The ULLYSES Director’s Discretionary Program

Charting Young Stars’ Ultraviolet Light with Hubble
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_☉)
A Spectroscopic Survey of High Mass Stars

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

✅ ISM
  - Chemical abundances
  - Depletions on dust

✅ CGM
  - Kinematics
  - Metallicity
  - Spatial distribution
A Spectroscopic Survey of Young Low Mass Stars

✓ T Tauri Stars
  o Accretion physics
  o UV radiation and impact on disk evolution and planet composition and atmospheric escape
  o Time monitoring component for 4 targets (100 orbits) to study accretion variability
Overview of ULLYSES target sample

- Targets were released to the community in early 2020
- ~330 (including 90 archival) targets will be included in the ULLYSES database
- Numerous coordinated and follow-up observations planned by community (see C. Espaillat’s talk):
  - Massive stars: VLT X-Shooter
  - T Tauri stars:
    - VLT X-Shooter
    - XMM-Newton and ISS/NICER
    - Magnetic mapping with spectro-polarimetry (CFHT)
    - IR spectroscopy (IRTF)
    - Photometric monitoring with LCOGT and other ground-based observatories
    - TESS

<table>
<thead>
<tr>
<th>Region</th>
<th># ULLYSES targets</th>
<th># AR targets</th>
<th># ULLYSES orbits</th>
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<td>LMC</td>
<td>98</td>
<td>34</td>
<td>225</td>
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<td>SMC</td>
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<td>41</td>
<td>220</td>
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<td>Sextans-A</td>
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<tr>
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<td>2</td>
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<tr>
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<td>4</td>
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<td>TOTAL</td>
<td>241</td>
<td>92</td>
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Overview of massive stars

NGC3109 (15% Solar Metallicity)

E20
(O8 I)

E7
(B0-1 Ia)

O
E34
(O8 I(f))

S8
(B0 I)

s4
(O6 I)

s2
(O3-5 I)

NGC 346
LMC
50% Solar Metallicity
132 targets O2-B9

SMC
20% Solar Metallicity
106 targets O2-B9

Sextans A (8% Solar Metallicity)
Target Selection – Sampling of SpT/LC

- 4-5 O I-V per SpT/LC bin
- 2-4 B0-B1 I-V stars per bin
- 2-4 B2-B4 I per bin
- 1-2 B5-9 I per bin
Target Selection – T Tauri Star Sample

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

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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

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<tr>
<th>Target</th>
<th>RA(J2000)</th>
<th>DEC(J2000)</th>
<th>Mass (M_{\odot})</th>
<th>Radius (R_{\odot})</th>
<th>Mass Accretion Rate (M_{\odot}/yr)</th>
<th>Rotational Period (days)</th>
<th>A_V (mag)</th>
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<td>GM Aur</td>
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<td>1.75</td>
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*Robinson & Espaillat (2019)*
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 below 1150 Å with archival FUSE data or COS/G130M/1096 for O stars if cost is reasonable
- STIS/E230M/1978 for 09-B9 I
- STIS/E230M/2707 or COS/G185M/1953+1986 for B5-9 I

### Graph

- **Sk-68 26 (BC2la)** (LMC)
- **STIS E140M or COS/G130M/1096**
- **STIS E230M/1978**

### Table

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**Legend:**

- X: Observed
- : Not Observed
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/2635 + 2950
Observing Status

• Massive stars:
  o LMC: 13 targets observed and 10 more will be observed by 10/31/2020
  o SMC: 25 targets observed
  o 65 fully archival targets in LMC+SMC combined
  o Remainder of LMC/SMC and low metallicity targets will observed over Cycles 28 and 29
  o HST/WFC3 pre-imaging scheduled for October-November 2020 (NGC 3109) and March 2021 (Sextans A) – F225W, F275W, F336W, F475W, F814W – Spectroscopy with COS/G140L/800 will follow

• T Tauri stars:
  o 13 Orion T Tauri stars to be observed in November-December 2020 in coordination with TESS
  o A fraction of T Tauri stars will be observed in coordination with TESS in March-June 2021 (the remainder will be observed at later dates)
  o 4 monitoring T Tauri stars will be observed in spring-summer 2021 (epoch 1) and 2022 (epoch 2)

• Observing status and scheduled can be checked at https://ullyses.stsci.edu
Data Products – Overview

• High-Level Science Products (HLSPs):
  - STIS and COS calibrated pipeline products and acquisition images
  - Co-added spectra for each grating setting
  - Spliced spectra (multiple grating settings, multiple instruments, e.g., FUSE + COS/STIS)

• Database
  - Repository of meta data that describes
    - New ULLYSES Data: coordinates, instrumental configurations, exposure times, etc.
    - Archival/Ancillary Data: archival HST and FUSE spectra; links to spectra from other facilities (e.g., VLT, LCOGT, XMM etc)
    - Targets: fundamental stellar parameters (with references)
  - Used to construct web interfaces and enable queries
    - Search form, filtering to refine queries, visual selection from interactive plots, API

• Quick-look tools: interactive plots of spectra with interactive S/N calculations

• Jupyter notebooks: demonstrate data handling and analysis techniques

• Website (https://ullyses.stsci.edu)
Data Products – Overview

• **DR1 planned for November 5, 2020:**
  - LMC/SMC targets observed up to October 15, 2020 (including archival targets)
  - Tabular search for targets
  - Link to tar-ball for download
  - No database yet

• **DR2 planned for spring 2021**
  - Database with UI (form + table)
  - All LMC/SMC targets observed to that point
  - NGC 3109 Images and photometry
  - HST spectra and LCOGT photometry for Orion T Tauri stars

• Quarterly data releases
Back-up slides
• 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 (Centro de Astrobiología (CSIC-INTA))
  o Chris Johns-Krull (Rice University)
  o Derck Massa (Space Science Institute)
  o Joan Najita (National Optical Astronomy Observatory)
Timeline and Milestones up to now

• 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
• February 18, 2020: Release of full target samples
• June 2020: First observations of LMC/SMC stars
• July 2020: Launch of website (ullyses.stsci.edu)
• August 2020: Beginning of LCOGT monitoring observations of Orion T Tauri stars
Timeline and Milestones

- November 5, 2020: First data release (LMC/SMC only)
- November-December 2020: HST observations of Orion T Tauri stars (with TESS, LCOGT)
- Spring 2021: DR2 (includes functional database and user interface – this is a working goal)
- Spring-summer 2021: Epoch 1 of monitoring stars, and more survey CTTS
- Quarterly data releases through the end of the program