

Report on Mind the Gap Session - Stephan McCandliss

Report on Mind the Gap & UVSTIG Joint Splinter Sessions at AAS 243 New Orleans

Raison d'être:

There will be a 10-20 year gap between the end of the Hubble Space Telescope (HST) mission and the beginning of a new flagship mission with ultraviolet spectroscopic capabilities.

In the interim, what science should potential small- and modest-sized missions focus on as precursor efforts that advance conceptual and technical readiness and foster core-excellence in early career scientists who will go on to be mainstream users of future flagship missions?

Three Sessions: Science, Technology and Mission in Development

Archives: https://cor.gsfc.nasa.gov/copag/meetings/AAS_Jan2024/AS2024-Agenda-MineTheGap-AM.php

Presenters	Mind the Gap Committee	UVSTIG Leadership
Ted Gull – GSFC	Joy Nichols - Harvard & Smithsonian CfA	Stephan McCandliss - JHU
Jeff Linsky - CU	Carol Grady - Eureka Scientific	Jason Tumlinson - STScI
Andrea Dupree - CFA	Ted Gull - NASA/GSFC (Emeritus) & STScI	Sarah Tuttle - University of Washington
Geraldine Peters -USC	Erika Hamden - University of Arizona	Camden Ertley - SWRI
Linda Smith - STScI	Keri Hoadley - University of Iowa	Derek Buzasi - Florida Gulf Coast University
John Hennessy - JPL	Al Holm - Retired; STSci Operations	Kevin France - CU, Boulder
April Jewell - JPL	Geraldine Peters - USC	Allison Youngblood - GSFC
Chaz Shapiro - JPL	Paul Scowen - GSFC/NASA	John Hennessy - JPL
John Vallergera – UCB/SSL	Chris Shrader - GSFC NASA	Erika Hamden - University of Arizona
Keri Hoadly - UIowa	Sarah Tuttle - University of Washington	Emily Witt - CU, Boulder
Manuel Quijada - GSFC		Keri Hoadley - University of Iowa, Iowa City
Sarah Tuttle - UWash		Shouleh Nikzad - JPL
Kevin France - CU		Jason McPhate - UC Berkeley
Alexandre David-Uraz - GSFC/HowardU		
Shouleh Nikzad - JPL		
David Ardilla (for Shkolnik) – JPL/ASU		
Paul Scowen - GSFC		
Emily Witt - CU		

Ted Gull

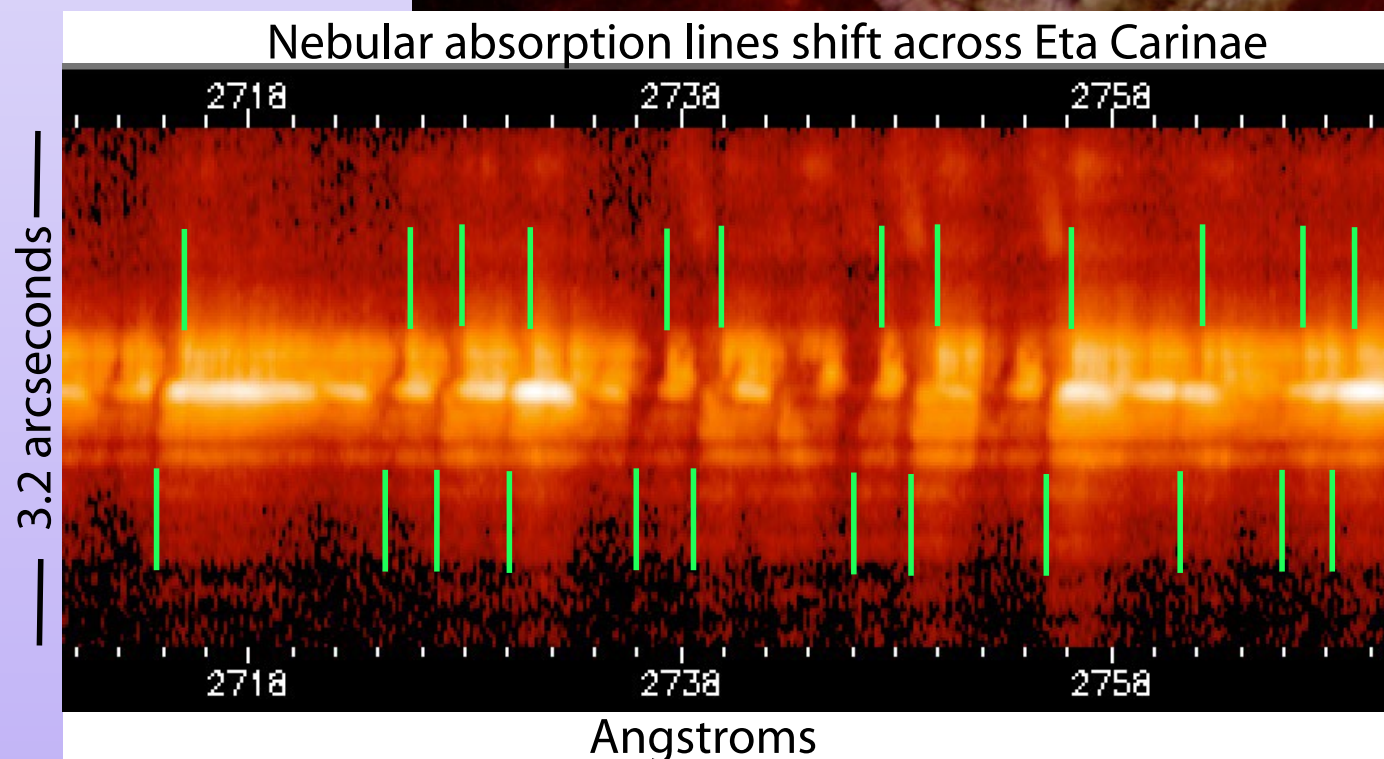
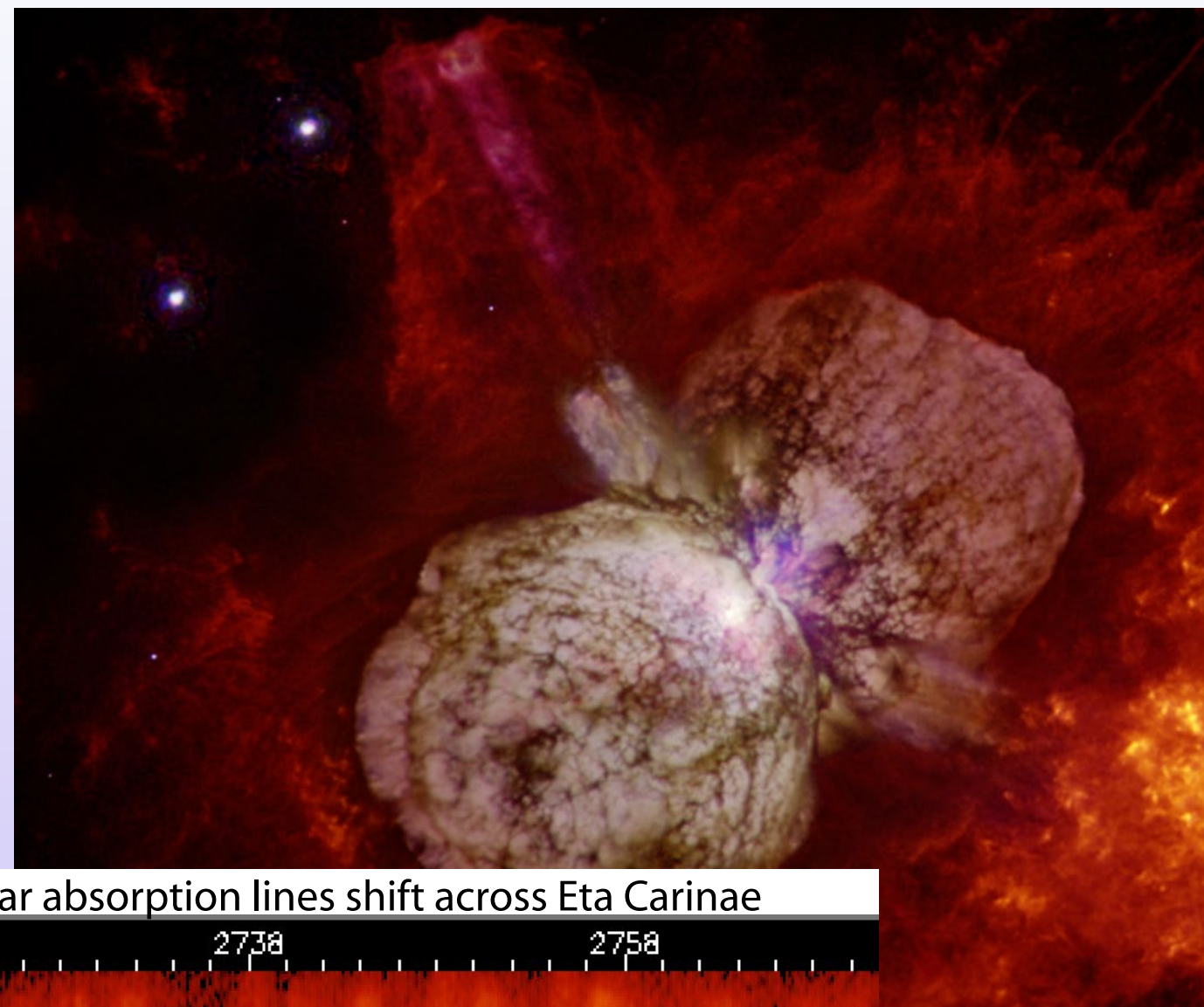
UV spectroscopy requires a selection of spectral resolving powers combined with excellent angular resolution:

The capability of HST/STIS must be built upon for the HWO

UV spectroscopy needs intermediate steps to get there

A spectrum is worth a thousand pictures ---- Blair Savage

A spectro-image is worth a thousand spectra!



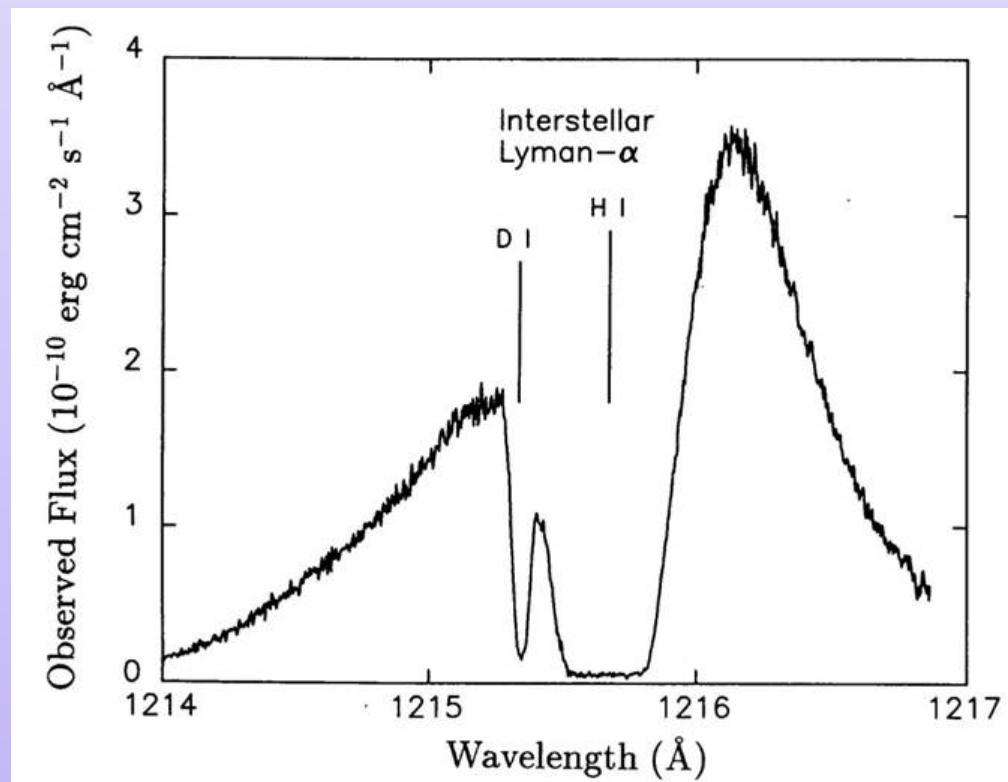
Jeffrey L. Linsky

Science topics requiring high-resolution UV spectroscopy

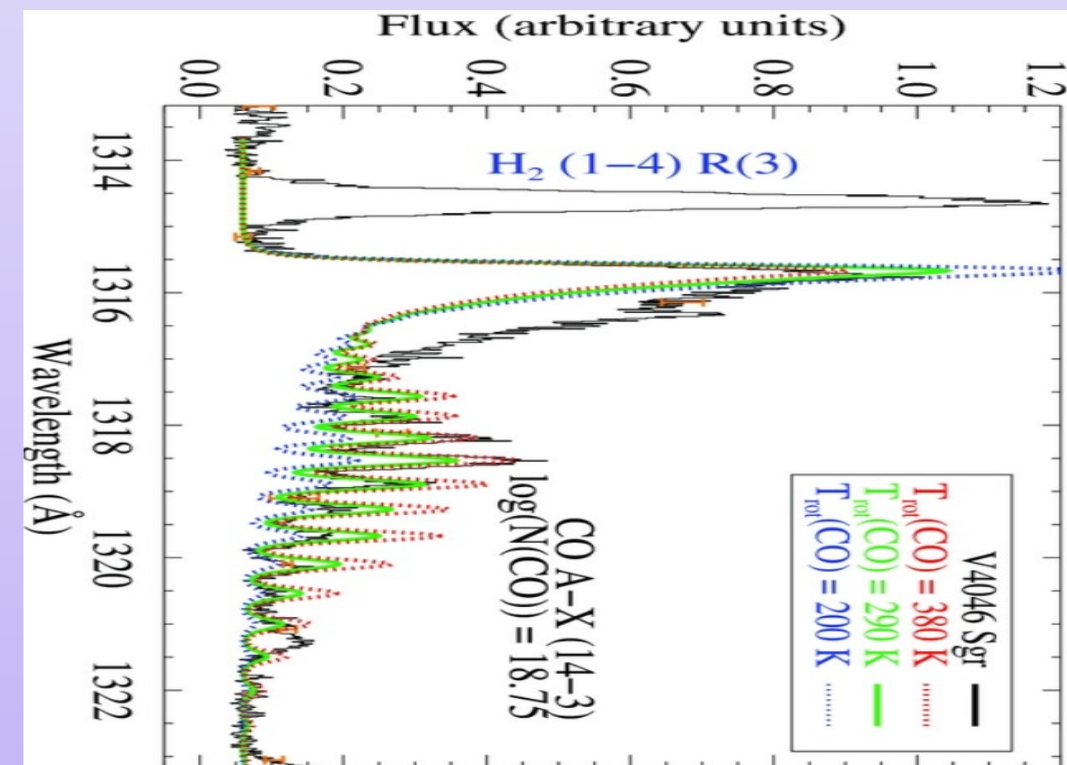
Science Topic	Need $R > 50,000$ (6 km/s)	Need $R > 100,000$ (3 km/s)
ISM kinematics and structure		X
Stellar emission line fluxes	X	
Stellar dynamics (flows, winds, flares)		X
Stellar accretion phenomena	X	
Exoplanet mass loss	X	

Capella observed with GHRS Ech-A (Linsky et al. 1993)

V4046 Sgr at COS resolution ($R=18,000$, 17 km/s) (France et al. 2012)



Lyman- α spectra of Capella at $R=100,000$ (3 km/s)



Andrea Dupree

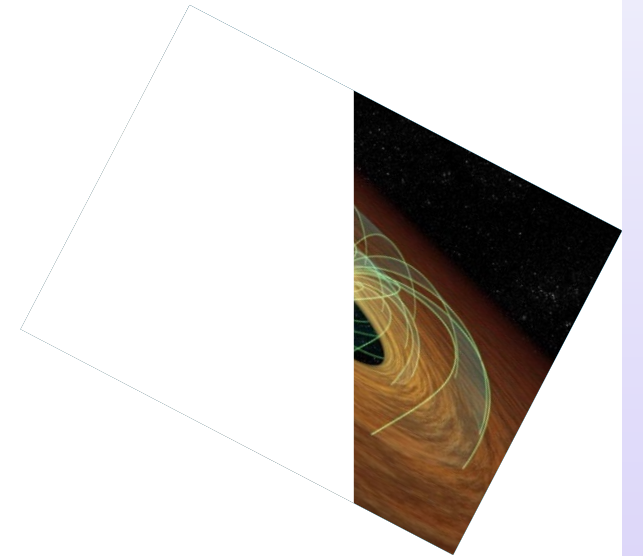
No UV? What will we lose from stellar astrophysics ???

Measures atoms (H I, D I, He I, O I ...), ions (He II, Mg II, C III, O VI...), molecules (H₂)...

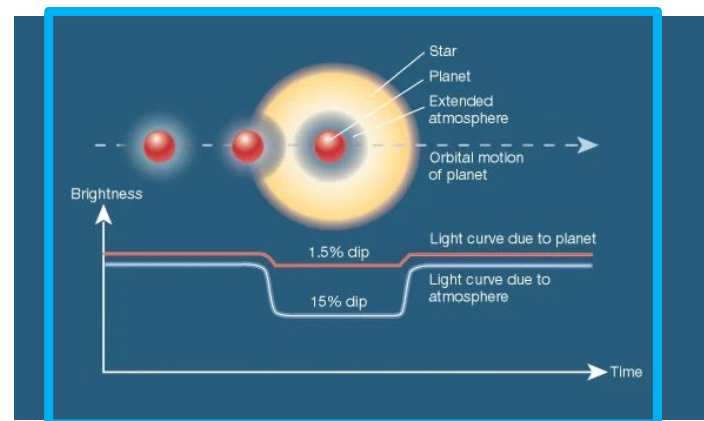
Spans temperatures from 10² - 10⁶ K... found in stars, exoplanets, and the ISM

Winds from Young Accreting Stars ...

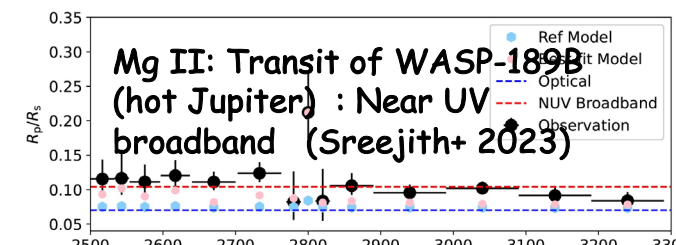
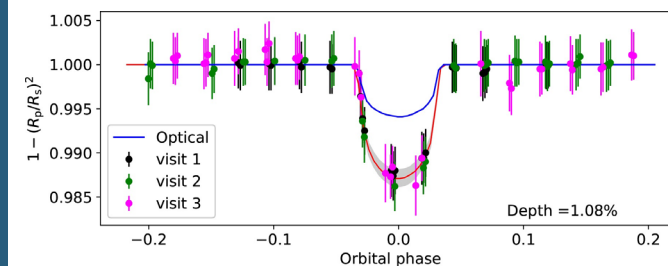
us in many ion species



Exoplanets: Transmission spectroscopy of escaping material



Lyman-alpha: escaping hydrogen HD 209458b (Vidal-Madjar+ 2003)



No gap!!!

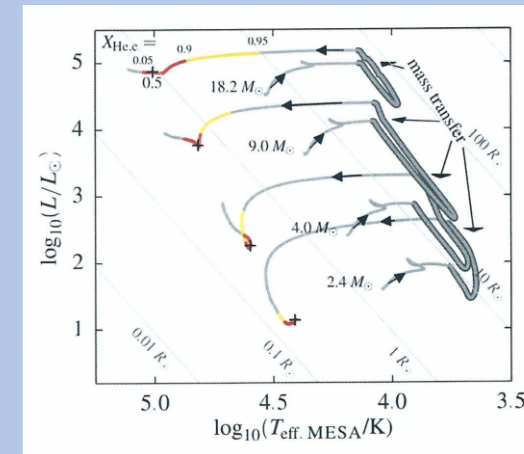
Gerrie Peters

New Perspectives on Stellar Evolution in the Upper Main Sequence

- The degree of mass loss to the **ISM** by late O/Early B-type interacting binaries is important for **galactic evolution** studies.
- A FUV/NUV spectropolarimeter with moderate/high spectral resolution can determine the degree of systemic mass and angular momentum loss to calculate evolutionary tracks of **close** binaries.
- For star cluster evolution the most important number is how many **close binaries are formed**.

What is Needed Next to Compute Realistic Evolutionary Tracks for OB Interacting Binaries?

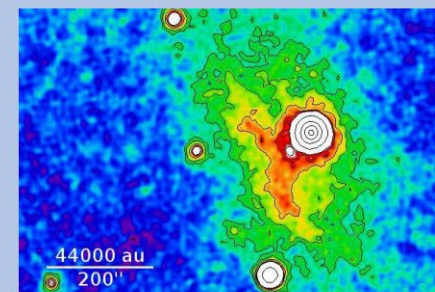
- State of the art: See Gotberg, et al. 2018, A&A, 615, A78 and references therein.
- There is a need for observations to constrain non-conservative calculations of evolutionary tracks.
- These observations must be in the FUV.



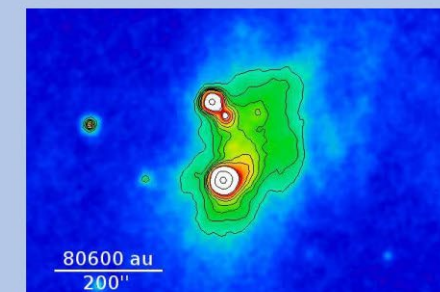
From Gotberg, et al. (2018)

The fraction of O-Early B stars in a star cluster that have their evolutionary tracks modified depends on how many close binaries are formed. Their initial separations (may be modified by third body interactions) must be approximately less than 20 AU ($r/a \sim \log q$). Wide binaries will undergo single star evolution.

Evidence for Mass Loss to the ISM by Be + sdO Systems and Other Be Binaries*



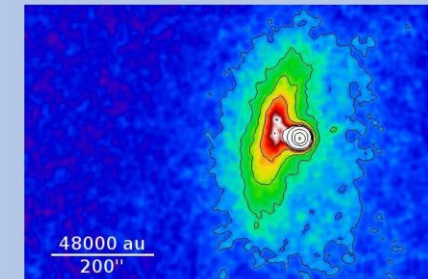
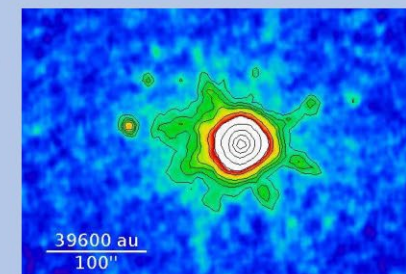
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HR 2142 (V696 Mon)

*IR images from WISE Spacecraft (Mayer et al. 2016, A&A 587, A30)

(right) CX Dra (Algol-type, B2.5V + F5III, P= 6.696 d)
(left) π Aqr (well-studied Be star)



Linda Smith

Spectroscopy of Massive Stars in the Nearby Universe: Lessons from ULLYSES for HWO

- 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)
- Designed by community
- Multi-object UV spectroscopy with HWO needed beyond the Milky Way and Magellanic Clouds to build a statistical sample of low Z OB stars

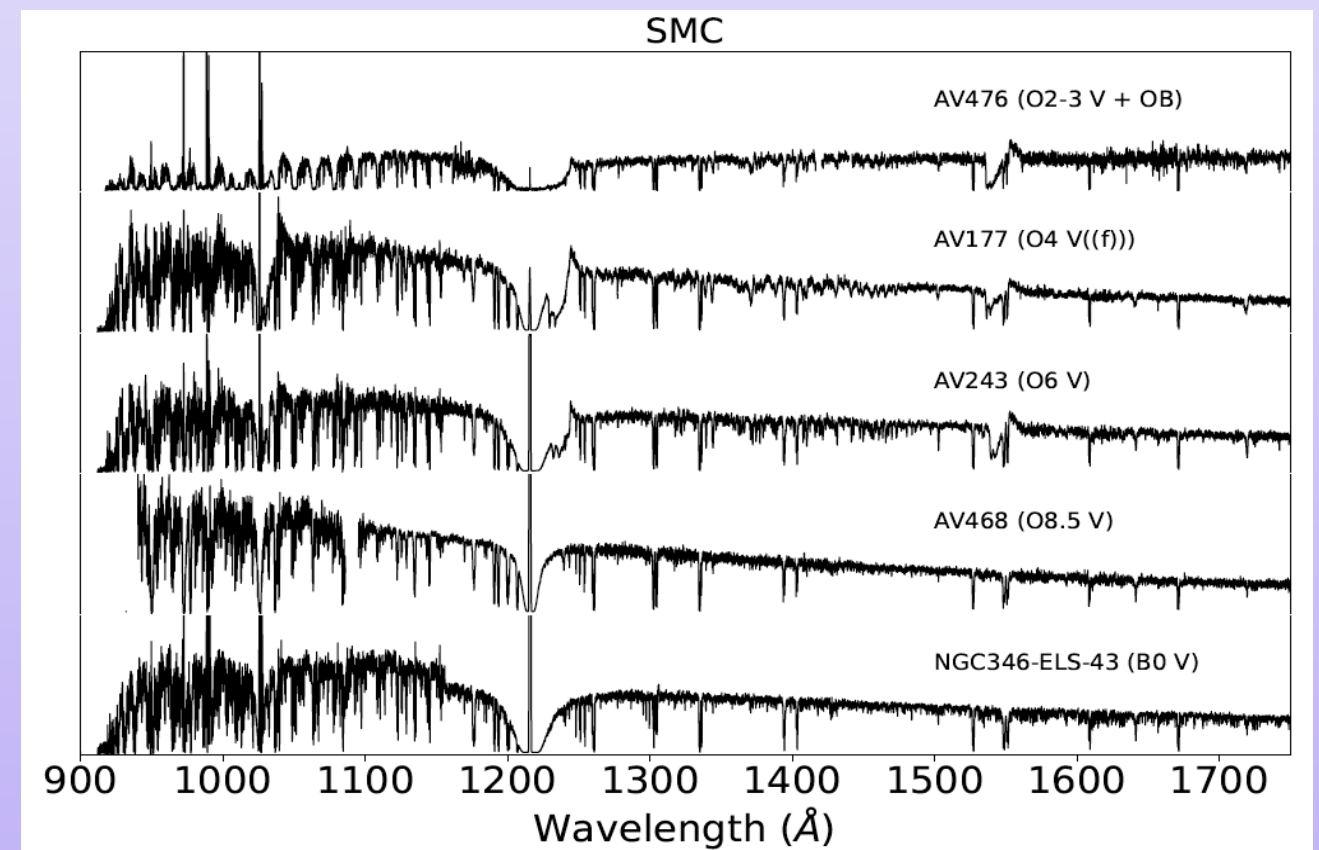
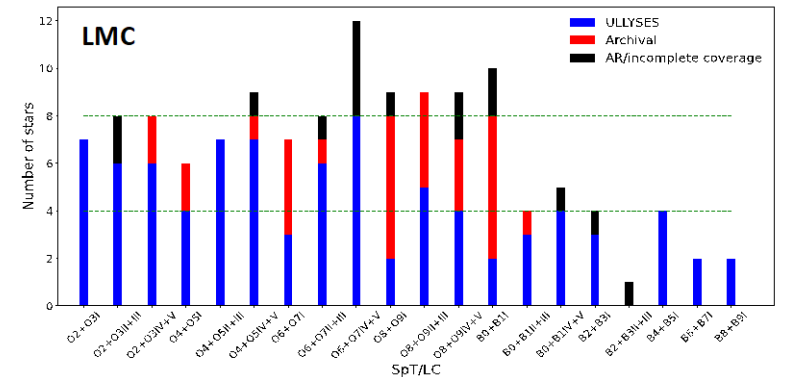
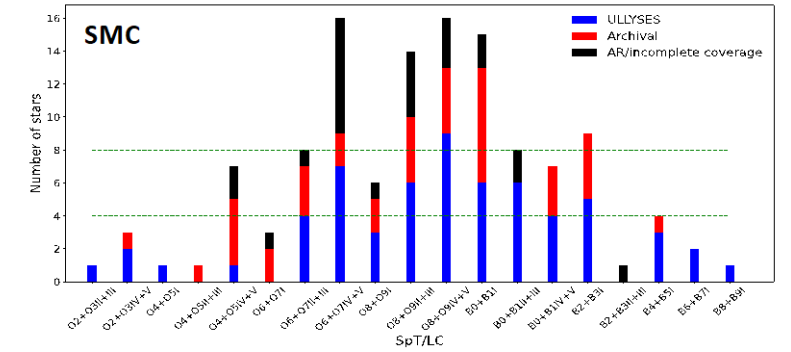


Final ULLYSES sample of massive stars



ULLYSES sample (including archival targets) covers massive star parameter space:

- At least 4 stars per bin of SpT/LC for O and early B stars
- 1-2 stars/bin for late B super-giants
- COS/G130M and G160M, or
- STIS /E140M
- Late O, B stars: NUV

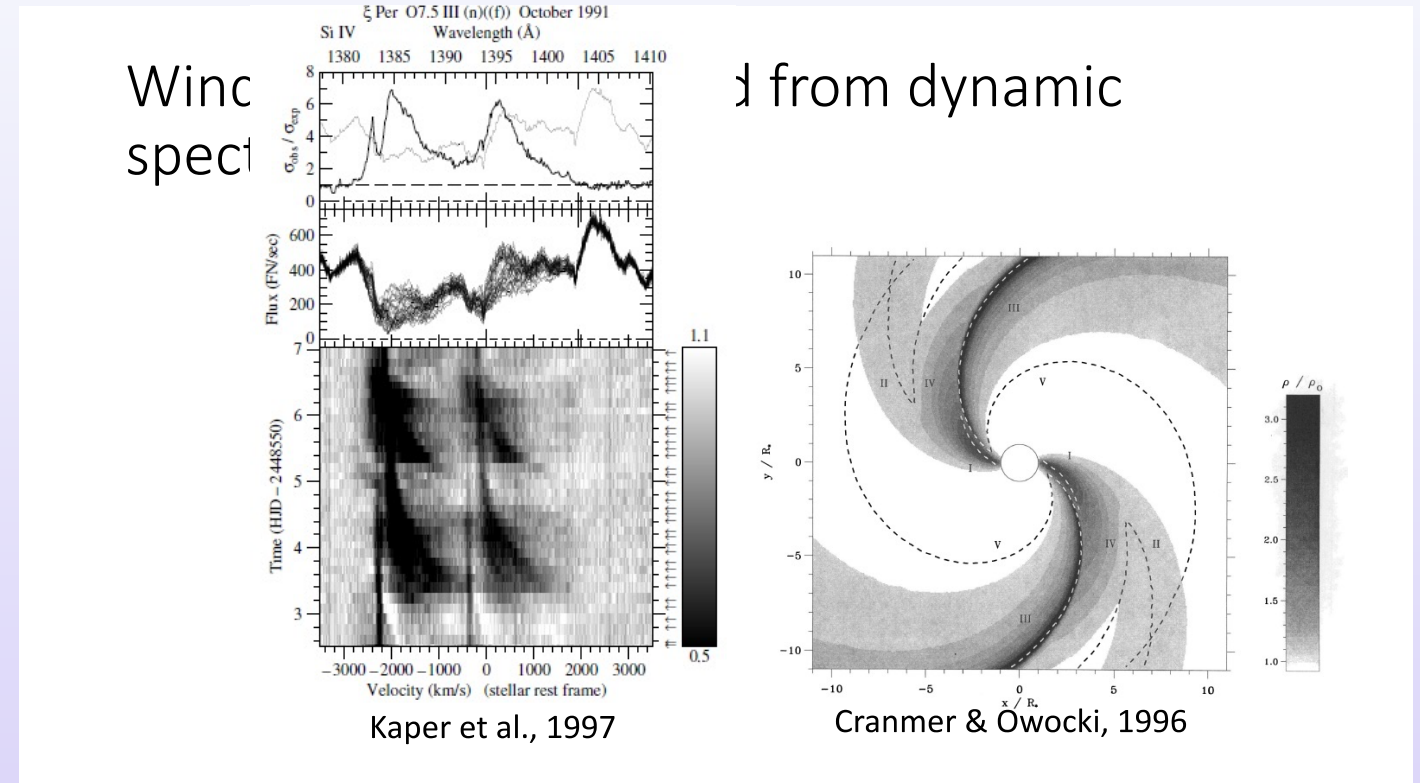


Alexandre David-Uraz

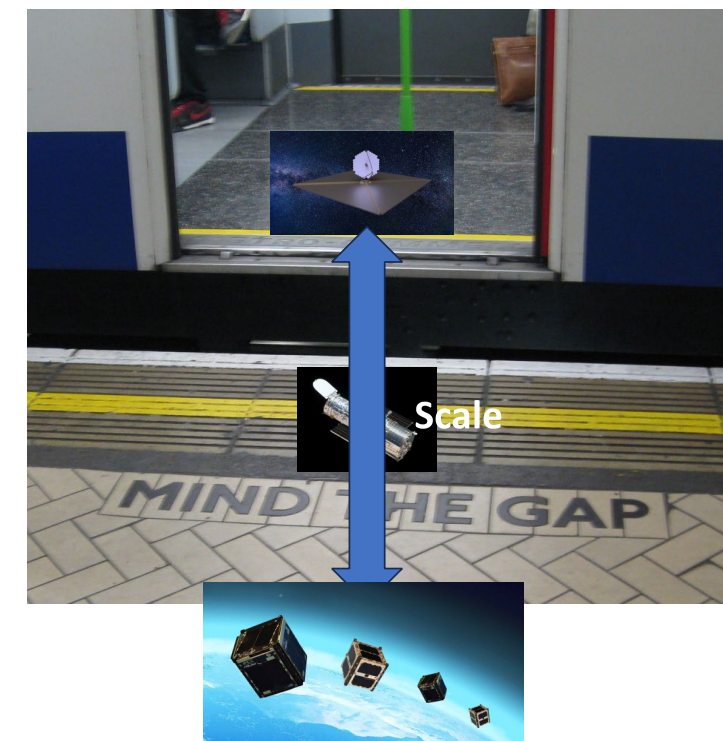
Star Wind Variability in the Ultraviolet

- The name of the game...
... is time-domain.

- To probe the multi-scale spatial and temporal properties of massive star winds, we must develop an agile suite of observing tools that can deliver *precision*, short *cadence*, and a long *temporal baseline*.



Mind the gap



Tech Presentations

John Hennessy	UV Mirror and Detector Coatings by Atomic Layer Processing
April Jewell	Detectors for UV/Visible Spectroscopy
John Vallerga	Latest developments of MCP detectors at Berkeley
Keri Hoadly	Advances in Diffraction Grating Fabrication for Space-UV Astrophysics
Manuel Quijada	Emerging Coating Technologies for Realizing High-Reflectance and Stable Mirror Coatings for Observations in the FarUV
Sarah Tuttle	UV Technology White Paper: Getting Ready for HWO

HF-based metal fluoride ALD processes

Material	Co-deposit with Anhydrous HF	Temperature (°C)	ALD Cycle (min)
AlF ₃	diethylaluminumchloride/magnesium	100-200	115-120
AlF ₃	trimethylaluminum	100-200	110-120
LiF	lithium bis(trimethylsilyl)amide	100-200	100-110
LuF ₃	tris(trimethylsilyl)borane/trimethylaluminum	175-200	100-140
CaF ₂	diethylaluminumchloride	150-200	105-130

Hennessy, J. et al., JSTP A 31, 01A-025 (2019)
 Hennessy, J. et al., JSTP A 31, 01A-020 (2018)
 Hennessy, J. et al., JSTP A 31, 01A-020 (2018)
 Hennessy, J. et al., JSTP A 31, 02A-025 (2021)

- Utilize anhydrous HF or HF-pyridine as the fluorine-containing precursor
- Can deposit majority of relevant fluoride materials for operation in the UV, most at substrate temperatures near 100 °C

ALD encapsulation of PVD mirror coatings for improved stability

Test coatings fabricated for the SPRITE (PI: Brian Fleming, CU) program demonstrated ALD MgF₂ encapsulation on CSFC eUV process

- The SPRITE CubeSat primary mirror 16 x 18 x 5 cm is largest optic coated to-date in this chamber.
- The same coating is being implemented on Asper-Flores (PI: Carlos Vargas, UIA)

ALD for metal-dielectric FUV bandpass filters

- Automated ALD/evaporator enables improved repeatability for multilayer metal-dielectric structures used as detector-integrated bandpass filters
- Developed for SPARCS CubeSat (PI: Evgeniya Shkolnik, ASU) and UVEX-MIDEX (PI: Fiona Harrison, Caltech)
- Concept extended to include graded thickness dielectric layers to improve throughput and red-rejection for spectroscopy applications

Summary and Next Steps

- Successfully demonstrated butcher block style AR coatings on two prototype detectors.
- Response behavior would be ideal for spectroscopy applications where each region of the detector would be optimized to match the spectral dispersion
- Explore region separation/overlap limits and "gap penalty"
- Improve deposition methods to eliminate cosmetic defects
- Environmental/stability studies
- Implementation with UV bandpass filters (ref. John Hennessy's presentation)

Microchannel Plate Detectors

How they work

- Photocathode converts photon to electron
Alkali halides, Multialkali, GaAs, GaN
- MCP(s) amplify electron by 10⁴ to 10⁷
- Patterned anode measures charge centroid
Cross strip, Cross delay line, Timepix ASIC or Phosphor.

Developments underway: Atomic layer deposited MCPs, large area borosilicate MCP substrates, cross strip and Timepix4 readouts, large area sealed tubes, and ASIC processing electronics

Timepix 4 – Advantages

- Extremely high resolution at low gain (lower HV and longer lifetime of MCP)
- Maintains performance when scaled to large area
- Huge dynamic range – Global 20 MHz event rate with centroiding
- Local pixel rate limit ~ 10 kHz, consistent with MCPs
- Data driven readout (photon counting)

USAF test pattern showing resolution better than 64lp/mm using Timepix readout

Advances in Diffraction Grating Fabrication for Space-UV Astrophysics

Presenter: Keri Hoadly
keri.hoadly@uow.edu.au

IQWA MindTheGap/UVSTIG AA 5 243 Splitter Session, 01/09/2023

Customizable Gratings for Space UV Spectroscopy

- "Customizable" = control over groove period, pattern, blaze angle, substrate curvature, size...
- Leads to innovative instrument concepts

ESCAPE grating: radially-ruled grooves with a "curved" (Grise: 11821-28, Kruczek: 11821-12)

CRISM Spherical Grating with two blaze angles. (Wilson et al. 2003)

Direct Write Blazing via TASTE (McCoy et al 2020, McCurdy et al. 2020)

IQWA MindTheGap/UVSTIG AA 5 243 Splitter Session, 01/09/2023

Approach: Using Low T_p Plasmas to Remove Oxide and Passivate Al surface with Fluorine

Initial Condition: Glass substrate with Al₂O₃ and Aluminum.

Plasma Treatment: Low T_p Plasma (AlF₃, F₂, SF₆, SF₄)

Final Condition: Low T_p Plasma (AlF₃, F₂, SF₆, SF₄)

Al₂O₃ etch threshold ~20 eV in SF₆ plasma

material removed: AlF₃, Al

Reactive Physical Vapor Deposition (rPVD)

Al (PVD) → Al (rPVD) → AlF₃ (rPVD) → AlF₃ (rPVD) → AlF₃ (rPVD) → AlF₃ (rPVD)

AlF₃ passivation right after Al layer is deposited

Mission Presentations

Charz Shapiro

CASTOR – Cosmological Advanced Survey Telescope for Optical and uv Research

CASTOR Mission Overview

- Light-weighted Zerodur 1m primary mirror
- Three Mirror Anastigmat with 0.25 deg FoV
- Active M2 for WFE compensation
- Fine steering mirror for image stabilization
- 1083 kg spacecraft and 10 Gbps optical downlink
- M-AC200-small-SAT bus
- 800 km polar BSO for efficient surveys
- Diffraction separation of wavebands
- Optical coatings on all mirrors for red leak control
- Minimum 5 year mission (Goal: 10 years)
- Combination of Legacy Surveys (84%), Guest Observer programs (25%), Target-40 opportunity programs (8%), and calibration time (3%)
- 14 candidate Legacy Surveys advanced to SFL4 during Phase 0
- To be revisited once the partnership is finalized

"Our highest recommendation at the very large investment scale is for CASTOR an exciting mission with a broad and compelling science case, and which would be Canada's first marquee space astronomy mission."
— Canadian Astronomy Long-Range Plan 2020

Kevin France

ESCAPE – Euv Stellar Characterization for Atmospheric Physics and Evolution

ESCAPE
Extreme-ultraviolet Stellar Characterization for Atmospheric Physics and Evolution
Exploring the Physics and Evolution of Potentially Habitable Worlds

Shouleh Nikzad / Evgenya Shkolnik

SPARCS CubeSat - NUV & FUV photometry of 20 low-mass stars, young and old.

SPARCS Baseline Design

NUV & FUV photometry of 20 low-mass stars, young and old.

KEY SPECIFICATIONS

- Spacecraft: 6U CubeSat, 9 cm telescope
- Orbit: Sun synchronous, inclination for continuous power, orbiting, and winter-sol observations
- Band: FUV (300-400 nm), NUV (200-300 nm)
- FOV: 10°
- Targets: Low-mass stars
- Pointing: Stable to 10"
- Camera: 0.1 μm substrates
- 1000 optical elements

Planetary Consequences of High Energy Radiation at Close Distances:

- Atmospheric ionospheric changes to ionosphere (E, D, F2) layers
- Atmospheric photochemistry (e.g. photodissociation of key molecules) by energetic FUV (Lyman-Werner) (FUV)
- Surface radiolysis
- Degradation of habitable and microbial planets (UV can create lethal conditions and sterilize organisms)

David Ardilla / Evgenya Shkolnik

UV-Scope - Science Drivers & Spectroscopic Capabilities for (MIDEX Concept)

Exoplanet Science Drivers for UV-SCOPE
UltraViolet Spectroscopic Characterization Of Planets and their Environments
Evgenya Shkolnik, Arizona State University / David Ardilla, Jet Propulsion Laboratory

Paul Scowen

POLSTAR - FUV Spectropolarimetry Mission (SMEX)

Polstar Science – The Role of Rapid Rotation in the Evolution of Massive Stars and the Galaxy

- Massive stars are the most important contributors to galactic cosmic evolution.
- They live out their entire lives and go supernova while low-mass stars are still forming.
- A host of theories predict profound, yet different, consequences for rapid rotation in these stars, so observational constraints are now essential.
- Polstar will use UV spectropolarimetry to capitalize on subtle stellar and wind asphericities induced by rapid rotation, to constrain the internal physics that dictates the evolution of the star and its impact on the Galaxy.
- Massive stars are very bright, mostly in the UV, providing a sample size of about a hundred suitable targets, so we can spend a lot of time on each one, meaning a large aperture is not required.
- Polstar will provide a new window, a new capability to view the Universe with.

Keri Hoadly / Allison Youngblood

SNOUT - SmallSat for EUV stellar flare effects on exoplanets

SNOUT: A SmallSat UV + Optical Telescope

Channel Name	Bandpass (nm)
EUV1	16-21
EUV2	24-29
EUV3	30-31
Visible	400-900

EUV Telescope: OAP, segmented 38 cm diameter with high-heritage Al foil filter

Visible Telescope: OAP, 7.5 cm diameter

Sensors: Teledyne e2v CCD 47-20

IOWA MindTheGap/UVSTG AAS 243 Splitter Session, 01/09/2023

Emily Witt

Efficient Spectral Multiplexing for Habitable Worlds Observatory - INFUSE: First FUV IFS Flown

INFUSE: First FUV IFS Flown

SUMO Secondary Payload, Electronics, Vacuum Port, 49 cm ø Primary Mirror, Carbon-fiber Metering Tube, Shutter Door, Forward Baffle Tube, Secondary Mirror, Star-tracker

Image Slicer
The INFUSE slicer consists of 26x 0.25 x 6.5 mm mirrors

MCP Detector
INFUSE Spectra are recorded on a 94 x 94 mm borosilicate glass cross-strip anode MCP detector

FUV Grating Array
An array of 26 gratings reflects and diffract light from the image slicer

For more, see AAS 243 (https://aas243.aas.org/)