Probing the intergalactic UV background with QSO absorption lines

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IGM group

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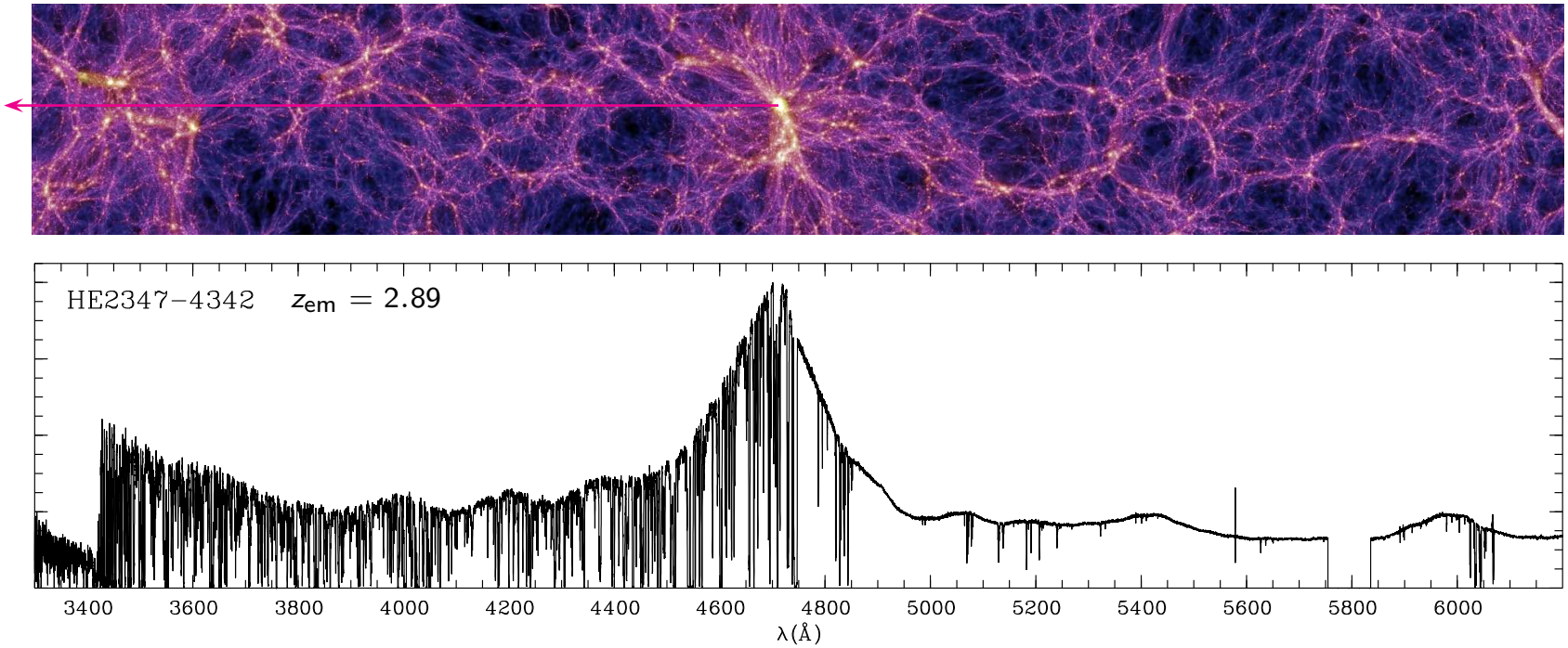
QSO absorption lines

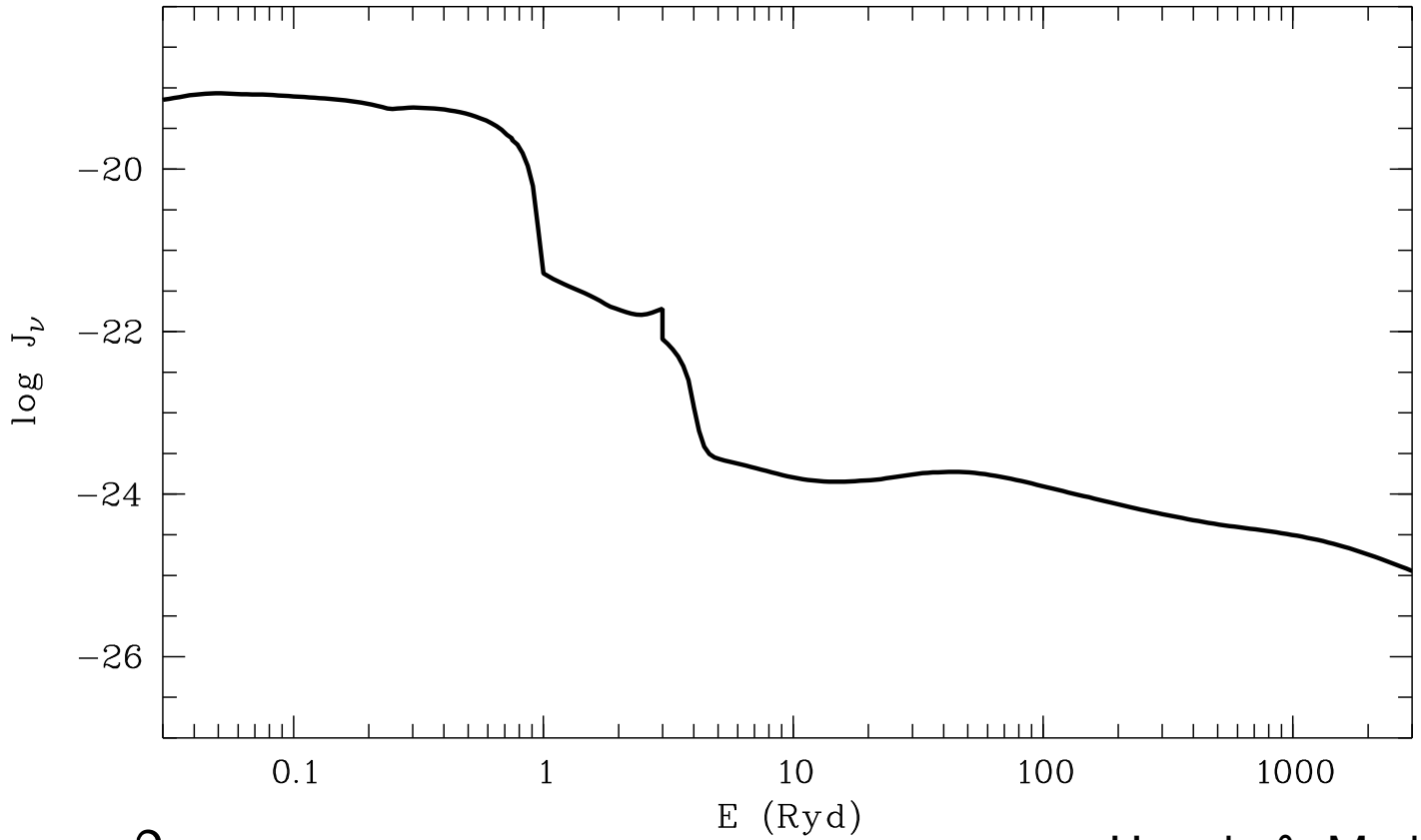


IGM is highly photoionized: $n_{\mathrm{H\,I}}/n_{\mathrm{H}} \sim 10^{-4}$

$\Rightarrow$ ionization corrections required (e.g. for metallicity estimates)

Spectral energy distribution

radiation of quasars and galaxies filtered while propagating through the IGM



$z \approx 2$

Haardt & Madau (2001)

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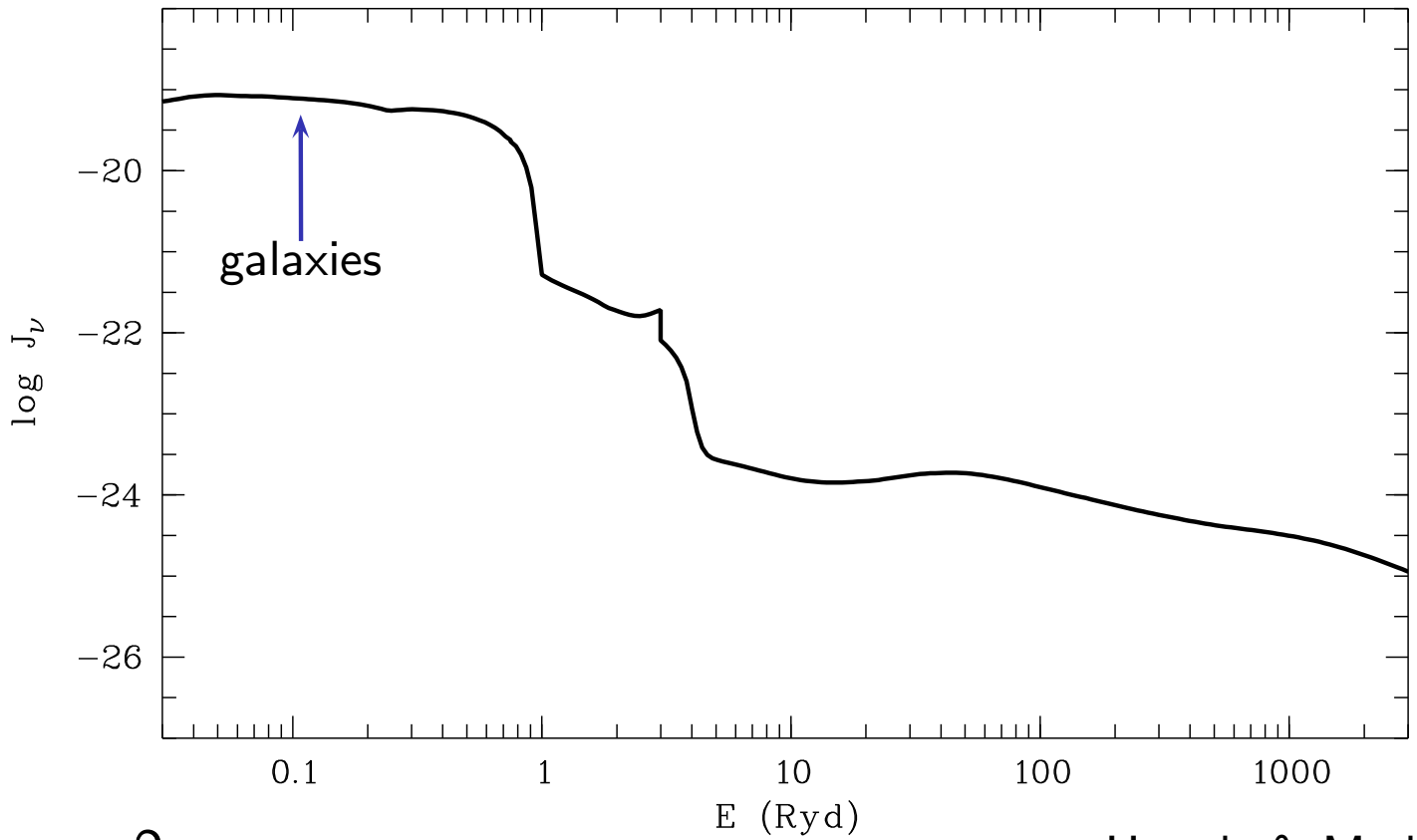

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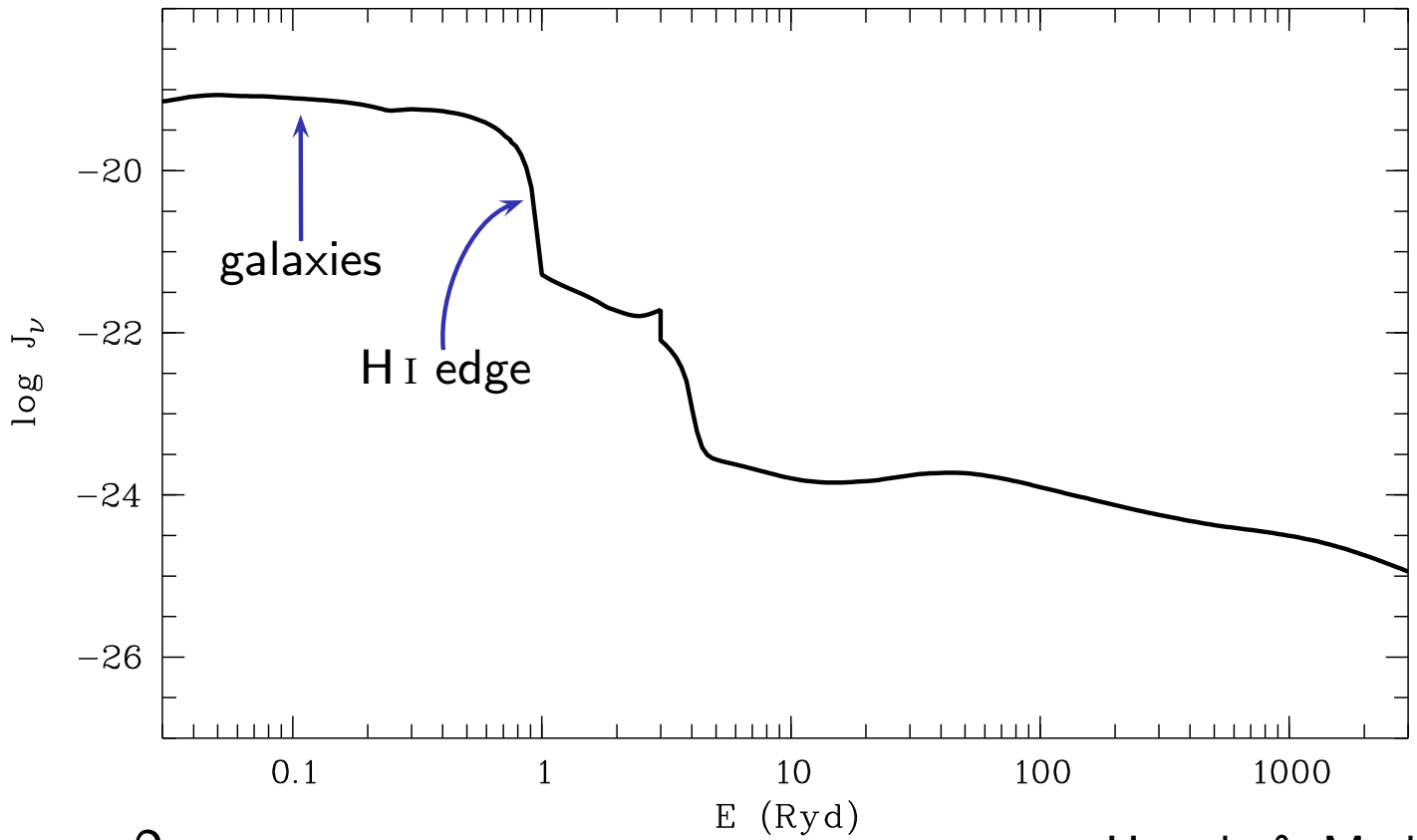

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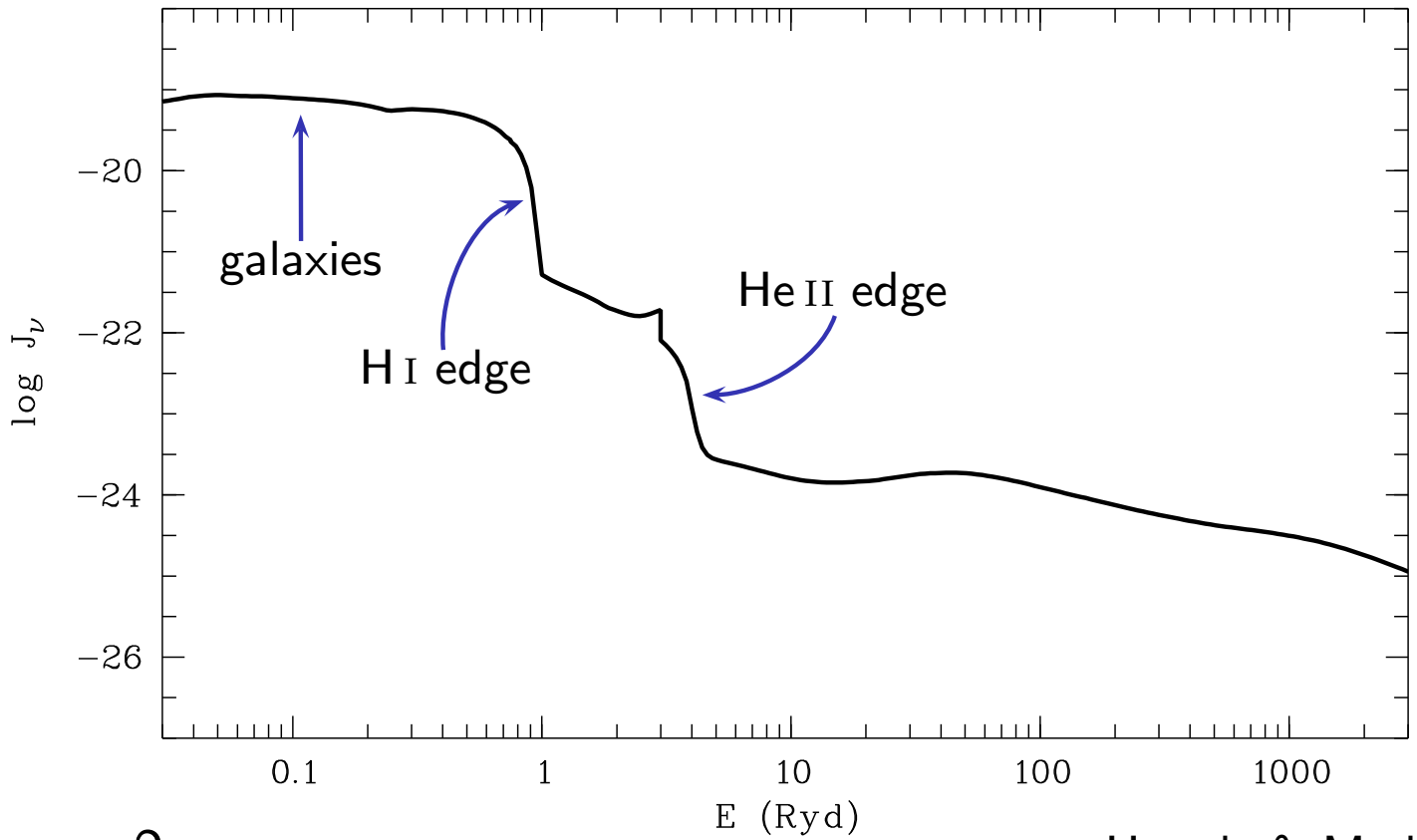

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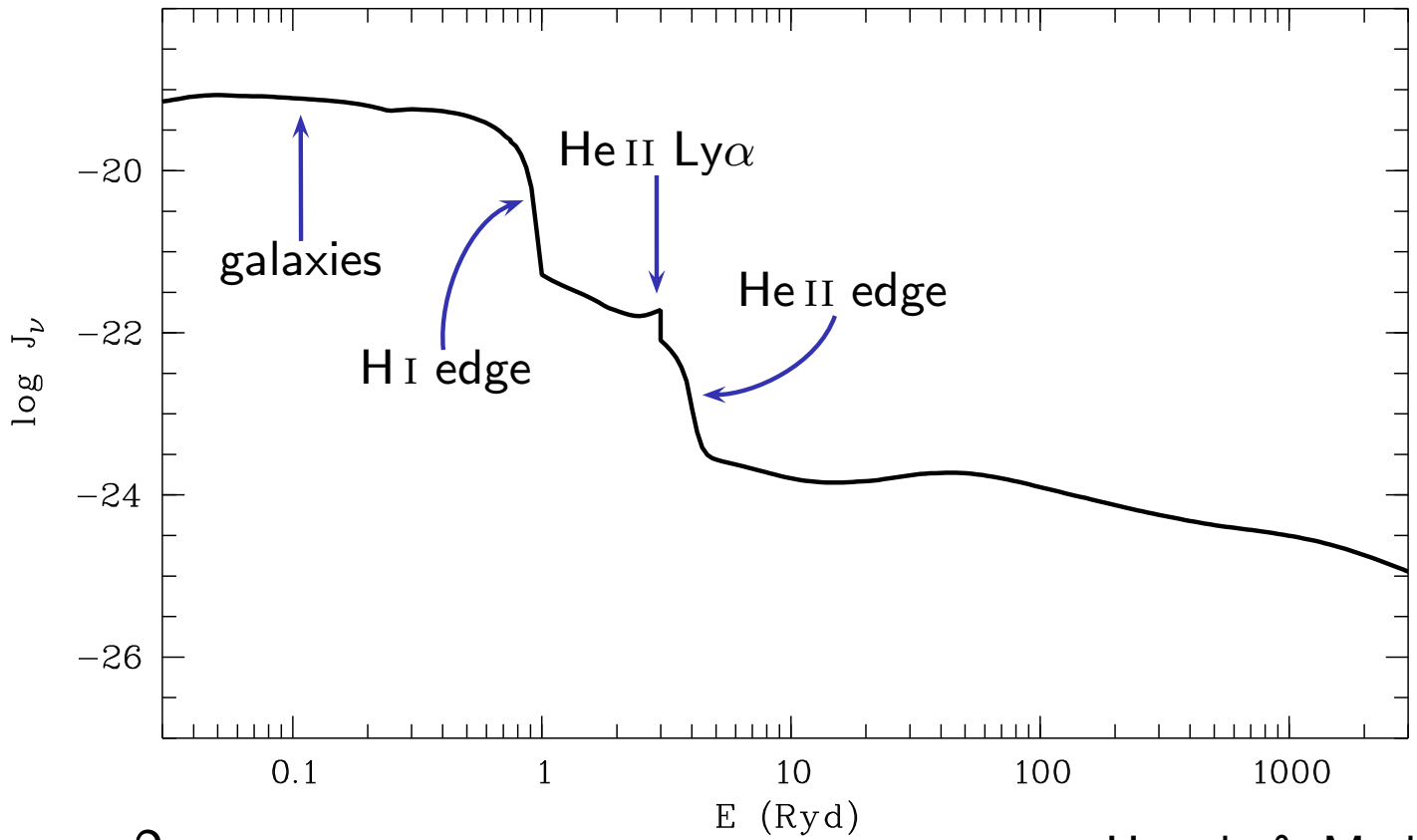

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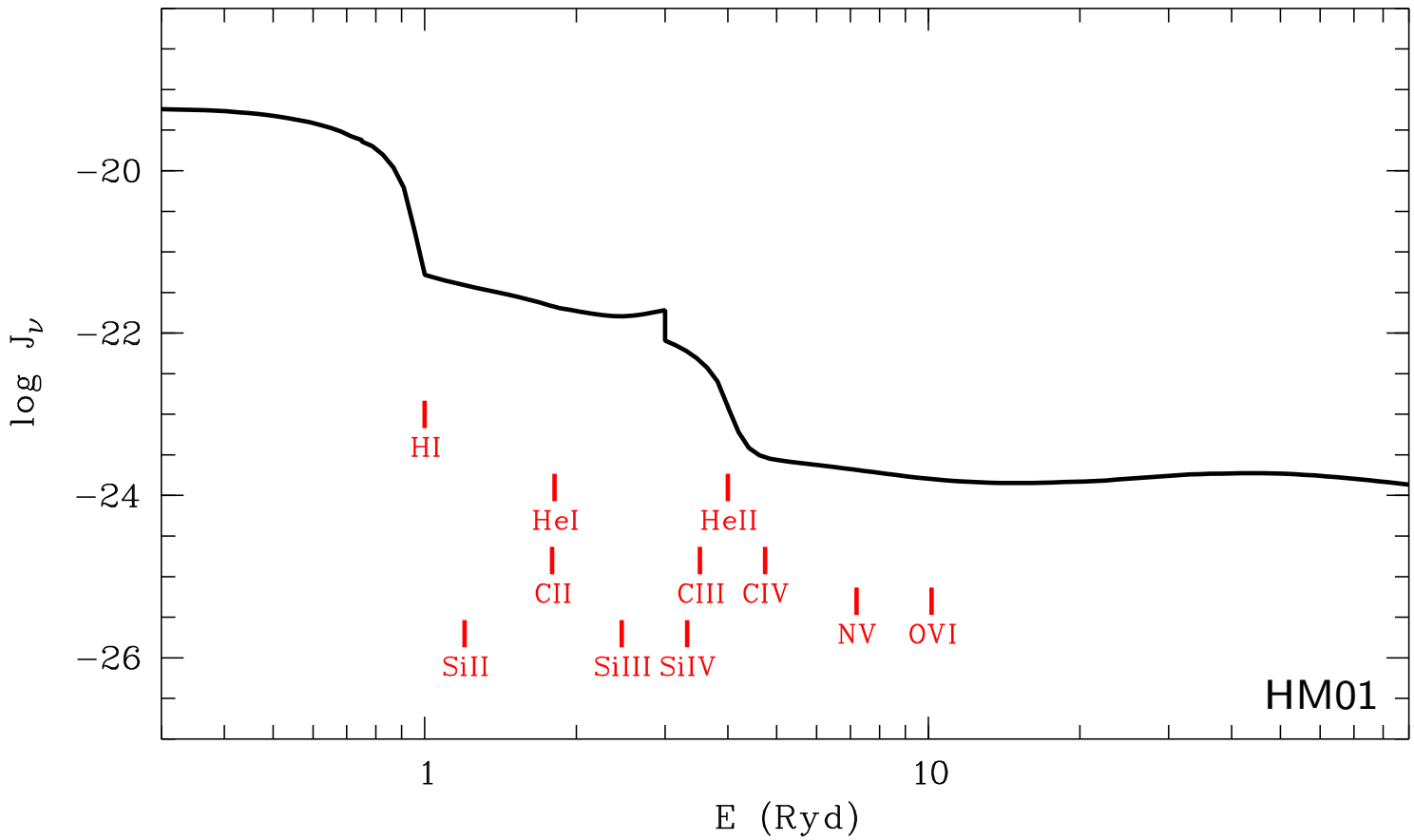
Metal line systems and the shape of the UV background



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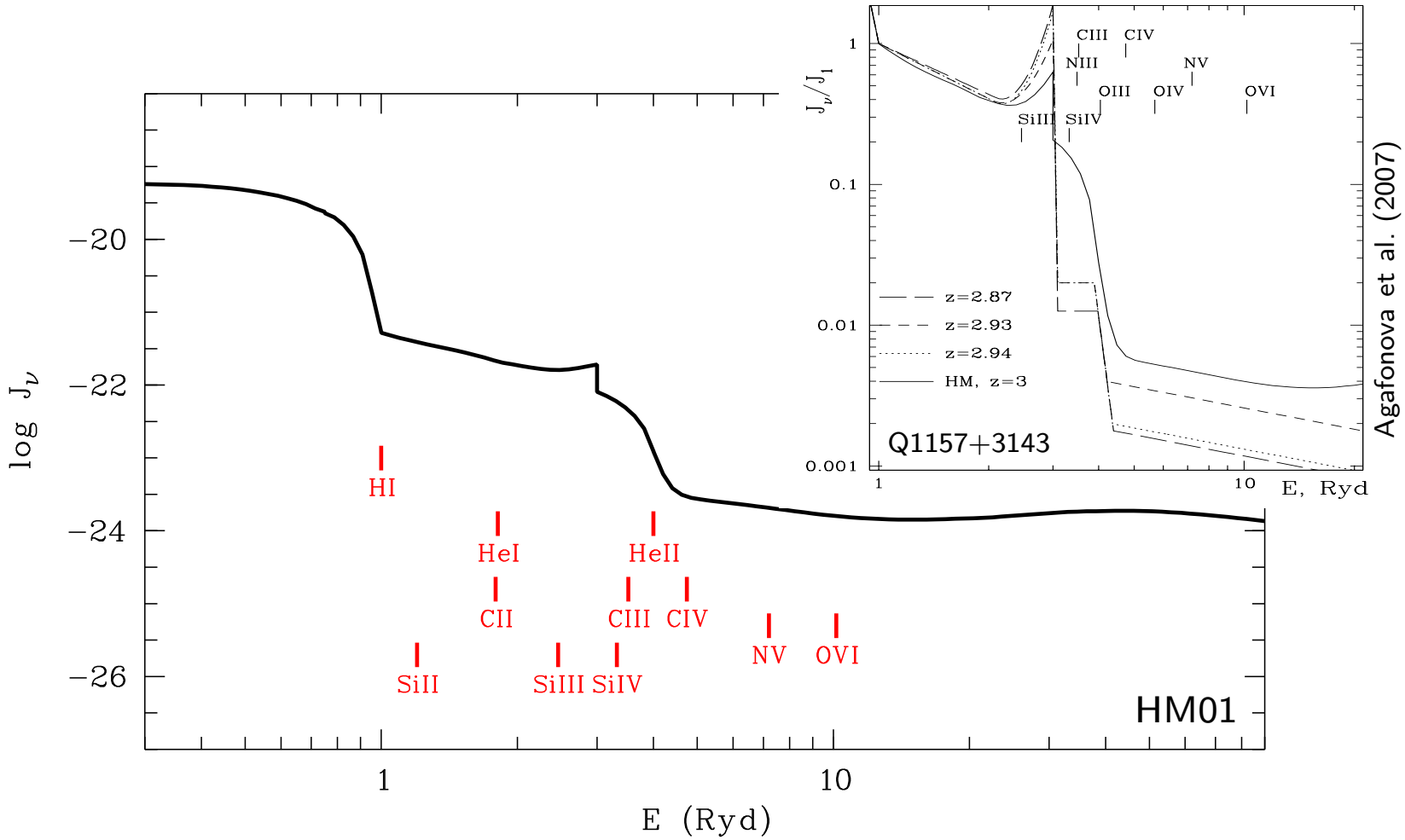

Deviations from HM01 are detected in several metal line systems!

Photoionization modeling of metal line systems

. . . with CLOUDY (Ferland et al. 1998)

- adopt spectral energy distribution of the UV background
- find ionization parameter (i.e. density) to match an observed column density ratio
- scale metallicity (and relative abundances) to match the observed column densities

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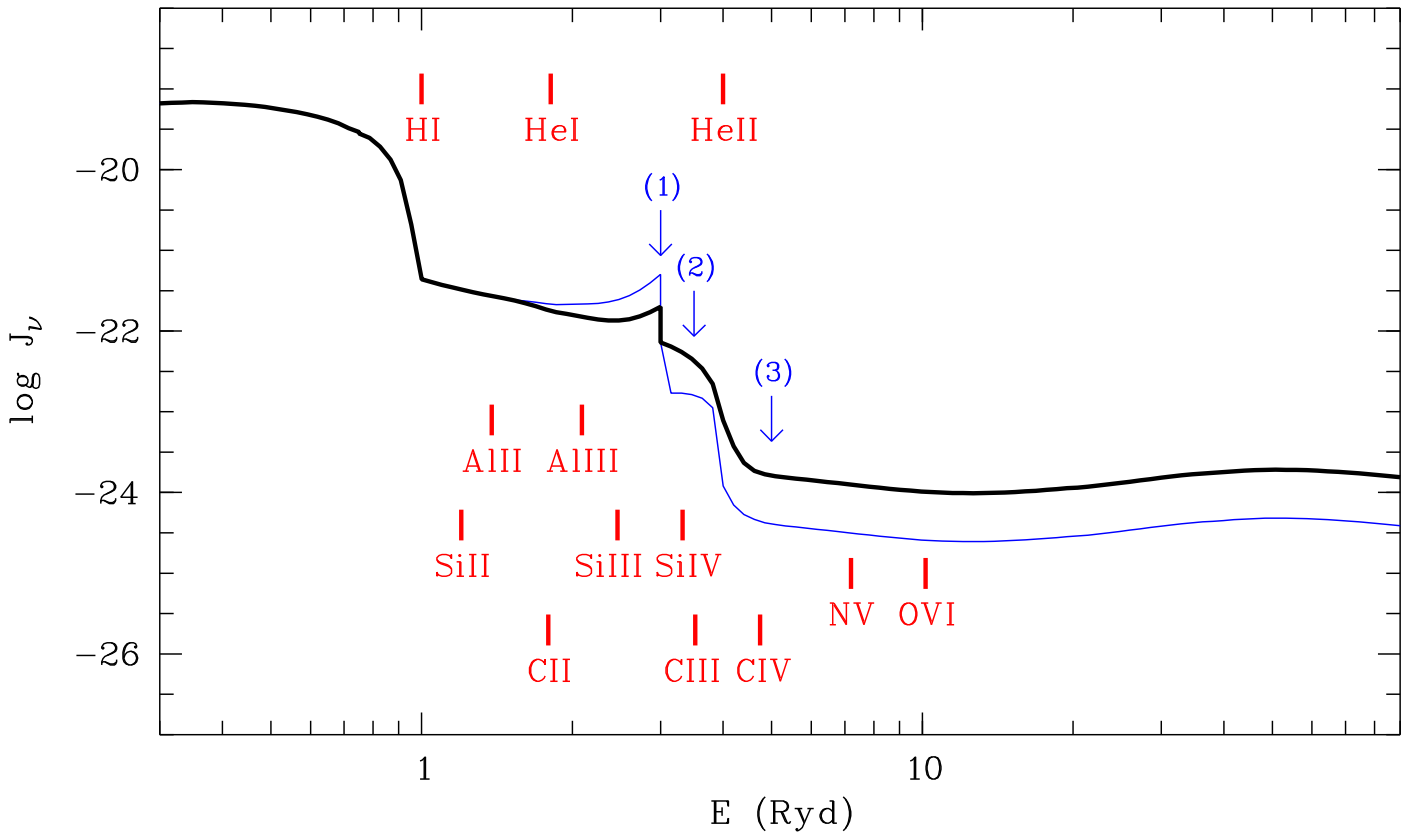
If two or more ratios are available, it is possible to . . .

- . . . estimate which spectral energy distribution is consistent with the data.
- . . . investigate the uncertainty of the model parameters with respect to the shape of the ionizing radiation.

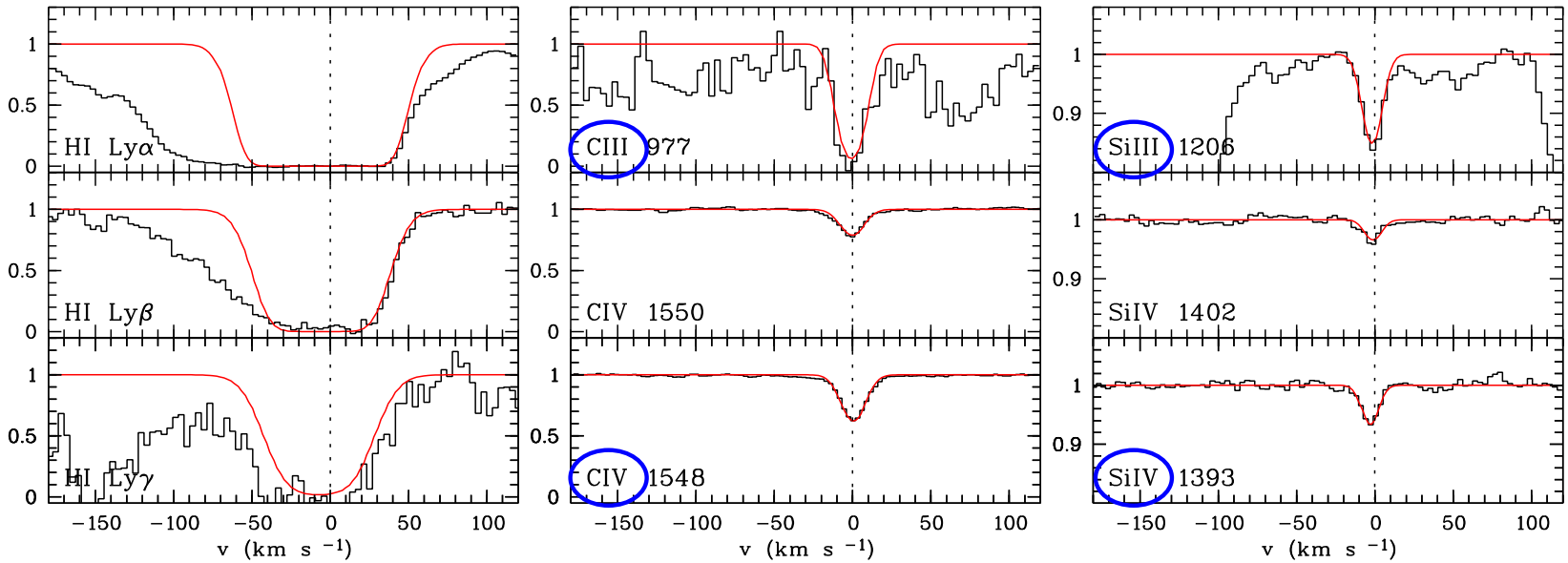
Variation of the UV background spectrum



change
- (1) height of 3 Ryd peak — $\Delta \log J(3\,\mathrm{Ryd})$
- (2) intensity between 3 and 4 Ryd — $\Delta \log J(3\text{-}4\,\mathrm{Ryd})$
- (3) strength of the 4 Ryd break — $\Delta \log J(4\,\mathrm{Ryd})$

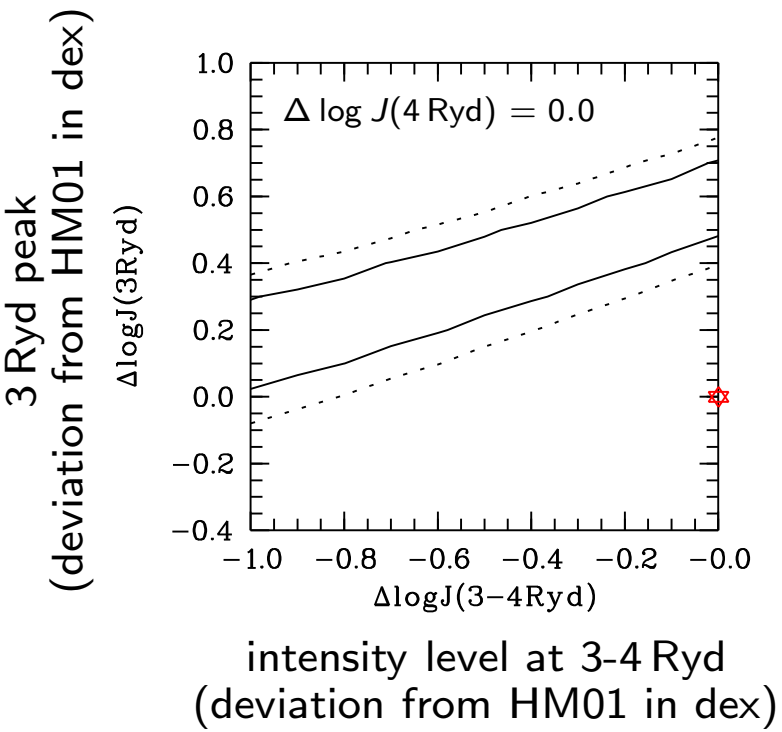
A system at $z \simeq 2.38$

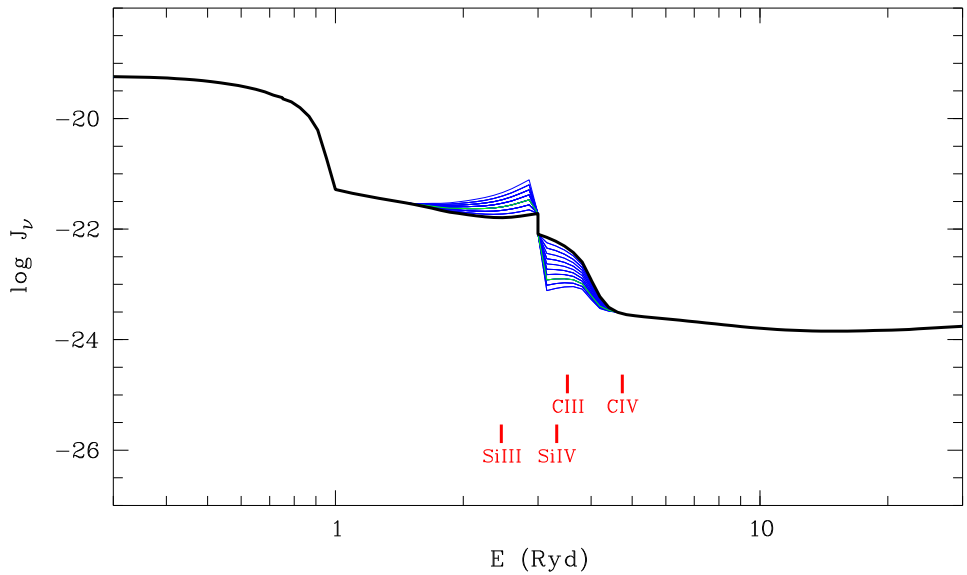
System at $z = 2.3799$ towards HS1700+6416 (Keck data)



single-component system
unblended features
C III/C IV and Si III/Si IV present

$z \simeq 2.38$: The ionizing spectrum at ~ 3 Ryd





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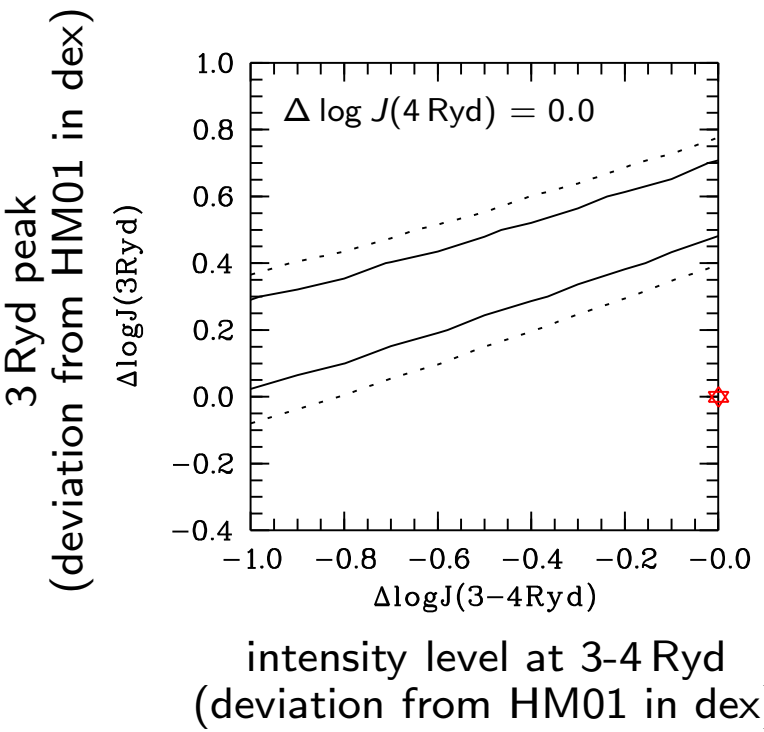
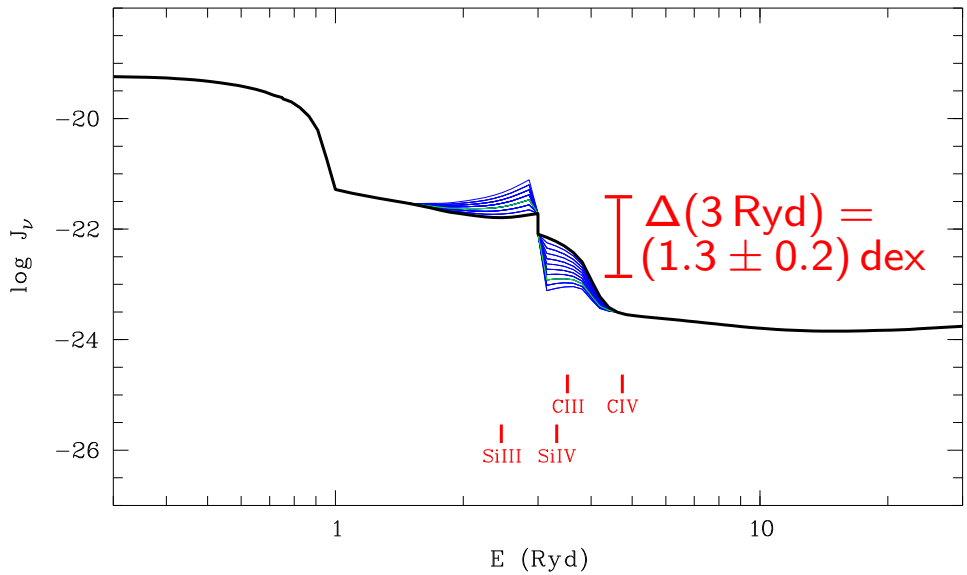
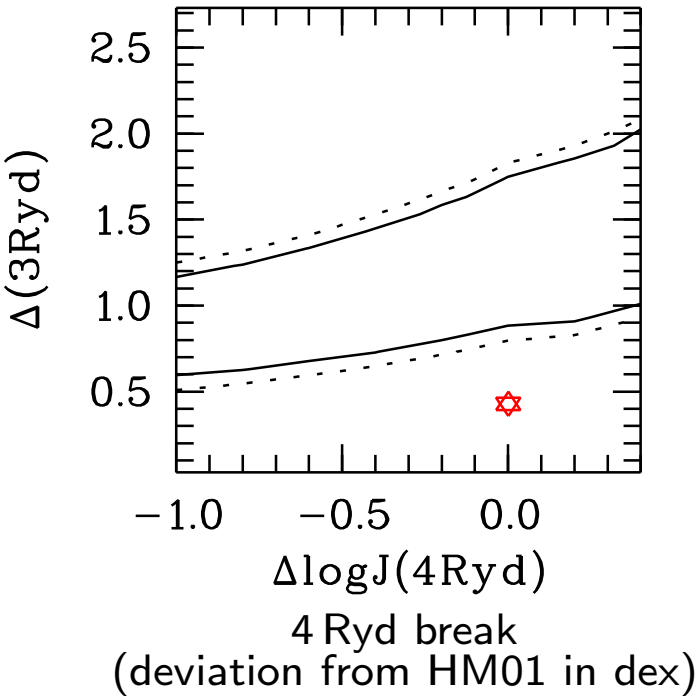




Si III/Si IV is sensitive to the spectrum near 3 Ryd.

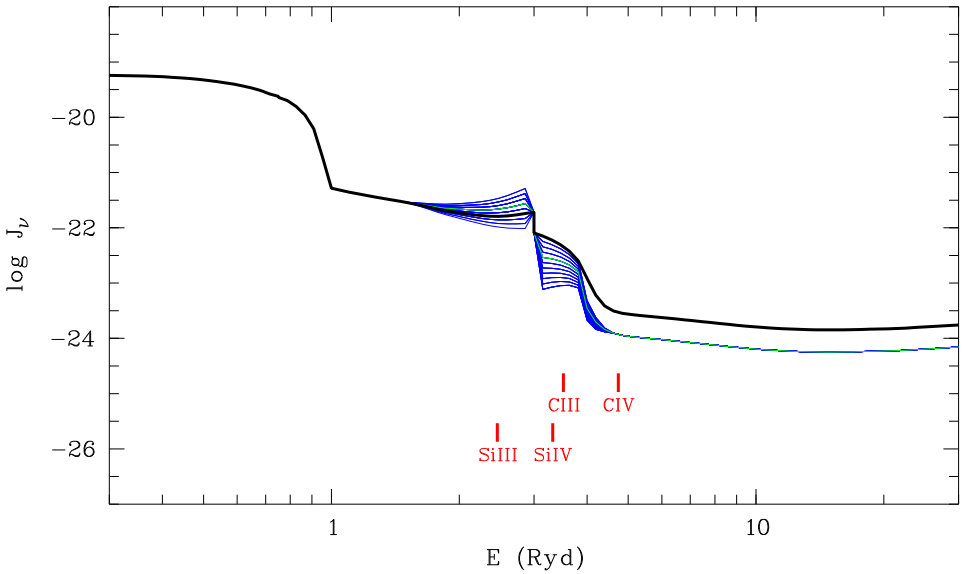
(see also Agafonova et al. 2007)

$z \simeq 2.38$: Best-fit ionizing spectral energy distributions



4 Ryd break
(deviation from HM01 in dex)

example $\Delta \log J(4\,\mathrm{Ryd}) = -0.4$:



$$\Delta(3\,\mathrm{Ryd}) = \log(J(3.0\,\mathrm{Ryd})/J(3.1\,\mathrm{Ryd}))$$

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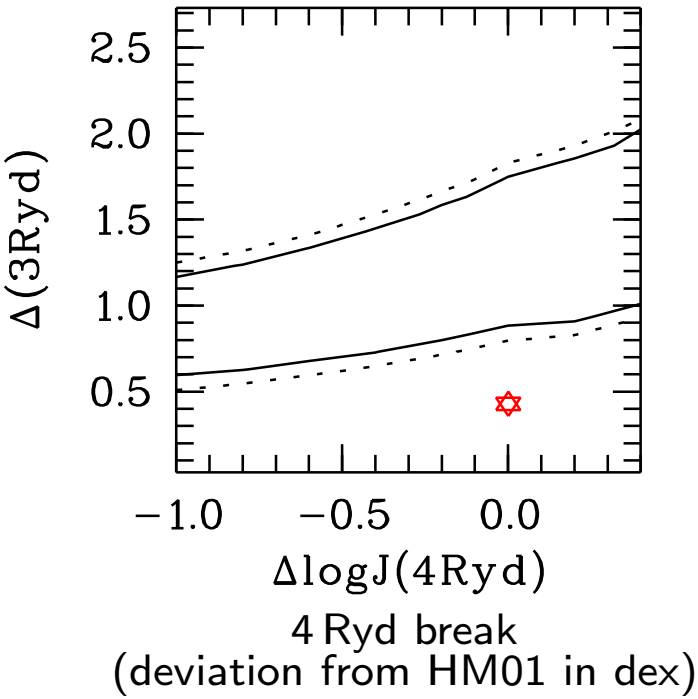

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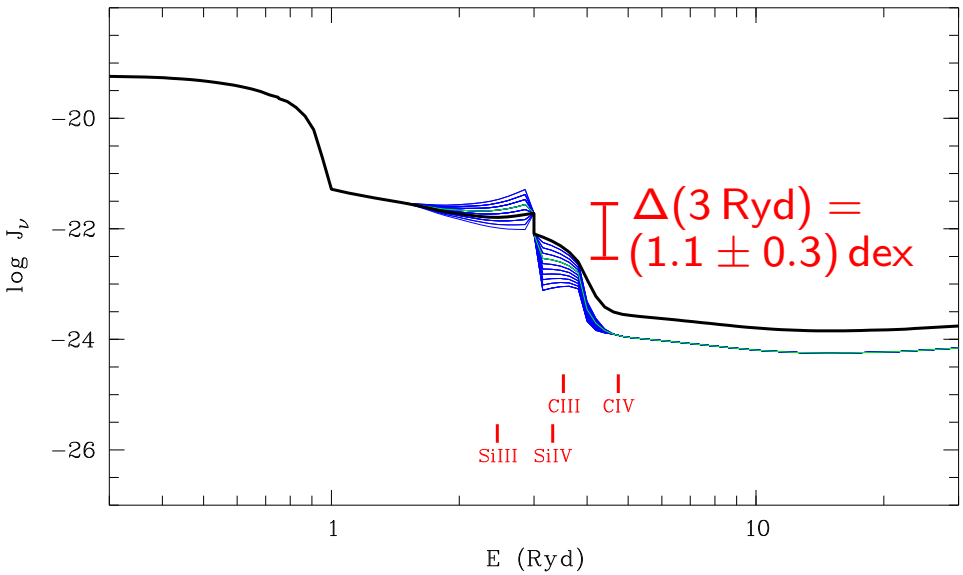
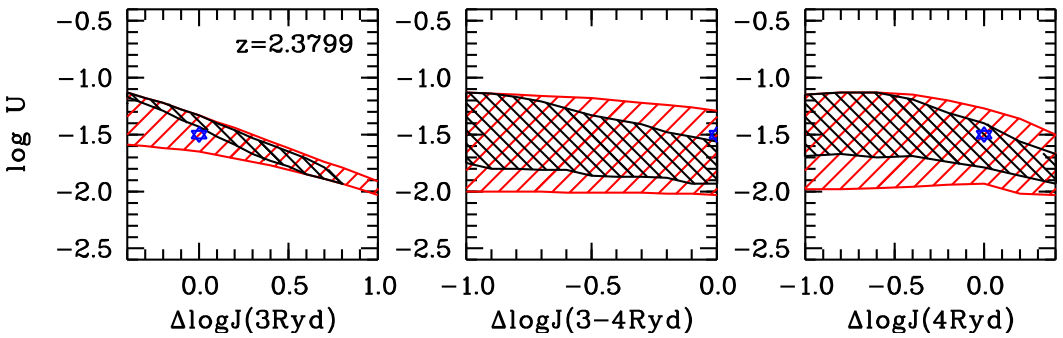


Results degenerated!

$\Delta(3\,\mathrm{Ryd}) = \log(J(3.0\,\mathrm{Ryd})/J(3.1\,\mathrm{Ryd}))$

$z \simeq 2.38$: Physical quantities and the ionizing spectrum

estimates for $1\,\sigma$ confidence-/all tested spectra:



ionization parameter:

$$\log U = -1.52 \pm^{0.39}_{0.41}$$

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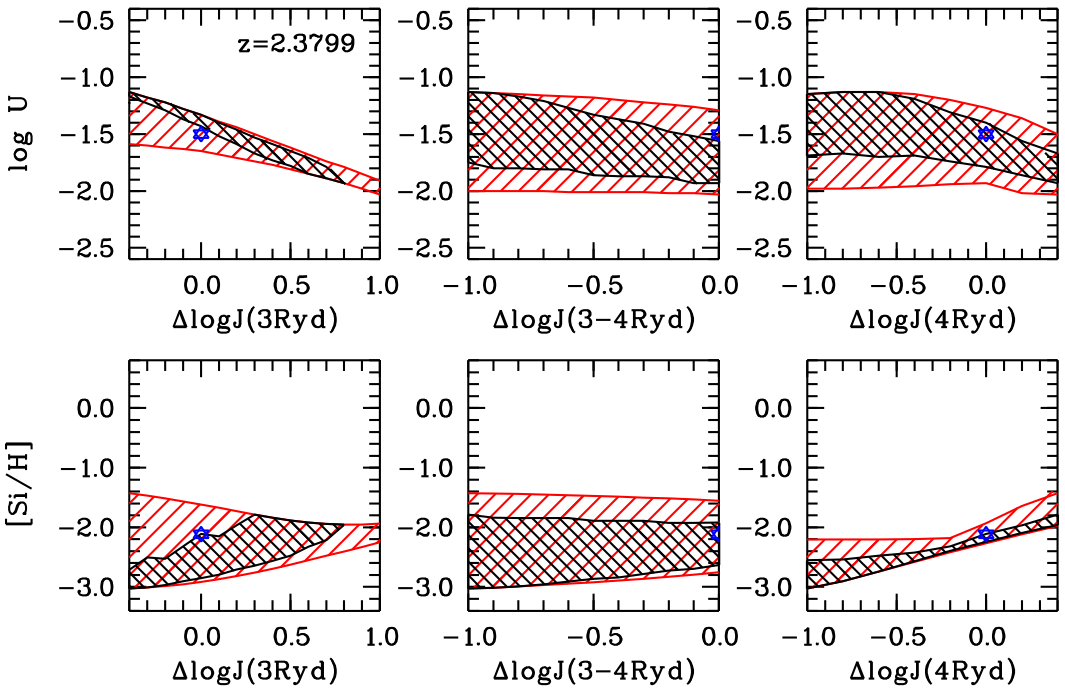

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$$[\mathrm{Si/H}] = -2.41 \pm^{0.63}_{0.61}$$

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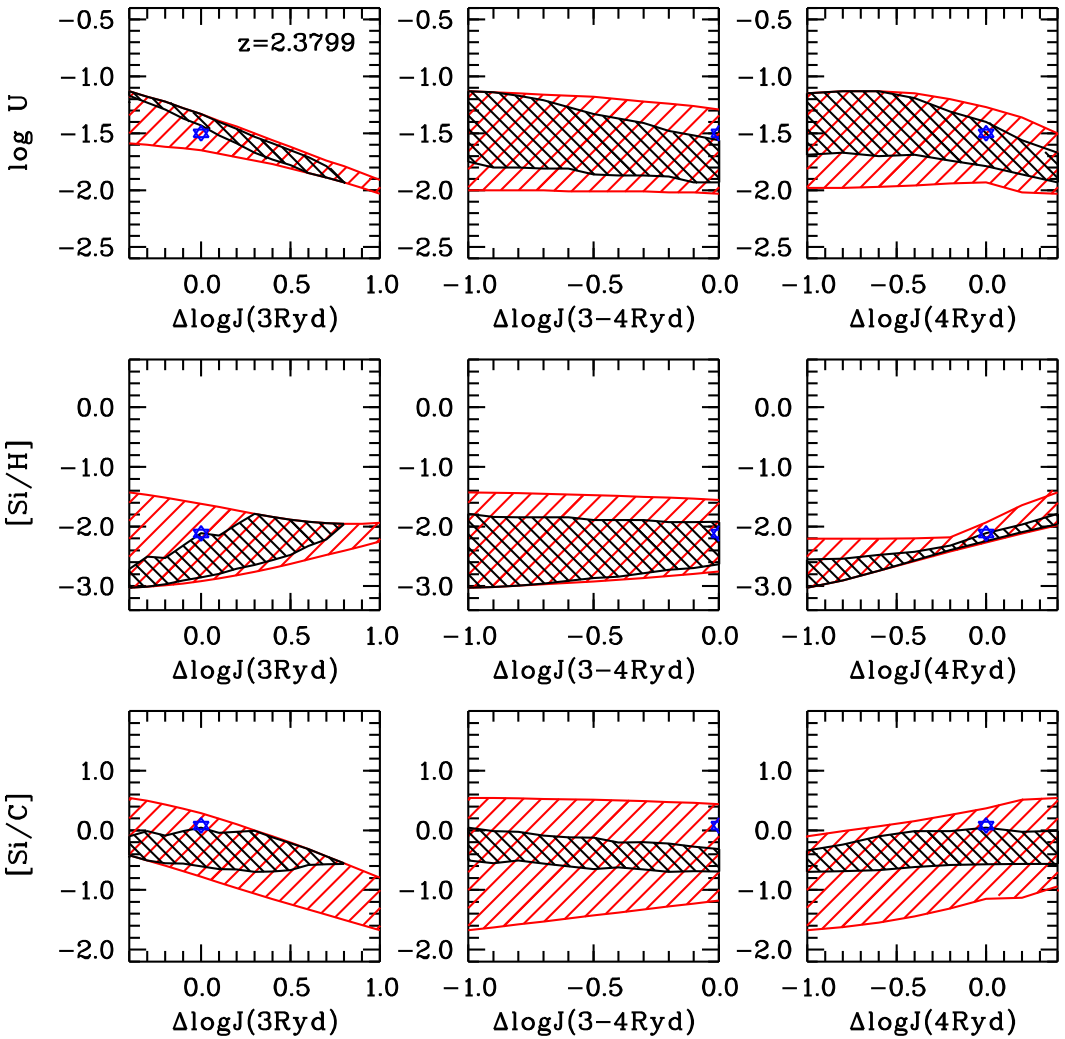

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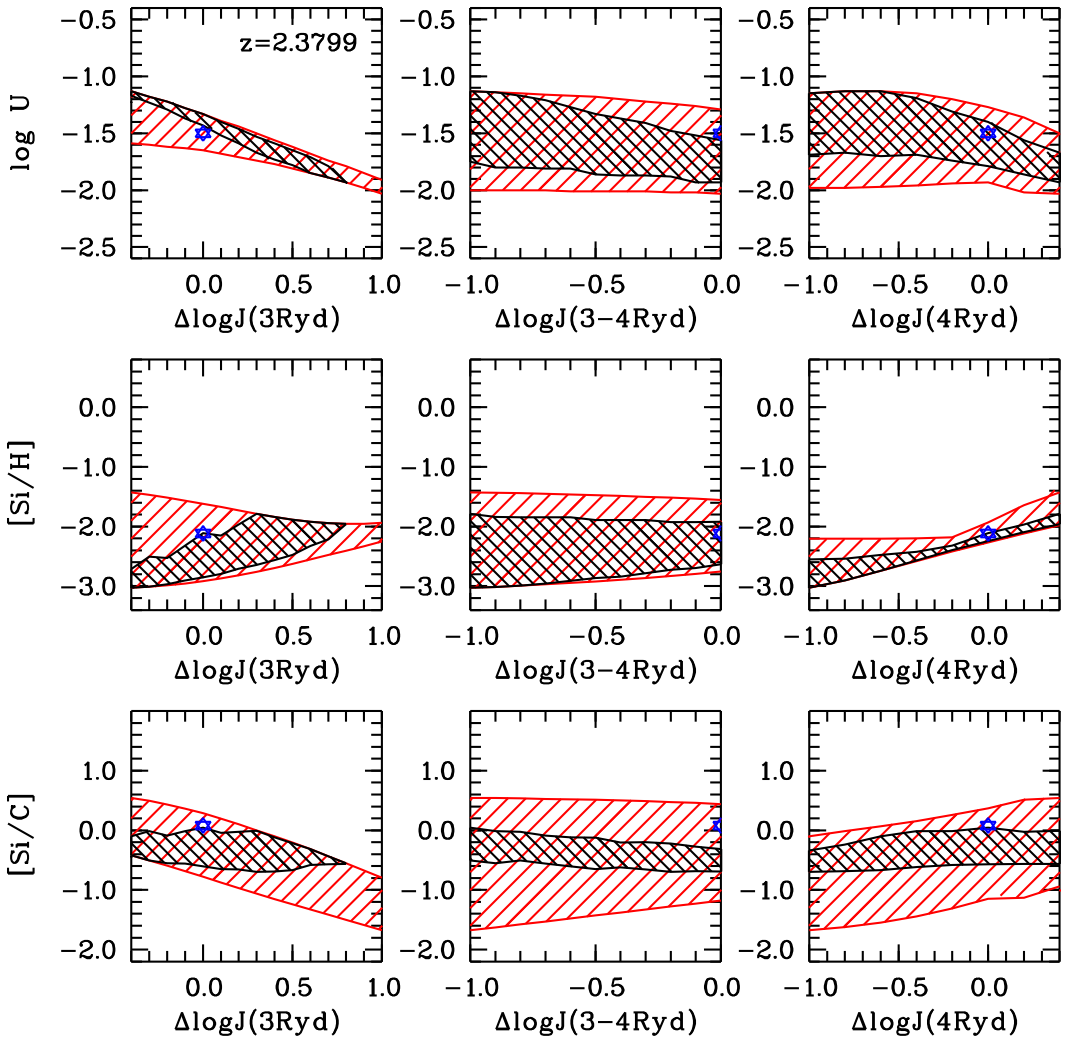

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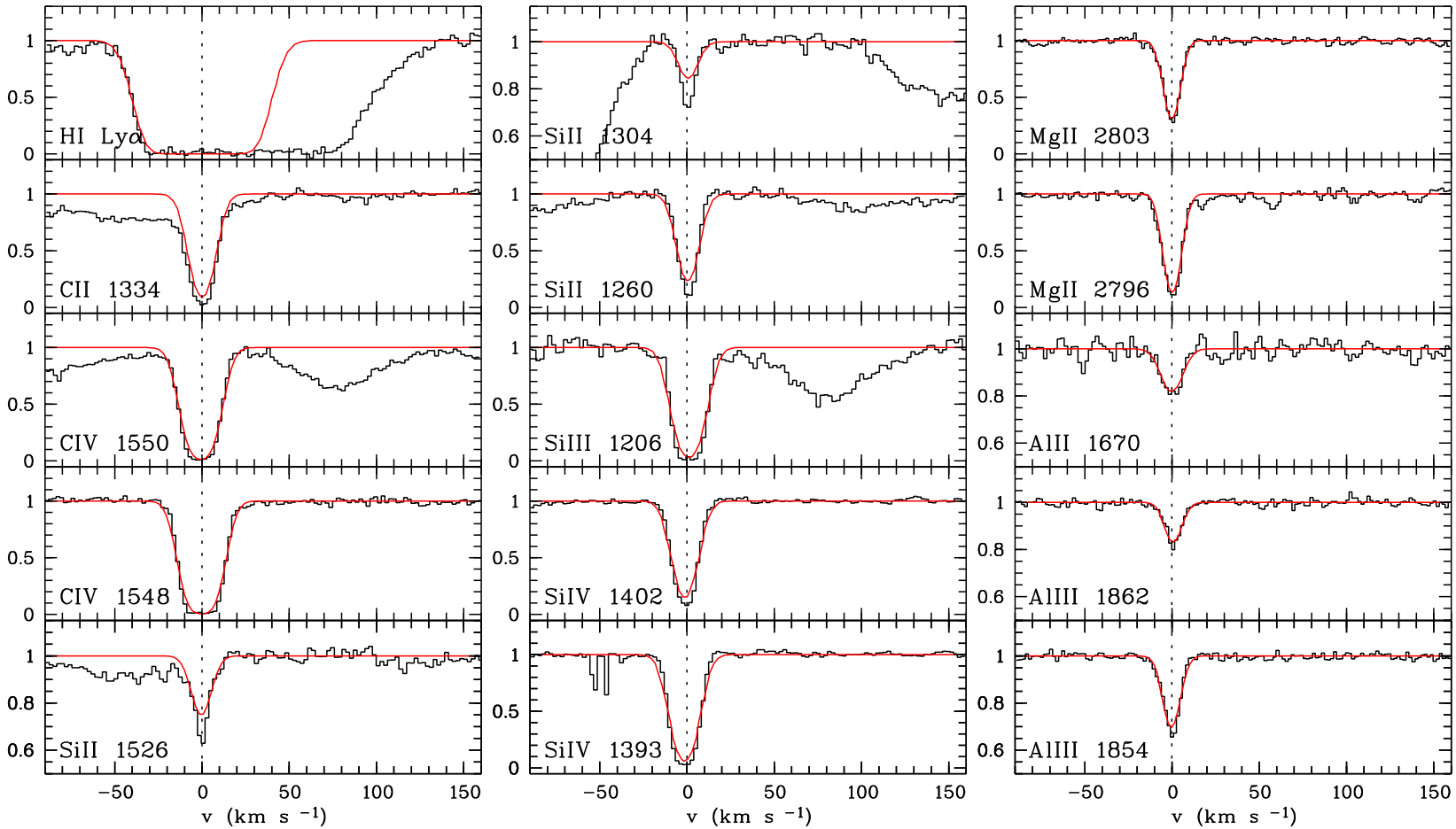
values spread over ~ 1 dex !

A system at $z \simeq 1.75$

System at $z = 1.7529$ towards HE1347-2457 (UVES data)



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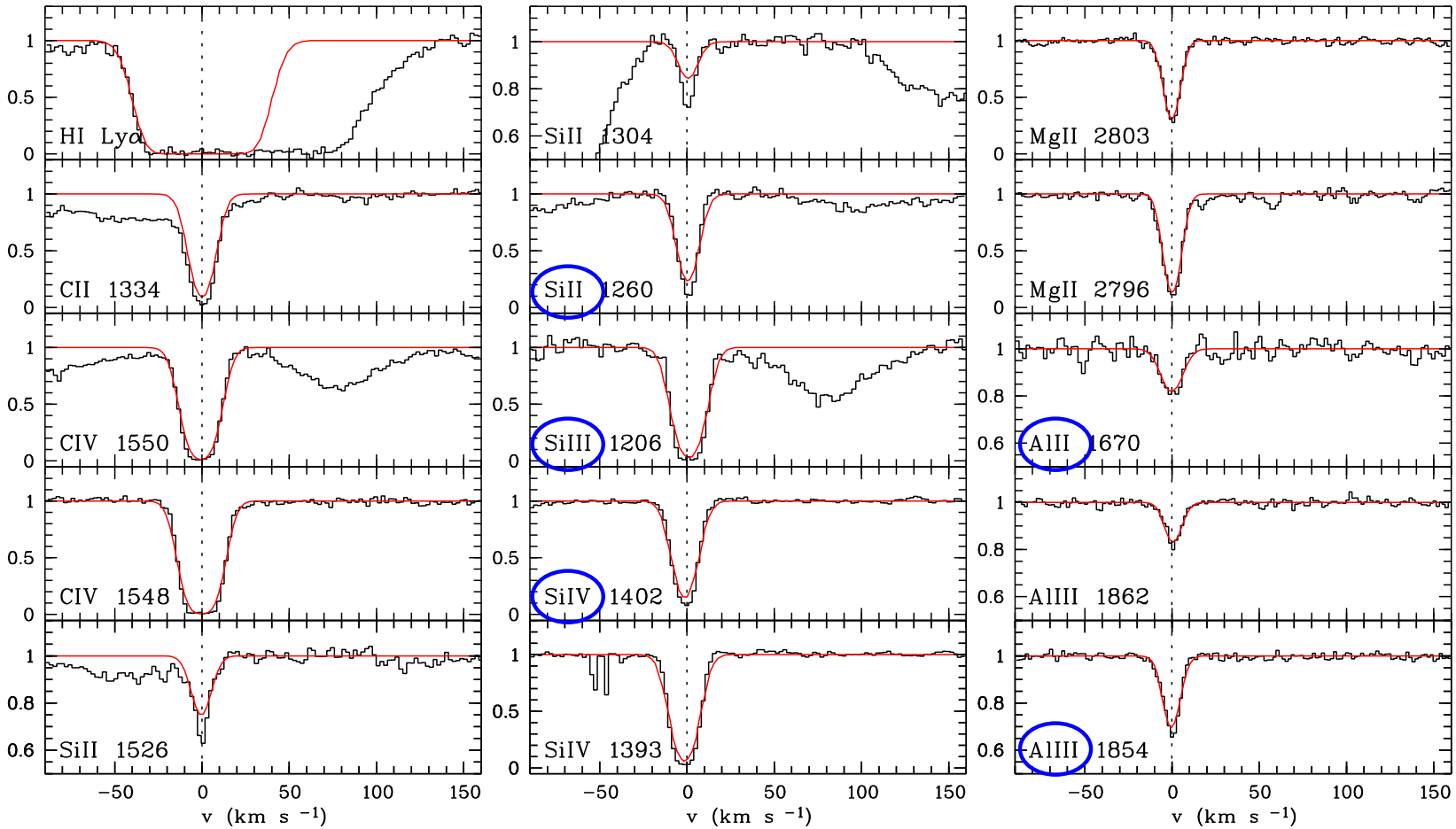
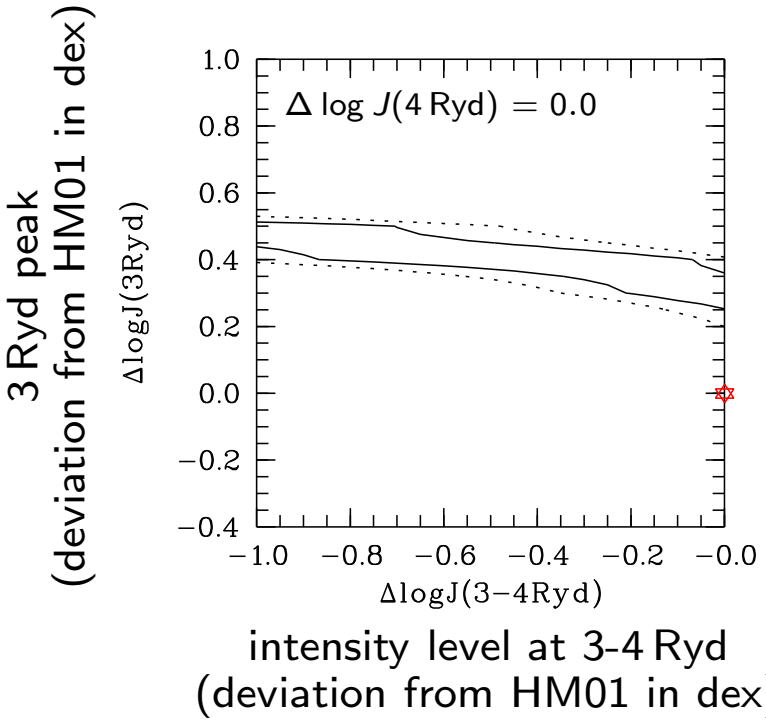
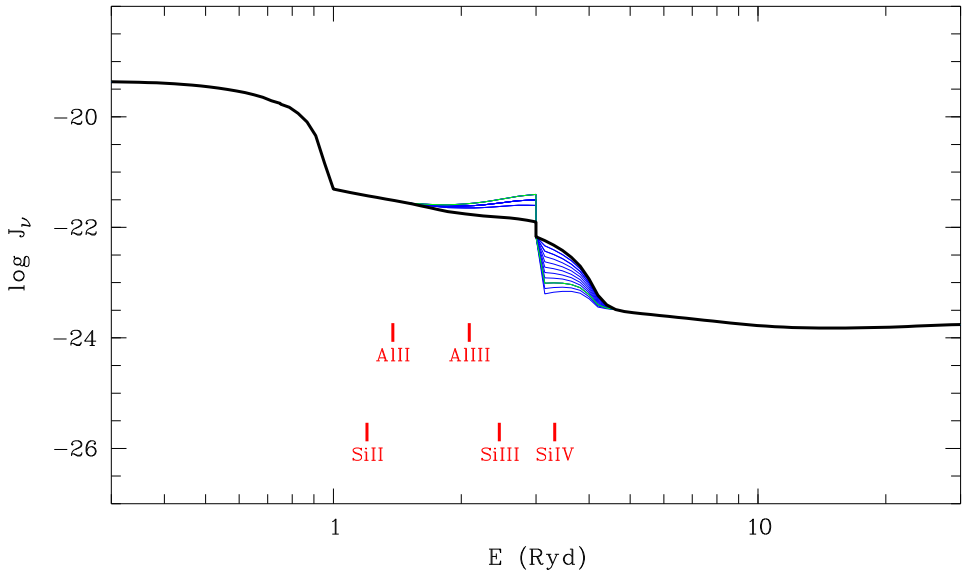


$z \simeq 1.75$: The ionizing spectrum at ~ 3 Ryd





well-constrained 3 Ryd peak
ionization potentials of considered species $\lesssim 3$ Ryd

$z \simeq 1.75$: Constraints on physical quantities

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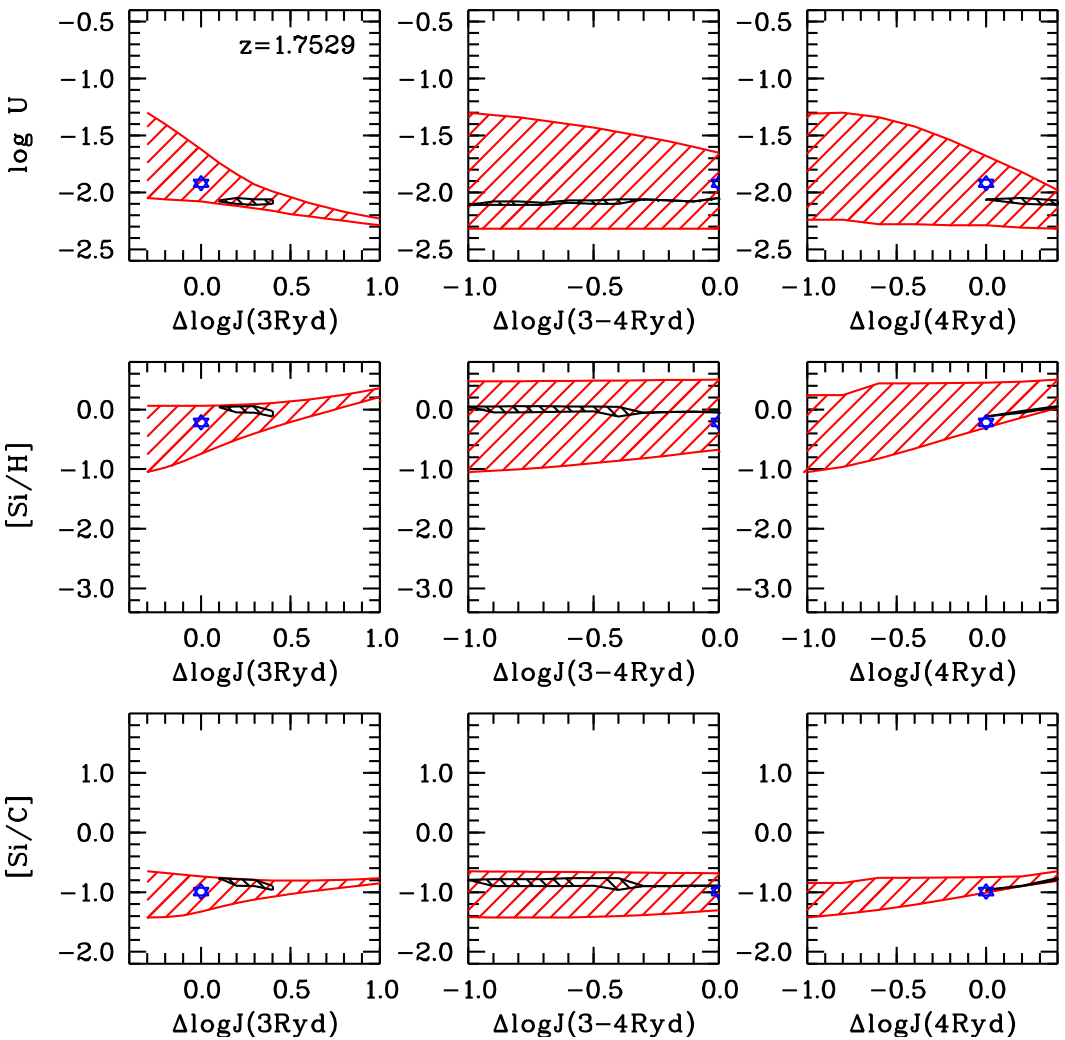

ionization parameter:

$$\log U = -2.09 \pm^{0.04}_{0.03}$$

metallicity:

$$[\mathrm{Si/H}] = 0.00 \pm^{0.05}_{0.12}$$

relative abundances:

$$[\mathrm{Si/C}] = -0.84 \pm^{0.08}_{0.12}$$

Summary and Outlook

promising approach to constrain the UV background spectrum with metal absorption systems

- select appropriate metal line systems

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  - the Si III/Si IV ratio depends on the spectrum at ~ 3 Ryd ($\rightarrow$ He II Lyα re-emission)
  - UV background appears to be rather hard at redshift $z < 2$
    (consistent with Agafonova et al. 2007 and Fechner at al. 2006)
  - derived physical parameters depend on the details of the ionizing spectrum
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  - derived physical parameters depend on the details of the ionizing spectrum (~ 3 Ryd $\rightarrow$ ionization parameter, hardness $\rightarrow$ metallicity)
- future work:
  - study more systems at various redshifts
  - include physics into the parameterization of the background spectrum