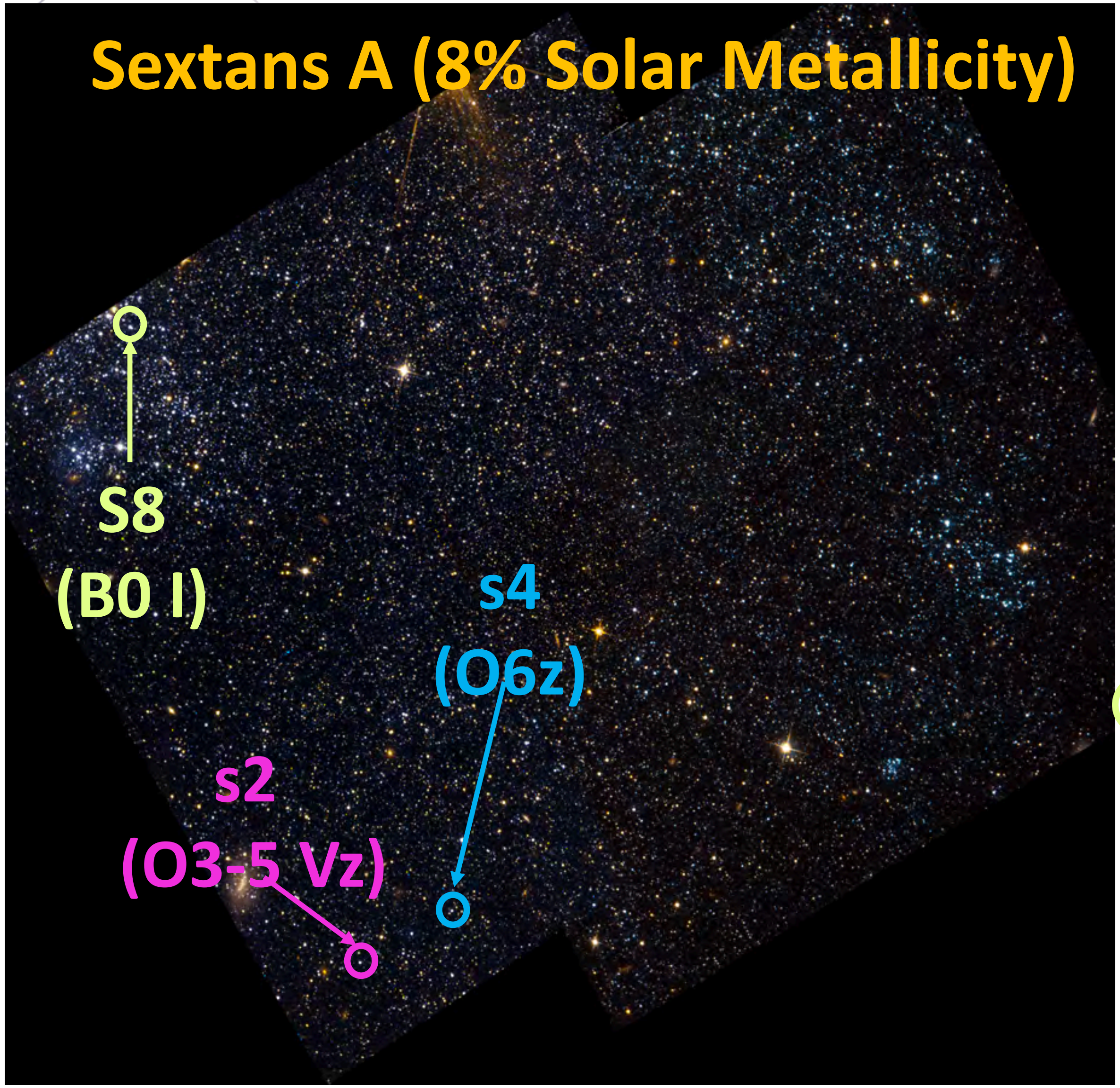
(Targets released February 18, 2020)

ULLYSES Targets at a Glance

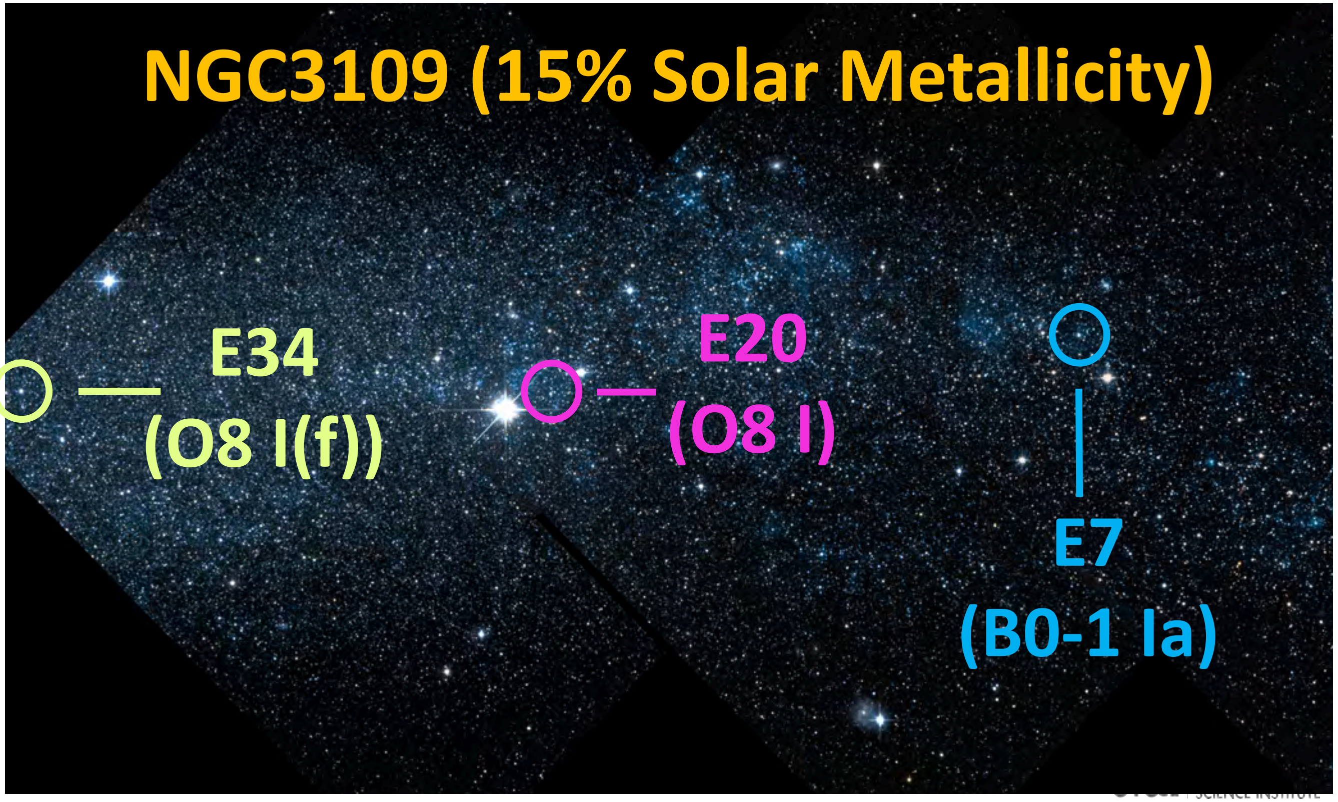
- Targets were released to the community on February 18, 2020
- Selection followed an objective, reproducible, and transparent process
- Process and outcome were documented, reviewed by the Science Advisory Committee (SAC), and approved with minor changes
- 240 targets will be observed by ULLYSES, and another ~90-100 archival targets will be included in the ULLYSES database
    - 497 orbits for massive stars
    - 451 orbits for T Tauri stars
- 2 orbits for WFC3/F225W pre-imaging of Sextans-A and NGC3109

Region	# ULLYSES targets	# AR targets	# orbits
LMC	98	34	225
SMC	66	40	222
Sextans-A	3	6	~37
NGC 3109	3	0	~15
Lupus	27	4	142
Cha I	16	3	97
e Cha	2	1	22
h Cha	5	3	20
Orion	10	0	45
s Ori	3	0	13
CrA	2	0	10
TWA	1	0	2
Monitoring CTTS	4	0	100
TOTAL	240	91	950

Target Selection - Low Metallicity Massive Star Sample



- ✓ **Sextans A** (8% solar metallicity)
  - 3 massive stars (O3 Vz, O6z, B0 I)
  - Also 6 more archival targets
- ✓ **NGC 3109** (0.1 Z_o in O, 0.2 Z_o in Fe)
  - 3 Supergiants O8 – B1



Target Selection – Process for the LMC/SMC

New

- Complete pool of potential targets and their parameters was assembled from the literature
    - List of papers and catalogs was defined by experts in the CIT and SAC
- Objects with incomplete information (SpT or LC, BV photometry) were removed from the master list
- Different catalogs were merged and duplications were eliminated by cross-matching coordinated in a 2.5” radius
- An automatic search for archival data in MAST and ESO was performed (2” search radius), and fluxes and S/N were computed in the archival data for pre-defined wavelength windows (1150, 1360, 1700, 2200 A)
- Calculation of exposure times and S/N (see S/N requirements in back-up slides) was scripted using our in-house ETC developed in python around PySynphot
    - Our scriptable ETC includes WM-Basic (O2-B1, Smith+2002), Castelli & Kurucz (B2-B9) and CMFGEN (WR, Smith+2002) models
    - Models were normalized to observed fluxes and compared to archival data when available

Target Selection – Process for the LMC/SMC

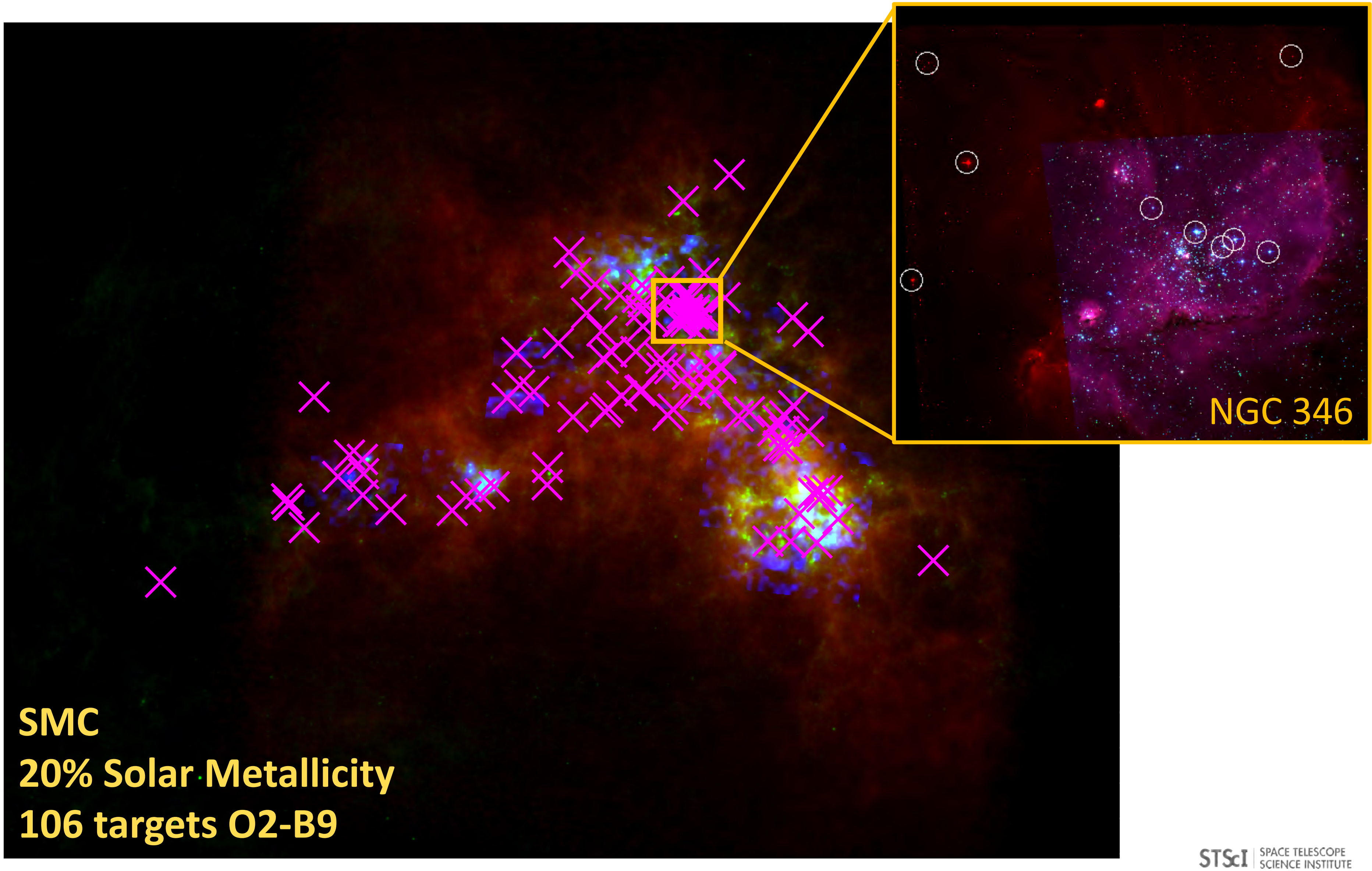
New

- Shortlists of targets were selected in each bin of SpT/LC based on pre-defined criteria:
  - Reasonable flux/exposure time, availability of HST and FUSE AR data with ULLYSES-compatible modes, availability of VLT data, targets from community proposals
  - All AR data, field were inspected for the shortlist targets
- Rotational velocities were tracked-down from the literature for shortlisted targets
- The final down-selection was performed to get the best trade-offs between:
  - Scientific value related to sampling of temperature, LCs, and rotational velocities
  - Prioritizing targets with partial UV coverage at medium-resolution in the archive
  - Prioritizing targets from community proposals
  - Exposure time
- Focus was put on O stars with at least 4 stars per SpT/LC bin, while goal was 2-3 stars for B0-B5 and 1-2 stars for B5-B9
- Coordinates were updated to 2MASS and GAIA, best available BV photometry was tracked for final targets
- Final sample was sent to SAC for review and approved

Target Selection - SMC

New

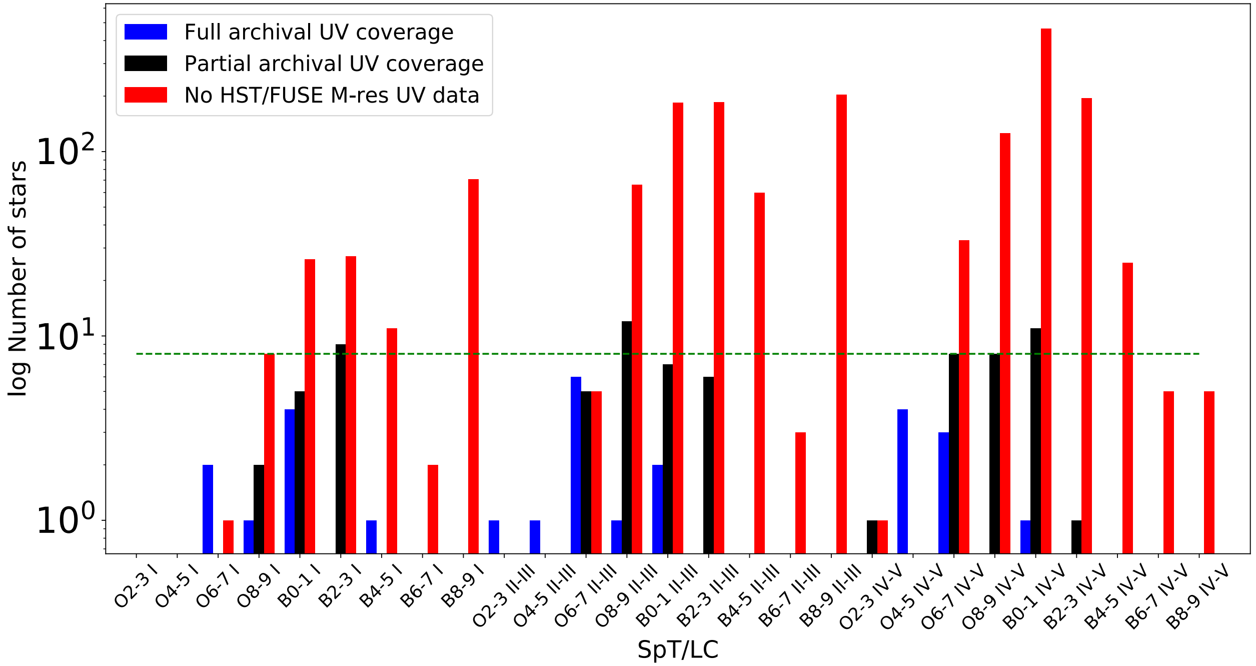
- 222 orbits
- 140 COS orbits (including 59 orbits with the 1096 setting at LP2)
- 82 STIS orbits
- 106 targets, including 40 stars with full archival UV coverage with FUSE and HST COS+STIS (920-2400 Å)
- Community input requested in fall 2019 led to prioritizing O stars in NGC 346
- 4 WR stars, 2 close binary systems



Target Selection - SMC

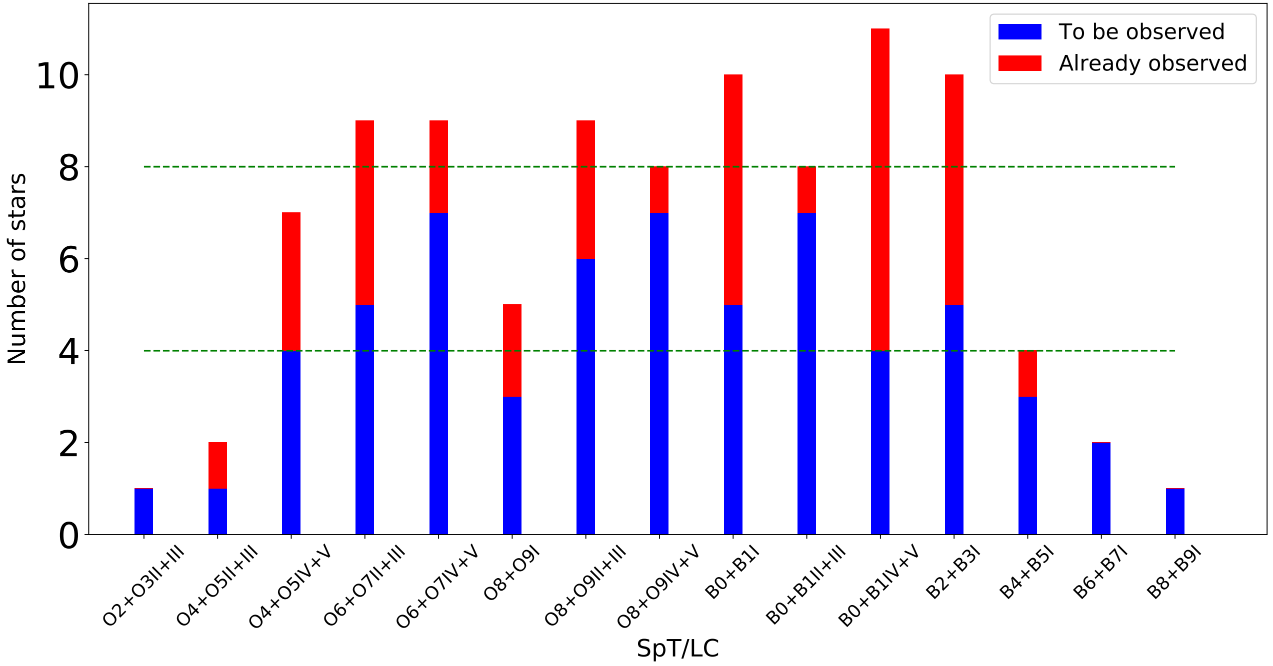
New

Initial pool of potential targets



Initial pool of targets had about several 1000s objects

Selected targets

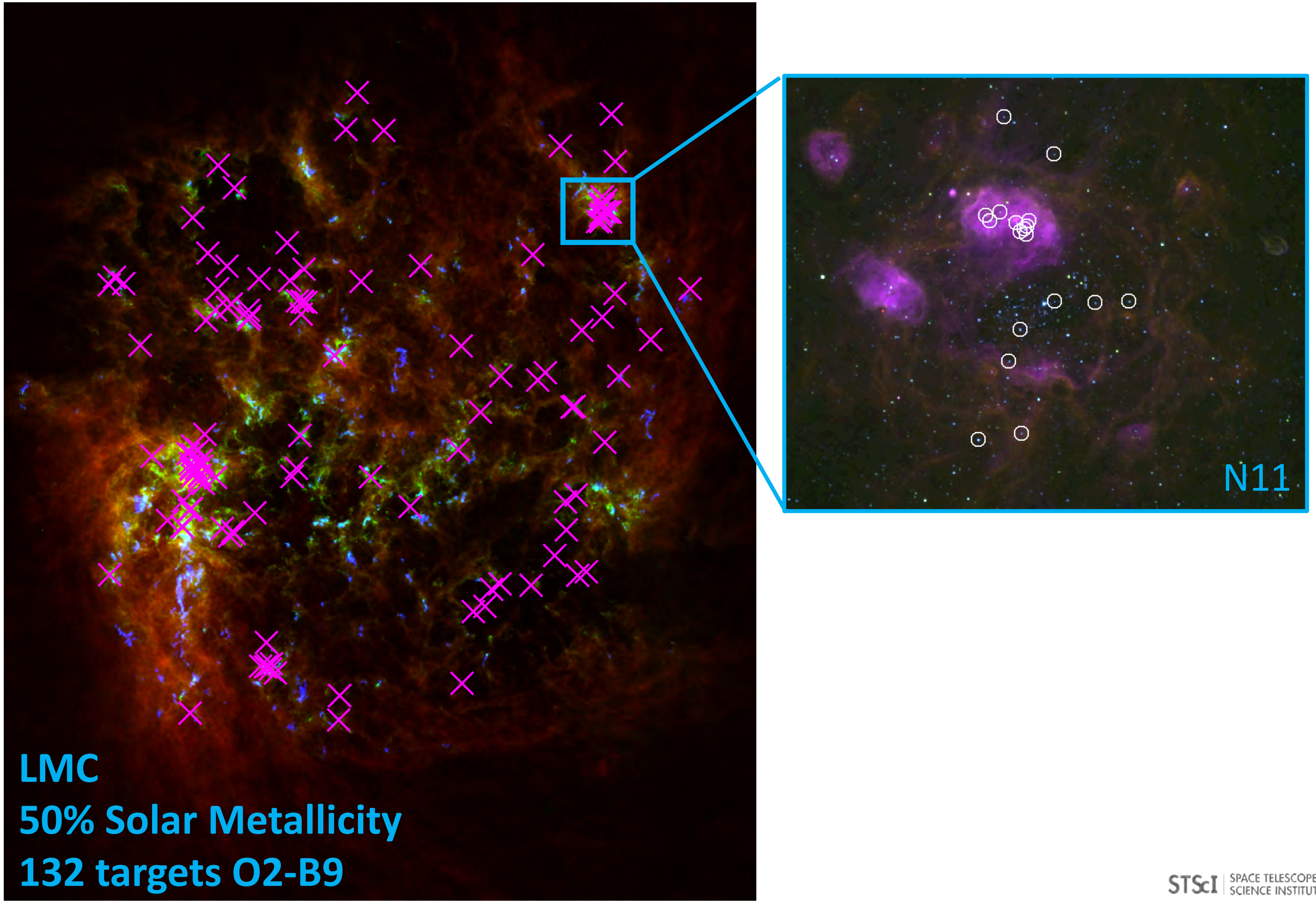


Final sample is balanced to at ~4 O-early B stars per SpT/LC, and 1-2 B4-B9 stars per bin

Target Selection - LMC

New

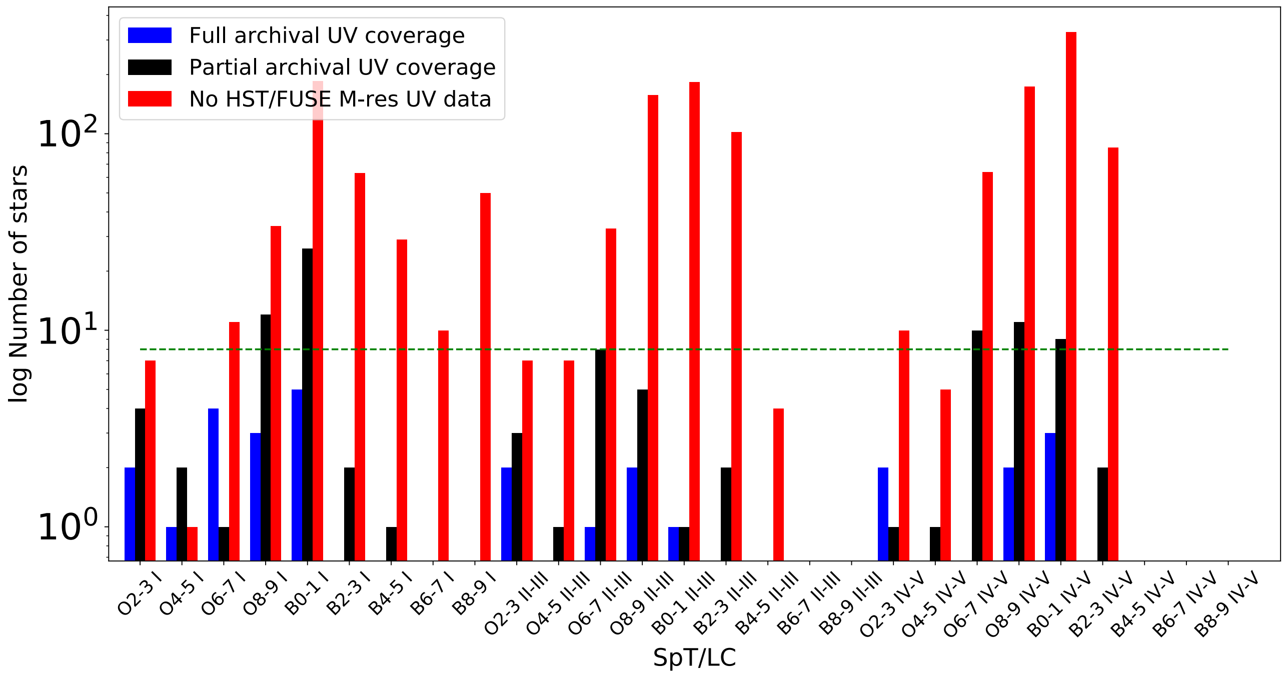
- 225 orbits
- 116 COS orbits (including 24 orbits with 1096 at LP2)
- 109 STIS orbits
- 132 targets, including 34 stars with full archival UV coverage with FUSE and HST COS + STIS (920-2400 Å)
- Community input requested in fall 2019 led to prioritizing O stars in N11
- 7 WR stars, 2 close binary systems



Target Selection - LMC

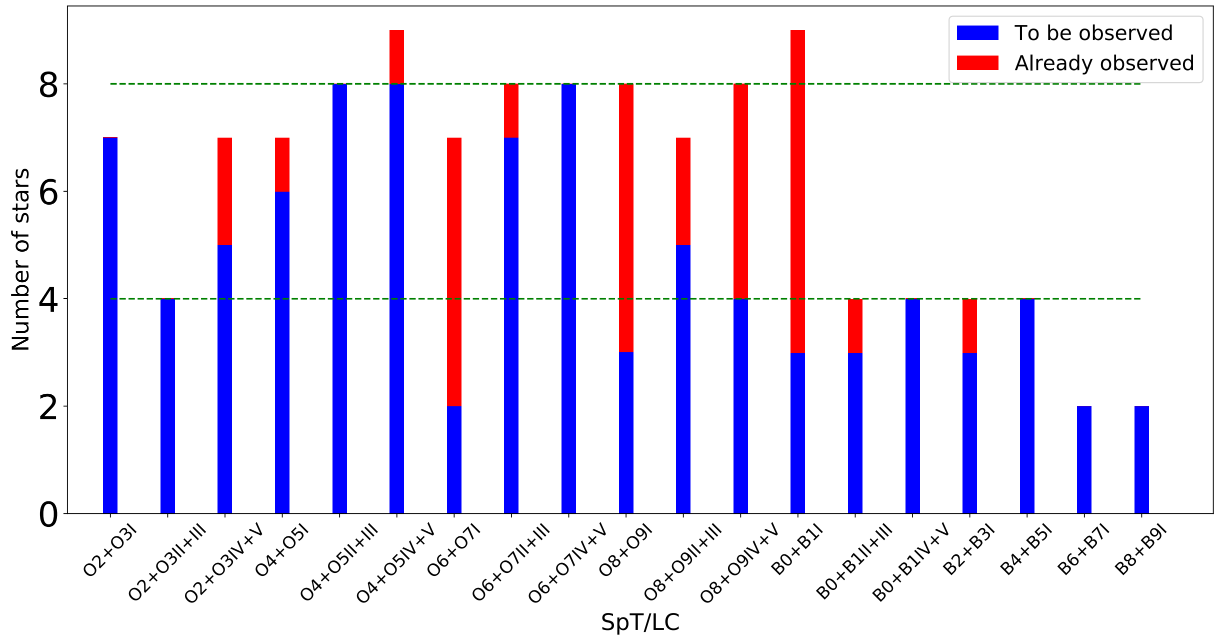
New

Initial pool of potential targets



Initial pool of targets had about several 1000s objects

Selected targets



Final sample is balanced to at ~4 O-early B stars per SpT/LC, and 1-2 B0-B9 stars per bin

Target Selection Process – T Tauri Stars

New

ULLYSES

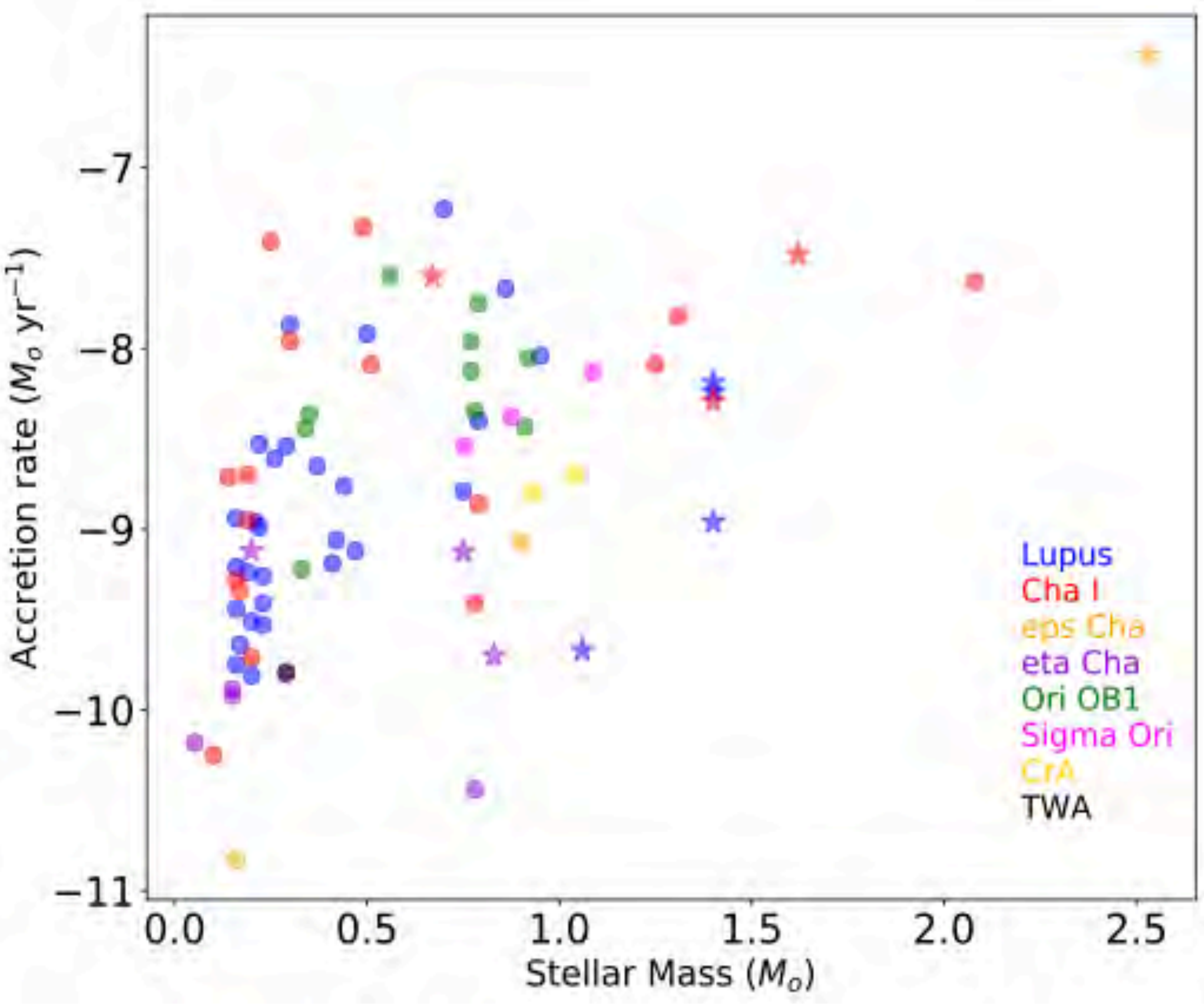
- Complete pool of potential targets and their parameters was assembled from the literature
    - List of papers and catalogs was defined by experts in the CIT and SAC
- Objects without masses or accretion rates were removed
- An automatic search for archival data in MAST and ESO was performed (5” search radius)
- Calculation of exposure times and S/N (see S/N requirements in back-up slides) was scripted using our in-house ETC developed in python around PySynphot:
    - Creation of templates scaled by A_V, M_{acc}, distance based on AR spectra of V836 Tau, DN Tau, and DR Tau
    - BOP checked using templates multiplied by a factor 4
    - Exposure times padded by a factor of 2 to account for variability
- Targets with exposures times > 15 orbits were removed from the sample
- Targets were sorted by mass, and within each 0.1 Mo interval, targets with a range of accretion rates were selected
- Targets from community proposal were selected when possible

Target Selection – T Tauri Star Sample

New

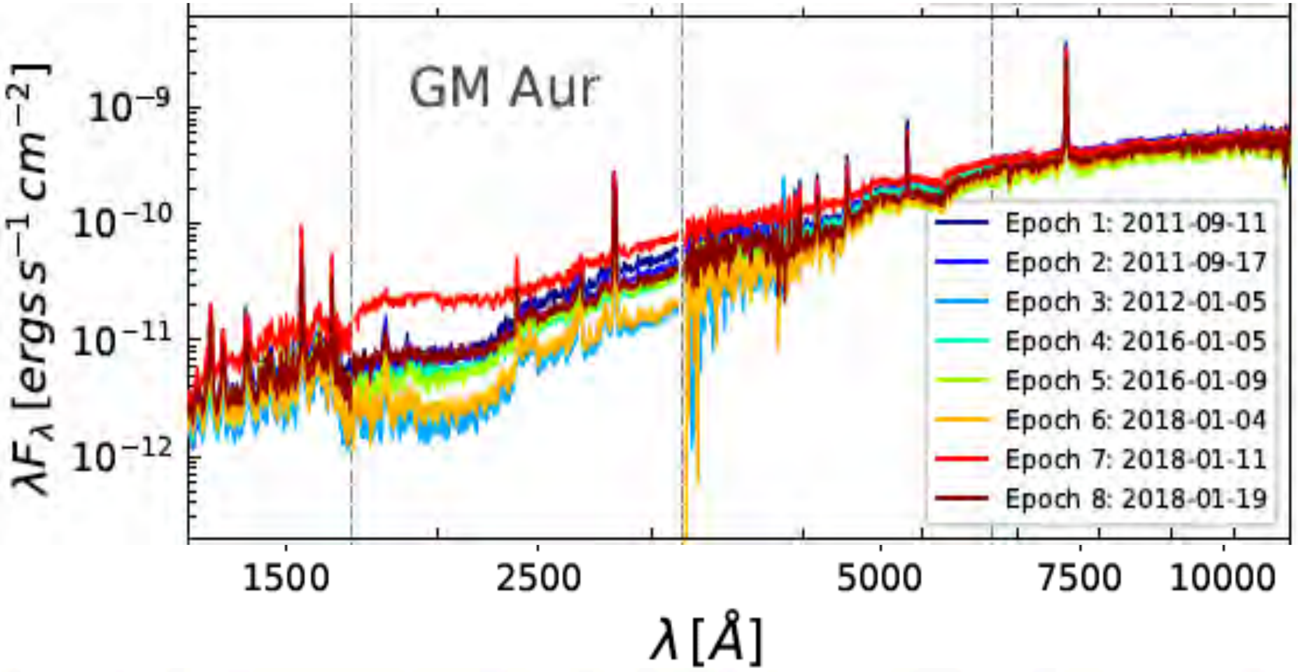
- 67 targets in 8 star-forming regions
- 355 orbits
- Complete sampling of mass and accretion rate

SF region	# of targets
Lupus	27
Cha I	16
ε Cha	2
η Cha	5
Orion	10
σ Ori	3
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 (COS G160M + G230L)



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

ULLYSES ETC

- We have developed a scriptable ETC that will be released to the community
  - The tool outputs plots and S/N for user-adjustable wavelength intervals
  - The tool includes WMBasic (Starburst99) models for massive stars and CMFGEN models for WR stars

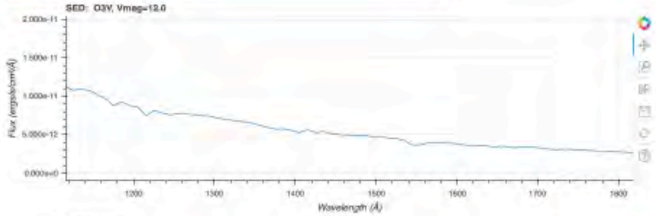
Lines (Final details TBD)

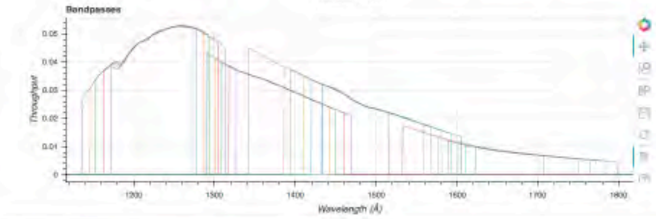
	Exptime (s)	Accretion & Transition																					
		N V 1239	N V 1243	N V 1240	He II 1640	C IV 1548	C IV 1549	C IV 1551	Si IV 1394	Si IV 1403	Si IV 1397	Mg II 1240	Mg II 1240	Mg II 2796	Fe II 1608	Fe II 2250	Fe II 2261	C II 1334	g160m break 1592	UV Ctm 1500	UV Ctm 1700	UV Ctm 2000	UV Ctm 2500
cos,g130m,c1291	50.0	GL	GL	GL	x	x	x	x	GL	GL	GL	GL	GL	x	x	x	x	GL	x	x	x	x	x
cos,g130m,c1300	50.0	GL	GL	GL	x	x	x	x	GL	GL	GL	GL	GL	x	x	x	x	GL	x	x	x	x	x
cos,g130m,c1309	50.0	GL	GL	GL	x	x	x	x	GL	GL	GL	GL	GL	x	x	x	x	GL	x	x	x	x	x
cos,g130m,c1318	50.0	GL	GL	GL	x	x	x	x	GL	GL	GL	GL	GL	x	x	x	x	GL	x	x	x	x	x
cos,g130m,c1327	50.0	GL	GL	GL	x	x	x	x	GL	GL	GL	GL	GL	x	x	x	x	GL	x	x	x	x	x
cos,g160m,c1533	50.0	x	x	x	G	G	G	G	G	G	G	x	x	x	G	x	x	x	G	G	G	x	x
cos,g160m,c1577	50.0	x	x	x	G	G	G	G	G	G	G	x	x	x	G	x	x	x	G	G	G	x	x
cos,g160m,c1589	50.0	x	x	x	21	30	30	30	x	48	49	x	x	x	23	x	x	x	25	37	18	x	x
cos,g160m,c1600	50.0	x	x	x	21	30	30	30	x	x	x	x	x	x	23	x	x	x	gap	37	18	x	x
cos,g160m,c1611	50.0	x	x	x	21	30	30	30	x	x	x	x	x	x	gap	x	x	x	28	37	18	x	x
cos,g160m,c1623	50.0	x	x	x	21	30	30	30	x	x	x	x	x	x	gap	x	x	x	28	37	18	x	x

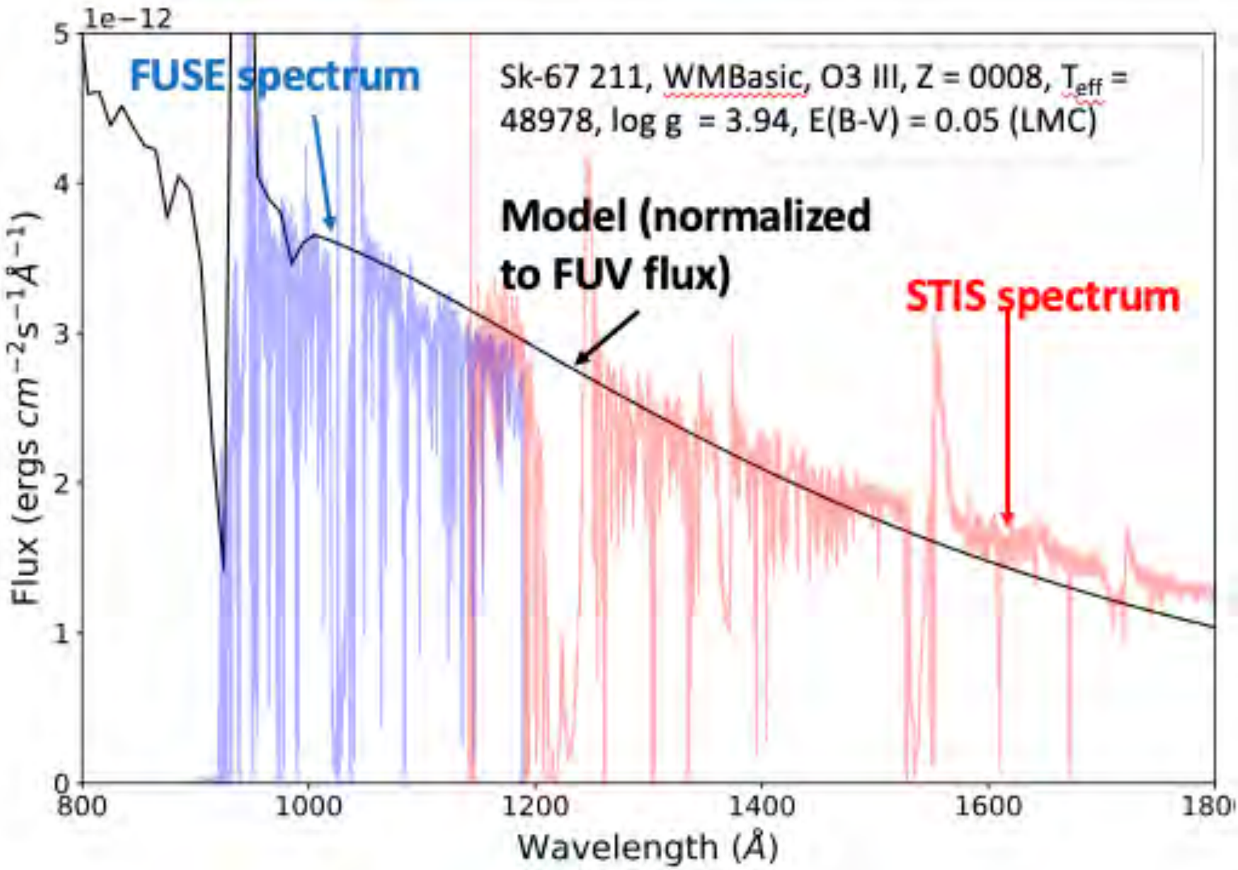
Key

Color bar

x = Out of bounds
G = Global limit exceeded
L = Local limit exceeded
gap = Line in detector segment gap
sag = Line in gain-sagged region (TBD)





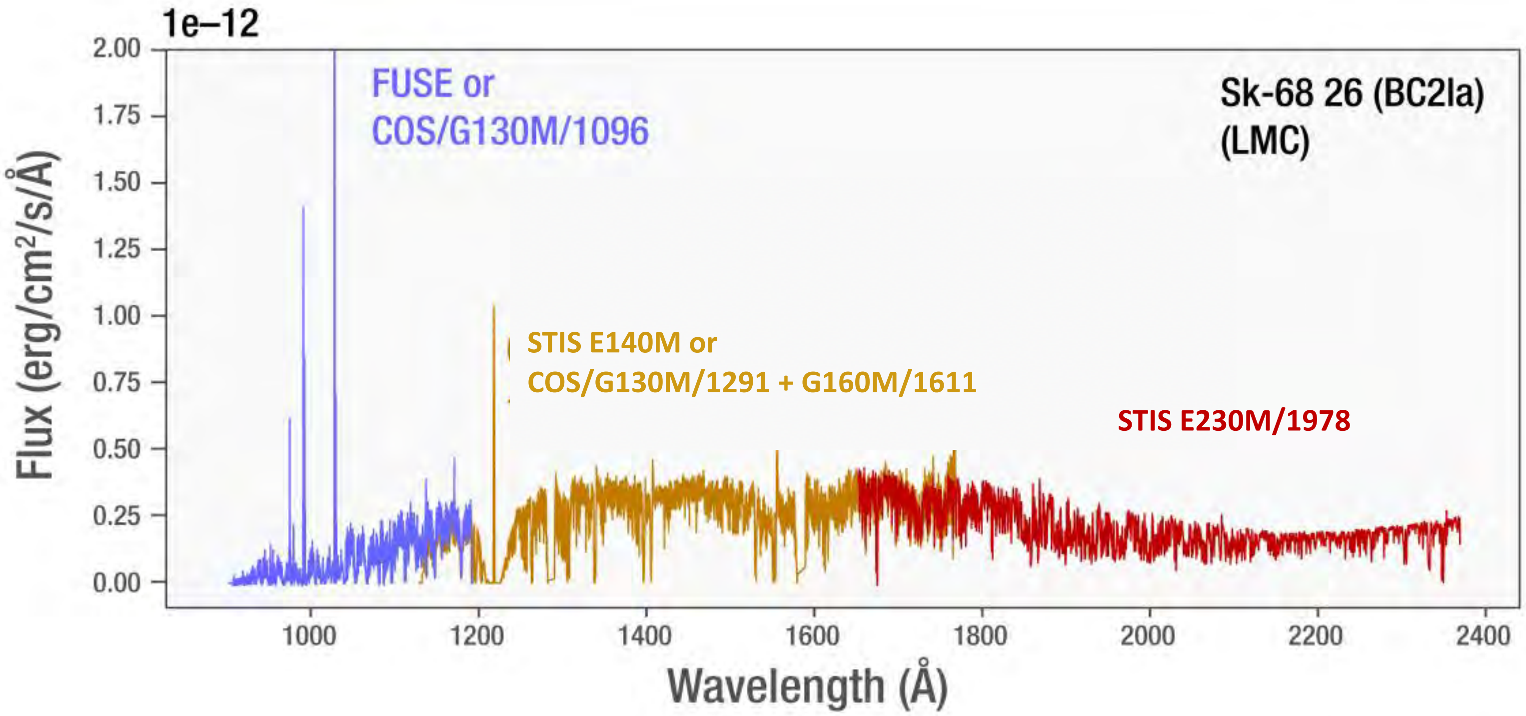


Observing Strategy and Technical

Observing Implementation

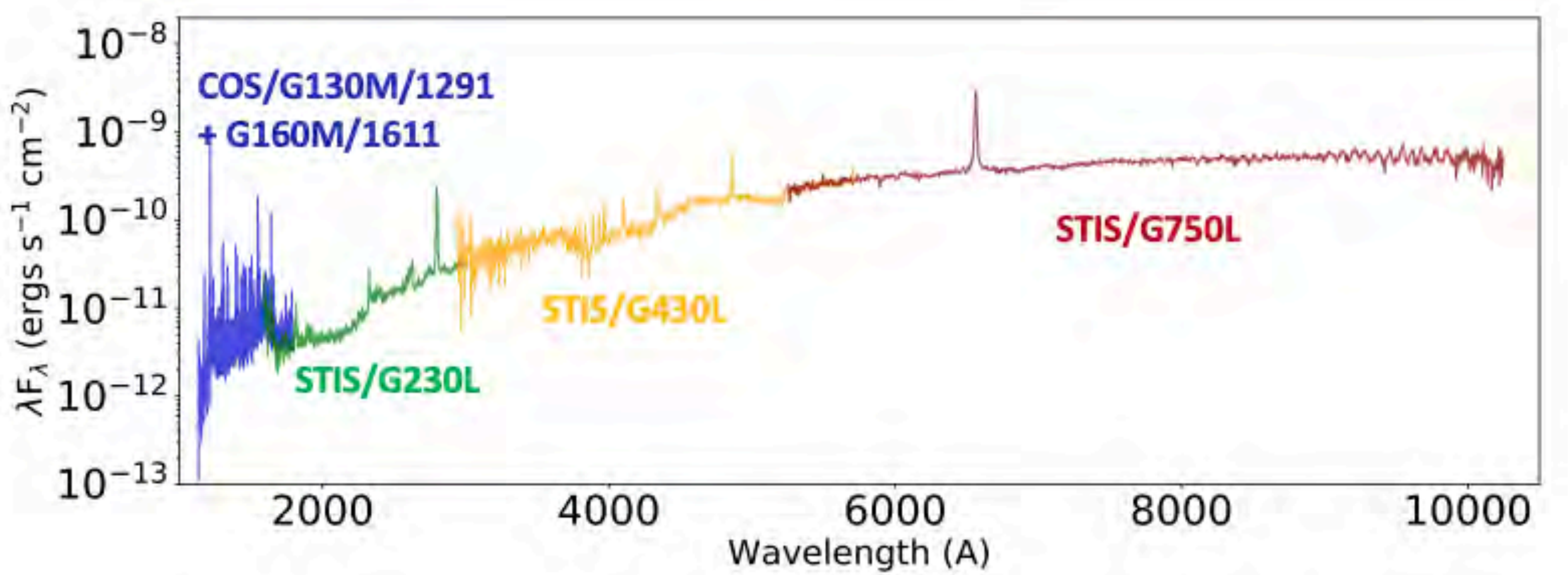
Observing Strategy – LMC/SMC Massive stars

- **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)



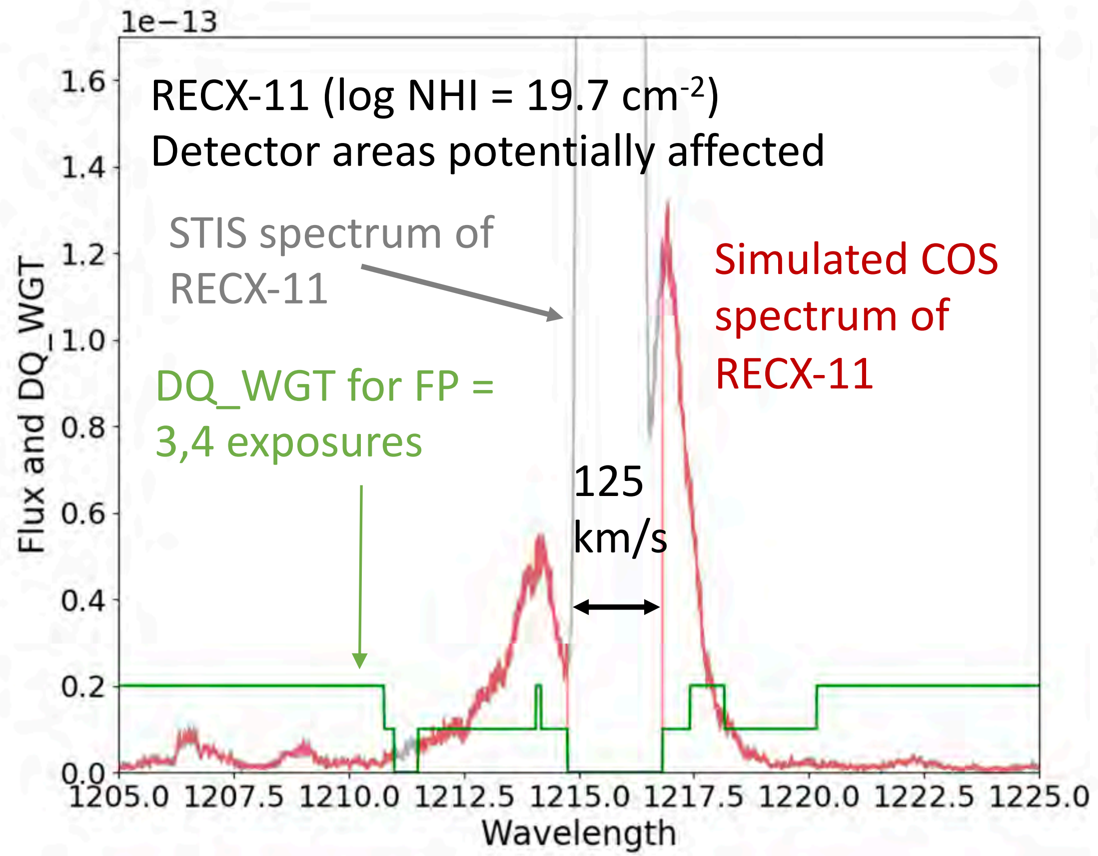
Observing Strategy – T Tauri Stars

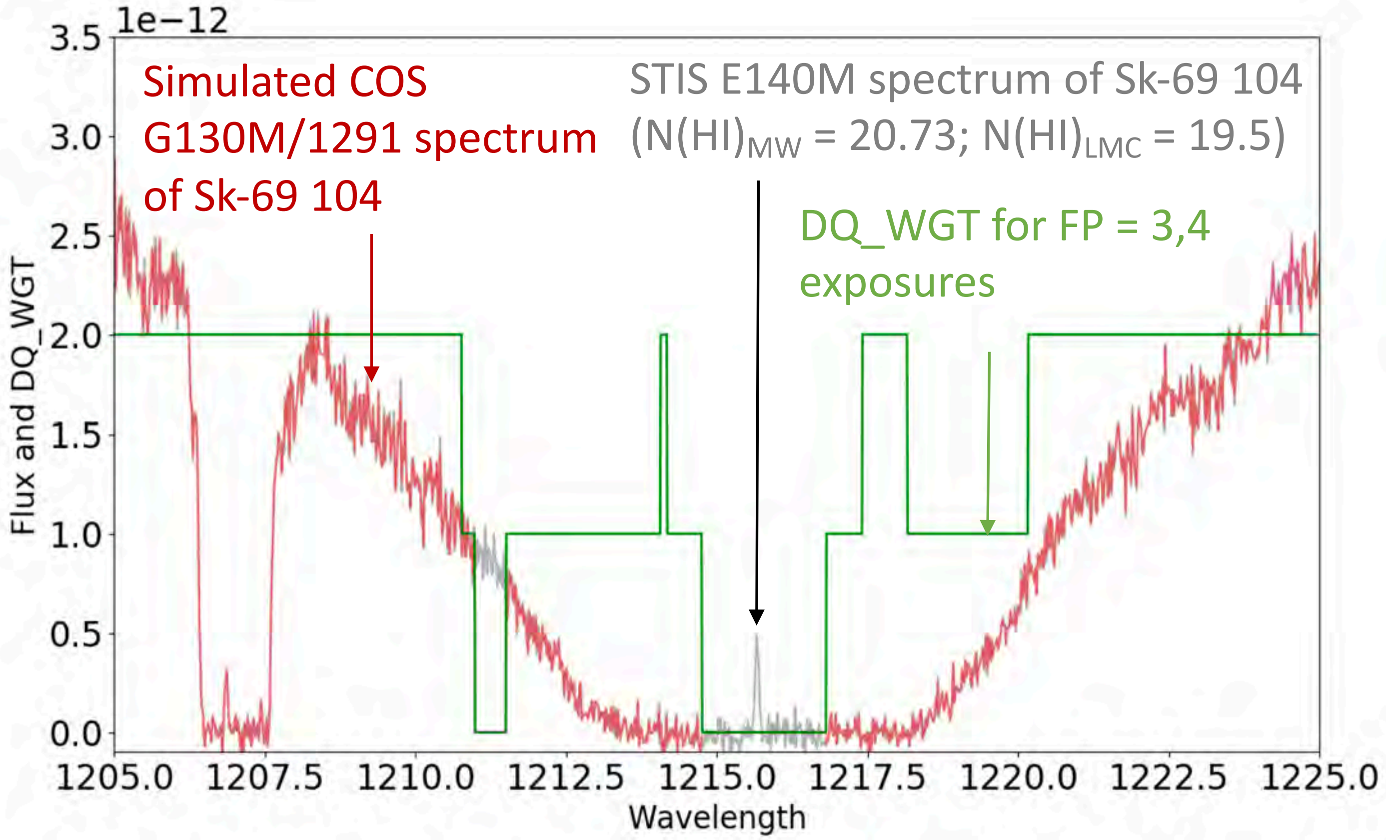
- Survey stars:
  - Medium-resolution UV coverage 1140-1780 Å with COS/G130M/1291 + COS/G160M/1611
  - NUV coverage at low resolution with STIS/G230L
  - Optical-NIR with STIS G430L and G750L
- Monitoring stars:
  - COS/G160M/1611 + COS/G230L/2950



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.



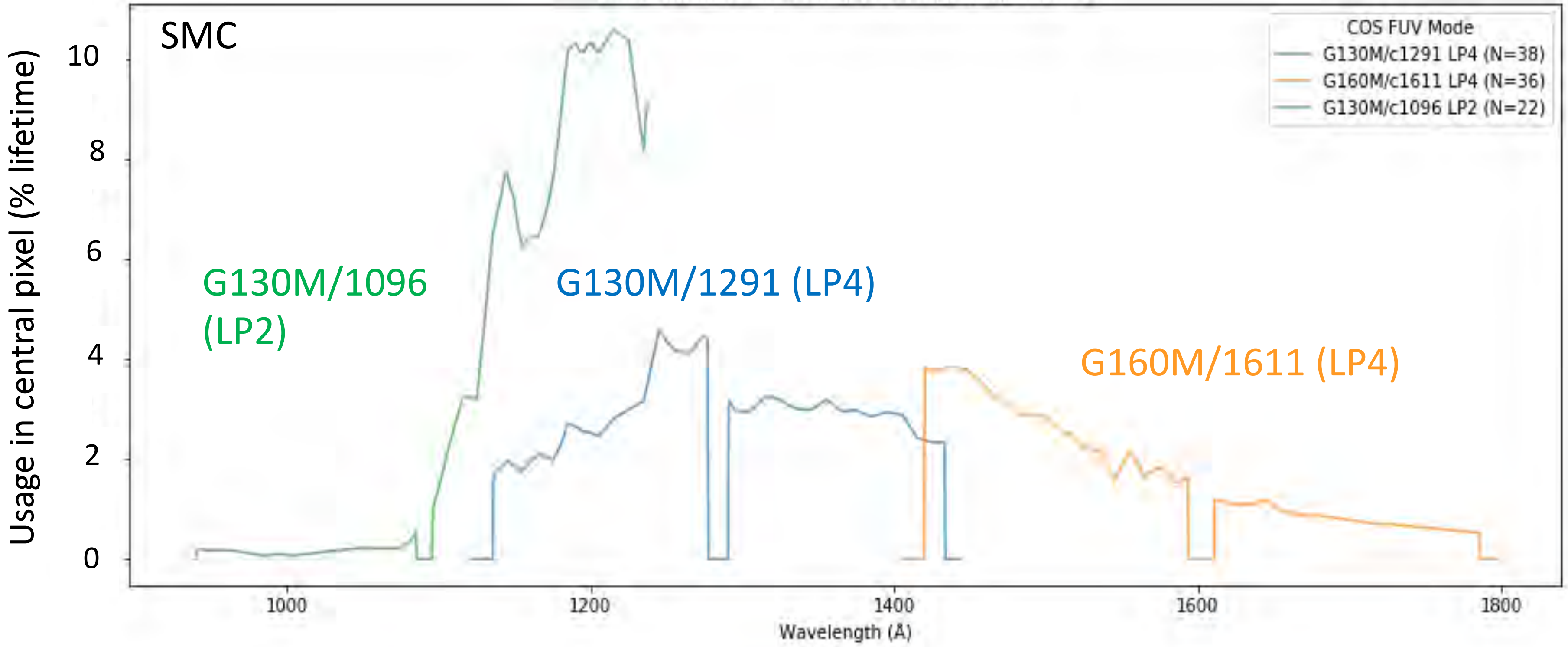


Gain-sag impact on COS – SMC

New

ULLYSES

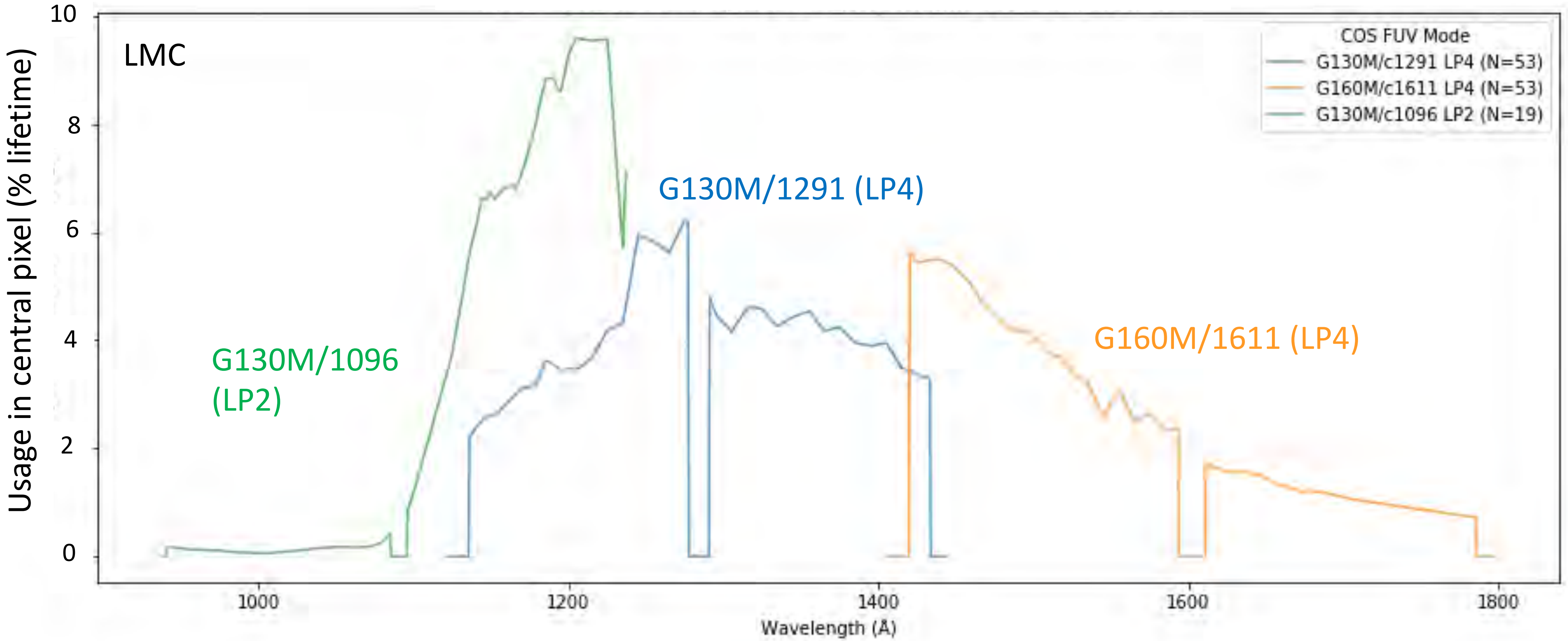
- Model SEDs and scriptable ETC used to estimate counts in the brightest pixel as a function of wavelength for each mode of observation
- Fraction of lifetime is counts/50,000
- Note: COS/G130M/1096 is operated at LP2 with high counts on FUVA



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 Overview

New

- Automated processes for initial draft phase 2 generation completed for hot stars
    - Will require some minor adjustments for T Tauri stars
- Procedures to finalize APT implementation and track work developed
    - Seven scientists trained in detailed procedures have started work
    - Tools to compare model SEDs with observed data and streamline BOP clearing of target and field
- Available LMC/SMC UV archival data downloaded and organized by target
- APT implementation started in March for 55 of the 164 LMC/SMC targets
    - These APT files to be finalized and submitted by end of May
- Other APT files to be completed on rolling basis between June 2020 and Sep 2021
    - 109 remaining LMC/SMC, 67 T Tauri Survey, 4 T Tauri Monitor stars (2 epochs each)
    - Requires averaging ~ 12 total targets / month, or about 2 / month / implementation scientist
- Working with HST Planners and Schedulers to determine LRP windows and flexibility for T Tauri targets for which coordinated observations are desired

Status of Phase 2 work – Hot Stars

New

- LMC/SMC (164 targets, 447 orbits, 41 separate PIDs)
  - Small visits, no scheduling constraints or visit links, may be pulled forward at any time
  - Initial group of APT proposals currently being implemented by STScI technical team
    - 55 targets, 139 orbits, 14 PIDs
    - Includes wide range of spectral types and luminosities in both LMC and SMC
    - Plan to complete submission of these by end of May, with most flight-ready by mid-summer
    - 1 proposal observing 5 targets using 17 orbits currently flight ready
  - Remaining LMC/SMC proposals
    - Continue submitting ~ 7 LMC/SMC targets/month, completing submissions of remaining 109 LMC/SMC targets by ~ August 2021
- Low-metallicity stars (3 targets in Sextans A and 3 targets in NGC 3109)
  - 2 orbits of WFC3/UVIS/F225W pre-imaging observations to be submitted before June 2020
  - 52 orbits of COS G140L/800 to be submitted over same time period as LMC/SMC proposals

Initial batch of SMC/LMC Proposals being implemented

New

ULLYSES

PID	Title	Orbits
16090	ULLYSES LMC O2/O3 Stars STIS	9
16091	ULLYSES LMC O7/O8 Stars STIS	12
16092	ULLYSES LMC Wolf-Rayet STIS	6
16093	ULLYSES LMC Early-O/WN COS	8
16094	ULLYSES LMC O4 Stars COS	5
16095	ULLYSES LMC O5/O6 Stars COS	5
16096	ULLYSES LMC O9-B1 Stars COS	12
16097	ULLYSES LMC late-B Stars COS/STIS	10
16098	ULLYSES SMC early Stars STIS	5
16099	ULLYSES SMC late-O/early B Supergiants STIS	13
16100	ULLYSES SMC O7-O9 Giants COS	8
16101	ULLYSES SMC B1 Stars COS	12
16102	ULLYSES SMC B2/B3 Supergiants COS/STIS	17
16103	ULLYSES SMC O Stars COS 1096	17

- Total: 139 orbits, 55 targets, 36 COS visits, 26 STIS visits
- APT files for this first batch of proposals to be submitted by end of May 2020
- Entire SMC/LMC sample will be ~ 447 orbits and 164 targets

Status of Phase 2 work – T Tauri monitoring targets

New

- 4 targets, each observed for 12 orbits distributed over 3 rotational periods
    - COS/G160M/1611 and COS/G230L/2950 together in each single orbit visit
    - Repeat each set after 6 to 24 months, so 4 targets x 12 orbits x 2 epochs = 96 total orbits
    - Earliest observations likely to be in 1st quarter of 2021
- Currently working on setting up detailed scheduling and coordinated observations
    - Draft proposals to allow detailed LRP planning to be submitted during April 2020
    - Working towards locking down windows for all monitor observations by June 2020
    - Our plans for each target's 2nd epoch of observations will prioritize simultaneous availability with both HST 1-gyro operations and JWST in 2022
- APT files for 1st epoch of each target to be finalized during mid-2020
    - Some adjustments to exact scheduling windows may need to be finalized closer to execution

Status of Phase 2 work – T Tauri Survey Targets

New

- 67 Survey targets, 351 total orbits (2 – 14 orbits each)
  - All to be observed with COS G130M/1291, G160M/1611 & STIS G230L/G430L/G750L
  - All data for each target to be collected within ~ 1 day
  - Earliest observations will start in fall 2020
- Working on detailed scheduling and coordinated observations
  - Want to lock down narrow LRP windows as far as possible in advance to allow planning of coordinated observations, with exact timing tied down ~ 6 – 8 weeks in advance
  - ~ 73% of survey targets have some TESS coverage between Nov 2020 and Jun 2021
    - Will work with HST schedulers to determine how many we can coordinate
  - Draft APT files to allow LRP planning to be submitted during April/May 2020
    - Will reflect planned instrument and orbit usage, but not all settings or final exposure times
    - Expect to iterate with schedulers to balance ULLYSES desires with impact on *HST* schedule
  - Finalized APT files for each target to be submitted several months prior to execution.

New

Technical Implementation – Automated Phase II Creation Process

ULLYSES

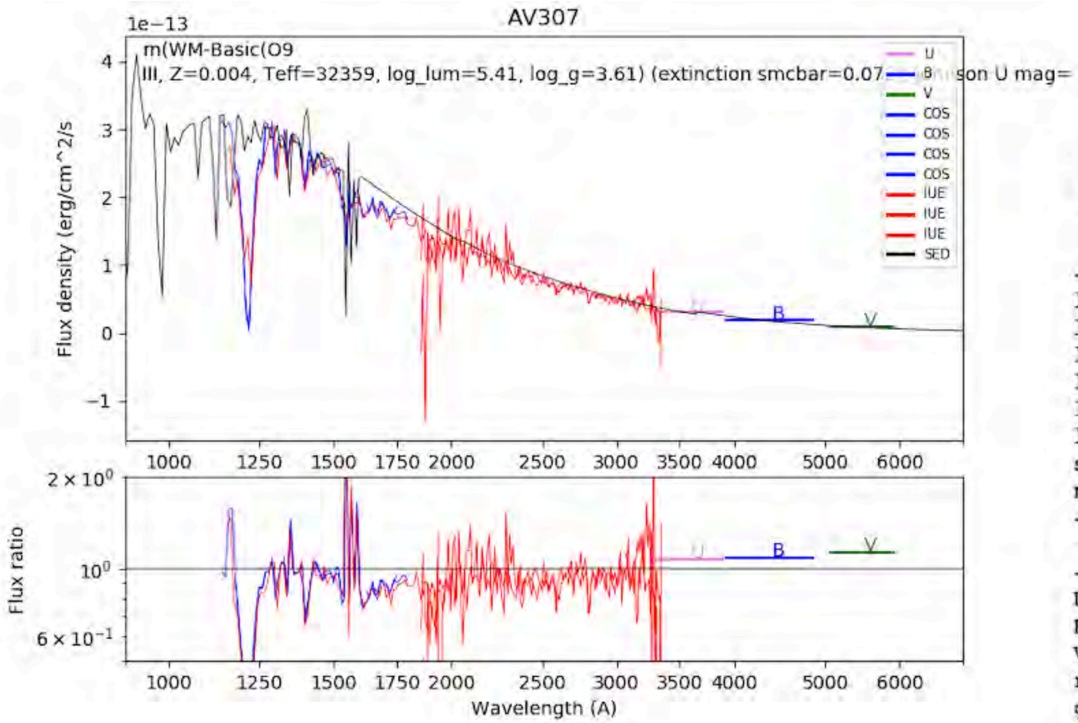
- Processes developed to speed generation of phase 2 APT proposals
- Initial draft of APT files automatically generated from same data used for target selection
    - Includes target information, standardized names, flux info, coordinates, exposure times, etc
    - Default science exposures are automatically entered with exposure and buffer times, including breakdown into desired COS FP-POS positions, with optional parameters properly populated
    - Keywords and checklists added to target & visit comments to allow tracking of preparation status
    - Adopted SED files, photometric data, & expo time calculations documented in comment lines
    - Each PID kept to no more than 5 targets to keep workflow manageable
- System of JIRA tickets set up to track work using keywords in APT comments

New

Technical Implementation – Automated Phase II Creation Process

ULLYSES

- Simple to use python plotting tools provided to compare adopted SEDs with available spectral and photometric data
  - Allows all planned observations to be visually compared with existing UV data
  - Both pre-calculated SEDs and available archival data have been collected on disk in standard formats
  - Implementers can easily revise SEDs and recalculate exposure times as needed using the same scriptable ETC routines developed for the target selection




```
        File           TARGNAME         Config          Min. wav  Max. wav
---------------------  --------  ------------------  --------  ---------
lb2a21010_x1dsum.fits  AZV-307   FUV G130M 1291 PSA    1130.0  1438.0686
lb2a21020_x1dsum.fits  AZV-307   FUV G130M 1327 PSA    1168.0  1476.3157
lb2a21030_x1dsum.fits  AZV-307   FUV G160M 1577 PSA    1380.0  1758.8695
lb2a21040_x1dsum.fits  AZV-307   FUV G160M 1623 PSA    1426.0  1805.8291
lwp05174mxlo_vo.fits   AV 307    LWP LOW LARGE         1857.0   3344.938
lwp05209mxlo_vo.fits   AV 307    LWP LOW LARGE         1857.0   3344.938
swp24876mxlo_vo.fits   AV 307    SWP LOW LARGE         1156.0  1975.3384
new_sed.fits           AV307                            140.0  1600000.0
-----------------------------------------------------------------------------------
 Band Magnitude Ratio to SED
 ---- --------- ------------
U         12.82    1.0151578
B          13.8    1.0583746
V         13.96    1.1075692
rn(WM-Basic(O9 III, Z=0.004, Teff=32359, log_lum=5.41, log_g=3.61) (extinction smcbar=0.072), johnson U mag=1
gamag)
```

New

Technical Implementation – Automated Phase II Creation Process

- Working drafts of APT files and all supporting material for each target kept in Box folders
  - Plots comparing adopted SEDs to archival data and images of the field can be saved here and made available to internal and Contact Scientist reviewers to speed resolution of BOP issues
  - Contact Scientists in the COS and STIS teams have been trained to process information available for BOP clearing of targets and fields in the APT files and Box folder

Bright Object Flare Safety

New

How to apply rules designed to protect against M dwarf flares to T Tauri stars?

- X-ray studies suggest that magnetic flaring in accreting T Tauri M stars, when scaled for the stellar bolometric luminosity, is reduced by a factor of two to three as compared with active M dwarfs
- However, variable accretion luminosity makes it difficult to directly observe and characterize magnetic flares in CTTSs
- The delta U methodology adopted for main-sequence dwarfs can’t be used directly, because the observed U band fluxes in CTTSs are dominated by accretion, not magnetic activity
- Our plan is to adopt observed J band magnitude as the best surrogate for the underlying stellar luminosity, and use a standard U-J color based on spectral type to apply the current M-dwarf rules, scaling as appropriate for the higher luminosity and distance of the TTSs.

Coordination of HST and other observations

Community-Led Observations – Massive Stars

New

- Massive stars:
  - IAU G2 group on massive stars leading proposal with VLT/XSHOOTER
- Program IDs and planned windows will be compiled and tracked on the ULLYSES website starting in early June 2020 to allow time coordination of ancillary observations
- HST observations of LMC/SMC stars starting in the spring 2020, spread out over Cycles 27, 28, 29
  - Program 16103 is flight-ready, with planned windows currently in August 2020 (but a good candidate to be pulled forward due to the easy schedulability of the LMC and SMC)

New

Community-Led Observations – T Tauri Stars Monitored Over Time

- Observations of monitoring T Tauri stars will start early 2021
- 4 observations per rotational period over 3 periods, with the same pattern repeated during two epochs 9-12 months apart
- **X-ray monitoring with XMM-Newton** near-simultaneous with HST led by C. Schneider et al.
    - Proposal will be submitted in October for observations of targets observed with HST after May 2021
    - DD proposal will be submitted for observations of targets observed with HST before May 2021
- **X-ray monitoring with NICER** (ISS X-ray instrument) near-simultaneous with HST led by M. Guenther et al.
- **Magnetic mapping with spectro-polarimetry** (CFHT/SPIRou) led by J.-F. Donati et al.
- **Ground-based optical/NIR spectroscopy** under works by various groups
- We are working to schedule the first epoch of **TW Hya with TESS (March-April 2021)**
    - The other 3 targets (RU Lup, GM Aur, BP Tau have already been observed with TESS)

Community-Led Observations – T Tauri Stars Monitored Over Time

- All 4 monitoring targets can be scheduled with HST 1-gyro mode (and 3-gyro) concurrently with JWST in 2022

T Tauri target	HST Epoch 1	HST Epoch 2
TW Hya	March - April 2021	January - February 2022
RU Lup	April - May 2021	February – April 2022
GM Aur	September 2021	September 2022
BP Tau	August - October 2021	August - October 2022

- We are currently delivering preliminary phase IIs to the schedulers to lock those observations in the LRP (more details in the technical observing section)
- A firm schedule for the 4 T Tauri stars monitored with HST will be made public on the ULLYSES website at the beginning of June 2020 to allow preparations of coordinated observations
  - The CIT is in contact with leads of coordinated observations as well

Community-Led Observations – Survey T Tauri Stars

New

- 67 targets in 8 star-forming regions
- VLT ESPRESSO + UVES + X-Shooter proposal led by C. Manara et al.
- IRTF 1.9-4.2 mm spectroscopy led by W. Fischer
- Others?
- The program-IDs and planned windows will be released and tracked on the ULLYSES website as they become available
- To the extent possible, we will freeze the schedules to within a day ~6-8 weeks in advance of the observations

LCOGT Photometric Monitoring

New

- We are working on a possible agreement between STScI and LCOGT (still very much open-ended and delayed due to covid-19) to perform systematic ground-based photometric monitoring in u' and V for ALL targets (survey and monitoring)
- Monitoring T Tauri stars:
  - 8-12 observations/period over the 3 periods monitored by HST
  - 10 min cadence during the HST observations
  - 2x/day for 10 days before and the after the 3 periods of HST observations
  - 8-12 observations/period over one period ~3 months before and ~3 months after the HST observations
- Survey T Tauri stars:
  - 8-12 observations/period during the period monitored by HST
  - 10 min cadence during the HST observations
  - 2x/day for 10 days before and after the period of HST observations
  - 8-12 observations/period over one period (1x/day for 10 days for objects without a well constrained period) ~3 months before and ~3 months after the HST observations.

LCOGT Photometric Monitoring

New

STScI would like to take the lead on these observations to:

- Ensure that all targets are observed using the same cadence/pattern, enhancing the scientific legacy of this very (the largest?) HST program
- Provide photometric monitoring a few months before the HST observations and ensure that the targets are not in a FU Ori burst state that could compromise the safety of the COS UV detectors

New

Scheduling of Survey T Tauri Stars

- To the extent possible, we will coordinate the HST scheduling of a some ULLYSES survey T Tauri stars with TESS
- However, TESS observations of the 8 target SF-regions only span November 2020-June 2021, meaning that only a fraction of the targets can be scheduled during this timeframe
- We are working with the schedulers to determine how many orbits can be coordinated
- We would welcome guidance from the STUC regarding how much pressure to allow on the HST schedule given the scientific scope and timeline for ULLYSES vs its impact on the scheduling of other programs

Star-forming region	TESS Sectors	TESS windows
s Ori	32	November-December 2020
Ori OB1a,b	32	November-December 2020
TWA	36	March - April 2021
Cha I	38,39	April – June 2021
Lupus	38	April – May 2021
e Cha	38, 39	April – June 2021
h Cha	37,38, 39	April – June 2021
CrA	None	None

ULLYSES Data Products

New

Data Products – Overview

- HSLPs: STIS and COS calibrated pipeline products , co-added spectra (within grating), spliced spectra (multiple gratings, multiple instruments, e.g., FUSE, COS/STIS), acquisition images
- Database:
    - High-level science products, ancillary data (e.g., VLT, Gemini, FUSE), meta-data on targets (e.g., coordinates, SpT/LC, mass, accretion rate) and observations (e.g., settings, exposure times)
    - Web interface and queries (filtering from tables, search form / box, visual selection from interactive plots, API)
- Quick-look tools (interactive plots of spectra with interactive S/N calculations)
- Jupyter notebooks (data handling and analysis, e.g., binning, time series)
- Website (to launch May 2020 with static information and schedules only, data release Summer 2020)

New

Data Products – High Level Science Data Products

- HLSP include the COS and STIS pipeline products, co-added products that include new+archival HST data + archival/new data from external facilities, light-curves and/or spectral cubes for time-varying sources, and target acquisition images.
- Spectra will be combined under variety of scenarios:
  - Co-addition (identical instrumental gratings at different times or central wavelengths to build S/N or study variability)
  - Splicing (creating continuous spectral coverage with data from different instruments and/or gratings)
- The splicing algorithm will come in two varieties
  - "Nearest-neighbor'' addition of input spectra onto the output wavelength scale, for use on input spectra of similar spectral resolution (e.g., inter-order combination of STIS echelle observations or different cenwaves of the same COS or STIS grating). This increases S/N in regions where wavelengths overlap.
  - "Abutting" of spectra, where the output spectrum switches discontinuously from one input spectrum to the next, for use on cases with no wavelength overlap or with disparate spectral resolution (e.g., different gratings)

Data Products – Database

New

- The database (DB) is envisioned to be the backend that supports the interactive capabilities of the webpages, allowing users to query on relevant scientific meta-data of the targets, including spectral classifications, sky location, group membership, HR diagram location, variability indicator, etc.

- Methods of data selection will include:
  - Filtering on pre-defined data-types
  - Sortable tables of targets and their parameters
  - Interactive selection from sky maps, HR diagrams, and plots of one target parameter (.e.g, mass) vs another (e.g., A_V)
  - Database query forms

Data Products – Quick-looks

A

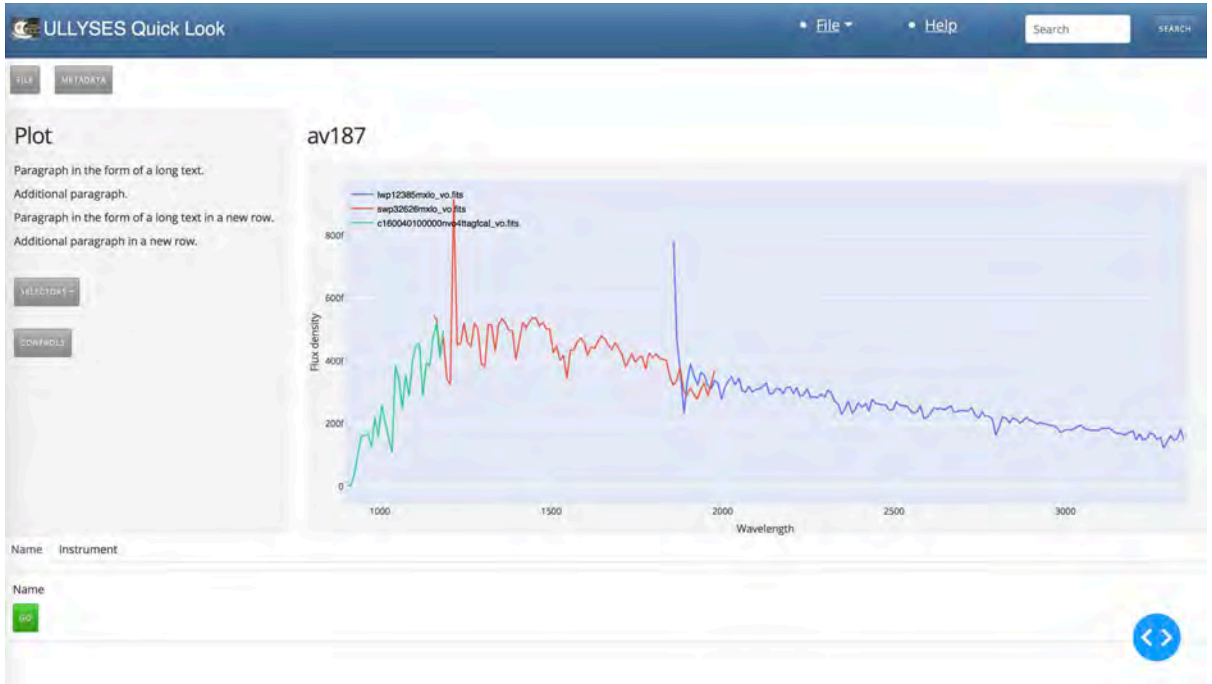
New

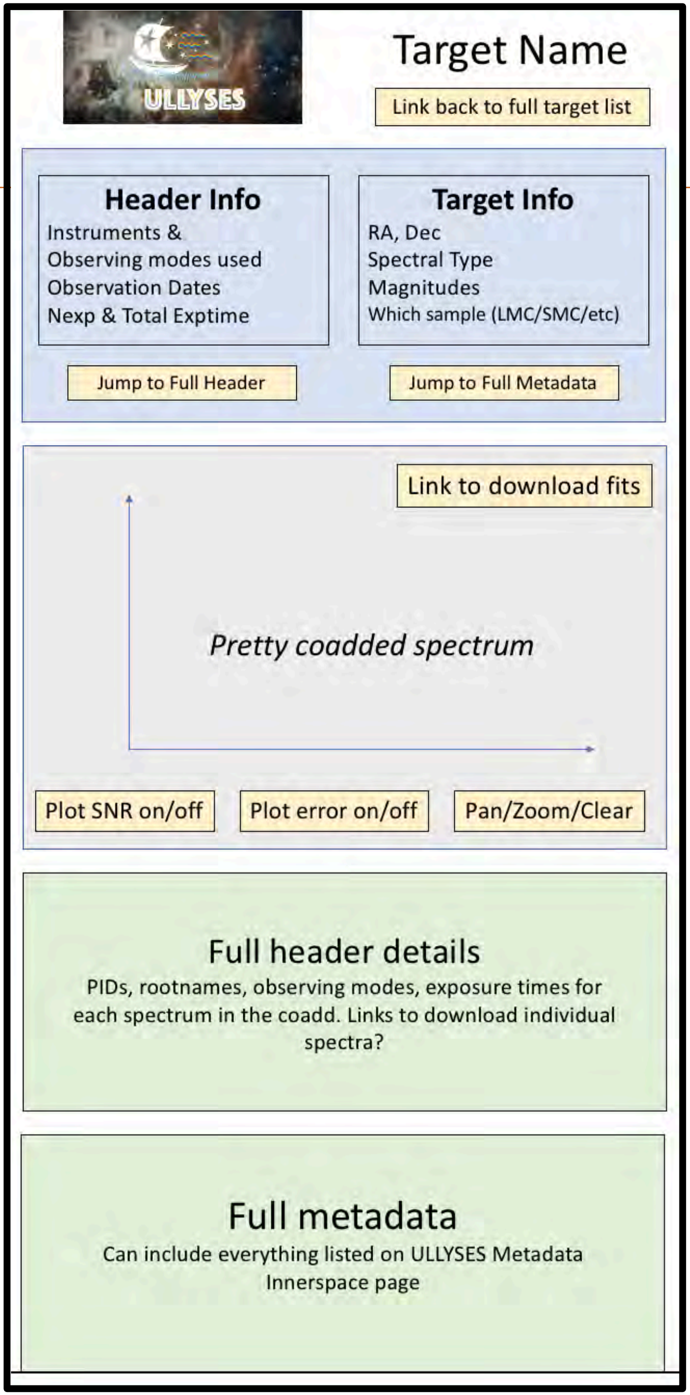
- Quick-looks allow interactive manipulation of single or co-added spectra, optionally overlaying errors, data quality flags, and signal-to-noise ratio.

A. Conceptual Layout

B. Plotly/dash proof-of-concept

B

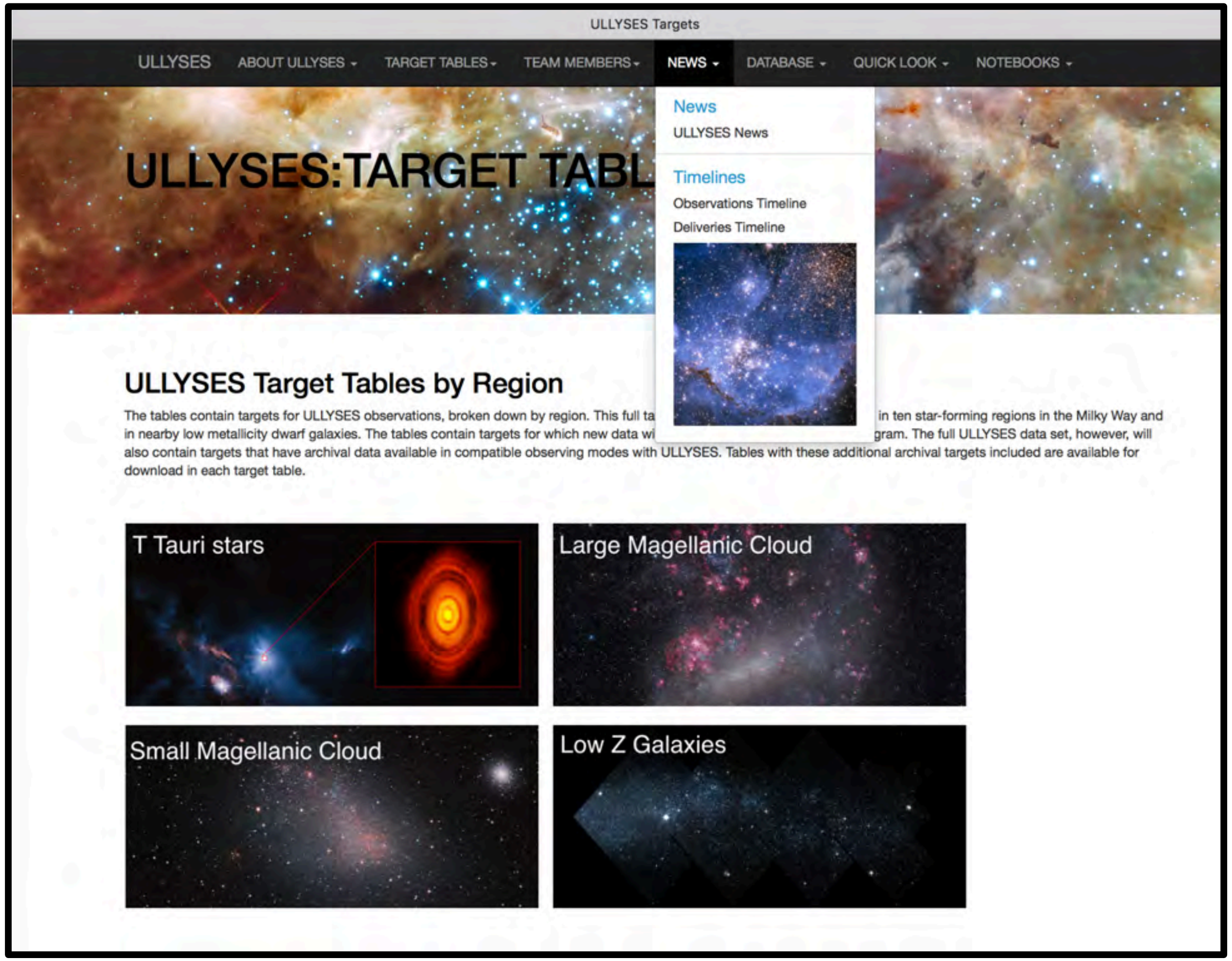




Data Products – Website

New

- The website is the user-facing product that allows access to the ULLYSES datasets and is designed for the novice and expert alike.
- Both high-level and detailed information is provided as well as multiple ways to explore the data
  - Users can browse target tables and see scheduling information
  - The Quick Look tool will be launchable from a dedicated page, housing all targets
  - An interactive interface to the database will allow custom selections of targets with the ability to launch the Quick Look tool or download data from MAST of those targets.



Data Products – Jupyter Notebooks

New

- The Jupyter notebooks are designed to help the community begin more complicated analyses that are the beyond the scope of the high level science product definitions.
- These build on the Institute-wide efforts to increase accessibility of data products with example data retrieval and analysis notebooks
- Example use cases include:
  - Selecting/visualizing target variability
  - Inspecting spatially resolved objects
  - Spectral line identification
  - Comparing spectra to toy models
- Jupyter notebook will be implemented toward the end of the project

Thank you

Back-up Slides

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/c1611: 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