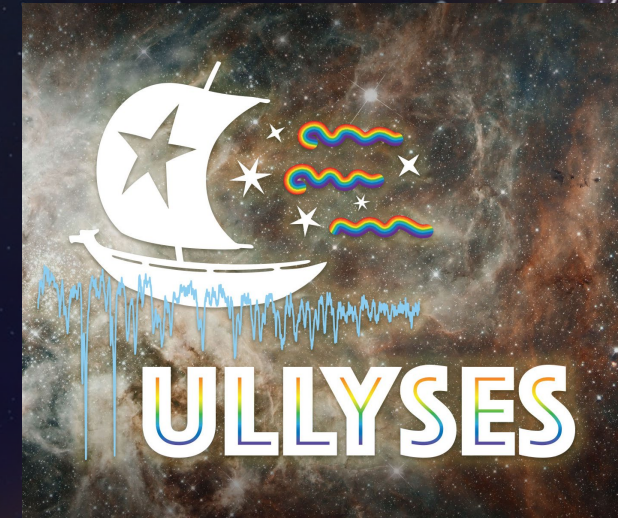


STScI | SPACE TELESCOPE
SCIENCE INSTITUTE

EXPANDING THE FRONTIERS OF SPACE ASTRONOMY



Overview and Status of the ULLYSES Director's Discretionary Program

Charting Young Stars' Ultraviolet Light with Hubble

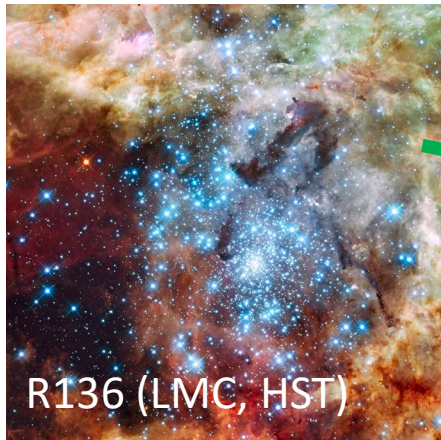
Julia Roman-Duval

ULLYSES Implementation Team Lead

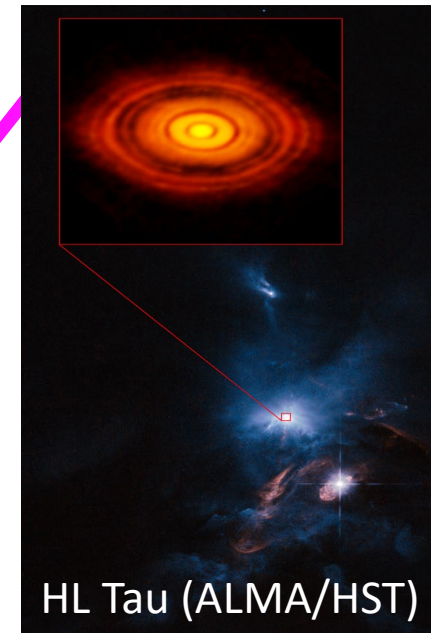
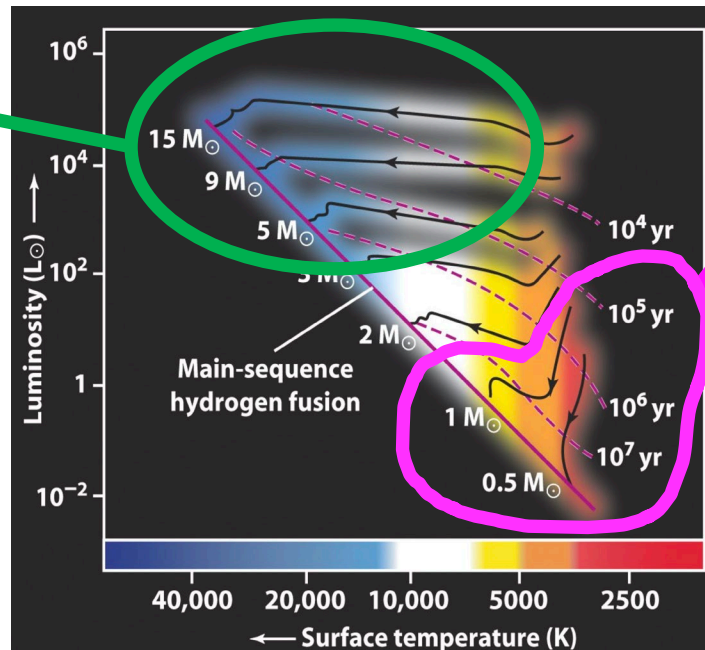


ULLYSES at a glance

- 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)

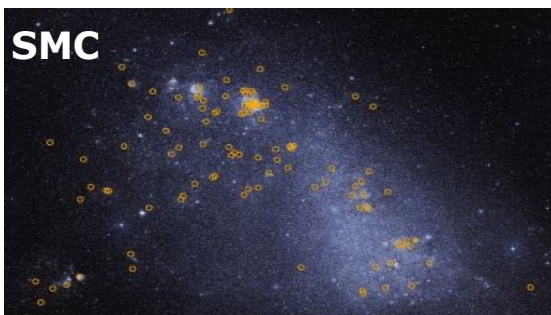
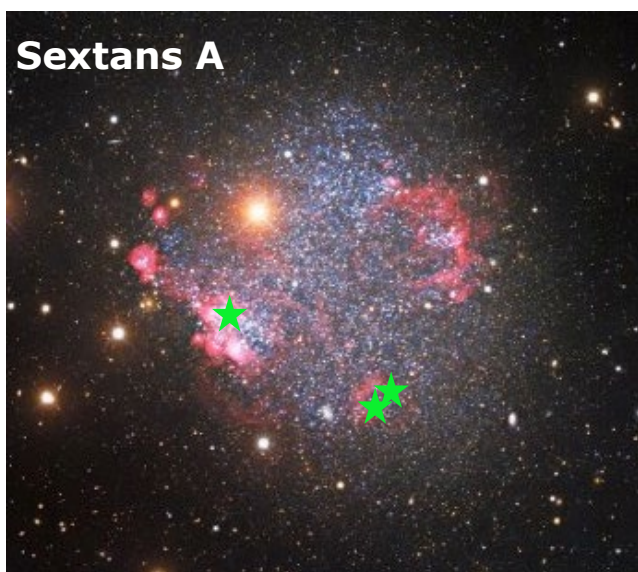
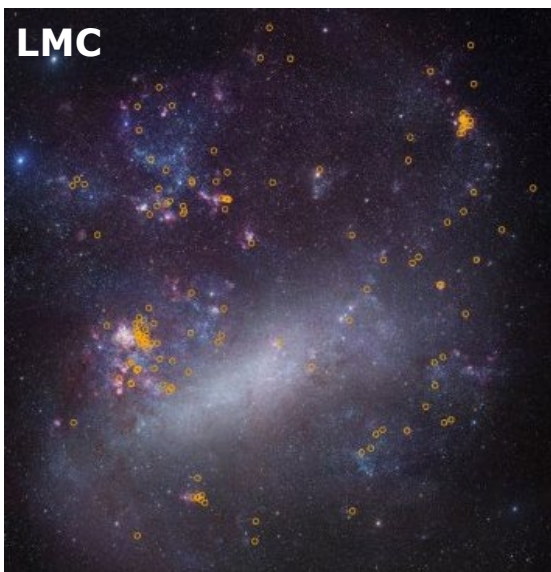


~500 orbits to obtain a spectroscopic library and time monitoring of T Tauri stars (younger than 10 Myr, mass < 1 M_o)

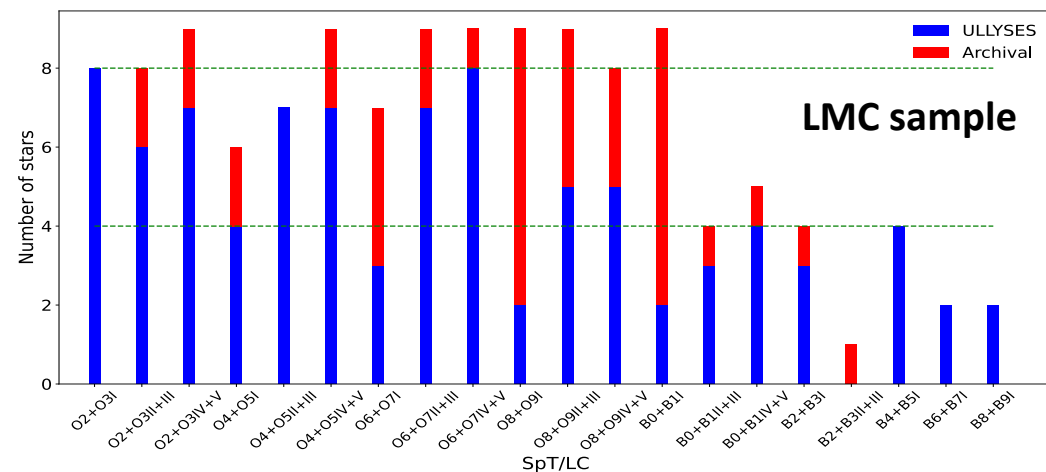


ULLYSSES Massive Stars (~500 orbits)

- ULLYSSES targets ~170 OB stars in 4 galaxies spanning a range of metallicities (8%-50% solar)
- Also includes ~140 OB stars with archival spectra in the same galaxies
- Statistical sample covering metallicity, temperature class, and luminosity class uniformly

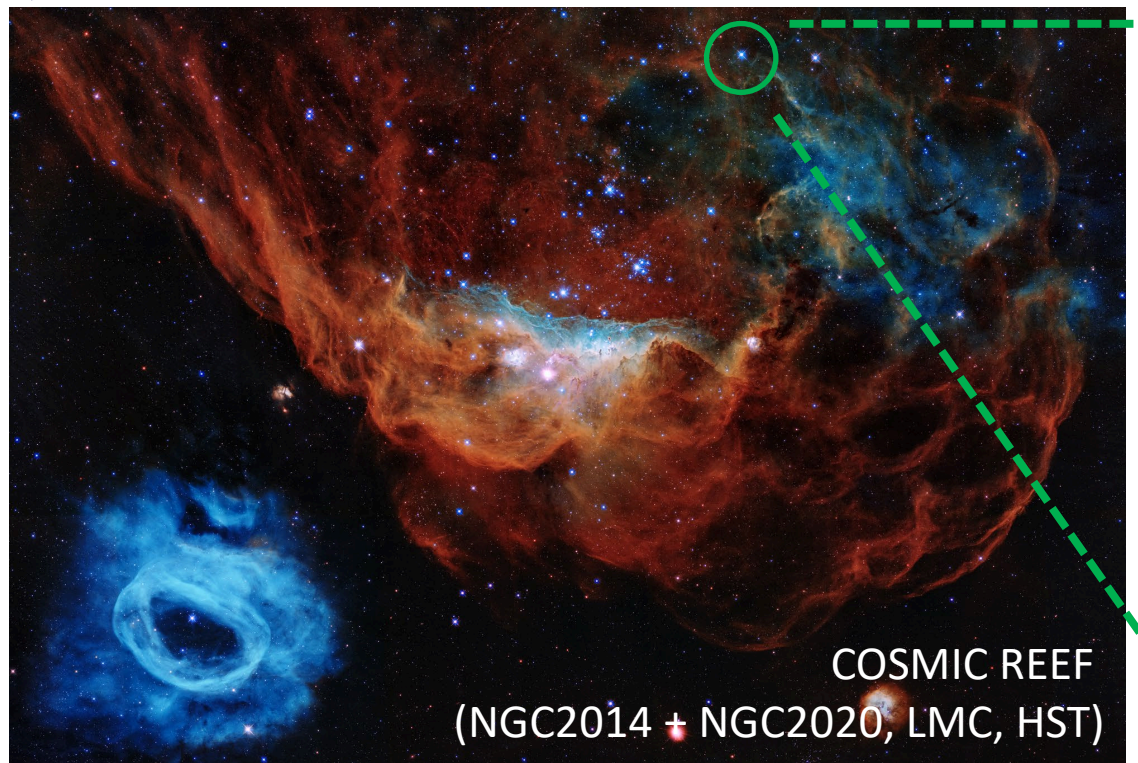


Galaxy	Distance	Metallicity	# targets Obs (AR)
LMC	50 kpc	0.5 Z_{\odot}	94 (54)
SMC	62 kpc	0.2 Z_{\odot}	60 (63)
NGC 3109	1.3 Mpc	0.15 Z_{\odot}	3 (0)
Sextans A	1.6 Mpc	0.08 Z_{\odot}	3 (9)

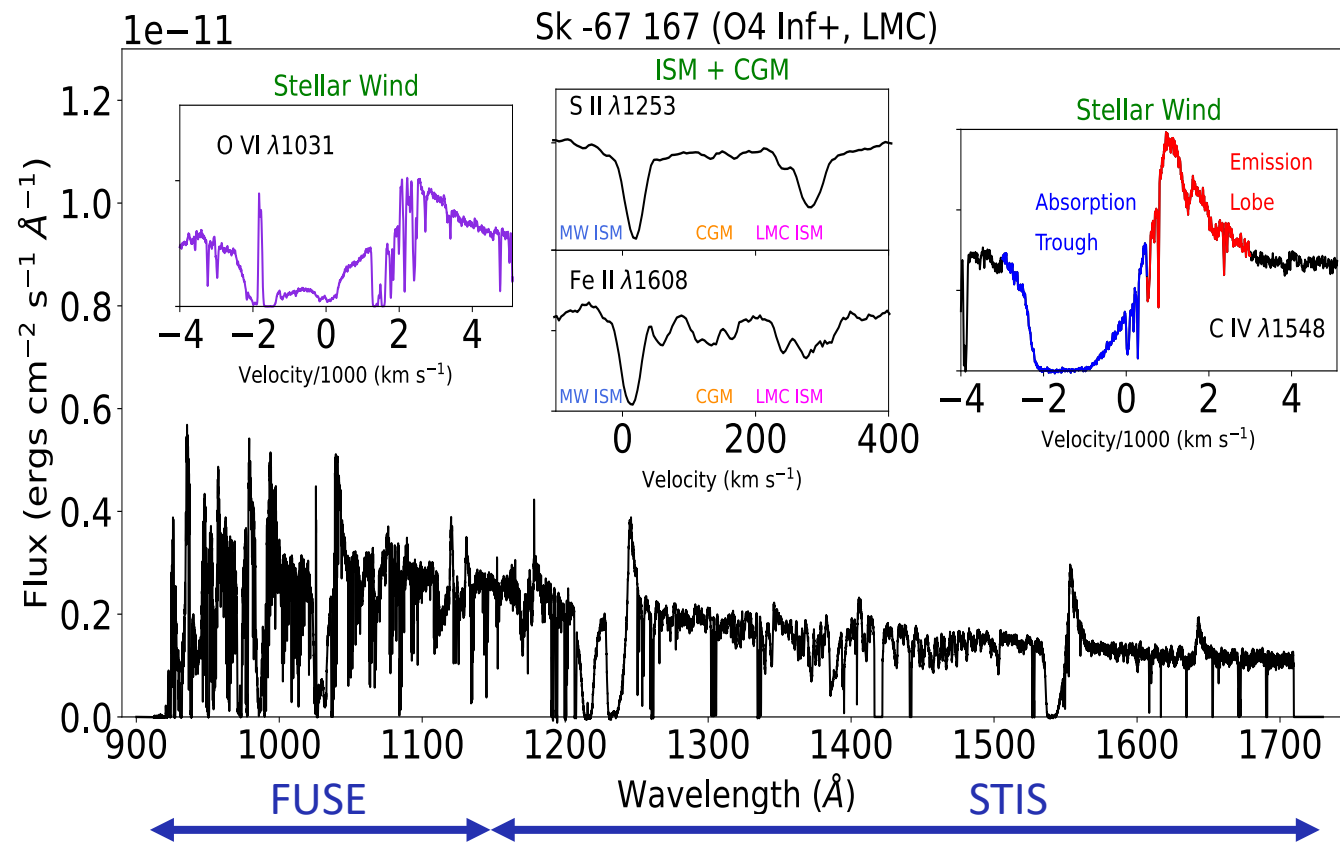




A Spectroscopic Survey of High Mass Stars



COSMIC REEF
(NGC2014 + NGC2020, LMC, HST)



✓ Massive Stars

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

✓ CGM

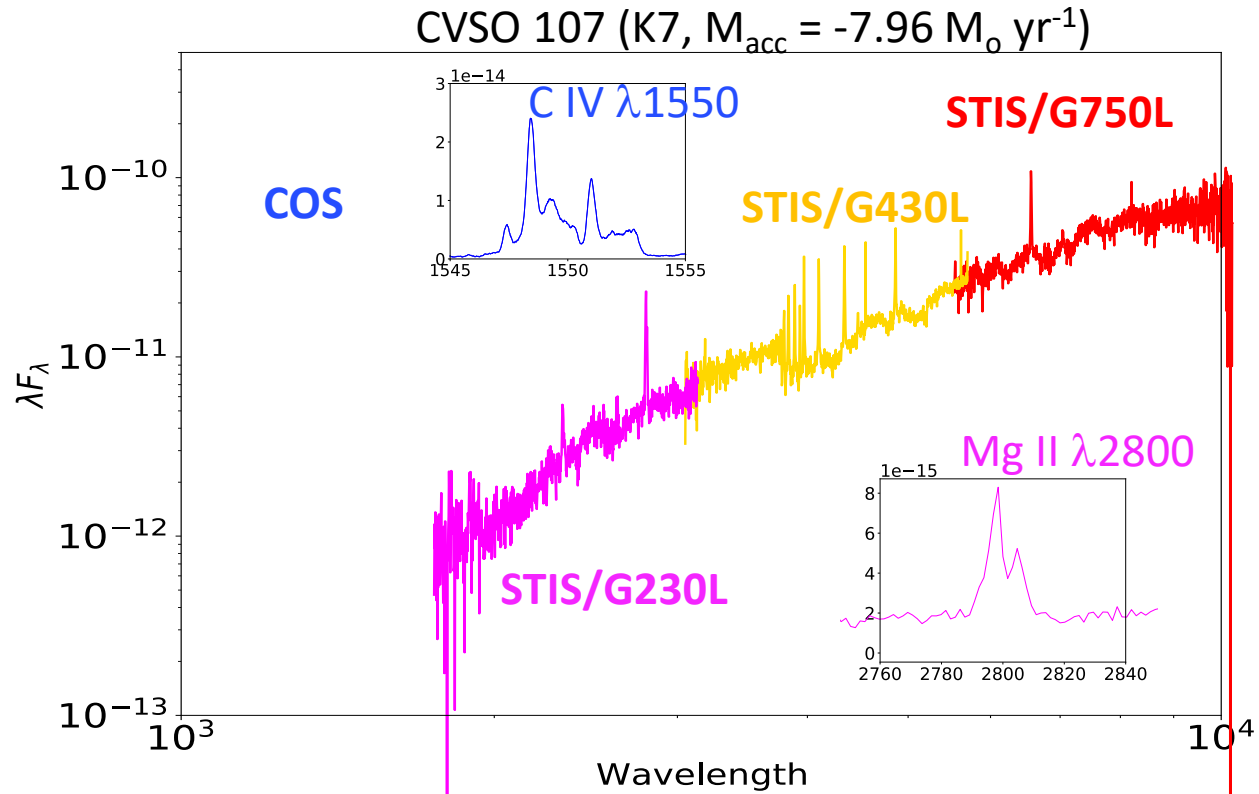
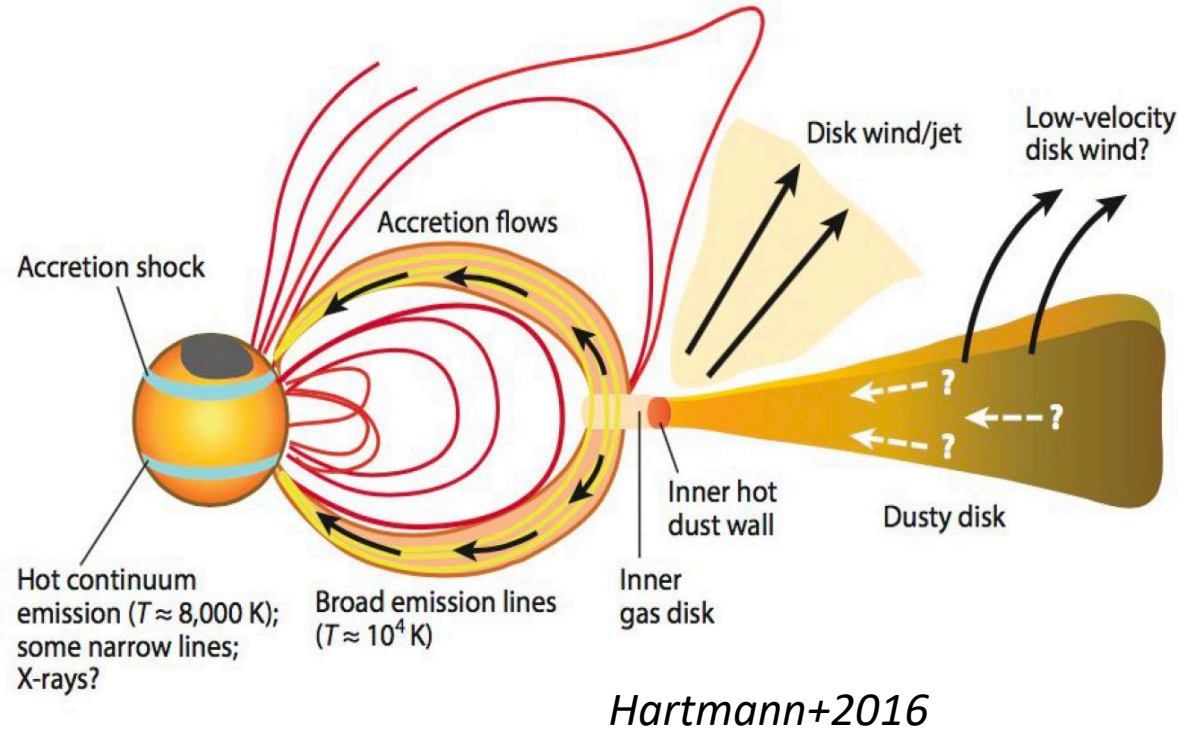
- Kinematics
- Metallicity
- Disk-halo interface/feedback

✓ ISM

- Chemical abundances
- Depletions on dust

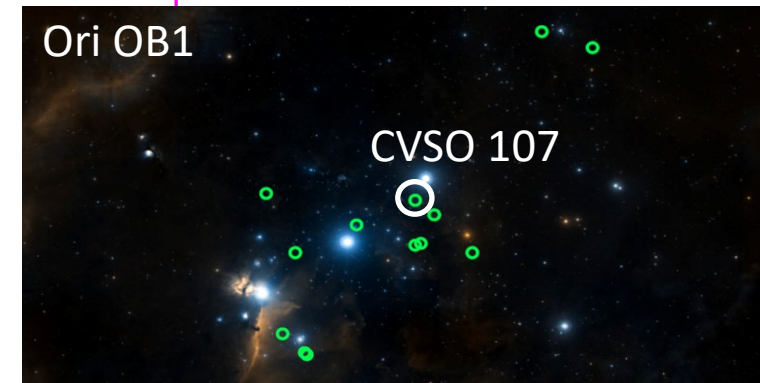


Strategy and Science goals of the low-mass star observations



✓ T Tauri Stars

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

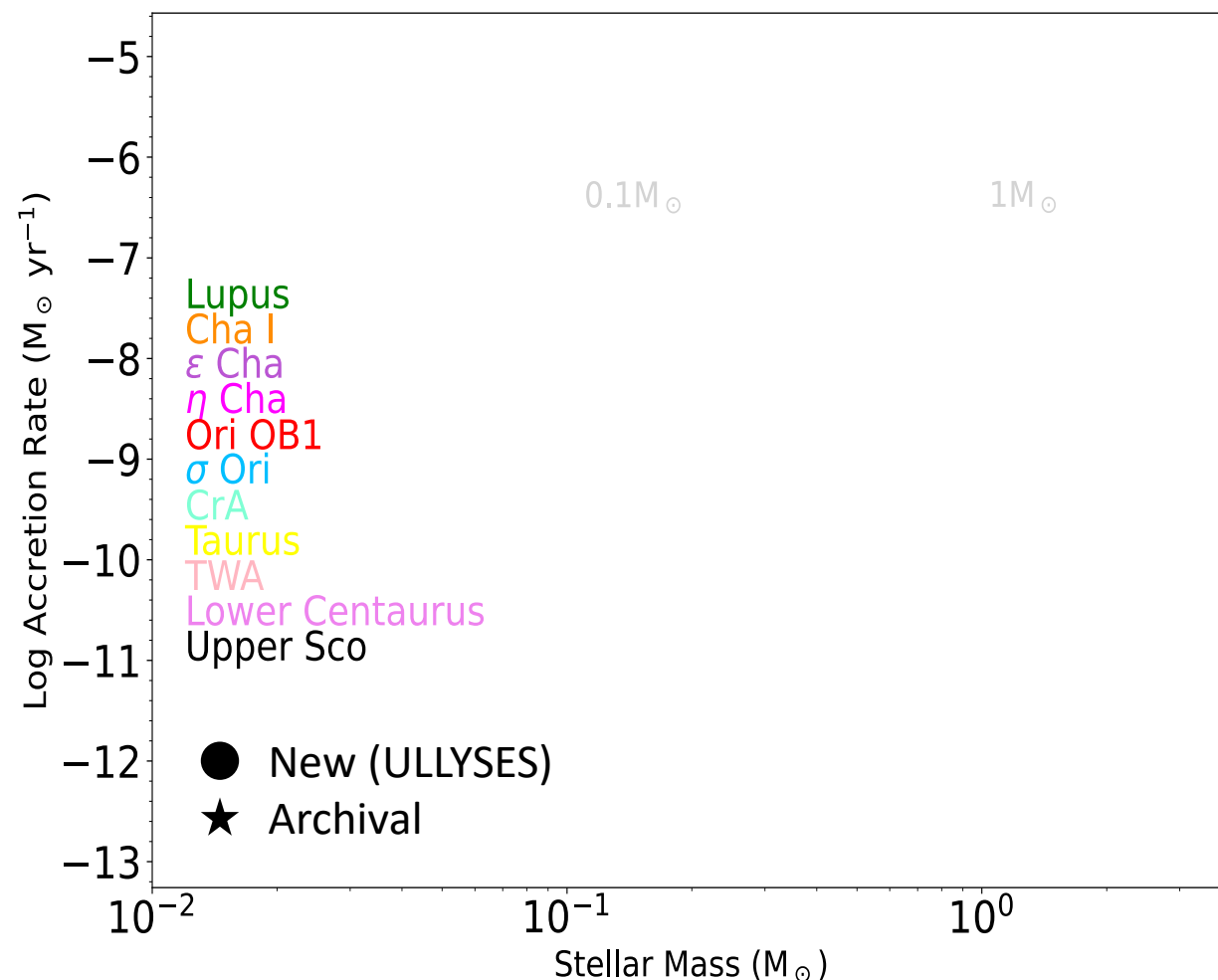




ULLYSES “survey” T Tauri stars (single-epoch observations)

- ULLYSES is targeting 58 stars in 8 star-forming regions in the Milky Way (~ 400 orbits)
- Also includes ~40 T Tauri stars with archival data in Taurus and other SF regions
- Uniform coverage of stellar mass and accretion rate

SF region	# of targets
Lupus	26
Chamaeleon I	11
ϵ Cha	1
η Cha	4
Ori OB1a, b	10
σ Ori	3
Corona Australis (CrA)	2
Taurus	1





ULLYSES T Tauri stars monitored with HST

- 4 stars monitored over time with COS/FUV + NUV:
 - ✓ TW Hya
 - ✓ BP Tau
 - ✓ RU Lup
 - ✓ GM Aur
- 12 observations over 3 rotational periods
 - Repeated over 2 epochs separated by 1 year
 - **COS/G160M + COS/G230L**
 - 1 orbit per observation
 - 100 orbits





Program Status

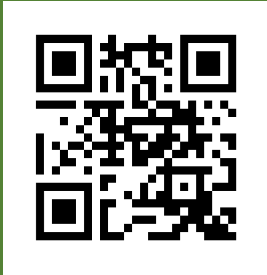


- As of January 2023, ULLYSES observing is **96% complete**
- **6 data releases (latest DR5b on November 15, 2022)**
 - **DR6 planned for early March 2023**
- **1 press release**
 - NASA** 
 - Hubblesite** 
- 8 peer-reviewed publications by the community (and counting)
- **Completion of the program expected by the end of 2023** (this is a working goal)
- All data products will have their final delivery as part of **DR7 in the fall/winter 2023**
- ULLYSES workshop at STScI penciled in for late 2023



ULLYSES Deliverables

WEBSITE
ullyses.stsci.edu



Program information
Observing status and schedule
Data product description
List of coordinated programs
Data release (DR) notes

PUBLIC CODEBASE
github.com/spacetelescope/ullyses

Custom calibration routines and config files
Photometry
Spectral coaddition and splicing
Spectral time-series
COS vignetting correction
Target metadata, alias information
Automatic webpage generation
Product data quality checks



INTERNAL DATABASE

Target metadata
Observational metadata

ULLYSES SEARCH FORM
mast.stsci.edu/search/ui/#/ullyses

Built on Missions MAST framework
Uses database and custom API



ULLYSES HLSPs

High level science data
products
See next slide



Description of data products

- **Flux-weighted co-added spectra** obtained with the same grating
 - E.g., different exposures with the same or different cenwaves and FP-POS
- **Spliced (abutted) spectra** between different gratings and instruments
 - E.g., FUSE + HST, COS + STIS
- **Vetted FUSE spectra for LMC/SMC massive stars**
- **Custom calibrated STIS G230L and CCD spectra of T Tauri stars**
 - In particular, **de-fringing of G750L** spectra, improved hot pixel flagging, and re-extraction of targets (as needed) and companions
- **Photometric (LCOGT) and spectroscopic (HST) time-series**
 - Spectroscopic time-series from HST only for T Tauri stars monitored over time
- **Drizzled WFC3 images** of NGC 3109 and Sextans A



Data Dissemination Platforms

Data can be downloaded from 3 different platforms



**ULLYSES SEARCH FORM
(HLSPs only)**



Built on Missions MAST framework
Uses database and custom API

**MAST DISCOVERY PORTAL
(HLSPs and contributing data)**



See instructions at the MAST
HLSP collection

**MAST ULLYSES HLSP
COLLECTION
(HLSPs only)**



Uses MAST portal interface

First time using the new ULLYSES search form? Welcome! Please feel free to visit our [documentation](#) to help get started. This form is a filter - press SEARCH immediately to return all ULLYSES targets, or enter values to focus your results.

Filtering data will return observations that include but are not limited to only those filters. For example, filtering by Observatory=FUSE will return targets that include FUSE data *and* data from other observatories.

Search for a specific target or all targets

Object name(s) and/or RA and Dec pair(s) 📄 UPLOAD LIST OF OBJECTS 🔍 RESOLVE Search radius (max: 30 arcminutes)
 Object(s)= Radius= Unit=

Filter by observatory, instrument, galaxy, or product type

Observatory= HST FUSE LCOGT HST Instruments= STIS COS WFC3
 Target Type= LMC SMC T TAU LOW Z Product Type(s)= SPECTRUM IMAGE TIME SERIES

Filter by grating

Names of Filters/Gratings, e.g. G130M or G750L Spectral band(s)
 Filter / Grating= Wavelength= FUV NUV OPTICAL NIR

Search by observational or astrophysical metadata (e.g., all the O stars)

Find data observed on or between these dates
 Obs Start Date= Time= to Obs Start Date= Time=

Add or remove additional columns to filter results
 Column Name= Condition= + ADD ANOTHER CONDITION

Select output columns

Choose output columns by name, header keywords, or description
 Output columns= 🌟 SELECT RECOMMENDED 📧 📄
 Ang Sep (") B Magnitude Dataproduct Type Dec(J2000) Filter Grating(s) Host Galaxy Name Instrument MAST Name RA(J2000)
 Spectral Type Star Mass Target Classification U Magnitude V Magnitude

Telescope= HST, FUSE, LCOGT Target Type= LMC, SMC, TTAU, LOWZ HST Instruments= STIS, COS, WFC3 HLSP Type= SPECTRUM, IMAGE, TS Wavelength= FUV, NUV, VIS, NIR Spectral Type= O* Columns= Ang Sep ...

DOWNLOAD DATA (2 DATASETS)

- Choose Files
- Quick API Script
- Recommended Files
- All Files

EXPORT TABLE

Rows per page: 500 1-134 of 134

	Classification	RA(J2000)	Dec(J2000)	Host Galaxy Name	Spectral Type	Star Mass	U Magnitude	B Magnitude	V Magnitude	Instrument	Grating(s)
<input type="checkbox"/>	Dwarf	21.1166061	-73.2374879	SMC	O9.7 V	35	12.78	13.77	13.97	COS	G130M; G160M
<input type="checkbox"/>	Supergiant	84.9612208	-69.4076306	LMC	O5 If		12.63	13.64	13.66	COS	G130M; G160M
<input type="checkbox"/>	Dwarf	84.8064943	-69.5013906	LMC	O3 V((f))		13.48	14.48	14.58	COS	G130M; G160M
<input type="checkbox"/>	Supergiant	9.2426668	-73.3925519	SMC	O8 Ib(f)		13.84	14.95	15.11	COS	G130M; G160M
<input type="checkbox"/>	Bright Giant	16.8094759	-72.2298699	SMC	O C7 II(f)		13.83	14.91	15.16	COS	G130M; G160M
<input type="checkbox"/>	Dwarf	22.6796167	-73.4178175	SMC	O6 V((f))z	19	13.93	15.01	15.27	COS	G130M; G160M
<input type="checkbox"/>	Mid O Dwarf	13.3035651	-72.6166619	SMC	O6V((f))			14	14.14	COS	G160M
<input type="checkbox"/>	Early O Dwarf	11.6359778	-73.1015508	SMC	O5 V	74	12.38	13.38	13.55	COS, FUSE, STIS	E140M; FUSE/LWRS; G185M
<input checked="" type="checkbox"/>	Late O Dwarf	13.4259785	-72.7098053	SMC	O8.5 V	19	12.92	13.92	14.12	COS	G130M; G160M
<input checked="" type="checkbox"/>	Mid O Bright Giant	11.6756704	-73.4154202	SMC	O7 V	47.2	11.9	12.93	13.12	FUSE, STIS	E140M; FUSE/LWRS
<input type="checkbox"/>	Late O Supergiant	13.9268014	-73.2918177	SMC	O9.7I			13.82	14.11	FUSE, STIS	E140M; FUSE/LWRS
<input type="checkbox"/>	Early O Dwarf	14.1837744	-72.0588053	SMC	O4 V((f))	38.8	13.27	14.32	14.53	COS, FUSE	FUSE/LWRS; G130M; G160M
<input type="checkbox"/>	Late O Giant	14.3622539	-72.5537720	SMC	O8.5 III((f))	32.2	12.75	13.77	13.98	COS	G130M; G160M
<input type="checkbox"/>	Early B Subgiant	14.3854865	-72.4808760	SMC	O9 V	18.8	13.32	14.26	14.37	COS	G130M; G160M
<input type="checkbox"/>	Mid O Giant	14.6382993	-71.9296494	SMC	O7 III((f))	22	12.99	14.05	14.25	COS, FUSE, STIS	E230M; FUSE/LWRS; G130M; G160M
<input type="checkbox"/>	Mid O Supergiant	14.7915474	-72.0967497	SMC	O7If			14.24	14.51	FUSE, STIS	E140M; FUSE/LWRS
<input type="checkbox"/>	Mid O Supergiant	14.8832439	-72.1794800	SMC	O7 Iaf+	35.3	11.15	12.15	12.35	FUSE, STIS	E140M; FUSE/LWRS
<input type="checkbox"/>	Mid O Dwarf	15.0280329	-72.7886511	SMC	O6 V	41	12.63	13.67	13.84	COS, FUSE	FUSE/LWRS; G130M; G160M
<input type="checkbox"/>	Mid O Dwarf	15.0923184	-72.5135422	SMC	O7.5 V		13.32	14.34	14.52	COS	G130M; G160M
<input type="checkbox"/>	Late O	15.1855103	-72.4973207	SMC	O9			13.7	13.69	STIS	E140M
<input type="checkbox"/>	Mid O Supergiant	11.9585471	-73.1391871	SMC	O6I(f)			12.29	12.46	FUSE, STIS	E140H; E140M; E230M; FUSE/LWRS
<input type="checkbox"/>	Late O Dwarf	15.3153942	-72.1098302	SMC	O8 V	21.5	13.53	14.58	14.84	COS	G130M; G160M
<input type="checkbox"/>	Late O Supergiant	15.4884399	-72.2117332	SMC	O9.5I			12.77	12.54	STIS	E140M
<input type="checkbox"/>	Late O Giant	15.6340989	-72.6618302	SMC	O9 III	22.5	12.82	13.8	13.96	COS	G130M; G160M
<input type="checkbox"/>	Early B Giant	15.7378517	-72.1358703	SMC	O9 II np		12.54	13.57	13.76	FUSE, STIS	E140M; E230M; FUSE/LWRS
<input type="checkbox"/>	Early B Subgiant	15.7886326	-72.4325390	SMC	O9 V	18.8	12.84	13.8	13.92	COS	G130M; G160M
<input type="checkbox"/>	Late O Bright Giant	15.7939600	-72.0373207	SMC	O9.5 II-Ibw	22.8	11.83	12.87	13.03	FUSE, STIS	E140M; FUSE/LWRS
<input type="checkbox"/>	Late O Supergiant	16.2322616	-72.7800457	SMC	O9.5 Iabw		11.41	12.44	12.59	FUSE, STIS	E140M; E230M; FUSE/LWRS



ULLYSES Core Implementation Team (CIT)



Julia Roman-Duval
(CIT Lead)



Jo Taylor
(DP Lead)



Rachel Plesha
(DP Deputy Lead)



Will Fischer
TTS Observing Lead (OB star Observing Lead)



Alex Fullerton
(Pre-imaging)



Alessandra Aloisi
(Public Outreach)



Chris Britt
(DP/software)



Ivo Busko
(Observing, DP)



Van Dixon
(Observing, DP)



Travis Fischer
(DP)



Elaine Frazer
(DP)



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(DP, software)



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(ETC, Obs)



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(Targets, DP)



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(DP)



Linda Smith
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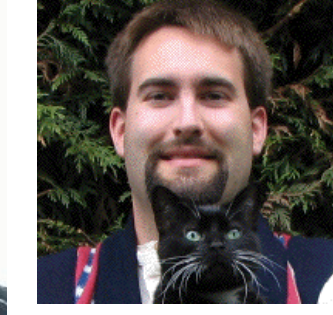
Debopam Som
(Targets, Observing)



Leonardo Ubeda
(Observing)



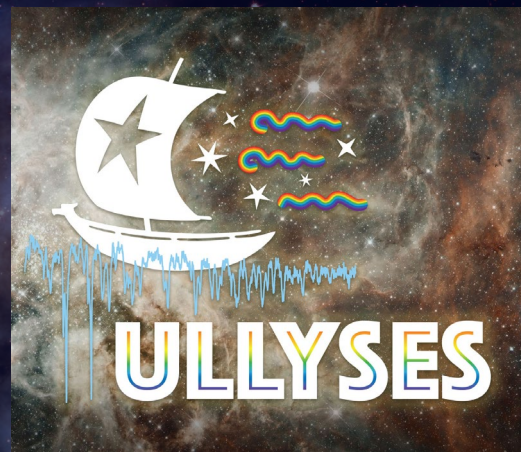
Dan Welty
(Website)



Dan Welty
(Targets, Obs, DP)

Brian York
(DP)

Thank you for your attention





Acknowledgements



Other STScI staff involved



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



Science Advisory Committee (SAC)

- SAC composition (Massive stars/T Tauri stars)
 - Jean-Claude Bouret (Laboratoire d'Astrophysique de Marseille)
 - Catherine Espaillat (Boston University)
 - Chris Evans (ESA@STScI, formerly UK Astronomy Technology Centre)
 - Kevin France (University of Colorado Boulder)
 - Miriam García (Instituto Nacional de Técnica Aeroespacial)
 - Chris Johns-Krull (Rice University)
 - Derck Massa (Space Science Institute)
 - Joan Najita (National Optical Astronomy Observatory)



Other community members



- Carlo Manara (ESO) for providing updated accretion rates and extinction values
- Jesus Hernandez and Javier Serna (UNAM) for providing TESS-based rotational periods
- ODYSSEUS team (led by Greg Herczeg) for interesting discussions about targets and coordination
- IAU G2 (massive stars) for useful feedback on implementation

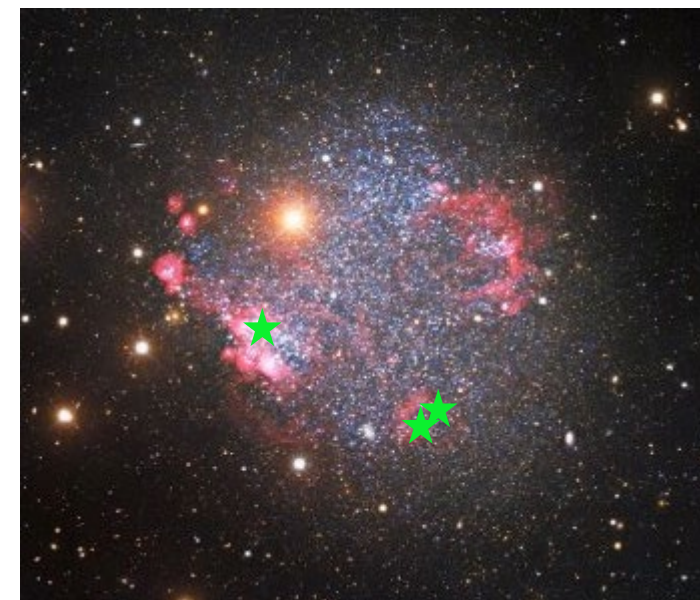
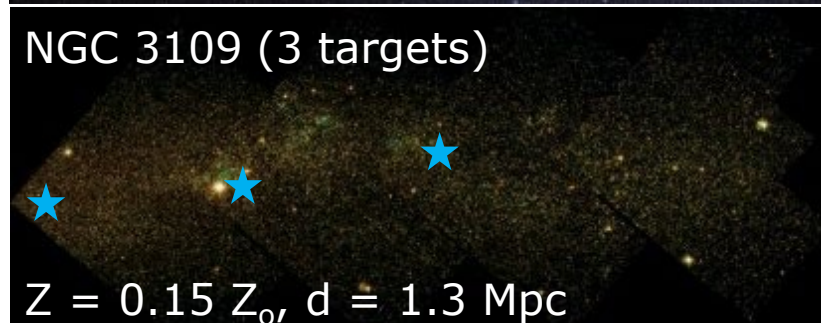
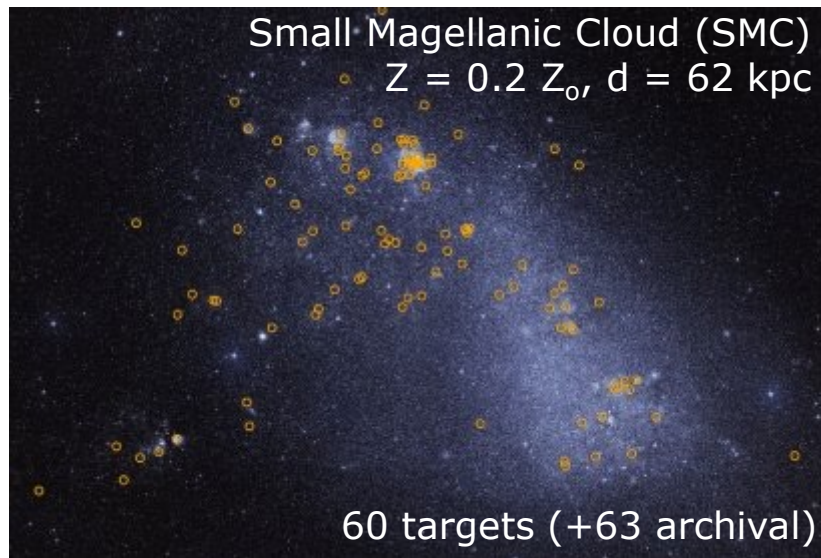
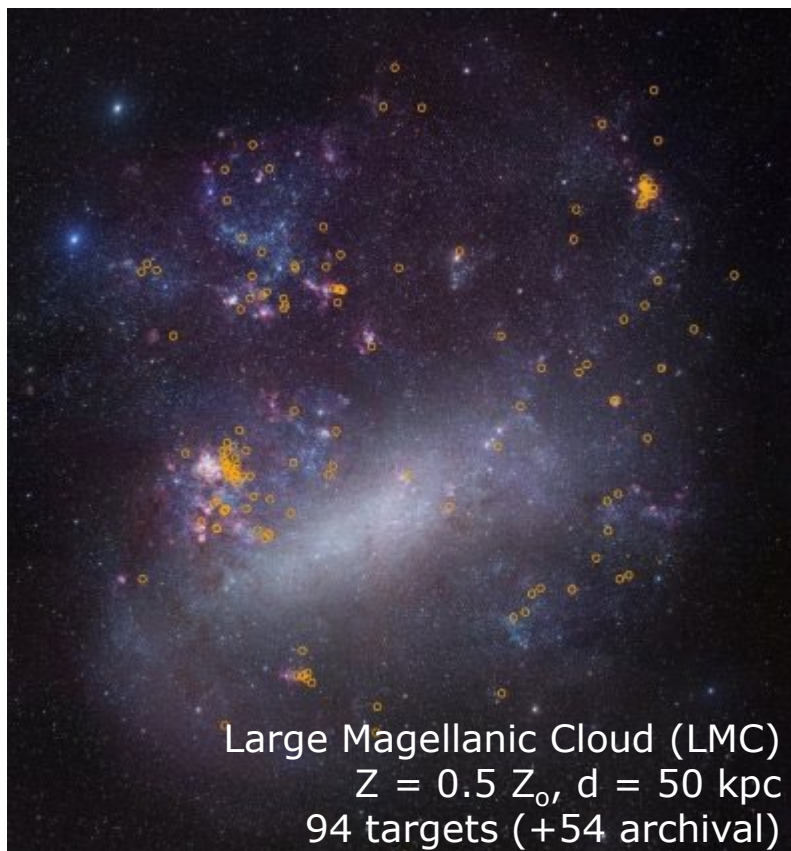
A background image of a starry night sky. On the left side, there is a large, diffuse nebula with shades of blue and purple, and some darker, brownish structures. The rest of the sky is filled with numerous stars of various colors, including blue, white, and yellow. A thin, horizontal orange line is drawn across the middle of the image, just below the text.

Back-up Slides



ULLYSES Massive Stars (~500 orbits)

- ULLYSES targets ~170 OB stars in 4 galaxies spanning a range of metallicities (8%-50% solar)
- Also includes ~140 OB stars with archival spectra in the same galaxies
- Statistical sample covering metallicity, temperature class, and luminosity class uniformly





Observing Status

LMC	Number	Complete	%
Targets	94	76	81%
Orbits	244	206	84%
Programs	33	26	79%
HOPRs	14	24 orbits repeated (14%)	

Survey TTS	Number	Complete	%
Targets	58	56	97*
Orbits	390	390	100
Programs	24	24	100
HOPRs	9	50 orbits repeated (13%)	

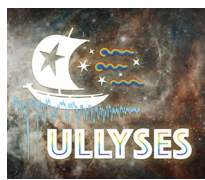
*2 targets dropped after failure

SMC	Number	Complete	%
Targets	60	59	98%
Orbits	205	204	99.5%
Programs	19	18	95%
HOPRs	19	42 orbits repeated (22%)	

Monitor TTS	Number	Complete	%
Targets	4x2	6	100
Orbits	96	96	100
Programs	8	8	100
HOPRs	6	6 orbits repeated (8%)	

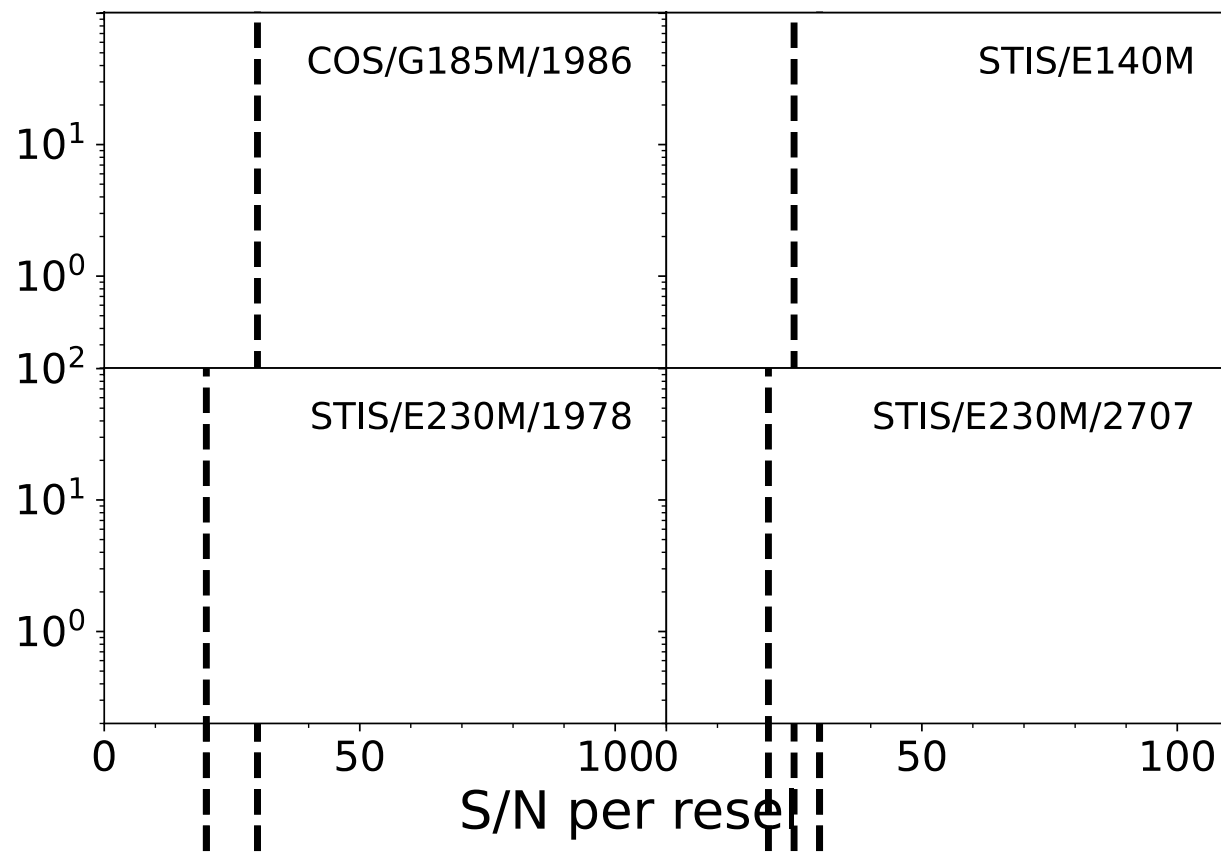
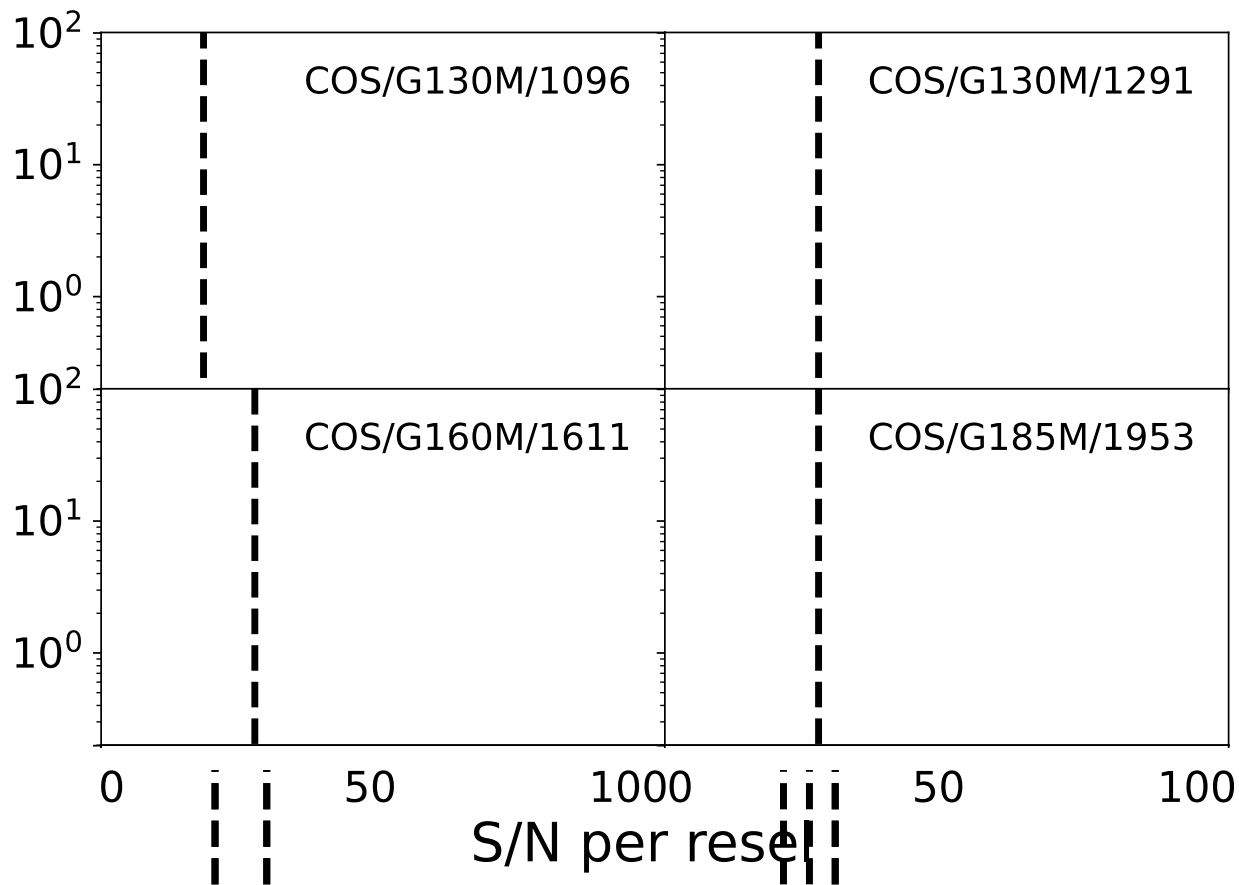
Galaxy	Metallicity	WFC3 Pre-Imaging *		COS G140L/800 Spectroscopy		
		Orbits	Status	Targets	Orbits	Status
NGC 3109	0.1 – 0.2 Z_{\odot}	4	Complete	3	9	Complete
Sextans A	< 0.1 Z_{\odot}	2	Complete	3	20	Complete

*F225W, F275W, F336W, F475W, F814W



Data Quality of COS and STIS observations of LMC/SMC stars

- Generally, the distribution of S/N is centered on the goal
- Exception of COS/G130M/1096, presumably due to estimation of exposure times based on SpT, E(B-V), and optical photometry



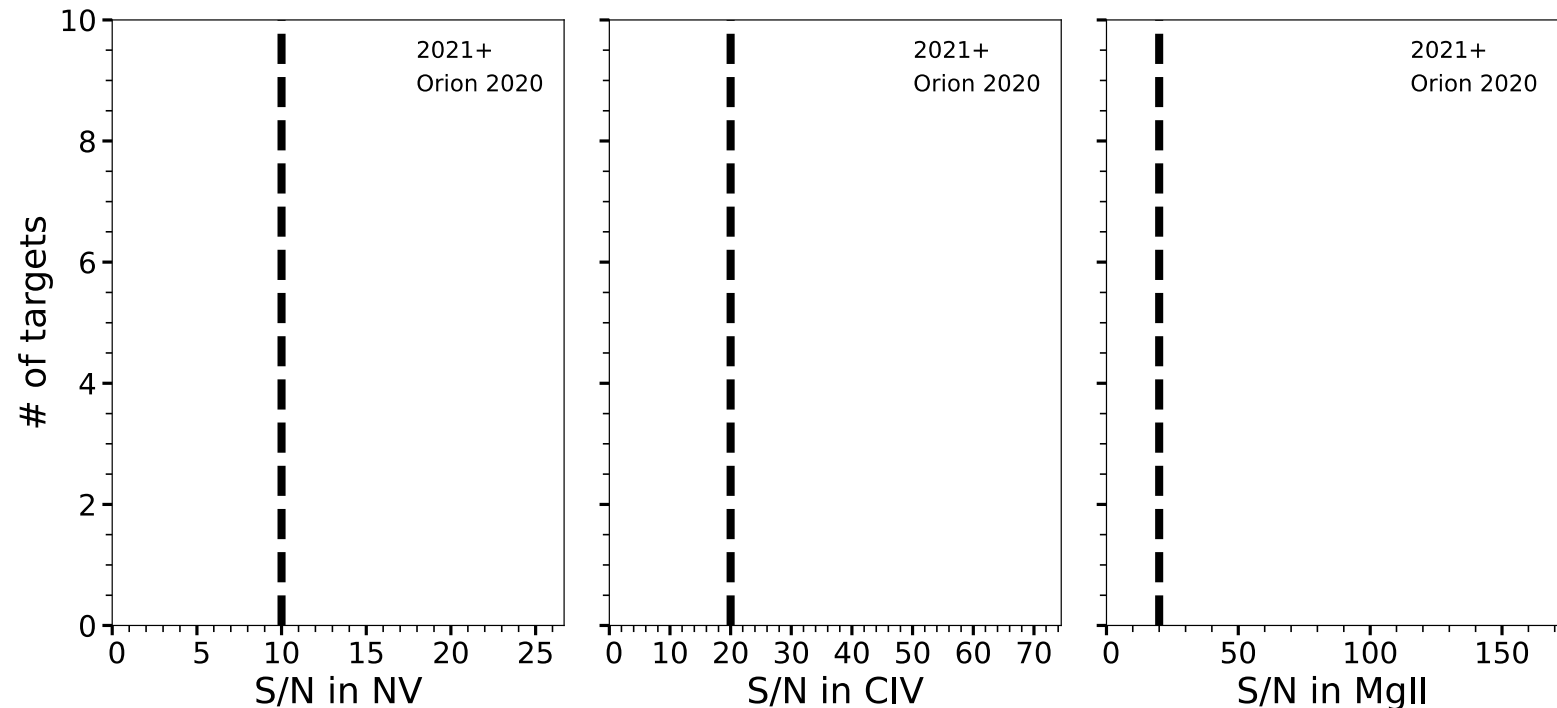


Observing: Survey T Tauri stars (58 targets/400 orbits)

	Number	Complete	%
Targets	58	56	97
Orbits	390	390	100
Programs	24	24	100
HOPRs	9	50 orbits repeated (13%)	



- ✓ The distribution of S/N is about on target
 - Some objects have low S/N due to accretion severely decreasing over time

✓ Observations for all single epoch (“survey”) T Tauri stars are complete!





DR5 and DR5b contents

- Latest data release (DR5, June 28 2022) includes:
 - COS spectra for 85 Tauri stars (41 with STIS NUV-optical-NIR)
 - COS spectroscopic time series for 4 T Tauri stars monitored with HST
 - Both epochs completed for TW Hydra!
 - LCOGT photometric time series for 40 T Tauri stars
 - HST UV spectra of **233 stars in the LMC and SMC**, plus **FUSE spectra** of 122 of those stars
 - COS/FUV/G140L/800 spectra of 3 massive stars in low metallicity galaxy NGC 3109 
 - Drizzled WFC3 imaging of NGC 3109 and Sextans A
 - STIS spectra of 9 non-ULLYSES targets present in STIS long-slit observations
 - **Publication of the HLSP-making code (including co-addition and time-series)** 
- DR5b includes HST products for **17 T Tauri stars observed since DR5**
 - Custom calibrated STIS G230L, G430L, G750L spectra
 - Co-added COS/FUV G130M + G160M spectra



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

Cycle	PID	Orbits	Title	Topic
27	GO-15967 PI Chisholm	49	Constraining the Stellar Astrophysics Powering Cosmic Reionization: Spectral Templates of Extremely Low-metallicity Main-sequence O-stars	Low-Z massive stars
27	Multiple PIDs PI C Murray	500	Scylla (PI C. Murray, multiple PIDs) – Scylla: A pure-parallel, multi-headed attack on dust evolution and star formation in ULLYSES galaxies	Parallel to LMC/SMC
28	GO-16233 PI Schneider	17	Jets and disk scattering – Spatially resolved optical and FUV observations of AA Tau	CTTS
28	SNAP-16239 PI Massa	200	A NUV SNAP program to supplement and enhance the value of the ULLYSES OB star legacy data	LMC/SMC STIS CCD spectra
28	AR-16148 PI Senchyna		Painting the first empirical picture of massive stars below the metallicity of the SMC with ULLYSES	Low-Z stars
28	AR-16129 PI Herczeg		Outflows and Disks around Young Stars: Synergies for the Exploration of ULLYSES Spectra (ODYSSEUS)	CTTS
28	AR-16131 PI Hillier		CMFGEN: A key spectroscopic tool for astrophysics	LMC/SMC/low-Z
28	AR-16133 PI Jenkins		A comprehensive investigation of Gas-phase element abundances and extinction by dust in the LMC and SMC	ISM LMC/SMC



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

Cycle	PID	Title	Topic
29	AR-16616 PI Howk	Interstellar tomography of highly ionized gas in the MW thick disk with ULLYSES	CGM
29	AR-16623 PI Leitherer	Feasting on the Riches of Odysseus' voyage	Population synthesis
29	AR-16640 PI Zheng	Braving the storm, quantifying the effects of Ram Pressure and Stellar Feedback in the LMC	ISM/CGM
29	AR-16602 PI Barger	The LMC's Galactic Wind through the eye of ULLYSES	ISM/CGM
29	AR-16635 PI Tchernyshyov	The first direct measurement of CO/H ₂ in subsolar environments using ULLYSES data	ISM



ULLYSES S/N Requirements



- **Massive SMC/LMC Stars**
 - COS/G130M/c1096: S/N = 20 / nine-pixel resel at 1080 Å continuum
 - COS/G130M/c1291: S/N = 30 / six-pixel resel at 1150 Å continuum
 - COS/G160M/c1589+1623: S/N = 30 / six-pixel resel at 1590 Å continuum
 - COS/G185M/c1953: S/N = 30 / three-pixel resel at 1860 Å continuum
 - COS/G185M/c1986: S/N = 30 / three-pixel resel at 1980 Å continuum
 - STIS/E140M/c1425: S/N = 20 / two-pixel resel at 1200 Å continuum
 - STIS/E230M/c1978: S/N = 20 / two-pixel resel at 1800 Å continuum
 - STIS/E230M/c2707: S/N = 20 / two-pixel resel at 2800 Å continuum
- **Massive Low Z Stars in Sextans A and NGC 3109**
 - COS/G140L/c800: S/N = 15 / six-pixel resel at 1600 Å continuum
- **T Tauri Stars**
 - COS G130M/c1291 S/N = 15 / six-pixel resel in peak of N V 1239 Å
 - COS G160M/c1611 S/N = 20 / six-pixel resel in peak of CIV 1549 Å
 - STIS G230L/c2376 S/N = 20 / six-pixel resel in peak of Mg II 2800 Å
 - STIS/G430L S/N=20 / two-pixel resel in continuum at 4000 Å
 - STIS/G750L S/N= / two-pixel resel in continuum at 5700 Å

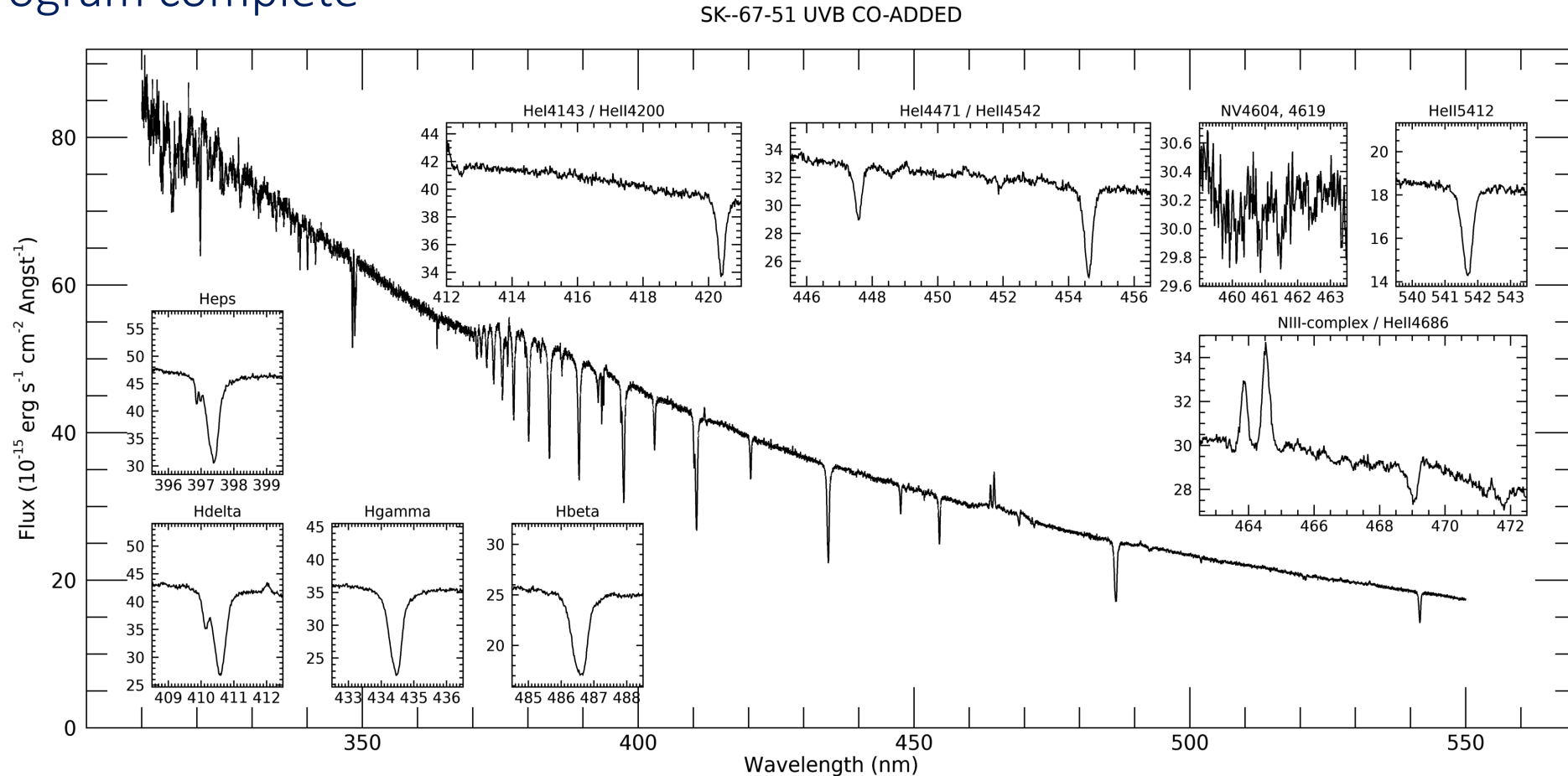


Coordinated observations



Coordinated programs for massive stars

- X-ShootU program led by IAU-G2
 - VLT X-Shooter for all ULLYSES targets
 - Program complete





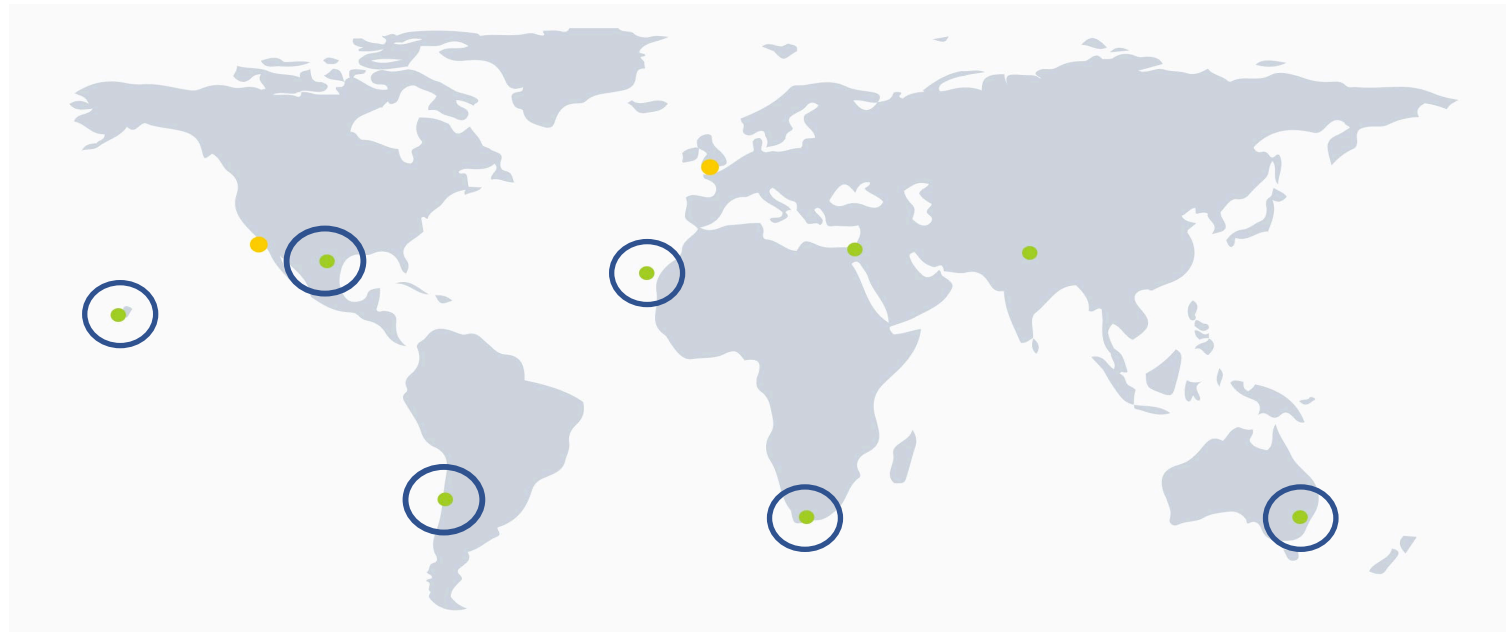
Coordinated programs for T Tauri stars

- Monitored stars only
 - **Chandra/XMM-Newton** (X-ray; accretion)
 - CFHT/SPIRou **spectro-polarimetry (magnetic field mapping)**
- Survey and monitored stars
 - **VLT X-Shooter, ESPRESSO, UVES** (accretion, extinction, stellar properties, kinematics)
 - **IRTF** (calibration of MIR accretion diagnostics in preparation for JWST observations of deeply embedded protostars)
 - **LCOGT photometric monitoring** led by our team (variability context + detector safety)
 - **TESS** (high cadence variability context, March-June 2021 only)
- All programs executing successfully
 - Some coordination with TESS and LCOGT lost when programs got bumped due to July 2021 safing



LCOGT Photometric Monitoring

- STScI implementation team designed a large LCOGT program to perform photometric monitoring in V , i' for survey and u' , V and i' for monitoring T Tauri stars
 - Program was accepted and started late August 2020
 - 545h approved in 2020B, 2021A, B, 2022A so far
- LCOGT has 0.4m robotic telescope network around the World (almost continuous longitudinal coverage)





LCOGT Photometric Monitoring

- Cadence:
 - 1x/day 3 months before/after HST epoch
 - 1x/day 10 days before/after HST epoch
 - 10x/period of the 1 (3) periods centered on the HST observations for the survey (monitoring) stars
 - 15 min cadence during the HST observations
- $S/N > 10$ for all targets/bands
- Flux calibration field (1x/night) for 3 targets (51 fields per target) – Use SkyMapper for other fields/targets
- u' exposure times predicted by LCOGT ETC are underestimated by a factor $\sim 100 \rightarrow u'$ monitoring is not feasible for the survey stars
 - We perform u' monitoring only for the brighter 4 CTTS monitored with HST

