Lyman Continuum Escape in Local Star Forming Galaxies with HST and COS

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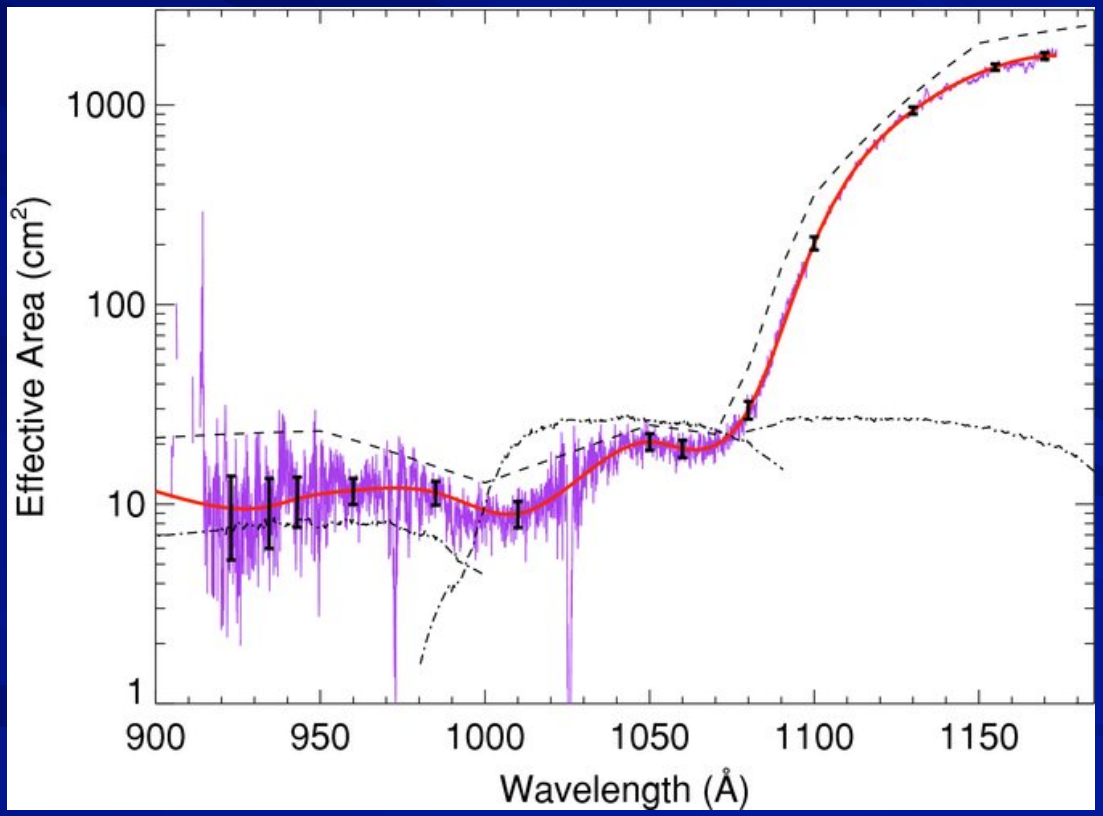
- Feasibility of observations down to 900 Å with the Cosmic Origins Spectrograph
- Measurement of the Lyman continuum in local star-forming galaxies
- Interpretation and the reliability of the models

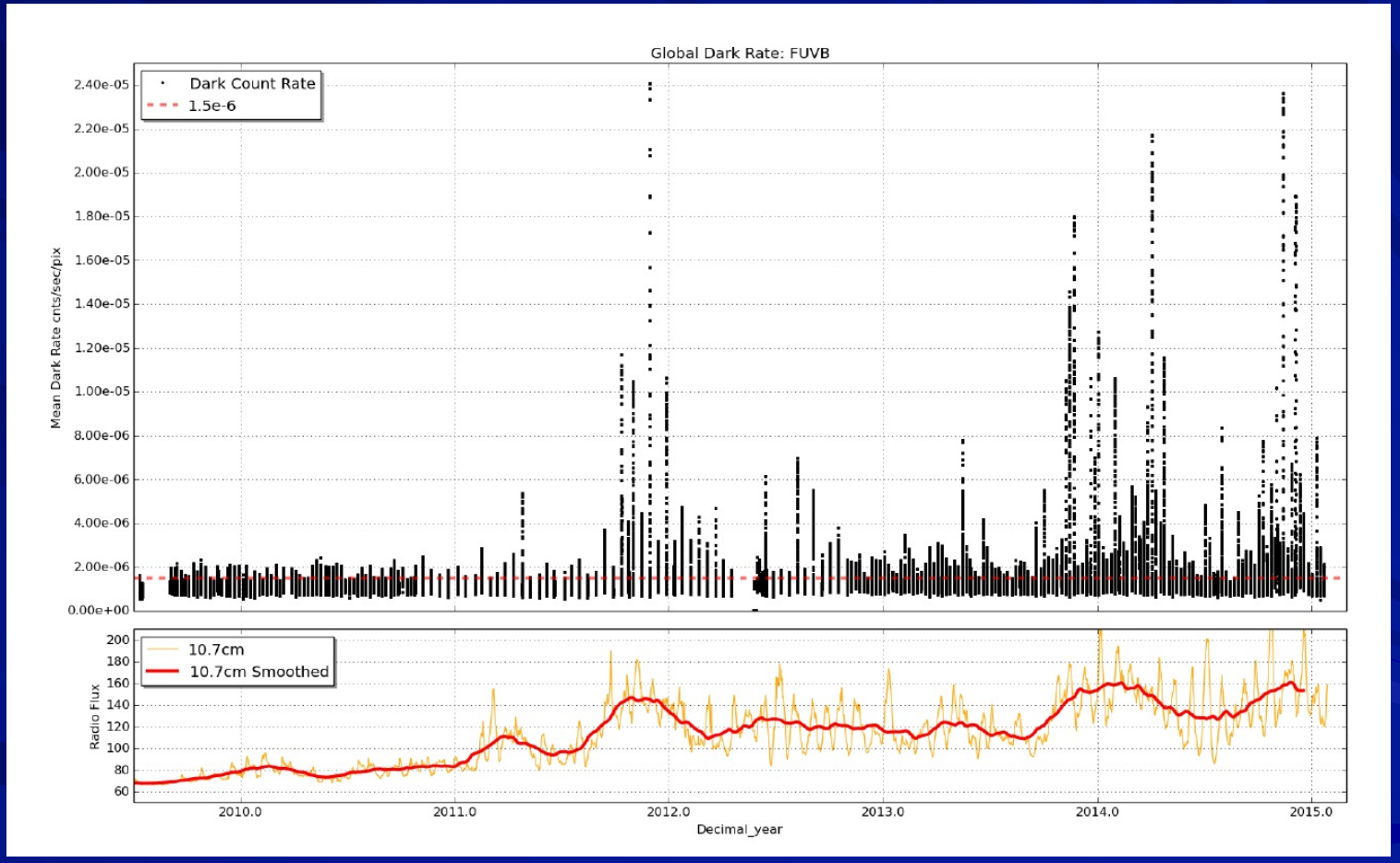
COS Capabilities at 900 – 1200 Å

- COS was designed for spectroscopy between 1150 and 3000 Å
- In the far-UV COS uses an XDL detector, which is identical to that used by FUSE
- Since there is no entrance window and only three reflections, some sensitivity down to (and below) 900 Å is expected

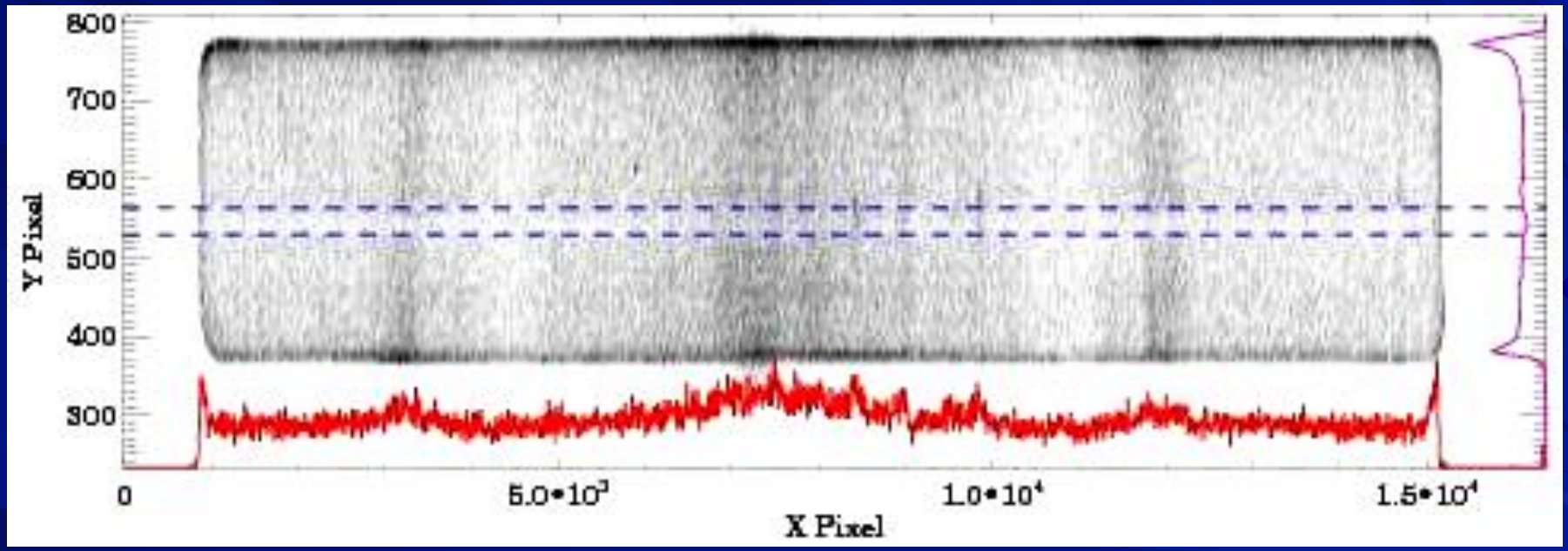
Effective area for G140L Segment B.
Purple: measurement; red: spline fit;
dashed: model for the effective area;
dash-dotted: FUSE SiC1b, LiF1a and LiF2a channels



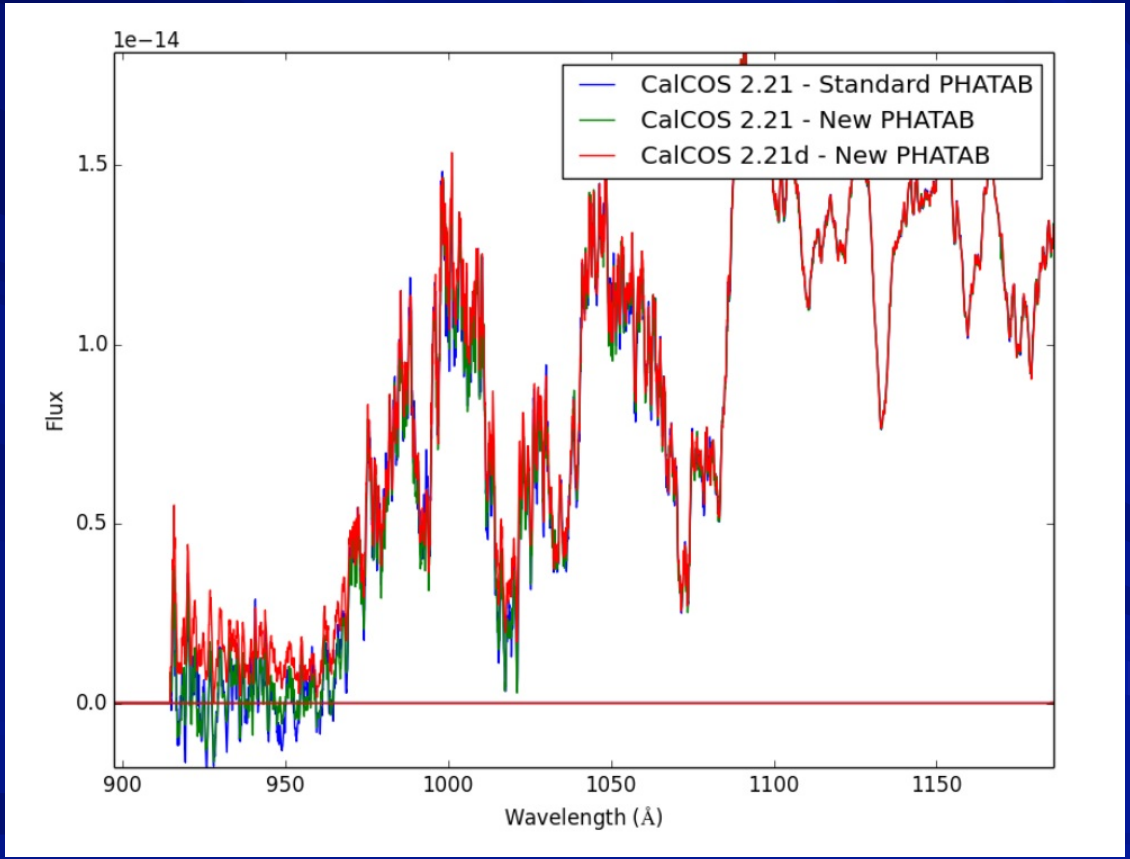
- COS dark rate is time variable and scales with the solar radio flux
- Need dedicated, contemporaneous dark files



- Standard COS pipeline overestimates the background at low flux levels
- The standard COS pipeline assumes a generic 1-dimensional dark correction
- Developed a revised background subtraction algorithm to account for time- and spatial variations



- Comparison of the processed spectrum with the standard and the new, dedicated pipeline



Lyman Continuum Escape in Local Star-Forming Galaxies

- Pilot study as a proof of concept; therefore the sample is driven by instrument requirements
- Preexisting UV spectra with $F(1100) > 1 \times 10^{-14}$
- $v > 10{,}000$ km s^{-1} $\Rightarrow \delta\lambda > 30$ Å
- Presence of O stars from UV spectra

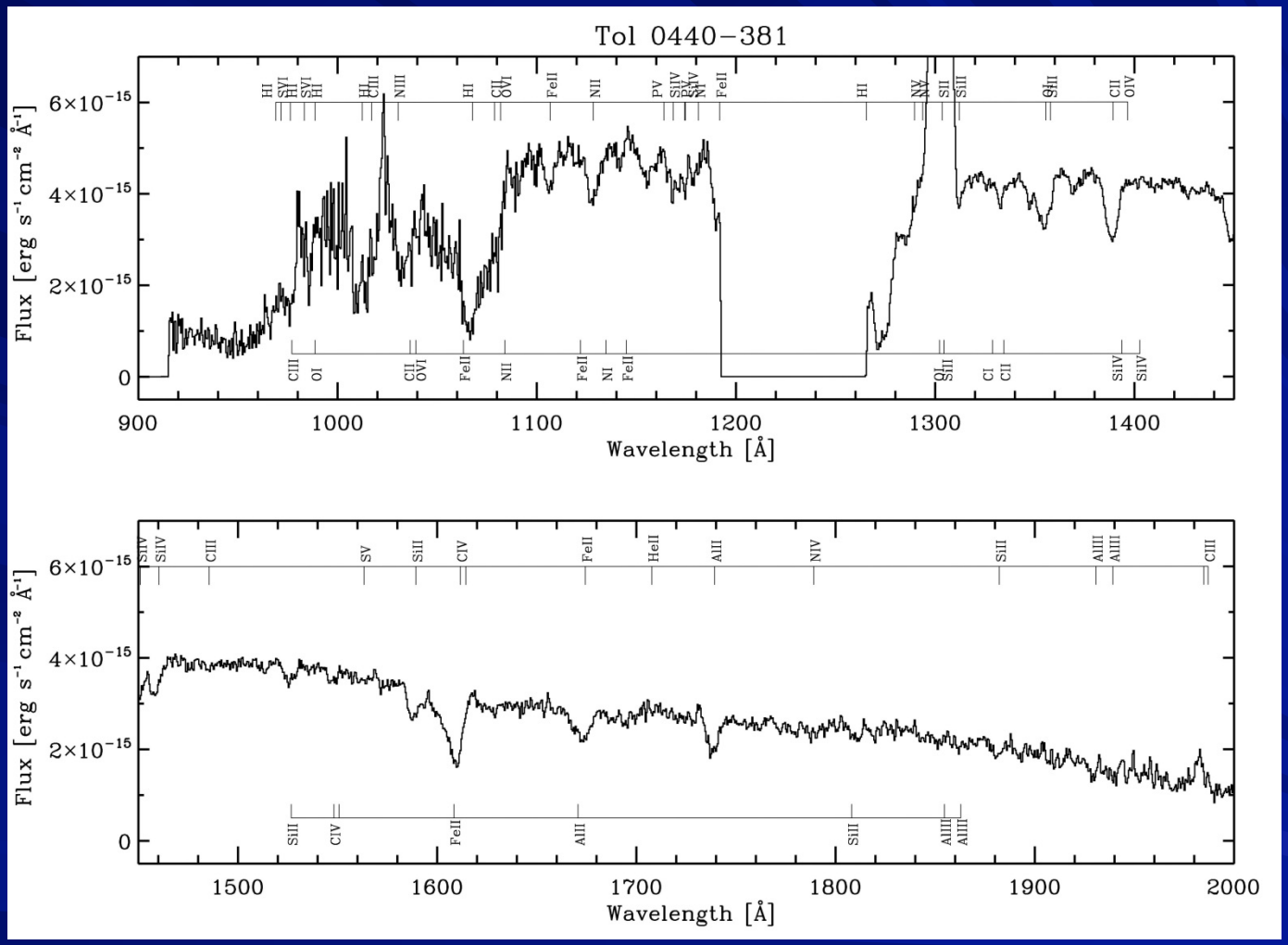
Galaxy Sample

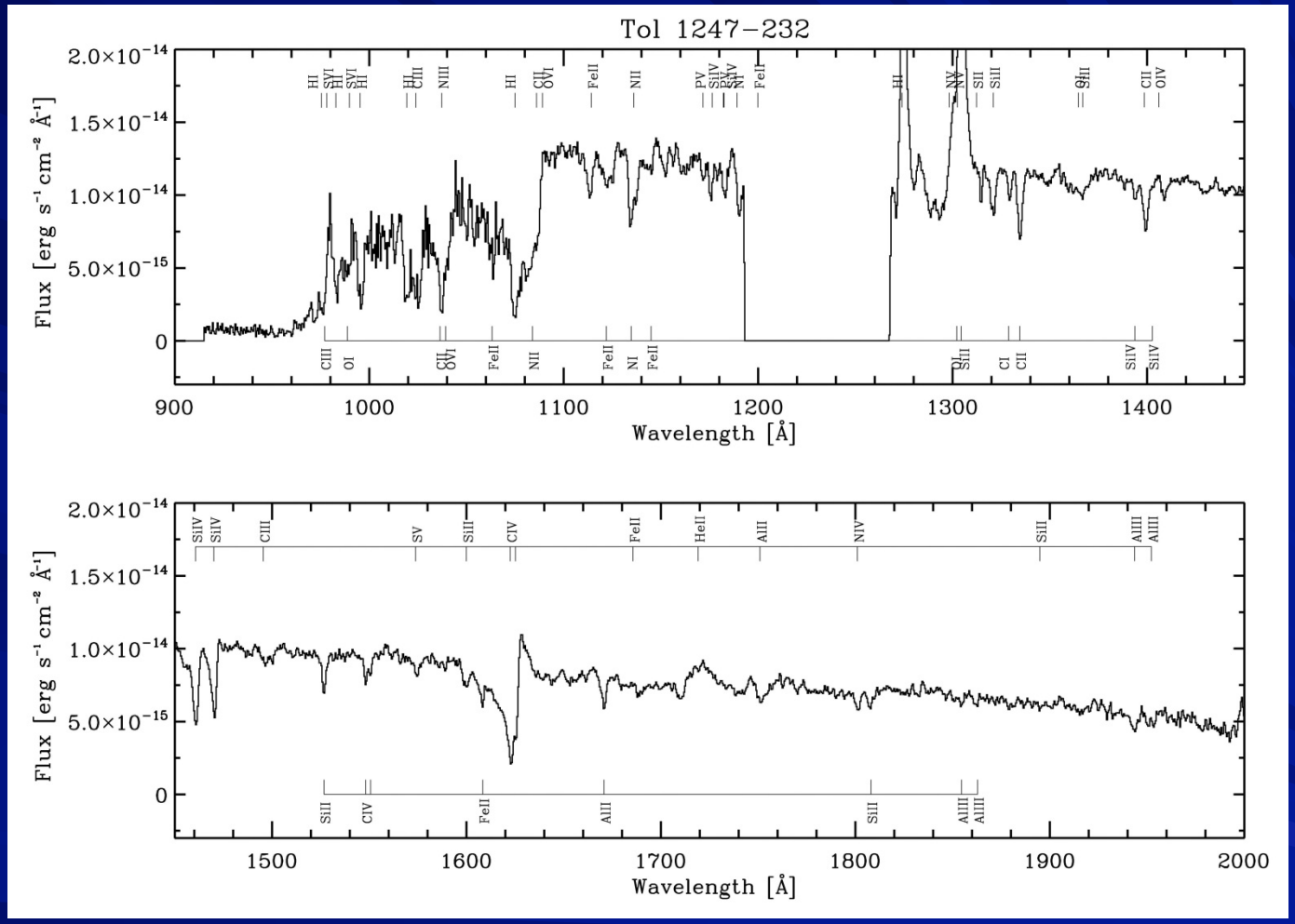
Galaxy	Type	$E(B-V)_{MW}$ (mag)	v_{LSR} (km s^{-1})	D (Mpc)	M_B (mag)	$E(B-V)_{int}$ (mag)	12+log O/H	SFR_{UV} ($M_\odot yr^{-1}$)
Tol 0440-381	HII	0.016	12,270	167	–20.2	0.15	8.2	3.2
Tol 1247-232	HII	0.089	14,400	207	–21.0	0.11	8.1	17
Mrk 54	BCG	0.015	13,470	191	–22.2	0.15	8.6	12

- The three galaxies were observed before with FUSE (Pellerin & Robert 2007; Grimes et al. 2009; Leitet et al. 2013)
- Several studies specifically targeted the Lyman continuum

New COS Observations

- G140L grating
- Wavelength coverage from <900 Å to ~2200 Å with a gap between 1165 Å and 1280 Å
- 0.48 Å resolution (point source)
- G140L vs. G130M; trade between resolution and wavelength coverage


Tol 0440−381
Flux [erg s⁻¹ cm⁻² Å⁻¹]
6×10⁻¹⁵
4×10⁻¹⁵
2×10⁻¹⁵
0
900
1000
1100
1200
1300
1400
Wavelength [Å]
HI
SiIV
CIV
NIII
HeII
NII
PV
OVI
FeII
NV
SiII
OI
CII
SiIV
Flux [erg s⁻¹ cm⁻² Å⁻¹]
6×10⁻¹⁵
4×10⁻¹⁵
2×10⁻¹⁵
0
1500
1600
1700
1800
1900
2000
Wavelength [Å]
SiIV
CIII
SV
SiII
CIV
FeII
HeII
AlII
NIV
AlIII
SiII
CIV
FeII
AlII
SiII
AlIII


Tol 1247−232
Flux [erg s⁻¹ cm⁻² Å⁻¹]
Wavelength [Å]
2.0×10⁻¹⁴
1.5×10⁻¹⁴
1.0×10⁻¹⁴
5.0×10⁻¹⁵
0
900
1000
1100
1200
1300
1400
HI
SiIV
OI
SiIV
HI
HI
CIII
NIII
HI
CII
OVI
FeII
NII
PV
SiIV
OVI
NV
FeII
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FeII
NI
FeII
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SiII
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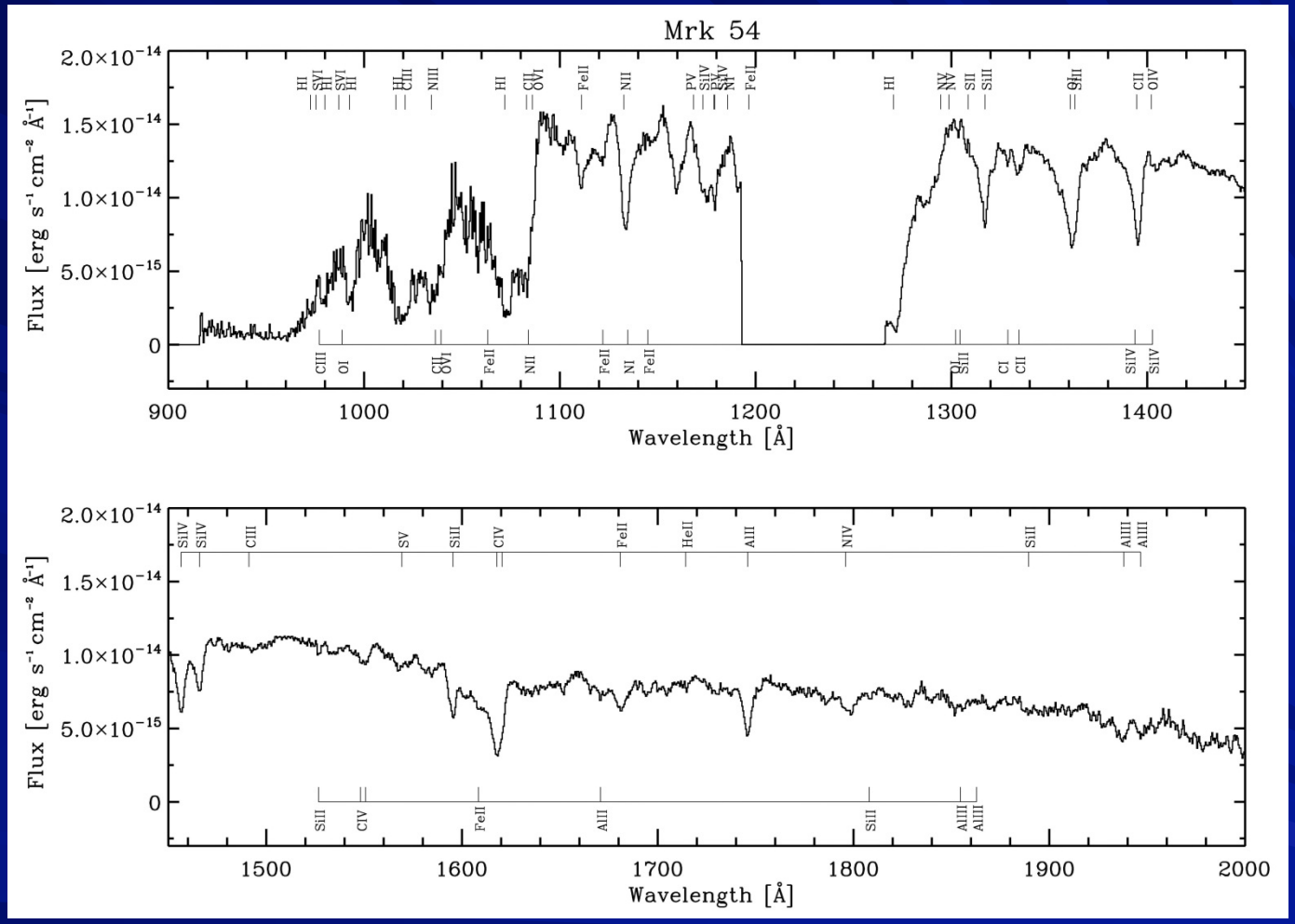
Mrk 54
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1.0×10⁻¹⁴
5.0×10⁻¹⁵
0
900
1000
1100
1200
1300
1400
Wavelength [Å]
HI
SiIV
CIV
SiIV
HI
HeII
CIII
NIII
HI
CIV
OVI
FeII
NII
PV
SiIV
CIV
NV
FeII
HI
NV
NV
SII
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5.0×10⁻¹⁵
0
1500
1600
1700
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2000
Wavelength [Å]
SiIV
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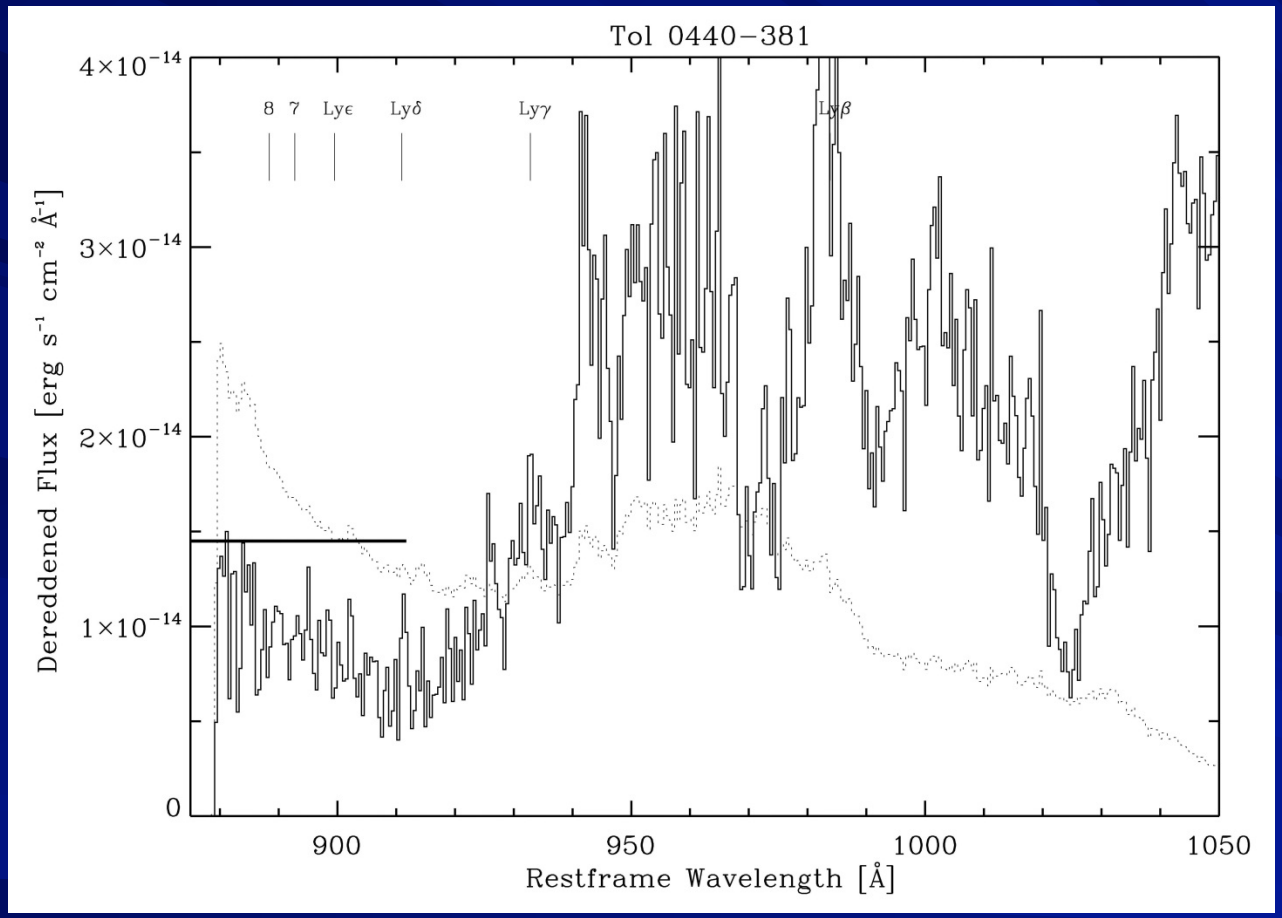


- Spectral region around the Lyman break
- Corrected for intrinsic reddening
- Dashed: noise
- Restframe
- ~35 Å of Lyman continuum
- Geocoronal Lyman lines denoted
- Thick bar: model
- T=20 Myr, const. SF, Kroupa IMF, Geneva models with rotation

Lyman continuum escape fractions

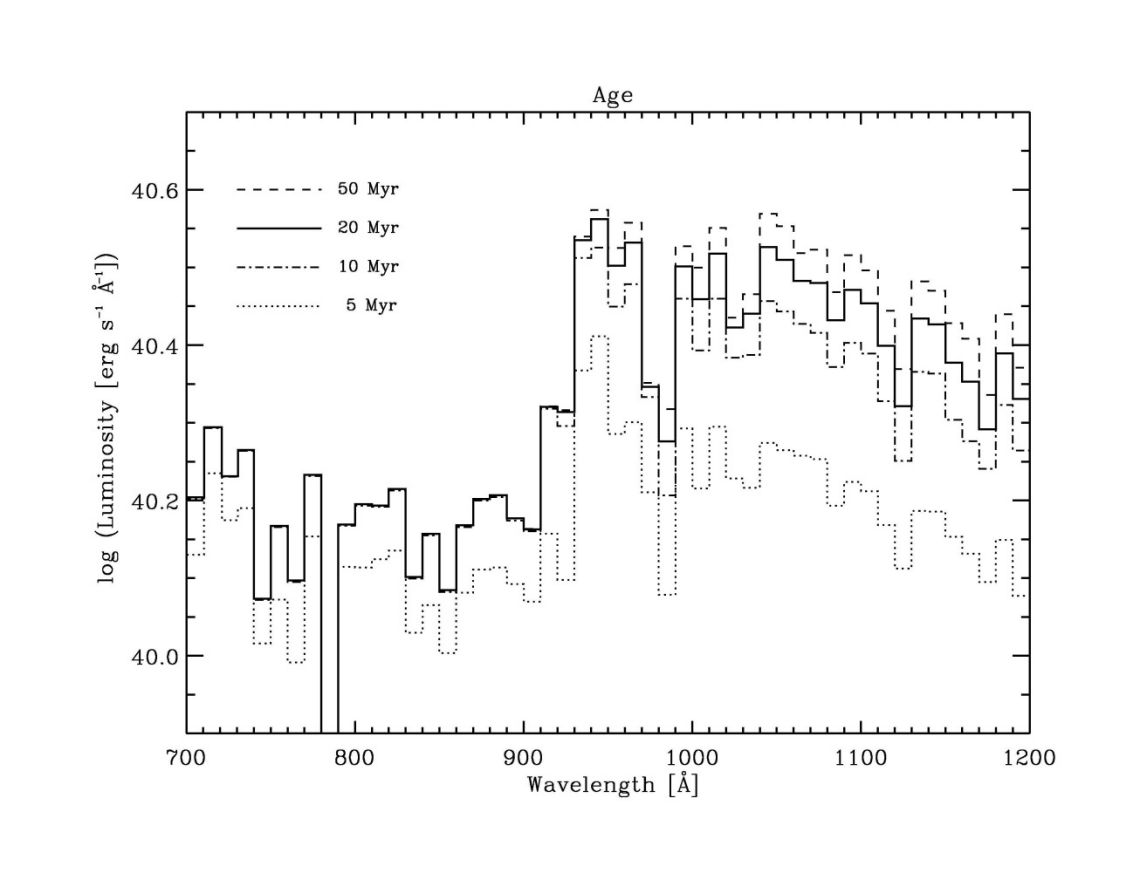
Escape Fraction	Tol 0440-381	Tol 1247-232	Mrk 54
$f_{esc/rel}$ (%)	< 60 ±13	22 ± 5.9	21 ± 6.1
$f_{esc/abs}$ (%)	< 7.1 ± 1.1	4.5 ± 1.2	2.5 ± 0.72

- Absolute escape fractions are a few %
- Consistent with optical depth and high covering factor suggested by CII λ1036
- Significantly lower than in some LBG's ⇒ different ISM properties?

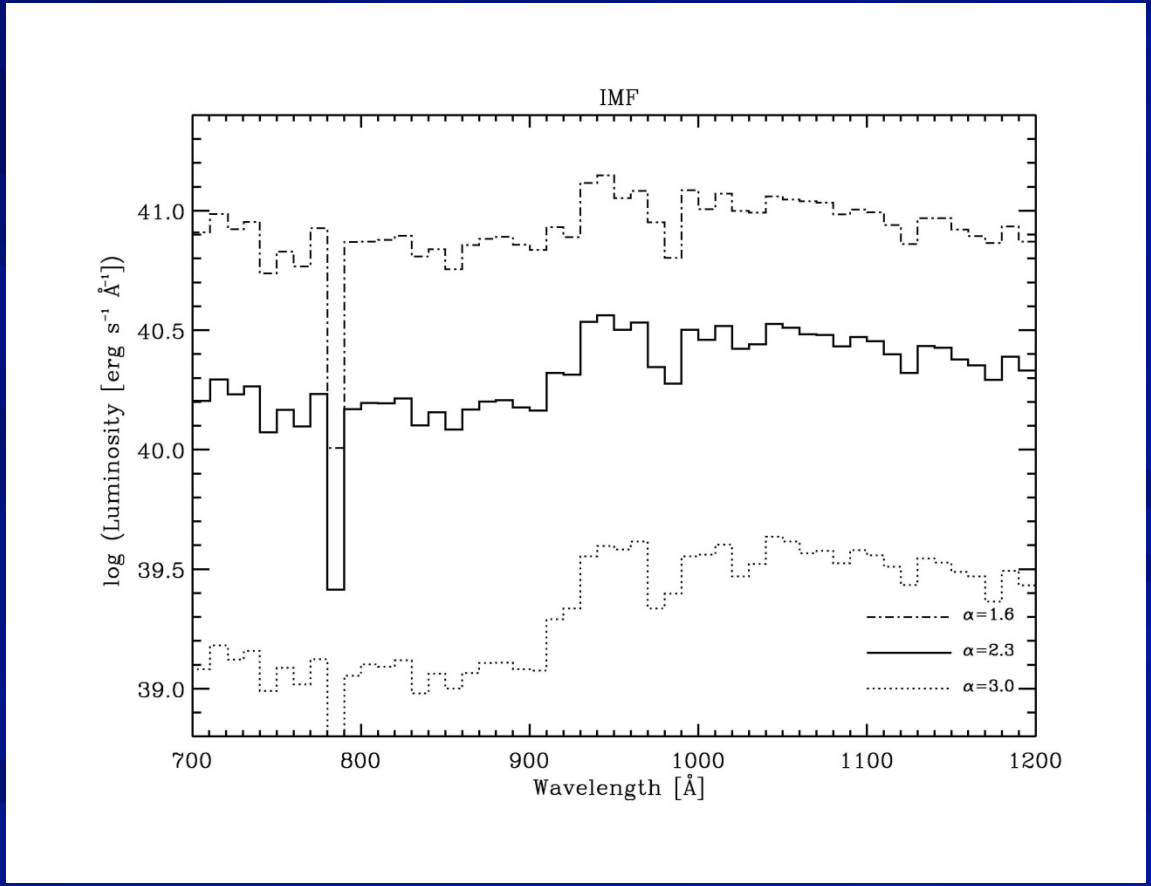
Reliability of the Models

- Model predicts an intrinsic Lyman break of ~0.4 dex for a standard population
- Kroupa IMF, constant star formation, T=20 Myr, Geneva evolution models with rotation, spherically extended, expanding, blanketed non-LTE atmospheres
- How do model assumptions and uncertainties affect the prediction?

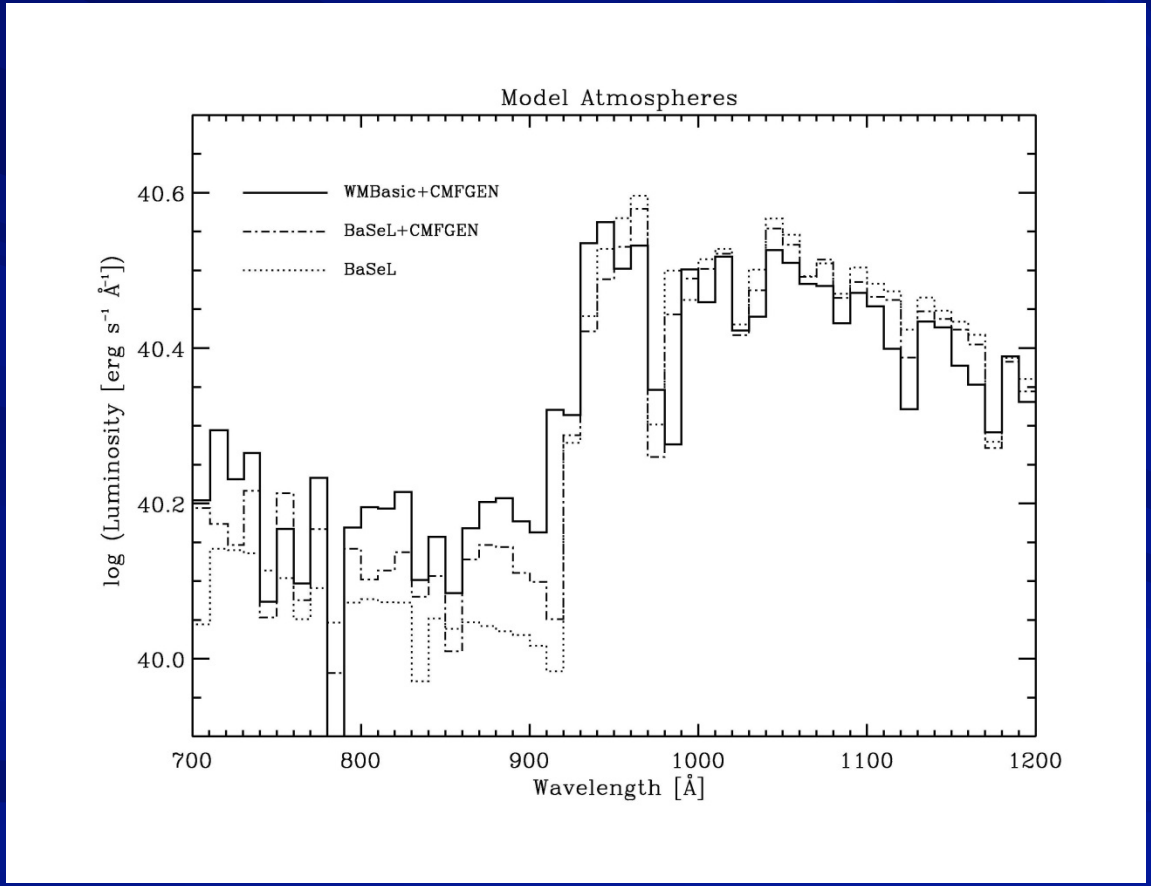
Varying the duration of the SF episode has little effect for T>5 Myr as massive stars have reached equilibrium



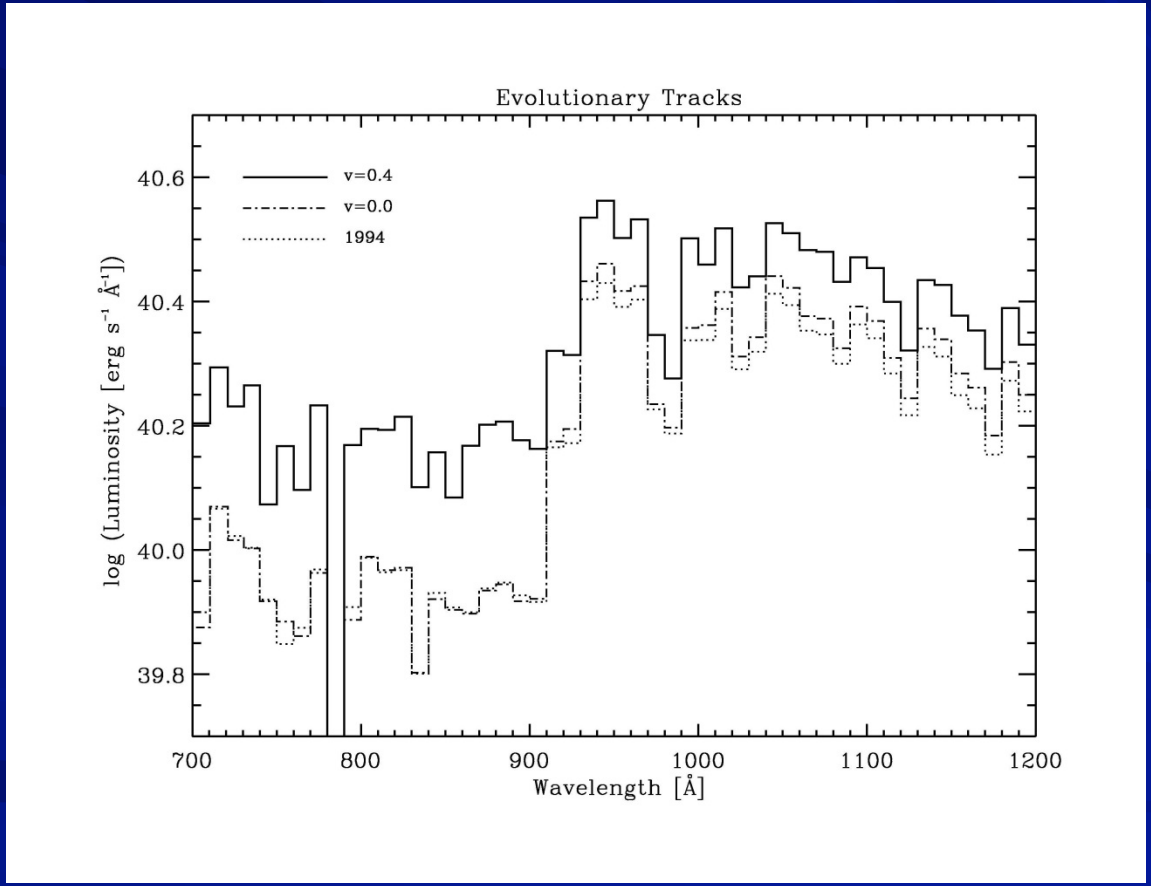
Varying the IMF exponent between 1.6 and 3 changes the flux level by a factor of ~100 but has a small effect on the break itself



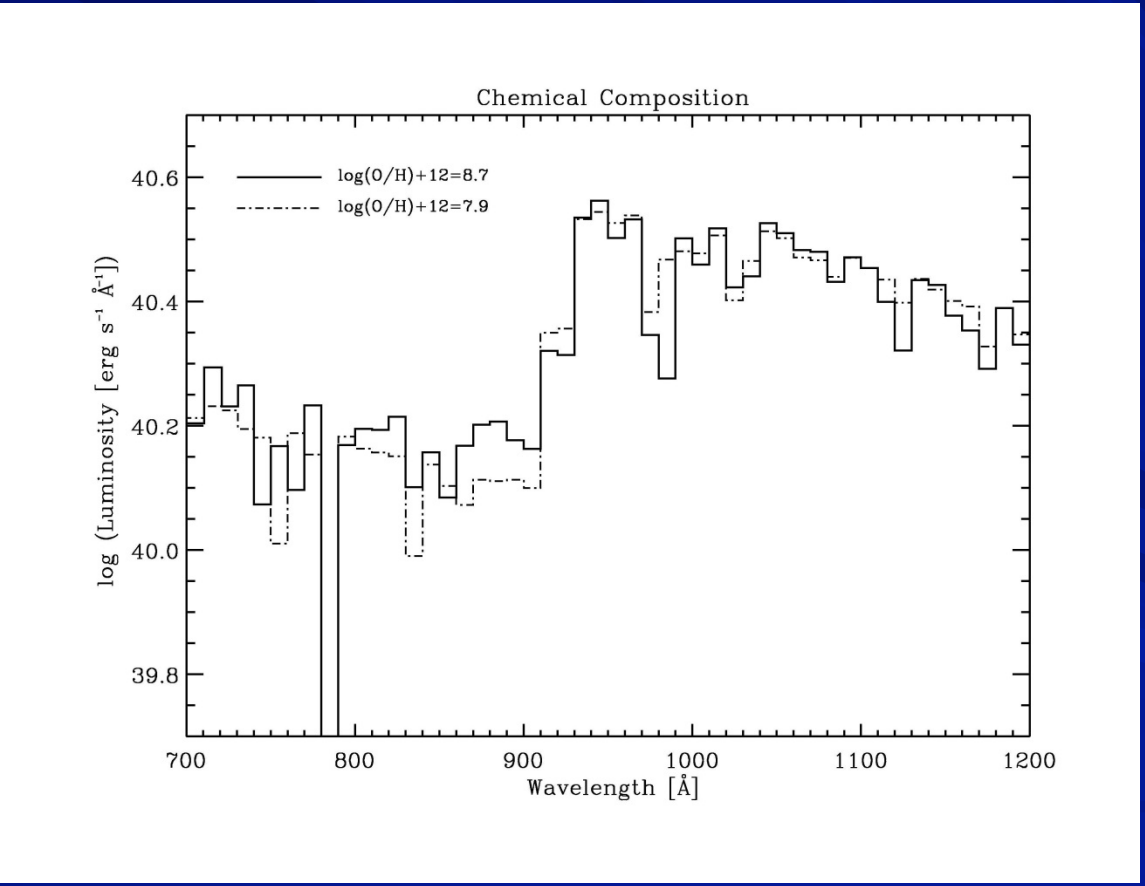
Extended model atmospheres accounting for winds decrease the break by up to 0.15 dex



Evolution models with rotation have hotter, more luminous stars and increase the Lyman continuum flux by ~0.2 dex



Chemical composition has a surprisingly small influence due to the compensating effects of atmospheres and evolution models



Take-away Points

- COS has excellent sensitivity down to 900 Å and is well suited for Lyman continuum observations in the local universe
- Two local star-forming galaxies have absolute escape fractions of a few %
- Stellar models for the Lyman continuum have uncertainties of up to a factor of 2, mostly because of uncertain stellar evolution models