STScI | SPACE TELESCOPE SCIENCE INSTITUTE

EXPANDING THE FRONTIERS OF SPACE ASTRONOMY

ULLYSES Status Update

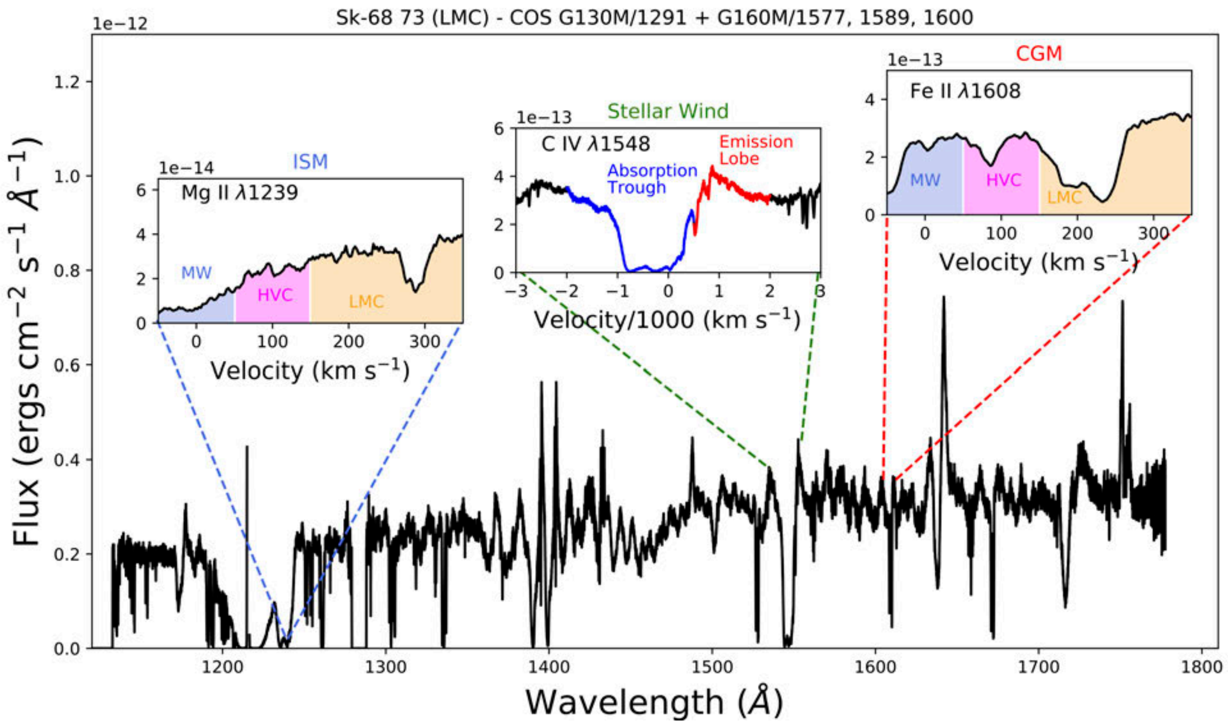
Julia Roman-Duval, Gisella De Rosa, Charles Proffitt, TalaWanda Monroe & the CIT

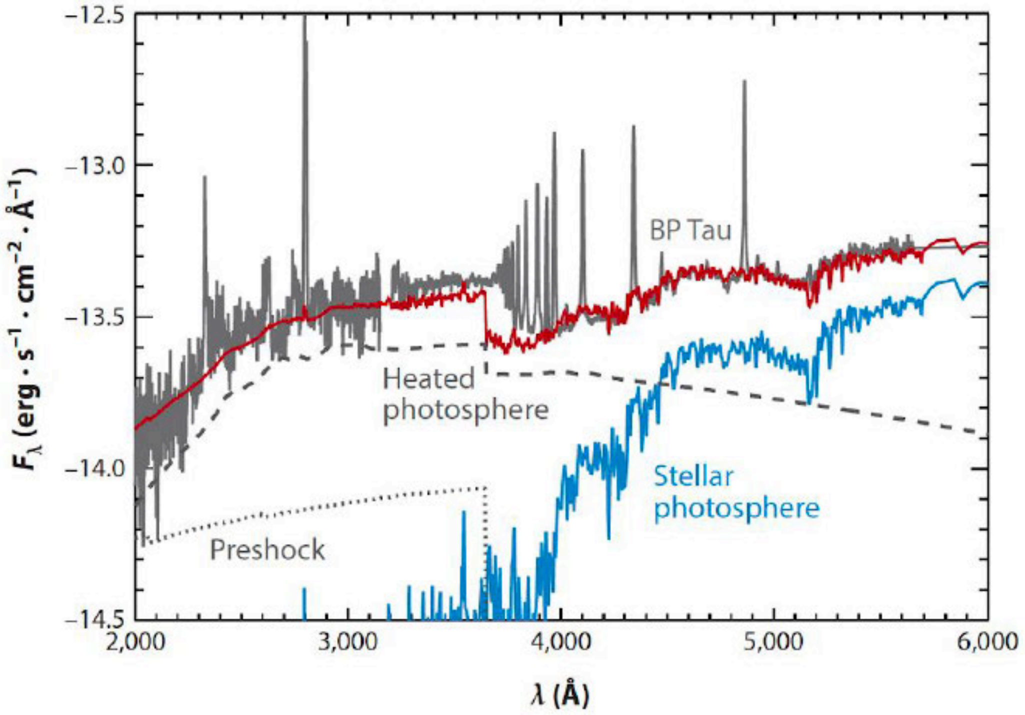
November 13, 2019

ULLYSES Scientific Goals

- The goal of the Hubble UV Legacy Library of Young Stars as Essential Standards (ULLYSES) is to provide a **UV spectroscopic reference sample of high mass and low mass young stars**
  - ➢ ULLYSES will extend the **massive star** parameter space to **low metallicity (< 50% solar)**
  - ➢ ULLYSES will extend the **low mass star** parameter space to **lower mass (< 0.5 M_o)**

- ULLYSES will invest **~1,000 HST orbits with COS and STIS** to observe ~200 high and low mass young stars

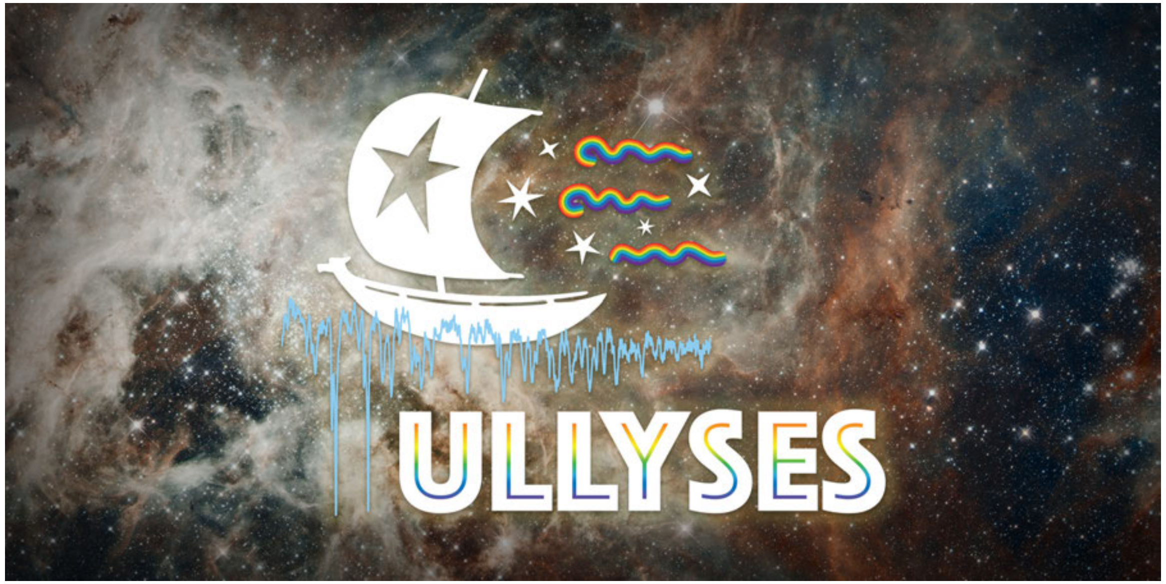




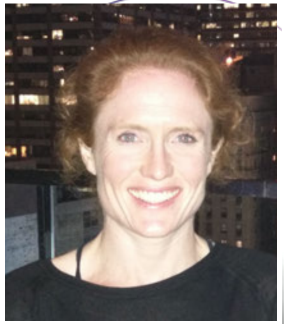
General updates

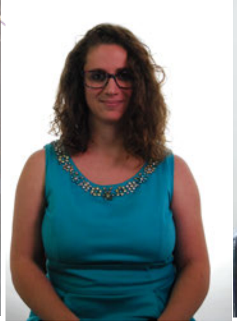
- The first of announcement of targets selected for observations was included with the launch of the ULLYSES “Splash” webpage on November 4.
  - See http://www.stsci.edu/stsci-research/research-topics-and-programs/ullyses

- Presence at AAS:
  - Engagement through Hyperwall talk and STScI Townhall
  - “Research” talk to discuss the more technical aspects of the ULLYSES implementation
  - Stickers with ULLYSES logo



ULLYSES Core Implementation Team (CIT)

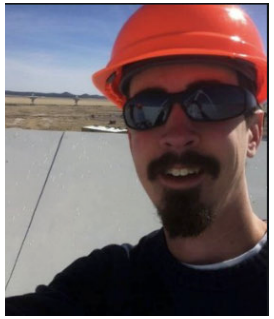

Julia Roman-Duval
(CIT Lead)


Gisella De Rosa
(DP technical Lead)


Charles Proffitt
(Observing Lead)


TalaWanda Monroe
(Observing Deputy Lead)


Alessandra Aloisi
(Pre-imaging)


Chris Britt
(Public Outreach)


Ivo Busko
(DP/software)


Joleen Carlberg
(Observing)


Will Fischer
(T Tauri target selection)


Andrew Fox
(DP)


Alex Fullerton
(LMC/SMC Targets)


Bethan James
(Observing)


Robert Jedrzejewski
(DP, software)


Sean Lockwood
(ETC, software)


Elaine Mae Frazer
(DP)


Cristina Oliveira
(Targets, Observing)


Rachel Plesha
(Targets, software)


Adric Riedel
(Targets, Software)


Allyssa Riley
(DP)


Richard Shaw
(DP)


Linda Smith
(Targets)


Tony Sohn
(Observing)


Jo Taylor
(DP)


Leonardo Ubeda
(Website)

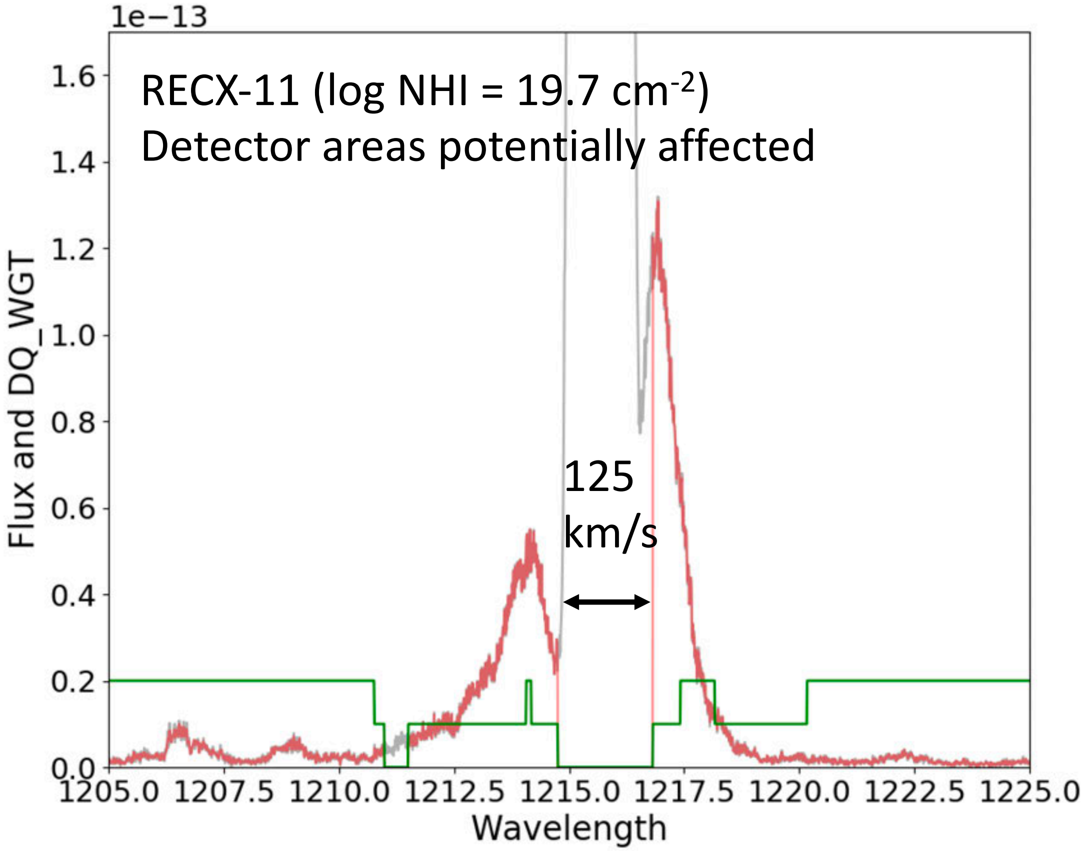

Dan Welty
(Targets, Observing)

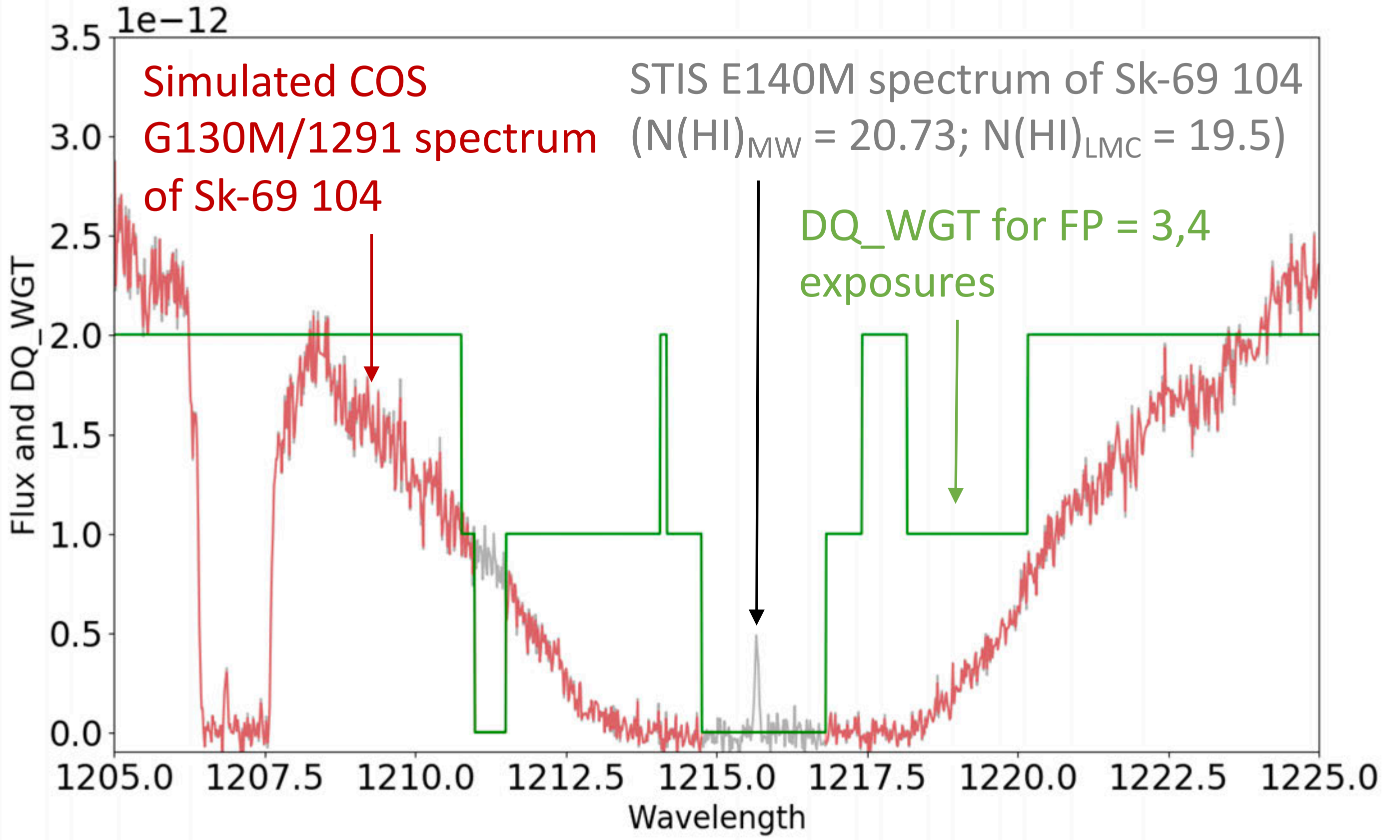
Science Advisory Committee (SAC)

- 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)
- The CIT has been communicating with the SAC via telecons and emails to determine the optimal observing strategy and target selection

Observing Strategy – Lyman-α

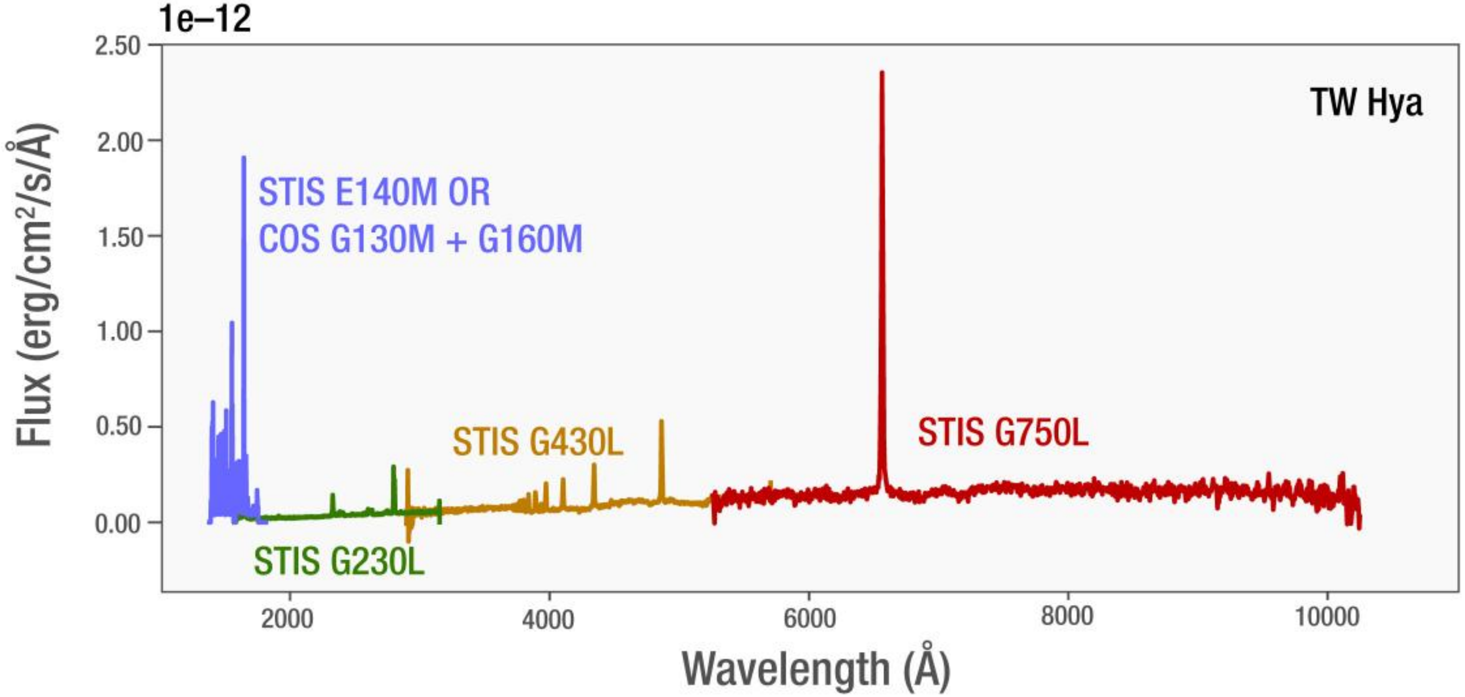
- Two gain-sag holes at LP4 make Ly-α unobservable with COS/G130M/1291 within +/- 65 km/s
- The wings of an interstellar Ly-α absorption line in the LMC or SMC, and of the emission profile of an accreting star fall outside the gain-sag holes and can be observed at LP4.

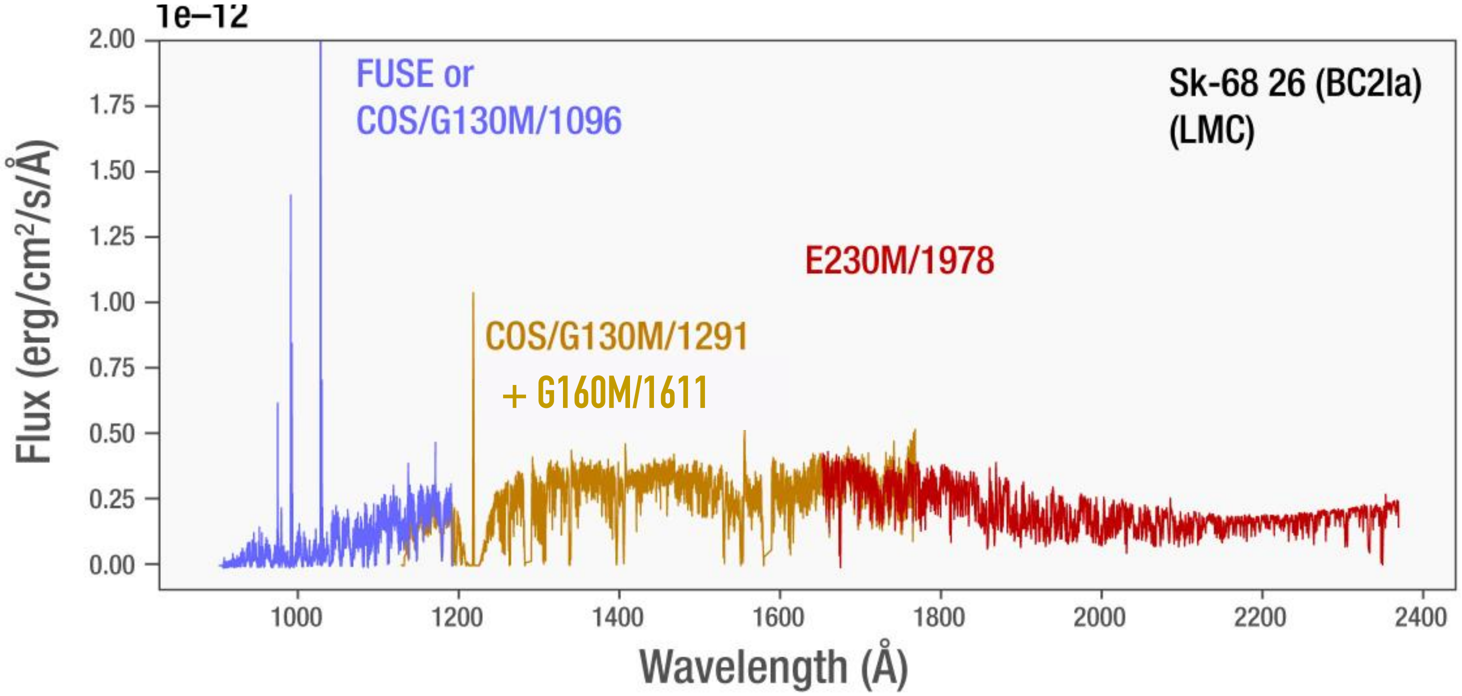




Observing Strategy

- FUV coverage with STIS/E140M or COS G130M/1291 + G160M/1611 (LP4) for all stars
- COS/G130M/1096 for brightest OB stars without FUSE coverage
- E230M/1978 for supergiants SpT O8-B9; dwarfs SpT O9-B1.5; giants SpT O9-B4
- E230M/2707 for supergiants B5-B9
- STIS/G230L, G430L, G750L for all T Tauri stars





Target Selection: Overview

- Strategy: Take a comprehensive, objective, and reproducible approach by compiling catalogs from the literature
    - Compile and merge exhaustive list of catalogs (provided by CIT experts and SAC) with all required information (SpT, LC, extinction for massive stars; mass, accretion rate for T Tauri stars)
    - Automatically query MAST and ESO archives on merged catalogs, measure fluxes and S/N
    - Automatically compute exposure times for ULLYSES settings
    - Sort targets by total exposure time cost
    - Prioritize targets based on exposure time and archival data availability, sampling of physical parameters, most compelling proposals from the community
- Tables of potential targets (several thousands in the MCs, several dozens of T Tauri stars) and their parameters will be published to maximize the scientific return of overall ULLYSES effort

Community Input

11 responses (7 for massive stars; 4 for T Tauri stars)

Author	Target(s)	Summary
LOW MASS STARS		
Costanza Argiroffi	BP Tau	Monitor BP Tau to understand accretion
C. Schneider	8 targets in Tau-Aur, TW Hya, Rho Oph, Lupus	Simultaneous UV and X-Ray observations of CTTS
Simon Joyce	PDS70	Determine if UV flux is due to magnetic activitiy or accretion in this star with disk and protoplanets
Thanawuth Thanathibodee	45 targets in the reports' SF region	Down-selection of targets from same catalogs identified by SAC and CIT, with ground-based monitoring during HST observations, immediately before/after
MASSIVE STARS		
Joachim Bestenlehner	N11 (LMC), NGC346 (SMC)	Unbiased sample of O stars with little or no UV archival coverage (but VLT)
Jan Cami	OB in LMC/SMC	ISM Gas and dust – UV spectra to complement optical-NIR (DIBS)
Lydia Cidale	20 Be stars LMC/SMC	Sample of 20 Be emission line stars (B0-B9) in the Magellanic Clouds to understand their winds/mass loss rates
Jiri Krticka	B[e] stars in LMC/SMC	7 B[e] stars in the LMC
Jorick Vink (IAU G2)	LMC/SMC	General recommendation on SpT sampling, Oe/Be, B[e], binarity
Dan Welty	LMC/SMC	Spectra at High resolution
Aida Wofford	LMC/SMC	Include close binaries for population synthesis

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

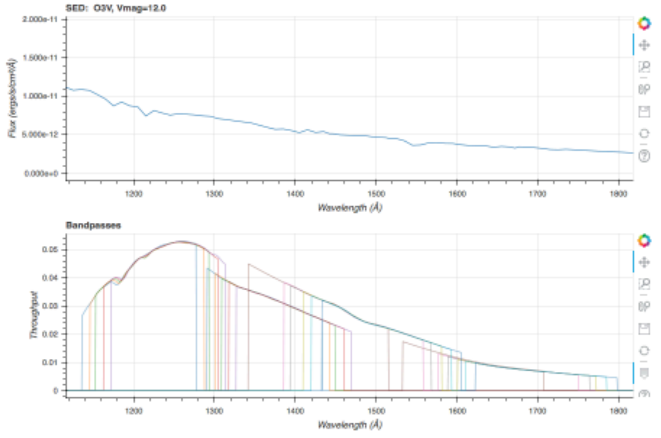
Lines (Final details TBD)

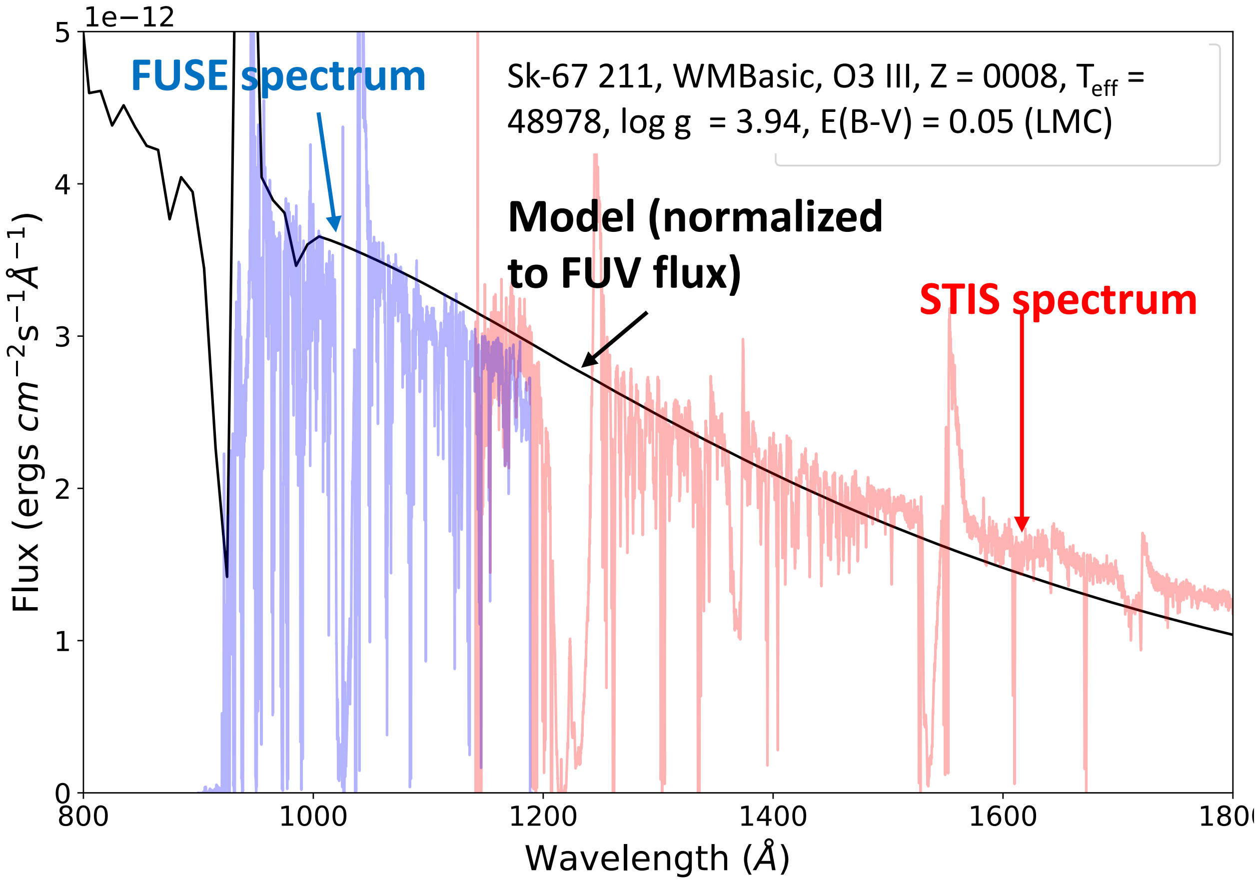
	Exptime (s)	Accretion & Transition																					
		N V 1239	N V 1243	N V 1240	He II 1640	C IV 1548	C IV 1549	C IV 1551	Si IV 1394	Si IV 1403	Si IV 1397	Mg II 1240	Mg II 1240	Mg II 2796	Fe II 1608	Fe II 2250	Fe II 2261	C II 1334	g160m break 1592	UV Ctm 1500	UV Ctm 1700	UV Ctm 2000	UV Ctm 2500
cos,g130m,c1291	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)





Target Selection: Low Metallicity Galaxies

- Targets were preferentially selected in Sextans A (8% solar metallicity)
- SagDig, Sextans B were excluded due to high extinction and lack of spectral-type catalogs
- NGC 3109 (10% solar metallicity in O, 20% solar in Fe) was selected as alternative
- All targets will be observed with COS/G140L/800 (6-25 orbits)

Low Metallicity Galaxy Targets

Galaxy	Star	RA(J2000)	DEC(J2000)	SpT	V	E(B-V)	Catalog
Sextans A	s2	10h10m58.59s	-04d43m28.9s	O3-5Vz	20.8	0.22	2019MNRAS.484..422G
Sextans A	s4	10h10m57.89s	-04d43m10.2s	O6z	20.9	0.05	2019MNRAS.484..422G
Sextans A	s8	10h11m05.69s	-04d42m13.6s	B0 I	19.7	0.05	Garcia, priv. comm.
NGC3109	7	10h02m54.69s	-26d08m59.64s	B0-1Ia	18.69	0.09	2007ApJ...659.1198E
NGC3109	20	10h03m03.22s	-26d09m21.41s	O8I	19.33	0.17	2007ApJ...659.1198E
NGC3109	34	10h03m14.24s	-26d09m16.96s	O8I(f)	19.61	0.1	2007ApJ...659.1198E

Target Selection: T Tauri stars for Time Monitoring

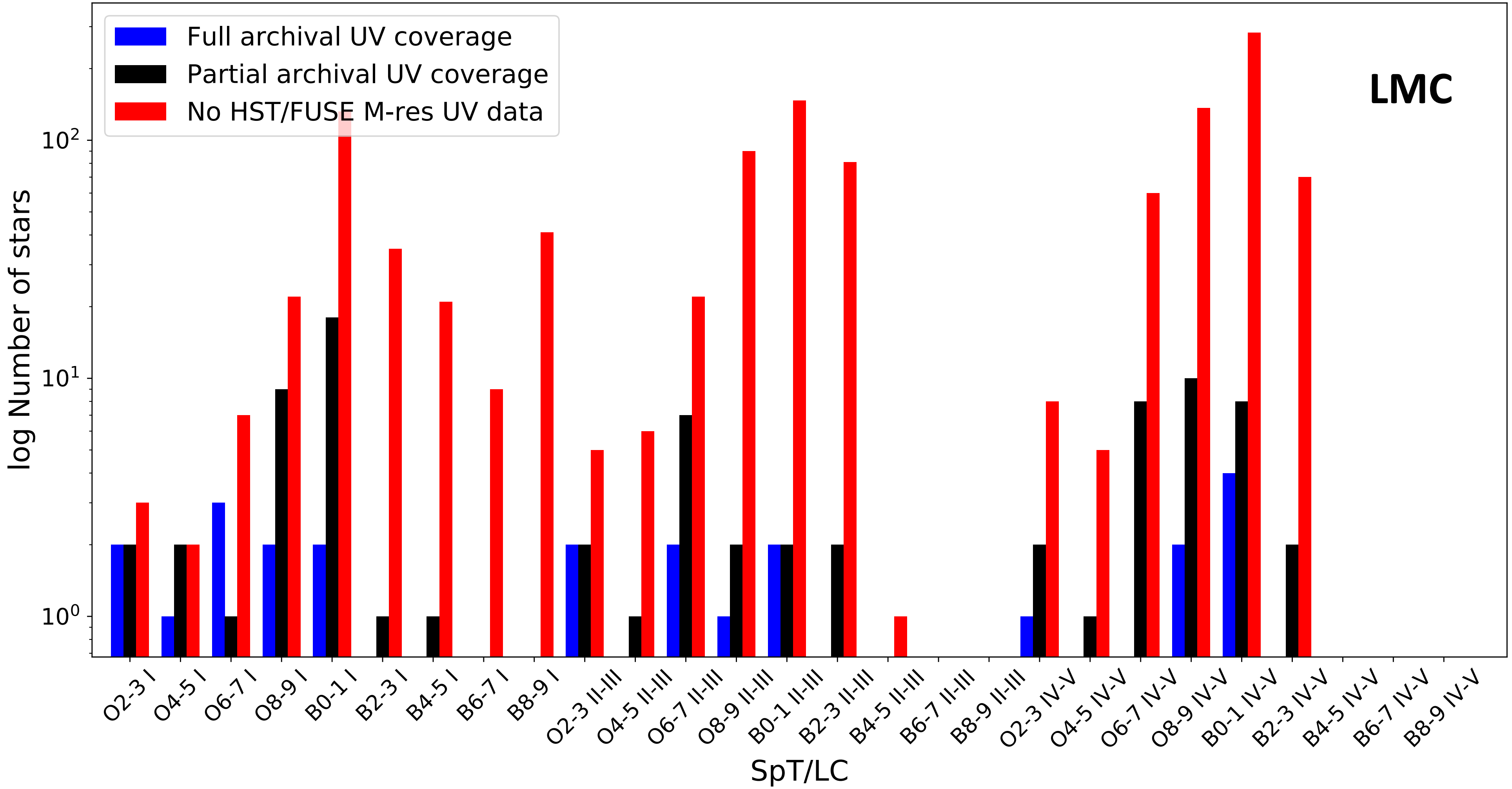
Selection criteria:

- Availability of archival HST UV spectra (COS, STIS) with detectable flux in C IV line
- Previous magnetic mapping using Zeeman Doppler Imaging (e.g., Johns-Krull+2007, Donati+)
- Sampling of accretion rate, X-ray luminosity, disk inclination
- Availability of ancillary data (ALMA, optical spectroscopy)

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	0.7	2.0	2.9E-08	7.6	0.51
GM Aur	04h55m10.98s	+30d21m59.1s	0.7	1.8	9.6E-09	12	0.31
TW Hya	11h01m51.95s	-34d42m17.7s	0.7	1.0	2.0E-09	2.2	0
RU Lup	15h56m42.31s	-37d49m15.47s	0.7	1.7	5.0E-08	3.7	0.07

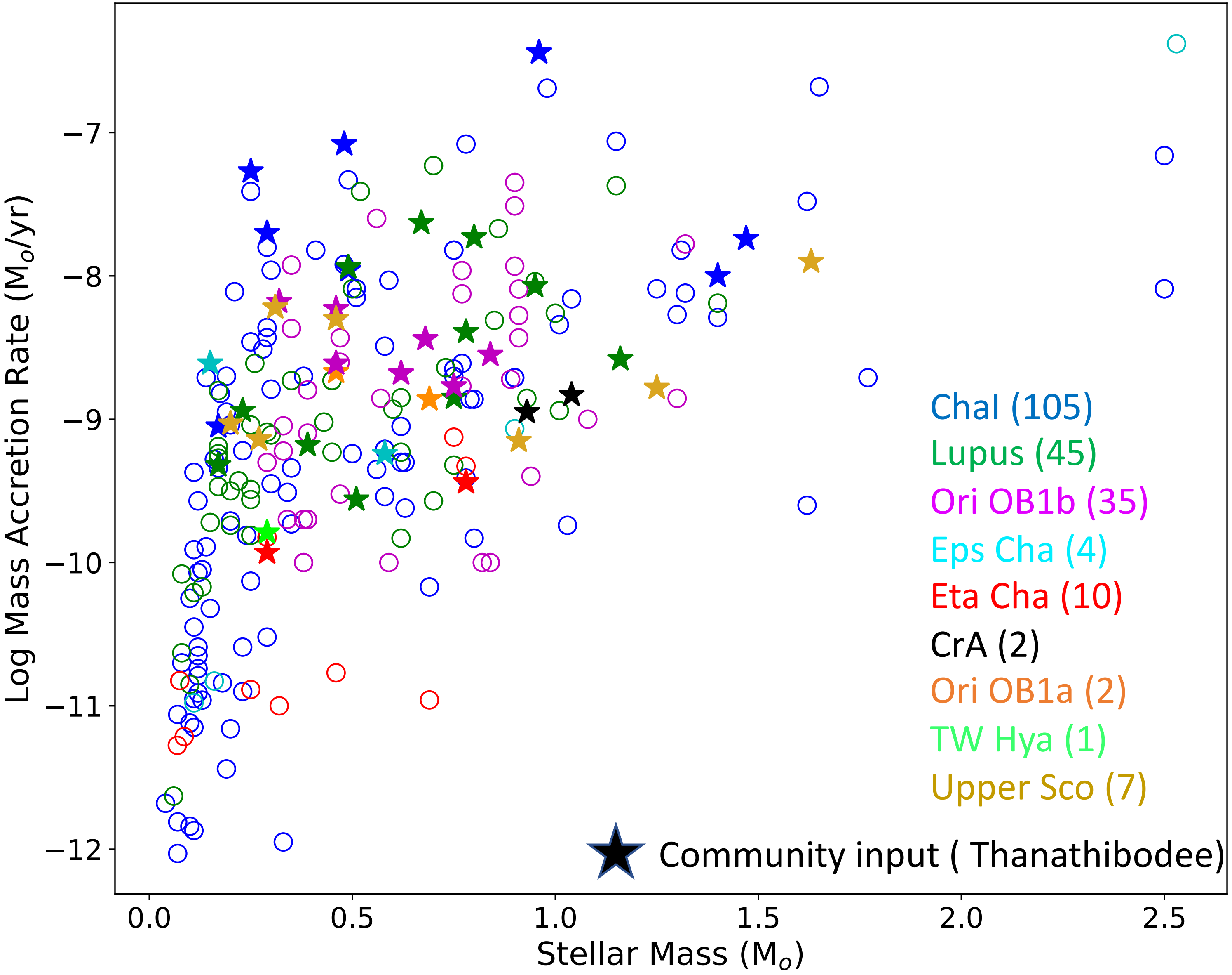
Target Selection: LMC and SMC massive stars

Merged catalogs, list of archival data, fluxes, S/N, and exposure times for ULLYSES are computed



Target Selection – T Tauri stars

- Catalogs of objects and their properties (mass, accretion rate) are more scattered in the literature
    - o A sparse sample of WTTS will be included for reference
- We have scripts querying and merging information from 14 catalogs
- List of archival MAST, ESO, Gemini data (and data info) available for each objects
- ULLYSES exposure times are computed from scaled templates (x0.25 for S/N, x4 for BOP)



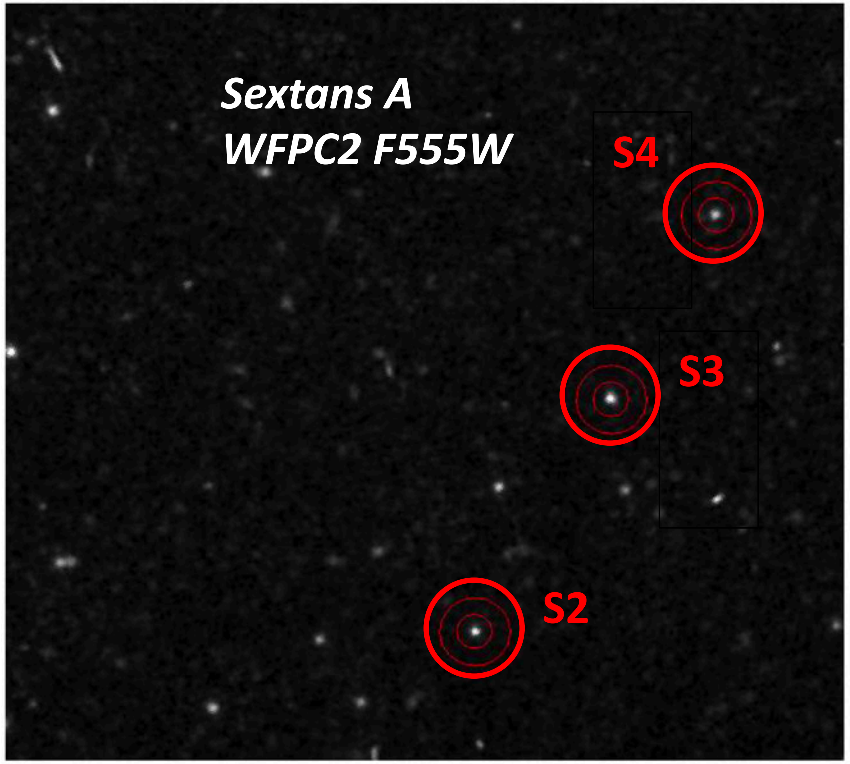
Technical Implementation Team

The ULLYSES Technical Implementation Team is laying the groundwork for rapid implementation of phase 2 proposals once targets and exposures are finalized

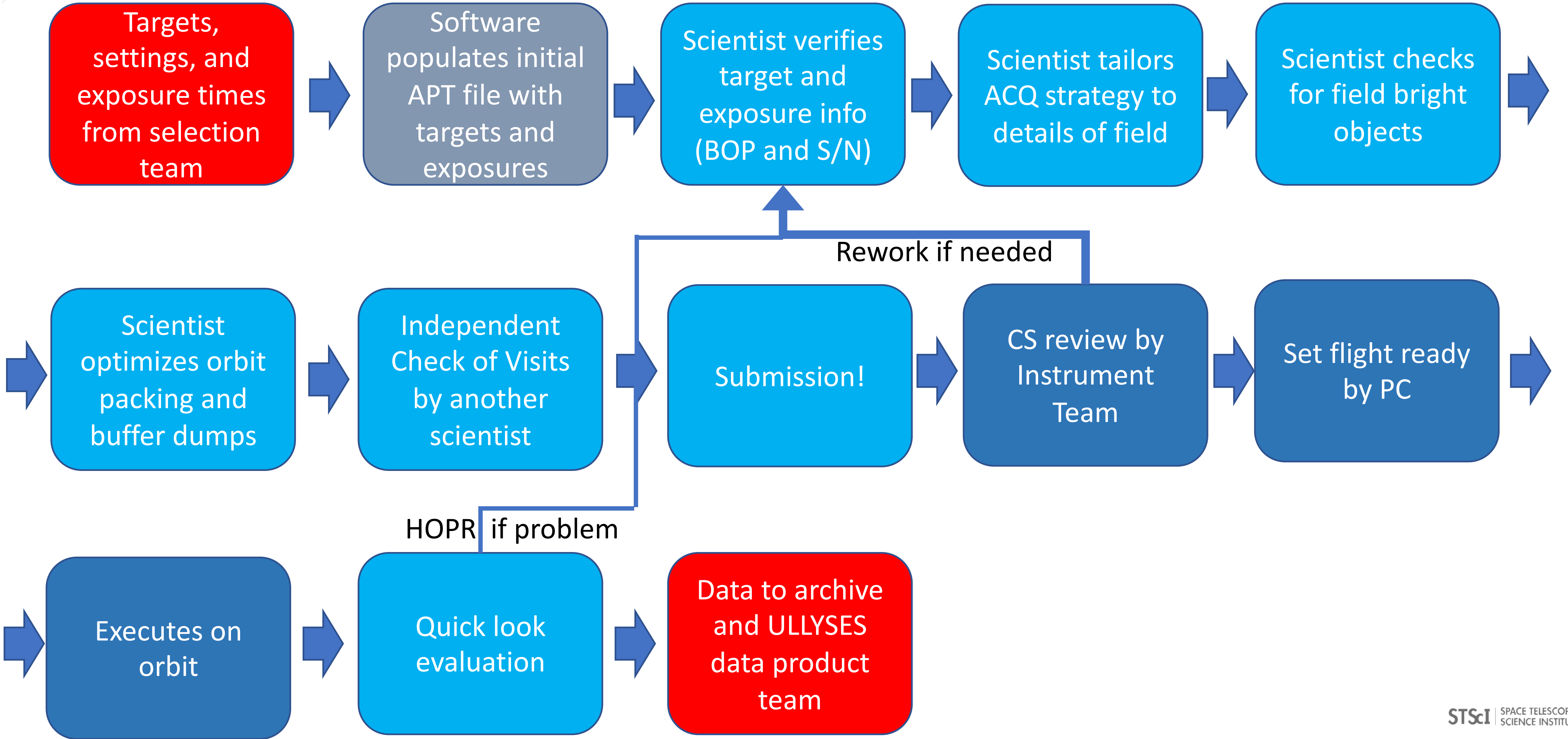
- Technical implementation team has extensive experience with COS and STIS both as PIs, and as Contact Scientists
  - Science expertise in both hot and cool stars
  - Expertise in programming utility tools and scripts to assist with APT and ETC calculations
- Scientists directly implementing phase 2 proposals will include:
  - Dan Welty, Tony Sohn, Cristina Oliveira, Bethan James, Tala Monroe, Joleen Carlberg, William Fischer, Alex Fullerton, Ale Aloisi, and Charles Proffitt
- Supporting scripting and programming also provided by
  - Sean Lockwood, Rachel Plesha, Jo Taylor, Elaine Mae Frazer

Technical Implementation Update: Massive Stars in Cycle 27

- Massive Stars in LMC/SMC, Cycle 27
  - ~ 200 LMC/SMC orbits to be submitted for Cycle 27
  - ~ 50 targets and 75 visits
  - Each visit to be implemented with 4 -5 hours of work
  - Expect to submit bulk of targets within ~ 8 weeks of final selection
- Pre-imaging FUV observations for ultra-low Z targets will also be implemented over this same period
- Remaining LMC/SMC targets will be implemented for Cycle 28 & 29 using similar procedures

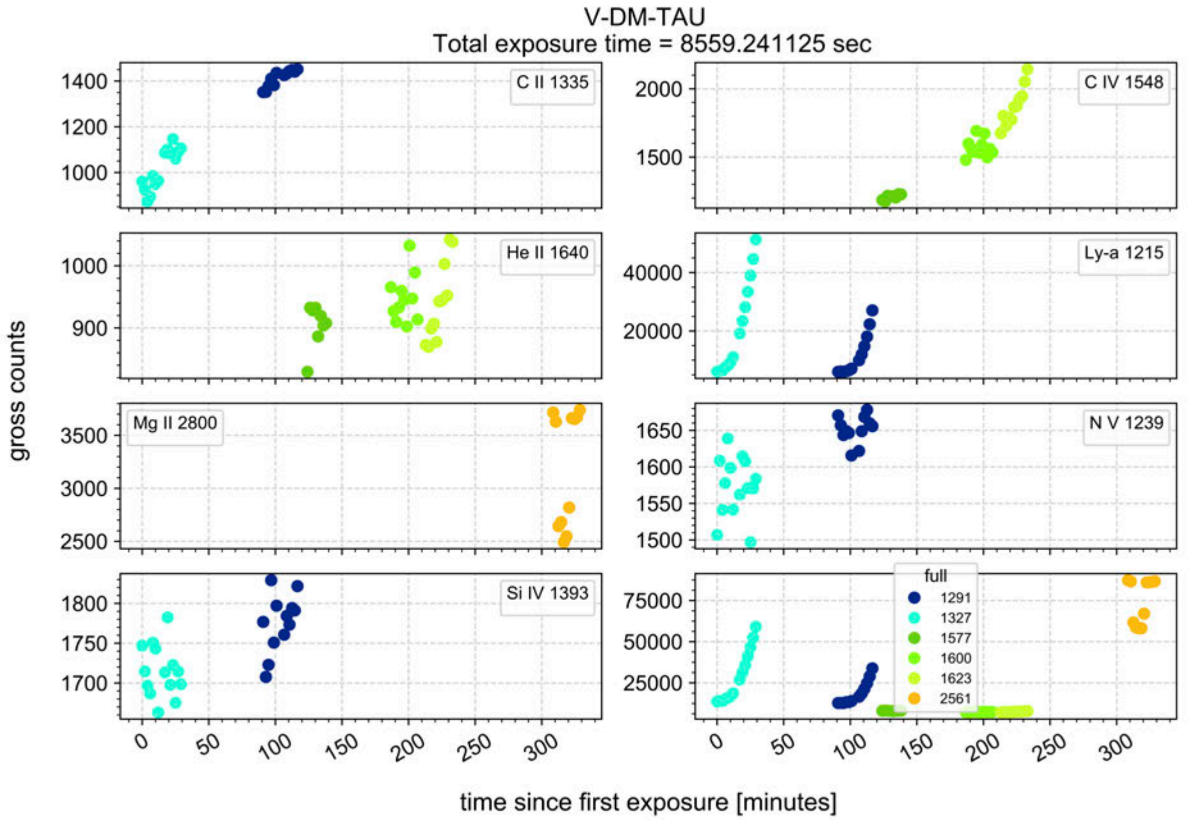


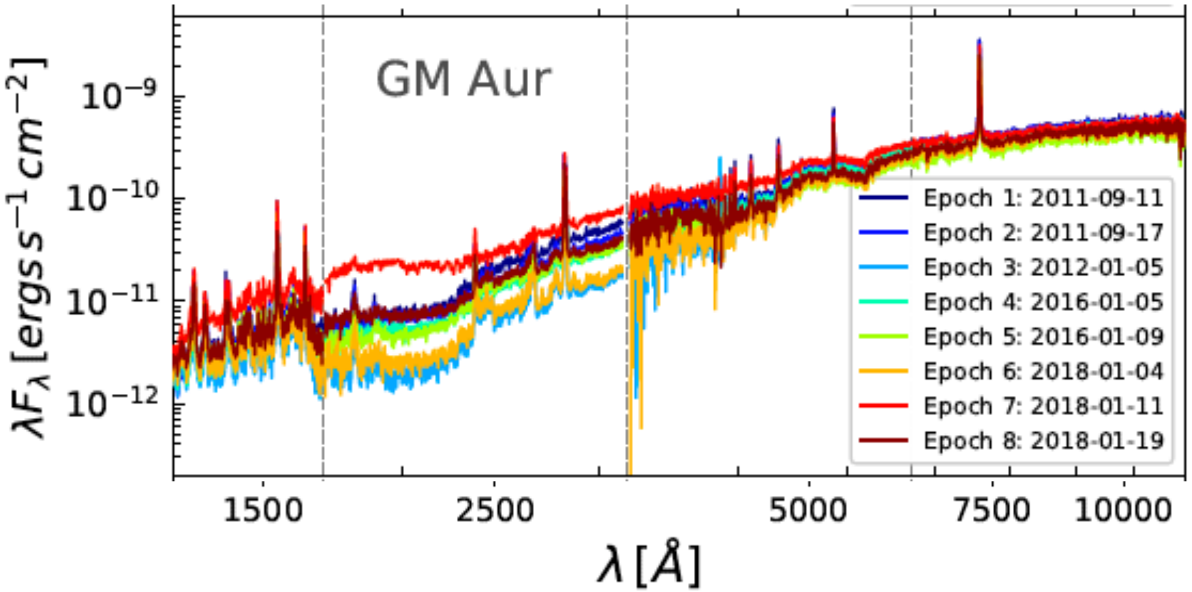
Basic work flow for individual APT files



BOP and UV Variability of CTTS

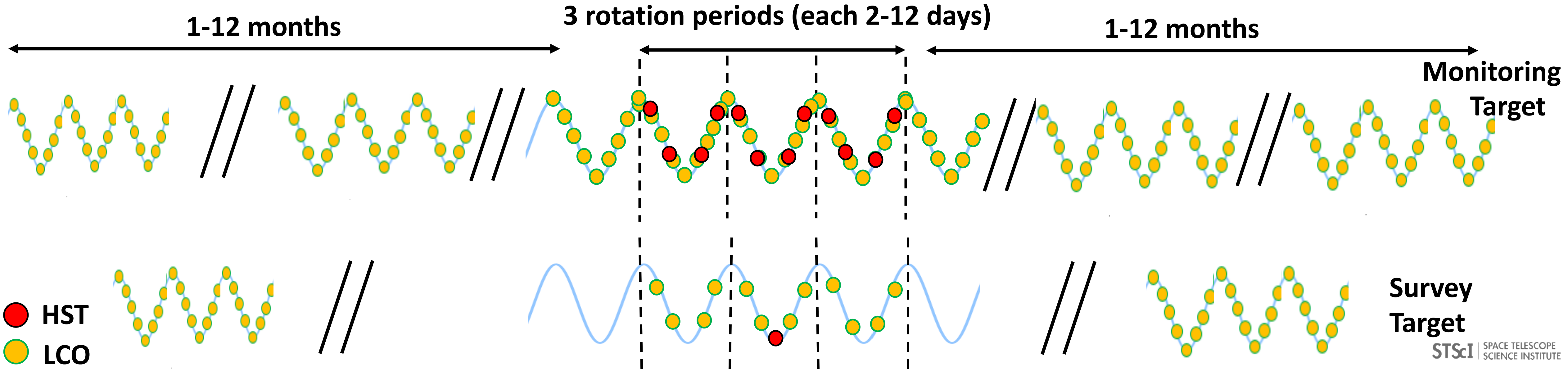
- T Tauri stars are variable over a wide variety of time scales
  - FU Ori outbursts of 4 – 6 magnitudes over timescales of years
  - EX Lupi outbursts of 2 – 4 magnitudes over timescales of months
  - Short time scale variability can var up or down by ~ 4X from mean
  - Magnetic flares can occur over a few minutes or hours (WTTS)
- Analysis of known variability suggests that planned monitoring and screening procedures can deal with these issues





Low Mass Star Observations Starting in Cycle 28

- Observations of T Tauri stars will begin in Cycle 28 to allow coordination of ground-based and X-ray observations
- All visits for each individual Library Star will be grouped within ~ 1 day
- Observations of the 4 time-monitoring targets will consist of 4 single orbit visits per rotation period repeated over three rotational periods, with the same pattern done again 9 – 12 months later.
- Ground based monitoring will be undertaken during, before, and after each group of visits on various time scales



Data Products Components

- High level science products:
  - DR1 STIS/COS calibrated pipeline products
  - DR1 STIS/COS co-added & spliced spectrum (multiple settings)
  - UV spliced spectrum (FUSE, STIS, COS)
  - Spliced SED (includes ancillary data)
  - STIS improved 2-D spectra
  - Acquisition images

- Database:
  - Content:
    - DR1 High level science products
    - Ancillary data
    - DR1 Metadata on targets
    - DR1 Metadata on observations
  - Web interface and queries:
    - DR1 Operations from tables
    - Search form / box
    - Visual selection from interactive plots
    - API

Data Products Components

- Quick-look tools:
  - DR1 • Interactive plots of spectra
  - DR1 • Plot multiple exposures, settings, epochs, datasets (individual target)
  - DR1 • Interactive SNR calculations
- Jupyter notebooks:
  - Specific user cases
  - Data handling and manipulation
  - Time series visualization and analysis

✓ Website :

- ✓ Splash Page
- ✓ Ullyses Hub:
  - DR1 ✓ All about ULLYSES (info for scientists)
  - DR1 o Database interface
  - DR1 o Quick-look interface
  - o Documentation and access to Jupyter notebooks

✓ Branding (OPO):

- ✓ Tagline
- ✓ Logo

Milestones

- Early December 2019: LMC/SMC target release
- January 2020: T Tauri target release
- Spring 2020: First data taken in the LMC and SMC
- Summer 2020: First data release
- October 2020: First data on T Tauri stars (to allow the community to submit ground-based proposals for the semester starting in October 2020)
- Quarterly data releases 2020-2023

Thank you!

EXPANDING THE FRONTIERS OF SPACE ASTRONOMY

Backup slides

Archival data for low-metallicity galaxies

Galaxy	star	SpT	V	E(B-V)	settings
Sextans A	OB521	O9.5III-V	19.4	0.04	1105; 1291; 1309 (LP3)
Sextans A	OB523	O9.7I(f)	19.5	0.04	1105; 1291; 1309 (LP3)
Sextans A	OB321	O9.7I(f)	19.6	0.04	1105; 1291; 1309 (LP3)
Sextans A	OB622	B0I	19.6	0.17	1105
Sextans A	OB326	O7.5IIIf	20.68	0.06	1105; 1291; 1309 (LP3)
Sextans A	s3	O9V	20.8	0.07	1291, 1600
Leo-P		O	21.5	?	G130M, G160M
WLM	A11	O9.7 Ia	18.4	?	G130M, G160M
WLM	A15	O7 V((f))	20.36	?	G130M, G160M

S/N and BOP for T Tauri stars

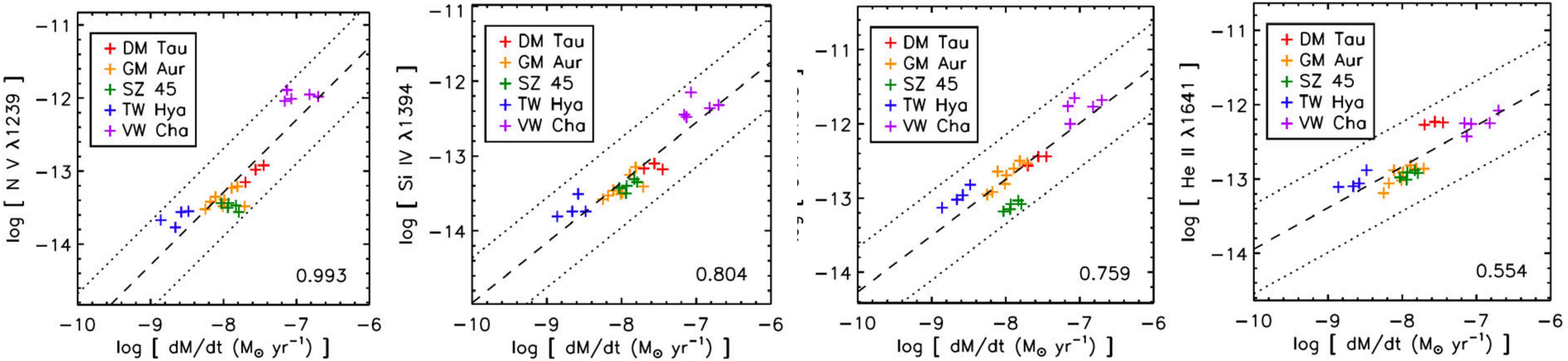
We have derived correlations between accretion rate and peak line flux at STIS low resolution from the data in Robinson & Espaillat (2019)

- Slope of correlation can be applied to spectra of medium-resolution

We have identified archival UV spectra with contemporaneous STIS optical spectra and corresponding published accretion rate (Ingleby+2013) to be used as templates

We will de-redden, scale, and re-redden the templates

- We can test the scaling algorithm against archival spectra (already identified)

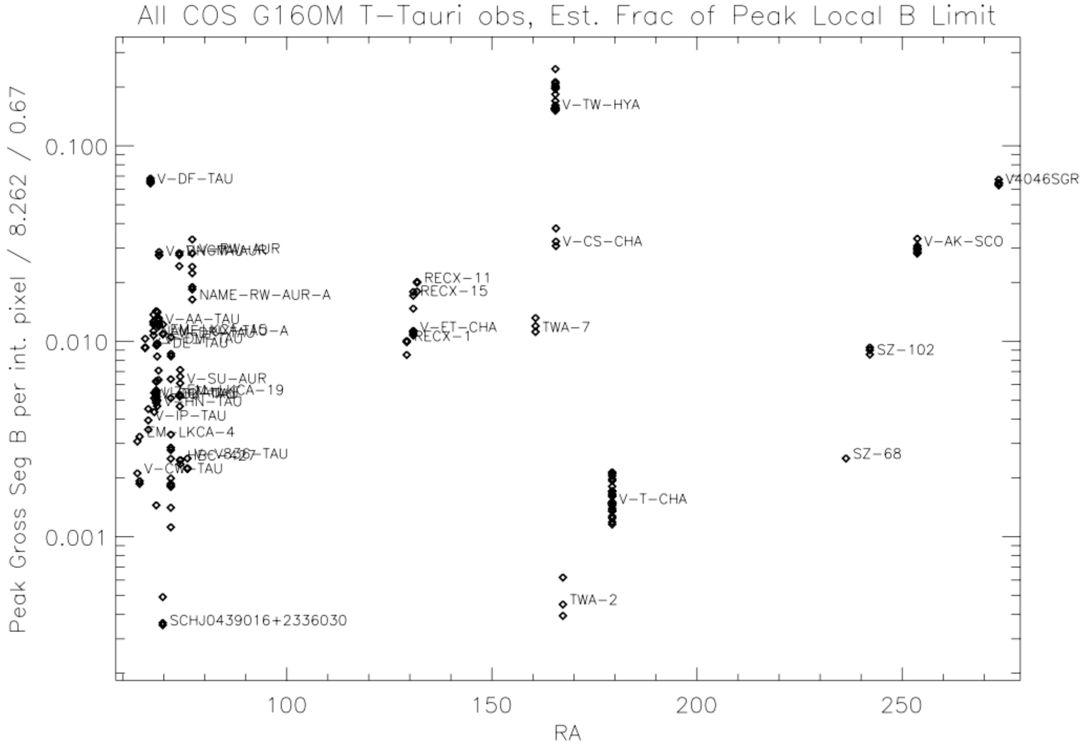


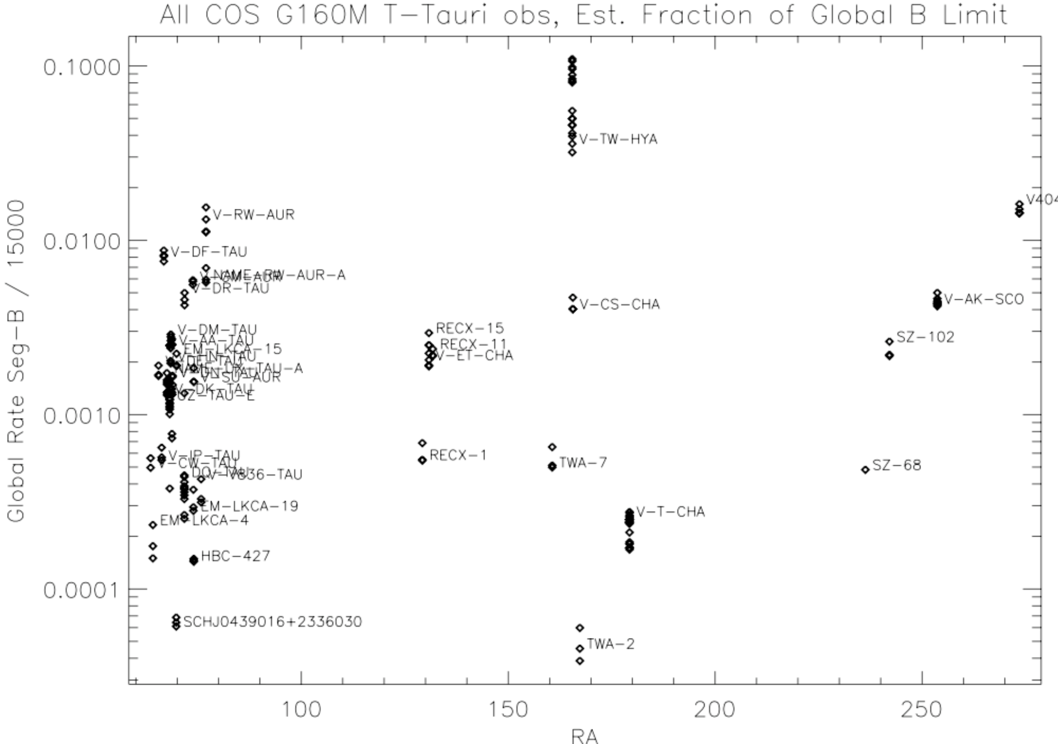
BOP Clearing for T Tauri stars

The upper envelopes of the correlations can be used for scaling the templates for BOP purposes, with additional multiplicative (x5-10) factor to account for variability

- We are creating light curve of all archival UV observations to determine max routine variability

Since EX Lup and FU Ori events ramp up on ~1 year timescale, we are planning to request ground-based monitoring 1-12 months prior to the HST observations for BOP clearing purposes, for objects within a factor 5-10 of the count rate limits.





UV Variability of T Tauri Stars

- T Tauri stars are variable over a wide variety of time scales
  - FU Ori Outbursts of 4 – 6 magnitudes over timescales of years
  - EX Lupi outbursts of 2 – 4 magnitudes over timescales of months
  - Short time scale variability by ~ 3X above and below baseline
  - Magnetic flares can occur over a few minutes or hours
- Solutions
  - Ground based observations 1 -12 months in advance will give warning of large outbursts
  - For observation planning, baseline spectra of T Tauri stars are estimated using scaling relations for line and continuum flux as a function of mass accretion rate as measured in HST observations of T Tauri stars. (E.g., Robinson and Espaillat 2019)
    - Required exposure times to reach S/N targets adopt 0.25 x estimated baseline, while BOP screening estimates using ~ 4x baseline
  - General trends in short timescale UV variability have been verified by producing light curves for selected features of in 116 pre-main-sequence stars observed with COS or STIS timetag observations (see following slide)
  - For M type stars, the probability of a dangerously bright flare will be estimated using a modified version of the scaling relations developed for M dwarf observations

• Coordinated Observations of Low Mass Ullyses targets

- Discussions are underway with the Los Campanas Observatory Global Telescope Network to obtain time for monitoring of the LCO targets
  - Obtain at least one observation 1 to 12 months before main observation to allow adjustment of observing plans in response to long term changes in accretion
  - For the four Monitoring Targets, we would like 8 – 12 photometric measurements per rotation period, with two to three similar measurements in the months preceding and following
  - For the 40 Library Targets, would like 4 measurements over the rotation period containing the ULLYSES observations with comparable data taken a few months before an after.
- Planned observation times for the Monitoring Targets will be planned and announced before the beginning of the cycle, to allow other coordinated observations to be scheduled
- To the extent possible, the scheduling of Library Targets will be announced several weeks in advance, to support both LCO and other coordinated observations