



Continuing the Voyage of Discovery

March 11-14, 2024



STScI

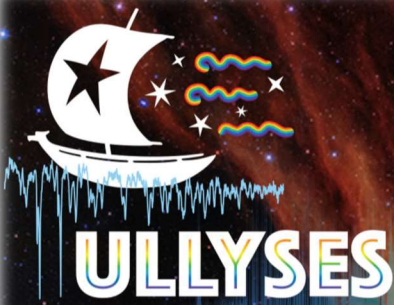


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The observational phase of the HST Ultraviolet Legacy Library of Young Stars as Essential Standards (ULLYSES) program initiated by the STScI Director in 2019 was completed in 2023. ULLYSES provides a legacy spectroscopic UV dataset for studying star formation both locally and across the universe. The program consists of two distinct components: ultraviolet-optical-infrared spectroscopy of T Tauri stars in star-forming regions of the Milky Way, and ultraviolet spectroscopy of metal-poor OB stars in the Magellanic Clouds and other nearby low metallicity dwarf galaxies. The dataset will establish a foundation for studying the final stages of low-mass star formation, and obtaining fundamental stellar parameters as a function of metallicity for high-mass stars. Although ground-based data contain much information necessary to advance understanding of these phenomena, ultraviolet spectroscopy provides powerful diagnostic information that cannot be obtained in any other way. This ambitious, multi-faceted project used 987 HST orbits in Cycles 27-29, making it the single largest program ever executed by HST.

The ULLYSES observations are complemented by community-led, ancillary ground-based surveys that will considerably enhance the legacy value of the program. With the completion of the ULLYSES observations and ancillary programs, a variety of data products are now available, both from STScI and from the community. Initial results based on ULLYSES data are beginning to appear in the refereed literature. The time is ripe to review plans for scientific exploitation of the data, and launch new plans for research in additional areas that utilize these foundational data, e.g., interstellar medium, star and galaxy formation at high redshift, and star-planet interactions.



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**Continuing the Voyage
of Discovery** March 11-14, 2024

Workshop Agenda



STScI

MONDAY, MARCH 11

TIME	TITLE	SPEAKER
8:30 AM	<i>Morning Coffee Break</i>	
9:00 AM	<i>Welcome Message</i>	
9:15 AM	<i>Why is the UV important for young low mass, cool stars?</i>	<i>Nuria Calvet</i>
9:45 AM	<i>Massive star science goals, importance of UV</i>	<i>Jorick Vink</i>
10:15 AM	<i>Design and Implementation</i>	<i>Julia Roman-Duval, Alex Fullerton, Will Fischer</i>
10:45 AM	<i>Mid-Morning Coffee Break and Poster Session</i>	<i>Sen, Sarwar, Chu, Horton, Soto, Nayak</i>
11:15 AM	<i>Description of Data Products</i>	<i>Jo Taylor</i>
11:45 AM	<i>ODYSSEUS and PENELLOPE: complementing and supporting the science outcome of the ULLYSES program</i>	<i>Carlo Manara</i>
12:15 PM	<i>XShootU: The ULLYSES and X-Shooter massive stars collaboration</i>	<i>Frank Tramper</i>
12:45 PM	<i>Lunch Break</i>	
1:45 PM	<i>Unique insights on massive stars from UV spectroscopy</i>	<i>Varsha Ramachandran</i>
2:15 PM	<i>Deriving the stellar and wind properties of massive stars from ULLYSES and XShootU</i>	<i>Joachim Bestenlehner</i>
2:45 PM	<i>Tests of population synthesis models courtesy of integrated UV spectroscopy of the Tarantula Nebula</i>	<i>Paul Crowther</i>
3:00 PM	<i>ULLYSES investigates the bi-stability jump</i>	<i>Olivier Verhamme</i>
3:15 PM	<i>PM Coffee Break</i>	
3:45 PM	<i>The XshootU Stellar Library: Hot Low Metallicity Stars</i>	<i>Lucimara Martins</i>
4:15 PM	<i>3D unified model atmospheres with winds for hot, massive stars</i>	<i>Jon Sunqvist</i>
4:45 PM	<i>New Observations of Very Metal-Poor O Stars to Enhance the Impact of ULLYSES</i>	<i>Grace Telford</i>
5:00 PM	<i>Poster Pop</i>	<i>Sen, Sarwar, Chu, Horton, Walter, Nayak</i>

TUESDAY, MARCH 12

TIME	TITLE	SPEAKER
8:30 AM	Morning Coffee Break	
9:00 AM	The significance of HST to accretion studies in classical T Tauri stars	Caeley Pittman
9:30 AM	UV Lines Modeling of T Tauri Stars in ULLYSES Observations	Thanawuth Thanathibodee
10:00 AM	Line Emission from FUV-heated disk winds	Uma Gorti
10:30 AM	Mid-Morning Coffee Break and Poster Session	Gunther, Walter, Singh, Majidi, Louison, Robinson
11:00 AM	Global 3-D Magnetospheric Accretion Simulations	Zhaohuan Zhu
11:30 AM	Characterizing outflows in T Tauri stars with ULLYSES data	Ana Gomez De Castro
12:00 PM	ULLYSES unveils links between protoplanets, disk substructures and disk winds	Justyn Campbell-White
12:15 PM	The power of simultaneous X-ray observations to study accretion in CTTS	Christian Schneider
12:30 PM	Lunch Break	
1:30 PM	The LMC's Galactic Wind through the Eyes of ULLYSES	Kat Barger
2:00 PM	Sailing on the winds of massive stars with ULYSSES	Dorottya Szecsi
2:30 PM	Theoretical Spectra for Massive Stars Observed by ULLYSES	Sara Heap
2:45 PM	Poster Pop	Sen, Günther, Singh, Majidi, Louison, Robinson
3:00 PM	Afternoon Break and Poster Session	
3:30 PM	Hands-on session	Jo Taylor, Rachel Plesha, and Elaine Frazer

TIME	TITLE	SPEAKER
8:30 AM	Morning Coffee Break	
9:00 AM	The Impact of UV Radiation on Protoplanetary Disks: An Observational Perspective	Nicole Arulanantham
9:30 AM	The impact of UV emission from T Tauri star on planets	James Owen
10:00 AM	Photoevaporation of disks from UV radiation emitted by T Tauri stars	Karina Mauco
10:30 AM	Mid-Morning Coffee Break and Posters	Deshmukh, Micolta, Poudel, Krishnaro, Zamora
11:00 AM	First Detection and Modeling of Spatially Resolved Ly α in TW Hya	Seok-Jun Chang
11:15 AM	Reconstructing Ly α Emission Profiles of Classical T Tauri Stars	Edwin Cruz Aguirre
11:30 AM	Atomic Depletions as a Guide for the Formation of Interstellar Dust in the Magellanic Clouds	Ed Jenkins
12:00 PM	Outflows in the LMC over sub-kpc scales, as impacted by star formation and Milky Way's CGM	Yong Zheng
12:30 PM	Lunch Break	
1:30 PM	Tomography of clouds in the MW using ULLYSES	Anyana Goon Tuli
1:45 PM	Benchmarking quantitative spectroscopy in ULLYSES/XShootU and Analysis of B-supergiants in the SMC	Mattheus Bernini Peron
2:00 PM	Discussion - What other datasets should be collected to enhance the return of ULLYSES?	
2:45 PM	ULLYSES: sailing from the past to future	Lida Oskinova
3:15 PM	Afternoon Break and Poster Session	Deshmukh, Micolta, Poudel, Krishnaro, Zamora
3:45 PM	Looking forward with ODYSSEUS	Catherine Espaillat
4:15 PM	Accretion Properties of a Young Brown Dwarf	Toni Panzera
4:30 PM	Poster Pop	Deshmukh, Micolta, Poudel, Zamora

WEDNESDAY, MARCH 13

<i>TIME</i>	<i>TITLE</i>	<i>SPEAKER</i>
<i>4:45 PM</i>	<i>Wrap Up</i>	
<i>6:00 PM</i>	<i>Workshop Dinner at Gertrude's Restaurant</i>	

THURSDAY, MARCH 14

TIME	TITLE	SPEAKER
8:30 AM	<i>Morning Coffee Break</i>	
9:00 AM	<i>Young stars and their circumstellar environments with future ground- and space-based observatories</i>	<i>Kevin France</i>
9:20 AM	<i>The future: next generation observatories and prospects for massive stars</i>	<i>Miriam Garcia</i>
9:45 AM	<i>Synergies between ULLYSES massive stars and SDSS V Local Volume Mapper</i>	<i>Aida Wofford</i>
10:00 AM – 1:00 PM	<i>Parallel sessions</i> <ol style="list-style-type: none"><i>1. Hack session to draft precursor science cases for HWO</i><i>2. In-depth data products exploration (complementing Tuesday's session)</i><i>3. Other (participants can express interests for collaboration meetings or topical discussions, we will support the organization)</i>	
11:00 AM	<i>Mid-Morning Coffee Break</i>	
1:00 PM	<i>Lunch Break</i>	



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Workshop Abstracts



STScI

ULLYSES: Continuing the Voyage of Discovery Workshop Abstracts

Invited Talks

The Impact of UV Radiation on Protoplanetary Disks: An Observational Perspective by Nicole Arulanantham

Astronomers have made groundbreaking detections of exoplanet atmospheres over the last ~15 years, work that was recently accelerated by the launch of JWST. Tracing the evolutionary history of these systems, a critical step toward eventually assessing their habitability, requires robust initial conditions derived at the onset of planet formation. The UV radiation fields generated by low-mass young stars play an important role in setting these initial conditions, by regulating the thermal structure and resulting chemistry within circumstellar protoplanetary disks. In this talk, I will provide an overview of past observational results showing evidence for UV-driven chemistry in protoplanetary disks. I will discuss how this work has progressed with ongoing modeling efforts and recent insights into the UV properties of young stars observed through the ULLYSES program. Finally, I will conclude with a summary of remaining open questions that we must ultimately address in order to map the chemical properties of planet formation across different stellar environments.

The LMC's Galactic Wind through the Eyes of ULLYSES by Kat Barger

Outflows from galaxies are known to have a significant impact on the physical processes driving star formation and the evolution of galaxies. These winds are complex, so outflows must be observed at sub-kpc scales to tie wind properties with local driving sources. The Large Magellanic Cloud offers an opportunity to resolve star-formation-driven outflows at the right scales: it is face on, lacks an AGN, and individual sources are resolved in stars, gas, and dust. We are leading an HST Archival Legacy program to map the LMC's galactic wind using massive stars observed in ULLYSES together with a wealth of ancillary HI, H-alpha, and O VI observations. Using the detailed profiles of absorption in multiphase diagnostic UV ions, we are (1) characterizing the ionization state and kinematics of the wind, (2) investigating the impact of the 30 Doradus starburst on the flow, and (3) assessing whether or not 30 Doradus is responsible for producing the high metallicity filament of the Magellanic Stream. This large-scale, resolved census of the LMC's outflow will fill a critical gap in our knowledge of how winds work with an unprecedentedly large sample of measurements right at the scale of the driving forces, in a galaxy where all the major influences can be resolved.

Deriving the stellar and wind properties of massive stars from ULLYSES and XShootU by Joachim Bestenlehner

I will review the approaches used to determine the physical and wind properties of massive stars, and present a homogeneous XShootU analysis of the entire ULLYSES sample using state of the art spectroscopic analysis techniques. I will highlight limitations of an optical-only approach and discuss the key role played by UV spectroscopy towards our understanding of the wind properties of massive stars. The review closes with an overview of on going projects and early combined UV+optical results.

Why is the UV important for young low mass, cool stars? by Nuria Calvet

In this talk, I will describe the impact of the observations provided by ULLYSES on our understanding of the processes that produce the emission lines and excess continua characterizing T Tauri stars - a few million years old, low mass stars. I will mention the different areas in which knowledge of the FUV and NUV fluxes provided by ULLYSES is necessary to interpret observations, from the X-rays to the sub-millimeter, and give a general overview of what will be presented in the conference. Lastly, I will highlight a particularly remarkable result of ULLYSES: the programs that sprung from it - ODYSSEUS and PENELLOPE - that have brought together most people working on T Tauri stars and related objects into on-going, worldwide collaborations.

Looking forward with ODYSSEUS by Catherine Espaillat

ULLYSES offers a unique opportunity to deepen our understanding of the connection between accreting young stars and their protoplanetary disks. This once-in-a-lifetime dataset motivated the creation of Outflows and Disks around Young Stars: Synergies for the Exploration of Ulyses Spectra (ODYSSEUS), a team of over 100 young star experts from around the world. The goals of ODYSSEUS are to (1) measure how the accretion flow depends on the accretion rate and magnetic structures, (2) determine where winds and jets are launched and how mass loss rates compare to accretion, and (3) establish the influence of FUV radiation on the chemistry of the warm inner regions of planet-forming disks. ODYSSEUS has also gathered contemporaneous observations at optical and near-IR wavelengths, most notably through PENELLOPE, to enhance the impact of the ULLYSES dataset. Here I will review results from ODYSSEUS as well as work that is underway. I will also discuss pathways for future work with HST as well as with other facilities including JWST and ALMA.

Young stars and their circumstellar environments with future ground- and space-based observatories by Kevin France

Significant observational investment on the ground and in space over the past two decades have shaped our view of young stars, how they accrete mass and disperse angular momentum, and how they influence the circumstellar disks and planets that orbit them. From mass accretion studies with HST, to the molecular gas content at terrestrial planet-forming radii with the VLT and Keck, to now seeing the first UV photochemistry signatures on exoplanets with JWST, these data form the basis for our understanding of young stars and their environments.

In this talk, I will describe how future observatories, including those under construction (ELTs), those proposed (Probe missions), and those just beginning their formulation (HWO), will expand on this work to make observational leaps in these areas. I will focus on three axes along which future observatories have the opportunity to make order-of-magnitude gains over our current capabilities and data sets: first, I will describe the power of multi-object spectroscopy, particularly at UV wavelengths, to access new disk diagnostics and dramatically increase the statistics for star/disk studies. Second, I will discuss the impact of increased angular and spectral resolution for the study of planets and disks around young stars. Finally, I will talk about the potential for simultaneous panchromatic observations and new spectral windows to provide new insights on protostellar mass accretion and the molecular gas reservoirs in planet-forming disks.

The future: next generation observatories and prospects for massive stars by Miriam Garcia

UV spectroscopy has been fundamental to progress on stellar astrophysics, with the ULLYSES initiative ensuring a legacy dataset that will warrant deep, thorough studies of low and high mass stars. However, many questions remain unanswered that require new UV instrumentation or larger UV observatories, and stimulate devising new missions to continue the scientific access to the UV range. In this talk I will outline the landscape of future UV missions and ultimately the Habitable Worlds Observatory, and I will showcase how they can contribute to the field of massive stars empowered by the incoming generation of 30m-class ground-based telescopes.

Characterizing outflows in T Tauri stars with ULLYSES data by Ana Gomez de Castro

The first observational signatures used to identify the T Tauri stars (TTs) was the detection of prominent emission lines and collimated large-scale jets. Both signatures are related with the prominent outflows from these sources, especially in the early Class 0-I stages. Outflows are ejected from three sources in the TTs environment: the star, the disk and the magnetically mediated interface between the disk and the star. In this contribution, the main models for the wind drives and the current status of research in the field will be reviewed.

Then, the characteristics of the data obtained through the ULLYSES program will be described as well as its potential for the study of the nature of the outflows. Important tracers of the outflows are MgII, FeII, CII lines as well as in the semi-forbidden transitions of CIII], SiIII], OIII] and CII] observed in the survey. Also, the high energy UV radiation from the star and the star-disk interface plays an important role in driving photo-evaporative flows from the disk.

Line Emission from FUV-heated disk winds by Uma Gorti

FUV photons irradiate the surfaces of protoplanetary disks and are a dominant heating mechanism in these regions. FUV photons can both launch photoevaporative that drive disk dispersal, and heat the base of magnetically driven winds that drive disk accretion. FUV photoprocessing dictates gas chemistry and can produce unique line emission signatures that can be used to diagnose conditions in the wind-emitting regions. I will describe theoretical modeling of FUV irradiation that makes use of high resolution HST spectra to determine photochemistry in the surface regions and present recent results on applications to extant observations. The goal of the modeling is to better understand the driving mechanisms of disk winds and the implications for disk evolution.

Atomic Depletions as a Guide for the Formation of Interstellar Dust in the Magellanic Clouds by Edward Jenkins

The LMC and SMC are low metallicity systems that are close enough that HST can obtain spectra of early-type stars with sufficient quality to yield good measurements of absorption features arising from interstellar gases. By comparing element abundances in such material to stellar abundances, we can learn about the character of depletion caused by dust formation. In turn, we gain insights on the composition of dust grains and conditions that regulate the ratio of dust to gas. Within the scope of the ULLYSES program plus additional data from other observations in the archive, we have measured features arising from the elements Mg, Si, P, Ti, Cr, Mn, Fe, Ni, and Zn in the STIS echelle spectra of 64 stars in the LMC and 63 stars in the SMC. Unfortunately, the most abundant dust constituents C and O cannot be measured.

We find that for differing dust concentrations, different elements deplete in lock-step with each other but at different rates, repeating a behavior found for the Milky Way. Our results show that when the metallicity of a system decreases, the ratio of dust to gas decreases even more rapidly. The depletion patterns for different elements are similar to those found for the Milky Way, but with some exceptions. Atomic depletions are more severe for sight lines with higher hydrogen column densities, a result that can arise from (1) more complete dust formation at higher densities and (2) probable dust destruction in low density gas that has been subjected to shocks from supernovae. The reduction caused by supernova shocks is supported by marginal evidence that gases with higher velocity dispersions have weaker depletions.

The XshootU Stellar Library: Hot Low Metallicity Stars by Lucimara Martins

Stellar spectral libraries are one of the main ingredients of stellar population models, powerful tools in the study of unresolved stellar systems. They can be either empirical or theoretical. Empirical libraries are based on observations, meaning that all features in models generated with them will be real. The disadvantage is that it will always be limited by the stars we can observe. Theoretical libraries do not have this setback, since it is possible to generate stellar spectra with any atmospheric parameters desired. However, models are based on approximations and simplifications, therefore not quite yet able to reproduce all features of real stellar spectra. That is why, despite the existence of several empirical libraries, there are still efforts to push their boundaries. One of the major deficiencies of the empirical libraries available today is the coverage of hot/young stars and low metallicity. In this work we present the XShootU stellar library, the most recent effort to try to fill this gap. The ULLYSES program devoted 450 HST orbits to create an UV spectroscopic library of 160 massive stars in the LMC and the SMC. It uniformly samples the parameter space of spectral type and luminosity class for massive OB stars. In parallel to ULLYSES, XShootU, is collecting high S/N spectra with $R \sim 10000$ over the spectral range 300 nm to 2.5 microns of these stars. This will vastly extend the power of ULLYSES spectra by merging the UV, optical, and NIR. ULLYSES + XShootU is by far the most complete, highest-S/N, and highest resolution library of hot, massive stars with the broadest spectral coverage. In combination with other stellar libraries available in the literature, XshootU will allow self-consistent population synthesis models of systems hosting both young and old stars.

ODYSSEUS and PENELLOPE: complementing and supporting the science outcome of the ULLYSES program by Carlo Manara

A large fraction of the ULLYSES program was devoted to the study of low-mass T-Tauri young stellar objects. The community working in this field has joint forces since the beginning of the ULLYSES program to exploit the wealth of scientific data available from this HST program. In this talk I will review the efforts done as a community, as part of the ODYSSEUS collaboration, and of the complementary programs that have been carried out with other ground-based and space-based observatories, such as the Large Program PENELLOPE carried out with the ESO Very Large Telescope (VLT), to complement the HST data with additional broad wavelength-coverage and higher resolution spectra.

I will outline the design, science goals, and synergies with the UV HST data, and show-case some of the scientific results and the plans for the further data exploitation in the years to come.

Photoevaporation of disks from UV radiation emitted by T Tauri stars by Karina Mauco

Circumstellar disks are observed to evolve and finally disperse over a timescale of a few Myr, which is comparable to the timescales for planet formation. UV radiation from the central star drives disk dispersal through internal photoevaporation strongly influencing the assembly and architecture of planetary systems, particularly in the inner 10 au where rocky planets form. This high-energy radiation field will mediate how the properties of the gas in the disk change, particularly how the chemical abundances and excitation conditions evolve along with inner disk dust evolution. UV spectroscopic diagnostic includes H₂ and CO fluorescence emission produced by the irradiation of Ly α photons generated at the accretion shocks. Thanks to the ULLYSES program, we now have surveyed tens of pre-main sequence stars in the UV allowing for an in-depth characterization of the molecular and atomic gas in the inner disk, opening new ways to study key trends between gas properties, UV radiation fields, disk winds and jets, and disk evolution. A complete scenario, however, requires the inclusion of stellar feedback from massive stars which disperse the outer disk of nearby systems. This process is understood to be the dominant environmental influence acting on planet-forming disks in typical star-forming regions. In this talk, I will present how UV-optical spectroscopy combined with interferometry observations of T Tauri stars have contributed to the current understanding of disk photoevaporation from UV radiation and its role in disk evolution.

ULLYSES: sailing from the past to future by Lidia Oskinova

The UV spectroscopy is the best method to study winds of hot massive stars. The consistent analysis of the UV, optical and IR spectra is necessary to determine stellar parameters, and, on this basis, to achieve understanding of the role massive stars play in cosmos. Stellar wind spectroscopy has significant international community, uses sophisticated methods, and delivers fundamental results quickly absorbed by various other branches of astronomy. In response to the ULLYSES initiative, the massive star community self-organized seeking the optimum way to exploit and utilize the ULLYSES data. Especially significant is the XShootU observing program in optical and near-IR which resulted in obtaining spectra for each of the ULLYSES targets. In this talk I will briefly outline the path forward to wrap up the analysis of ULLYSES and XSHOOTU data. I will also discuss the possibility and the need for follow up observations, with a special emphasis on observations in X-rays. I will present some of the first results of the XShootU collaboration, discuss the limitations of current datasets, and show that completing ULLYSES starts a new scientific Odyssey in the low-metallicity Universe.

The impact of UV emission from T Tauri star on planets by James Owen

UV emission can heat the upper atmospheres of close-in planets, driving mass-loss. This is most important during the T Tauri phase when the UV emission from the planet's host star is strongest. The mass loss that occurs during the planet's early lifetime can cause a dramatic evolution in the mass in the planet's atmosphere, as well as its composition. I will discuss this process, demonstrating how understanding a star's UV spectrum is critical to getting the mass-loss model correct, as well as how we are observing these outflowing planetary atmospheres both in the UV and at other wavelengths.

The significance of HST to accretion studies in classical T Tauri stars by Caeley Pittman

Classical T Tauri stars coevolve with their surrounding protoplanetary disks, with the two being connected by the stellar magnetic field. This connection is strongest in the inner disk where terrestrial planets may form. Disk material flows along magnetic field lines, crashing onto the star and producing an accretion shock with emission that dominates in the near-ultraviolet (NUV). In this talk, I will present magnetospheric accretion model fits to NUV-optical spectra of 60 classical T Tauri stars as part of the Outflows and Disks around Young Stars: Synergies for the Exploration of ULLYSES Spectra (ODYSSEUS) Survey. We used contemporaneous VLT spectra from the PENELLOPE Large Programme to determine stellar parameters and measure accretion-induced veiling. We then utilized 2,000-10,000 Angstrom HST/STIS spectra from the ULLYSES program to model accretion shock emission. We find that the best-fit accretion flow structure and extinction measurement strongly depend on whether or not NUV spectra are included. This has significant implications for the future of accretion studies once NUV spectral observations are no longer available.

Unique insights on massive stars from UV spectroscopy by Varsha Ramachandran

Hot massive stars have their energy distribution peaks in the UV range, making UV spectroscopy an ideal tool for studying their properties. This talk will explore how UV spectroscopy, when integrated with state-of-the-art atmosphere models, provides valuable insights into the physical properties of massive stars. Importantly, due to the presence of numerous resonance lines that are more sensitive to lower mass-loss rates than conventional optical wind lines, such as H alpha, UV spectra are crucial for studying the stellar wind properties in low-metallicity environments. I will discuss the key diagnostic lines in the UV range for OB stars to understand their stellar and wind parameters, along with an overview of the empirical results from recent studies. The abundance determination via UV spectrum analysis, with a particular focus on the abundance of Fe in the iron forest, will also be addressed. I will further discuss how UV spectroscopy provides diagnostics to identify and characterize massive stars in binaries.

Overview and initial results of ULLYSES by Julia Roman-Duval

Specifically selected to leverage Hubble's unique ultraviolet (UV) capabilities, the Hubble Ultraviolet Legacy Library of Young Stars as Essential Standards (ULLYSES) is a large Director's Discretionary program of approximately 1000 orbits --- the largest ever executed with Hubble. The ULLYSES program recently completed an ultraviolet spectroscopic library of young high- and low-mass stars in the local universe, leveraging a considerable amount of archival observations. Half of the program is dedicated to the study of accretion physics through UV-optical-NIR spectroscopy of young, low mass accreting (T Tauri) stars in 8 star-forming regions in the Milky Way. The other half of the program is focused on the characterization of the winds and photospheres of massive stars as a function of stellar parameters, through UV spectroscopy toward O and B stars sampling temperature, luminosity class, and metallicity in nearby galaxies. While the scientific objectives of ULLYSES were defined by the community through a UV legacy working group of experts, the implementation of the program was carried out at STScI by a Core Implementation Team (CIT) composed of scientists, technical staff, software engineers, and public outreach experts, and under the guidance of a Science Advisory Committee (SAC) composed of community experts. The ULLYSES observations of 220 targets were completed in July 2023, and the final data release, which includes new and archival observations of about 500 stars, occurred in December 2023. In this talk, we will provide important information related to the objectives of the program; the design of the program, in particular the observing strategy and target selection, which were carefully optimized to achieve those science objectives; the execution of ULLYSES, and exciting initial results.

3D unified model atmospheres with winds for hot, massive stars by Jon Sundqvist

Observations and theory show that the atmospheres and winds of hot, massive stars are highly turbulent, variable, and multi-dimensional. But while 3D model atmospheres of sun-like stars have been on the market for quite some time, for hot, massive stars we still rely solely on results derived from (inadequate?) 1D and stationary simulations. As such, when performing quantitative spectroscopy (e.g., from ULYSSES data), present-day modeling tools need to introduce ad-hoc quantities such as photospheric macro and microturbulence, wind clumping, etc, to fit the observations.

In this talk we present first multi-D, time-dependent, radiation-hydrodynamical simulations for hot, massive stars that in one unified approach encapsulate the deeper sub-surface envelope and atmosphere as well as the overlying supersonic radiation-driven wind outflow; an overarching aim is to develop a framework that is free from the ad-hoc prescriptions that plague present-day 1D models.

We analyze a first small set of such simulations (e.g., for O- and Wolf-Rayet stars), and compare to atmospheric structures predicted by their 1D counterparts. Routes toward performing spectroscopy using 3D model atmospheres with winds are discussed, as well as the need for better calibration of current 1D models to account for 3D effects when deriving fundamental stellar and wind parameters from observed spectra.

Sailing on the winds of massive stars with ULYSSES by Dorottya Szecsi

Pun intended, I am going to review stellar theory and current challenges in massive-star research, with special focus on how the ULYSSES data can help to solve them. References to Greek mythology may abound.

ULLYSES Data Products by Jo Taylor

The UV Legacy Library of Young Stars as Essential Standards (ULLYSES) implementation team at STScI delivered its final data release (DR7) in December 2023. DR7 includes ~4000 high-level science products (HLSPs) for 495 stars. HLSP types include co-added spectra, abutted spectra, sub-exposure and exposure level spectral time-series, photometric timeseries, custom-calibrated STIS spectra, and drizzled images. The ULLYSES HLSP collection uses data from HST (COS, STIS, WFC3), FUSE, and the Las Cumbres Observatory (LCO). Products can be queried based on observational (e.g., instrument, grating) and/or astrophysical metadata collected from the literature (e.g., spectral type, stellar mass, accretion rate) and downloaded from a dedicated ULLYSES catalog integrated in MAST. Individual contributing COS and STIS exposures can be retrieved from the MAST portal. In this talk, we will present the ULLYSES data products, the decision-making behind their design, and the platform developed to disseminate them.

UV Lines Modeling of T Tauri Stars in ULLYSES Observations by Thanawuth Thanathibodee

Far-UV spectra of Classical T Tauri stars (CTTS) are abundant in atomic and molecular emission lines originating from various components in the stars' circumstellar environments. Several hot atomic lines are ubiquitous in T Tauri spectra and have been the subjects of many studies in the past. Nevertheless, many of these lines' formation mechanisms are poorly understood. The multi-wavelength contemporaneous observations by HST ULLYSES and its community-led ancillary programs provide a unique opportunity to study the formation of these hot atomic lines. Here, we present a self-consistent model of the Carbon IV doublet, one of the brightest lines in CTTS FUV spectra associated with accretion. Using constraints from accretion shock and accretion flow modeling, we reconstruct the C IV line fluxes and profiles of a sample of ULLYSES targets, including those in Orion OB1 and the ULLYSES monitoring targets. Our results provide insight into the properties of accretion shock and showcase the C IV doublet as a probe of elemental abundance in the inner region of protoplanetary disks where rocky planets are thought to form.

XShootU: The ULLYSES and X-Shooter massive stars collaboration by Frank Tramper

In this talk I will introduce the XShootU project, an open international collaboration initiated by the massive stars IAU commission G2. XShootU complements the ULLYSES UV data of massive stars with spectra taken with the X-Shooter spectrograph on ESO's Very Large Telescope, covering the full near-UV to near-IR wavelength region (300-2500 nm). These spectra enable the derivation of key stellar parameters which cannot be accurately obtained from the UV alone, such as effective temperature and surface gravity. I will discuss the plethora of scientific questions the XShootU collaboration aims to tackle using the combined HST and X-Shooter data sets. I will also present the upcoming first public data release, which contains the near-UV and optical data and includes slit-loss corrected, telluric absorption corrected, absolute flux calibrated, and normalized spectra.

The nature-nurture dilemma in planet and star formation by Eva Villaver

Stars and planets do not form in isolated environments. Most stars grow in clusters and can therefore be affected by processes induced by the energetic emission from nearby massive stars. In this talk, the impact of winds and radiation from massive stars on low-mass star formation and disk evaporation will be reviewed. In particular, how the evolution of objects immersed in such environments may be affected.

Massive star science goals, importance of UV by Jorick Vink

HST observes hundreds of massive stars in the Small and Large Magellanic Clouds, along with a few dwarf galaxies with even lower metallicity (Z). The close proximity of these galaxies positions them as ideal laboratories for investigating the ionizing feedback produced by low- Z stars. According to radiation-driven wind theory, stellar winds are expected to exhibit a notable dependence on the iron content of the host galaxy. While initial studies seem to support the predicted Z -dependent mass-loss, the UV region with its distinctive P Cygni lines plays a crucial role in testing these predictions on a significant sample for the first time. In this talk, I outline the key scientific questions that the massive star community anticipates to address with ULLYSES in the coming years. ULLYSES will have a lasting impact for our understanding of massive star feedback, stellar evolution, stellar populations, and gravitational wave events in low- Z environments.

Outflows in the LMC over sub-kpc scales, as impacted by star formation and Milky Way's CGM by Yong Zheng

The Large Magellanic Cloud (LMC) is home to many HII regions, which may lead to significant outflows that await to be investigated. In this talk, I'll present recent results on quantifying disk-wide, warm, ionized outflows in the LMC using stellar sight lines from the ULLYSES program. I will present a new stellar continuum fitting algorithm based on the concept of Gaussian Process regression to minimize contamination from stellar features on interstellar absorption lines. I'll show that the LMC bulk outflows are gravitationally bound to the galaxy with velocities of ~ 20 - 60 km/s, and they are likely to be driven by the LMC's present-day star-formation activities. I will also show that the outflows exhibit signs of co-rotating with the LMC disk but at a slower rate, and their kinematic signatures do not seem to be significantly impacted by external forces. I will discuss the potential existence of a bow shock leading the LMC that may shield the outflows as the LMC travels through the MW's CGM.

Global 3-D Magnetospheric Accretion Simulations by Zhaohuan Zhu

Magnetospheric accretion is a universal process occurring in magnetized astronomical objects, ranging from neutron stars and white dwarfs to young stars (YSOs) and planets. In the context of neutron stars, this process is linked with phenomena such as X-ray pulsars and ultra-luminous X-ray sources (ULXs). For YSOs, it results in ultraviolet (UV) excess and atomic emission lines. Despite the wide variance in the observation energy range, the underlying physical accretion process exhibits many similarities, primarily due to the governing role of magnetic fields. Understanding these dynamic processes is essential for interpreting observational data and sheds light on the impact of accretion on star/planet evolution. We have carried out first-principle three-dimensional magnetohydrodynamic (MHD) simulations to study magnetospheric accretion onto young stars. I will present the physical insights gained from these simulations, which include filamentary accretion onto stars, asymmetric disk structures, variability in accretion, outflow structures, and the influence of stellar spin. Finally, I will explore the potential observational implications of these findings.

Contributed Talks

Reconstructing Ly α Emission Profiles of Classical T Tauri Stars by Edwin Cruz Aguirre

Far-ultraviolet (FUV) emission from Classical T Tauri Stars (CTTSs) is dominated by the broad H I Lyman α (Ly α) emission feature. This emission is a primary driver of photochemistry and fluorescence within the protoplanetary disks (PPDs) of CTTSs. Direct observations of these Ly α profiles prove to be impossible due to line-of-sight absorption of atomic hydrogen present in outflowing disk material and in the interstellar medium. Ly α emission from the Earth's geocorona further obscures stellar Ly α profiles when observing with point-source FUV spectrographs such as the Cosmic Origins Spectrograph (COS) on board the Hubble Space Telescope (HST). A common method for determining the Ly α emission profiles of CTTSs is through profile reconstruction, utilizing observations of Ly α -induced H₂ and CO fluorescence within PPDs. Alternatively, the Ly α profile can be reconstructed from direct Ly α observations by accounting for the various sources of absorption and emission. We present a method for direct Ly α reconstructions by adapting main sequence stellar Ly α reconstruction techniques to CTTSs. In a sample of 17 CTTSs observed with HST/COS we find general agreement between our results and those derived from fluorescent reconstructions, to within a factor of 5. We discuss complements between the Ly α reconstruction methodologies, and plans for reconstructing the Ly α profiles of CTTSs observed through the ULLYSES program.

ULLYSES unveils links between protoplanets, disk substructures and disk winds by Justyn Campbell-White

I will present a case study of results from the ULLYSES low-mass star, PDS 70. In order to investigate potential connections between winds, disk substructures, and planets, we turn to the one system where we have directly detected the protoplanets. I will show how the HST UV spectra complement the optical and NIR wavelength data, allowing us to fully characterize the inner-disk of this system.

We have carefully applied established techniques to the high-resolution ground-based spectra to reveal previously unseen forbidden emission profiles. These results suggest a significant wind originating from the inner-disk. The HST ULLYSES spectra also confirm the presence of molecular hydrogen in the inner-disk. Mass accretion rate measurements from the HST spectra are concurrent with those from the optical spectra. We compare the wind results and measurements of the mass accretion rate and disk properties to those of other weakly accreting young stars and those with transition disks and highlight the power of the wide wavelength spectral coverage made possible by ULLYSES.

This presentation will also showcase the open-source package, STAR-MELT, which was designed for efficient emission line analysis of the ULLYSES sample and contemporaneous data from the ESO/VLT PENELLOPE program. Recent developments to STAR-MELT, as applied to the PDS 70 case study, include automated photospheric absorption removal for all of the spectra. This novel tool unveils the energetic spectral features resulting from disk and accretion processes, allowing for highly accurate measurements of both outflow and accretion tracing emission lines. By applying this method to the PENELLOPE and ULLYSES data, we will produce a more complete statistical survey of winds/outflows, whilst allowing for a thorough exploration of the relation to disk substructures and potential protoplanets within the full ULLYSES low-mass star sample.

First Detection and Modeling of Spatially Resolved Ly α in TW Hya by Seok-Jun Chang

UV radiation is crucial to understanding the chemical composition and molecular medium in T-Tauri stars since UV radiation photodissociates molecules and pumps molecules to induce the emission features. Lyman- α (Ly α) is the strongest emission line in UV spectra from T-Tauri stars. Due to its resonant nature, Ly α emission can be spatially extended and show a complicated spectral profile via scatterings with atomic hydrogen. It allows Ly α to carry information about the physical properties of the neutral medium. In this talk, I present spatially resolved Ly α emission across a protoplanetary disk in the iconic face-on T-Tauri star TW Hya, observed with HST-STIS at spatial offsets. The observation shows that Ly α emission has doublet peaks with a red-enhanced peak and is spatially extended to the protoplanetary disk in a radius of > 20 AU. To comprehensively interpret these Ly α spectra, we utilize a 3D Monte-Carlo radiative transfer simulation named 'RT-scat' in a wind-disk geometry. We constrain the wind properties, the H I column density ($\sim 10^{20} \text{ cm}^{-2}$), and the outflow velocity ($\sim 200 \text{ km s}^{-1}$). Furthermore, to explore the effect of Ly α radiative transfer in T-Tauri stars, we compute the radiation field within the scattering medium and reveal that the wind reflection causes more Ly α photons to penetrate the disk. Understanding the role of Ly α emission in T-Tauri stars is pivotal for decoding the complex interactions between the winds, protoplanetary disks, and surrounding environments, which can significantly impact the chemistry in the protoplanetary disk. Our observation and modeling of Ly α in TW Hya show the necessity of spatially resolved Ly α observation of a broad range of targets.

Tests of population synthesis models courtesy of integrated UV spectroscopy of the Tarantula Nebula by Paul Crowther

The Tarantula Nebula is the richest star-forming region within the Local Group, and serves as a prototype for studies of extragalactic stellar nurseries since, uniquely, its massive star population can be resolved from ground- and space-based observations. The integrated FUV spectrum of its central ionizing region NGC2070 has previously been characterised with IUE, albeit at low resolution. The advent of ULLYSES FUV spectroscopy of LMC OB template stars together with UV photometry from the Hubble Tarantula Treasury Program permits the individual contributions of ~ 1000 OB, Wolf-Rayet, to its cumulative FUV spectrum to be carried out, including the role played by very massive stars. This has recently been undertaken for NGC2070 (Crowther & Castro arXiv:2311.07642) permitting tests of contemporary population synthesis models (SB99, CB19, BPASS). Empirical results extending to the complete Tarantula Nebula (up to ~ 100 pc from R136) will be presented and confronted with predictions for young starbursts at LMC metallicity.

Theoretical Spectra for Massive Stars Observed by ULLYSES by Sara Heap

We present a library of theoretical EUV-UV-optical $R \sim 20,000$ spectra of over 2000 stars in support of ULLYSES observations of stars in the LMC, SMC, and clusters of even lower metallicity. This new library, which is available to all, represents a significant expansion of Lanz & Hubeny's (2003, 2007) non-LTE photospheric spectra of OB stars by: reaching down to lower temperatures and gravities; covering a wider wavelength range (200-10,000 Å); and having a higher spectral resolution than previous works. The EUV segment can be used to predict the emission and absorption spectra of nebulae and ISM surrounding hot, massive stars through the use of CLOUDY (Ferland et al. 2017) and CLOUDSPEC (Hubeny et al. 2000). The library includes spectra of both non-rotating stars and rapidly rotating stars. The digital $R \sim 20,000$ spectra (78,324 wavelengths, 3.8MB) are presented in both continuum-normalized form (I/I_{cont}) and absolute form (erg/s/Msun/Åstrom), the latter providing a check on the derived properties of the target star. The library is organized by stellar age and mass, so it can be used to help understand stars in clusters and low-mass galaxies of ages 1-10 Myr. At the conference, we will show by example how the properties of a star of a given spectral type can be made quantitative and refined, and how it fits into the larger picture of evolution of stars born in clusters.

Accretion Properties of a Young Brown Dwarf by Toni Panzera

Young stars which have just emerged from their natal nebulae go through a very active T Tauri phase, where accretion of material from the circumstellar disc onto the star plays an important role in both the star's evolution and its ability to host planets. The accretion properties of low-mass stars have been relatively well-studied, and recently accretion onto planetary mass objects has been discussed in the literature. Brown dwarfs are the link between low-mass stars and giant planets. Here I present ULLYSES HST observations of a young 52M_{Jup} brown dwarf, J0844, that exhibits signs of accretion. I analyse the C IV doublet in terms of an origin of emission in accretion and/or magnetic activity, and find that J0844 shows a much lower level of C IV emission compared to the magnetic activity level of T Tauri stars, as well as much narrower line profiles akin to those of weak T Tauri stars. In order to estimate the level of emission from magnetic activity, I compare the C IV emission to other non-accreting magnetically-active late M-type stars VB 8, VB 10 and LHS 2065, which in general show levels of C IV well below the expected magnetic activity level of higher mass stars. In comparison to these, J0844 shows a larger amount of C IV flux indicative of accretion processes in addition to its transition region activity. I speculate as to what causes the observed differences and whether accretion or magnetic activity is the dominant process. Studying objects such as J0844 will help extend our current knowledge of stellar accretion down to the lowest masses, and into the planetary regime.

Benchmarking quantitative spectroscopy in ULLYSES/XShootU and Analysis of B-supergiants in the SMC by Matheus Bernini Peron

Explaining the behaviour and evolution of massive stars ($M > 8M_{\text{sun}}$) is paramount to understanding several key aspects of the Universe. Across the cosmic history, these stars have been strongly impacting their surroundings and are major feedback sources in their host galaxies throughout their lives and their usually violent deaths.

The ULLYSES' spectra plus the optical and infrared counterpart acquired by the XShootU collaboration provides the astronomical community a unique opportunity to analyse and constrain the stellar and wind properties of OB stars at different evolutionary stages at subsolar metallicity environments (i.e., in conditions similar to the earlier stages in cosmic history).

In this talk, I will present two new results from the open XShootU collaboration. The first one will be a systematic comparison of different methods applied to study LMC and SMC stars. Uncovering the parameters of hot stars requires performing quantitative spectroscopy with sophisticated stellar atmosphere models. By performing different methods commonly employed in the community we can get a hint of their systematics as well as their strengths and limitations.

Afterwards, I will present a concise and homogeneous analysis of SMC B-supergiant stars (BSGs). Knowing the stellar and wind properties (especially the mass-loss rates) of these evolved objects is fundamental to constrain the evolution of high-mass stars towards cooler temperatures, as their parameter space crosses the presumed bi-stability jump regime, where some wind properties of BSGs change relatively abruptly with temperature. We find evidence that the late BSGs appear to be core-He-burning stars, while the early BSGs are harder to interpret from evolutionary models. Moreover, we find evidence for an increase in mass-loss rates in the Bi-stability region. Additionally, our analysis for the first time establishes limits on the X-ray luminosity of these stars (which affects diagnostics spectral lines for mass-loss rates).

The power of simultaneous X-ray observations to study accretion in CTTS by Christian Schneider

In classical T Tauri stars (CTTS), accretion generates X-rays in addition to the UV-emission targeted by ULLYSES. We performed XMM-Newton observations strictly simultaneous to the CTTS-monitoring part of ULLYSES to provide a complete picture of accretion variability. We present results for the first two targets, RU Lup and BP Tau. In addition to general X-ray properties, we specifically looked at correlated X-ray and UV variability. We found that the observation averaged X-ray luminosity changes by a factor three over the course of the campaign for BP Tau and that the X-ray line ratios imply plasma densities of $n_e \sim 1e12 \text{ cm}^{-3}$ for RU Lup. We discuss how these results fit into the general picture with structured (density stratified) accretion columns. Also, we show how variability in X-rays and in accretion tracing UV lines such as C IV are related, i.e., that accretion appears to negatively impact coronal X-ray emission, perhaps by disrupting those magnetic field structures that are required for powerful coronal emission. Finally, we put those results into the broader high-energy context of CTTS, i.e., the early evolution of coronal and accretion-generated X-ray emission.

New Observations of Very Metal-Poor O Stars to Enhance the Impact of ULLYSES by Grace Telford

JWST is revealing the low-metallicity galaxies that likely powered cosmic reionization at high redshift. These observations are revolutionizing our view of the early universe, but the community is under-prepared to interpret them because models of massive OB stars remain highly uncertain at the relevant, low metallicities. To address this glaring issue, the ULLYSES program has established a densely sampled FUV spectral atlas of OB stars in the Magellanic clouds, enabling robust calibration of stellar mass-loss and evolution models at 20-50% solar metallicity. ULLYSES also compiled HST/COS spectra of O stars at lower metallicities, including all available archival data and new observations of six OB stars in galaxies at the edge of the Local Group. Yet, because these stars are more distant and fainter, few FUV spectra below 20% solar metallicity exist and their coverage of O-star parameter space remains incomplete.

In this talk, I will present new modeling of the combined HST/COS FUV and Keck/KCWI optical spectra of three very low-metallicity (3-14% solar) O stars that are part of the ULLYSES low-metallicity galaxy archival sample. I will show how these observations constrain key stellar and wind parameters and test the predictions of theoretical stellar models that are used to model chemically unevolved galaxies, particularly at high redshift. I will then describe a new Cycle 31 Large Treasury HST program, the Treasury of Extremely Metal-Poor O Stars (TEMPOS; GO-17491), that is assembling a comprehensive FUV and optical spectral library of 29 O stars at $\sim 5\text{-}15\%$ Z_{\odot} . The reduced TEMPOS observations will be made public to complement the the ULLYSES dataset and enable new investigations of stellar and ISM physics at very low metallicity. Together, ULLYSES and TEMPOS will guide the next generation of stellar evolution and spectral models at low metallicity, and ultimately improve our understanding of galaxies' early evolution and contribution to cosmic reionization.

Tomography of clouds in the MW using ULLYSES by Ananya Goon Tuli

We probe the structures embedded in the foreground Milky Way ISM and CGM using pairs of OB stars in the Large and Small Magellanic clouds. The UV spectra of the massive hot OB stars (130 in the LMC and 120 in the SMC) from various instruments (i.e., COS, FUSE, and STIS) have been archived as part of the Hubble director's discretionary program ULLYSES. We have conducted a pilot study using a subset of the LMC targets observed with STIS and FUSE to assess the characteristics of the Al III, Si IV, C IV, and O VI bearing structures. The pairwise angular separation of the targets ranges between 0.002-6 degrees. Our analysis reveals the presence of statistically significant column density variation at all angular scales probed by the pilot sample. We also see a positive auto-correlation at sub-degree scales, indicating our smallest-separation sightlines probe scales smaller than the typical structures found in the foreground gas.

ULLYSES investigates the bi-stability jump: Using UV and optical spectroscopy to derive accurate mass loss rates by Olivier Verhamme

Radiation-driven mass loss is an important, but still highly debated, driver for the evolution of massive stars. Current massive star evolution models mostly rely on mass loss rate prescription for massive stars which include a sudden increase in mass loss below an effective temperature of about 22 500 K (Vink et al. 2001). However, new mass loss rate predictions show no such bi-stability jump (Björklund et al. 2022). Instead, stellar mass loss decreases with decreasing stellar luminosity/temperature. This will heavily impact the evolutionary models we currently rely on for these stars.

The ULLYSES data set provides a unique opportunity to observationally investigate the theoretical bi-stability jump dichotomy. By utilizing UV spectra from ULLYSES combined with X-shooter optical data it is possible to obtain mass-loss rate constraints, that are no longer degenerate to the effects of wind clumping, and derive novel empirical constraints on the mass-loss behavior across the temperature range of the presumed bi-stability jump.

We obtain stellar and wind parameters through spectral fitting using the 1D spectral synthesis code FASTWIND. To fit synthetic spectra to observations we use genetic algorithm code Kiwi-GA. In my talk, I will show the results of this method on Large Magellanic Cloud B-supergiants in the ULLYSES data set for which we have X-shooter optical follow up data. The discussion will focus on the clumped nature of these winds, showing both that the often used simplification where the clumps contain almost all mass does not hold while also showing that there is no empirical evidence pointing towards a bi-stability jump in mass loss rate.

Synergies between ULLYSES massive stars and SDSS V Local Volume Mapper by Aida Wofford

The Magellanic Clouds (MC) and the Local Volume Sextans A and NGC 3109 galaxies are main targets of: i) ULLYSES; ii) the complementary XShootU, a 3,000-25,000 Ang spectroscopic follow up of ULLYSES massive stars with X-shooter on the Very Large Telescope; and iii) the Local Volume Mapper (LVM), a 3600-10000 Ang integral-field spectroscopy survey of interstellar gas emission that is part of the Sloan Digital Sky Survey V. In this talk, I will describe synergies between these high-quality datasets and show preliminary work aimed at deepening our understanding of massive-star feedback.

Posters

α -element enhancements in the Magellanic Interstellar Medium: evidence for recent star formation by Annalisa De Cia

What is the chemical composition in the neutral ISM in the LMC and SMC? Direct measurements were missing until now. The observed metal abundances depend on metallicity, the depletion of metals into dust, and nucleosynthesis effects such as α -element enhancement. We collect pre-ULLYSES metal column densities in the neutral ISM in the LMC and SMC. We determine dust depletion, metallicities, and α -element enhancements. The latter can be directly compared with stars. Most systems show α -element enhancements (and Mn under-abundance) in the neutral ISM, higher than for stars at similar metallicities. This is likely due to core-collapse supernovae following bursts of star formation. We find total neutral ISM metallicities that are mostly consistent with hot stars metallicity in the LMC and the SMC, except near the Magellanic Bridge, a region known for having a lower metallicity. Our results can be an important pathfinder for ULLYSES.

Extending Kwan-Fischer Models With More Realistic Accretion Column Simulation by Suyash Deshmukh

Comparison of accretion modeling results with observations can help us to understand how star formation and planet formation differ. The Kwan & Fischer local line excitation model we are focusing on outputs various emission line strength ratios but it works with the assumption that the emitting region (in our case, the accretion column) is of uniform temperature and density. We aim to extend the Kwan & Fischer models by exploring how multiple density and/or temperature regions might influence the output. These more physically realistic models can inform the interpretation of observational data, especially those made possible by JWST and HST. Different substellar formation models predict different accretion signatures for planet vs star formation (such as the Aoyama planetary shock models vs the Kwan & Fischer models), with significant differences in line flux ratios for different emission lines. Simulating accurate emission from an accretion column might help us determine the accretion process of an observed body. This in turn will help us get more accurate accretion rates and eventually allow us to distinguish formation processes, an especially important task for the case of brown dwarfs which might form via either star-like or planet-like formation processes.

X-ray monitoring of ULLYSES monitoring targets by Hans Guenther

We performed contemporaneous NICER X-ray observations of the four low-mass CTTS monitored by ULLYSES. Additionally, the brightest of the four targets (TW Hya) was monitored with high-resolution grating spectroscopy with Chandra. We will present the X-ray data from these monitoring observations. X-rays originate in the corona and possibly in the hot accretion shock, while the ULLYSES UV emission is dominated by the cooler parts of the accretion shock. Depending on how much of the accretion happens in fast, dense streams, and what the ratio of accretion to coronal emission is, we expect a different degree of correlation between shock properties measured from the UV and the soft X-ray emission seen in NICER, and, in TW Hya, the density of the X-ray emitting material seen in the grating spectra. This turns out to be hard, because all targets have a low signal in X-rays, given the short exposures times we could achieve with the scheduling constraints to follow the UV observations. However, the absence of any strong, obvious correlation indicates two things: (1) The X-rays are coronally dominated and (2) the properties of the corona are not changed drastically by changes in the accretion properties. It has been suggested in the past that the infalling material may alter the structure of the stellar magnetic field or dilute the hot coronal material with cooler infalling material. If either of those effects happens, they are so subtle that we don't see them in our data.

A Tale of Winds, Tides, and Ram-Pressure Stripping: Determining Properties of the Magellanic Stream by April Horton

Gaseous debris forcefully expelled from the disk of a galaxy can form galactic winds. These winds can be pulled and swept away by gravitational interactions and ram-pressure stripping occurring in the environment. One of the most prominent examples of these interactions is the Magellanic Stream (MS): a trail of gaseous material flowing behind the Large Magellanic Cloud (LMC). To characterize its chemical properties, we probe OB stellar sightlines along the MS using a combination of UV absorption-line spectroscopy from HST's Ultraviolet Legacy Library of Young Stars as Essential Standards (ULLYSES) survey and H I emission-line data from the Galactic Australian Square Kilometre Array Pathfinder (GASKAP) and the Galactic All Sky Survey (GASS) programs. We kinematically separated the LMC's disk from the MS using two methods: calculating column density-weighted central velocity and widths from position-velocity maps and performing Gaussian decomposition on the H I emission. We conclude part of the MS is kinematically between $+235 \leq v_{lsr} \leq +350$ km/s by comparing the H I emission data with the UV-absorption-line spectra. We selected low and intermediate-ionization species (e.g., Fe II, Fe III, S II, Ni II, Al II, and Al III) with MS absorption features to explore column densities, doppler parameters, and central velocities. Our goal is to better understand the kinematics and ionization properties along the MS while helping to constrain its origin.

UV Observations of a Magellanic Corona by Dhanesh Krishnarao

Recent measurements of a relatively high mass for the Large Magellanic Cloud (LMC) imply the LMC should host a massive Magellanic Corona, a collisionally ionized, warm-hot gaseous halo at the virial temperature ($\sim 10^{5.4} \text{K}$) initially extending out to the virial radius (100 - 130 kpc). Such a Magellanic Corona would have shaped and fed the formation of the Magellanic Stream (e.g. Lucchini et al. 2020, Nature). We have found direct observational evidence for this Magellanic Corona via highly ionized oxygen (O VI), and indirect detections via C IV and Si IV, seen in UV absorption toward background quasars using data from HST and FUSE (Krishnarao et al. 2022, Nature). We find that the Magellanic Corona is part of a pervasive multiphase Magellanic CGM seen in many ionization states with a declining projected radial profile out to at least 35 kpc from the LMC and a total ionized CGM mass of $\log(M/M_{\odot}) = 9.1 \pm 0.2$. The evidence for the Magellanic Corona is a crucial step forward in characterizing the Magellanic Group and its nested evolution with the Local Group and helps diagnose the impact of galactic scale winds emerging from star formation feedback in the LMC. This Corona and complex CGM will additionally be present in absorption line studies of ULYSSES targets, many of which are being analyzed now through our ongoing work from an HST Legacy Archival Program (PI: Kat Barger), as we work to disentangle feedback driven winds from Milky Way and LMC CGM gas.

Probing the Formation Mechanisms of Brown Dwarfs and Planetary-Mass Objects using Keck/LRIS by Jada Louison

The relationship between accretion luminosity measurements and line luminosity measurements for several diagnostics of young stellar objects have been previously studied (Alcala et al.). Additionally, studies of excess continuum and line emission have enabled accretion comparisons across mass regimes, ranging from stellar-mass T Tauri stars to substellar objects. However, any astrophysical differences in accretion between these objects remain unclear. Thus, we present a two-year study using the Keck Low Resolution Imaging Spectrometer (LRIS) in order to expand the sample of substellar objects with these measurements from Herczeg et al. (2008) into a lower-mass regime across a broad, multiwavelength range spanning 3200-10000 Å. Prior to our study, only four substellar objects had both spectroscopic continuum and line excess measurements and our sample doubles this population, allowing us to probe the physical mechanisms producing substellar accretion emission. In particular, we honed in on a sample of six substellar objects ranging in spectral type from M5.5-M9.25 and with masses $\sim 8-60 \text{ MJup}$. Measuring accurate accretion rates of stellar and substellar objects as well as comprehensive characterization of accretion from both continuum excess and line emission is necessary to calibrate scaling relations and improve accretion models. Once we have finalized our spectral analysis, we plan to measure the empirical accretion luminosity of all our objects and investigate whether stellar and planetary scaling relationships between accretion luminosity and line emission remain true in the substellar regime. This will allow us to distinguish the formation mechanisms of planetary and stellar accretion models, as well as our general understanding of the accretion physics of young protoplanets.

Mauve: A UV-Vis Cubesat dedicated to studying the Stellar Magnetic Activity by Fatemeh Zahra Majidi

Mauve is a UV-Visible, 13-cm Cubesat (with an operative wavelength range of 200-700 nm) conceived to measure the stellar magnetic activity and variability. The science program will be delivered via a multi-year collaborative survey program, with thousands of hours each year available for long baseline observations of hundreds of stars, unlocking a significant time domain astronomy opportunity. Mauve's mission lifetime is 3 years with the ambition of 5 years, and will cover a broad field of regard (-46.4 to 31.8 degrees in ICRS) during this period. The planned talk will contain a general description of Mauve's design as well as the mission's broad scientific goals. Besides its already defined science cases, as Mauve was conceived to support pilot studies and new ideas in science, the spectrometer's data can be utilized as:

- a pathfinder for other facilities to justify their observations or define/complete their target sample;
- follow-up to the known astronomical objects in the UV regime, such as benchmark classical or weak T Tauri stars, Herbig Ae/Be stars, Wolf-Rayet stars, contact binaries of different kinds such as RS CVn variables, symbiotic stars etc., to provide a large, homogeneous database of long baseline observations of specific targets;
- contemporaneous, coordinated observations with other facilities to observe targets of opportunity or transients.

Following dust evolution with the Ca II and Mg II lines by Marbely Micolta

The inner regions of protoplanetary disks are nurseries for a wide diversity of exoplanets. Analysis of the emission lines of refractory elements allows us to trace their abundance in the inner gas disk and discern the footprints of planet formation by accessing the bulk of surviving material reaching the star. Our work focuses on Mg and Ca, two of the most refractory elements, which trace planetesimal and planet formation in the disks. We present a study of Mg II and Ca II emission lines using ULLYSES data and the magnetospheric accretion model. We will also use optical spectra available in the Penelope collaboration and obtained at the Magellan Observatory with the MIKE instrument. We will connect the behavior of the Mg lines with the already characterized Ca lines and their relation with dust evolution in the disk.

Investigating variable accretion in T Tauri stars using FUV spectroscopy with UVIT/AstroSat by Prasanta Nayak

T Tauri stars (TTS) are low-mass pre-main-sequence (PMS) stars, surrounded by protoplanetary disks. Accreting TTS are called Classical TTS (CTTS) and are characterized by strong line emission in UV (C IV, Si IV, He II) and optical (H α). Non-accreting, disk-less weak-line TTS (WTTS) show weak emission lines due to chromospheric activity and lack of H₂ emission from disks. Variability in line luminosities is one of the defining characteristics of CTTSs. The main source of variability is the change in accretion rate. While optical spectroscopic and photometric surveys commonly search for variability, a few TTS have repeated observations in the UV. The evolution of the UV spectrum is moreover unknown, despite UV's importance in heating the disk gas, influencing gas chemistry and driving photo evaporative winds. Recently, we developed FUV spectroscopic monitoring observations of TTS using UVIT on AstroSat. 30 ksec was allotted as a part of a pilot study to observe a TTS (HD202917) and the observation was completed. We also obtained simultaneous ground-based optical spectra using CHIRON at the SMARTS telescope. I will present the results from this UVIT program and discuss whether UVIT can be used to make a complementary program to the ULLYSES.

Studying the Gaseous Blowout of the 30 Doradus Starburst Region using ULLYSES Observations by Suraj Poudel

Widespread galactic winds emanate from the Large Magellanic Cloud (LMC), with the 30 Doradus starburst region generating the fastest and most concentrated gas flows. We report the gas distribution, kinematics, and ionization conditions of the near-side outflow along 8 down-the-barrel sightlines using UV absorption-line observations taken with the Hubble Space Telescope's (HST) Space Telescope Imaging Spectrograph (STIS) instrument and the Far Ultraviolet Spectroscopic Explorer (FUSE) as part of the ULLYSES program. We compare this with the neutral hydrogen using H I 21 cm radio emission-line observations from the Parkes Galactic All-sky Survey (GASS) and Galactic Australian Square Kilometre Array Pathfinder (GASKAP) survey. We find that within a projected radius of about 0.5 degrees from 30 Doradus the wind speed in the LMC standard of rest frame ranges from $-175 \lesssim v(\text{LMCSR}) \lesssim -30$ km/s. The integrated low-ion column densities across all wind velocities are highest in the central region of 30 Doradus and decline gradually with the projected distance from the center. We measure an outflow mass of $M(\text{outflow}) \gtrsim 0.6 \times 10^6 M_{\odot}$ for the low ionization species within 0.5 degrees of the 30 Doradus. The observed ion ratios—together with photoionization modeling—reveal that this wind is roughly 50% to 97% ionized. We also find evidence for dust depletion based on the observed [Si ii/S i] ratios and photoionization modeling. The average larger linewidths for the high ions C IV and Si IV and the ion ratio $\langle N(\text{C IV})/N(\text{Si IV}) \rangle = 4.2 \pm 3.1$ suggest that the gas probed by these high-ions is collisionally ionized.

Extracting magnetospheric truncation radii via multi-band light curves in preparation for ESPEX by Connor Robinson

Rotation has a large impact on stellar evolution and activity and is one of the most fundamental properties of stars. Young stars rotate slower than one would expect from simple conservation of momentum arguments, likely due to complex interactions in the central region between the star, disk, and winds. Determining the relative importance of each process is a long-standing problem. Measuring where the magnetic field truncates the inner disk relative to the co-rotation radius is critical for calculating the torque imposed by accretion but typically requires detailed modeling of spectra to determine. We present a new analysis of magnetospheric accretion simulations, which we have used to infer the magnetic truncation radius of T Tauri stars via multi-color light curves. We applied this technique to an optical sample of stars observed with the LCO network as a proof of concept. Ultimately, we plan to apply our technique to data from the Early Star and Planet eXplorer (ESPEX), an in-development SMEX Mission that will obtain month-long simultaneous ultraviolet + optical light curves of many young stars. The color information of the ESPEX light curves will provide a new view of accretion and the angular momentum budget of young stars that was not possible from previous similar missions like TESS and K2.

Progenitors of LGRBs: Are single stars enough? By Rafia Sarwar

The ULLYSES Project will provide unprecedented observational constraints on OB stars residing in low metallicity galaxies. These massive stars strongly affect their surrounding environments through processes such as star formation, stellar winds, ionizing radiation, feedback mechanisms, and core-collapse supernovae. The final fate of evolved massive stars is classically linked to energetic and luminous transient sources, long-duration gamma-ray bursts (LGRBs). In this work, I present the revised and expanded single-star models using MESA along with new observational comparisons. My study demonstrates the impact of rotation during the evolution of these stars, leading to chemically homogeneous evolution followed by various types of supernova explosions. I also compare these theoretical models with the observed number of LGRBs to date with known redshifts. The comparison reveals a discrepancy between the population of single-star models and observations, most likely because the majority of massive stars are in binary systems, and single-star models alone are insufficient to explain progenitors of LGRB.

Observable properties of Wolf-Rayet+O star binaries on the main sequence by Koushik Sen

Recently, it has been shown that hydrogen-rich Wolf-Rayet stars on the main sequence can originate from binary interactions. Mass transfer on the main sequence significantly reduces the donor stars' mass while their luminosity, set by the convective core mass, remains similar. This increased luminosity-to-mass ratio leads to stronger winds and higher wind optical depths for the donor stars, forming WR-like emission line features in the donor spectrum. Contrary to conventional binary evolution, envelope stripping in very massive donors may not lead to mass ratio inversion of the binary, making the less massive and less luminous companion difficult to detect observationally. Using detailed binary evolution models, we perform a binary population synthesis study of the observable properties of these hydrogen-rich Wolf-Rayet stars in the Large Magellanic Cloud, such as the orbital periods, mass ratios, rotational velocities and elemental surface abundances. Our models predict ~5% of massive main sequence binaries, or ~20 binaries in this configuration in the LMC, in the 30-90 Msun range. The systems are identifiable through large radial velocity variations of the primary and an order of magnitude higher wind mass-loss rate than ordinary O stars at the same luminosity. Observational constraints on the model predictions are essential to determine the mass distribution of black holes expected to form from these binaries, interstellar feedback from massive star winds and the properties of stripped-envelope supernovae. As such, the Hubble ULYSSES program provides an unprecedented collection of observed massive stars to test such predictions.

Migration of Accretion-induced Hotspot over the Stellar Surface during an Outburst in a YSO: EX Lupi by Koshvendra Singh

In this talk, I will present our discovery of migration of the accretion-driven hotspot over the stellar surface during an episodic increase in mass-accretion rate (outburst) in a young stellar object (YSO): EX Lupi. This hotspot migration was predicted in a 3D MHD simulation about a decade ago. The YSOs accrete disk matter along the stellar magnetic field lines known as the accretion funnel. The base of the accretion funnel at the stellar surface is ~10000 K and is known as a hotspot. EX Lupi is a touchstone YSO as it has undergone several outbursts since the 1940s. It again went into an outburst ($\Delta g \sim 2$ mag) in March 2022. We followed photometrically and spectroscopically the outburst and subsequent quiescent of EX Lupi with TMMT, LCRO, CTIO and HRS on SALT. Our high cadence observations along with archival data of ASAS-SN, AAVSO and TESS revealed a sudden increase in the phases of the periodically modulating (EX Lupi's rotation period is 7.417 ± 0.001 days) multiband lightcurves during the outburst. I will talk about how the sudden phase change can be explained by an azimuthal migration of the hotspot over the stellar surface which in turn gives us an understanding of the reconfiguration of the accretion funnel during the outburst. We also found an increase in the radial velocity amplitude during the outburst which I will explain in terms of the latitudinal migration of the hotspot. We have further found that the outburst generated a temperature gradient in the hotspot and also that the matter accreted during the outburst was not streamlined but clumpy. Our mass estimates of the clumps range between $0.1 - 19.2 \times 10^{-5}$ lunar mass ($\equiv 300 - 57000$ Halley's comet's mass). Three of these possible matter clumps are also caught in our high-resolution spectra and our distance estimates confirm them to be within the accretion funnel.

Interplay of Close-in Planets with Disk Magnetospheric Accretion by Arturo Cevallos Soto

We present a series of 3-D ideal MHD simulations of magnetospheric accretion onto a non-rotating star with planets embedded into the disk at various distances. These vary in mass ratio with respect to the star (q) from 0.01 to 10^{-4} . Their locations vary from 0.5 to 2 times the magnetospheric truncation radius (R_T).

We find that even for the largest planets ($10 M_J$), the accretion rate onto the star remains relatively steady like that obtained from MHD simulations without planets present. Therefore, detection of planets via periodogram analysis is still an open question.

On the other hand, the magnetospheric accretion has a significant impact on planet formation. We find that the planet inside R_T won't be able to accrete disk material if the planet's Bondi radius (R_B) is smaller than the planet's radius (R_P), which is the case for sub-Jupiter mass planets. Thus, giant planet in-situ formation in this region appears implausible. The planet needs to be already large enough (e.g. $\geq 10 M_J$) to be able to successfully accrete in this region.

Circumplanetary disks (CPD) can then form around the planet, which brings part of the stellar magnetic field towards the planet. This magnetic field in CPD acts like a magnetosphere around the planet and interacts with that of the host star. This allows for the formation of a bowshock, like the one due to the interaction between the Solar Wind and Earth's magnetosphere.

How high-cadence ground based spectroscopy and photometry aid the interpretation of ULLYSES spectra by Frederick Walter

We report on high resolution optical spectra (408-890 nm; $R=27,800$) from the Chiron fiber-fed spectrograph on the brighter targets ($V<16$) of the ULLYSES observing campaign on accreting T Tauri stars. Spectra were obtained on a nearly nightly cadence for the 4 monitoring targets, and on 3-5 nights surrounding the HST observations of the other targets. The optical spectra reveal a wealth of variations in emission line strengths and profiles on timescales of a day or less. We use these data in concert with simultaneous TESS photometry in an attempt to deconvolve the systems into an underlying photosphere, dark starspots, accretion hot spots, magnetospheric flares, and obscuration by circumstellar (both ejected and infalling) material. We will summarize the available data, and present examples of short-timescale variations in the optical. Such data will assist in interpreting the ultraviolet spectra which were obtained at much lower cadences.

Understanding Accreting Brown Dwarfs Through Simulation Tools by Catalina Zamora

Many fundamental questions of brown dwarf formation remain unanswered. For example, what proportion of them form like stars and what proportion form like planets? To examine this question we observe accreting substellar objects, as their accretion rates are a useful probe of formation pathways and disk evolution. Stellar accretion rates tend to scale linearly with the mass of the star, however this trend becomes less robust at substellar masses. However, the distribution also shows quite a bit of scatter, making quantitative analyses of trends more difficult. We present our work to improve a Monte Carlo simulation tool that models possible sources of observational uncertainty and physical effects (e.g. age, variability) that cause scatter. This simulation tool was previously demonstrated to be successful in replicating the observed stellar distribution, and we now extend this work to substellar masses. We will present, in particular, our efforts to compare simulation results to the Comprehensive Archive of Substellar and Planetary Accretion Rates catalog (CASPAR, Betti et. al 2023), a uniformly re-derived catalog of all observed accreting substellar objects. We hope to use the data from this catalog to delve further into the differences in substellar formation; such as model a separate population of objects that formed via disk fragmentation. Modeling scatter can grant us a thorough understanding of substellar accretion rates and can give us insight into their formation and accretion physics.