STScI | SPACE TELESCOPE SCIENCE INSTITUTE

EXPANDING THE FRONTIERS OF SPACE ASTRONOMY

The ULLYSES Director's Discretionary Program

Charting Young Stars' Ultraviolet Light with Hubble
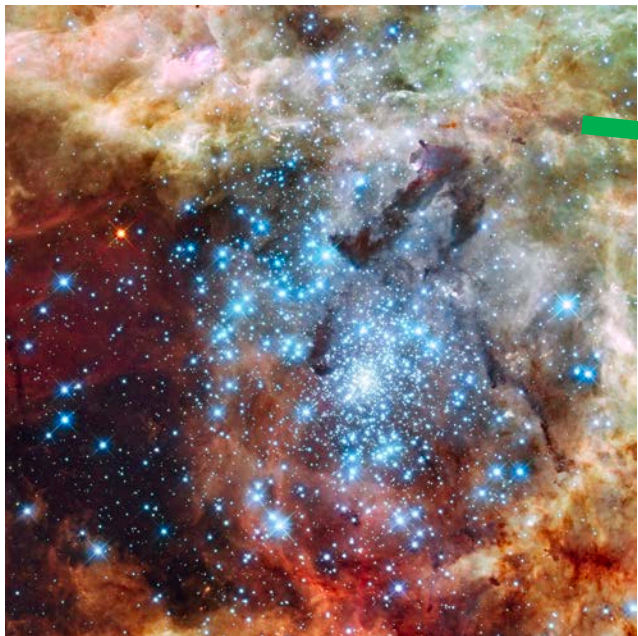
Julia Roman-Duval

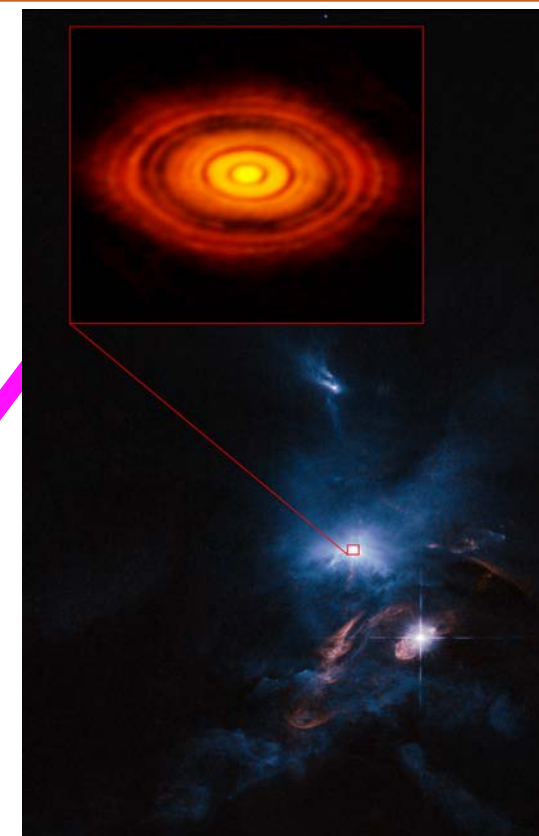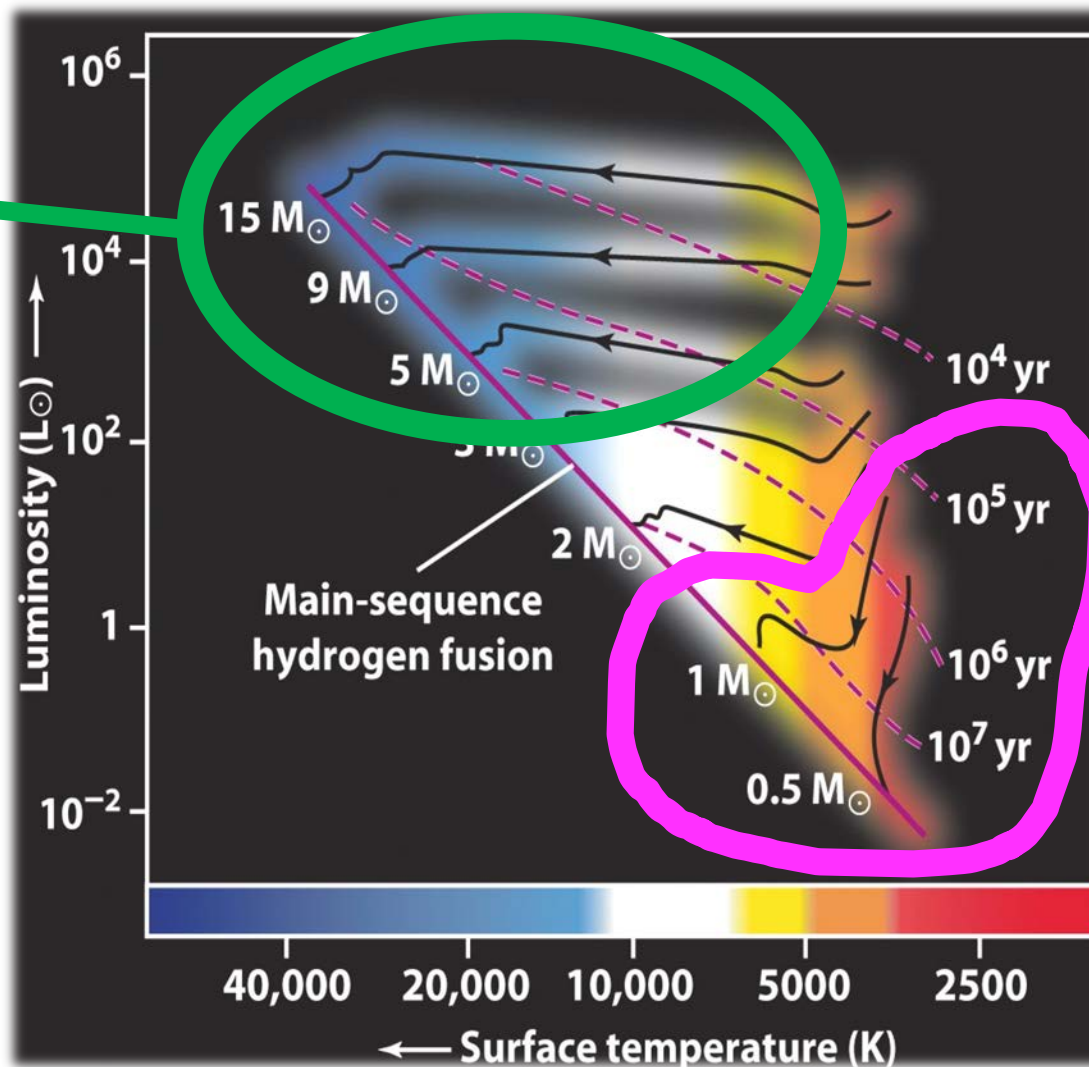Space Telescope Science Institute

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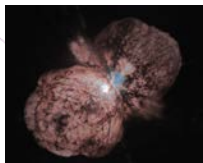
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~500 orbits to extend the spectroscopic library of O and B stars to low metallicity (0.08 - 0.5 Z_o)

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

✓ Stellar Astrophysics

o Stellar winds and abundances

o Ionizing radiation

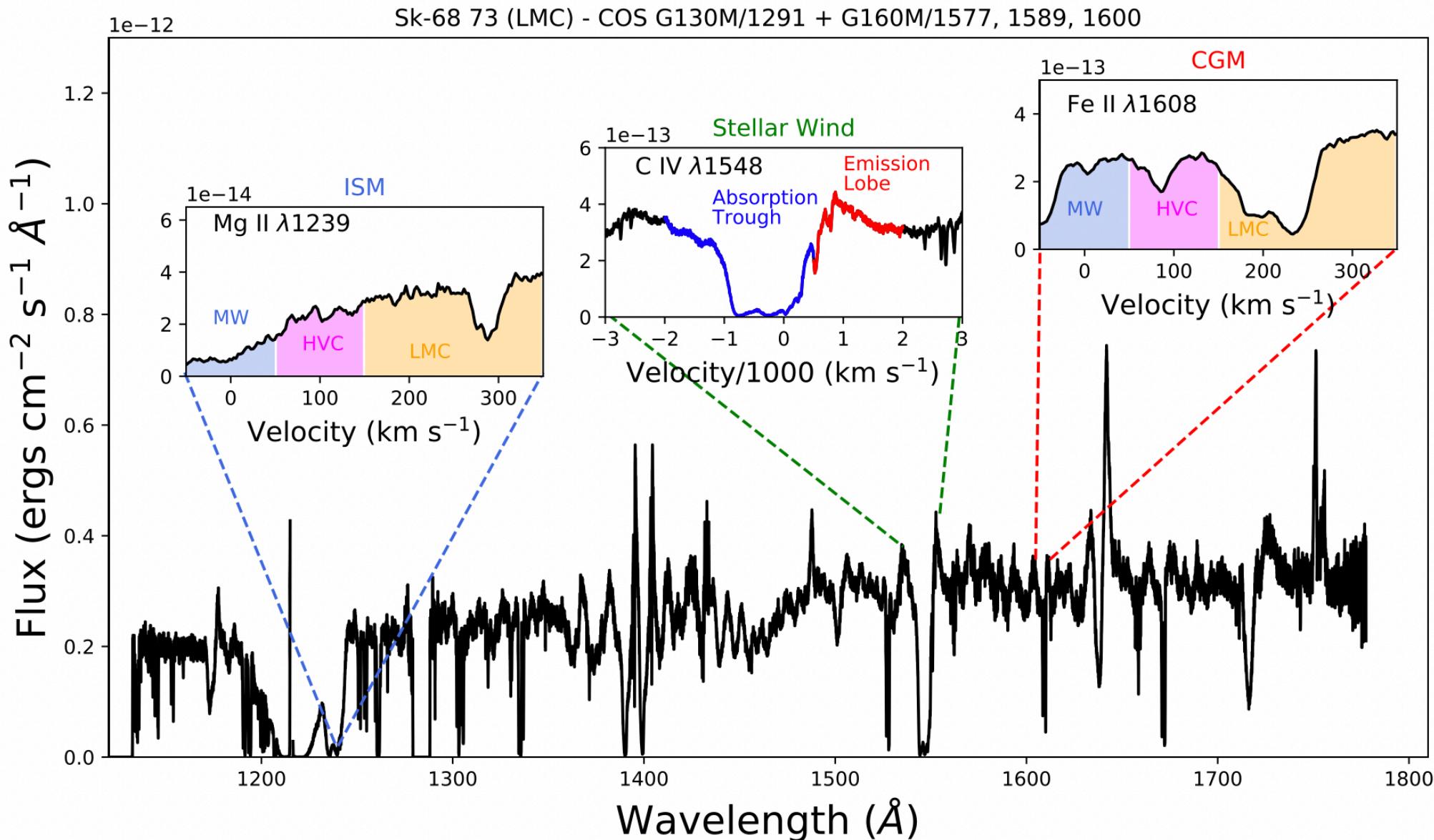o Spectral templates for population synthesis
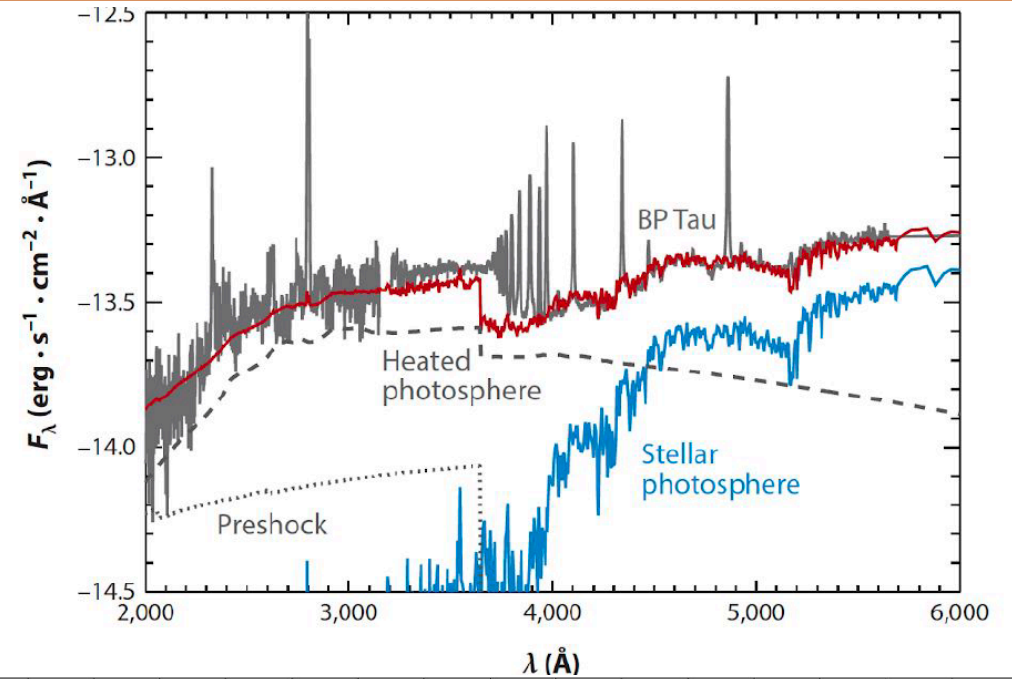
✓ ISM

o Chemical abundances

o Depletions on dust

✓ CGM

o Kinematics

o Spatial distribution

o Metallicity (with GASKAP)

Sk-68 73 (LMC) - COS G130M/1291 + G160M/1577, 1589, 1600
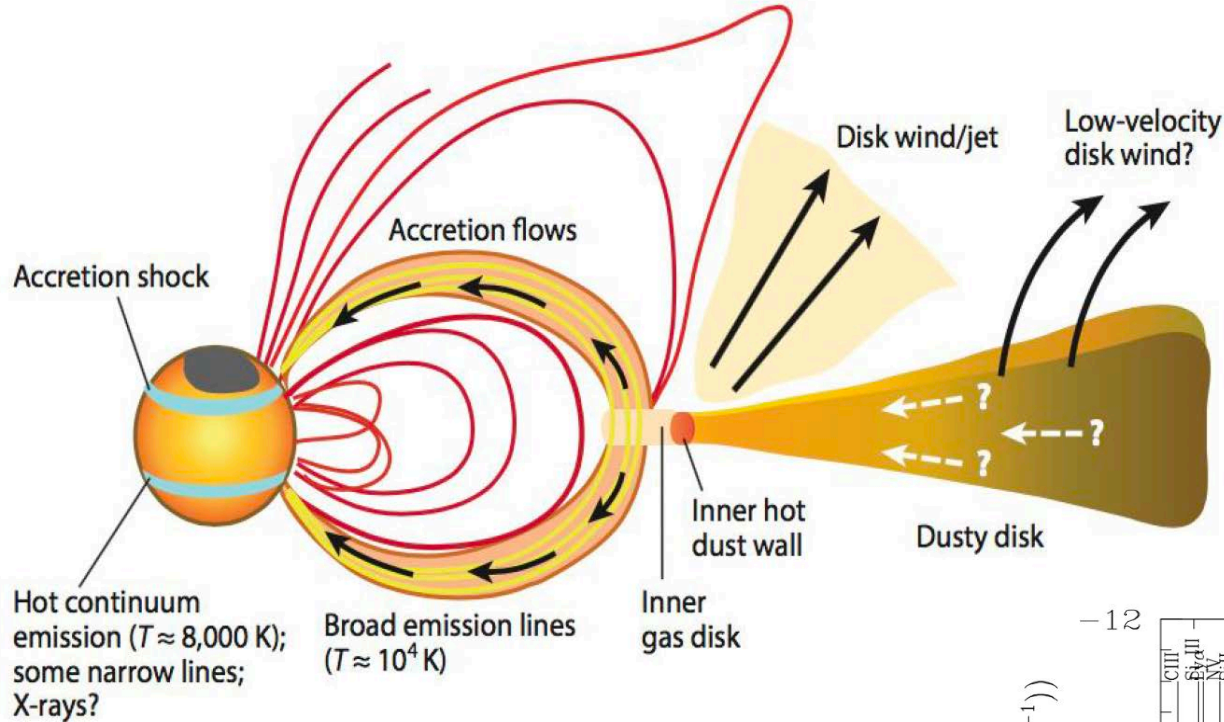
✓ **Accretion physics in T Tauri Stars**

o Emphasis on low mass (<0.5 M$_o$)

o Accretion shocks, flows, disks, and jets in UV-NIR

o Time monitoring component (100 orbits)
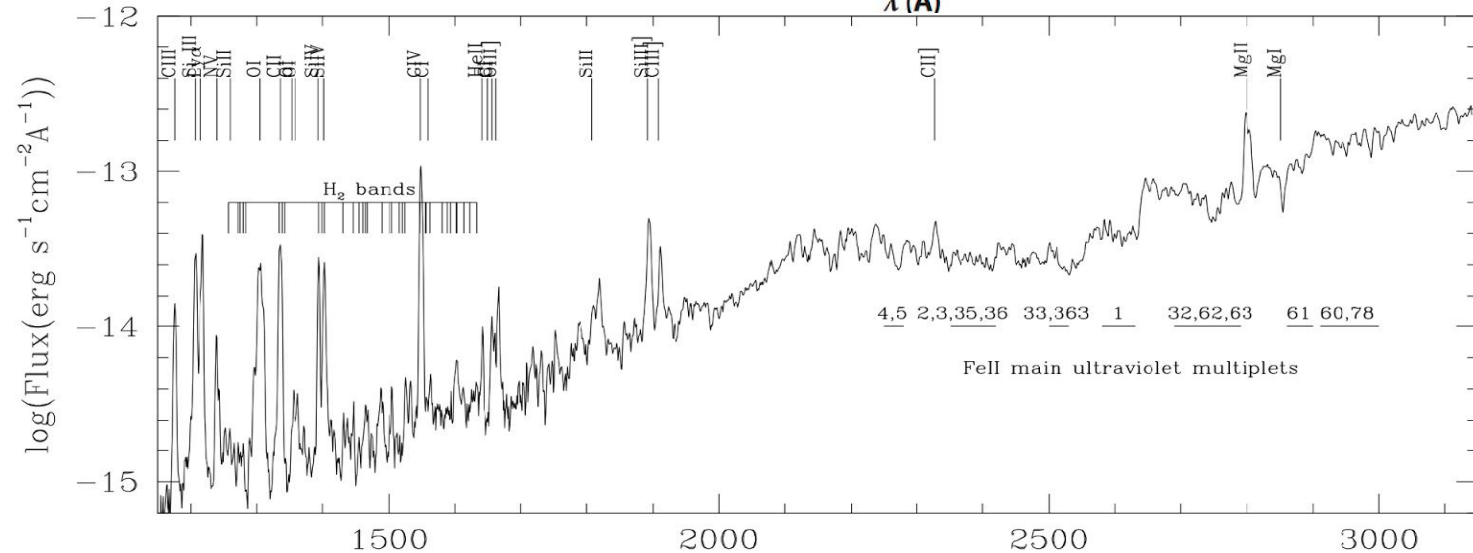
Target Selection

Sextans A (8% Solar Metallicity)

S8
(B0 I)

s4
(O6z)

s2
(O3-5 Vz)
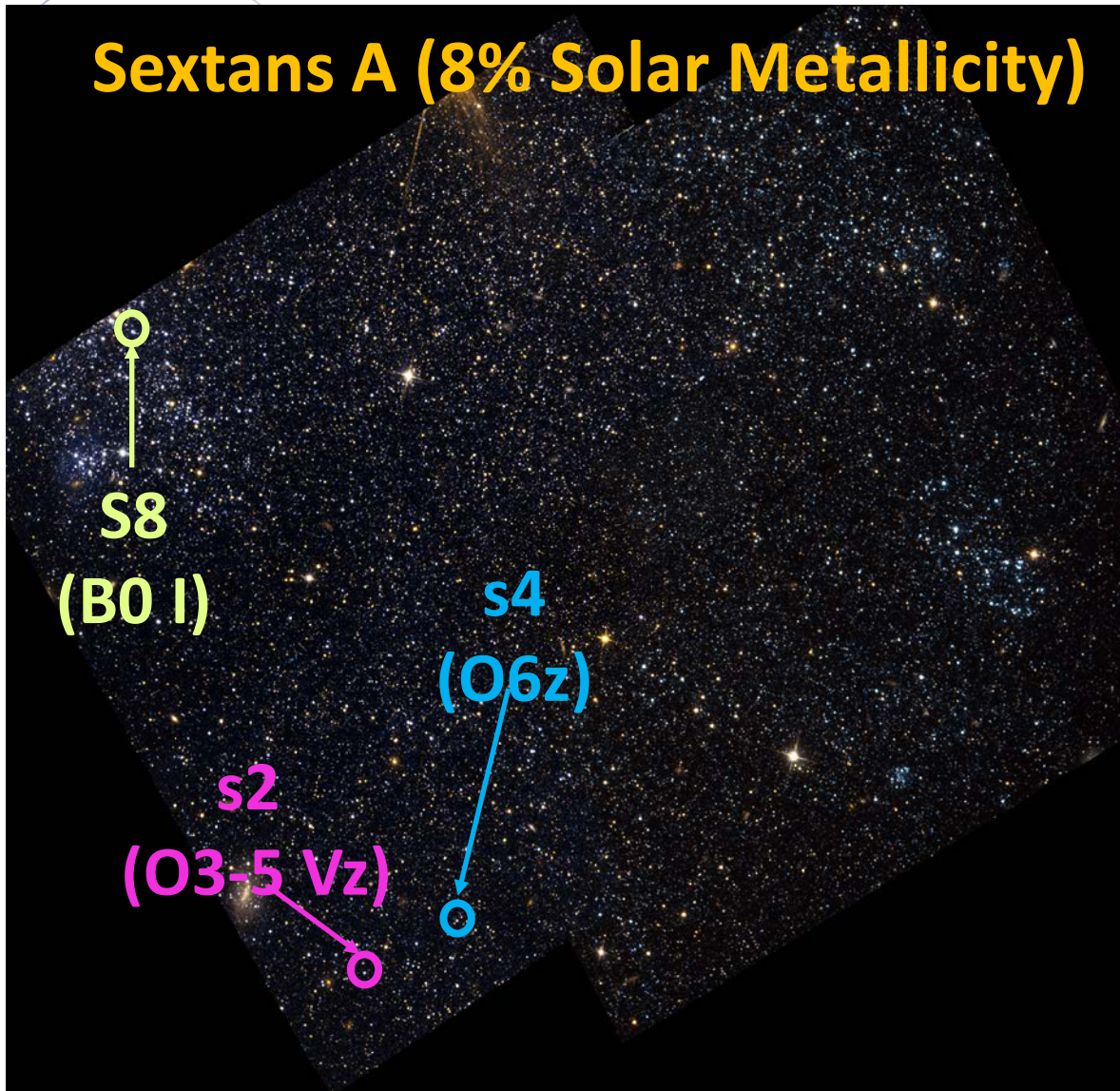
- ✓ Sextans A (8% solar metallicity)
  - ○ 3 massive stars (O3 Vz, O6z, B0 I)
- ✓ NGC 3109 (0.1 Z_o in O, 0.2 Z_o in Fe)
  - ○ 3 Supergiants O8 – B1

NGC3109 (15% Solar Metallicity)

E34
(O8 I(f))

E20
(O8 I)

E7
(B0-1 Ia)

- Nominally 250 orbits for the SMC (Z = 0.2 Z_o) and 200 orbits for the LMC (Z = 0.5 Z_o)

- About 70 targets in each galaxy complementing the HST COS + STIS and FUSE archives (920-2400 Å)

- Community input requested in fall 2019 led to prioritizing O stars in N11 (LMC) and NGC 346 (SMC)

NGC 346

N11

SMC
20% Solar Metallicity
70 targets O2-B9

LMC
50% Solar Metallicity
70 targets O2-B9
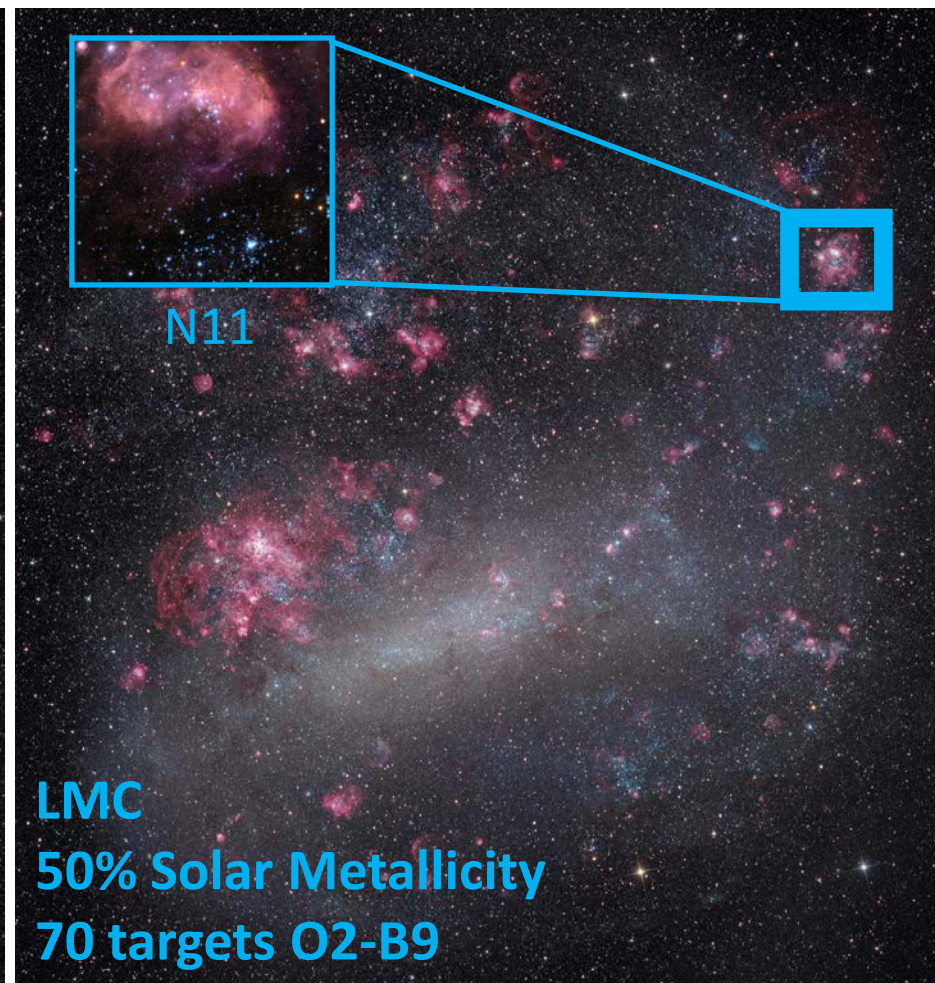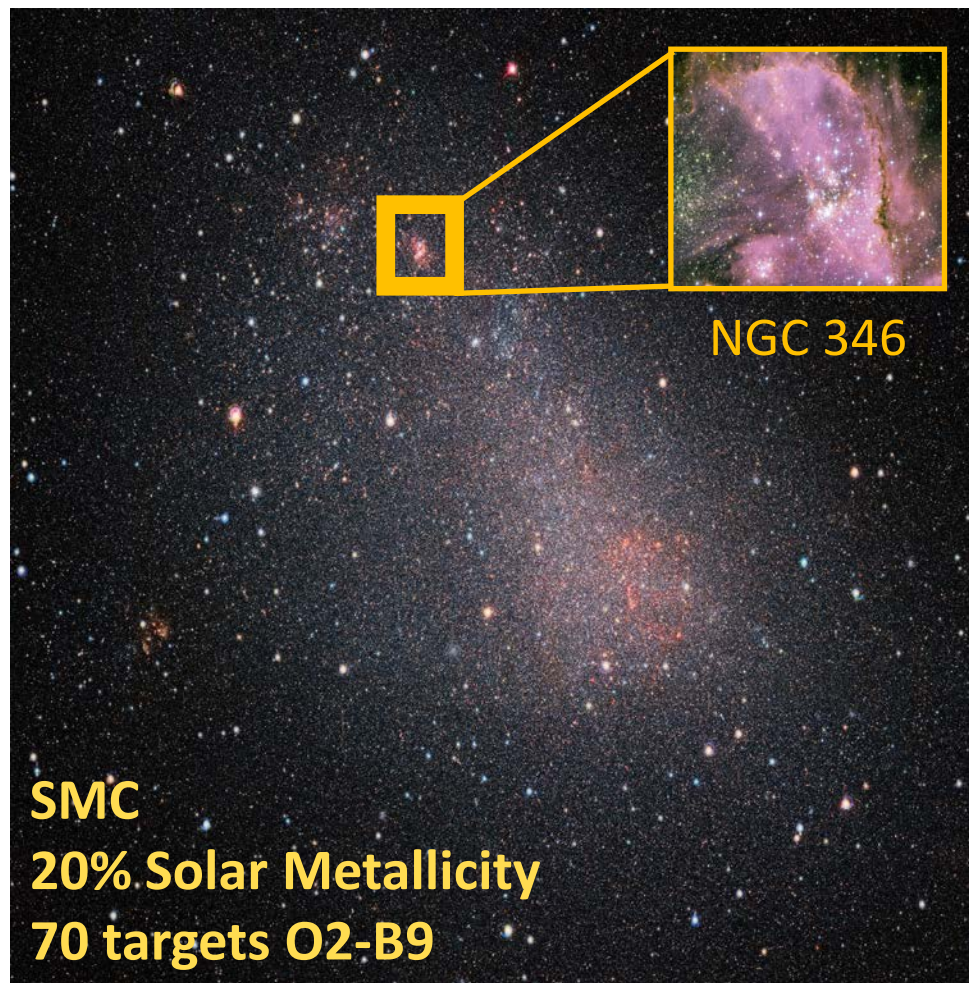
Target Selection - LMC and SMC OB Star Sample

- LMC/SMC massive star samples are being finalized and will be released in early 2020

- Pool of targets of a few thousand objects collected from literature catalogs

- 4 targets per bin of spectral type and luminosity class (O2-9 I-V, B0-9 I, B0-1.5 II-V)

- Targets with archival UV coverage (HST, FUSE) are prioritized

- Archival IUE, HST/FOS, and VLT also preferred

- Catalogs of objects, their properties (mass, accretion rate), and associated archival data (MAST, Gemini, ESO) have been compiled

- Target selection is being finalized and will be released early 2020, in time for preparation of coordinated ground-based observations for fall 2020.

- Targets will sample mass and accretion rate in 9 star-forming regions in the Milky Way, with a focus on the lower mass end (<0.5 M_o)

- A sparse sample of WTTS will be included for reference

ChaI (105)
Lupus (45)
Ori OB1b (35)
Eps Cha (4)
Eta Cha (10)
CrA (2)
Ori OB1a (2)
TW Hya (1)
Upper Sco (7)

★ Community input

Log Mass Accretion Rate (M_o/yr)

Stellar Mass (M_o)
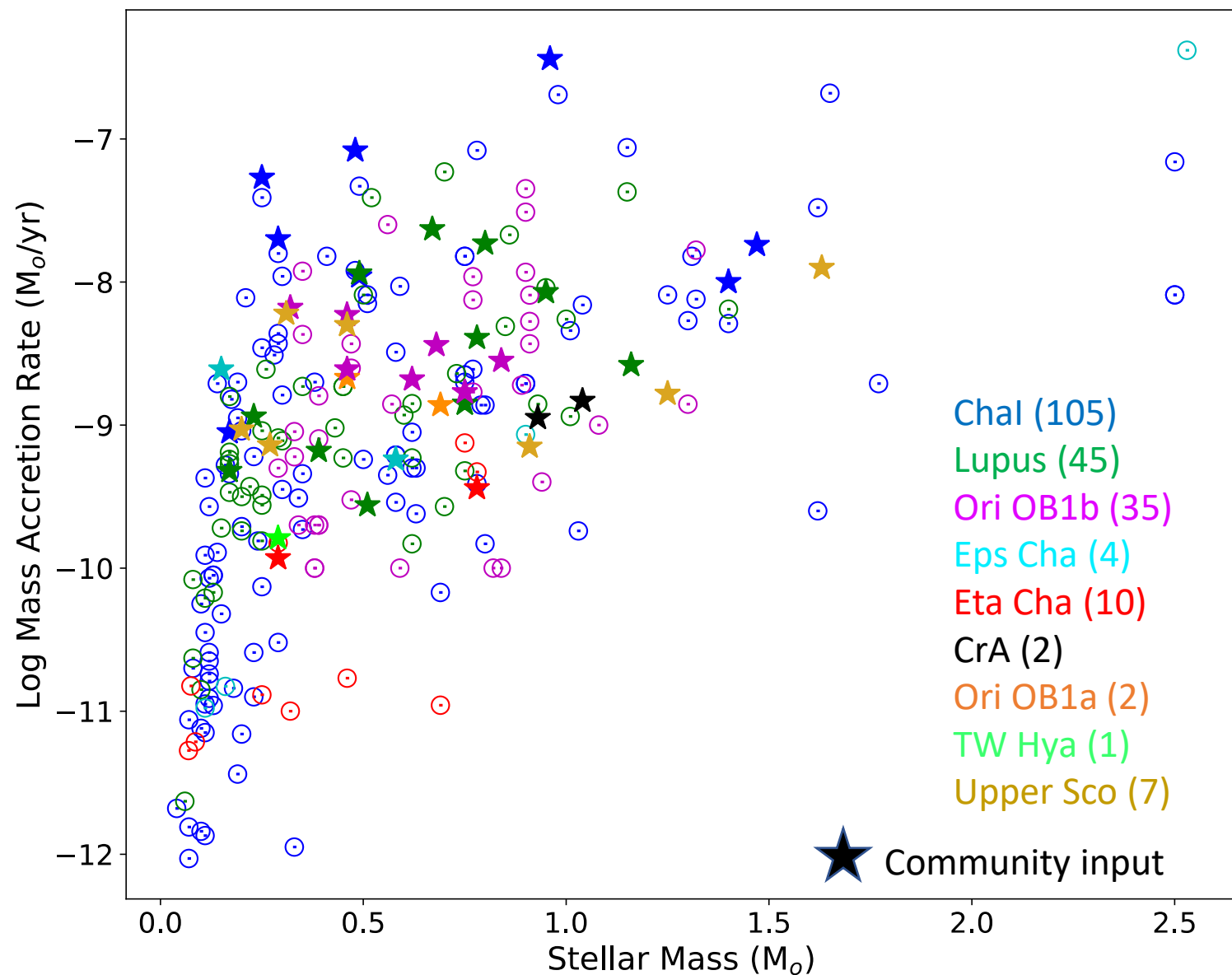
Target Selection – T Tauri Stars Monitored Over Time

- 4 T Tauri stars selected from time monitoring with HST

- Two epochs spaced out by 9 months, with 4 observations per rotation period for 3 periods during each epoch

- UV coverage 1400-3000 Å (COS G160M + G230L)

GM Aur

Epoch 1: 2011-09-11
Epoch 2: 2011-09-17
Epoch 3: 2012-01-05
Epoch 4: 2016-01-05
Epoch 5: 2016-01-09
Epoch 6: 2018-01-04
Epoch 7: 2018-01-11
Epoch 8: 2018-01-19
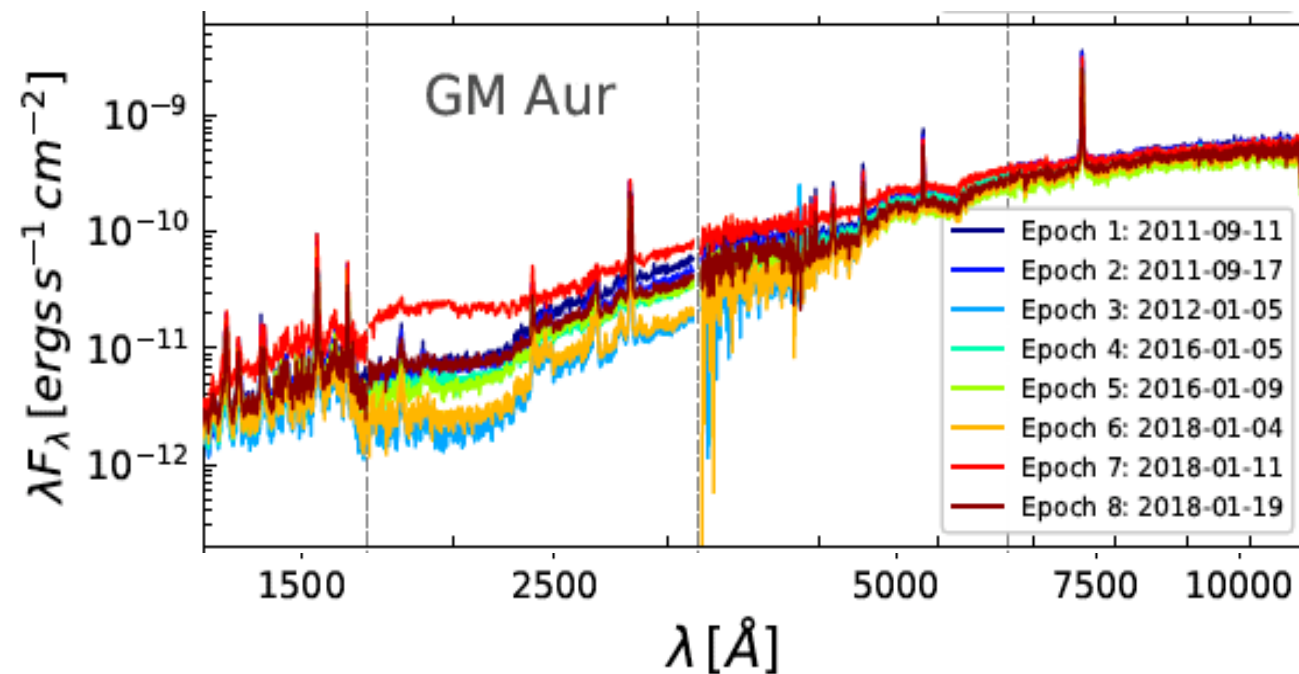
| Target	RA(J2000)	DEC(J2000)	Mass (M_sun)	Radius (R_sun)	Mass Accretion Rate (M_sun/yr)	Rotational Period (days)	A_V (mag)
BP Tau	04h19m15.86s	+29d06m27.2s	0.7	2.0	2.9E-08	7.6	0.51
GM Aur	04h55m10.98s	+30d21m59.1s	0.7	1.8	9.6E-09	12	0.31
TW Hya	11h01m51.95s	-34d42m17.7s	0.7	1.0	2.0E-09	2.2	0
RU Lup	15h56m42.31s	-37d49m15.47s	0.7	1.7	5.0E-08	3.7	0.07

Observing Strategy and Data Products

- **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

- Massive stars:
  - Coverage below 1150 Å with archival **FUSE** data, or COS/G130M/1096 if cost is reasonable
  - Supergiants (luminosity class I) of spectral type O8 and later will also be observed with the E230M/1978, extending coverage to 2400 Å

- T Tauri stars:
  - NUV coverage at low resolution with STIS/G230L
  - Optical-NIR with STIS G430L and G750L
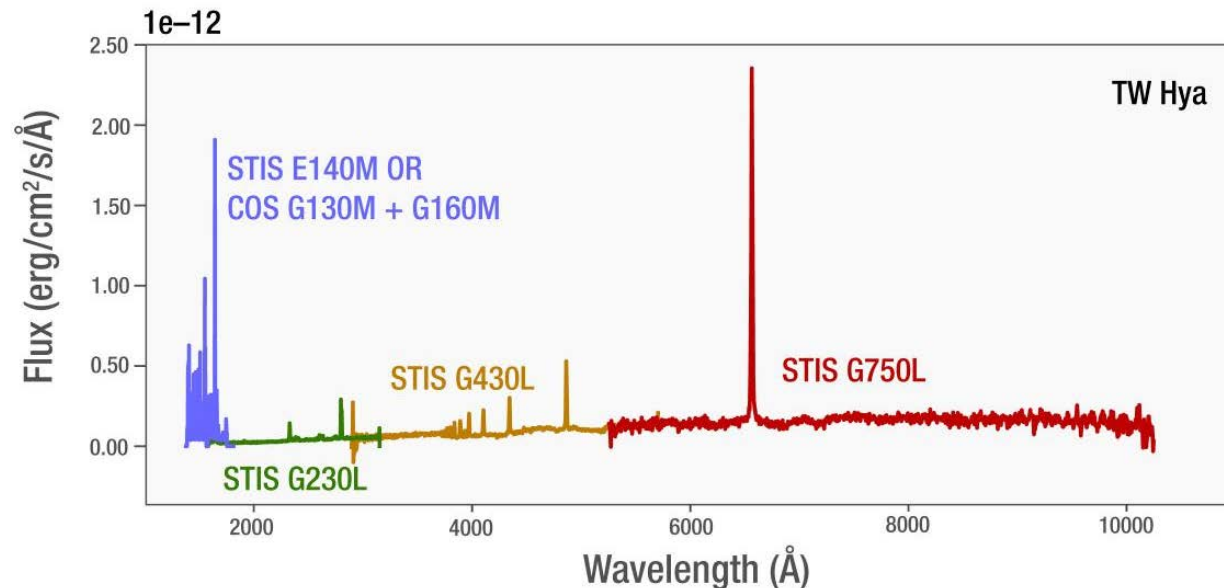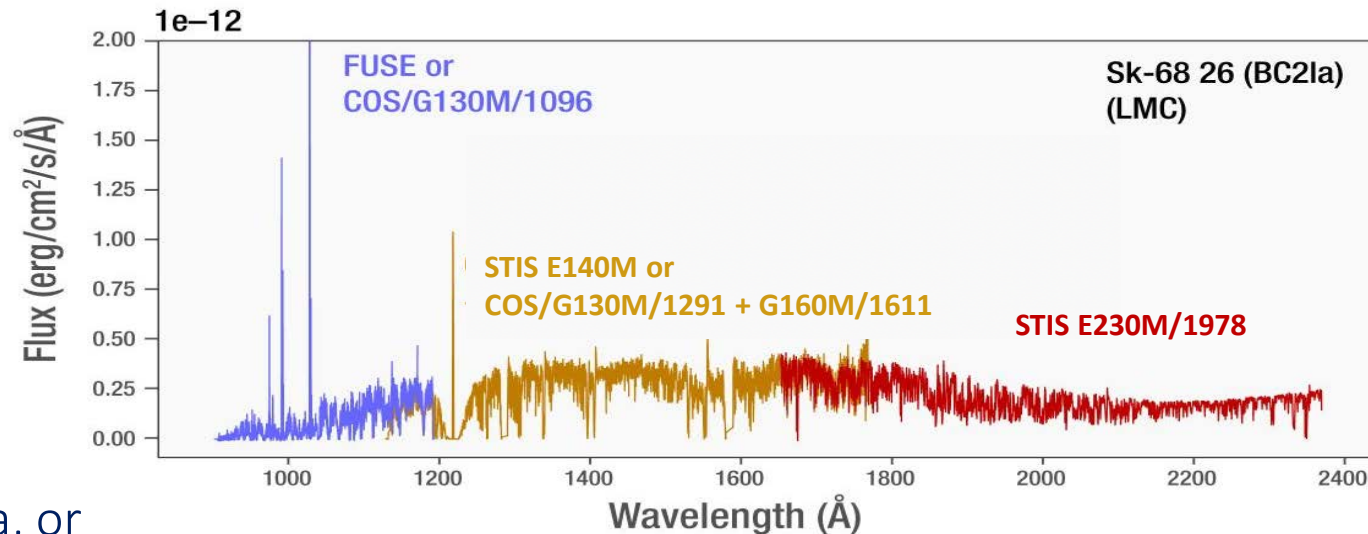
Data Products

- High-level science products: STIS/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 (operations 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 manipulation, e.g., binning, time series)

- Website (to be launched summer 2020)

Milestones

- Early 2020: Release of full target samples

- March 6, 2020: **HST proposal deadline**
  - *The community is encouraged to consider submitting Cycle 28 proposals (GO and AR) to supplement and complement ULLYSES. GO programs that are recommended by the Cycle 28 will have priority over the UV Legacy DD program.*

- May 1, 2020: JWST proposal deadline

- Late spring 2020: First light

- Summer 2020: Launch of website and first data release (DR1)

- Quarterly data releases beyond fall 2020

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)
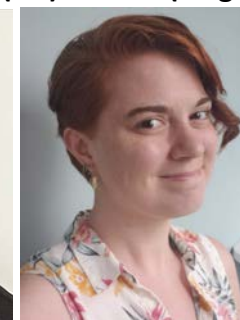
Bethan James (Observing)

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)

David Sahnow (Observing)

Richard Shaw (DP)

Linda Smith (Targets)

Tony Sohn (Observing)

Jo Taylor (DP)

Leonardo Ubeda (Website)

Dan Welty (Targets, Observing)

Thank you