

# ULTRAVIOLET ASTRONOMY IN THE XXI CENTURY



**e-Workshop 2020 – October 27-29**



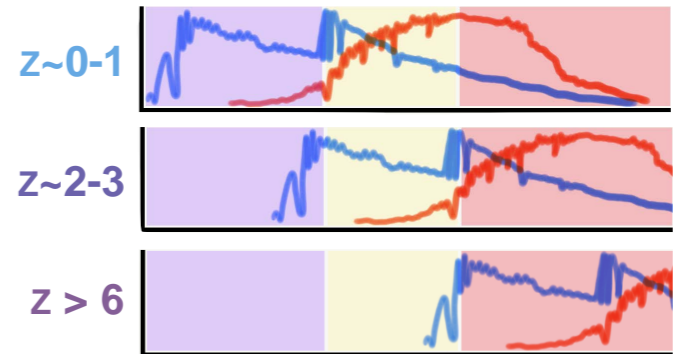
# **COS LEGACY ARCHIVE SPECTROSCOPIC SURVEY: A TREASURY OF STAR-FORMING GALAXIES**

**NUVA OCTOBER 2020**

**BETHAN JAMES, ON BEHALF OF THE CLASSY COLLABORATION  
SPACE TELESCOPE SCIENCE INSTITUTE**

# REST-FRAME UV SPECTRA WILL BRIDGE THE NEARBY AND DISTANT UNIVERSE\*

**REST-FRAME UV SPECTRA CAN CHARACTERIZE STELLAR AND NEBULAR EVOLUTION ACROSS ALL REDSHIFTS**



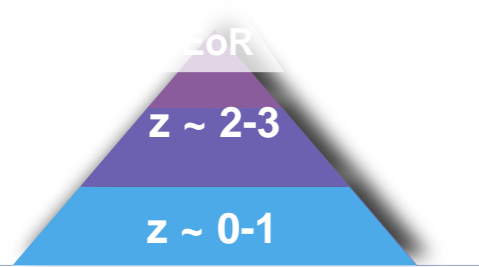
**1. REST-FRAME UV SPECTRA CAN CHARACTERIZE THE STELLAR POPULATIONS DRIVING FEEDBACK AND PRODUCING EMISSION-LINES**

**3. STRONG CIV EMISSION PROFILES TELL US ABOUT HIGH-IONIZATION GAS PROPERTIES AND THE POTENTIAL FOR HIGH-ENERGY PHOTON ESCAPE**

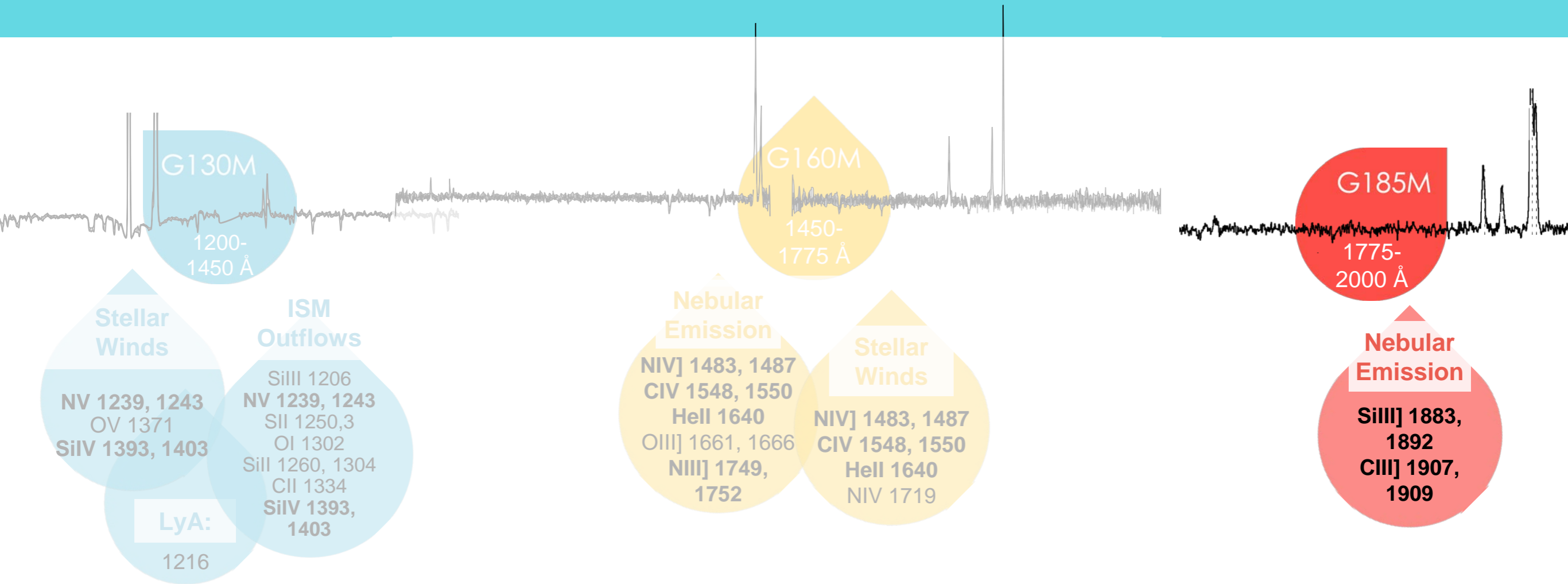
**4. HIGH-IONIZATION NEBULAR UV EMISSION LINES HELP CONSTRAIN GALAXY PROPERTIES BUT THEIR PRODUCTION AND ABUNDANCE PATTERNS ARE NOT YET UNDERSTOOD**

**2. STRONG NEBULAR HE II EMISSION INDICATES LARGE NUMBERS OF HIGH ENERGY PHOTONS ARE PRODUCED**

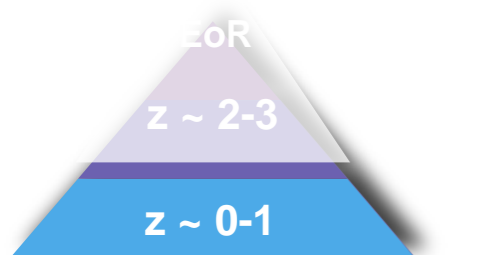
**\*IF PROPERLY CALIBRATED**



# CHALLENGE: PIECEMEAL UV ARCHIVE LIMITS ABILITY TO INTERPRET DISTANT UNIVERSE



**TYPICALLY, PREVIOUS STUDIES HAVE ONLY USED ONE OF THESE GRATING SETTINGS, ACCESSING A LIMITED RANGE OF DIAGNOSTICS**





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

PI: DANIELLE BERG

Co-PIs CHISHOLM, HECKMAN, JAMES, MARTIN, STARK  
& AN INTERNATIONAL TEAM OF 38 CO-IS

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



1200-1450 Å

1450-1775 Å

G185M  
1775-2000 Å

**Stellar Winds**

NV 1239, 1243  
OV 1371  
SiIV 1393, 1403

**ISM Outflows**

SiIII 1206  
NV 1239, 1243  
SII 1250,3  
OI 1302  
SiII 1260, 1304  
CII 1334  
SiIV 1393, 1403

**LyA:**  
1216

**Nebular Emission**

NIV] 1483, 1487  
CIV 1548, 1550  
HeII 1640  
OIII] 1661, 1666  
NIII] 1749, 1752

**Stellar Winds**

NIV] 1483, 1487  
CIV 1548, 1550  
HeII 1640  
NIV 1719

**Nebular Emission**

SiIII] 1883, 1892  
CIII] 1907, 1909

**Stellar Photospheric**

CIII 1247  
SiIII 1299  
SiII 1417  
CIII 1428  
FeV 1430

**Fine Structure**

SiII\* 1265, 1309  
CII\* 1335

**ISM Outflows**

SiII 1527  
CIV 1548, 1550  
FeII 1608  
AlII 1671

**Fine Structure**

SiII\* 1533

**ISM Outflows**

SiII 1808  
Al III  
1854, 1863

z ~ 0-1



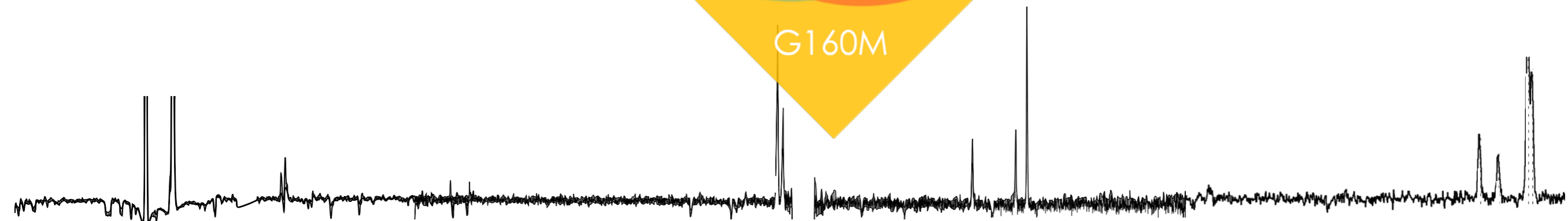
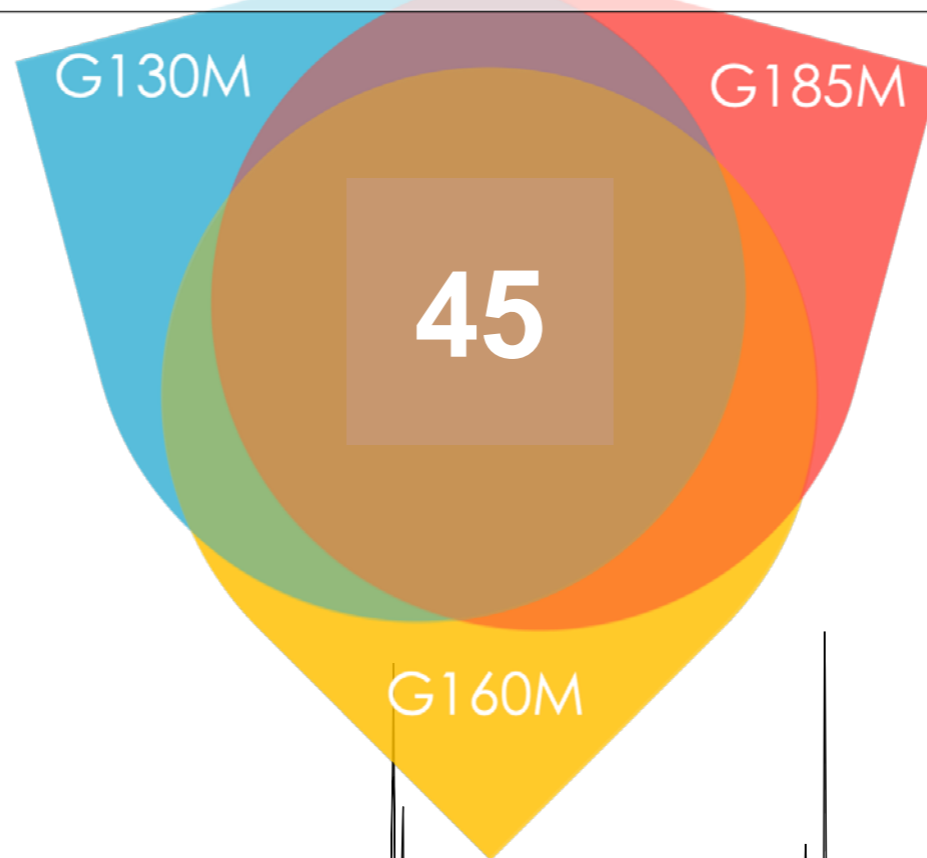
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State of HSLA Archive after CLASSY



## SYNERGISTIC FUV SCIENCE

Resolving  
ISM+Stellar+Nebular  
Blended Features

Stellar+Nebular  
Constraints on EUV  
Ionizing Spectrum

ISM+Stellar+Nebular  
Metallicities

Stellar+Nebular  
Ionizing Photon  
Indicators

ISM+Stellar+Optical  
Interpretation of  
Nebular Emission  
Observed at High-z

z ~ 2-  
z ~ 0-1

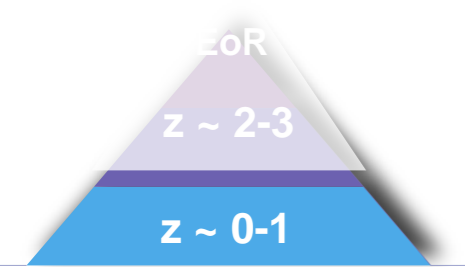
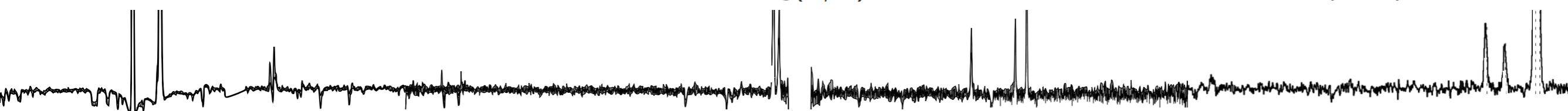
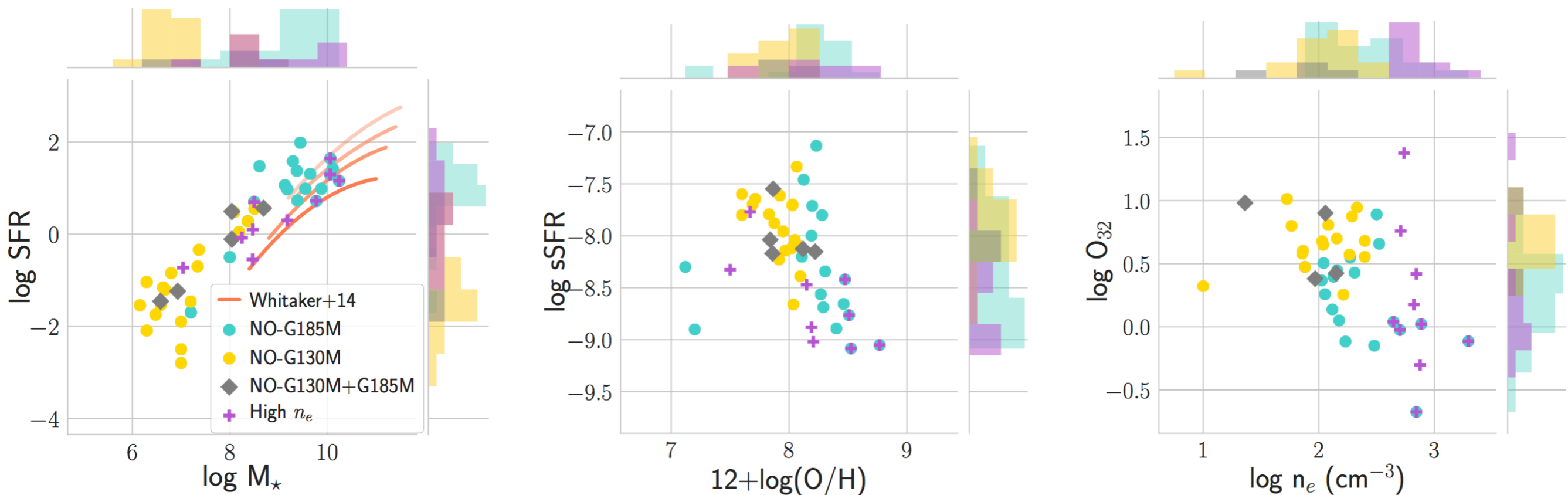


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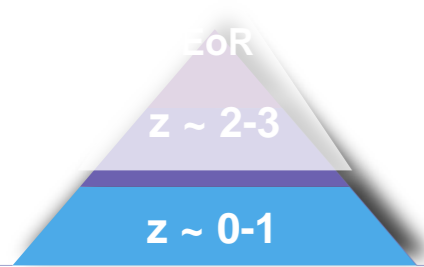
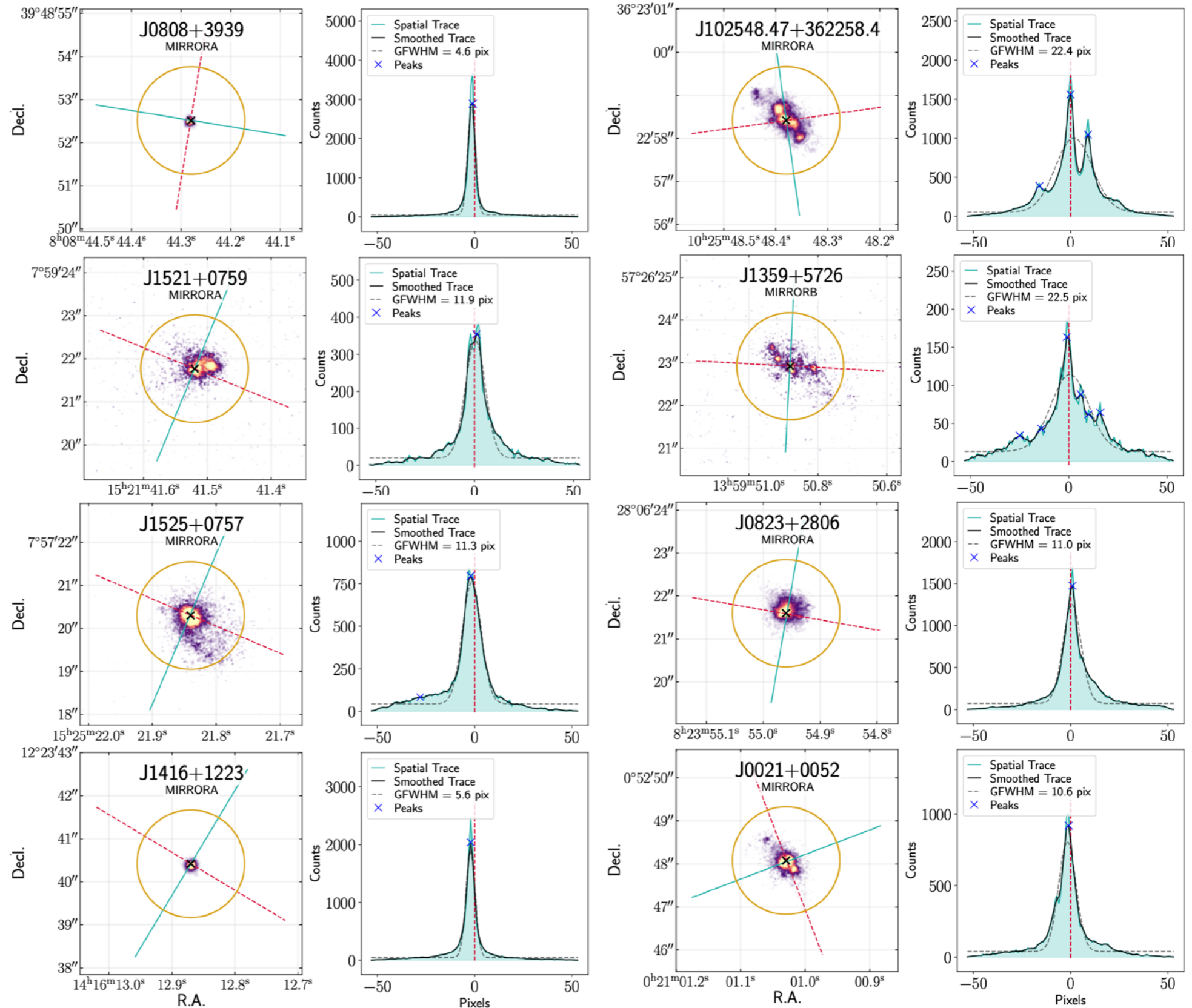


# THE COS LEGACY SPECTROSCOPIC SURVEY

**SURVEY NOW 95% COMPLETE**

**> MOST OF NUV LIGHT ENTERS COS APERTURE**

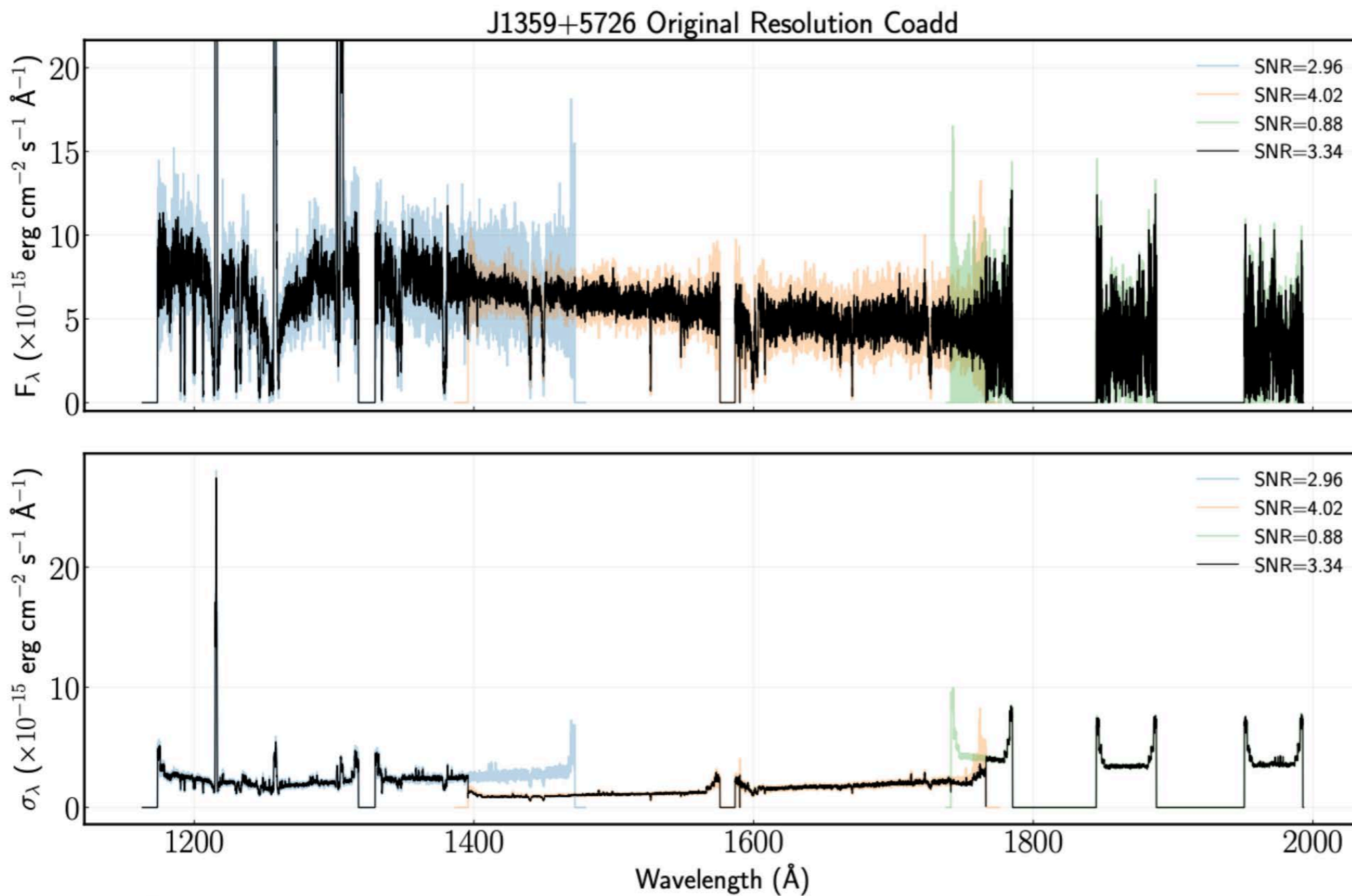
**MEASURE SPATIAL LIGHT PROFILE AND USE TO DETERMINE INDIVIDUAL LINE SPREAD FUNCTIONS**





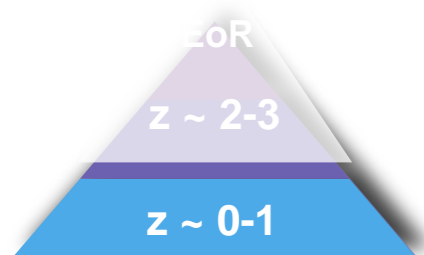


# THE COS LEGACY SPECTROSCOPIC SURVEY



**CLASSY DATASET = 93**  
**ARCHIVAL DATASETS**  
**(177 ORBITS)**  
**+**  
**58 NEW DATASETS**  
**(135 ORBITS)**

**MULTI-VISIT, MULTI-GRATING SPECTRA ARE CAREFULLY CO-ADDED TO CREATE FINAL SPECTRAL TEMPLATES**





# THE COS LEGACY SPECTROSCOPIC SURVEY

**FINAL CO-ADDED SPECTRA ARE HIGH S/N, HIGH RESOLUTION SPECTRA.**

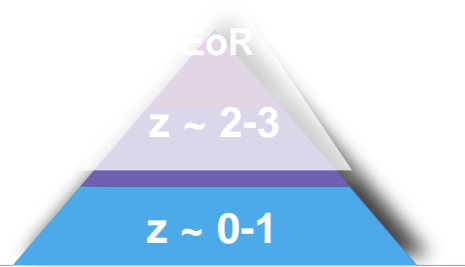
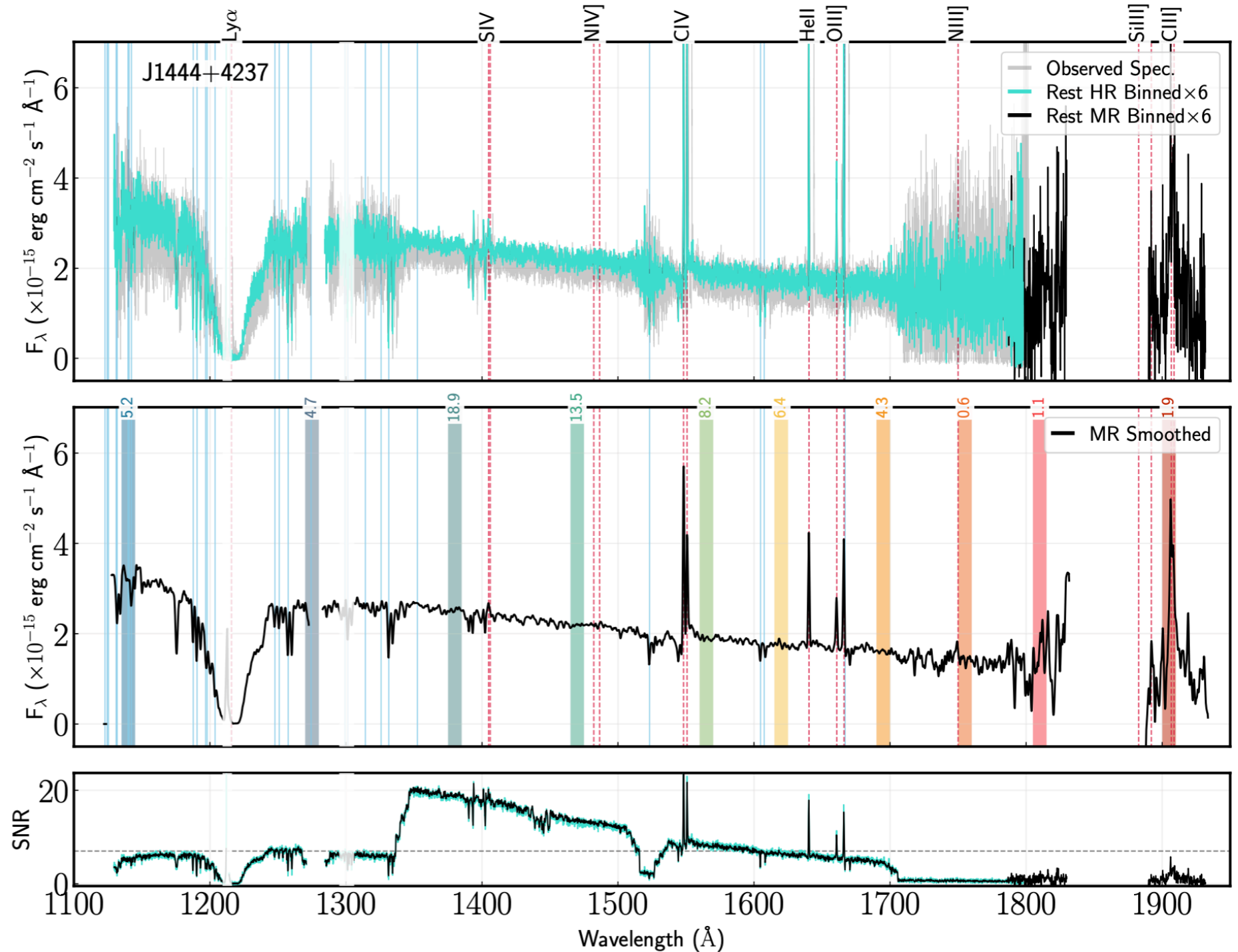
**VHR (G130M):**  
**0.060 Å/RESEL**  
**14.77 KM S<sup>-1</sup>/RESEL AT LYA 1215**

**HR (G130M+G160M):**  
**0.073 Å/RESEL**  
**14.20 KM S<sup>-1</sup>/RESEL AT CIV 1550**

**MR (G130M+G160M+G185M):**  
**0.222 Å/RESEL**  
**34.89 KM S<sup>-1</sup>/RESEL AT CIII 1909**

**LR (G130M+G160M+G140L):**  
**0.498 Å/RESEL**  
**78.3 KM S<sup>-1</sup>/RESEL AT CIII 1909**

**AT 1135 Å:**  
**AVG S/N = 5.6**  
**MED S/N = 4.7**





# THE COS LEGACY SPECTROSCOPIC SURVEY

## TREASURY VALUE: HIGH LEVEL SCIENCE PRODUCTS (HLSPs)

### **HLSP 1: CLASSY spectral atlas of 46 individual galaxies and stacked galaxies**

- High-resolution, high-S/N, co-added multi-grating FUV spectral templates of **46 CLASSY star-forming galaxies** created from **~600 exposures (312 orbits)**, plus aperture corrected optical spectra, covering a broad dynamic range of metallicities, stellar masses, star formation rates (SFRs), and ionizations
- Composite spectra stacked in characteristic bins of observable parameters
- Additional versions of the atlas convolved to different resolutions

### **HLSP 2: Compiled ancillary data across the electromagnetic spectrum of all CLASSY galaxies**

### **HLSP 3: CLASSY stellar continuum fits**

### **HLSP 7: Database of nebular properties**

### **HLSP 8: UV Diagnostic Tools**

### **HLSP 9: Database of chemical abundances and individual, tailored chemical evolution models**

### **HLSP 10: Database of feedback properties**

### **HLSP 11: Predictive tools of inferred escape fractions of ionizing photons**

### **HLSP 12: Improved stellar models and prescriptions**

### **HLSP 13: User-friendly CLASSY tutorials**

CoR  
z ~ 2-3  
z ~ 0-1



# THE COS LEGACY SPECTROSCOPIC SURVEY

## PRELIMINARY EMISSION LINE STATS:

- **24 HeII EMITTERS**
  - 19 NARROW EMITTERS
  - 5 W/A BROAD COMP.
- **12 CIV EMITTERS**
  - 8 PURE EMITTERS
  - 4 W/P-CYGNI CONTAM.
- **25 C/O DETECTIONS**
- **27 CIII] DENSITIES**
- **2 SIII] DENSITIES**

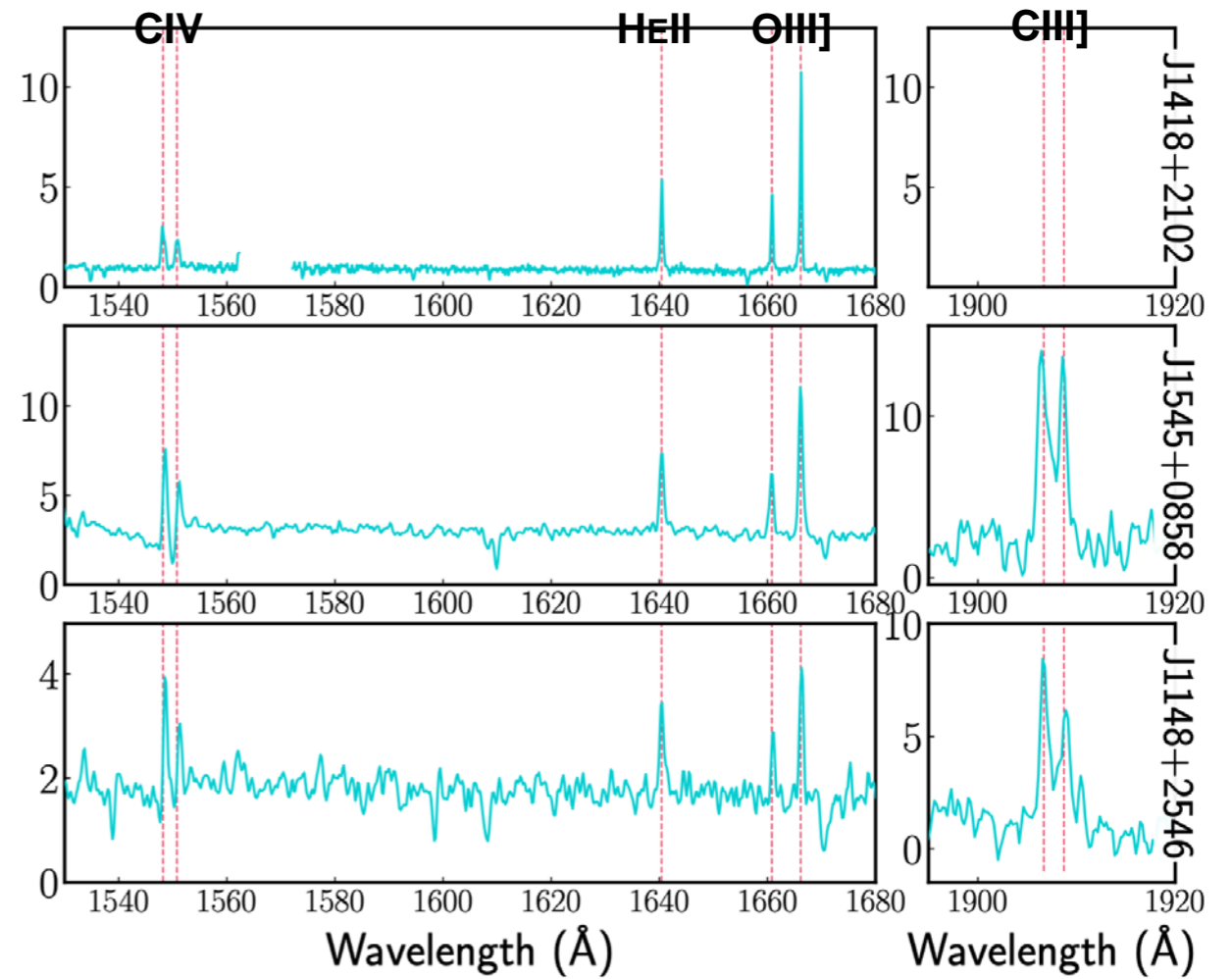
- POTENTIAL DETECTIONS:
- 7 NIV] EMITTERS
  - 7 NIII] EMITTERS
  - 15 SIV EMITTERS

CIV

HeII

OIII]

CIII]

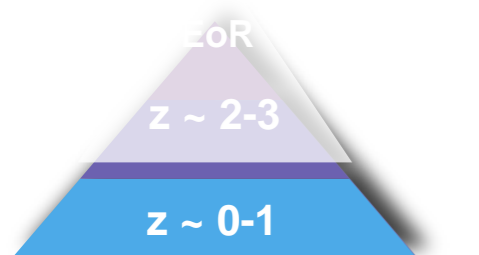


Wavelength (Å)

Wavelength (Å)

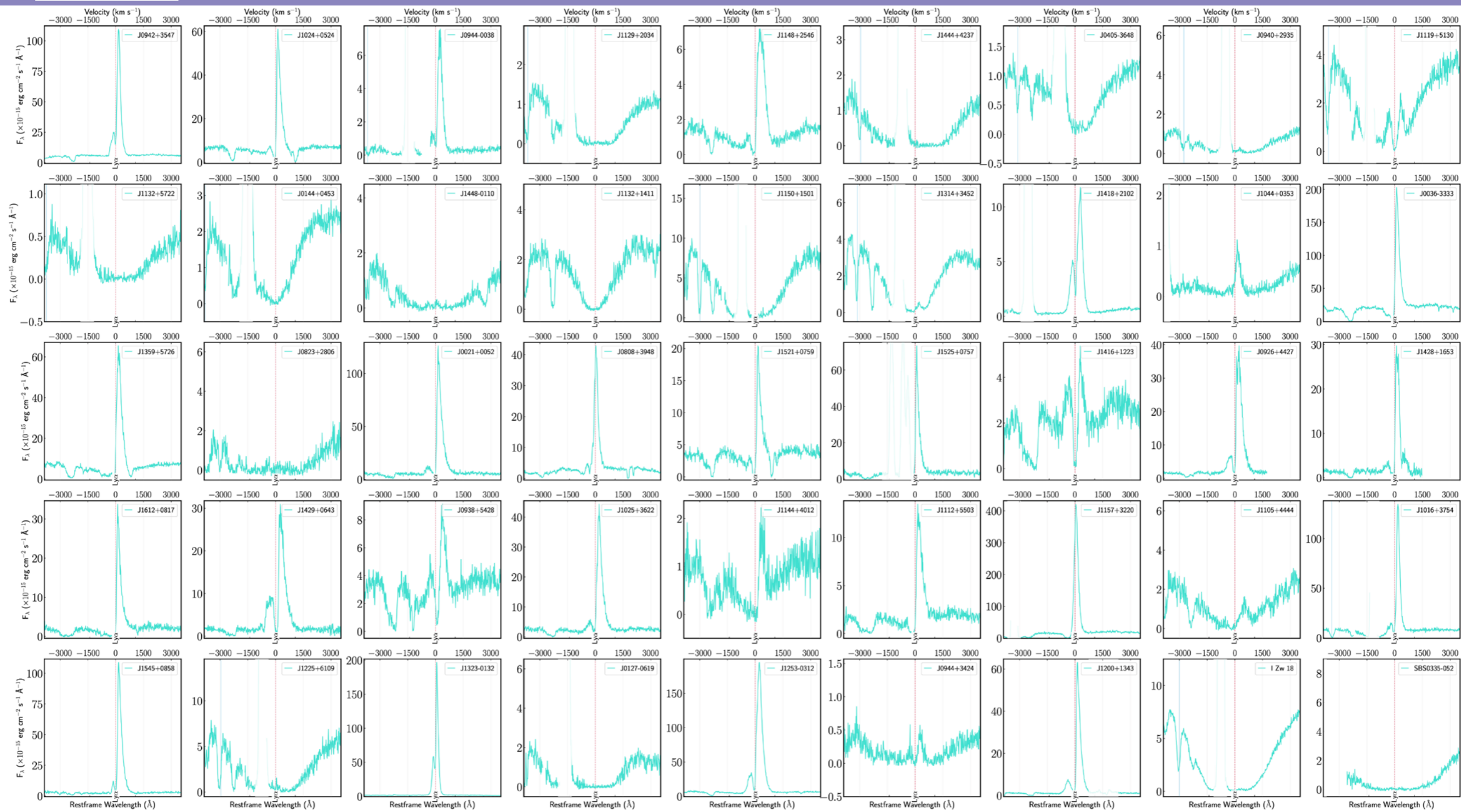
Wavelength (Å)

Wavelength (Å)





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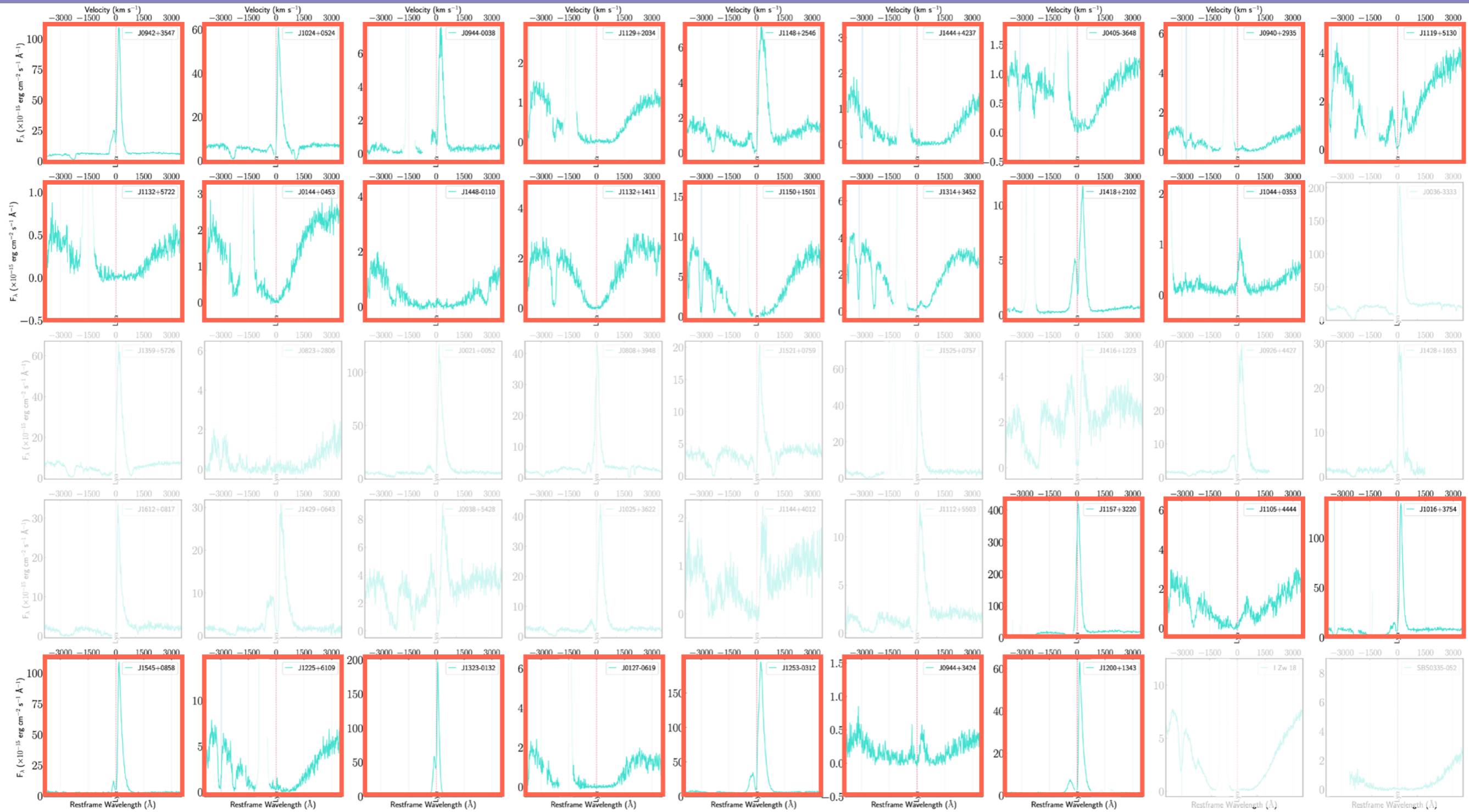
$z \sim 2-3$

$z \sim 0-1$

**LYA PROFILES**



# THE COS LEGACY SPECTROSCOPIC SURVEY



$z \sim 2-3$

$z \sim 0-1$

**27 NEW LY $\alpha$  SPECTRA**



# THE COS LEGACY SPECTROSCOPIC SURVEY

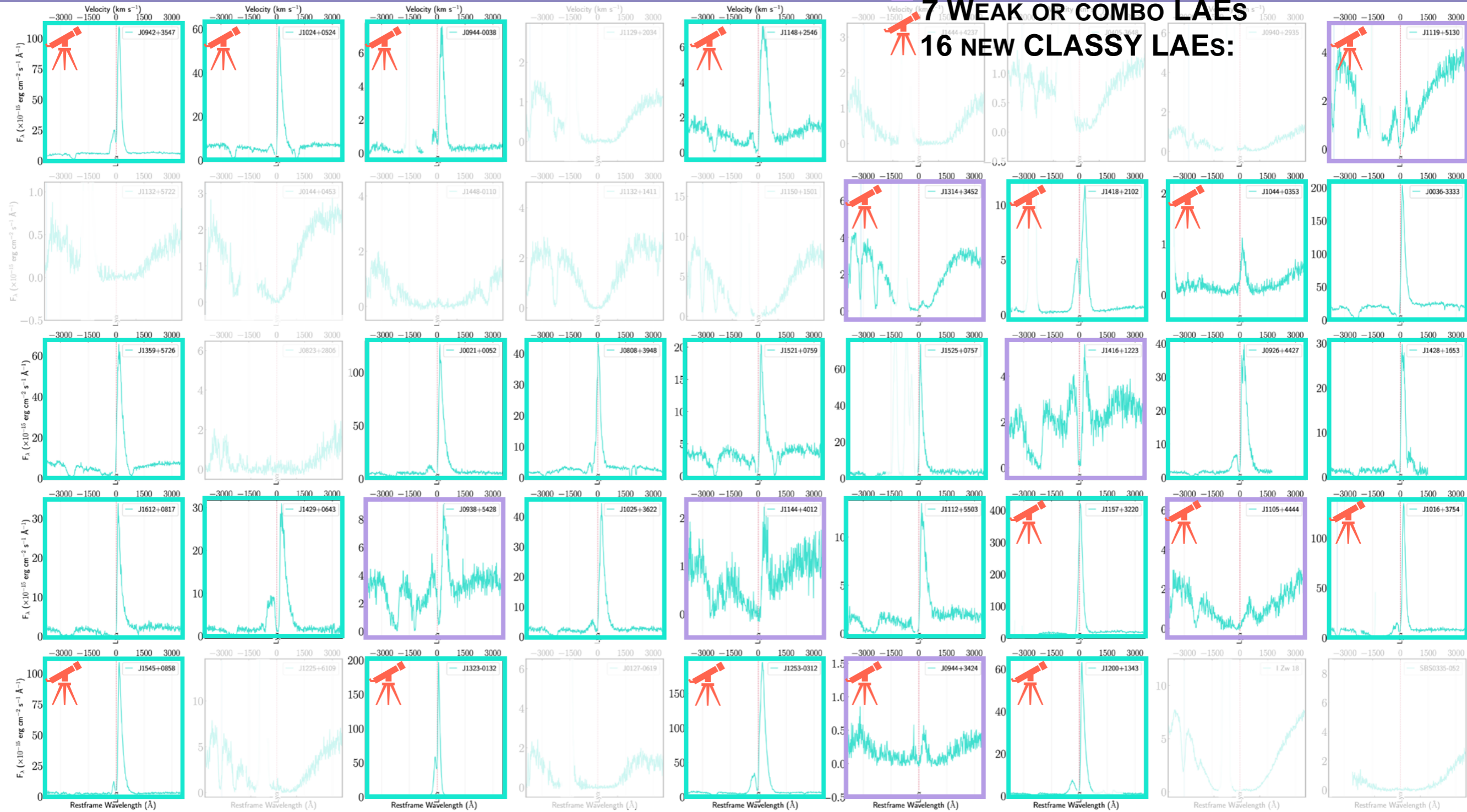


24 STRONG LAEs



7 WEAK OR COMBO LAEs

16 NEW CLASSY LAEs:

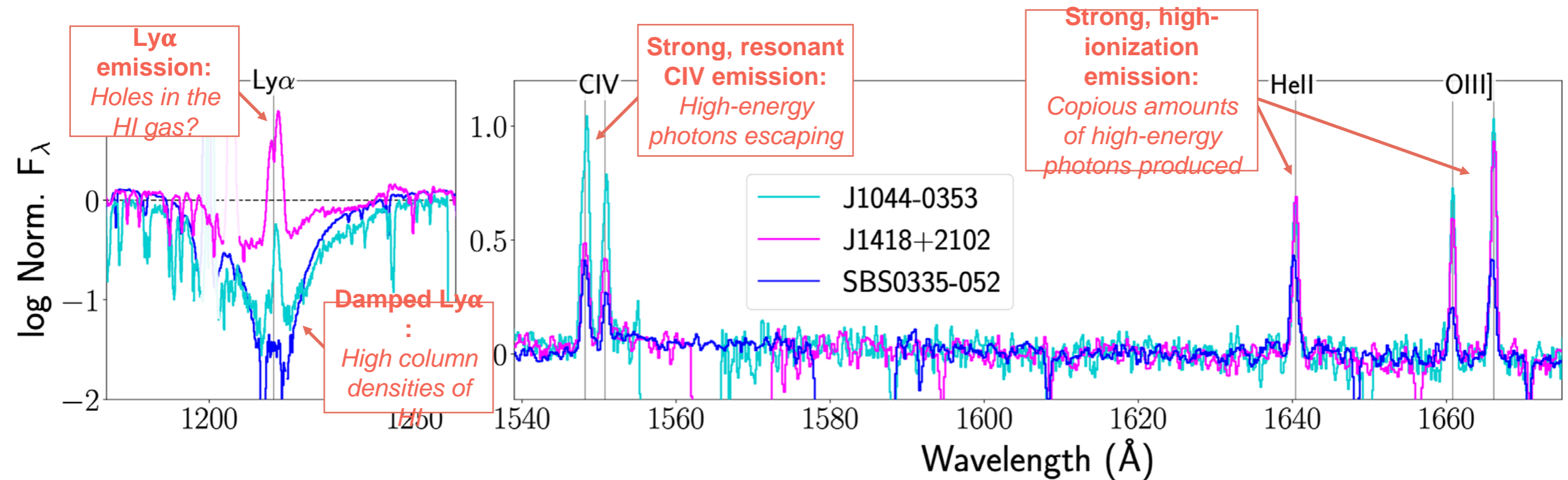


$z \sim 2-3$

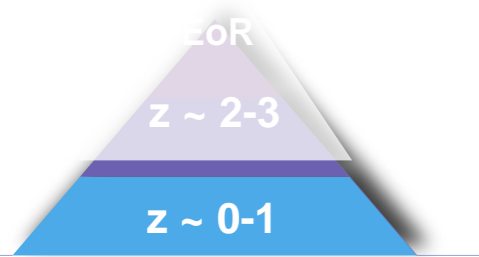
$z \sim 0-1$



# THE COS LEGACY SPECTROSCOPIC SURVEY



CLASSY WILL ALLOW US TO COMPARE LIKELY CONDITIONS OF PHOTON ESCAPE THROUGH LOW- AND HIGH-IONIZATION GAS







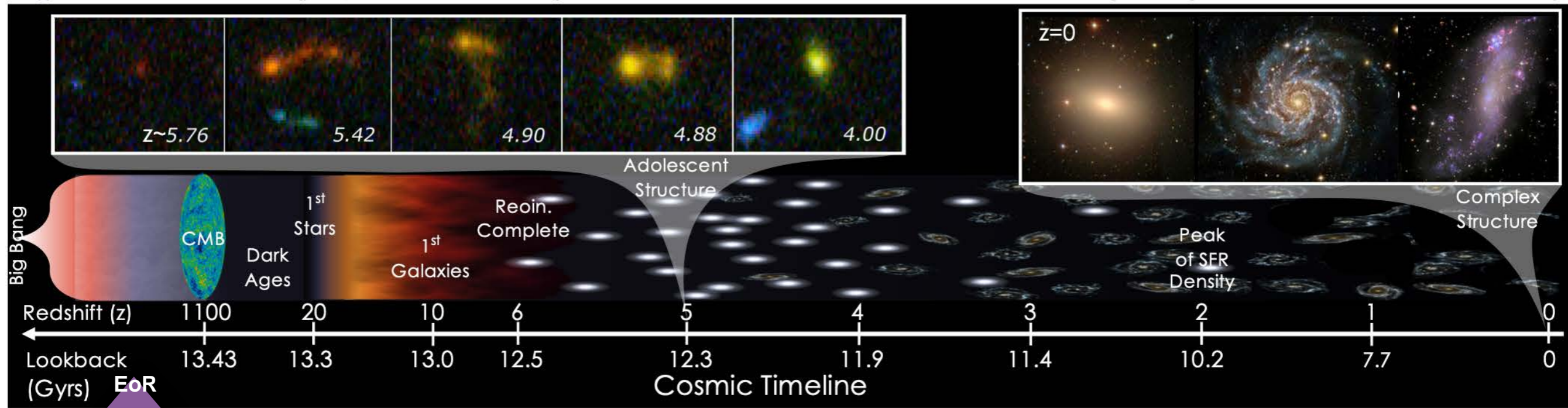
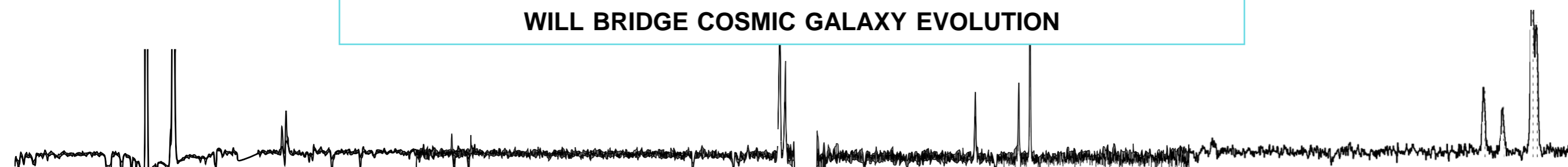
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THE CLASSY TEMPLATES +  
THE STELLAR AND NEBULAR DIAGNOSTIC POWER OF THE FUV +  
THE ACCESSIBILITY OF FUV SPECTRA  
WILL BRIDGE COSMIC GALAXY EVOLUTION



z ~ 2-3

z ~ 0-1