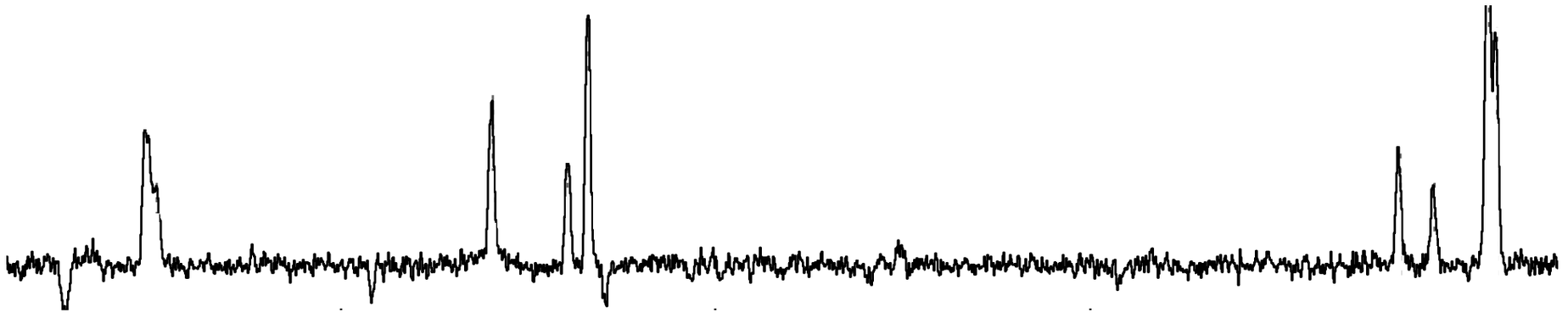
Calibrating the FUV Diagnostic Emission-Line Toolbox with UVEX: Probing the Evolution of the Lowest-Mass Galaxies



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03.23.2023

UVEX
Ultraviolet Explorer

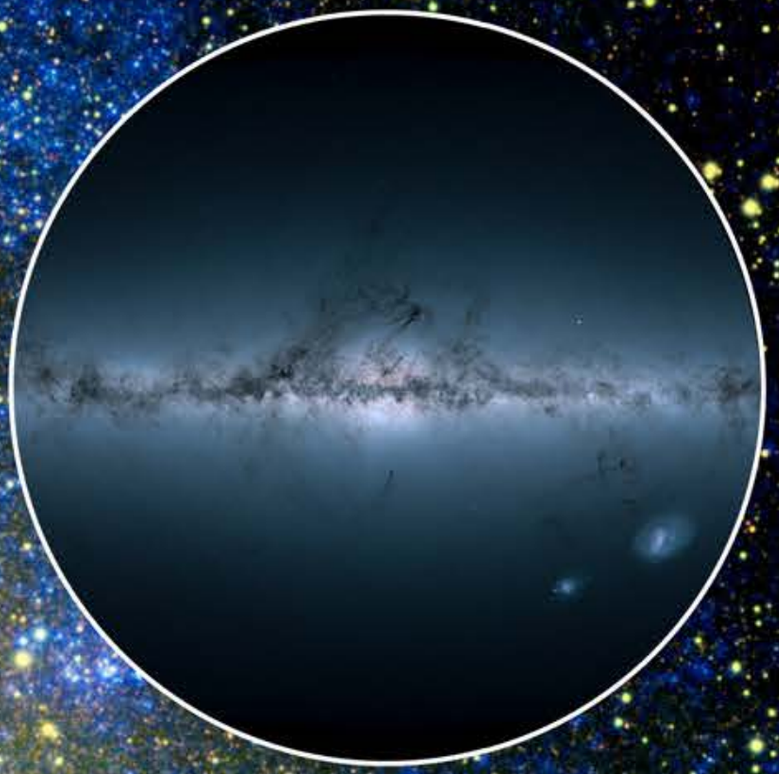
All-Sky Imaging

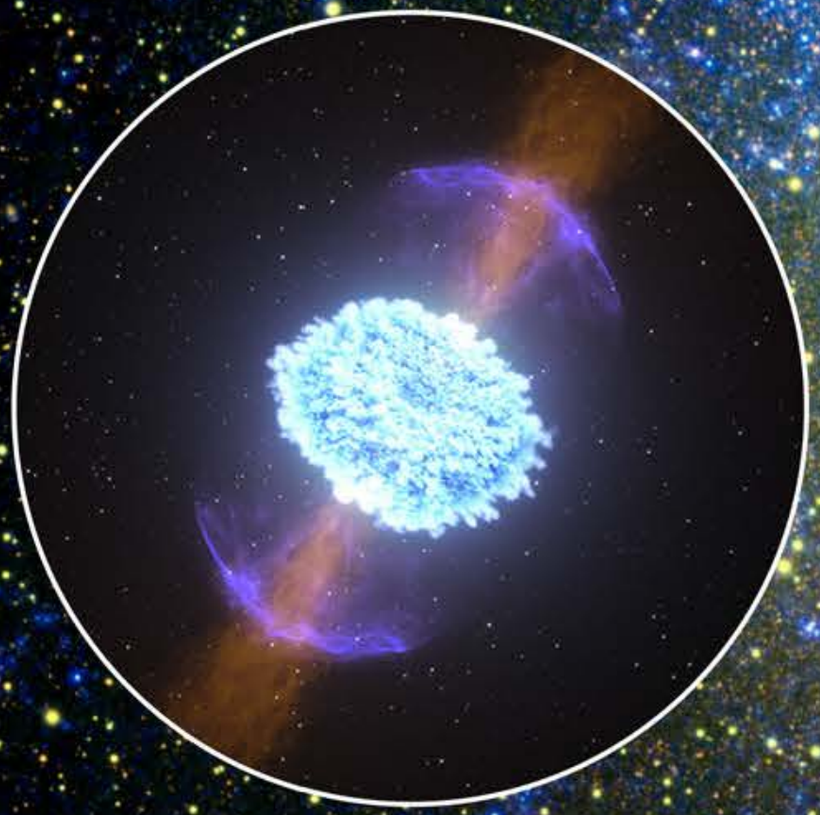
Time Domain

Spectroscopy

Exploring the Low Mass Galaxy Frontier

Special thanks to **Dan Weisz** and **Peter Senchyna**





Legacy of Deep Synoptic Surveys

New Views of the Dynamic Universe

PRINCIPAL INVESTIGATOR

Fiona A. Harrison
California Institute of Technology

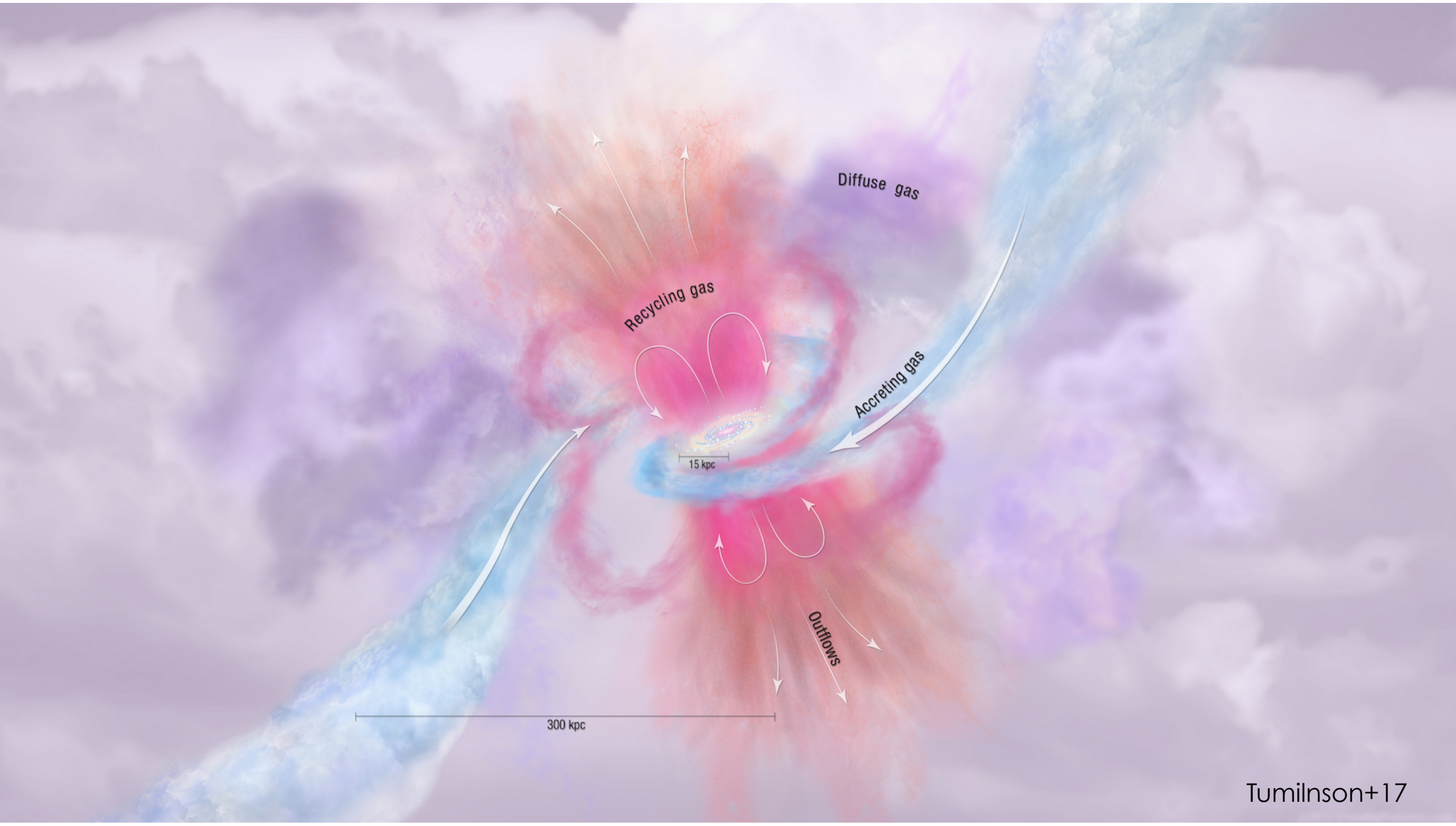
AUTHORIZING OFFICIAL

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

DECEMBER 9, 2021

Submitted in response to:
MIDEX 2021
AO NNH21ZDA018O

UVEX probes the processes of the baryon cycle that shapes galaxy evolution



Tumilnson+17

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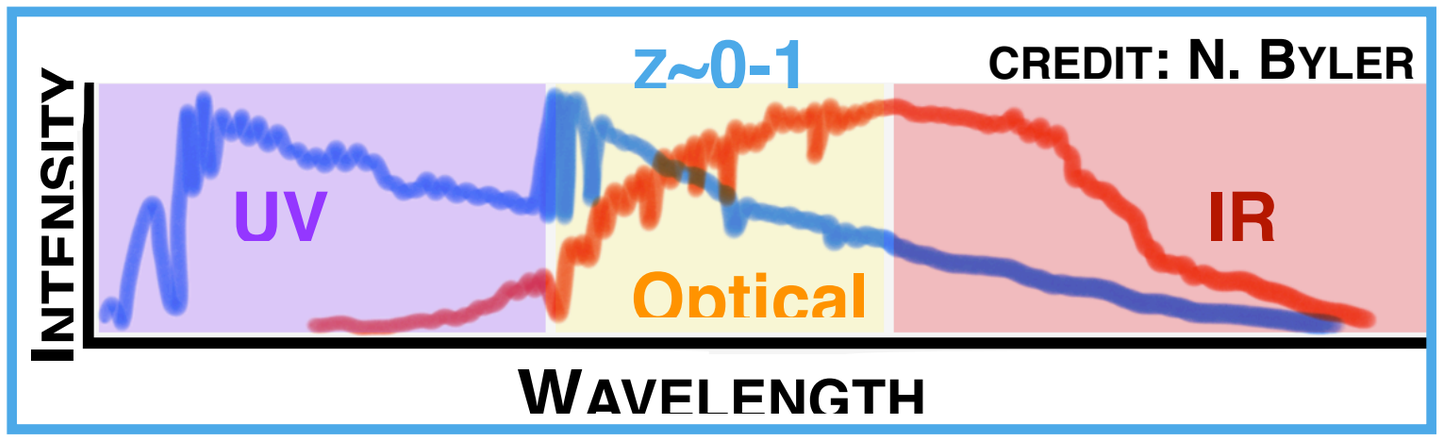
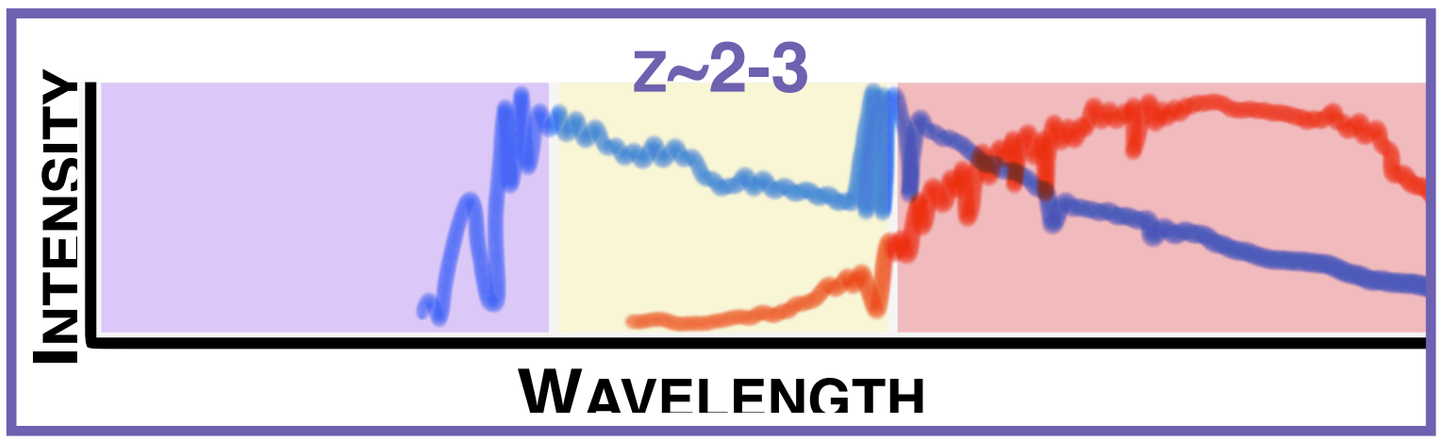
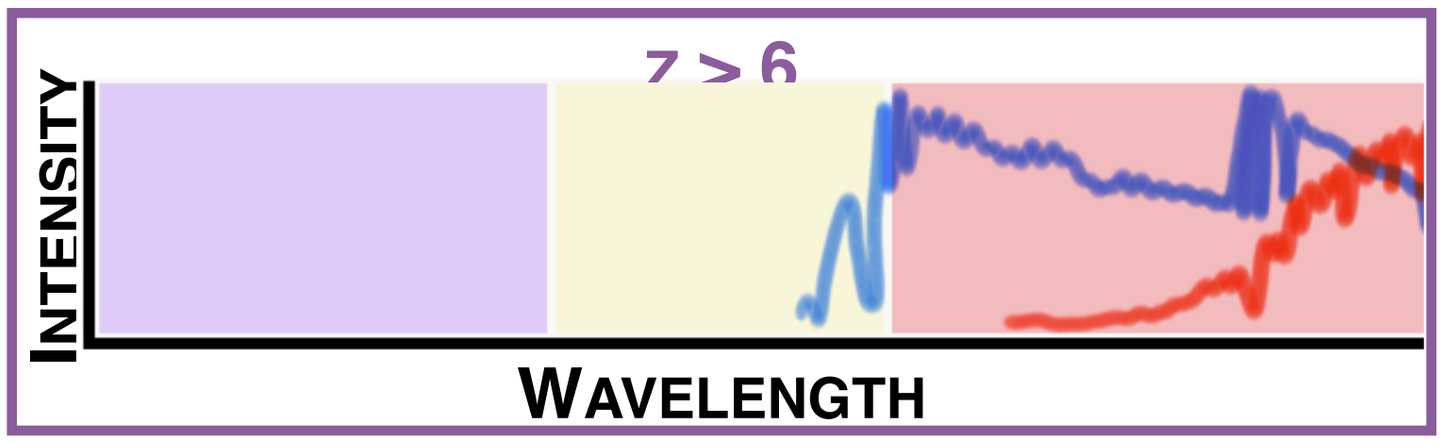
03.23.2023

UVEX

UVEX leverages the diagnostic power of the FUV: Can probe evolution from reionization to today







Rest-frame UV spectra characterize galaxy evolution across all redshifts

1. Nebular gas
2. Stellar populations
3. Feedback
4. Escaping radiation

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UVEX

UVEX leverages the diagnostic power of the FUV: FUV emission is our best diagnostic toolset of galaxy evolution

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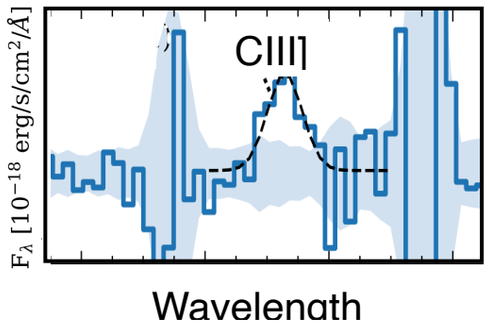

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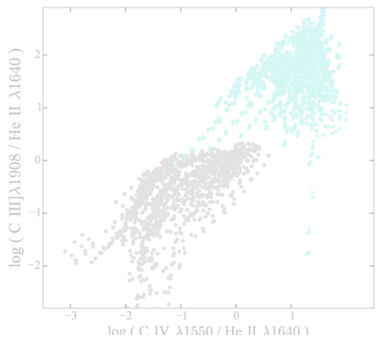

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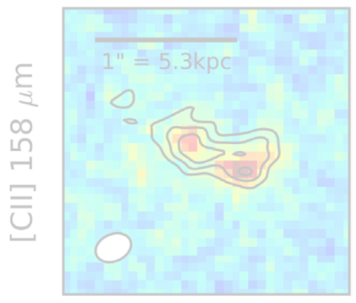

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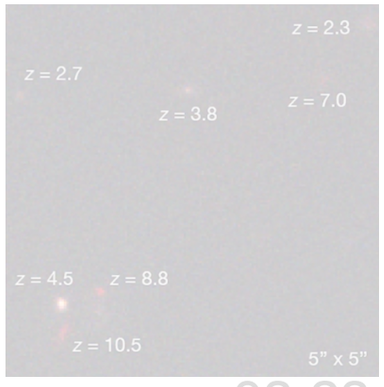

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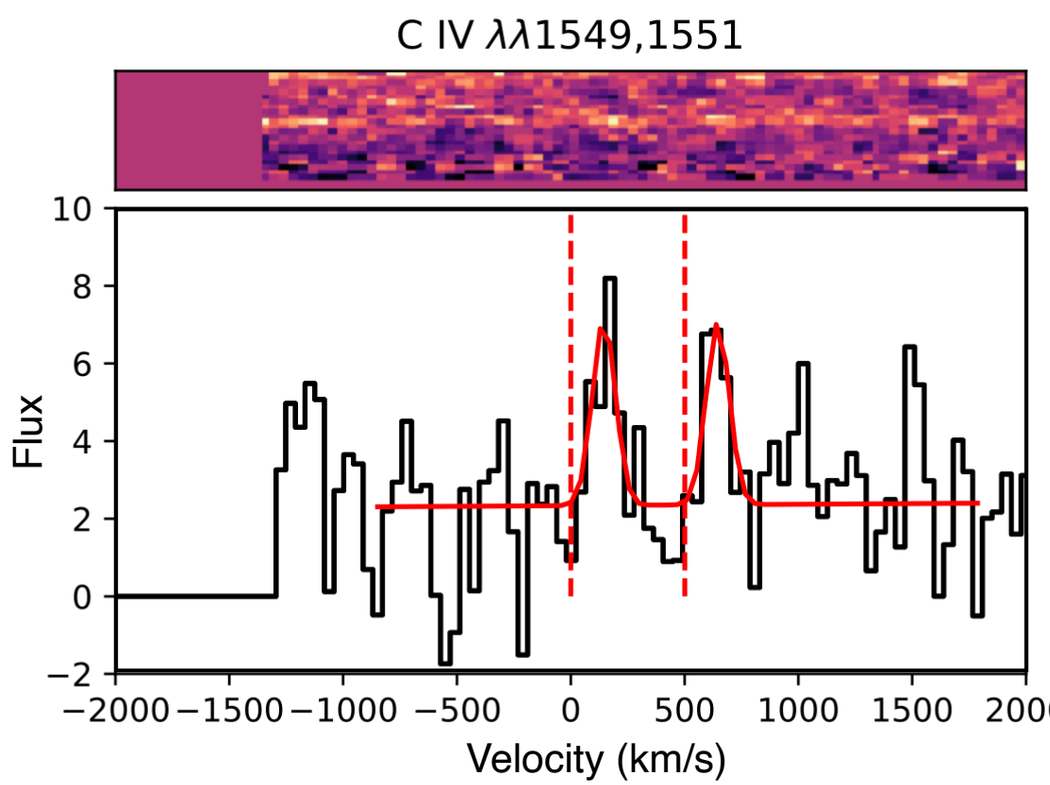
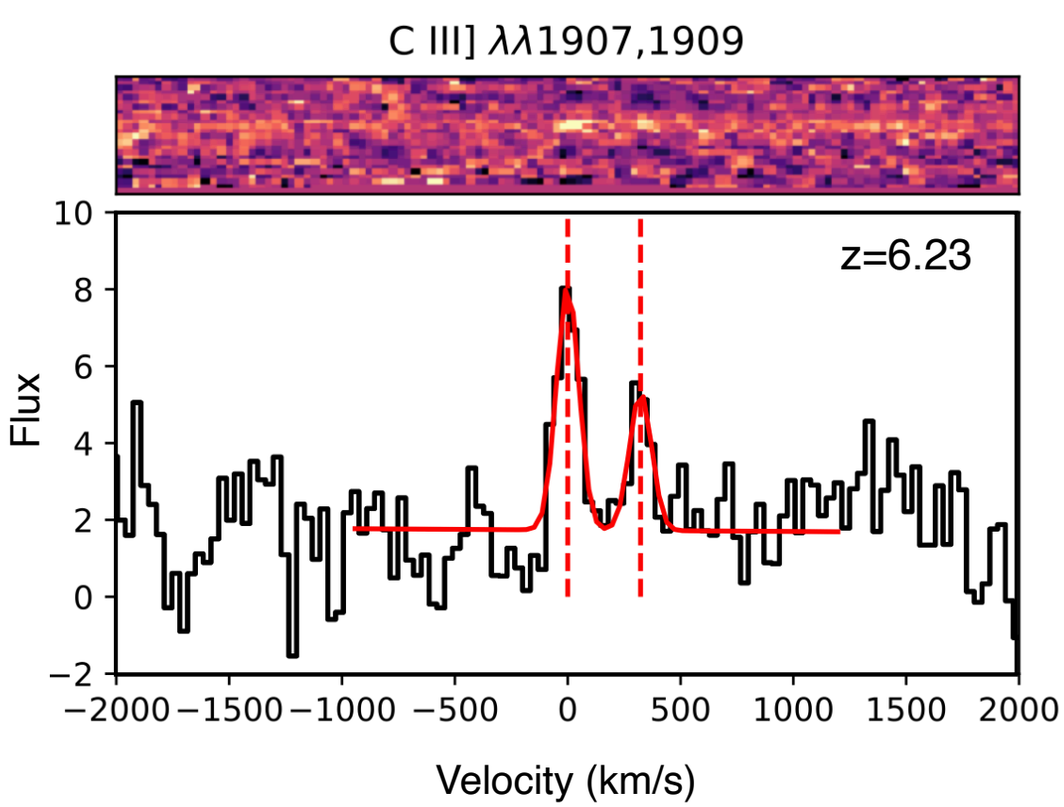
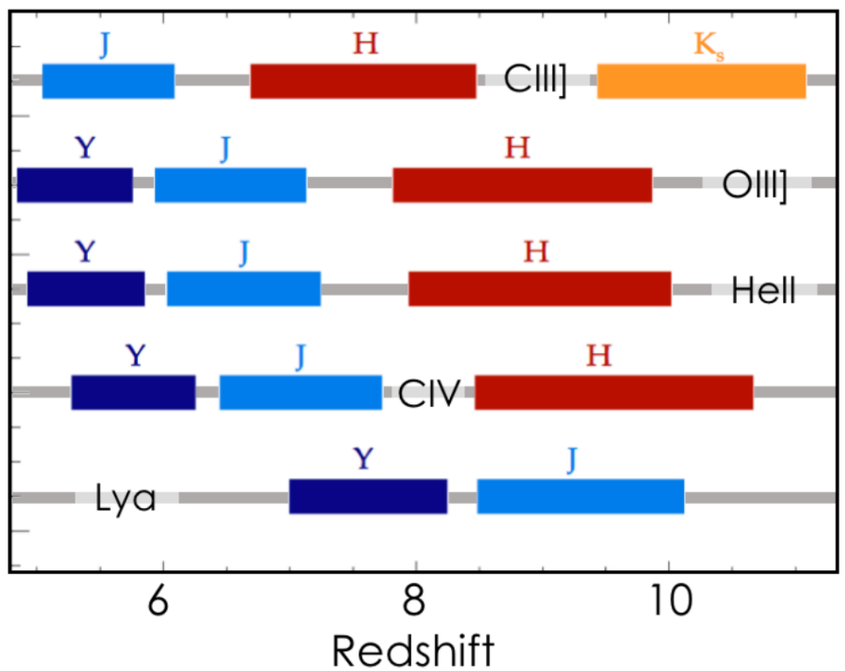
UVEX leverages the diagnostic power of the FUV: LMLZ star-forming galaxies have strong UV emission





High-ionization lines appear to be common in high-redshift star-forming galaxies



e.g., **Stark+15**a,**b**, **Mainali+17**, Schmidt+17, Shibuya+18, **Hutchison+19, Sobral+19, Arellano-Córdova+22, *Jones+23***

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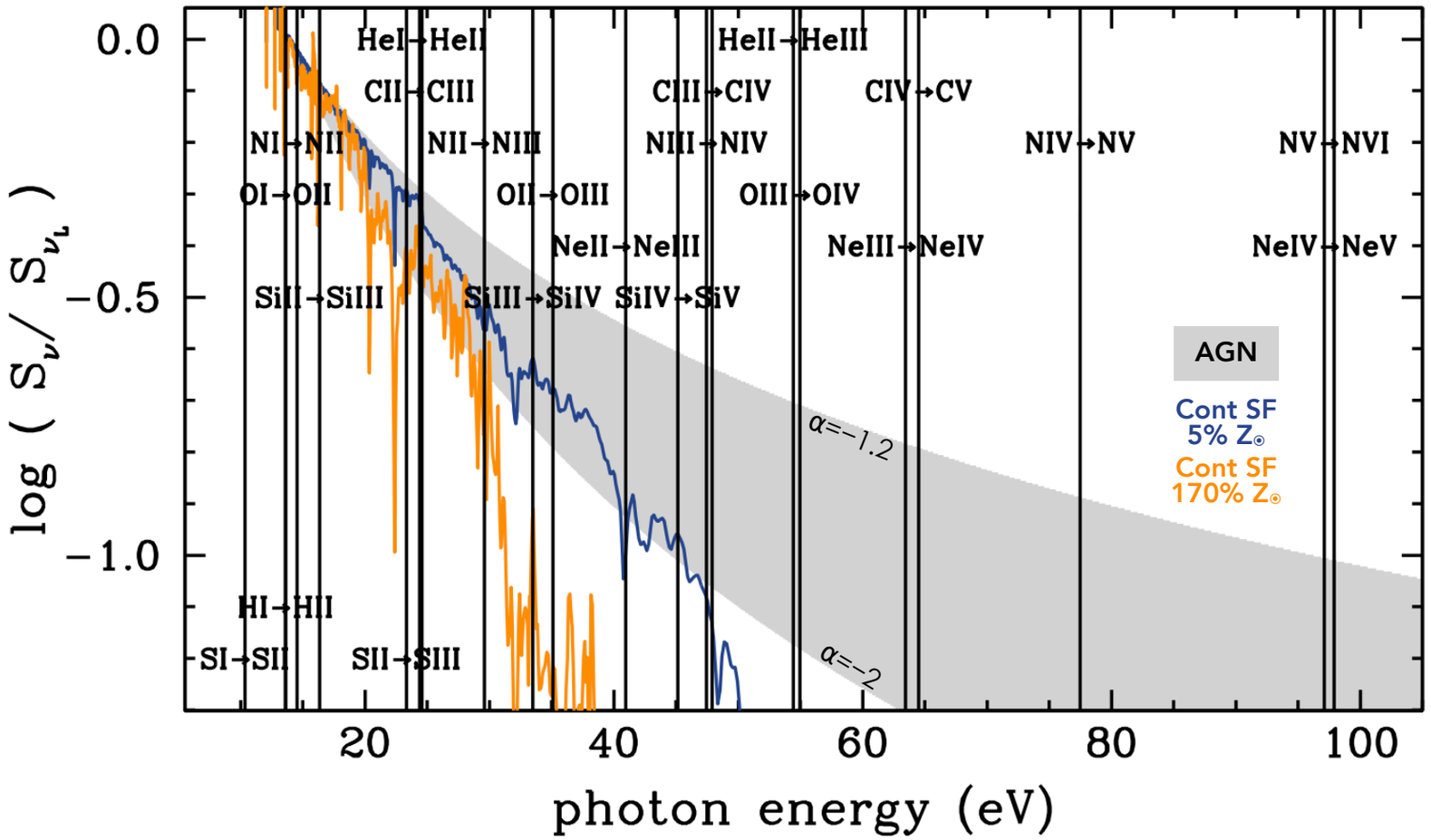
03.23.2023

UVEX

UVEX leverages the diagnostic power of the FUV: FUV line ratios can characterize ionizing sources

But previews of these observations at high redshift are challenging to interpret:
High-ionization UV emission lines are not typically produced by stellar photoionization



Feltre+16

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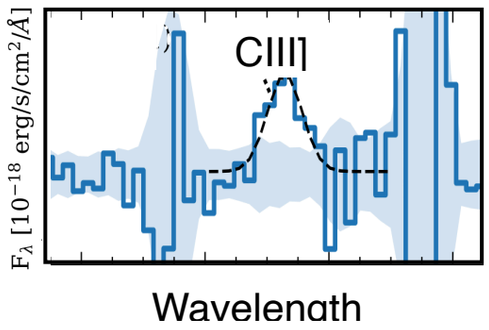

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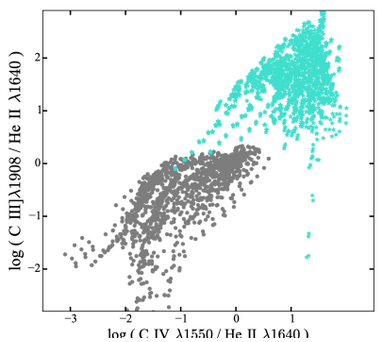

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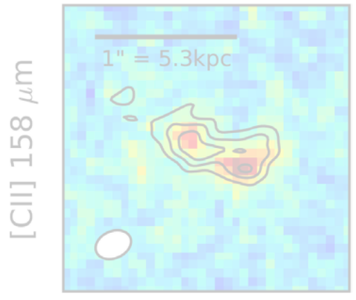

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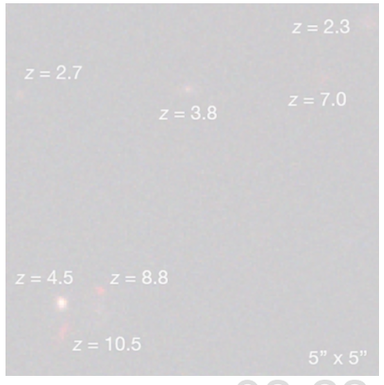

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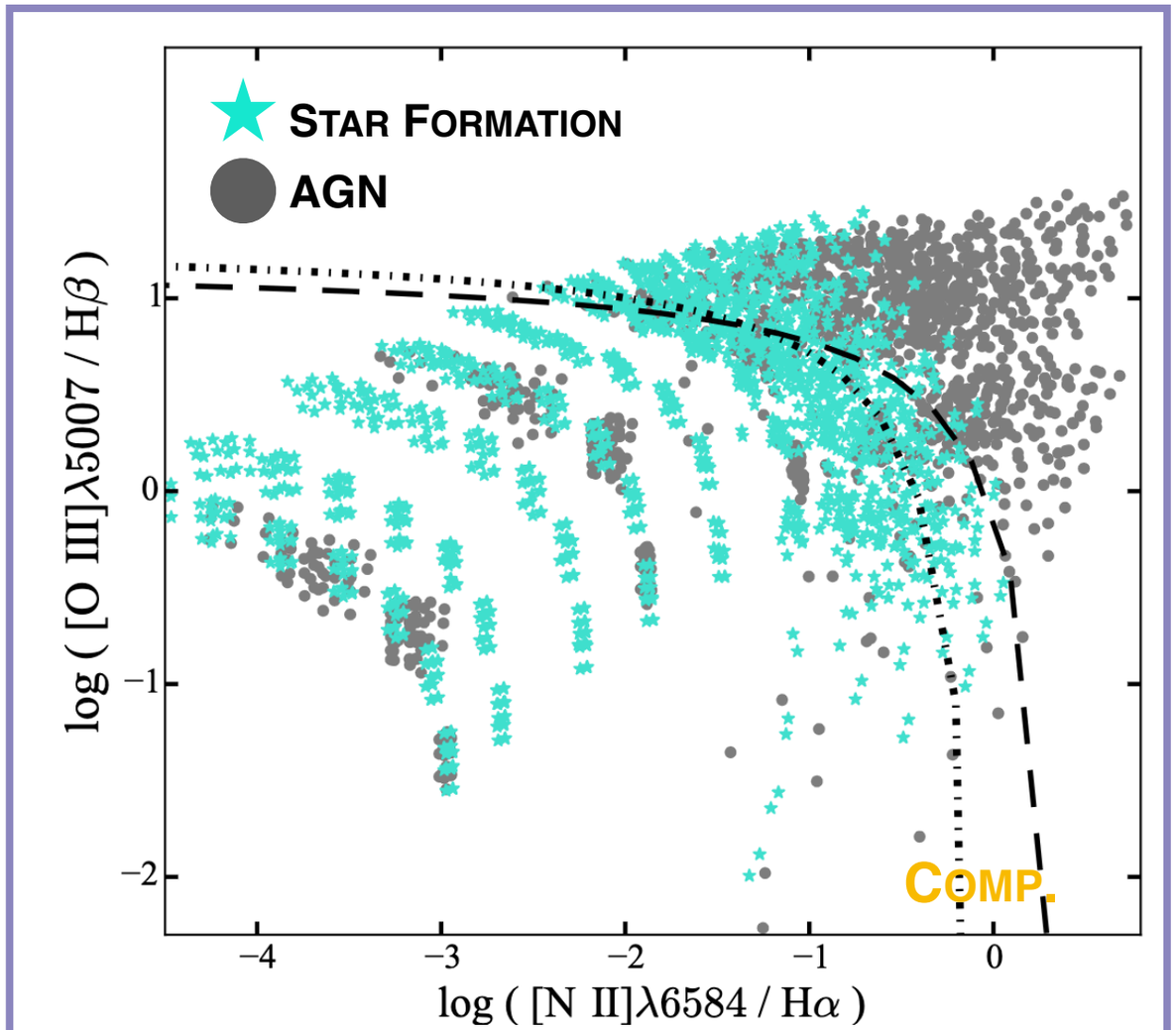

Classic Optical BPT Diagnostic Diagram

Feltre+16

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UVEX

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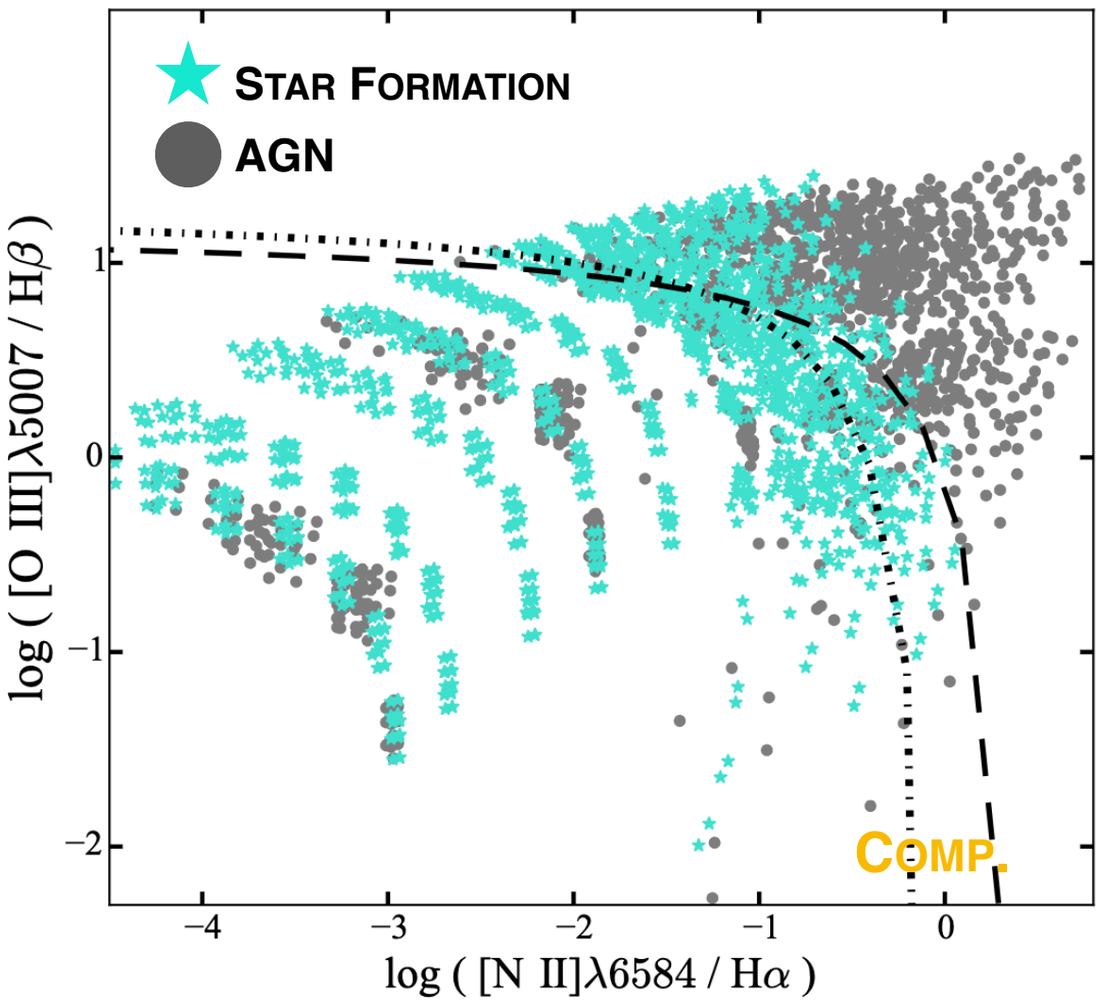

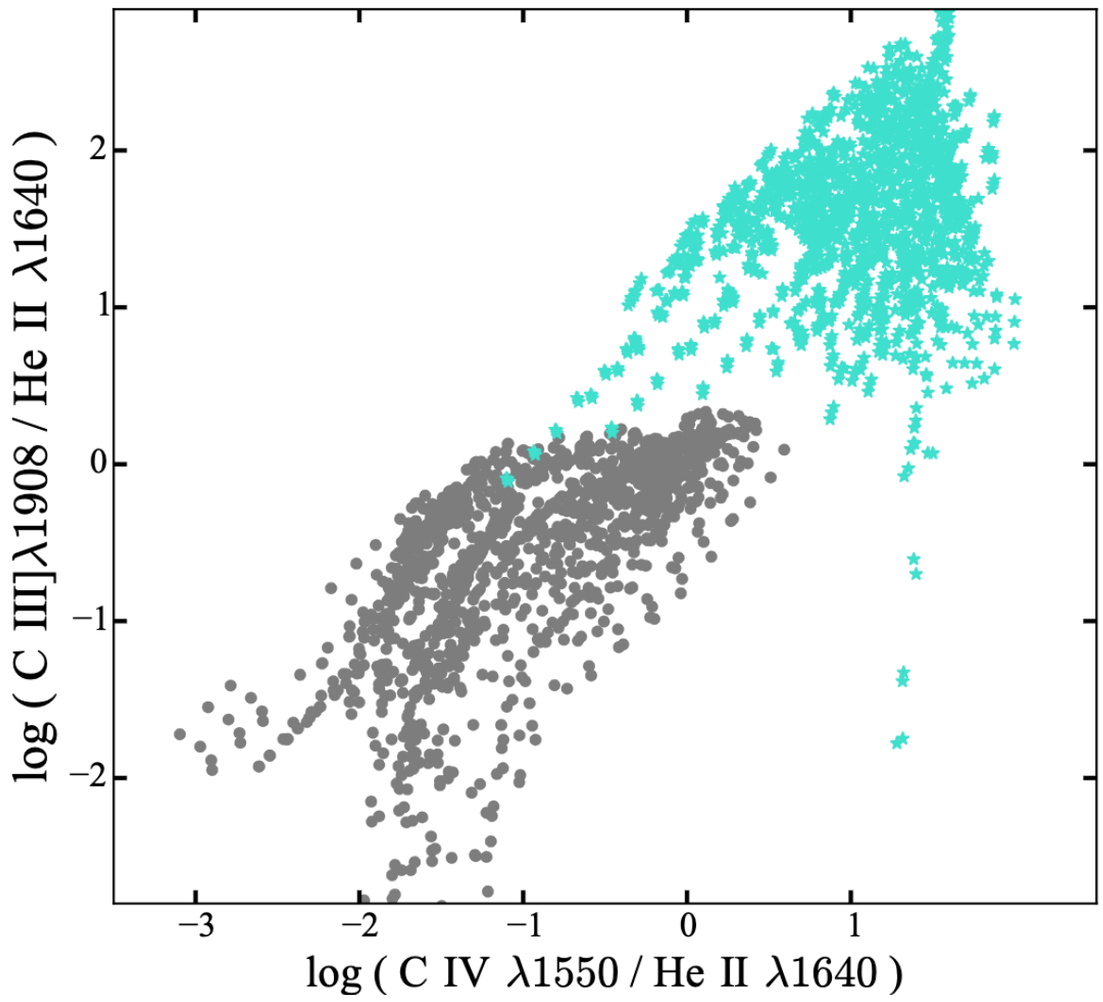

Proposed FUV BPT Diagnostic Diagram

See Matilde Mingozzi's talk (next) for an update!

Feltre+16

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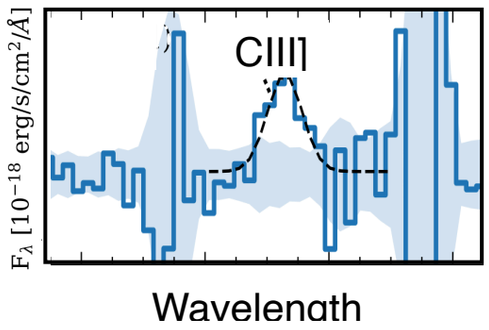

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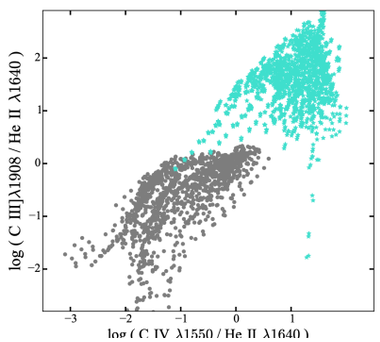

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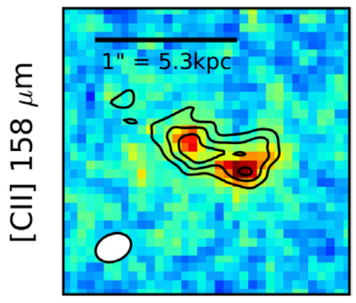

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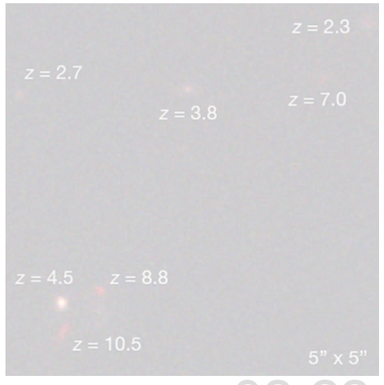

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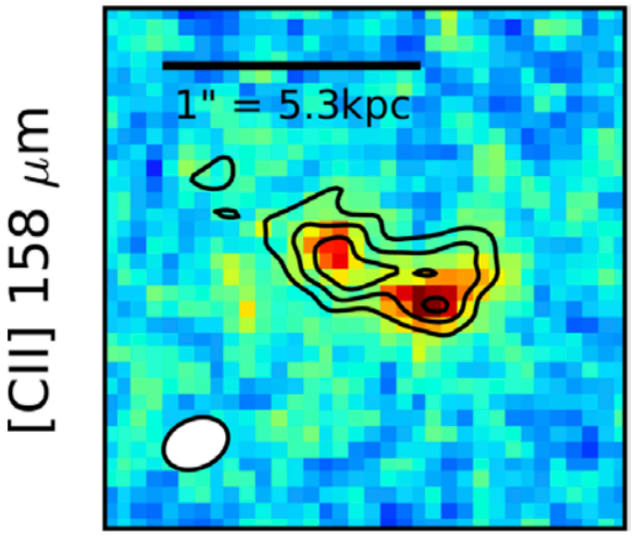

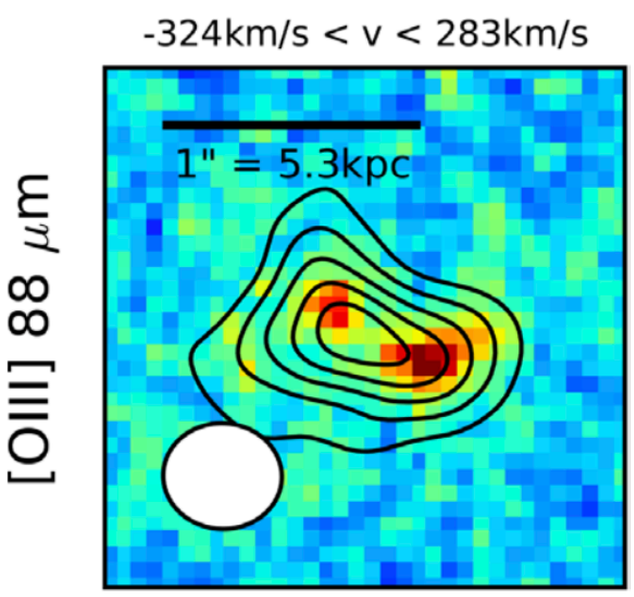

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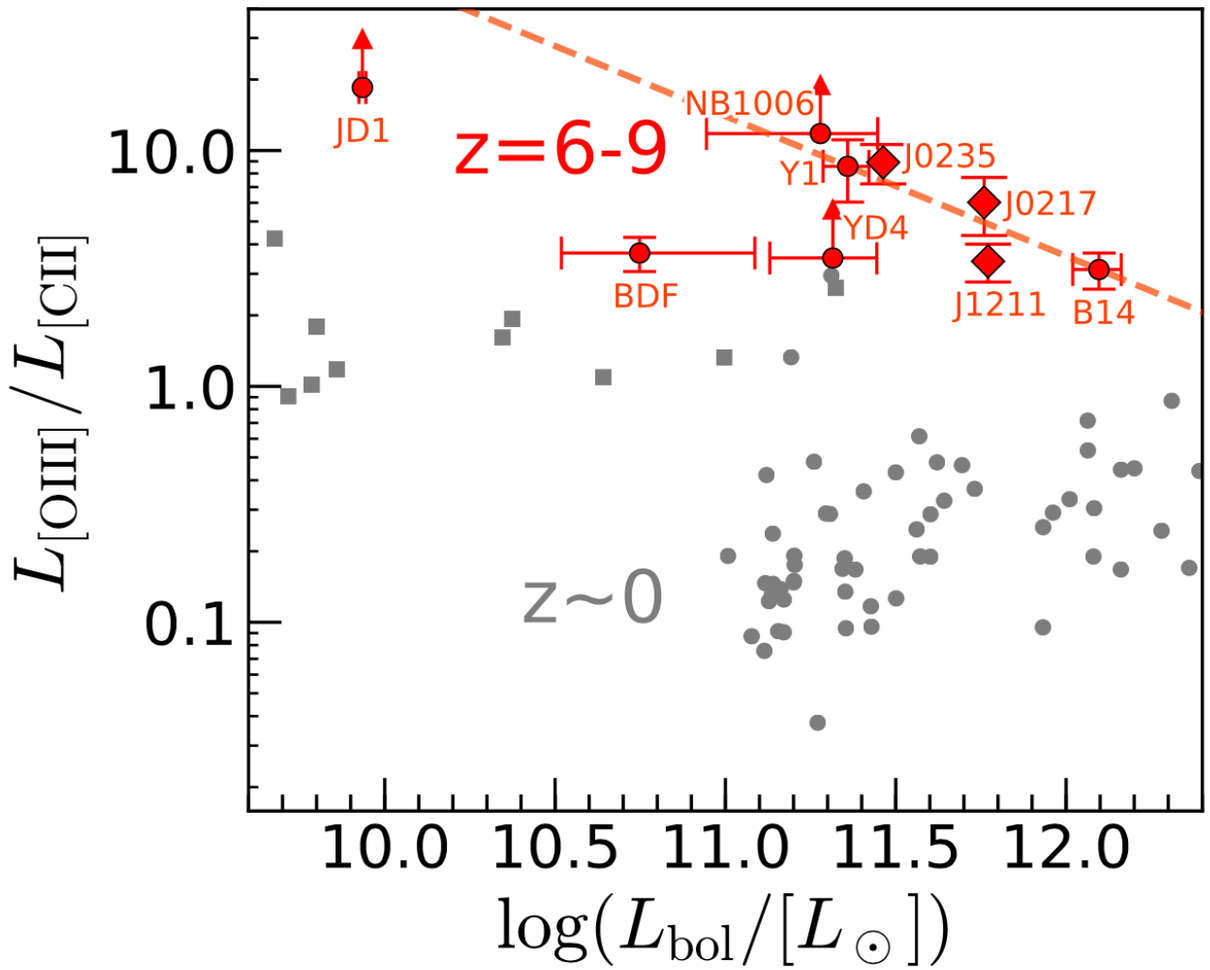

e.g., Inoue+16, **Hashimoto+18,19,** Laporte+19, **Harikane+20**, Carniani+20

ALMA observations of reionization-era systems reveal systematically enhanced [O III]/[C II] ratios, indicative of some combination of highly-ionized gas and potentially depressed C/O ratios

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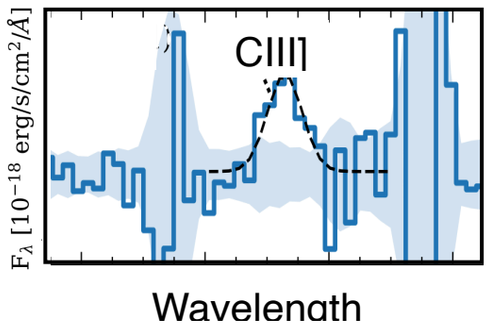

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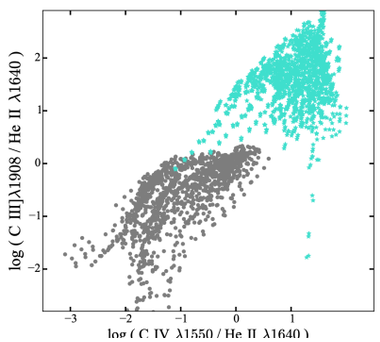

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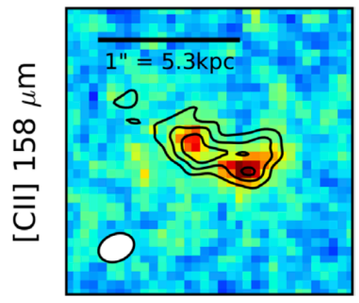

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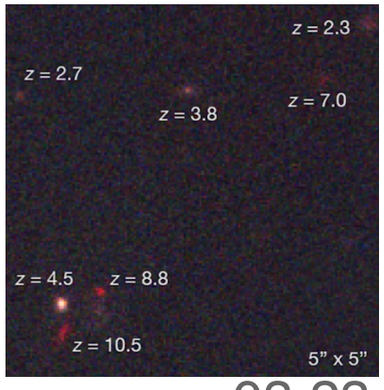

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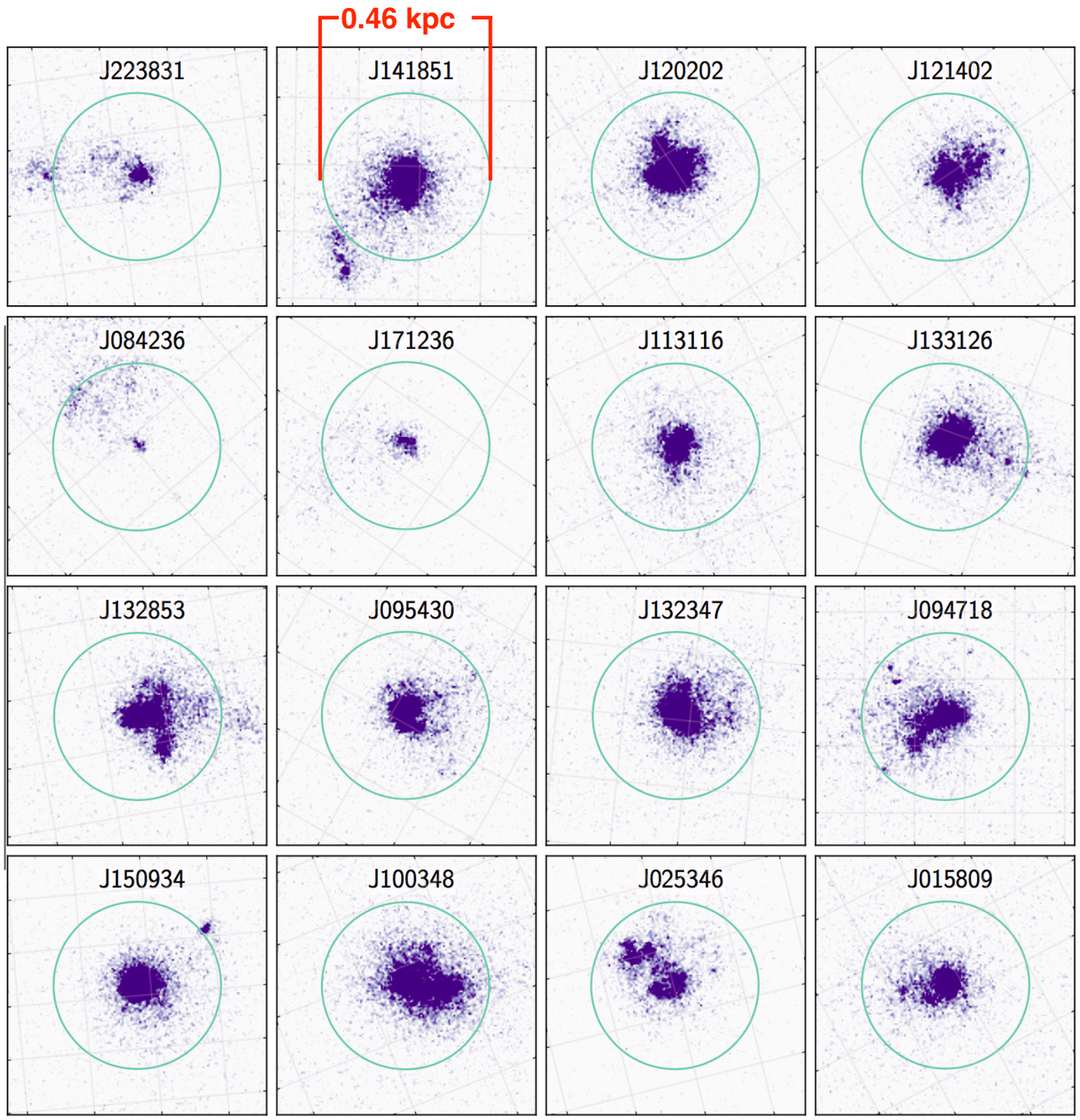
UVEX leverages the diagnostic power of the FUV: Need to calibrate FUV toolset in nearby universe

HST (in particular COS) has made huge strides in identifying galaxies approaching extreme high-z conditions

z~0 EoR analogs allow us to study conditions with high-ionization UV emission lines:

Rest-frame UV observations of local dwarf galaxies w/ HST COS

Berg+16
Berg+2019a,b
Berg+2021
Senchyna+17,19
Pena-Guerrero+17
Ravindranath+20



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UVEX

UVEX leverages the diagnostic power of the FUV: Need to calibrate FUV toolset in nearby universe

HTTPS://MAST.STSCI.EDU/SEARCH/UI/#/CLASSY

COS LEGACY ARCHIVE SPECTROSCOPIC SURVEY: A TREASURY OF STAR-FORMING GALAXIES

PI: DANIELLE BERG

AND AN INTERNATIONAL TEAM OF 46 CO-IS

45 NEARBY STAR-FORMING GALAXIES WITH FULL REST-FRAME FAR-UV SPECTRAL COVERAGE OF STELLAR, NEBULAR, AND ISM FEATURES

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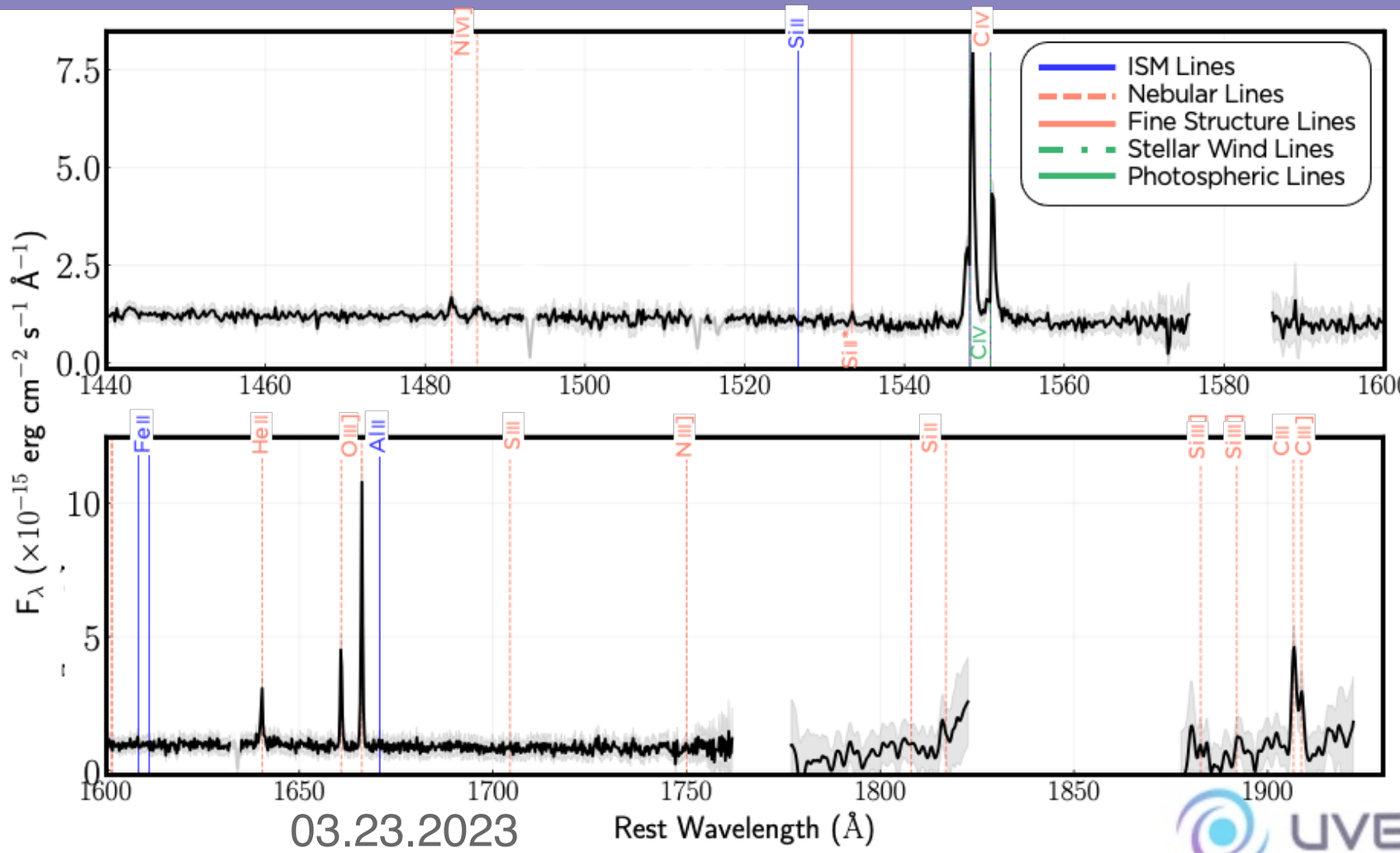
See Matilde Mingozzi's talk (next) for more!



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UVEX

UVEX leverages the diagnostic power of the FUV:
Need to calibrate FUV toolset in nearby universe

But what can we learn from FUV emission lines?

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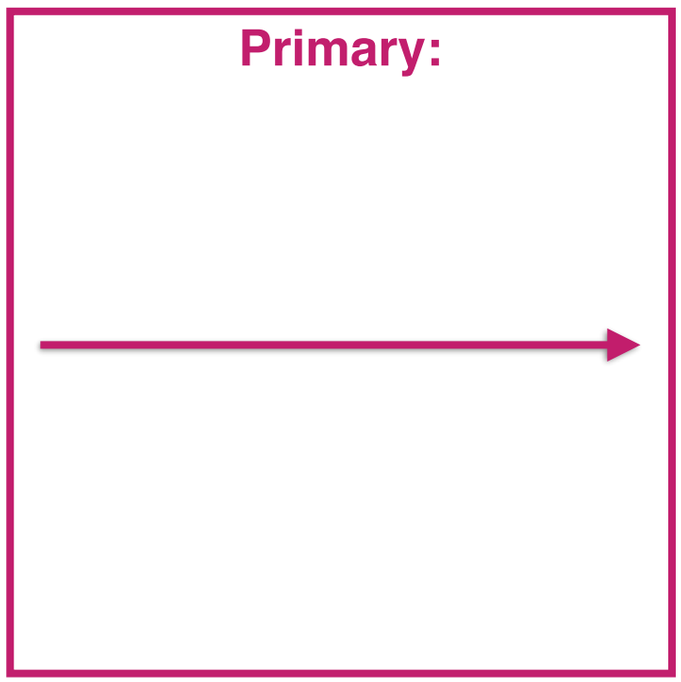
C/O vs O/H

Theoretical Expectation:



Observed (1990s-2000s):

Relative abundances probe yields, feedback, and timescales

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

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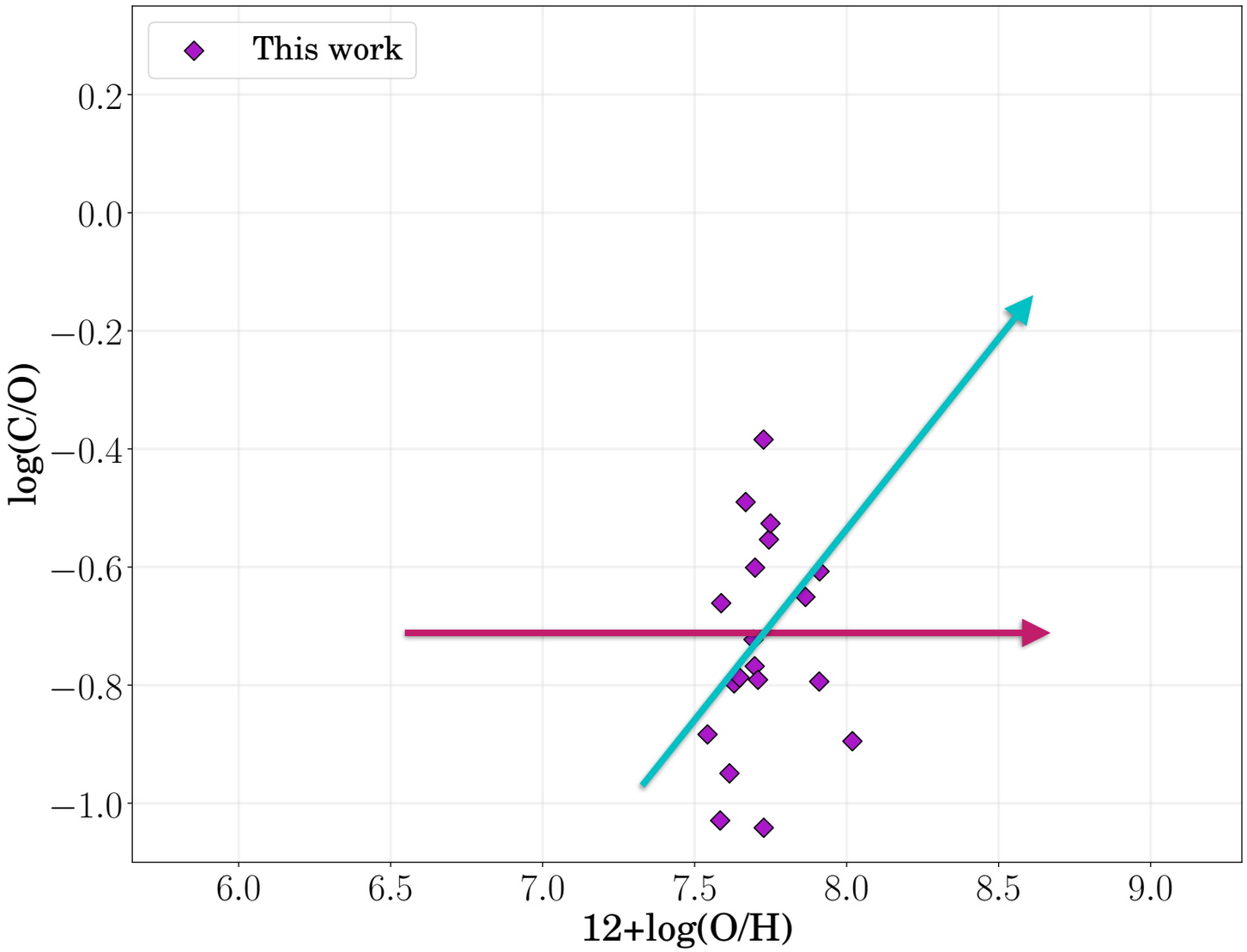

Berg, D.A., et al. 2019a

UVEX leverages the diagnostic power of the FUV: Need to calibrate FUV toolset in nearby universe

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

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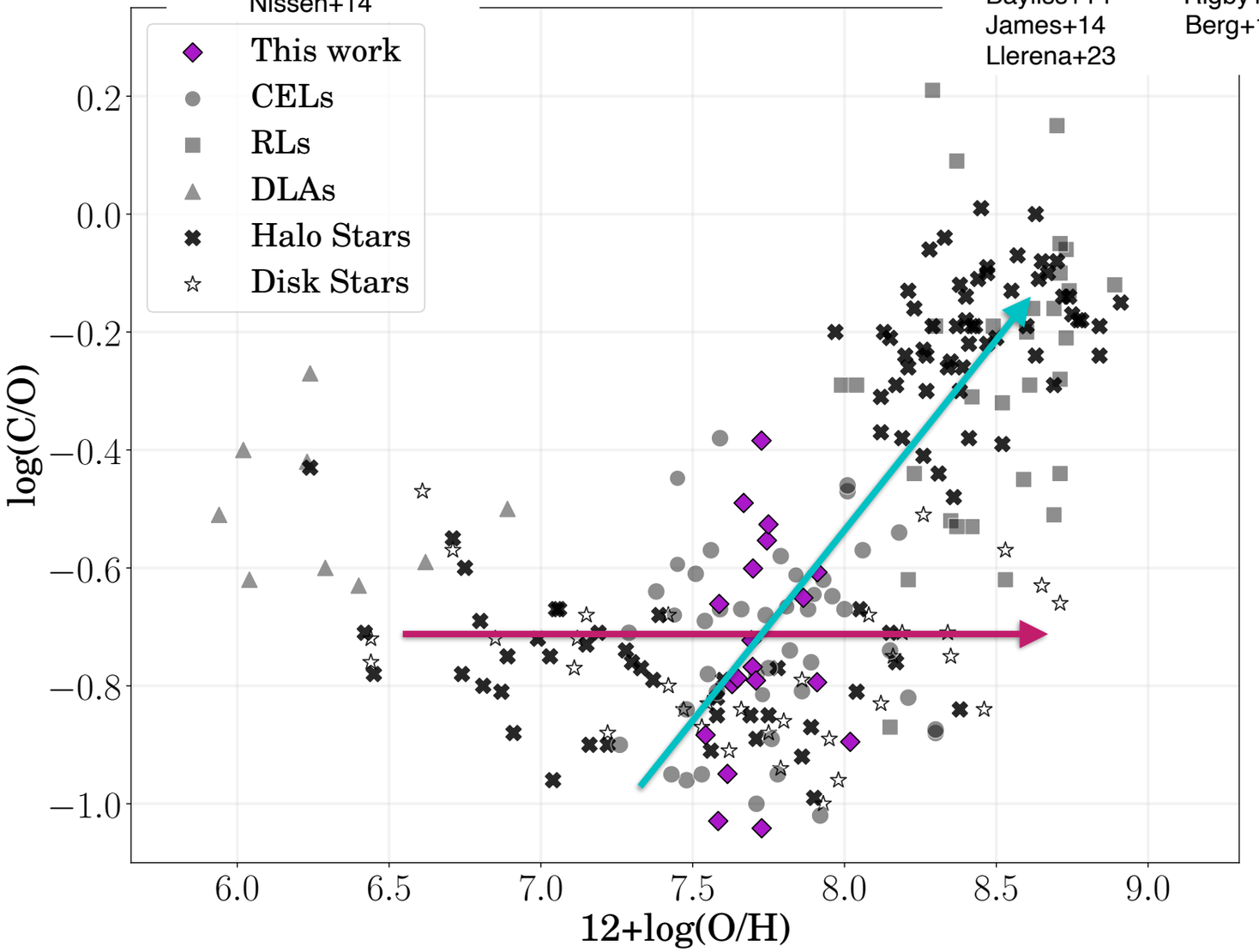
Peimbert+05
García-Rojas+07
López-Sánchez+07
Esteban+09
Esteban+14



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

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

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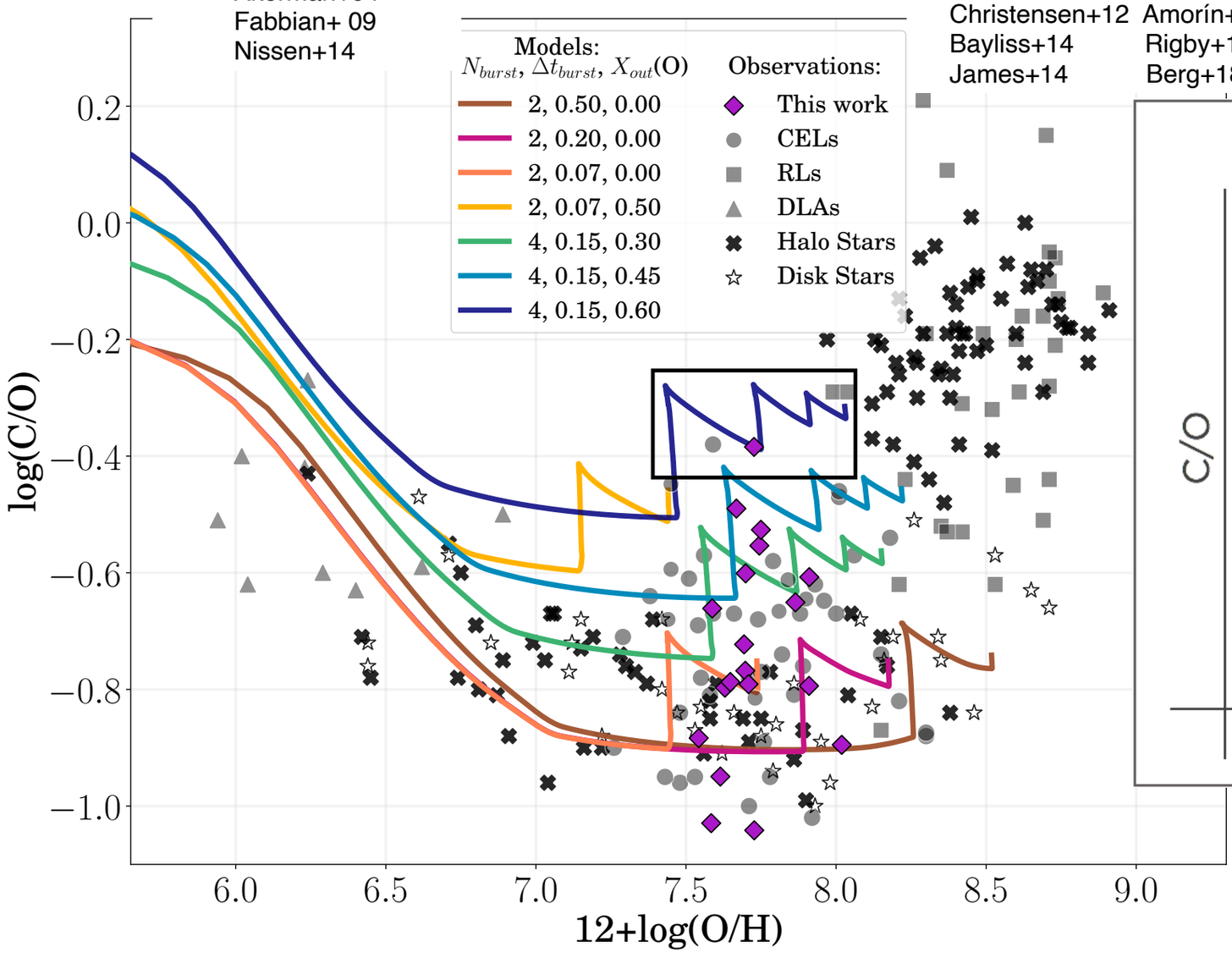

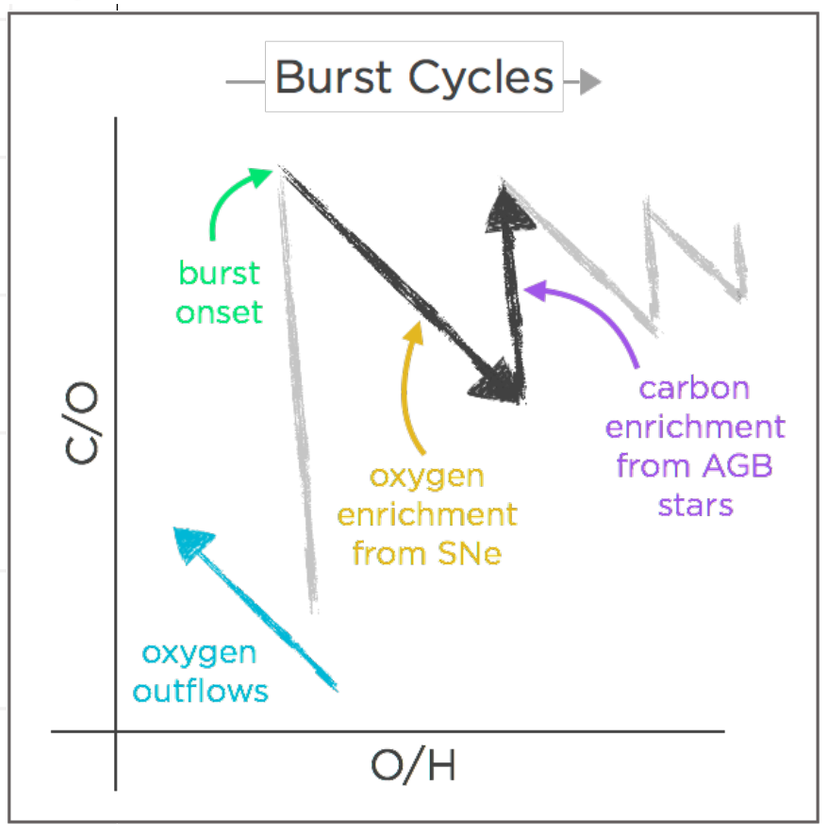

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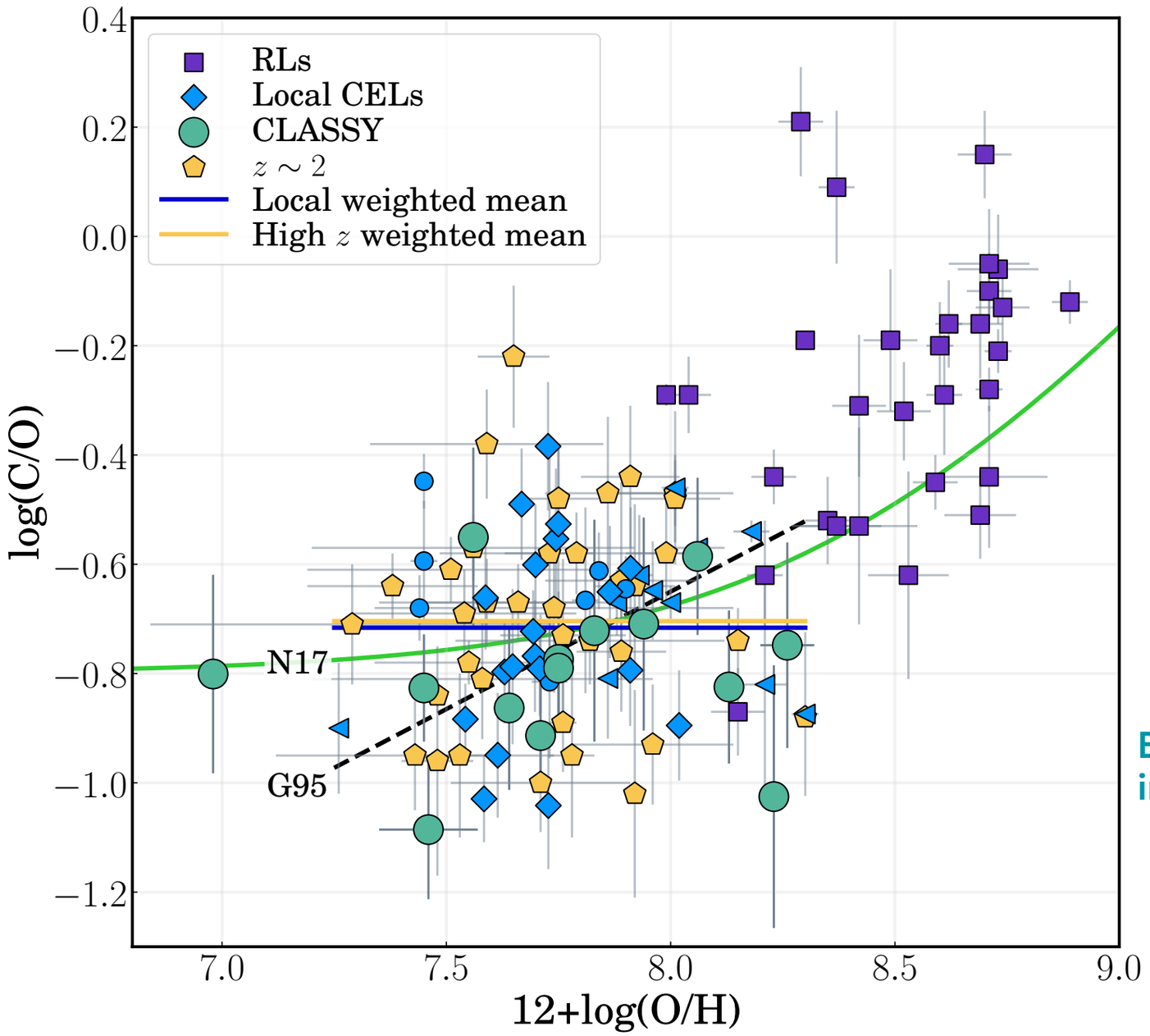

Berg, D.A., et al. 2023, in prep.

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

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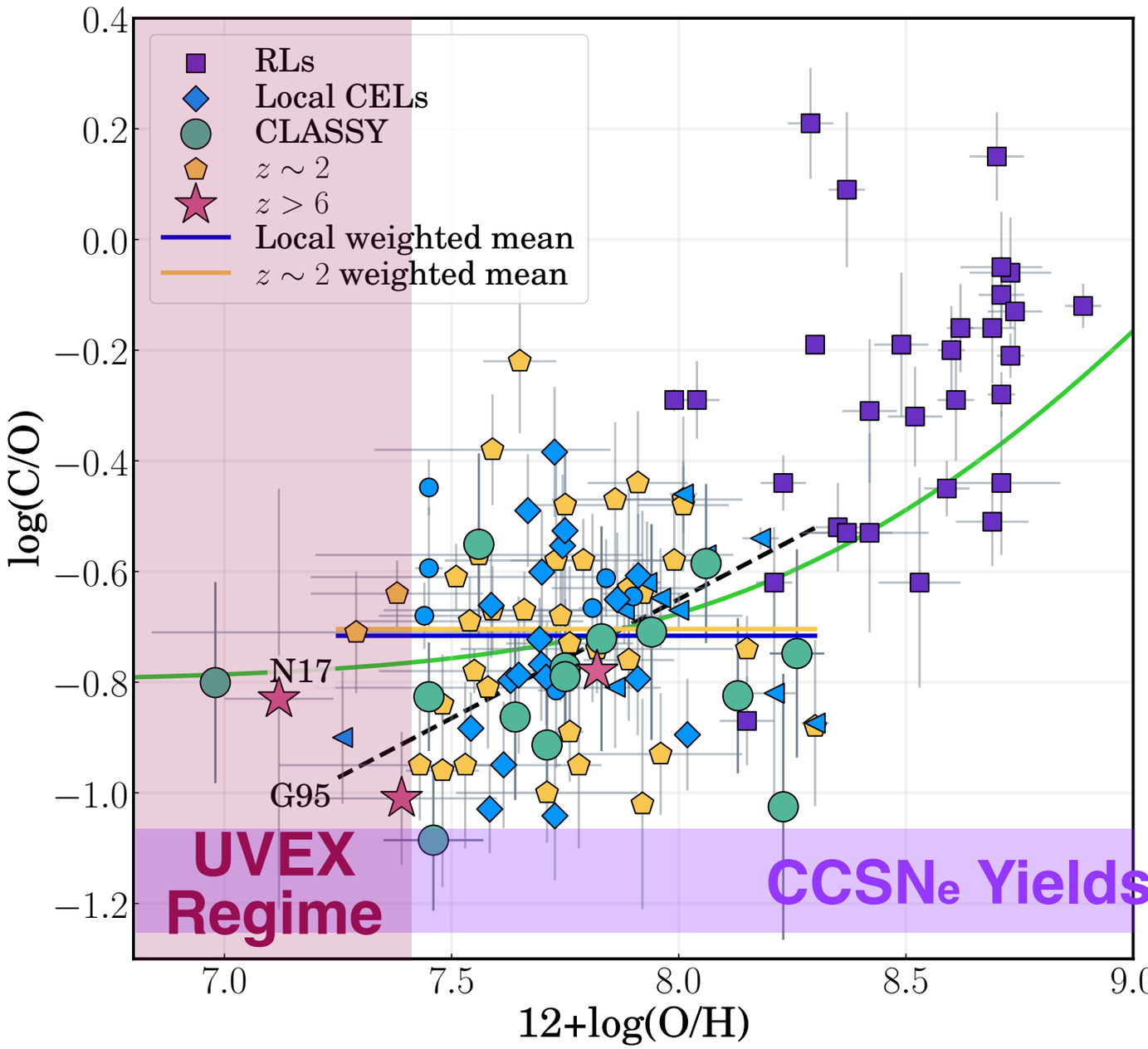
UVEX

UVEX leverages the diagnostic power of the FUV: Need to calibrate FUV toolset in nearby universe



Berg, D.A., et al. 2023, in prep.

Arellano-Cordova+22
Jones+23
Cameron+23

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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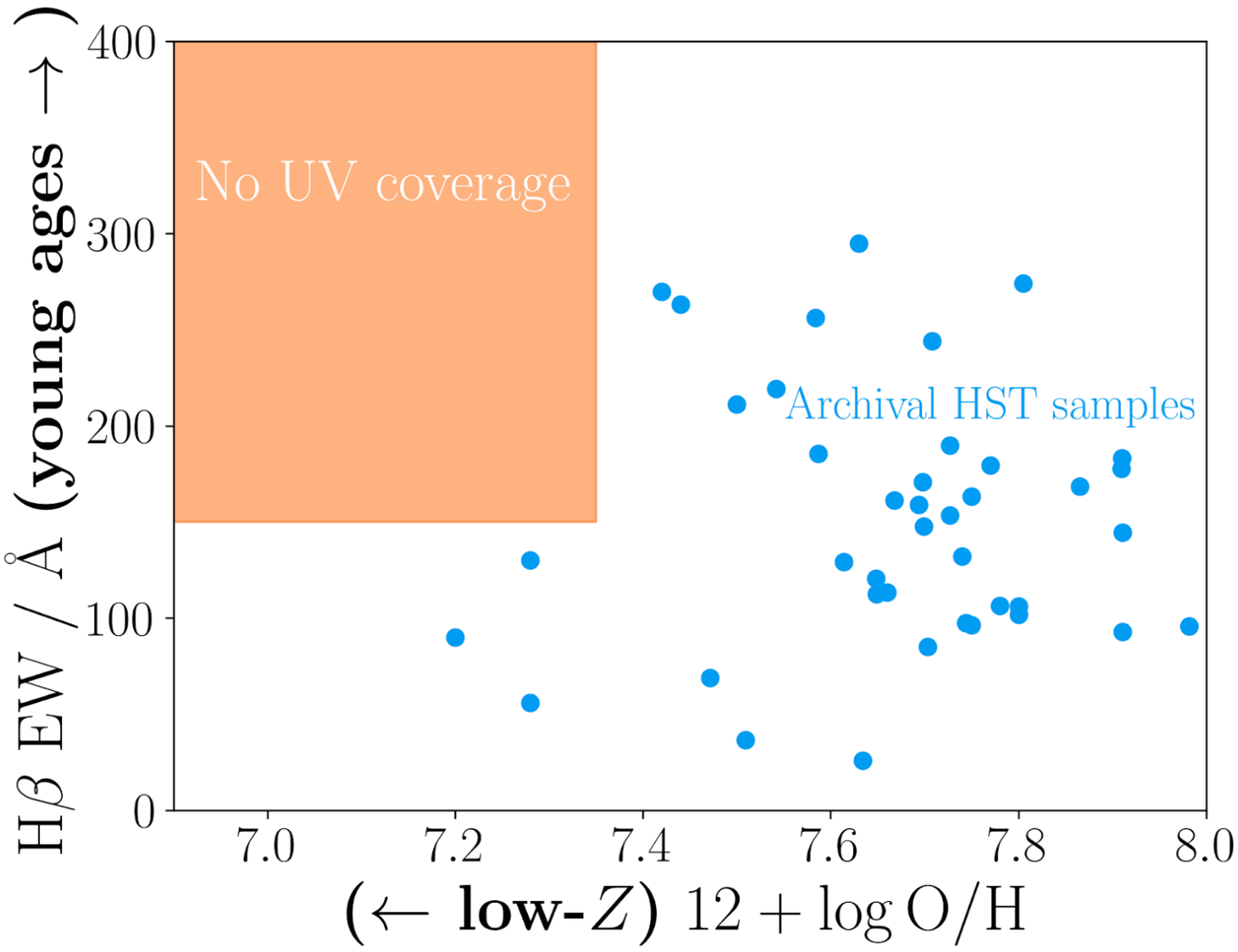
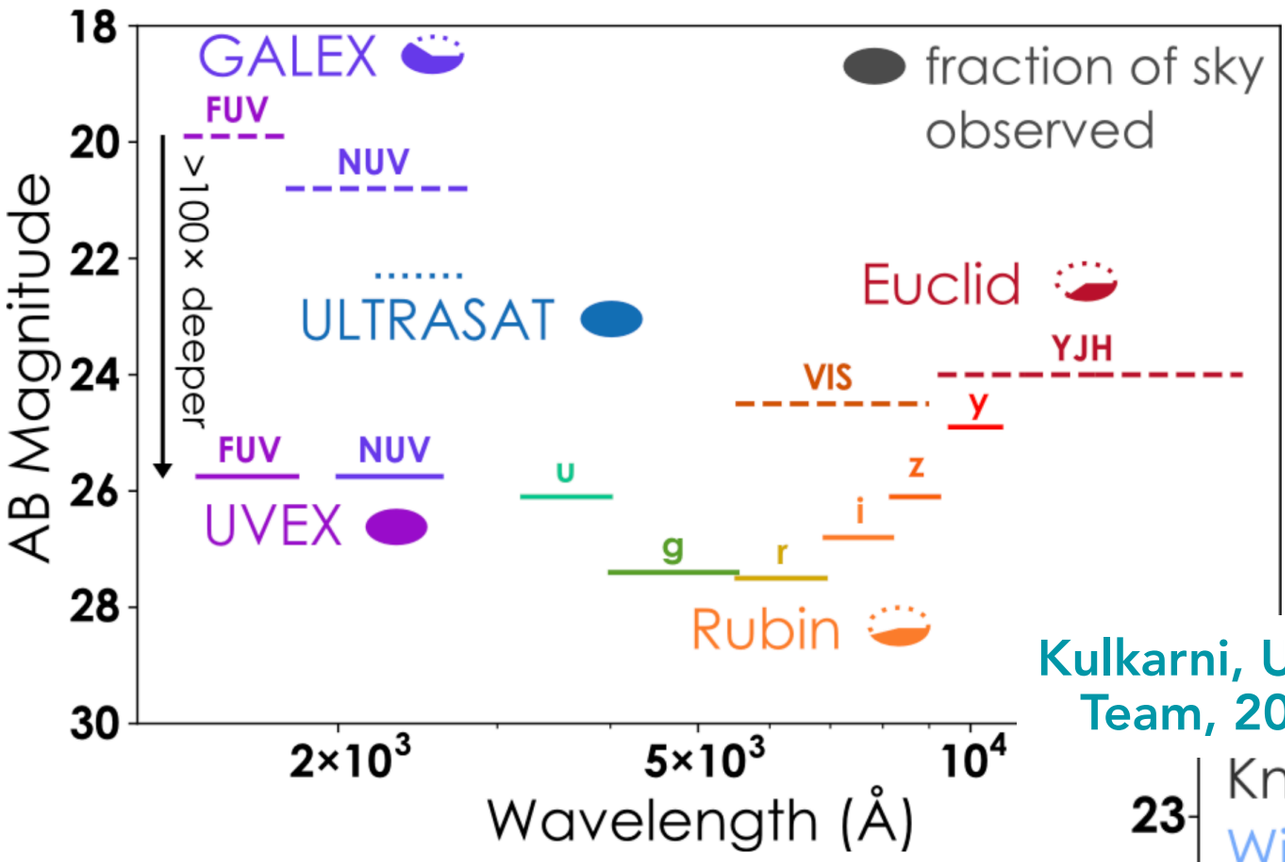
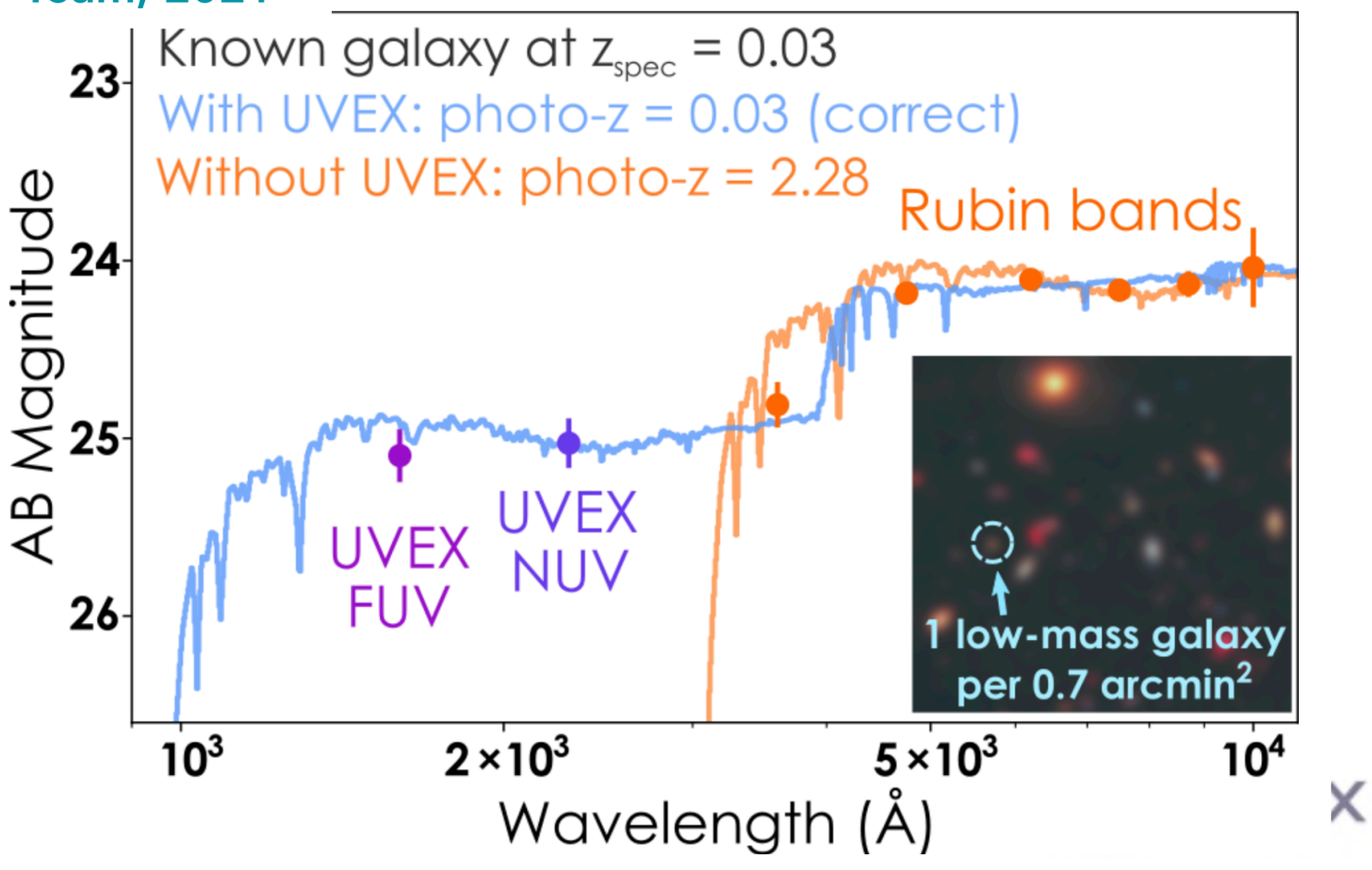
Despite this progress, we are still **missing coverage at the youngest ages and lowest metallicities** most crucial for understanding galaxies in the primordial Universe



UVEX imaging will identify large numbers of LMLZ galaxies



Kulkarni, UVEX Team, 2021



UVEX will make progress by:

1. Discover LMLZ galaxies:

Uncovering orders of magnitude more low-metallicity galaxies below the detection thresholds of previous large spectroscopic surveys.

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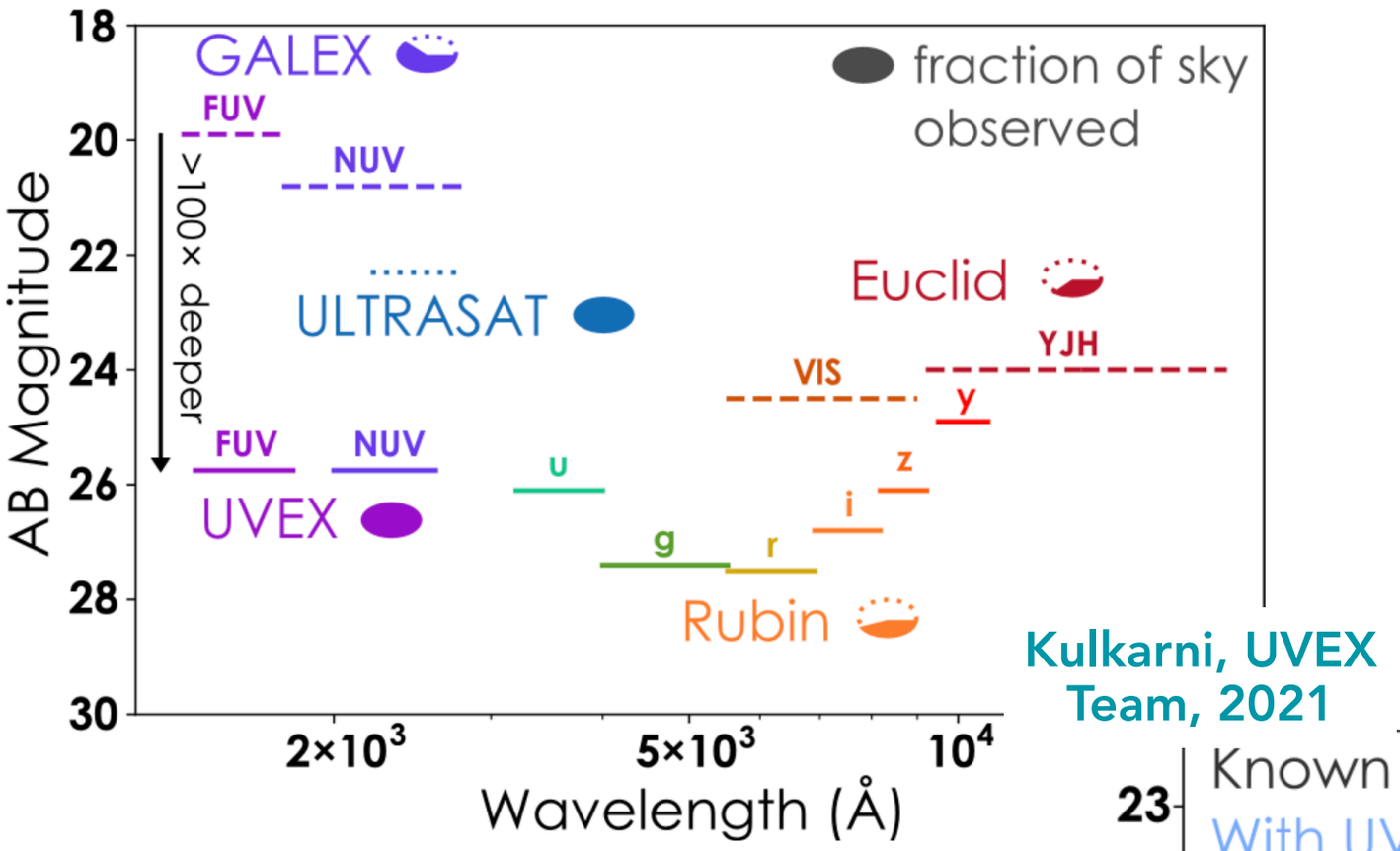
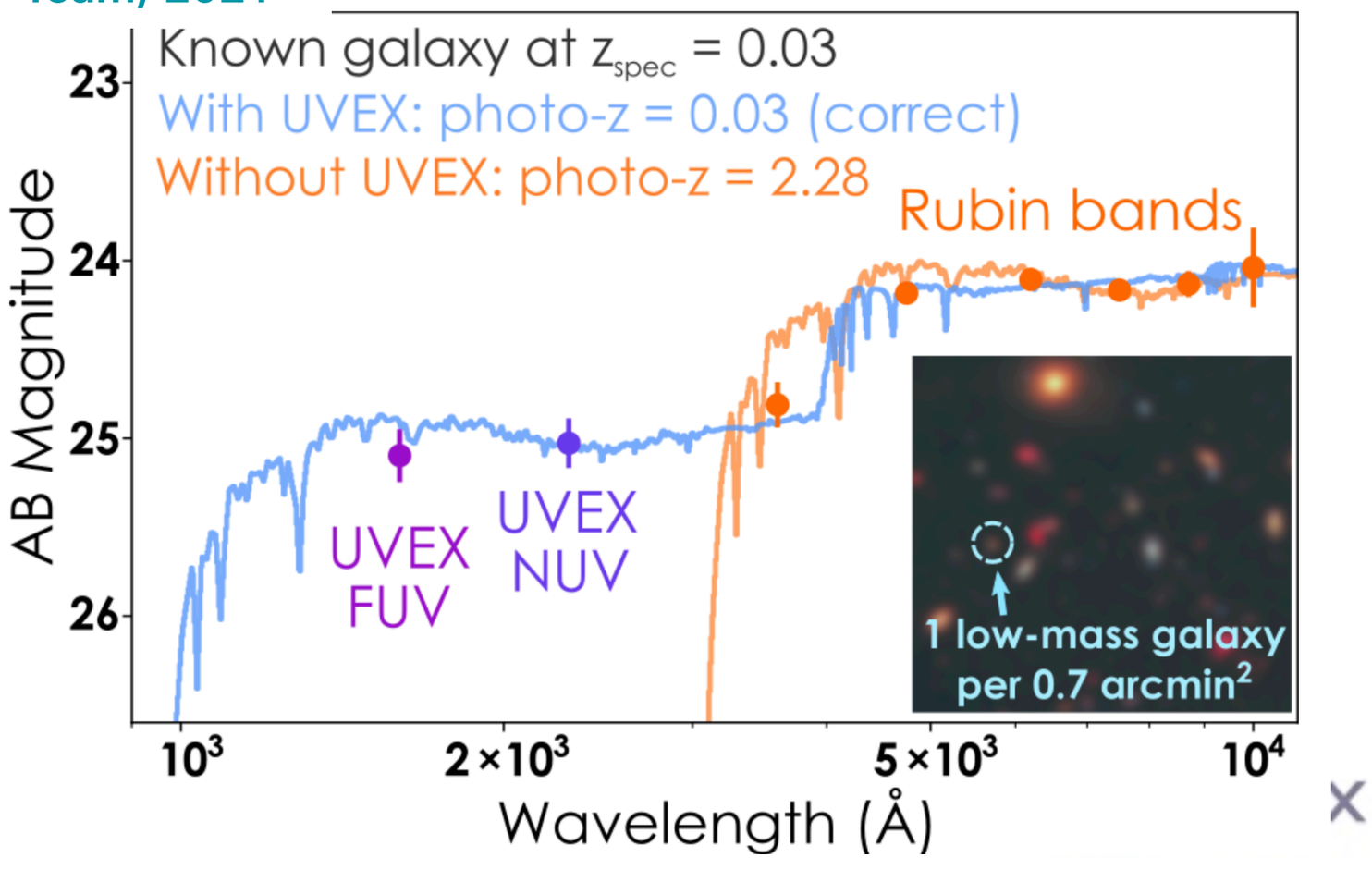
UVEX imaging will identify large numbers of LMLZ galaxies



Kulkarni, UVEX Team, 2021



UVEX will make progress by:

1. Discover LMLZ galaxies:
Uncovering orders of magnitude more low-metallicity galaxies below the detection thresholds of previous large spectroscopic surveys.

2. Compile LMLZ galaxies:
Follow-up photometric discoveries with ground-based optical spectroscopy to measure metallicity.

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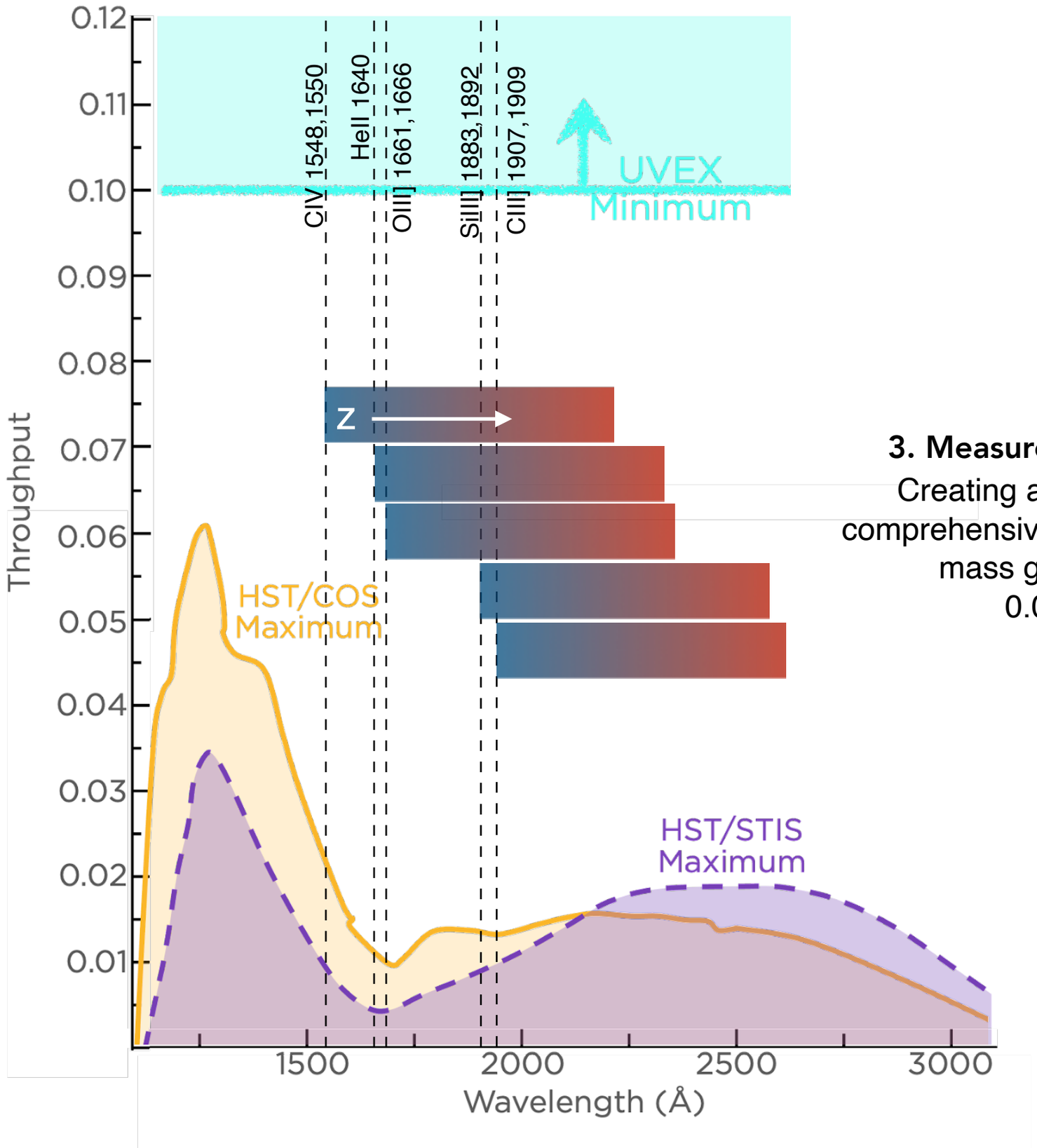
UVEX is optimized for observing FUV emission lines for LMLZ galaxies at $0 < z < 0.3$



3. Measure their FUV spectra: Creating a homogeneous and comprehensive database of FUV low-mass galaxy spectra for $0.03 < z < 0.3$.

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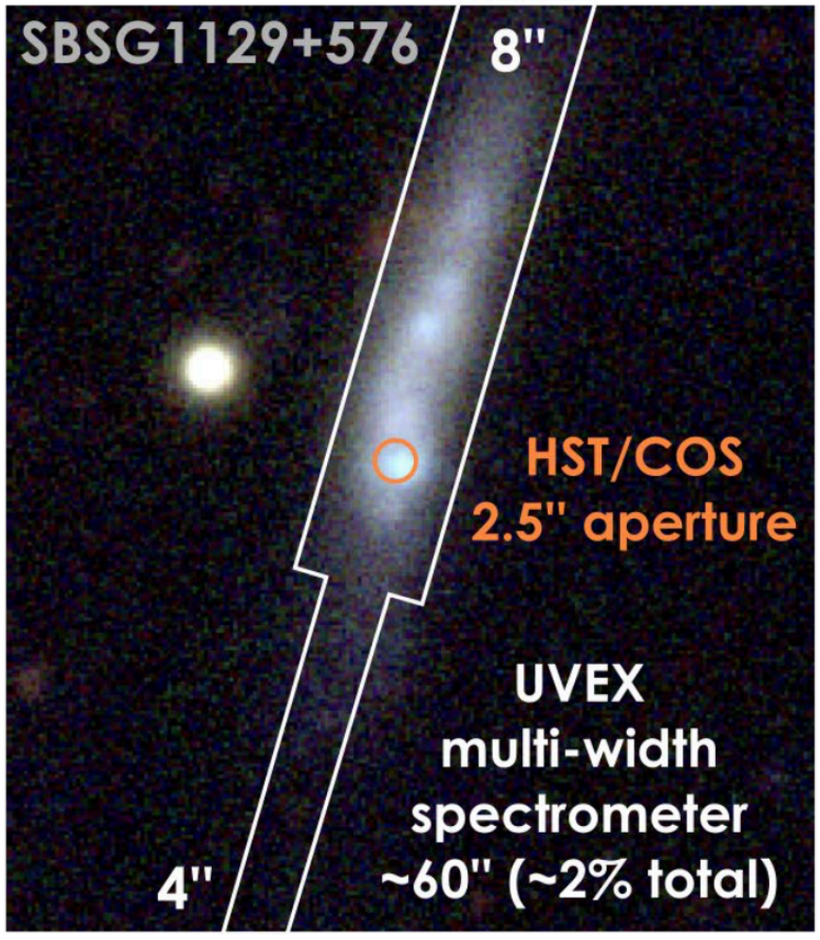
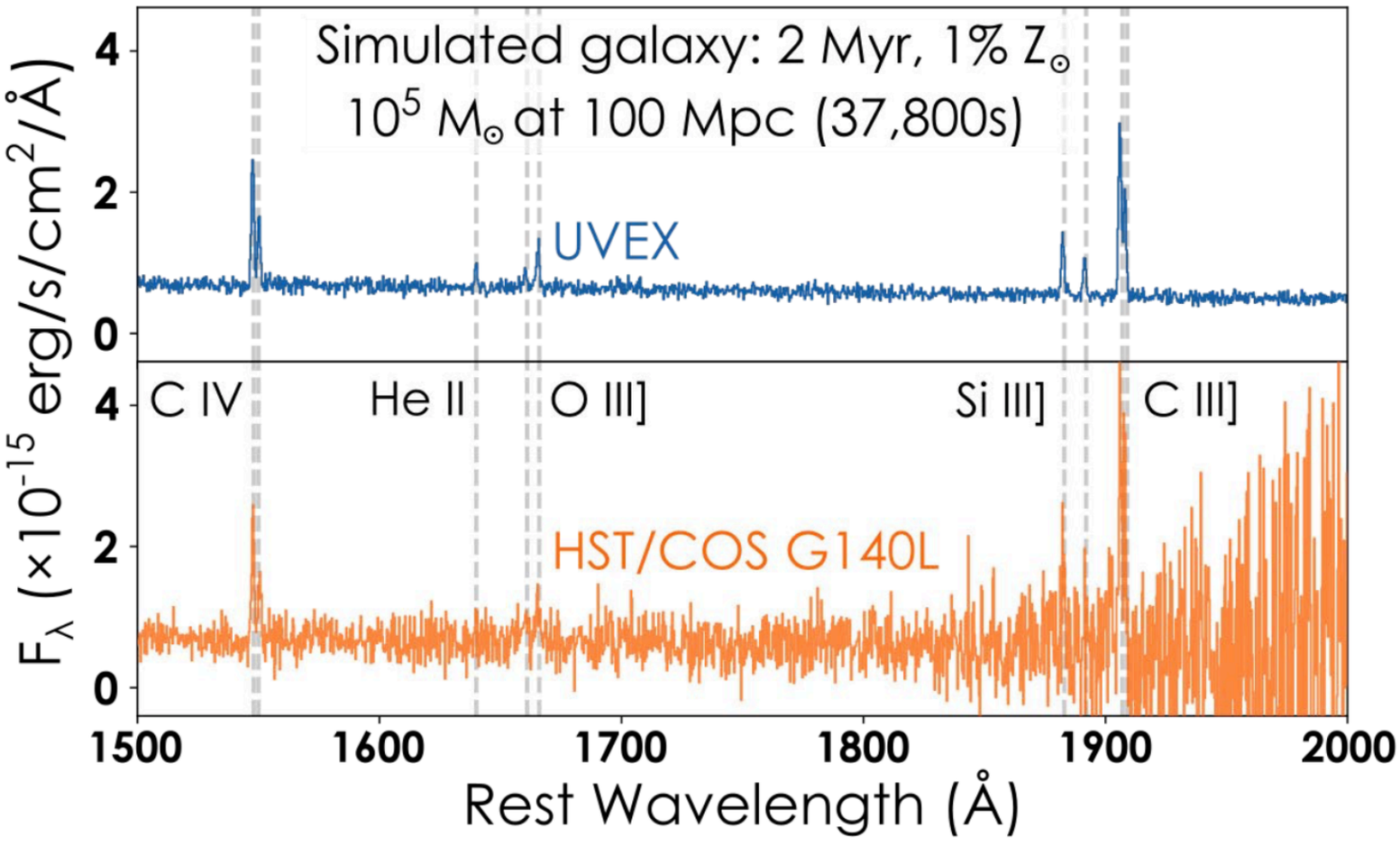
UVEX spectroscopy will measure FUV emission lines for a statistical sample of LMLZ galaxies for the 1st time

The optimized throughput and sensitivity of UVEX will enable
unprecedented studies of UV emission lines in metal-poor galaxies.





Kulkarni, UVEX Team, 2021

UVEX spectroscopy will detect emission line fluxes down to 3×10^{-16} erg s^{-1} cm^{-2} with a S/N = 10 in 20,000 ks.

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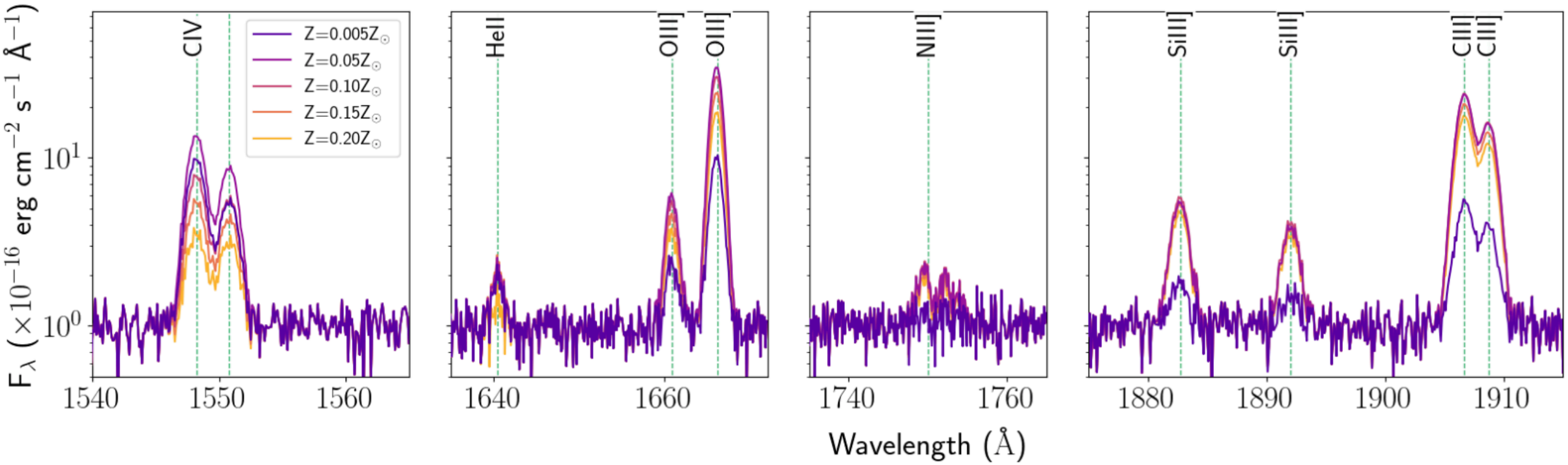
UVEX spectroscopy will measure FUV emission lines for a statistical sample of LMLZ galaxies for the 1st time



Based on photoionization models, **we expect to see strong nebular UV emission** at low-metallicities and young stellar ages.

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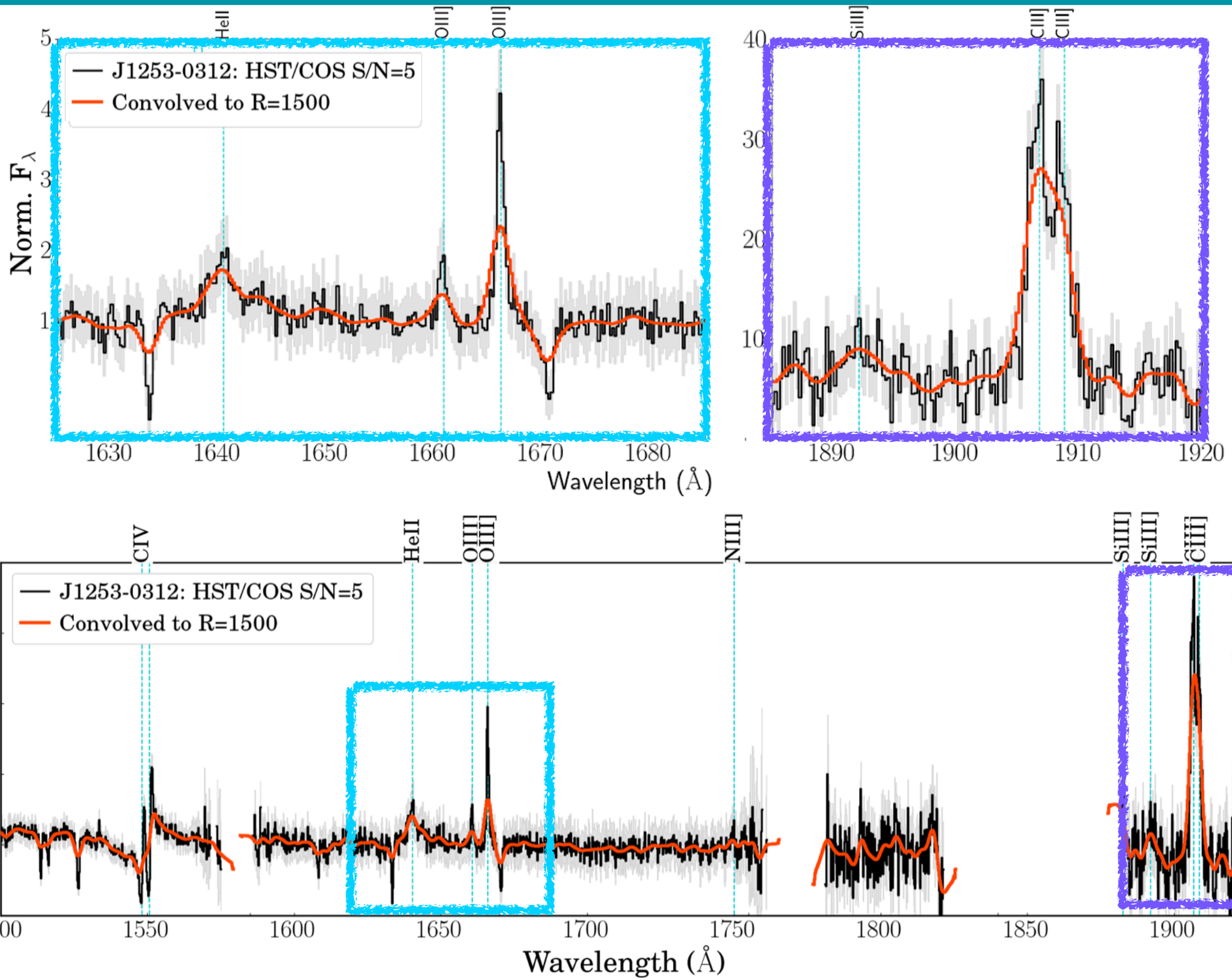
UVEX is optimized for observing FUV emission lines for LMLZ galaxies at $0 < z < 0.3$

The sensitivity of UVEX will allow us to detect all of the necessary nebular emission features, **plus stellar wind and some ISM absorption features.**



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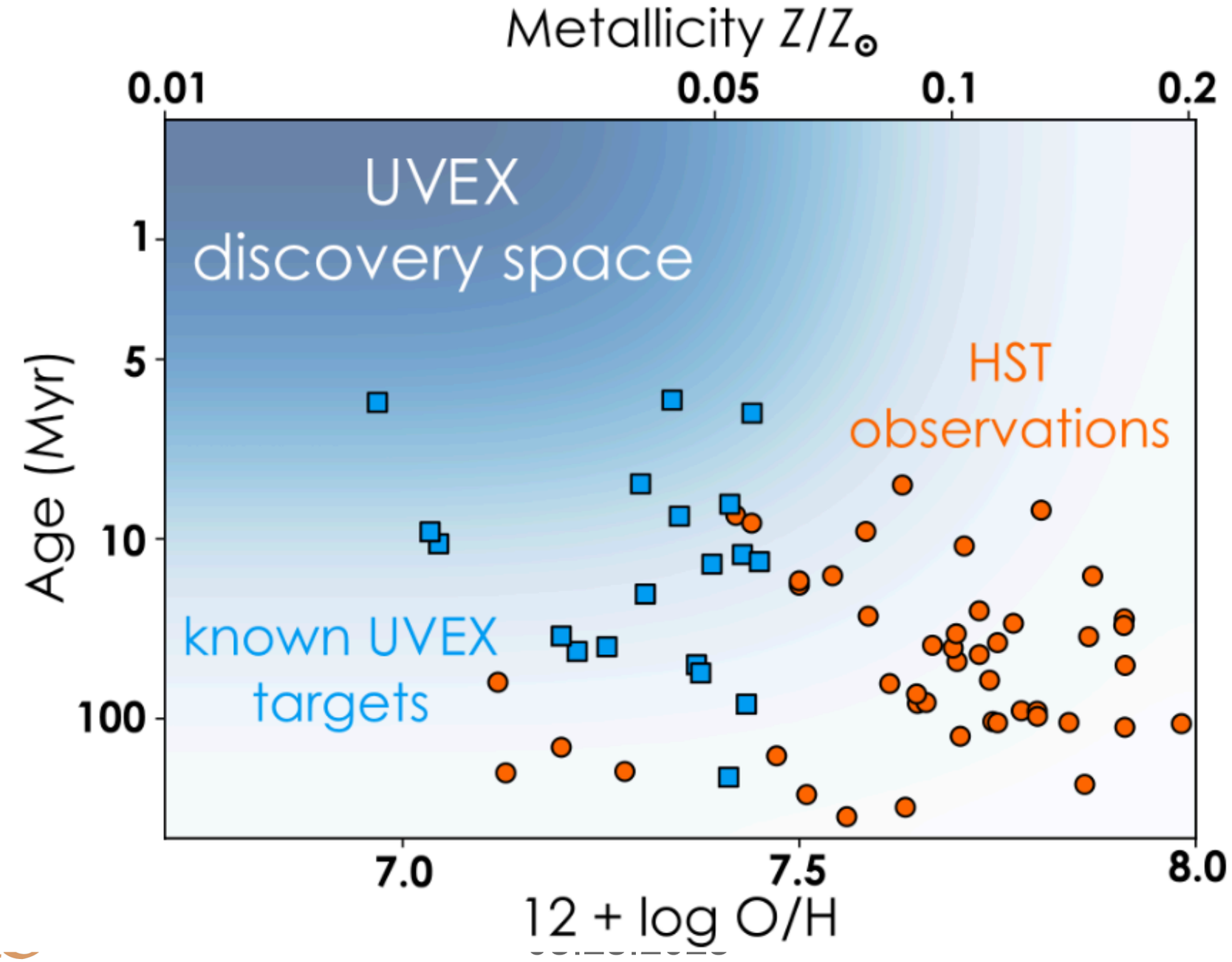
UVEX is optimized for observing FUV emission lines for LMLZ galaxies at $0 < z < 0.3$

UVEX will fill-in the critically missing galaxies that are **dominated by young (< 5 Myr), very low-metallicity (Z < 5% $Z_\odot$) stellar populations**, where both chemical enrichment and stellar evolution predictions are most uncertain.



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