Broad absorption lines in DESI Y1 QSO spectra

Luz Ángela García

Universidad ECCI

DARK ENERGY SPECTROSCOPIC INSTRUMENT

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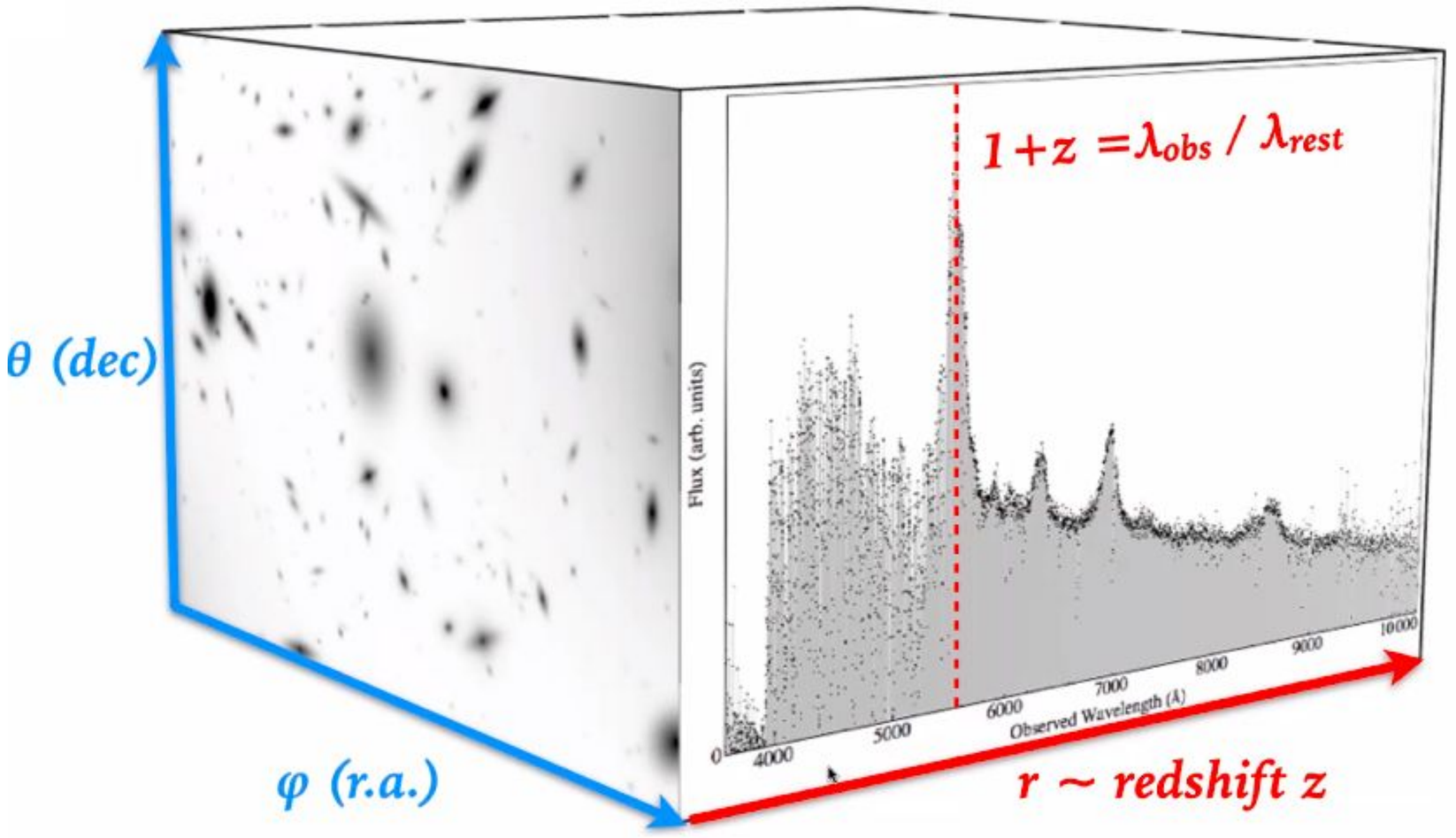
Work in collaboration with Paul Martini, Alma X. González, Andreu Font-Rivera, Hiram Herrera -DESI collaboration-

Cosmology from Home 2023



The optical sky is a data cube: $\theta \times \varphi \times r$

Credit: David Kirkby

DESI

~ 14000 deg^2

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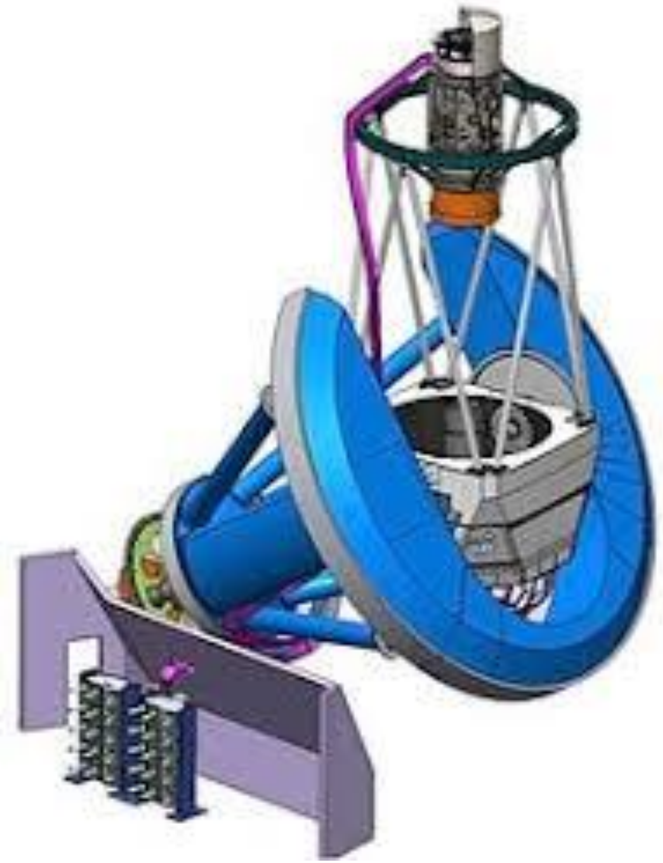

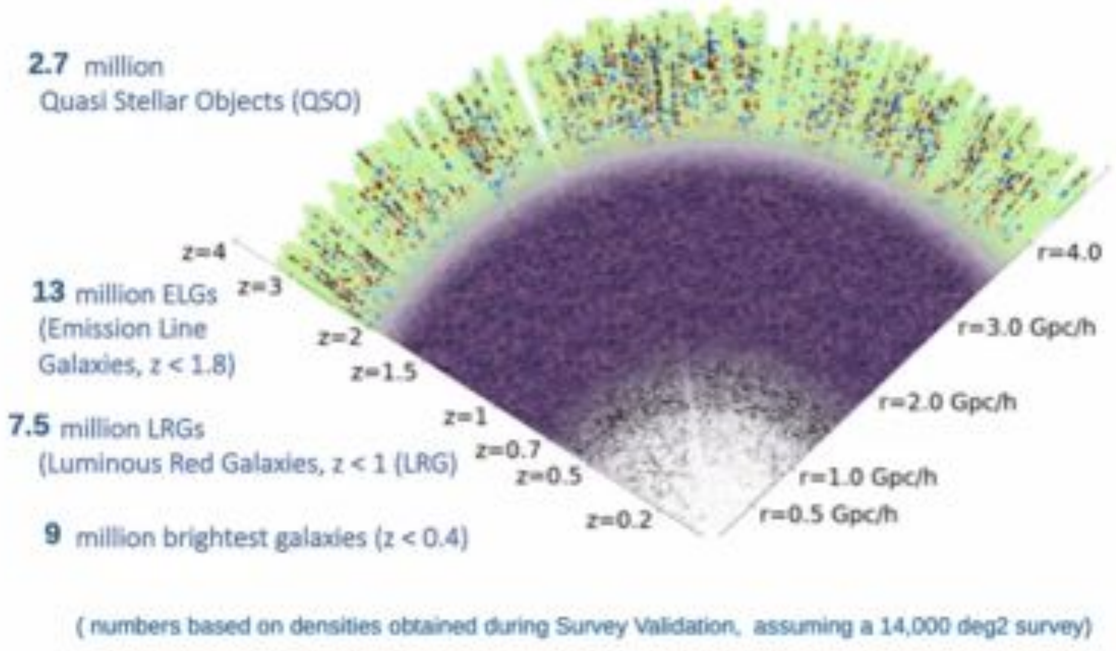

(numbers based on densities obtained during Survey Validation, assuming a 14,000 deg2 survey)

~ 3.2 deg

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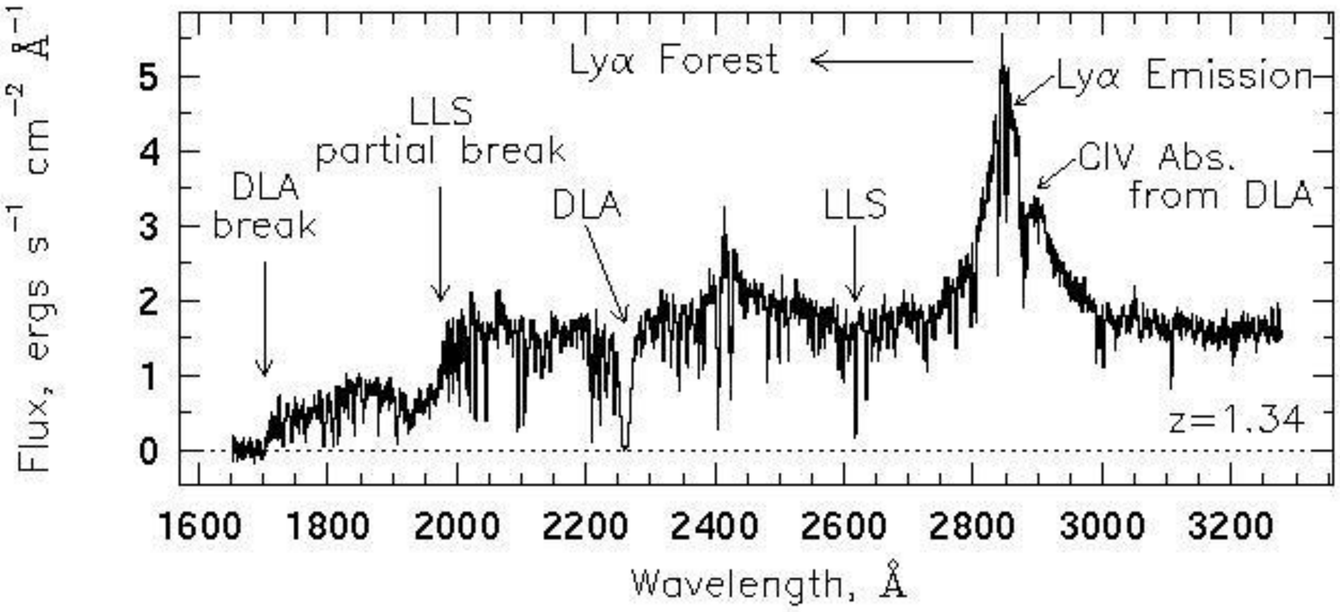
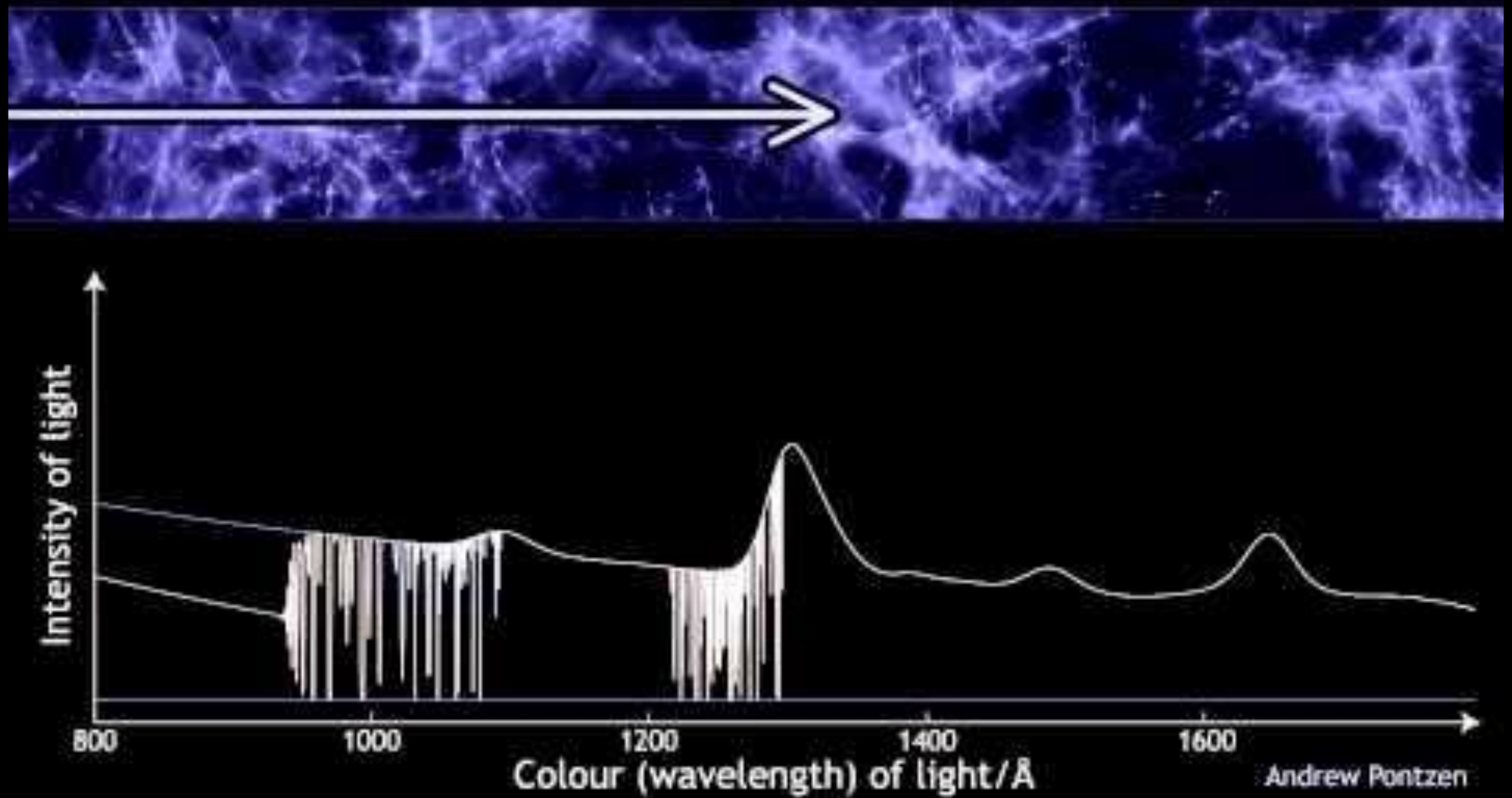
Quasar Spectra



https://ned.ipac.caltech.edu/level5/Charlton/Charlton1_1.html

Situado a sólo 690 millones de años después del Big Bang, este cuásar (conocido técnicamente como ULAS J134208.10+092838.61) tiene 800 millones de masas solares

Crédito: Robin Dienel / Carnegie Institution for Science.


Intensity of light
800
1000
1200
1400
1600
Colour (wavelength) of light/Å
Andrew Pontzen

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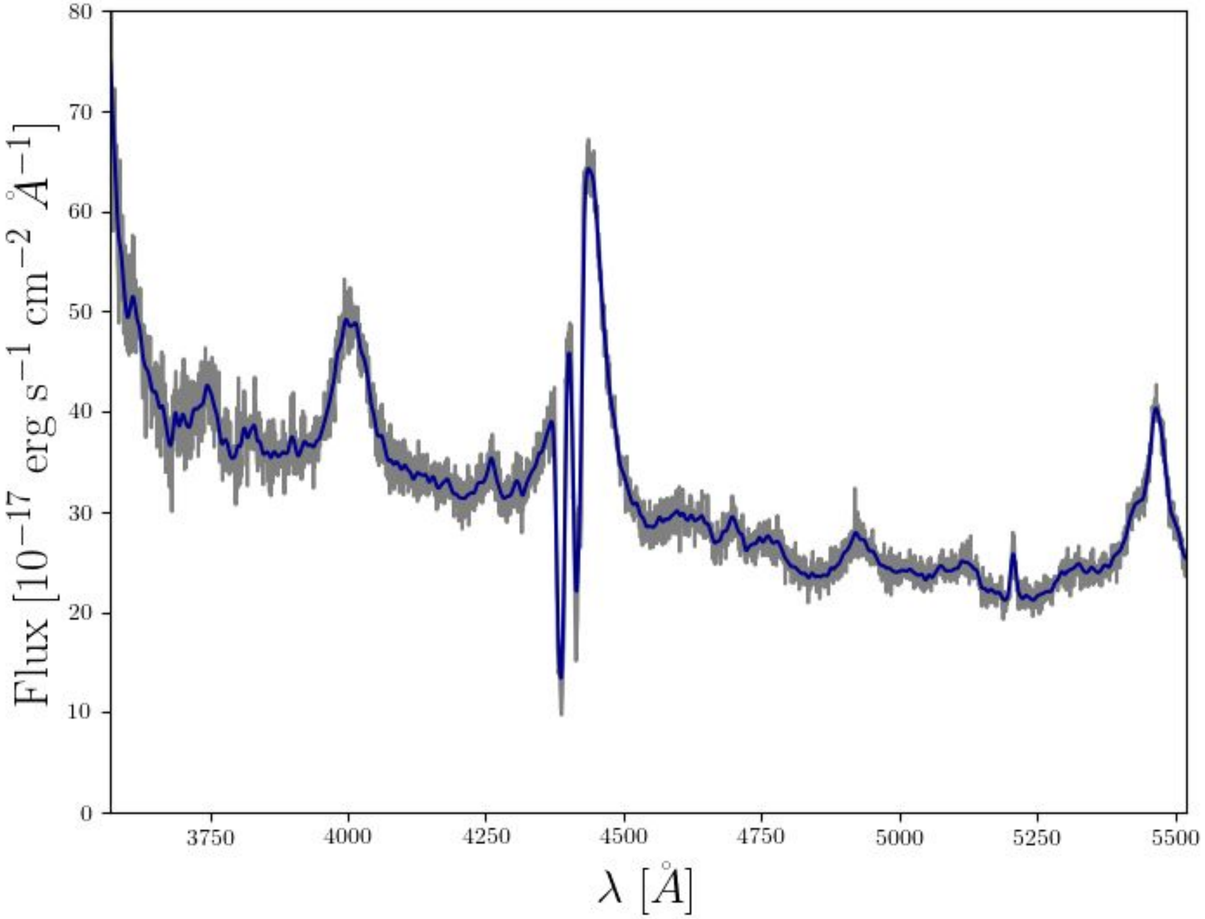
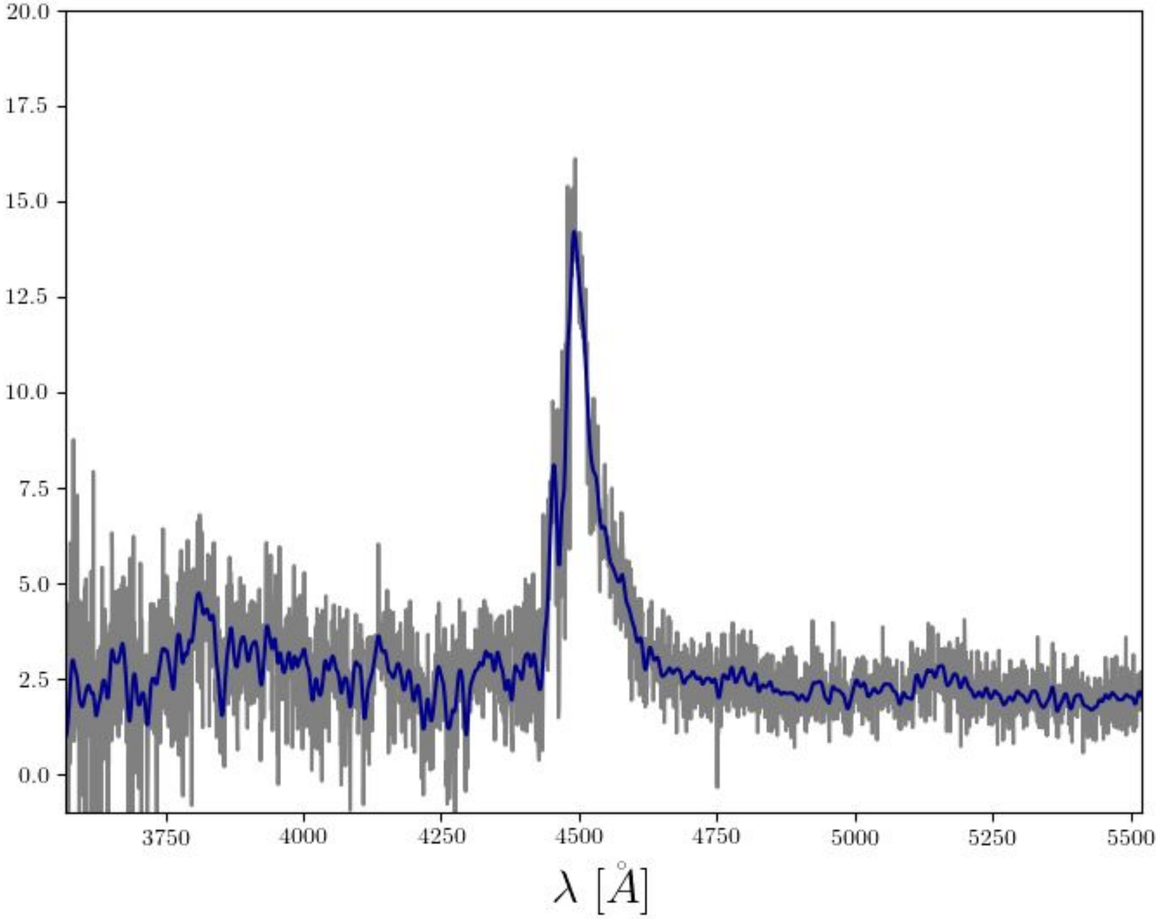
Synthetic spectra of quasars





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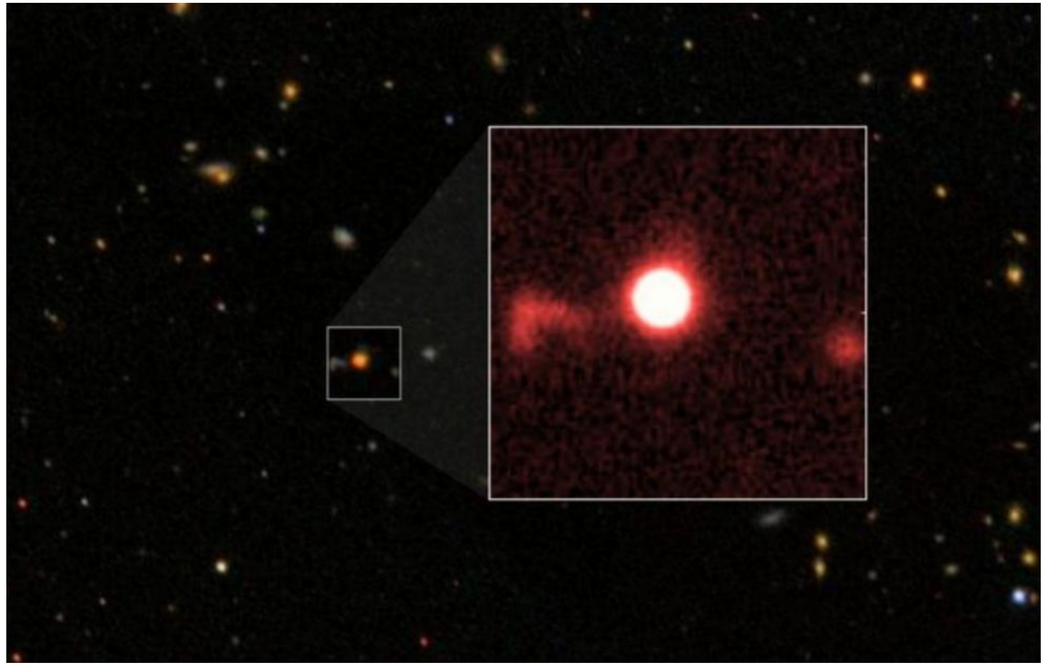
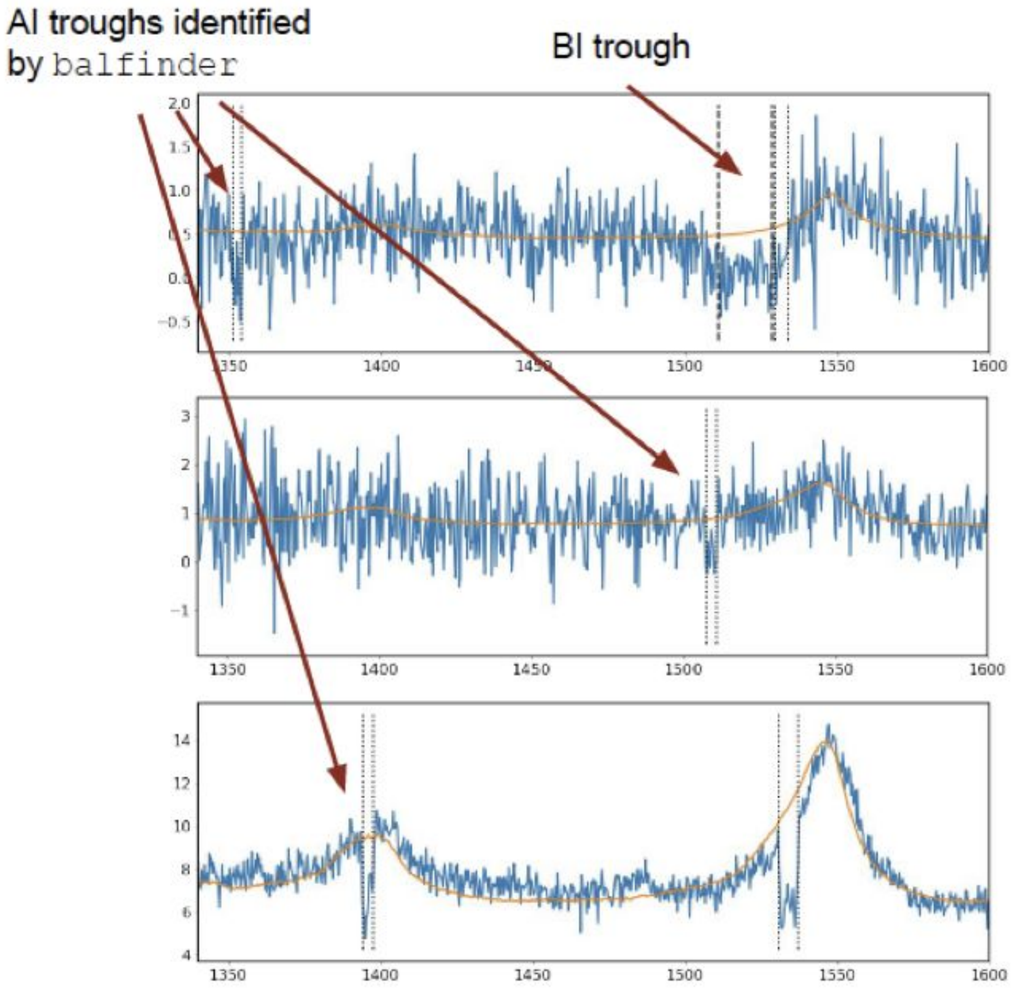
What are BAL?





Credit: Paul Martini

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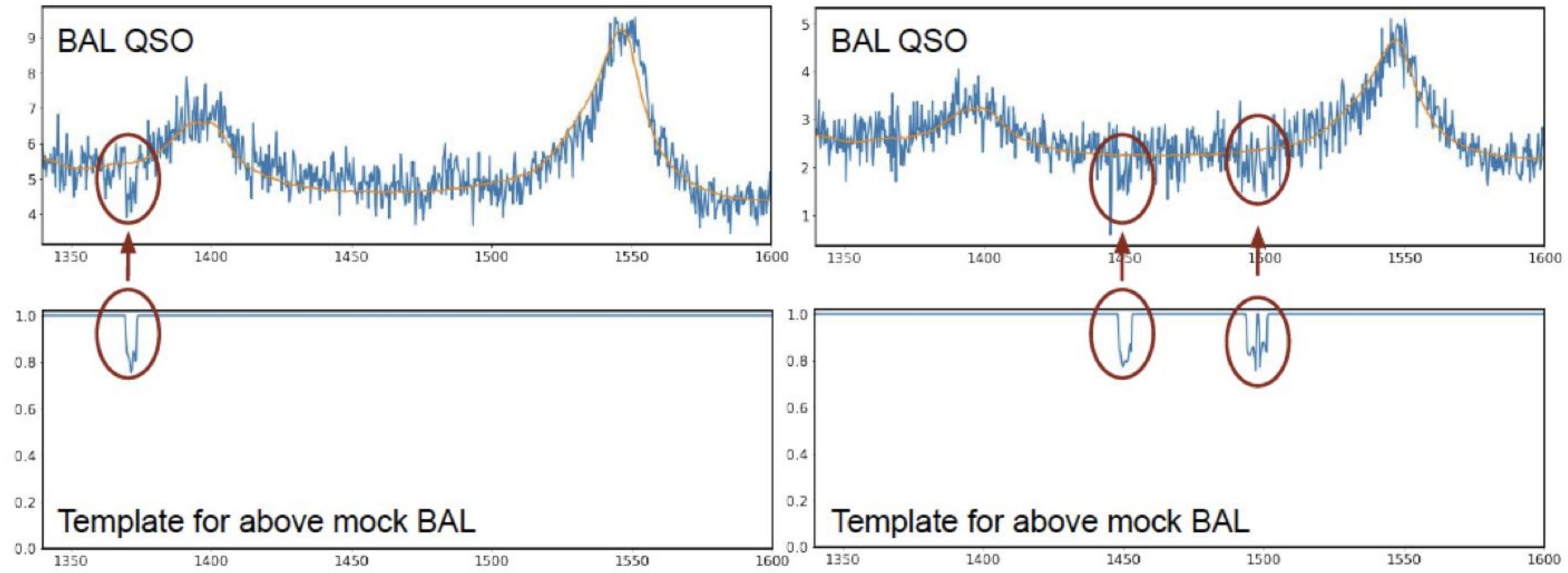
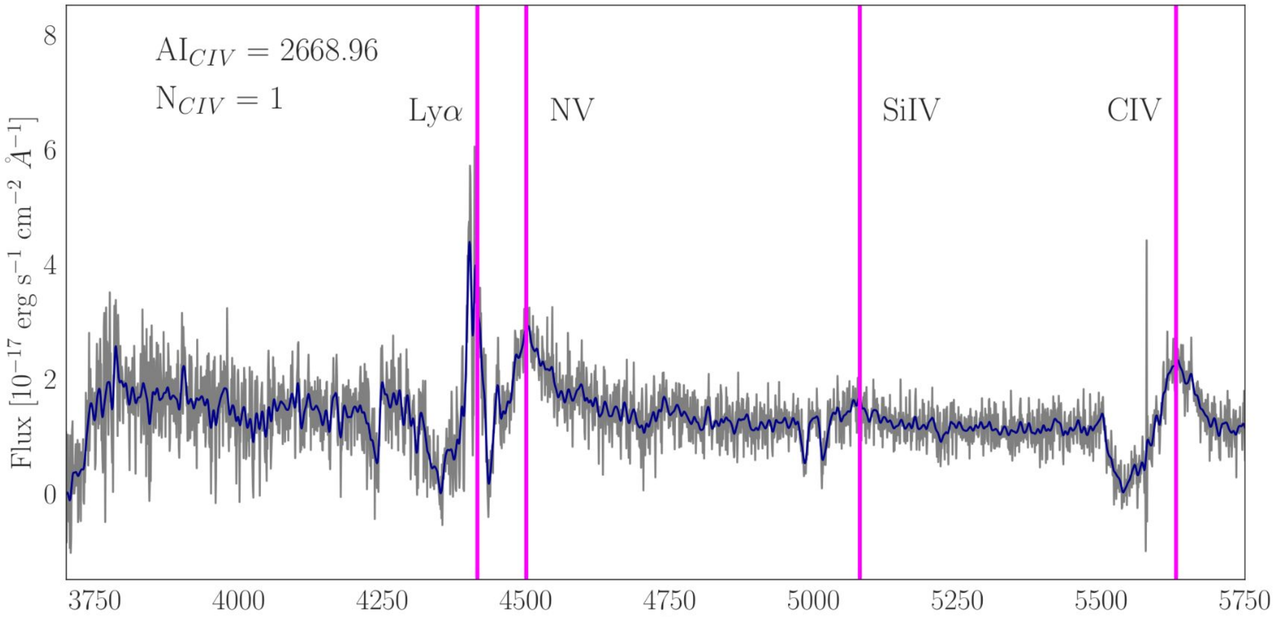
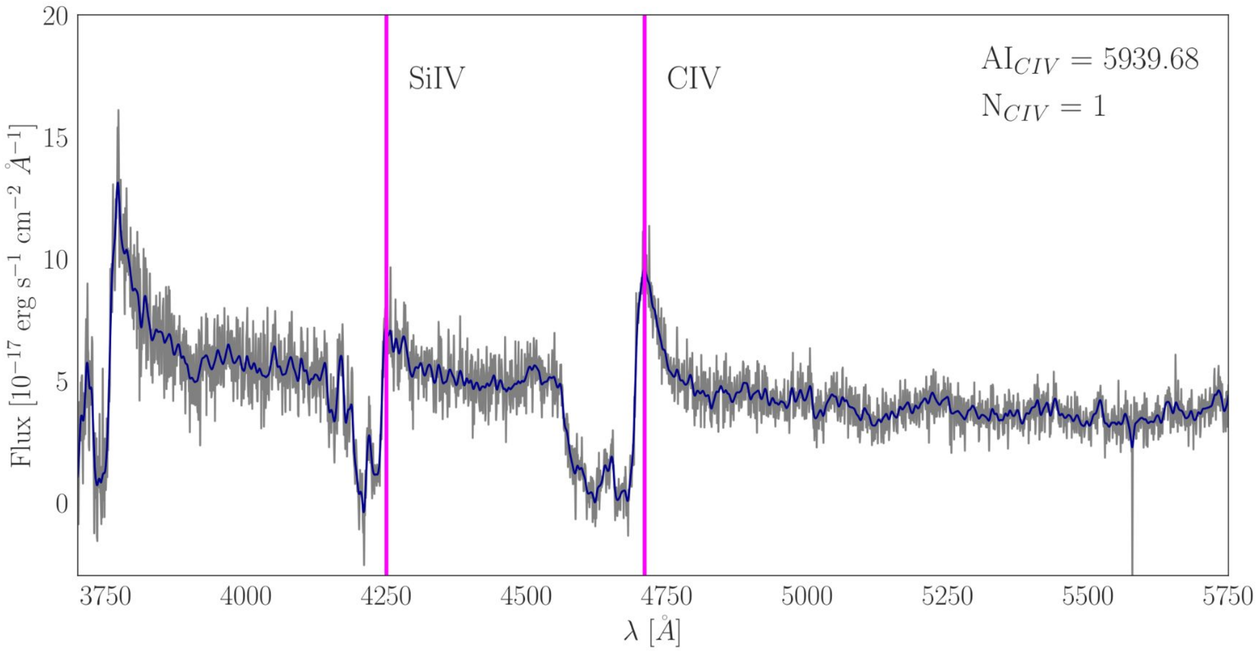


Credit: Paul Martini





Emission line	λ_{RF} (Å)
CIV	1548.21
SiIV	1393.76
Lyα	1215.67
NV	1238.82

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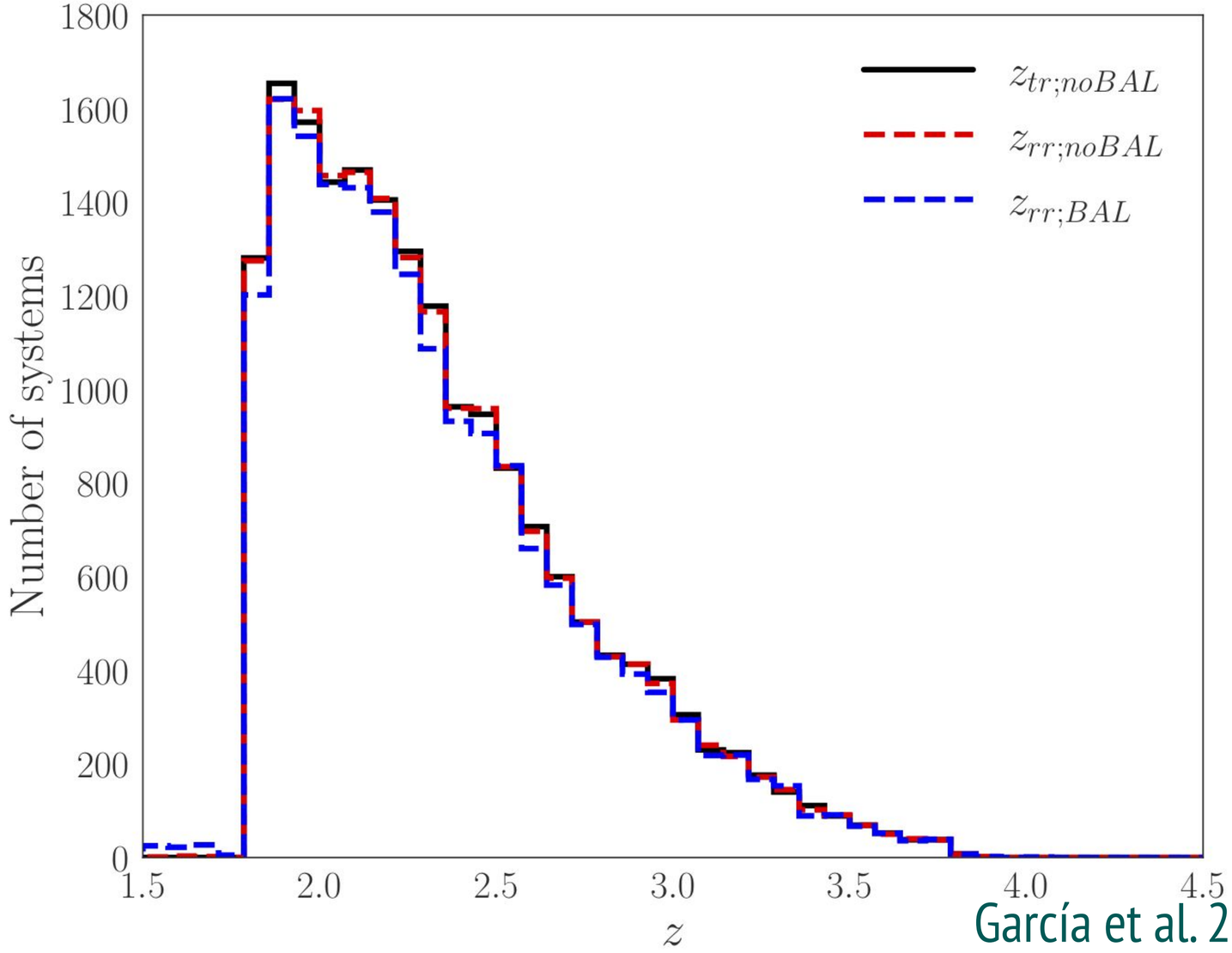
Why bother about BAL-QSO?



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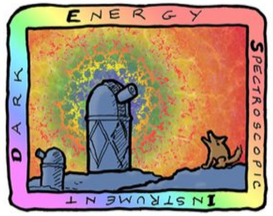

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Mocks de espectros de cuásares

- **DESI Y1-0.0:** Spectra with Lyα only, in multiple exposures. One exposure corresponds to 1000 s (or one observation).
- **DESI Y1-0.2-BAL:** Spectra with Lyα, Lyβ, and BAL, in multiple exposures.

QSO synthetic spectra sample: 116750 (1.8 < z < 3.8)

Number of BAL-QSO: 18555 (16%) Guo & Martini 2019

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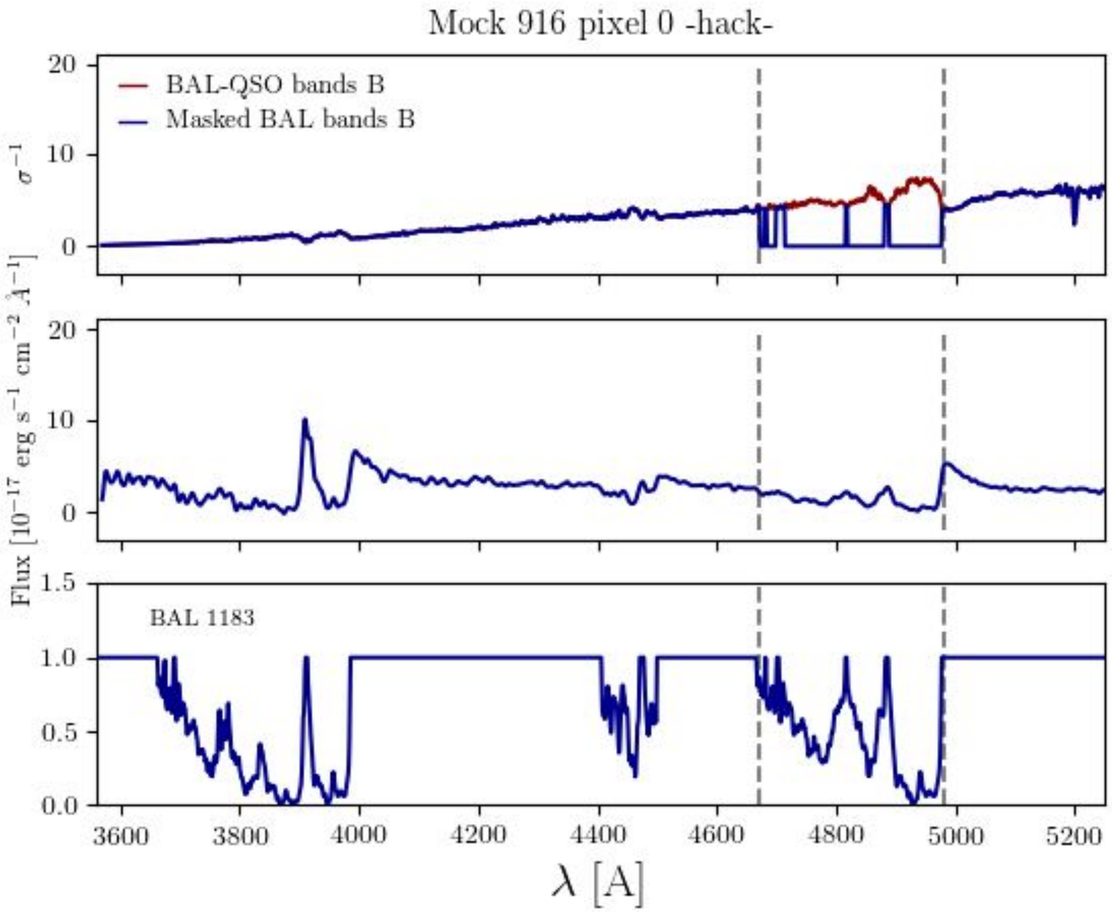
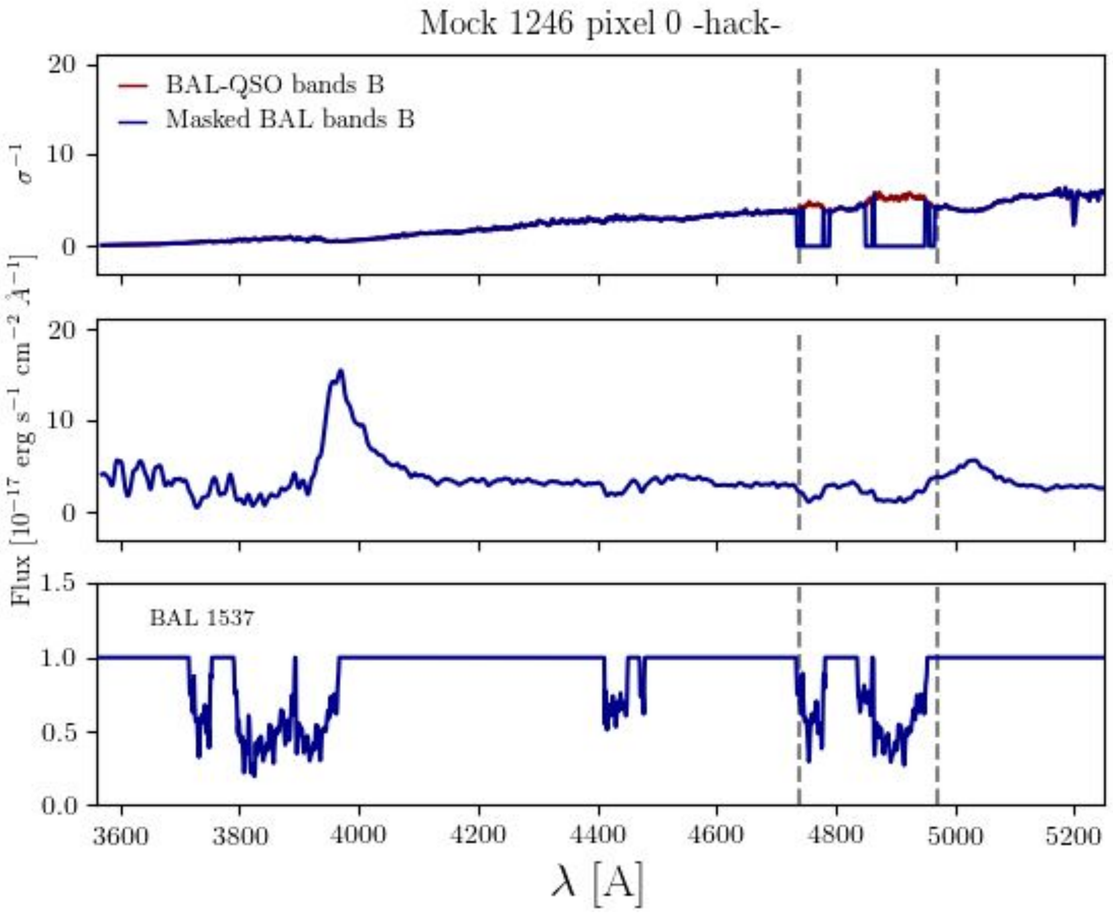

Mock 916 pixel 0 -hack-
BAL-QSO bands B
Masked BAL bands B
σ^{-1}
Flux [10^{-17} erg s^{-1} cm^{-2} Å^{-1}]
BAL 1183
λ [A]

N-CIV = 5


Mock 1246 pixel 0 -hack-
BAL-QSO bands B
Masked BAL bands B
σ^{-1}
Flux [10^{-17} erg s^{-1} cm^{-2} Å^{-1}]
BAL 1537
λ [A]

N-CIV = 6

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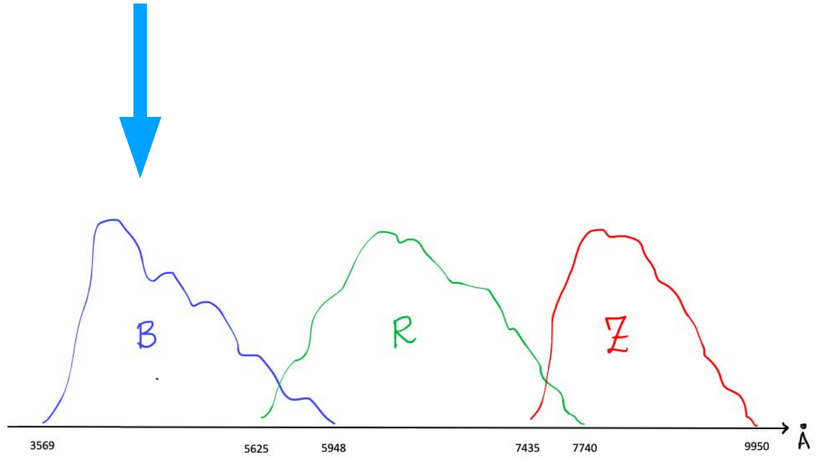
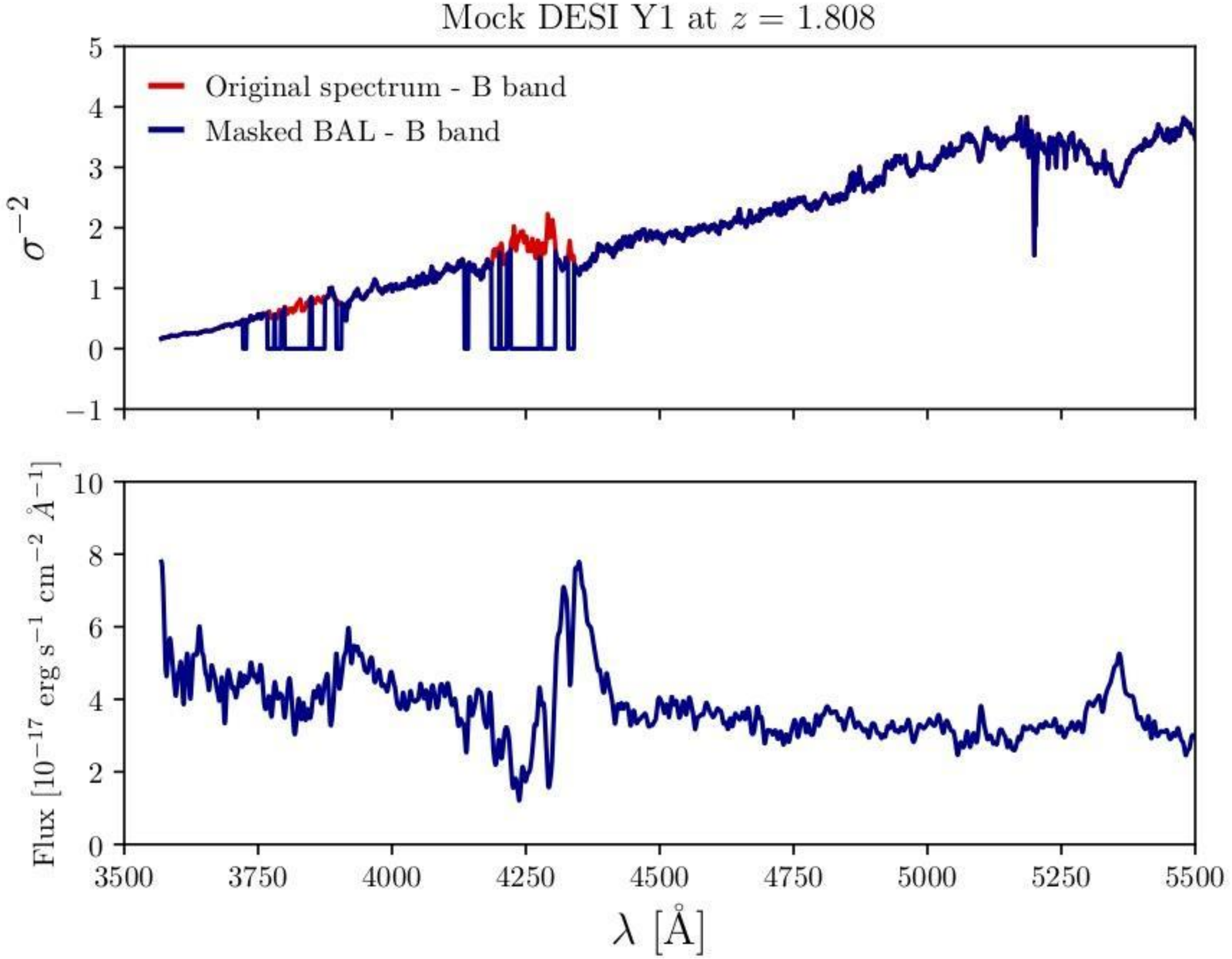


$$\lambda = \lambda_{\mathrm{CIV,\,RF}} \left(1 - \frac{v}{c}\right)$$

$$\lambda_{\mathrm{obs}} = (1+z)\lambda$$



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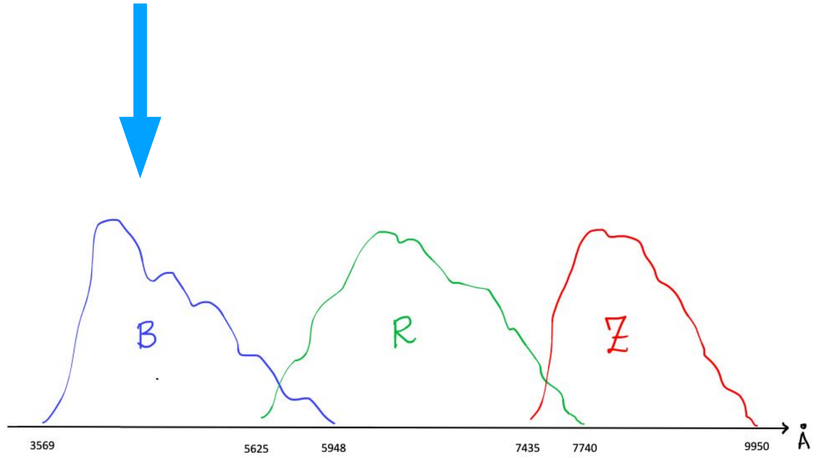

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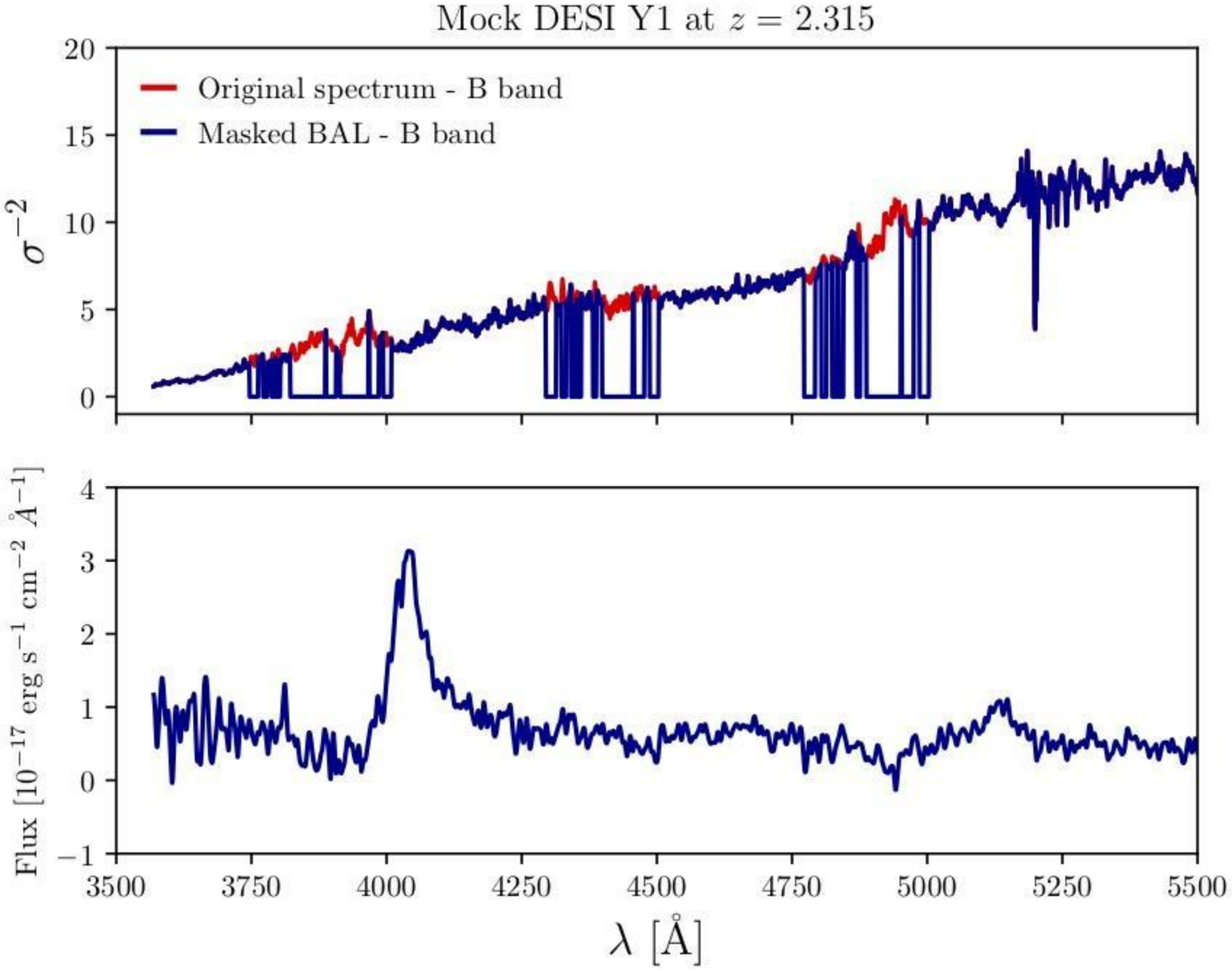

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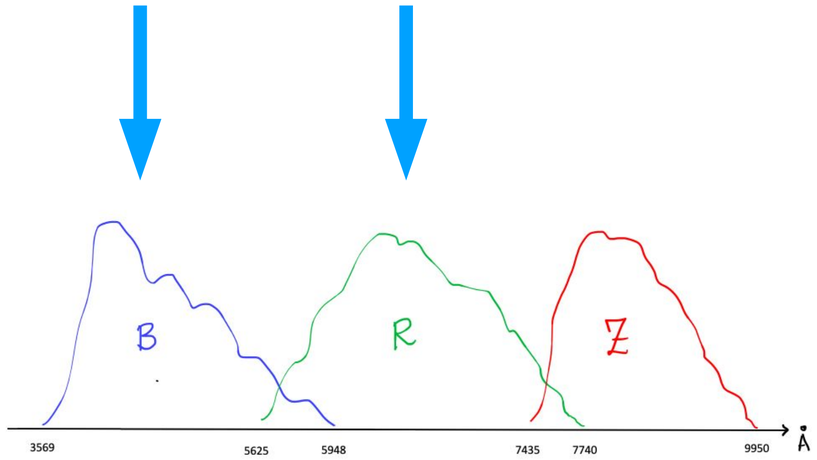

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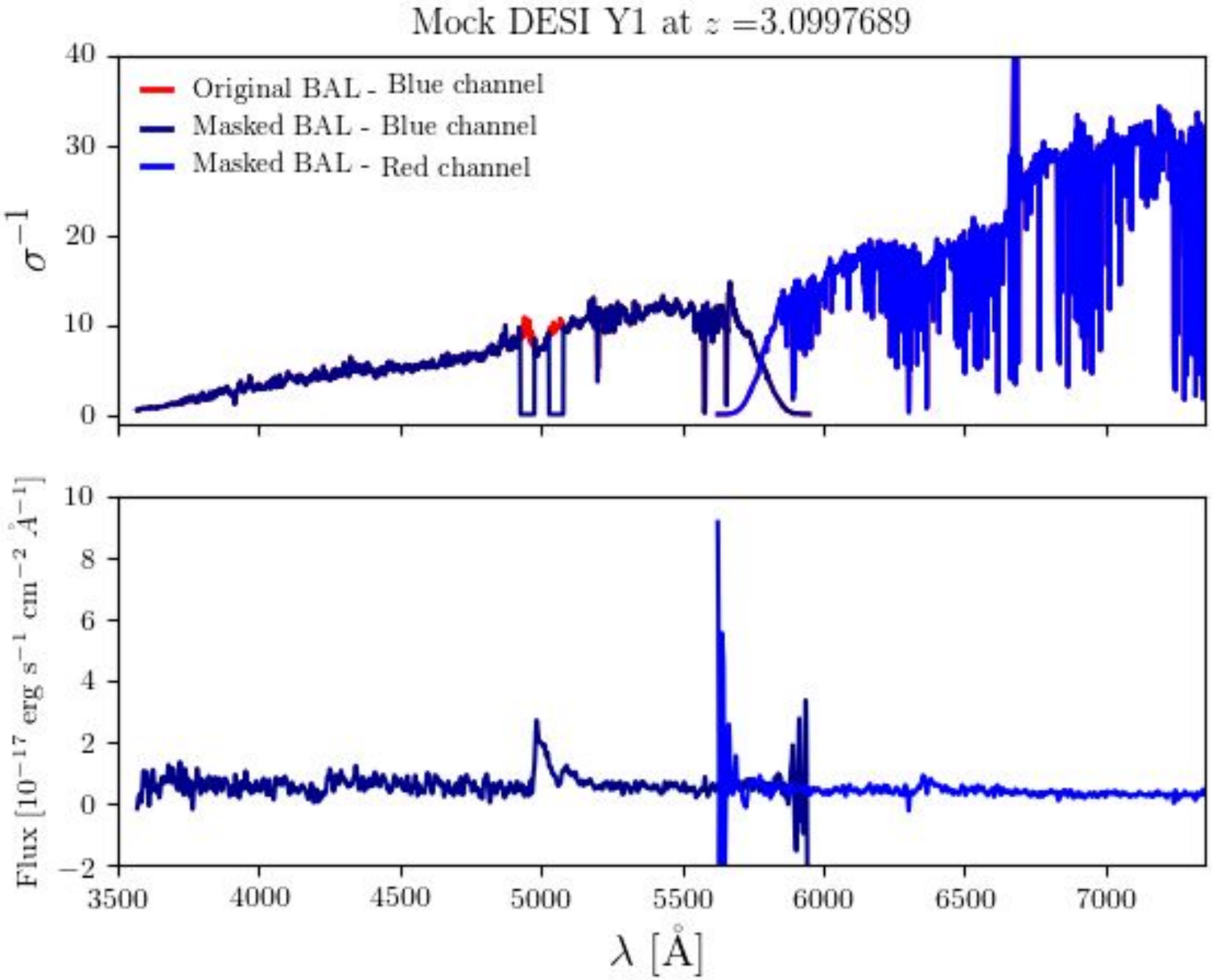

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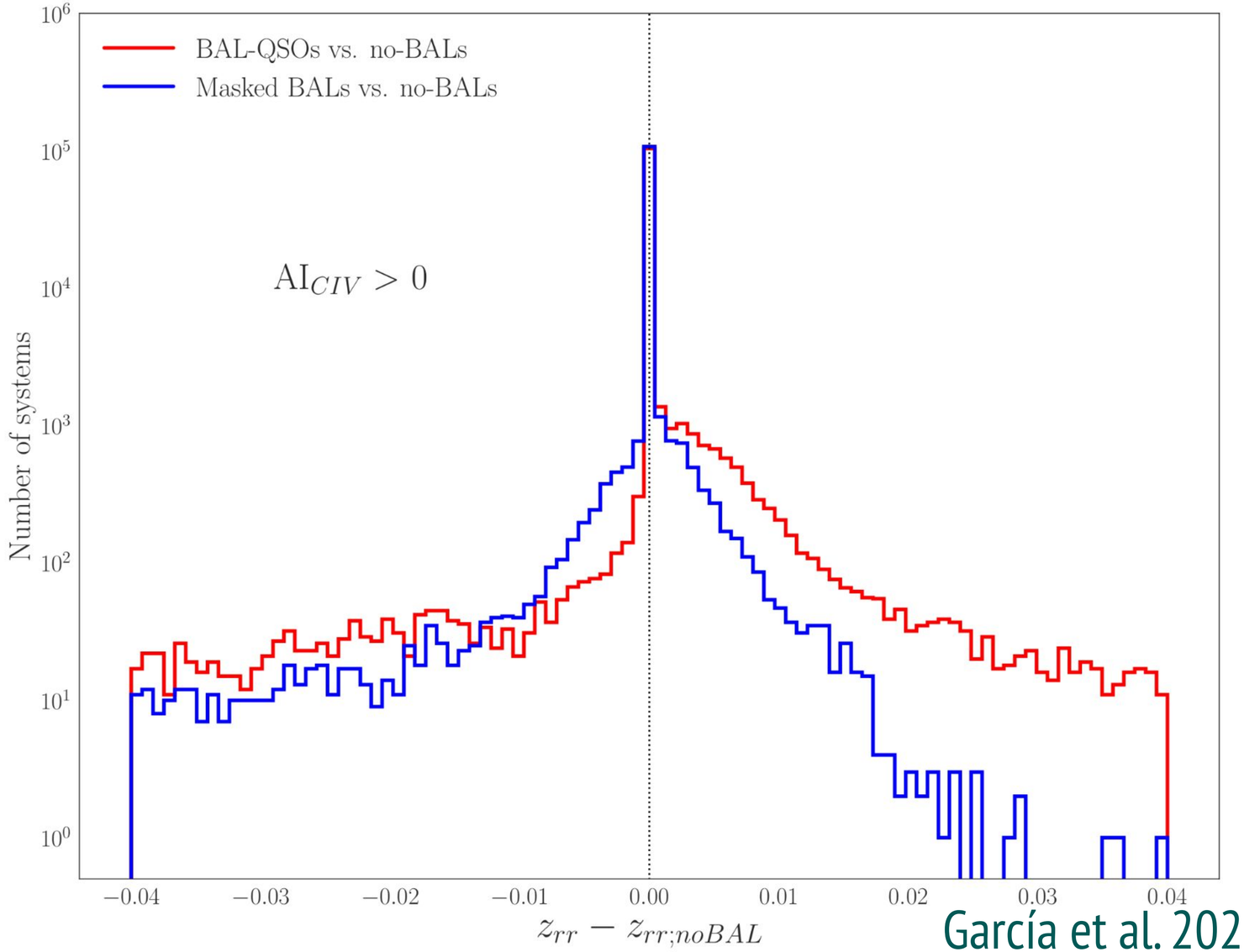
Estimated redshift by Redrock z_{rr}



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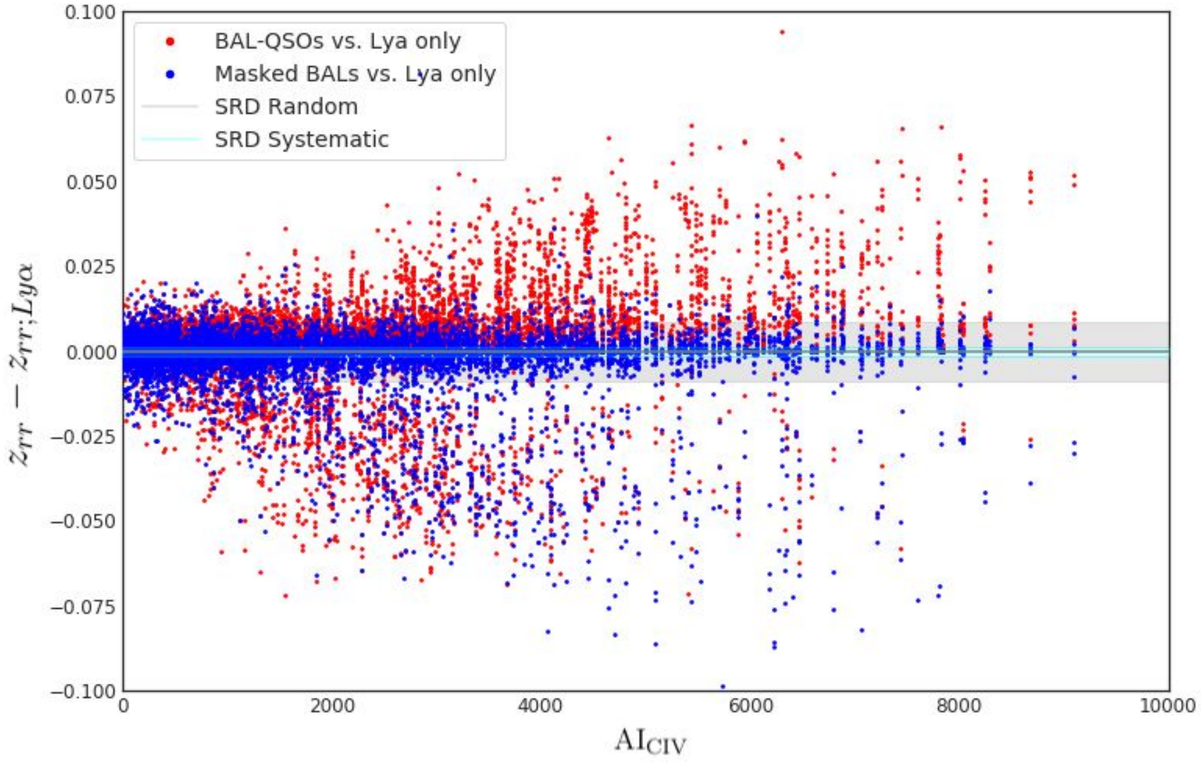
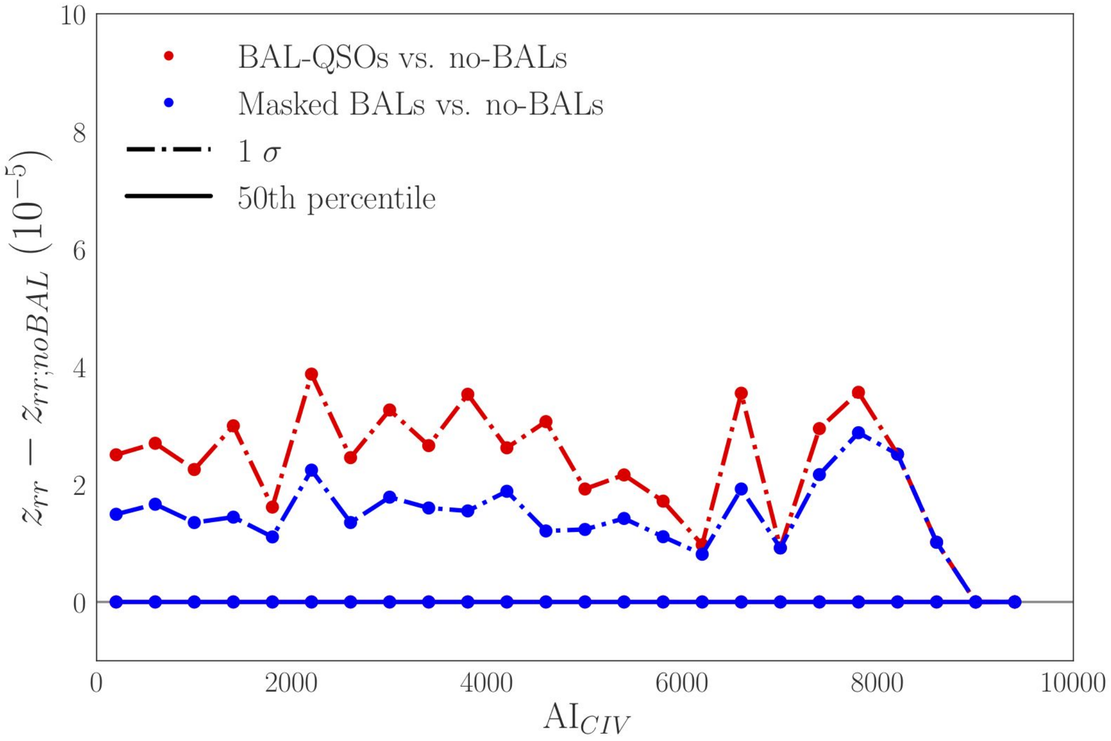
Absorption Index (AI_{CIV})

$$\mathrm{AI_{CIV}} = -\int_{25000}^{0} \left[1 - \frac{f(v)}{0.9}\right] C(v) dv$$





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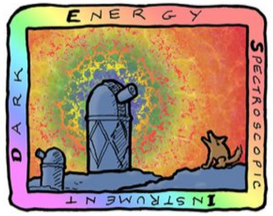

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"Wrong/Poor" fits

	QSO (%)	Galaxy (%)
Lyα only	98.4	1.6
Lyα + BAL	96.4	3.6
Lyα + masked BAL	98.0	2.0

	ZWARNING $= 0$ (%)	ZWARNING $\neq 0$ (%)
Lyα only	98.0	2.0
Lyα + BAL	97.5	2.5
Lyα + masked BAL	97.8	2.2

Threshold = $\frac{|z_{rr} - z_{rr;Lya}|}{z_{rr;Lya}}$ = 0.05

	$dv_{rr} < -15000$ km/s (%)	$dv_{rr} > 15000$ km/s (%)
$z_{rr;\mathrm{BAL}} - z_{rr;Lya}$	2.9	0.1
$z_{rr;\mathrm{mas}} - z_{rr;Lya}$	0.5	0.1

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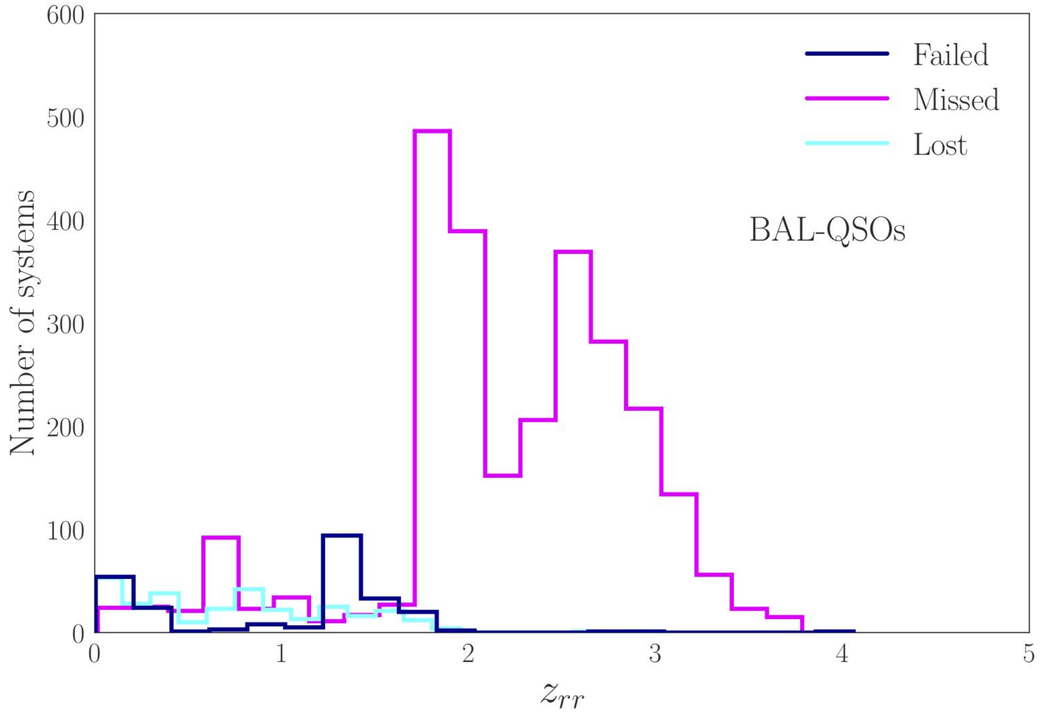
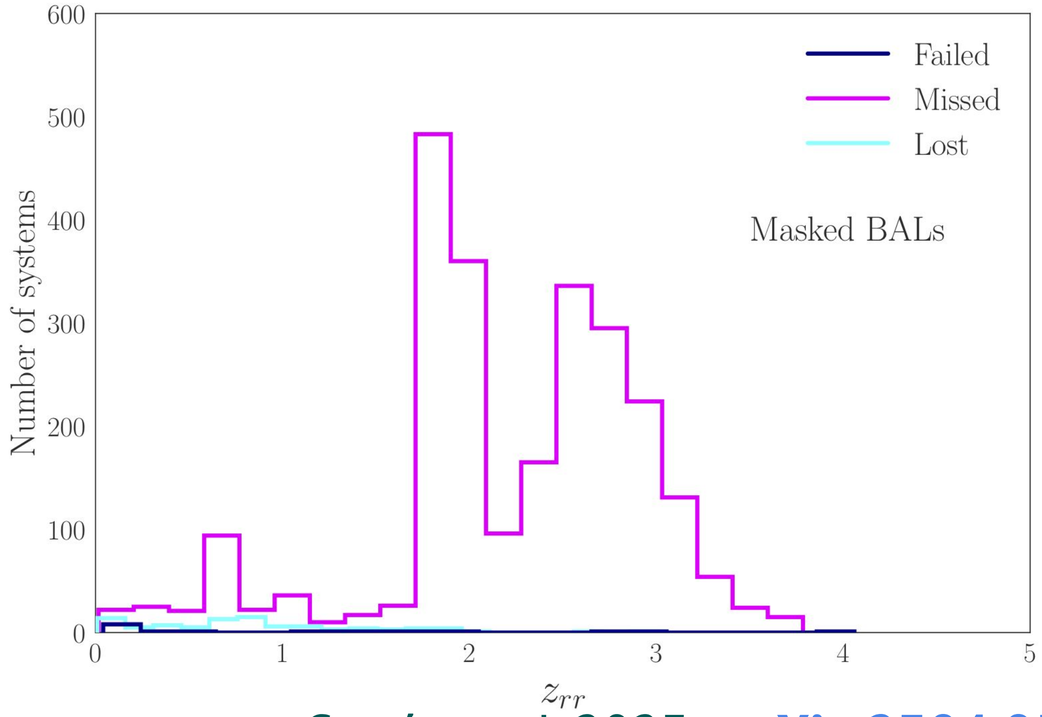
- *good fit*: difference in redshift below a threshold (compared with the *true* redshift $z_{rr;\mathrm{Ly}\alpha}$) and `ZWARNING` = 0 (**good**),
- *failed fit*: difference in redshift above a given threshold (compared with the *true* redshift $z_{rr;\mathrm{Ly}\alpha}$) and `ZWARNING` = 0 (catastrophic failures; **failed**),
- *missed opportunities*: difference in redshift below a threshold (compared with the *true* redshift $z_{rr;\mathrm{Ly}\alpha}$) and `ZWARNING` ≠ 0 (**missed**),
- *lost:* difference in redshift above a threshold (compared with the *true* redshift $z_{rr;\mathrm{Ly}\alpha}$) and `ZWARNING` ≠ 0 (**lost**).

Fit	Good (%)	Failed (%)	Missed (%)	Lost (%)
$z_{rr;\mathrm{BAL}} - z_{rr;Lya}$	97.29	0.11	2.14	0.46
$z_{rr;\mathrm{mas}} - z_{rr;Lya}$	98.10	0.05	1.83	0.02

$$\text{Threshold} = \frac{|z_{rr} - z_{rr;Lya}|}{z_{rr;Lya}} = 0.05$$





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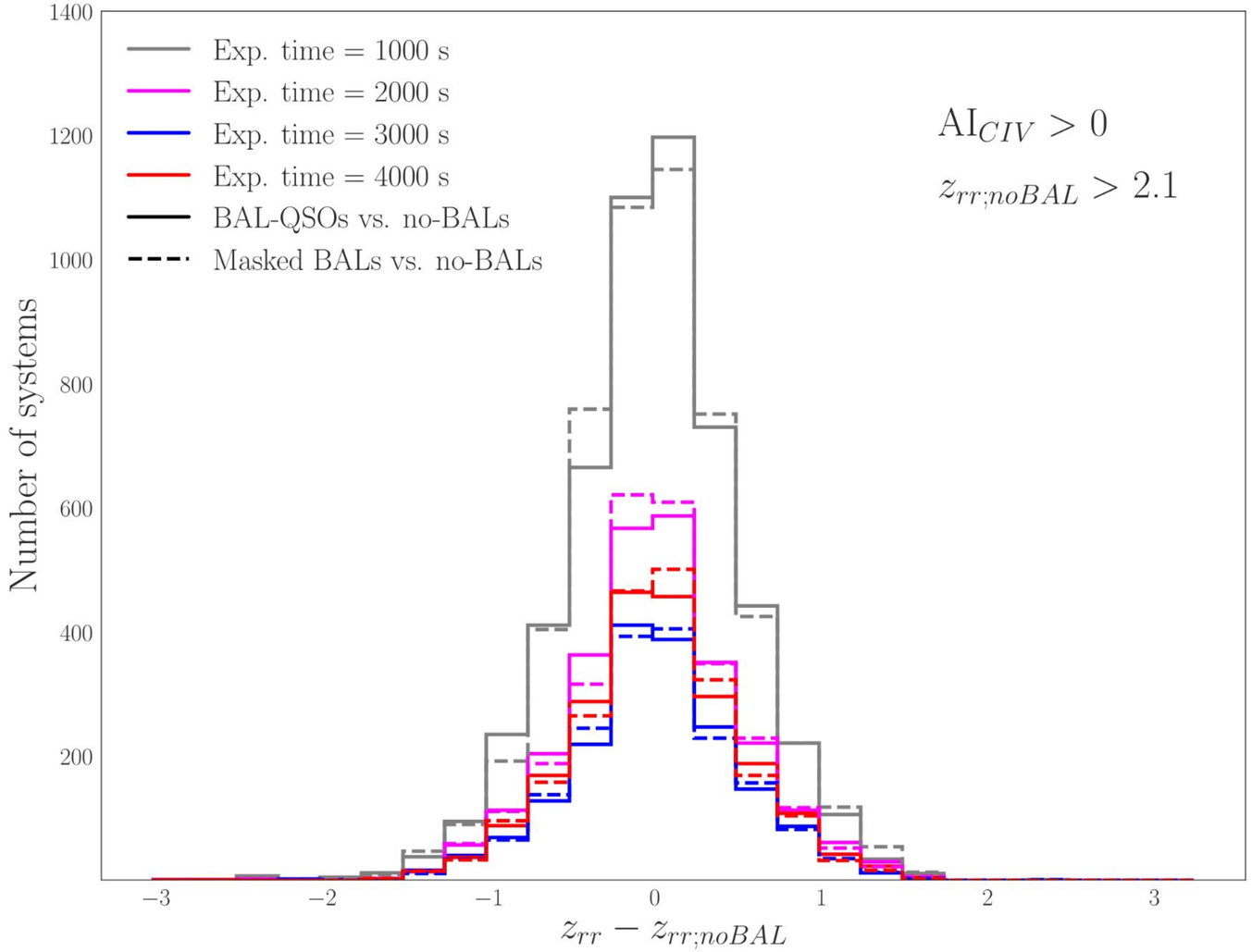
Distribution with different exposures

Number of Exposures	1000 s	2000 s	3000 s	4000 s
Tracer QSOs	41366	0	0	0
Lyα QSOs	33371	16935	11372	13706



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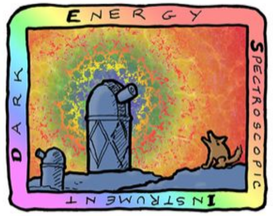

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Conclusions

- Broad absorption line (BAL) features are present in 15-20% of all quasars, and these features can introduce systematic redshift errors, and in extreme cases produce misclassifications.

- Our synthetic quasar spectra match the signal-to-noise ratio and redshift distributions of the first year of DESI observations, and include the same synthetic quasar spectra both with and without BAL features.

- We demonstrate that masking the locations of the BAL features decreases the redshift errors by about 1% and reduces the number of catastrophic redshift errors by about 80%.

- We conclude that identifying and masking BAL troughs should be a standard part of the redshift determination step for DESI and other large-scale spectroscopic surveys of quasars.

@PenLua

lgarciap@ecci.edu.co