UV diagnostics of the Starburst ISM

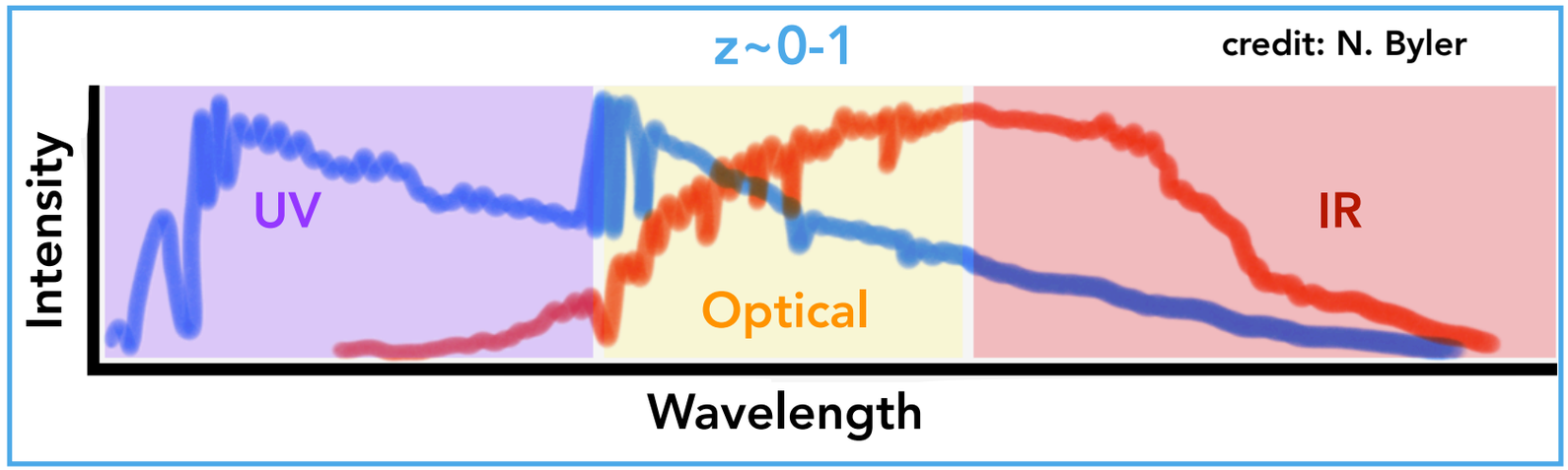
Danielle A. Berg
UT Austin

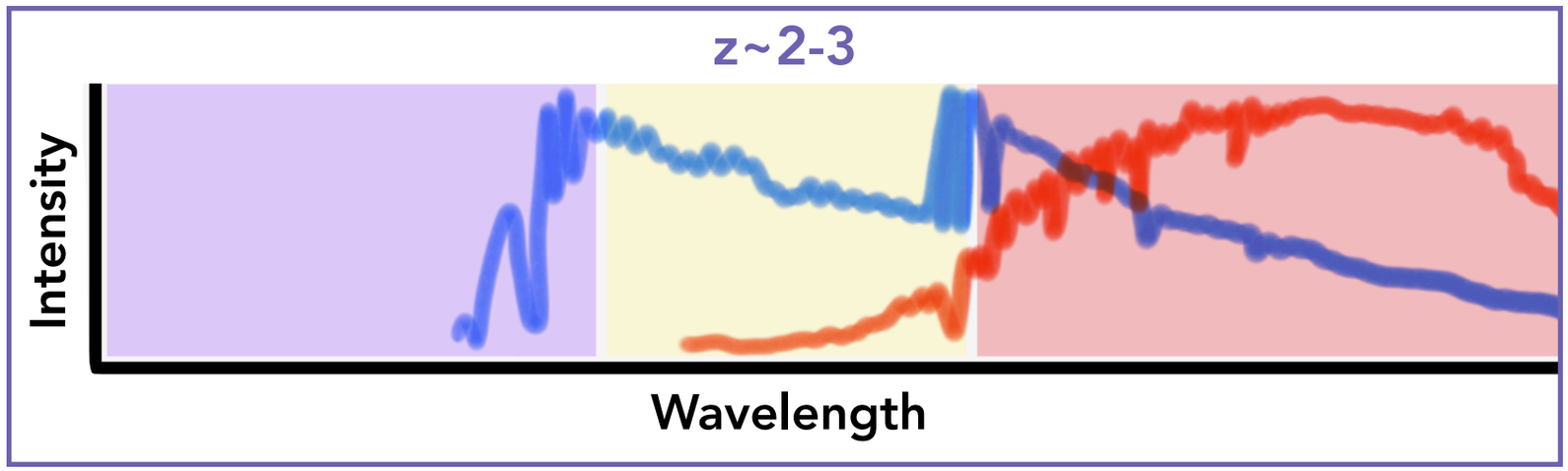
Image Credit: NASA/Swift/Stefan Immler (GSFC) and Erin Grand (UMCP)

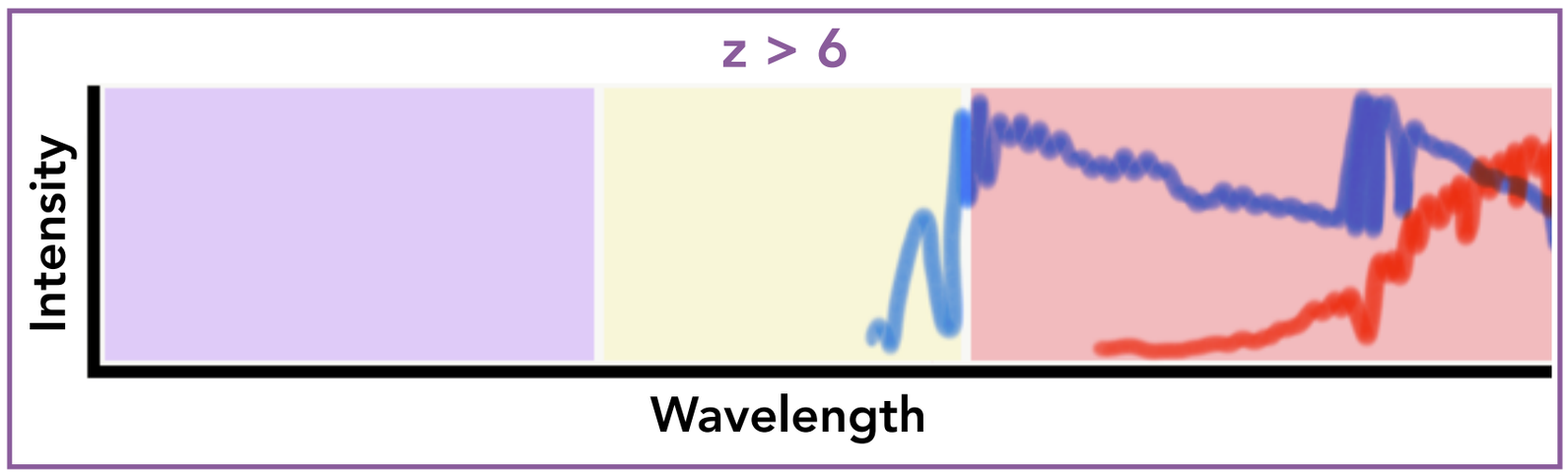
Rest-frame UV spectra characterize galaxy evolution **across all redshifts**

Danielle A Berg

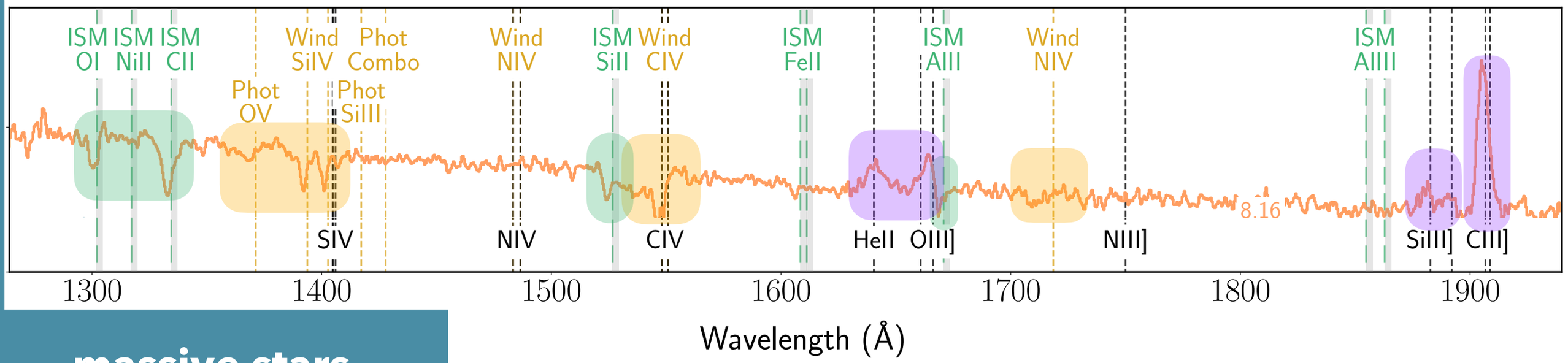
Rest-frame UV spectra characterize galaxy evolution **across all redshifts**







The UV hosts numerous spectral features that allow important interlinked processes to be traced within the **same galaxies**



massive stars
feedback
nebular gas
escaping ionizing radiation

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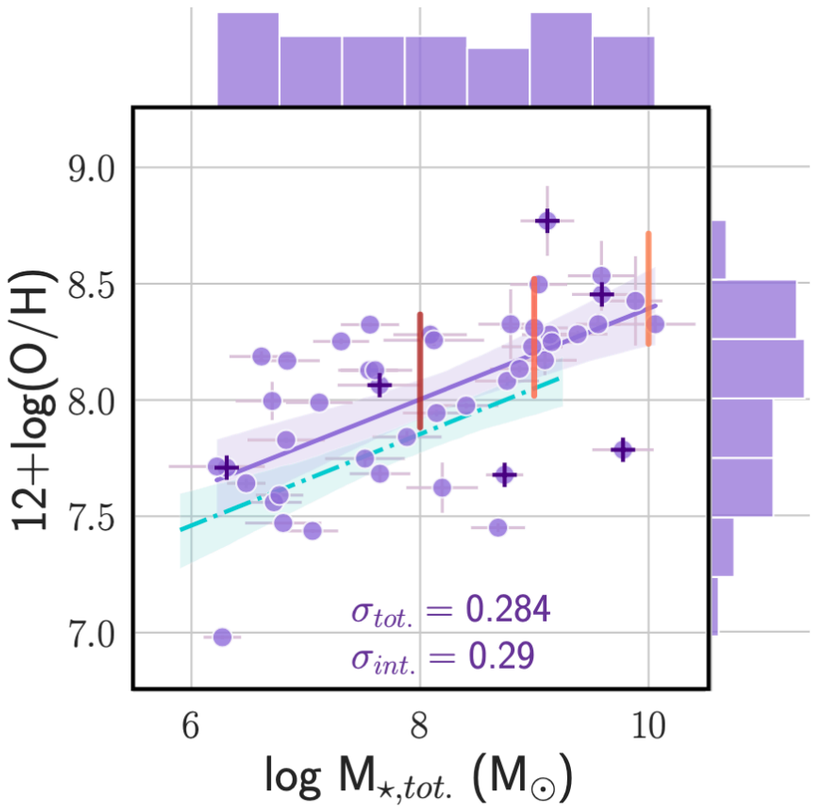
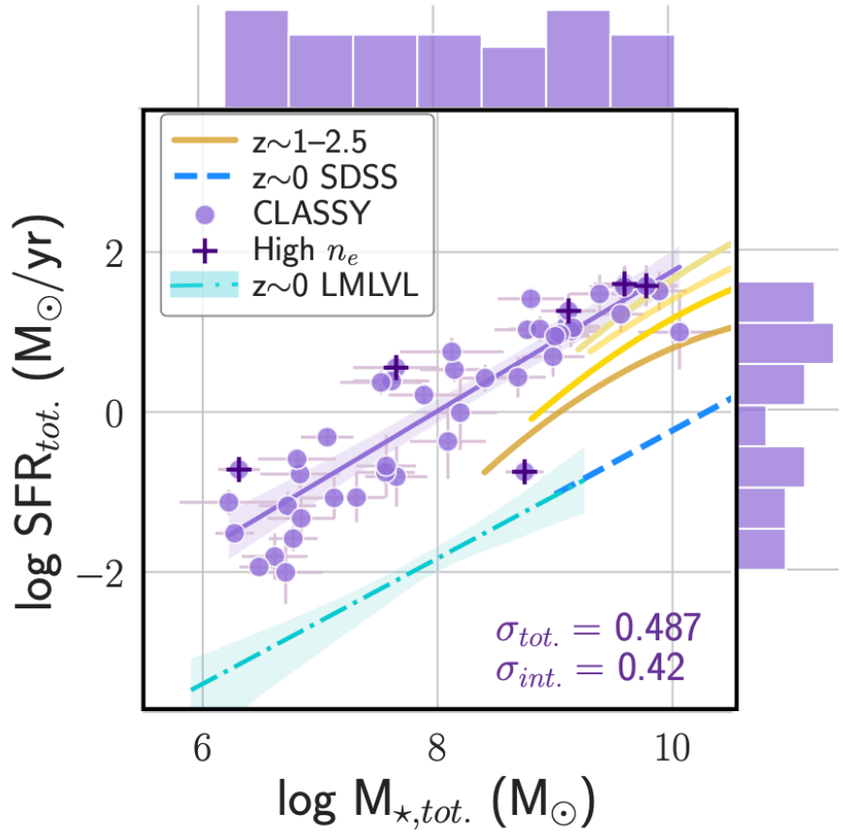
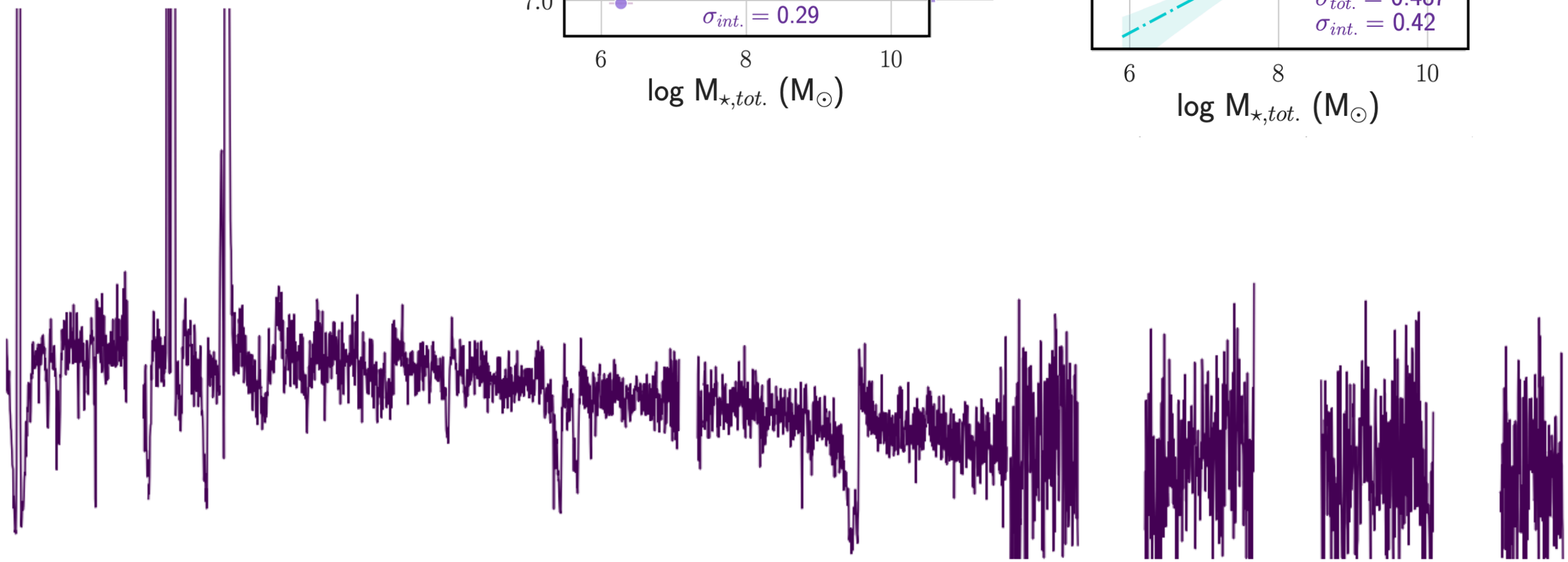
The COS Legacy Spectroscopic SurveY







Berg & the CLASSY Team, 2022

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01.7.2024

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FUV emission lines diagnose nebular gas physical conditions

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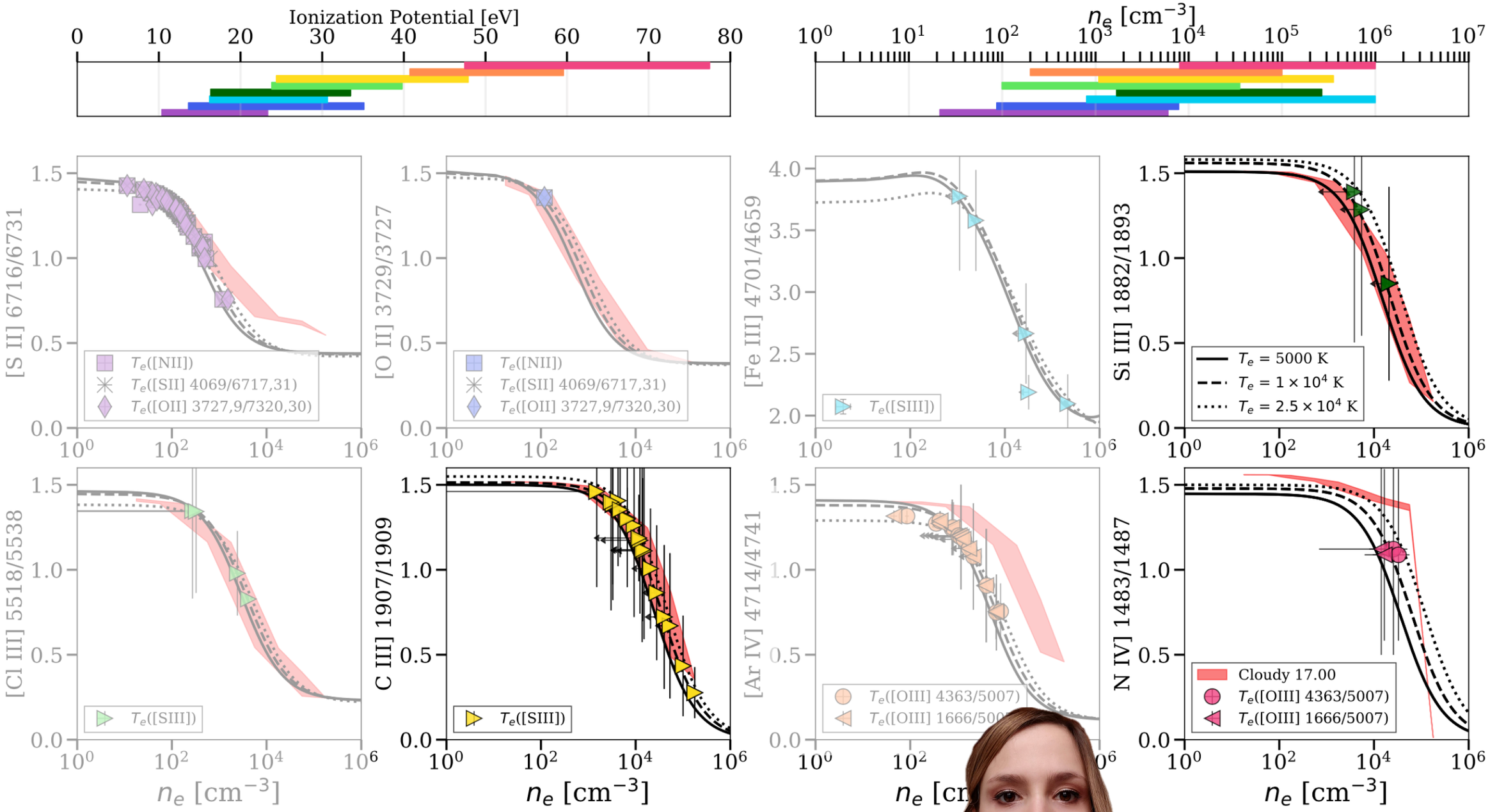
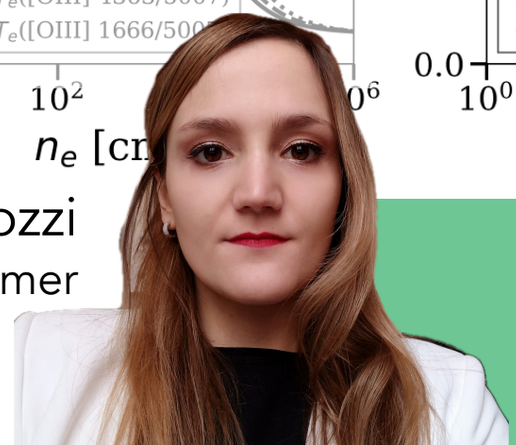
01.7.2024

CLASSY is improving the **calibration of FUV ionization, T_e, n_e, and metallicity diagnostics**

Mingozzi, Berg, and the CLASSY Team, 2022



Matilde Mingozzi
STScI Astronomer



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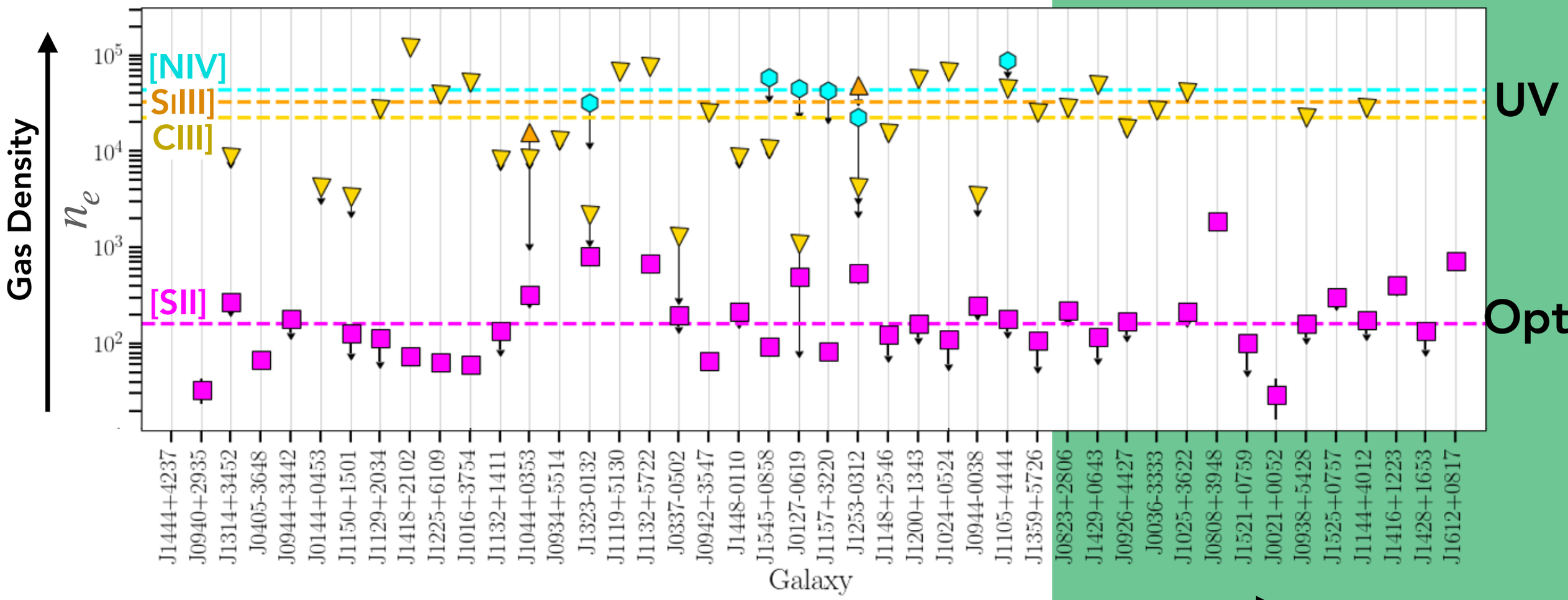
Densities from **UV** diagnostics are **higher than optical** diagnostics by 1-2 dex on average

see, also, e.g., Hainline+09, Maseda+17, Berg+18

CLASSY is improving the **calibration of FUV ionization, T_e, n_e, and metallicity diagnostics**



Mingozzi, Berg, and the CLASSY Team, 2022

Matilde Mingozzi
STScI Astronomer

Danielle A Berg

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Abundances serve as **evolutionary milestones**

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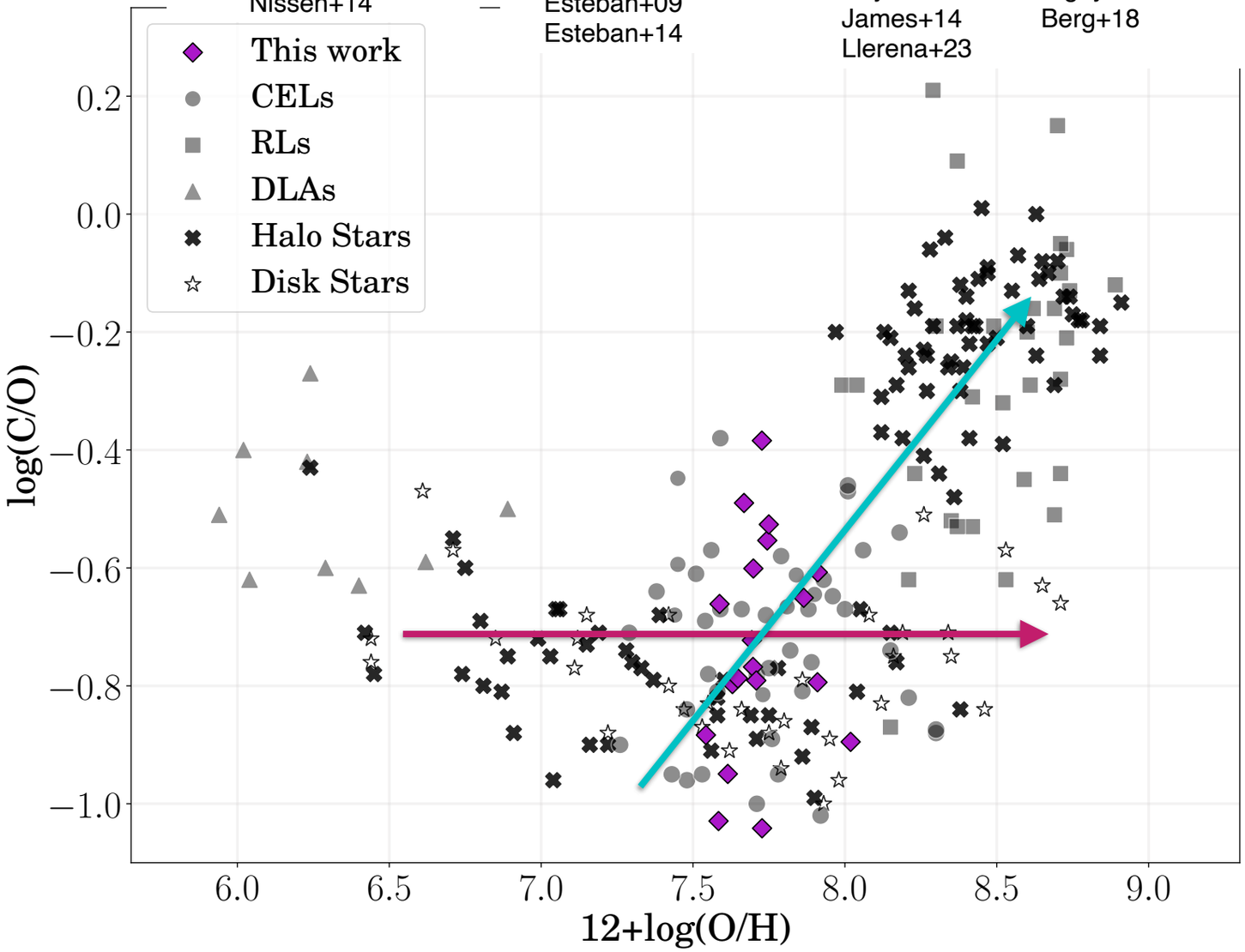
C O

C/O relative abundances
probe yields, feedback,
and **timescales**

Disk Stars:
Gustafsson+ 99
Halo Stars:
Akerman+04
Fabbian+ 09
Nissen+14

RLs:
Esteban+02
Peimbert+05
García-Rojas+07
López-Sánchez+07
Esteban+09
Esteban+14

DLAs:
Cooke+ 2017
High z:
Pettini+02
Fosbury+03
Erb+10
Christensen+12
Bayliss+14
James+14
Llerena+23
Stark+14
Steidel+16
Vanzella+16
Amorín+17
Rigby+17
Berg+18



Berg, D.A., et al. 2019a

Relative CNO abundances trace
Metal retention / CGM & IGM enrichment

C O

C/O relative abundances **probe yields, feedback,** and **timescales**

Disk Stars:
Gustafsson+ 99
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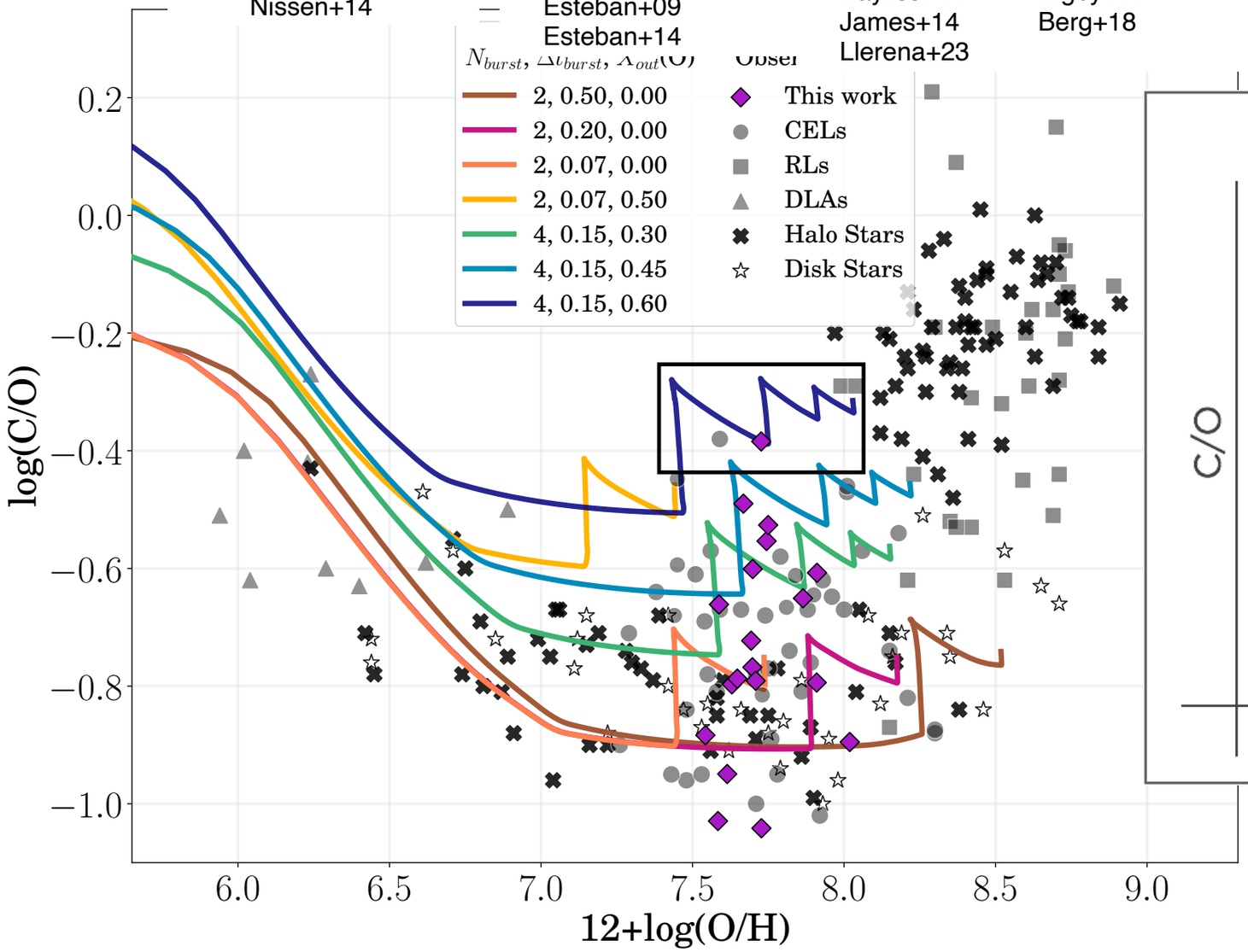
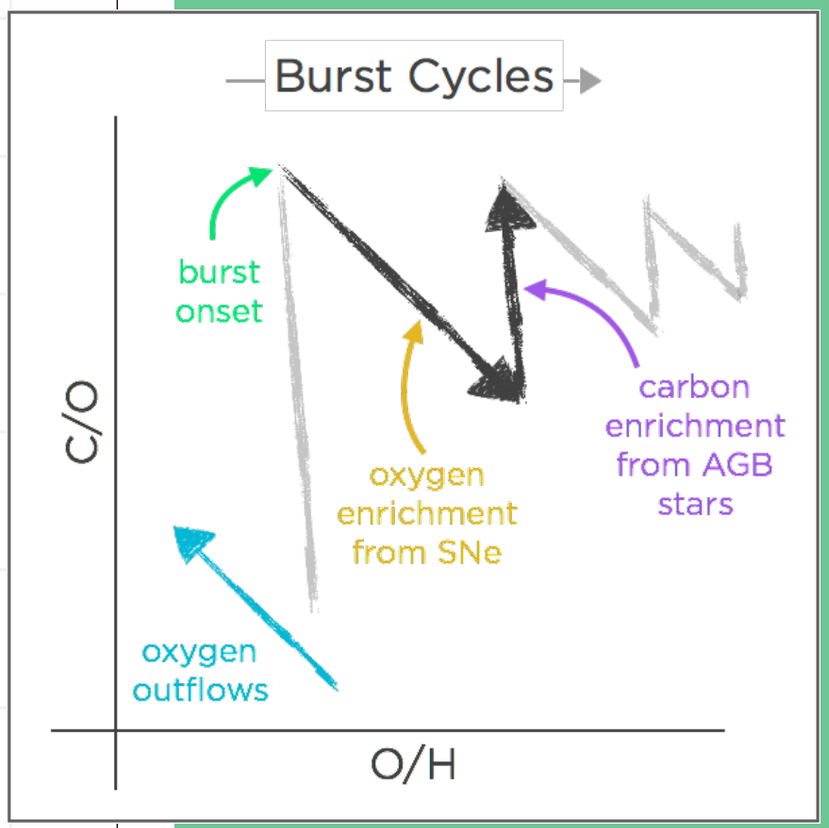




The C/O ratio depends critically on its **specific star formation history** and **effective yields**

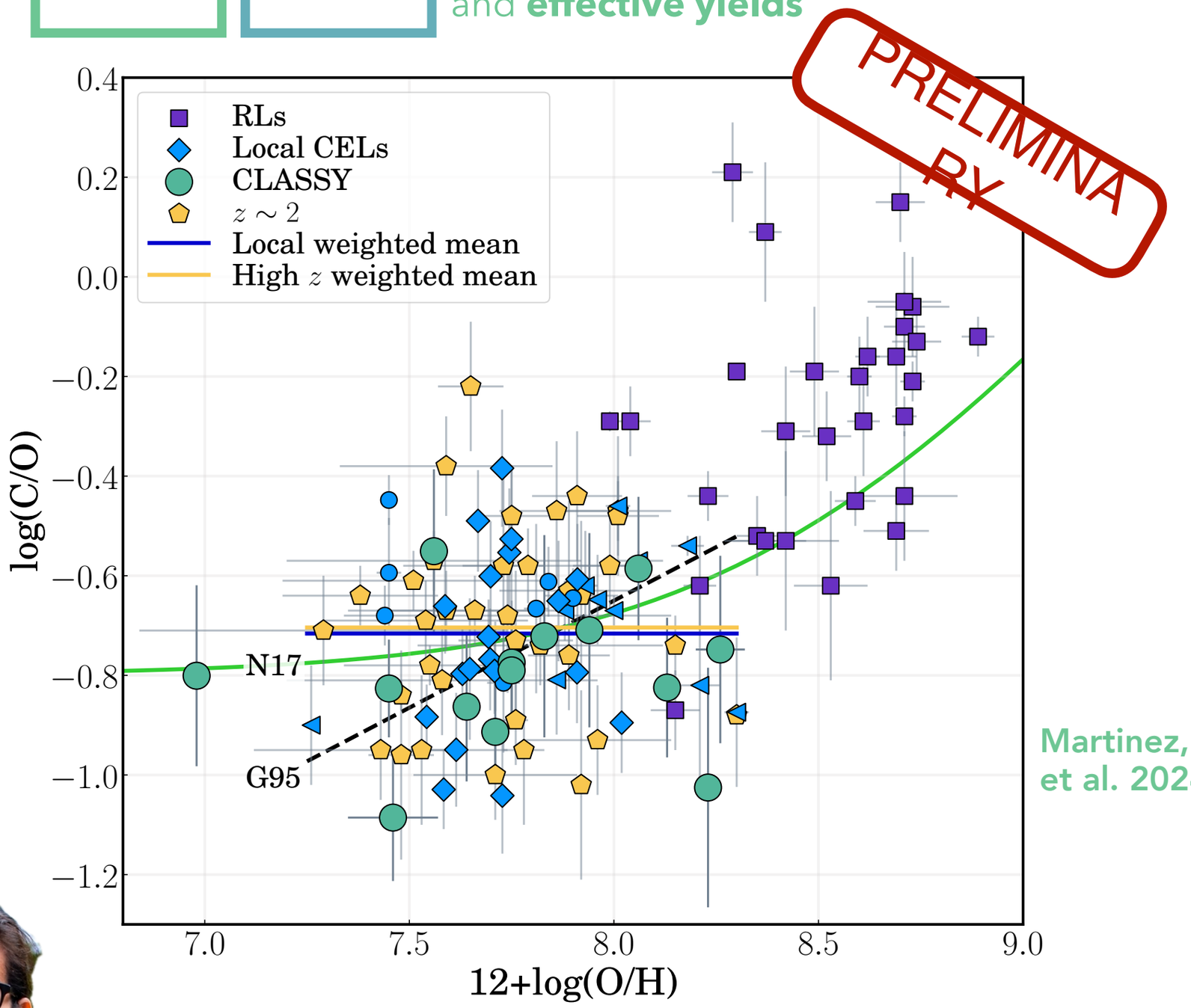
Relative CNO abundances trace **Metal retention / CGM & IGM enrichment**

Berg, D.A., et al. 2019a

Relative CNO abundances trace **Metal retention / CGM & IGM enrichment**

C O

The **C/O** ratio depends critically on its **specific star formation history** and **effective yields**



Martinez, Berg, D.A., et al. 2024, in prep.

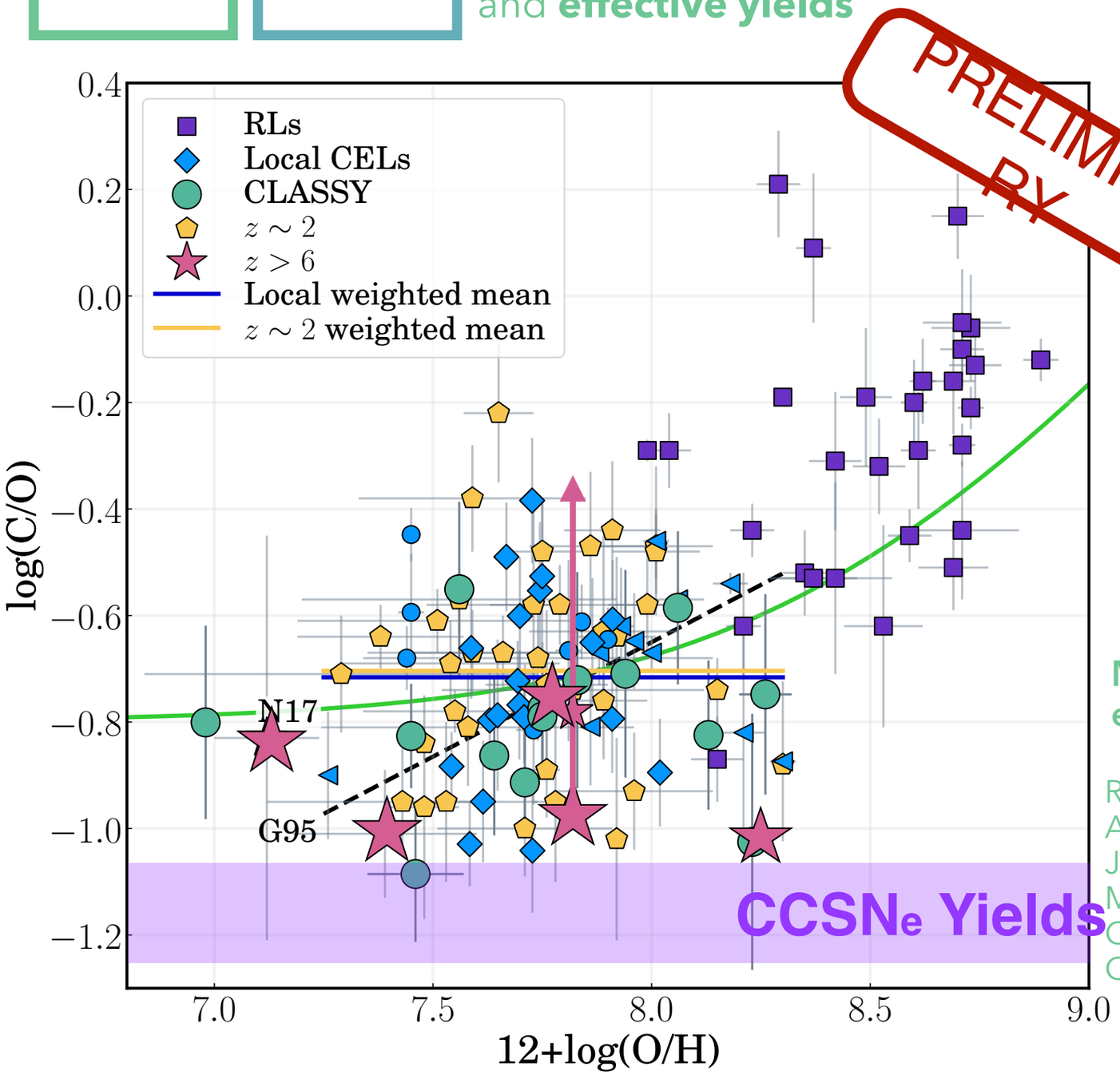
Zorayda Martinez
Graduate Student
UT Austin

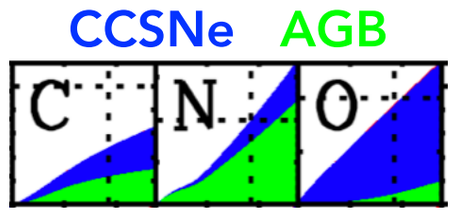
Our current measurements show **no evolution of C/O**.

Relative CNO abundances trace **Metal retention / CGM & IGM enrichment**

C O

The **C/O** ratio depends critically on its **specific star formation history** and **effective yields**





Kobayashi+2020

Martinez, Berg, D.A., et al. 2024, in prep.

References (left to right):
Arellano-Cordova+22 (z=8.5)
Jones+23 (z=6.2)
Marques-Chaves+23 (z=8.7)
Cameron+23 (z=10.6)
Citro, Berg, D.A.+23 (z~4)

Could C/O be used as a diagnostic of very young galaxies?

Given the time delay in C production, we might expect to see a delay in C enrichment at high-z …

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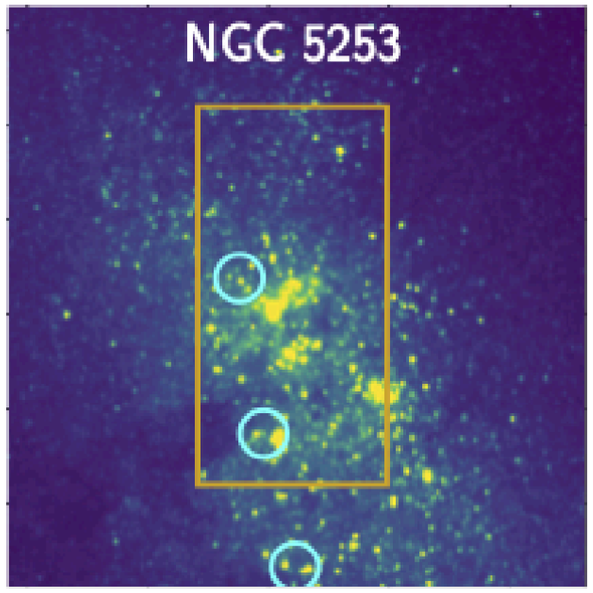
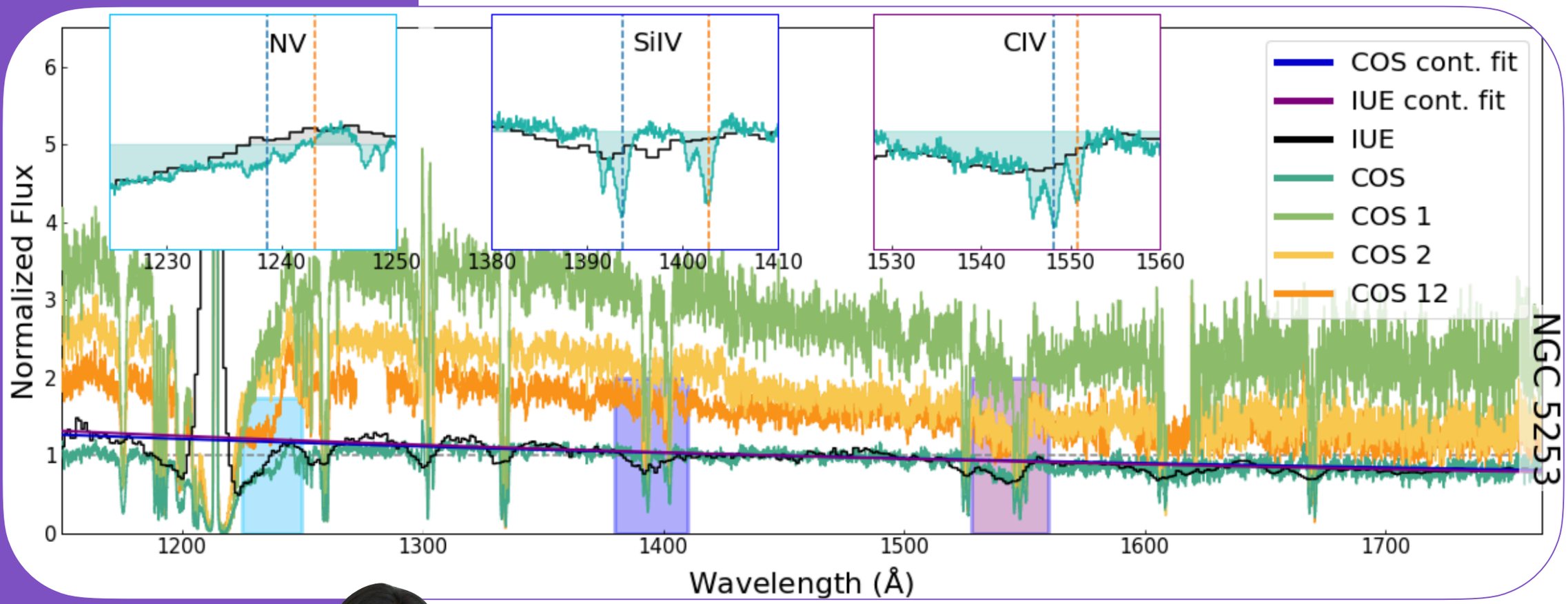
Spatial & Spectral resolution are important for rest-frame UV absorption-line spectra





Clark,Berg+2024, submitted

Ilye Clark
Graduate Student
UC San Diego

01.7.2024

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FUV resonant line emission tells us about the **porosity of the CGM** and the **escape of ionizing radiation**

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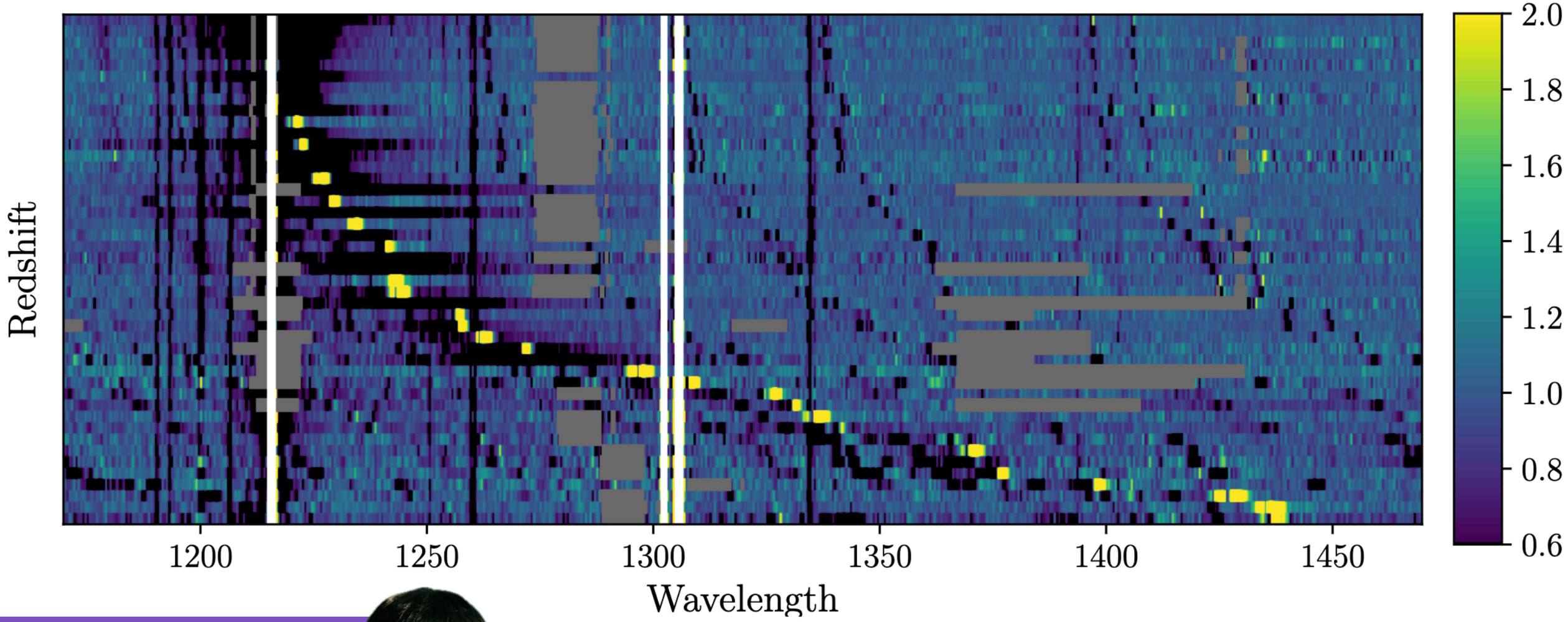
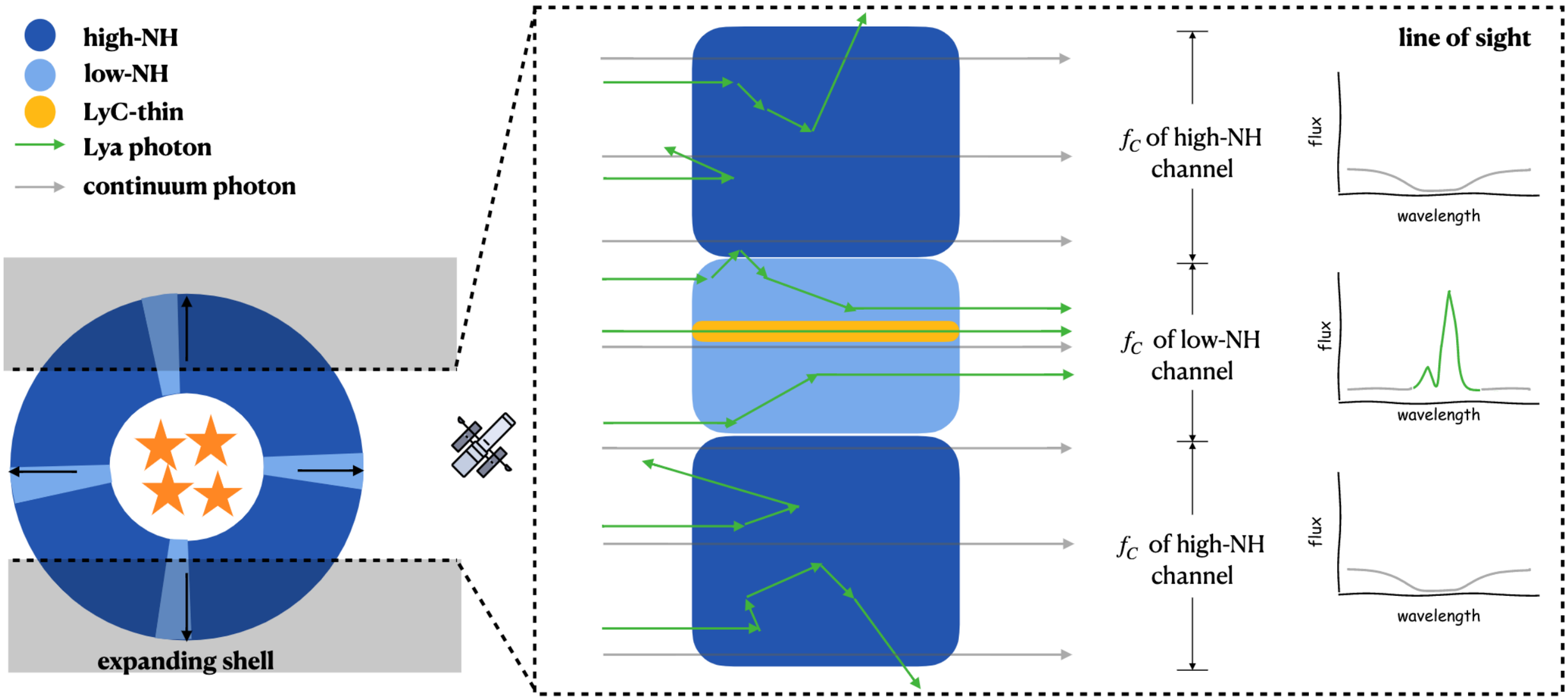
Local evolution shows increase in neutral H at recent times



Weida Hu
Postdoc
Texas A&M

Hu, W.; Berg, D.A.; and the CLASSY team, 2023

CGM gas is complex. LyA profile observed depends on both aperture and viewing angle.

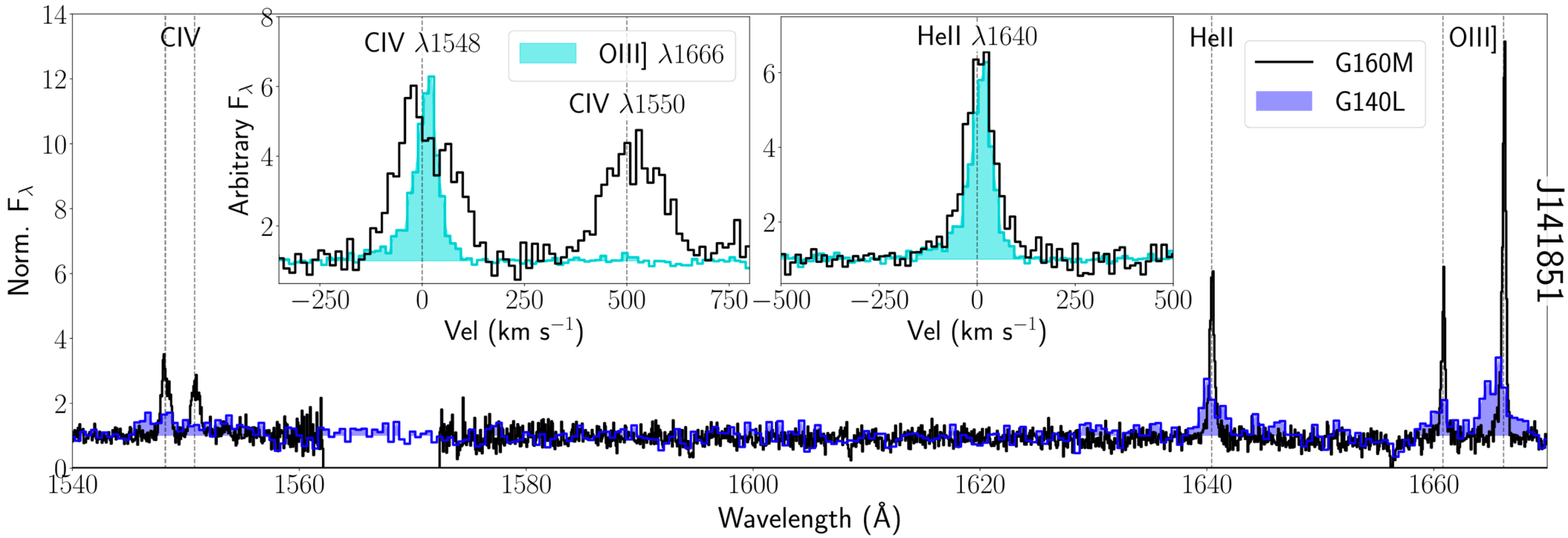


Weida Hu
Postdoc
Texas A&M

Hu, W.; Berg, D.A.; and the CLASSY team, 2023

01.7.2024

High-ionization emission indicates **production of very high-energy photons**



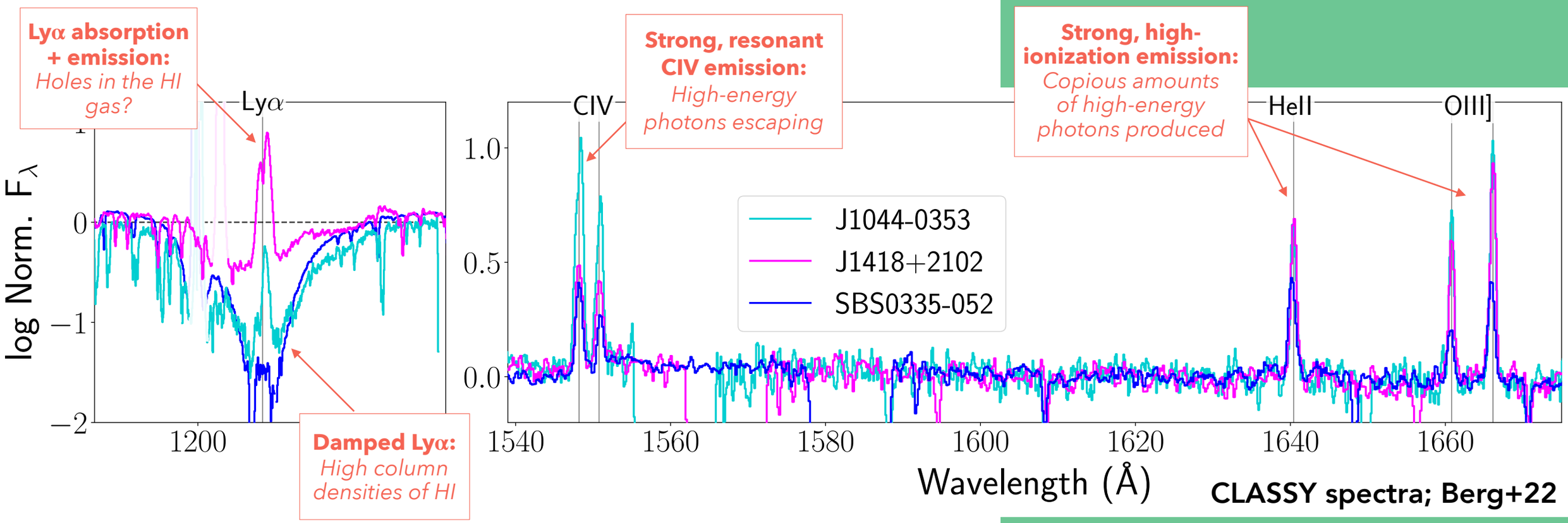
Resonant CIV emission suggests **high-energy photons can escape**

Berg et al, 2019b

C

Resonant transitions can tell us about the column density of different **ionized gas populations**

If gas within a galaxy **is generally uniform and low-column density**, then all resonant lines should have **narrow, symmetric emission** profiles



CLASSY spectra; Berg+22

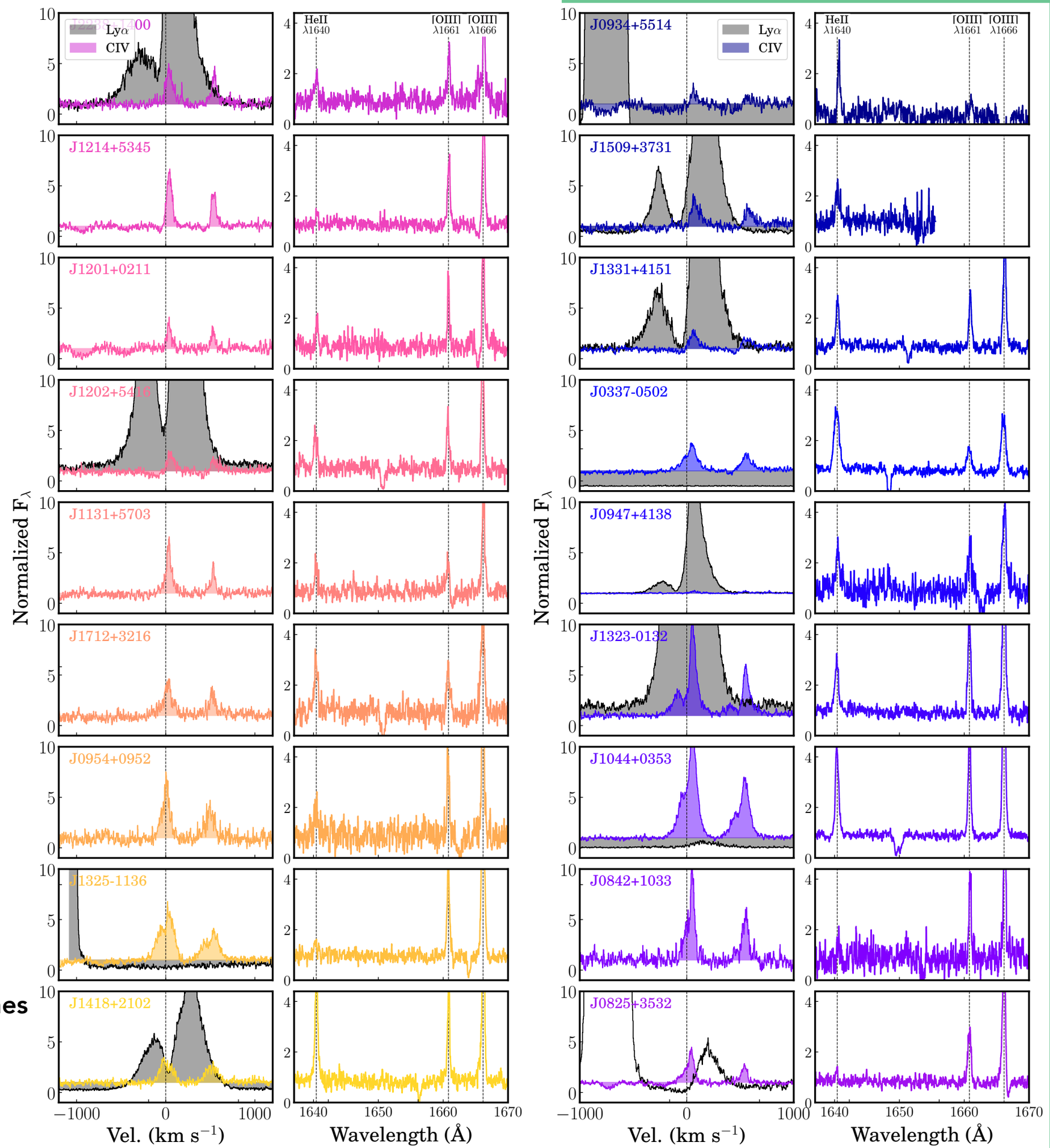
Resonant transitions of different ions will allow us to trace the escape of **both low- and high-energy ionizing photons** through **neutral/low- and high-ionization gas**

C

Resonant transitions that can tell us about the column density of different **ionized gas populations**

Gazagnes, Berg, et al. 2024, in prep.

PI: Simon Gazagnes
Postdoc
UT Austin



C

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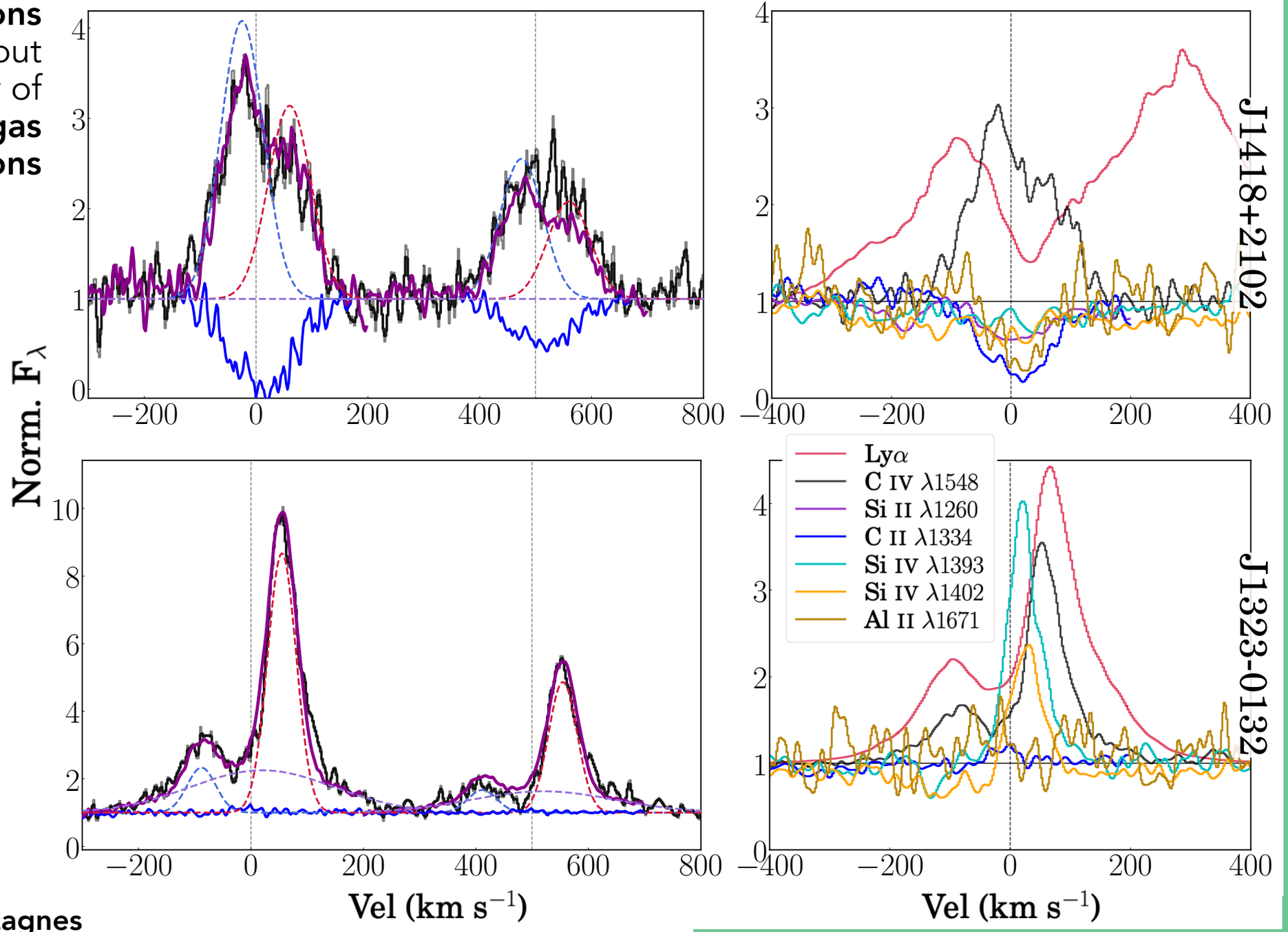
Gazagnes, Berg, et al. 2024, in prep.



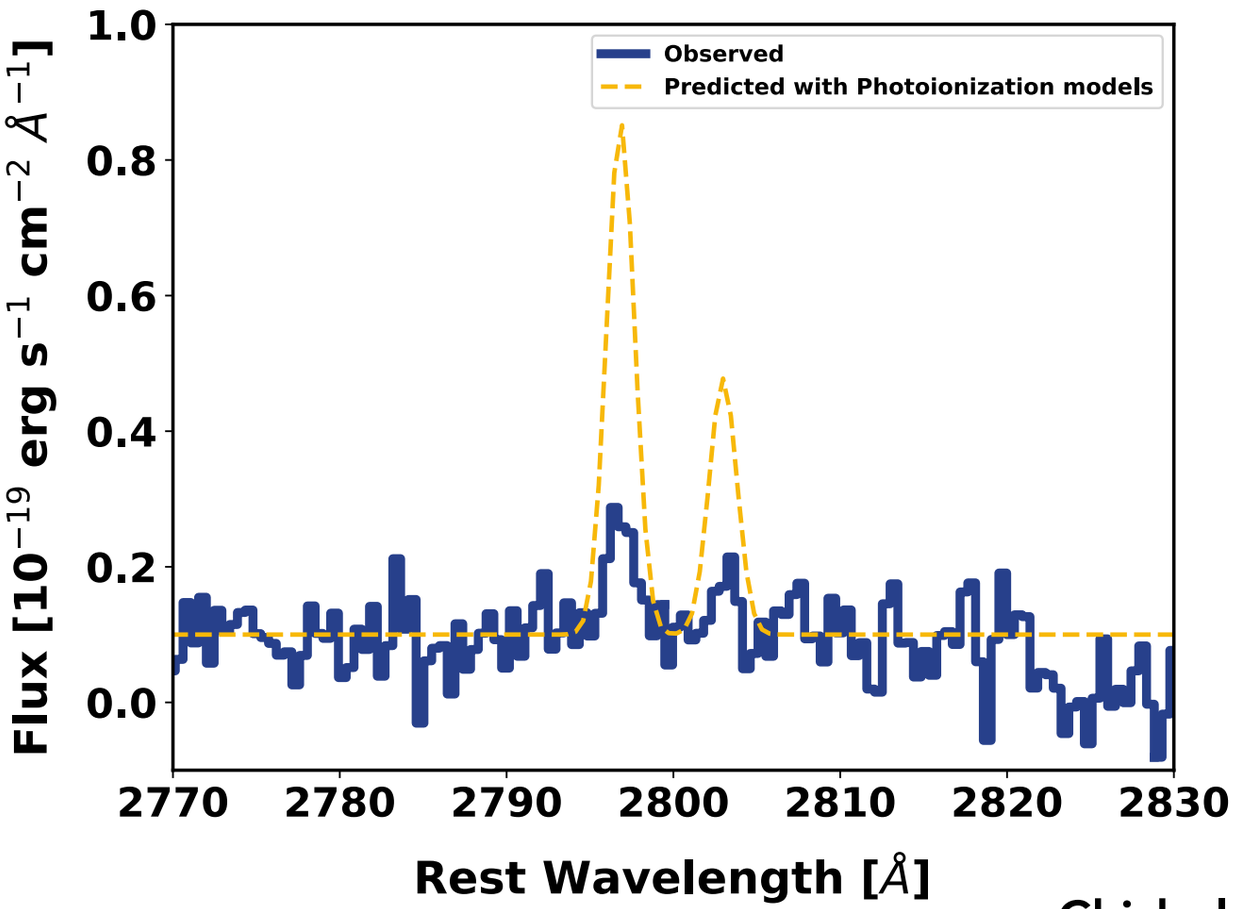
PI: Simon Gazagnes
Postdoc
UT Austin

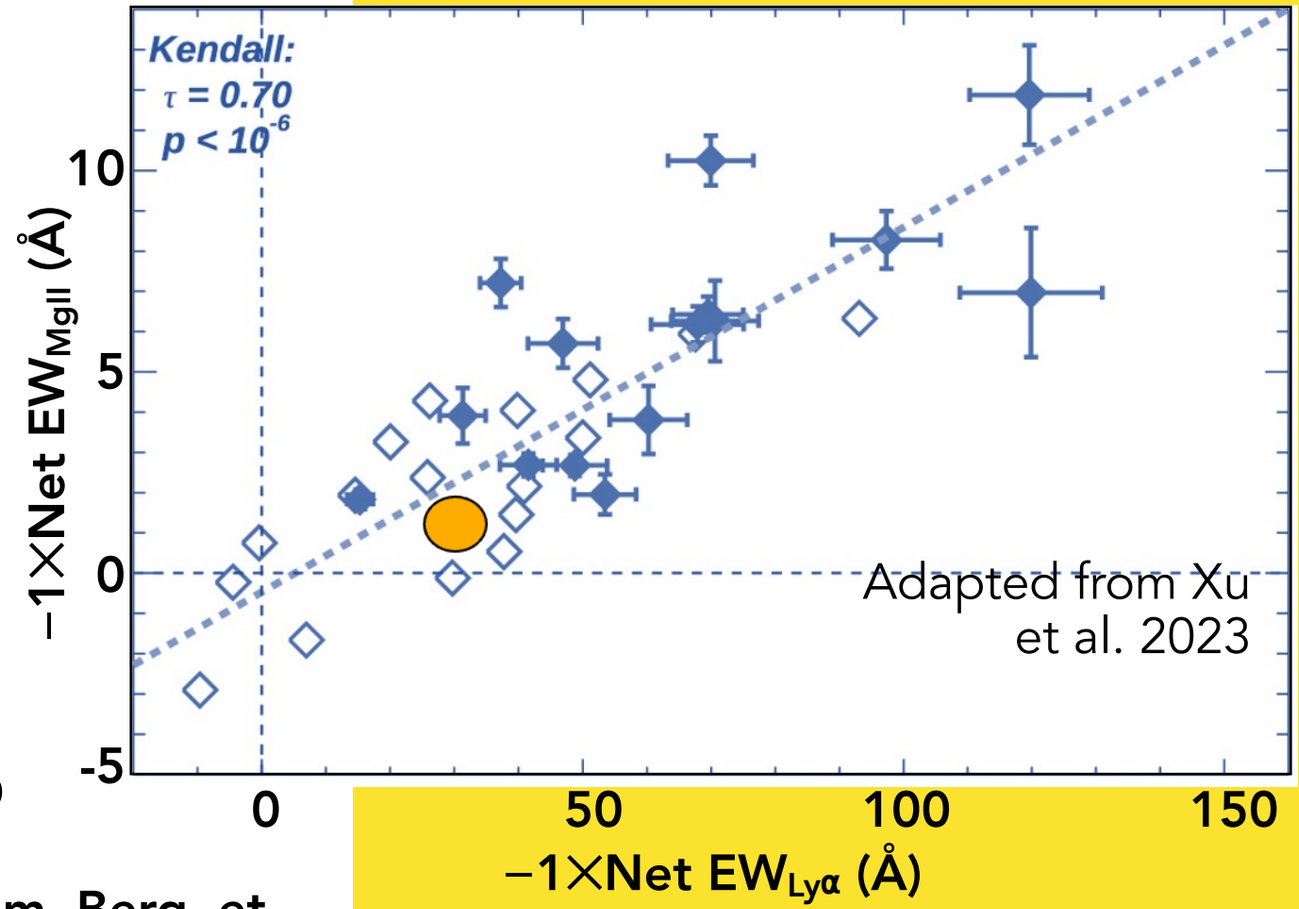
Mg

Resonant transitions can tell us about the column density of different **ionized gas populations**

Mg II detected in a z=7.5 galaxy.

MgII is much weaker than predicted by the photoionization models, suggesting **very little Mg II or LyC escapes** this system





Chisholm, Berg, et al., 2024 in prep.

NUV MgII λλ2796,2803 emission probes LyC emission into the epoch of reionization

FUV spectra characterize the massive star populations (age, metallicity, ionizing continuum)

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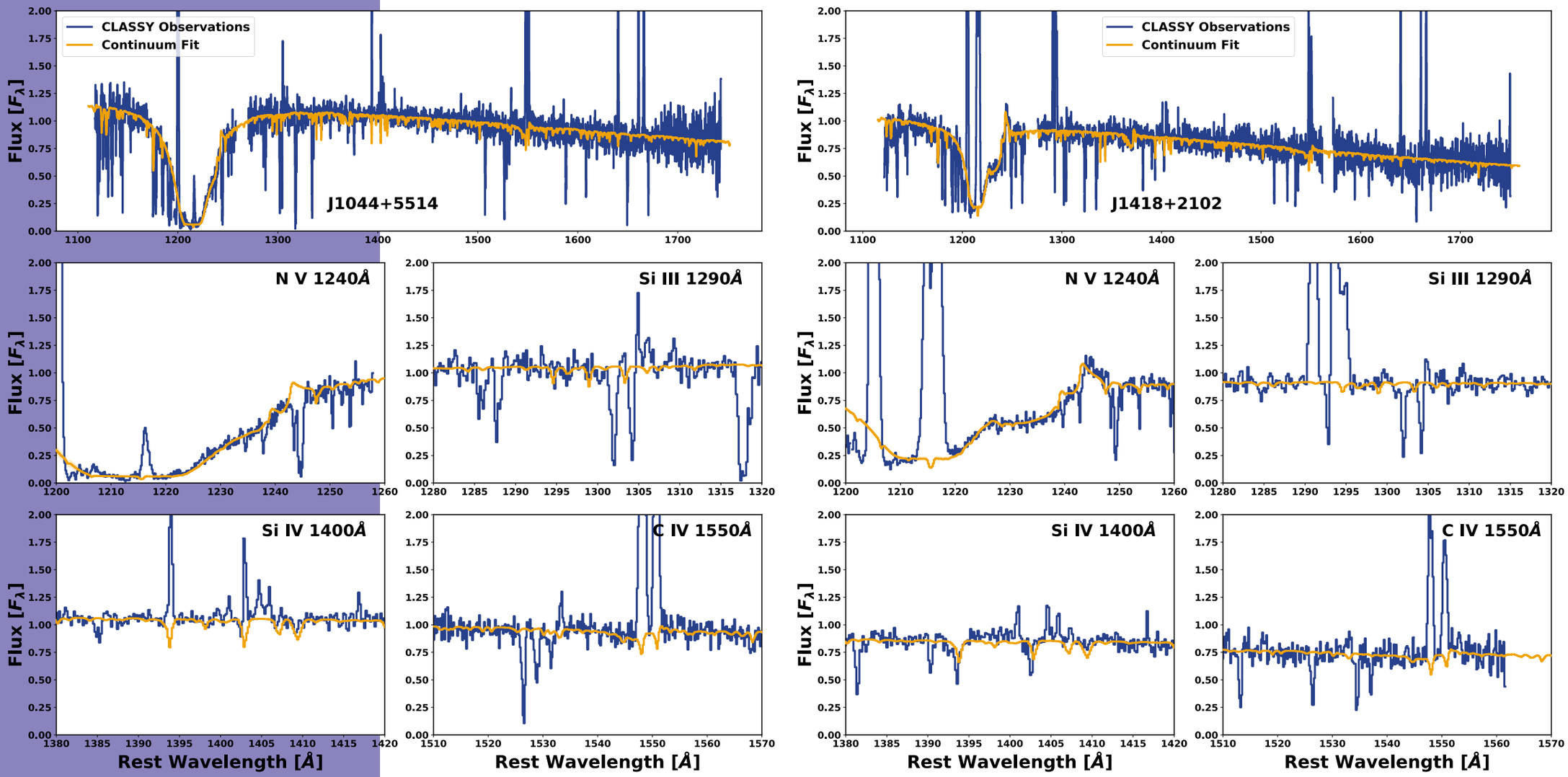

Olivier, Berg, et al. 2022

Stellar continuum fits are critical for predicting the **ionizing continuum**

Grace Olivier
Postdoc
Texas A&M

01.7.2024

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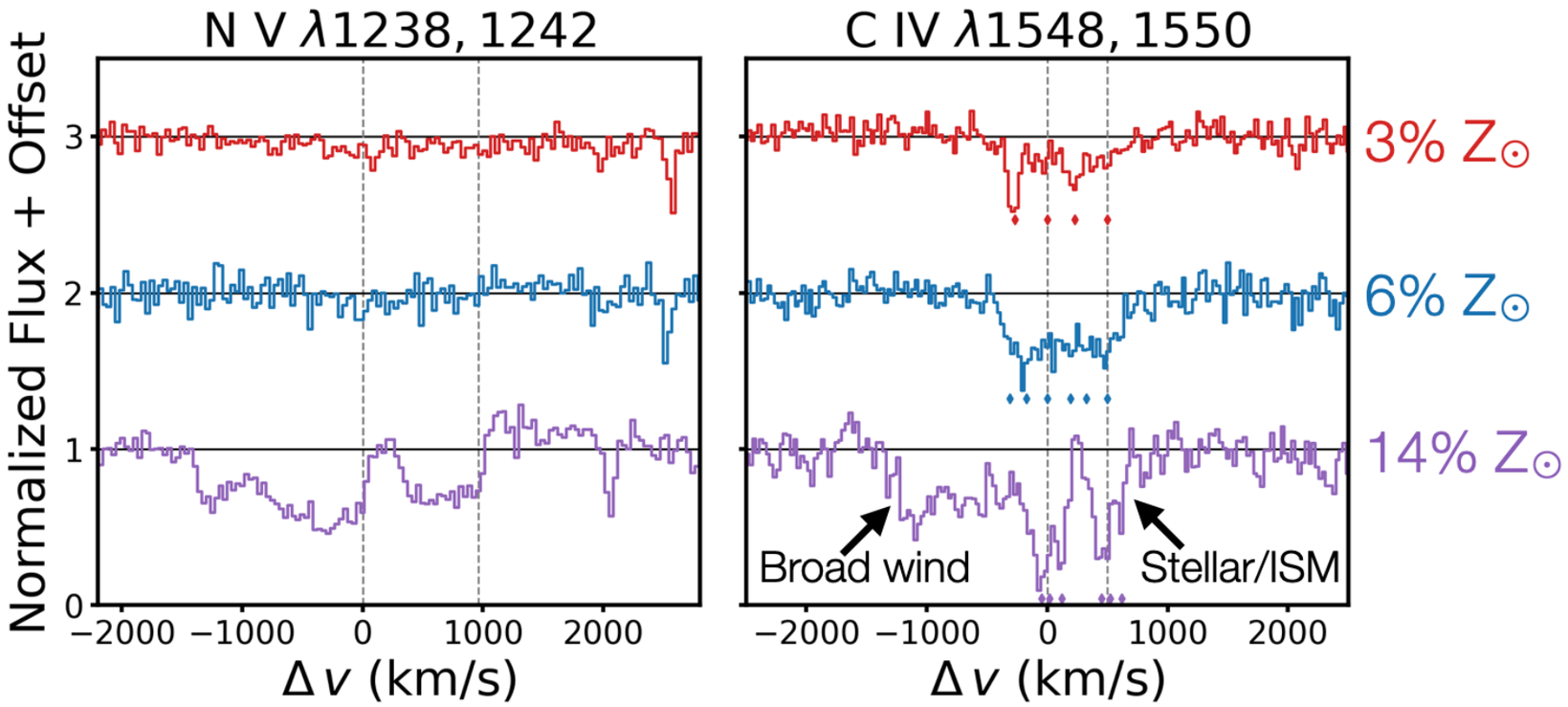
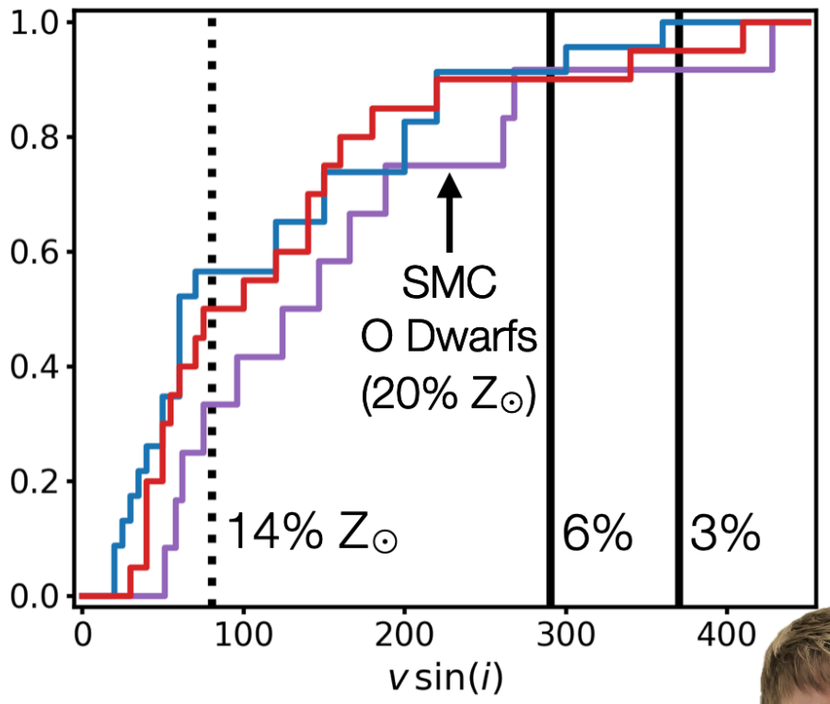
Cosmic Origins



Wind features are very weak below 10% $Z_\odot$, implying long stellar lifetimes and low opacity to ionizing photons

Telford, Berg, et al. 2021

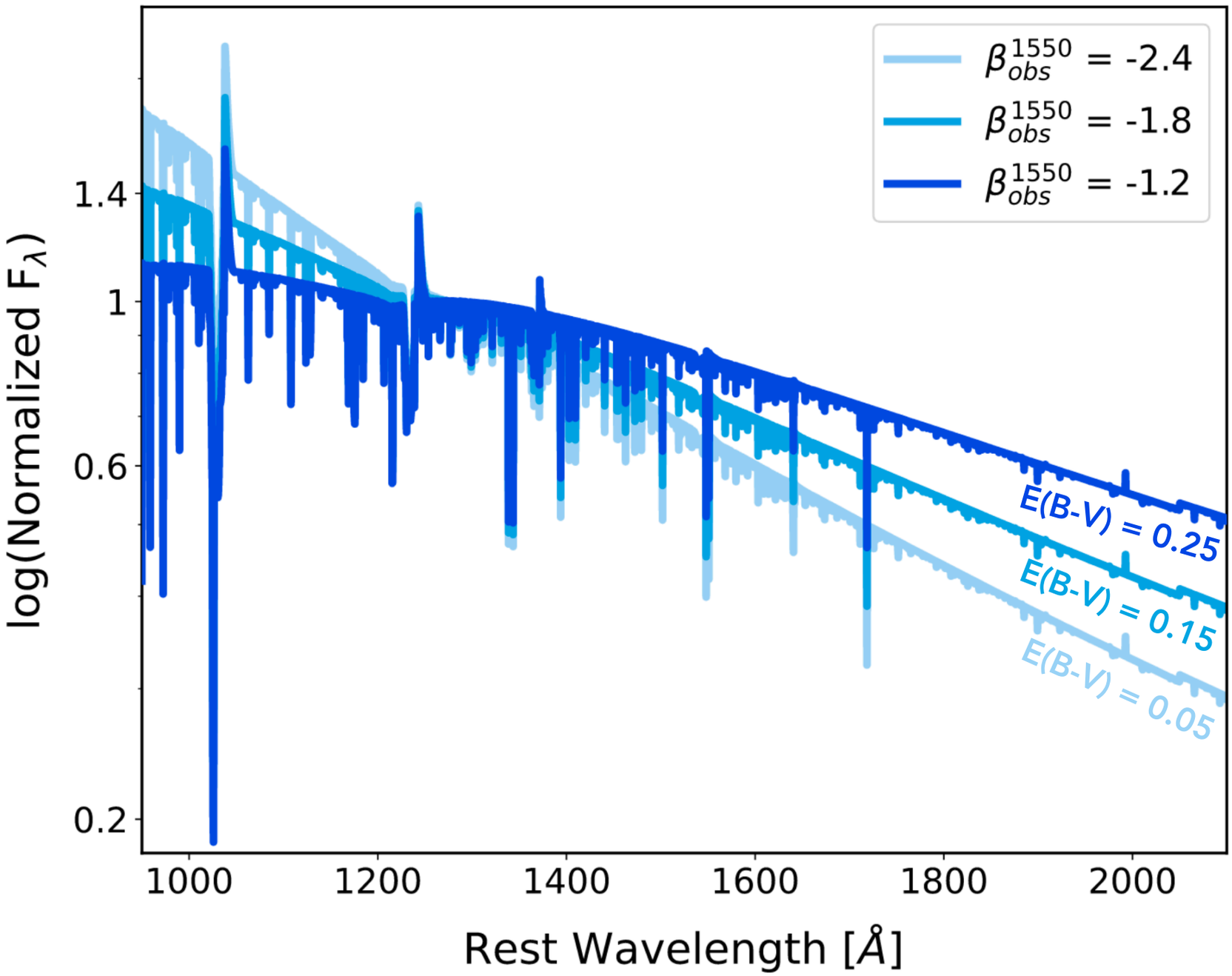


High-resolution rest-frame FUV spectra with ELTs will help constrain physics of very-metal-poor stars

Observed high vsin(i) below 10% $Z_\odot$ favors rotating stellar evolution models with higher ionizing photon production

Grace Telford
Carnegie-Princeton Postdoc

Chisholm, et al. 2022



The stellar continuum slope (β slope) diagnoses the attenuation due to dust

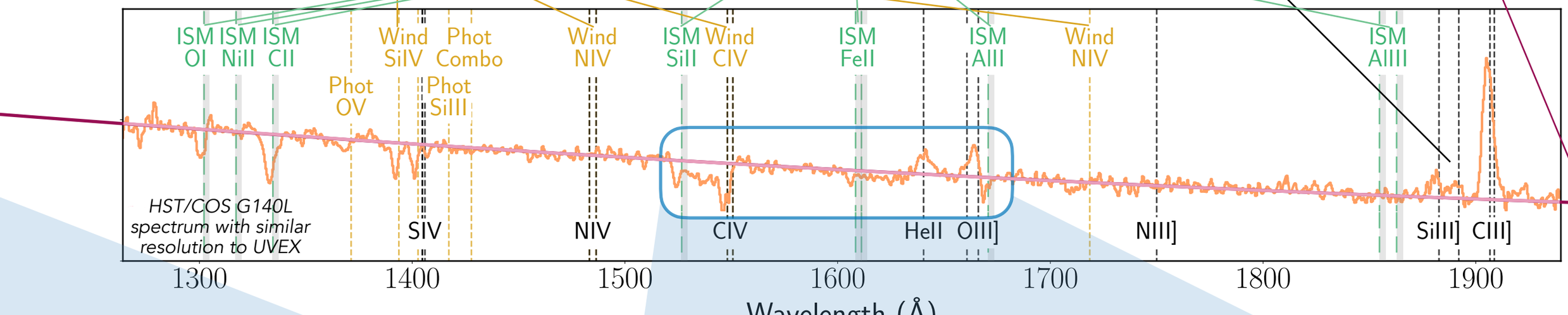
The UV is a power regime for diagnosing the conditions in star-forming galaxies

Stellar wind P-Cygni features *characterize the massive star populations (age, metallicity, ionizing continuum) driving feedback and producing emission-lines*

ISM absorption features *diagnose properties of gas along line of sight: metallicity, outflow/inflow velocity, porosity, turbulence, etc.*

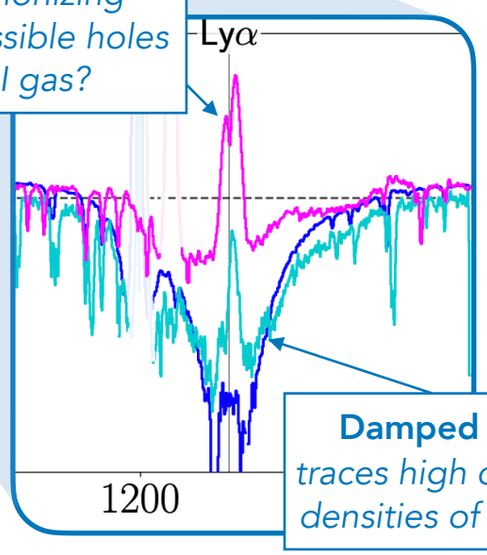
Some emission lines *diagnose nebular conditions* (e.g., $n_e \propto$ Si III] λ1892/λ1883)

Stellar continuum slope *diagnoses dust attenuation*



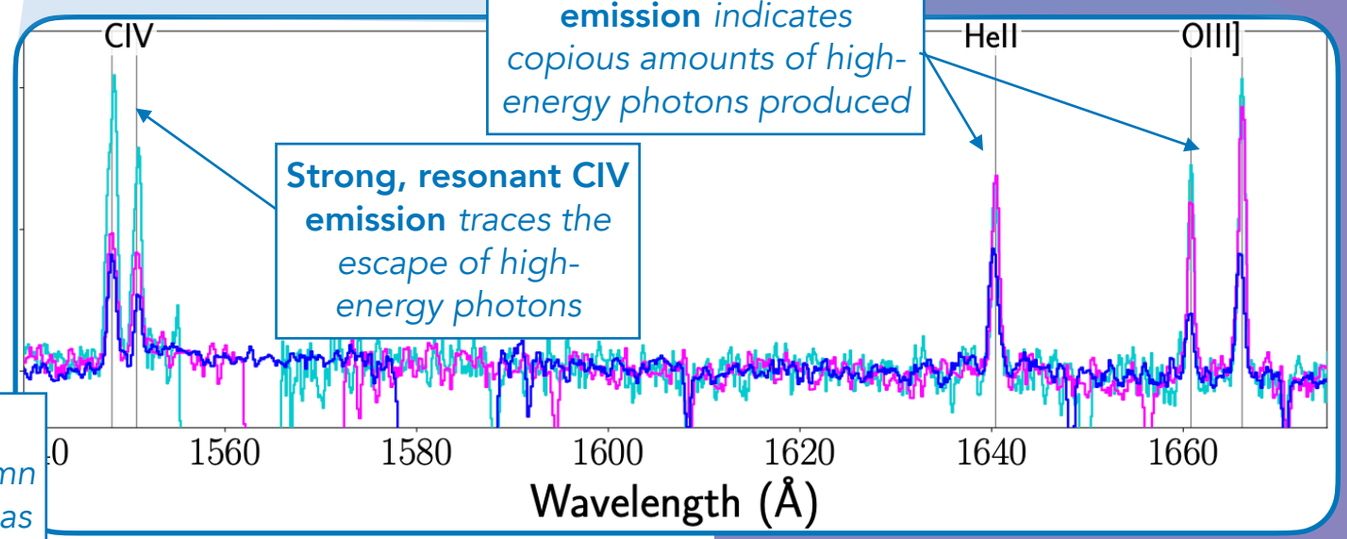
Lyα emission *traces the escape of ionizing photons; possible holes in the HI gas?*

Damped Lyα *traces high column densities of HI gas*



Strong, high-ionization emission *indicates copious amounts of high-energy photons produced*

Strong, resonant CIV emission *traces the escape of high-energy photons*



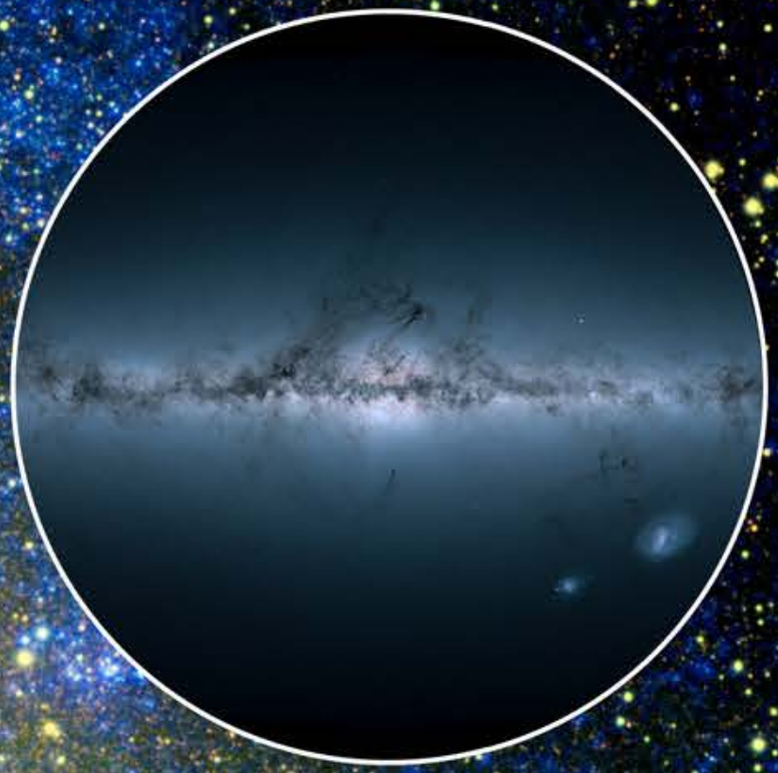
UVEX
Ultraviolet Explorer

All-Sky Imaging

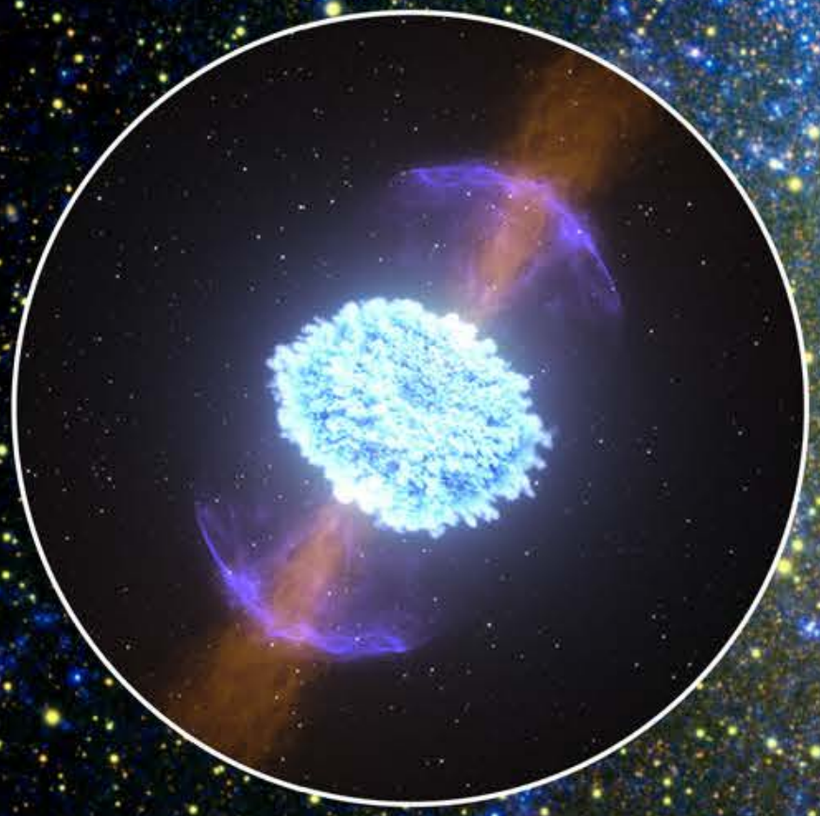
Time Domain

Spectroscopy

Exploring the Low Mass Galaxy Frontier



Legacy of Deep Synoptic Surveys



New Views of the Dynamic Universe

PRINCIPAL INVESTIGATOR

Fiona A. Harrison
California Institute of Technology

AUTHORIZING OFFICIAL

David J. Mayo
Director, Office of Sponsored Research
California Institute of Technology

DECEMBER 9, 2021

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