The ULLYSES Director’s Discretionary Program
Charting Young Stars’ Ultraviolet Light with Hubble

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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 ULYSES 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
Science Advisory Committee (SAC)

• SAC composition (Massive stars/T Tauri stars)
  o Jean-Claude Bouret (Laboratoire d’Astrophysique de Marseille)
  o Catherine Espaillat (Boston University)
  o Chris Evans (UK Astronomy Technology Centre)
  o Kevin France (University of Colorado Boulder)
  o Miriam García (Instituto Nacional de Técnica Aeroespacial)
  o Chris Johns-Krull (Rice University)
  o Derck Massa (Space Science Institute)
  o 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_{\odot})

~500 orbits to obtain a spectroscopic library and time monitoring of T Tauri stars (younger than 10 Myr, mass < 1 M_{\odot})
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 $M_\odot$)
  - 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

<table>
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<tr>
<th>Region</th>
<th># ULLYSES targets</th>
<th># AR targets</th>
<th># orbits</th>
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<tr>
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<td>40</td>
<td>222</td>
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<tr>
<td>Sextans-A</td>
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<td>6</td>
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<tr>
<td>NGC 3109</td>
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<td>~15</td>
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<tr>
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<tr>
<td>Cha I</td>
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<td>97</td>
</tr>
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<td>s Ori</td>
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<td>100</td>
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<tr>
<td><strong>TOTAL</strong></td>
<td><strong>240</strong></td>
<td><strong>91</strong></td>
<td><strong>950</strong></td>
</tr>
</tbody>
</table>
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\(_{\odot}\) in O, 0.2 Z\(_{\odot}\) in Fe)**
  - 3 Supergiants O8 – B1
Target Selection – Process for the LMC/SMC

• Complete pool of potential targets and their parameters was assembled from the literature
  o 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
  o Our scriptable ETC includes WM-Basic (O2-B1, Smith+2002), Castelli & Kurucz (B2-B9) and CMFGEN (WR, Smith+2002) models
  o Models were normalized to observed fluxes and compared to archival data when available
Target Selection – Process for the LMC/SMC

- 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 ULYYSES-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

- 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

SMC
20% Solar Metallicity
106 targets O2-B9
Target Selection - SMC

Initial pool of potential targets

Initial pool of targets had about several 1000s objects

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

- 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

LMC
50% Solar Metallicity
132 targets O2-B9

New
Initial pool of potential targets

- Full archival UV coverage
- Partial archival UV coverage
- No HST/FUSE M-res UV data

Initial pool of targets had about several 1000s objects

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

Selected targets

- To be observed
- Already observed
Target Selection Process – T Tauri Stars

- 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 $A_V$, $M_{\text{acc}}$, 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

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

<table>
<thead>
<tr>
<th>SF region</th>
<th># of targets</th>
</tr>
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<tbody>
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<td>Lupus</td>
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<tr>
<td>σ Ori</td>
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</tr>
<tr>
<td>CrA</td>
<td>2</td>
</tr>
<tr>
<td>TWA</td>
<td>1</td>
</tr>
</tbody>
</table>
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)

<table>
<thead>
<tr>
<th>Target</th>
<th>RA(J2000)</th>
<th>DEC(J2000)</th>
<th>Mass (M_☉)</th>
<th>Radius (R_☉)</th>
<th>Mass Accretion Rate (M_☉/yr)</th>
<th>Rotational Period (days)</th>
<th>A_v (mag)</th>
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<tr>
<td>BP Tau</td>
<td>04h19m15.86s</td>
<td>+29d06m27.2s</td>
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<td>2.00</td>
<td>2.9E-08</td>
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<td>GM Aur</td>
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<td>+30d21m59.1s</td>
<td>1.36</td>
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<td>TW Hya</td>
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<td>RU Lup</td>
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<td>-37d49m15.47s</td>
<td>0.70</td>
<td>1.64</td>
<td>5.0E-08</td>
<td>3.71</td>
<td>0.07</td>
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</table>
ULLYSES ETC

• We have developed a scriptable ETC that will be released to the community
  o The tool outputs plots and S/N for user-adjustable wavelength intervals
  o The tool includes WMBasic (Starburst99) models for massive stars and CMFGEN models for WR stars
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-\(\alpha\)
- 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:
  o Medium-resolution UV coverage 1140-1780 Å with COS/G130M/1291 + COS/G160M/1611
  o NUV coverage at low resolution with STIS/G230L
  o Optical-NIR with STIS G430L and G750L

• Monitoring stars:
  o 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**

- 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.

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![Graph showing usage in central pixel (% lifetime) vs. wavelength for different modes of observation.](image-url)
Gain-sag impact on COS - LMC

- 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

• Automated processes for initial draft phase 2 generation completed for hot stars
  o Will require some minor adjustments for T Tauri stars

• Procedures to finalize APT implementation and track work developed
  o Seven scientists trained in detailed procedures have started work
  o 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
  o 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
  o 109 remaining LMC/SMC, 67 T Tauri Survey, 4 T Tauri Monitor stars (2 epochs each)
  o 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

- **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

<table>
<thead>
<tr>
<th>PID</th>
<th>Title</th>
<th>Orbits</th>
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<tbody>
<tr>
<td>16090</td>
<td>ULYSES LMC O2/O3 Stars STIS</td>
<td>9</td>
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<tr>
<td>16091</td>
<td>ULYSES LMC O7/O8 Stars STIS</td>
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<td>ULYSES LMC Wolf-Rayet STIS</td>
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<tr>
<td>16093</td>
<td>ULYSES LMC Early-O/WN COS</td>
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<td>ULYSES LMC O4 Stars COS</td>
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<td>ULYSES LMC O9-B1 Stars COS</td>
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<td>16103</td>
<td>ULYSES SMC O Stars COS 1096</td>
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</table>

- 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

• 4 targets, each observed for 12 orbits distributed over 3 rotational periods
  o COS/G160M/1611 and COS/G230L/2950 together in each single orbit visit
  o Repeat each set after 6 to 24 months, so 4 targets x 12 orbits x 2 epochs = 96 total orbits
  o Earliest observations likely to be in 1st quarter of 2021

• Currently working on setting up detailed scheduling and coordinated observations
  o Draft proposals to allow detailed LRP planning to be submitted during April 2020
  o Working towards locking down windows for all monitor observations by June 2020
  o 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
  o Some adjustments to exact scheduling windows may need to be finalized closer to execution
Status of Phase 2 work – T Tauri Survey Targets

• 67 Survey targets, 351 total orbits (2 – 14 orbits each)
  o All to be observed with COS G130M/1291, G160M/1611 & STIS G230L/G430L/G750L
  o All data for each target to be collected within ~ 1 day
  o Earliest observations will start in fall 2020

• Working on detailed scheduling and coordinated observations
  o 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
  o ~ 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
  o 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 ULYSES desires with impact on HST schedule
  o Finalized APT files for each target to be submitted several months prior to execution.
Technical Implementation – Automated Phase II Creation Process

- 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
Technical Implementation – Automated Phase II Creation Process

- 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
Technical Implementation – Automated Phase II Creation Process

• Working drafts of APT files and all supporting material for each target kept in Box folders
  o 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
  o 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
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

• Massive stars:
  o 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
  o 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)
• 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

<table>
<thead>
<tr>
<th>T Tauri target</th>
<th>HST Epoch 1</th>
<th>HST Epoch 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>TW Hya</td>
<td>March - April 2021</td>
<td>January - February 2022</td>
</tr>
<tr>
<td>RU Lup</td>
<td>April - May 2021</td>
<td>February – April 2022</td>
</tr>
<tr>
<td>GM Aur</td>
<td>September 2021</td>
<td>September 2022</td>
</tr>
<tr>
<td>BP Tau</td>
<td>August - October 2021</td>
<td>August - October 2022</td>
</tr>
</tbody>
</table>

• 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
  o The CIT is in contact with leads of coordinated observations as well
Community-Led Observations – Survey T Tauri Stars

- 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 ULLYES 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

- 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.
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
Scheduling of Survey T Tauri Stars

- To the extent possible, we will coordinate the HST scheduling of 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.

<table>
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<tr>
<th>Star-forming region</th>
<th>TESS Sectors</th>
<th>TESS windows</th>
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<tr>
<td>s Ori</td>
<td>32</td>
<td>November-December 2020</td>
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<tr>
<td>Ori OB1a,b</td>
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<td>CrA</td>
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</tbody>
</table>
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)
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:
  o Co-addition (identical instrumental gratings at different times or central wavelengths to build S/N or study variability)
  o Splicing (creating continuous spectral coverage with data from different instruments and/or gratings)

• The splicing algorithm will come in two varieties
  o “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.
  o “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

• 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:
  o Filtering on pre-defined data-types
  o Sortable tables of targets and their parameters
  o Interactive selection from sky maps, HR diagrams, and plots of one target parameter (e.g., mass) vs another (e.g., $A_V$)
  o Database query forms
Data Products – Quick-looks

- 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
Data Products – Website

• 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
  o Users can browse target tables and see scheduling information
  o The Quick Look tool will be launchable from a dedicated page, housing all targets
  o 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.
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
ULLYSES S/N Requirements

• Massive SMC/LMC Stars
  o COS/G130M/c1096: S/N = 20 / nine-pixel resel at 1080 Å continuum
  o COS/G130M/c1291: S/N = 30 / six-pixel resel at 1150 Å continuum
  o COS/G160M/c1611: S/N = 30 / six-pixel resel at 1590 Å continuum
  o COS/G185M/c1953: S/N = 30 / three-pixel resel at 1860 Å continuum
  o COS/G185M/c1986: S/N = 30 / three-pixel resel at 1980 Å continuum
  o STIS/E140M/c1425: S/N = 20 / two-pixel resel at 1200 Å continuum
  o STIS/E230M/c1978: S/N = 20 / two-pixel resel at 1800 Å continuum
  o STIS/E230M/c2707: S/N = 20 / two-pixel resel at 2800 Å continuum

• Massive Low Z Stars in Sextans A and NGC 3109
  o COS/G140L/c800: S/N = 15 / six-pixel resel at 1600 Å continuum

• T Tauri Stars
  o COS G130M/c1291 S/N = 15 / six-pixel resel in peak of N V 1239 Å
  o COS G160M/c1611 S/N = 20 / six-pixel resel in peak of CIV 1549 Å
  o STIS G230L/c2376 S/N = 20 / six-pixel resel in peak of Mg II 2800 Å
  o STIS/G430L S/N=20 / two-pixel resel in continuum at 4000 Å
  o STIS/G750L S/N= / two-pixel resel in continuum at 5700 Å