

# **Voigt profile fitting and Ionisation modelling results**

April 30, 2024

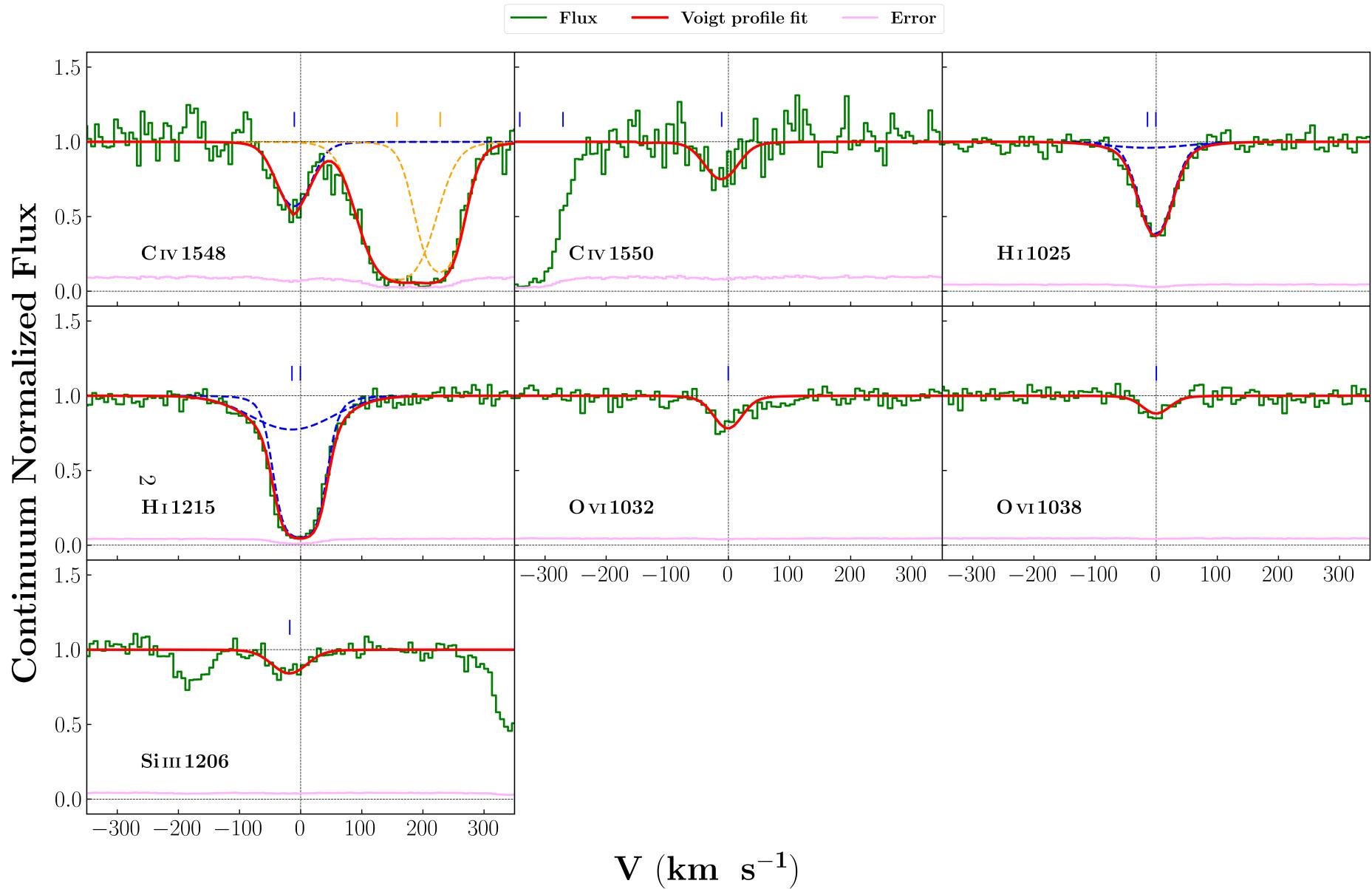
## System plots

- Velocity taken to be 0 at  $z_{abs}$  given on the title of the plots
- Blue dashed curves are the individual components and orange dashed curves are the contamination

## Ionisation modelling

- PI CLOUDY models with varying  $\log n_H$  ( $cm^{-3}$ ) from -5 to 1 at constant metallicity of  $\log Z = -1$
- Column densities are scaled with metallicity
- This approximation is valid for metallicities less than around  $\log Z < 1$
- If solution from MCMC gives metallicity of around or above  $\log Z = 1$ , in such cases CLOUDY models are run at base metallicity of  $\log Z = 1$
- $n_H$  and  $Z$  values are reported for both excluding and including O VI cases.
- In case if some component doesn't have O VI, column density of O VI from other component is taken for the sake of solution
- CI : collisional ionisation, PI : photoionisation

### 3C263 ( $z_{\text{abs}} = 0.140756$ )



<b>Ion</b>	<b>v (km s<sup>-1</sup>)</b>	<b>b (km s<sup>-1</sup>)</b>	<b>log [N cm<sup>-2</sup>]</b>
Si III	-18 ± 8	35 ± 11	12.39 ± 0.09
C IV	-10 ± 3	33 ± 0	13.71 ± 0.04
O VI	0 ± 2	26 ± 4	13.63 ± 0.04
H I	-14 ± 1	87 ± 10	13.49 ± 0.06
H I	0 ± 1	28 ± 1	14.49 ± 0.02

$$N(H\text{I})=13.49$$

$$\log Z_{ref} = -1$$

Excluding O VI : $n_H = -3.88 \pm 0.04$	$Z = 1.06 \pm 0.05$
Including O VI : $n_H = -4.13 \pm 0.02$	$Z = 0.99 \pm 0.04$

$$\log Z_{ref} = 1$$

Excluding O VI : $n_H = -4.14 \pm 0.04$	$Z = 1.69 \pm 0.08$
Including O VI : $n_H = -4.45 \pm 0.01$	$Z = 1.30 \pm 0.05$

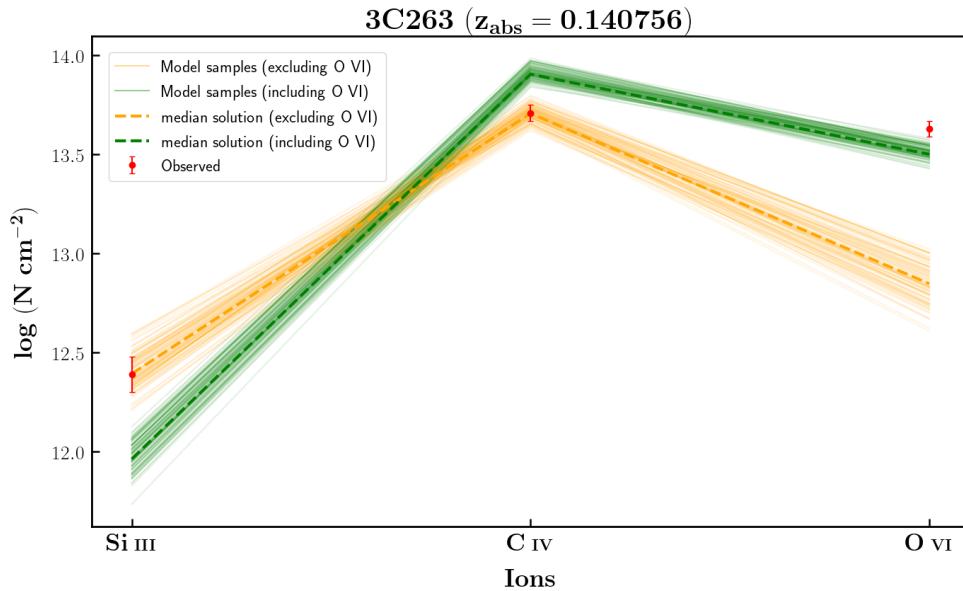


Figure 1:  $\text{N(H I)}=13.49$ ,  $\log Z_{ref}=-1$

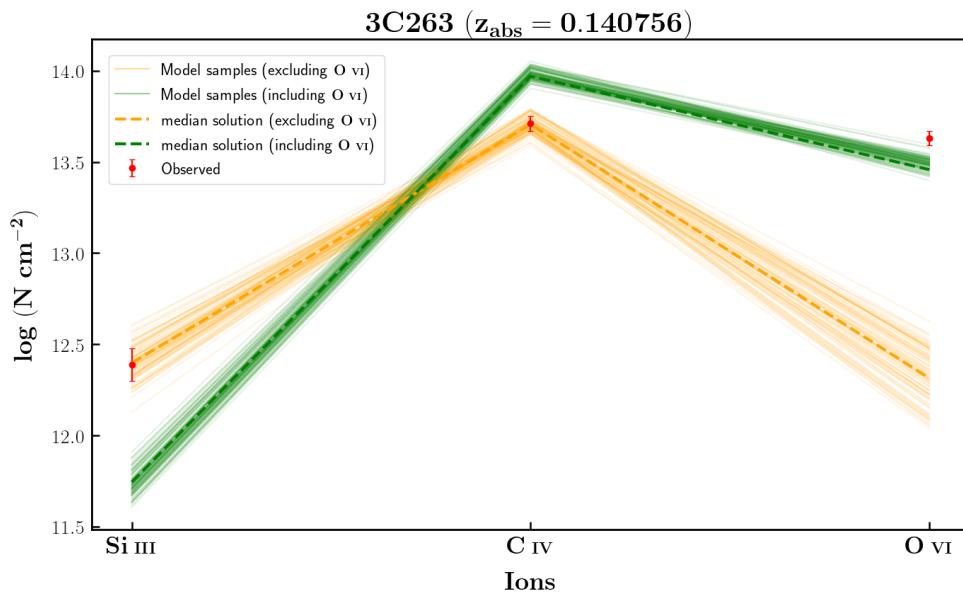


Figure 2:  $\text{N(H I)}=13.49$ ,  $\log Z_{ref}=1$

## Non-detections

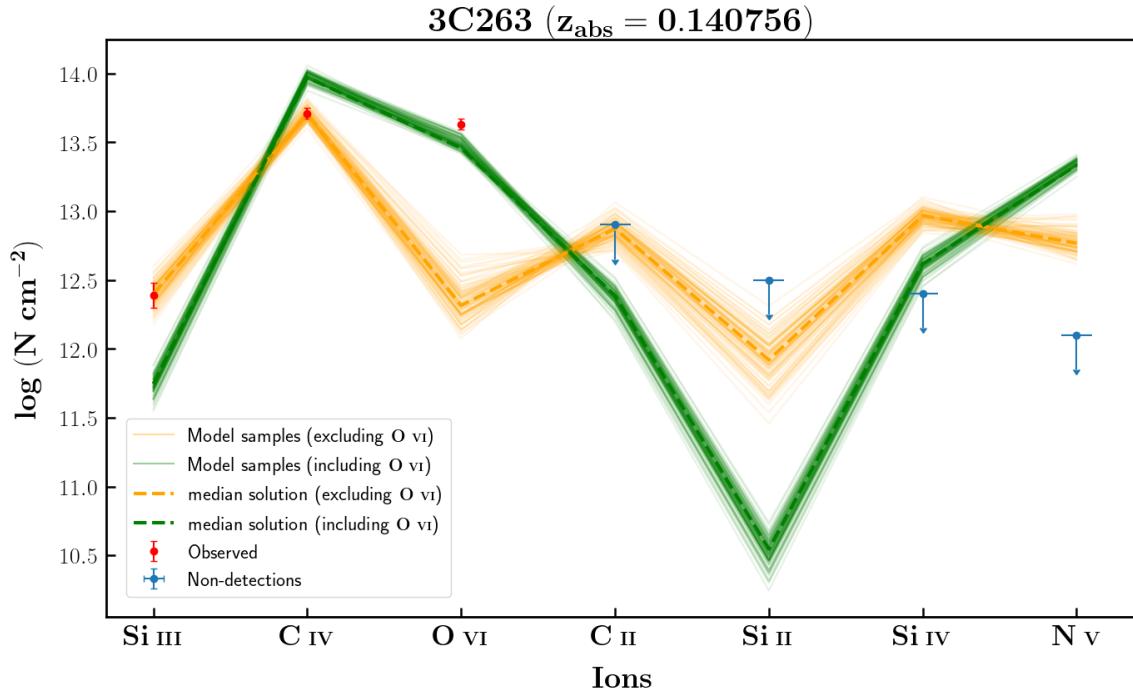
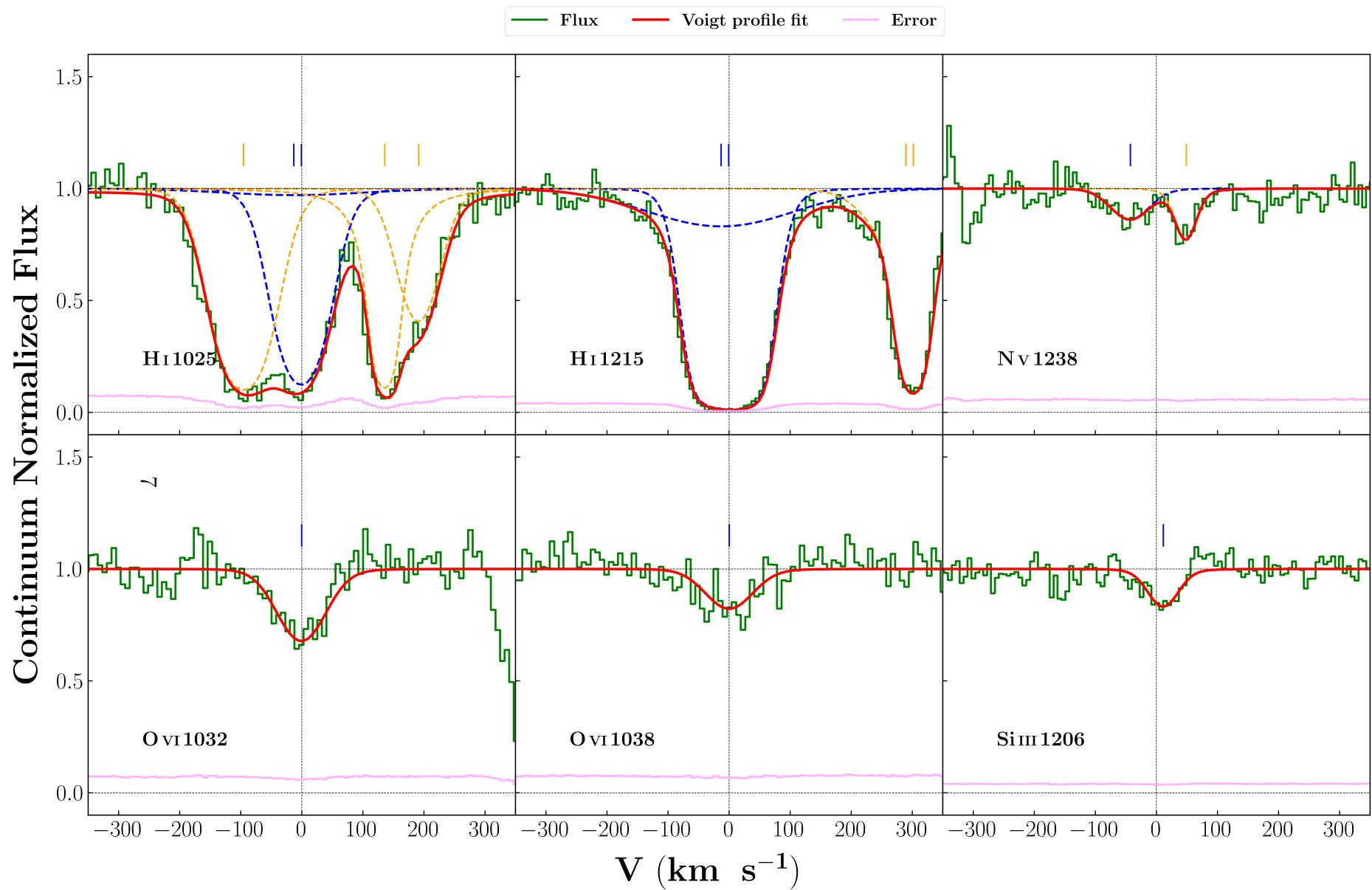


Figure 3:  $N(\text{H I})=13.49$ ,  $\log Z_{\text{ref}}=1$

## Comments

- All 3 ions couldn't be explained together
- O VI is underproduced when excluded
- Reference metallicity was initially used as  $\log Z = -1$ , resulted in metallicity to be around 1, so later modelled with reference metallicity of  $\log Z = 1$ .
- Ionisation : CI
- BLA : +ve

PKS0637 – 752 ( $z_{\text{abs}} = 0.161064$ )



<b>Ion</b>	<b>v (km s<sup>-1</sup>)</b>	<b>b (km s<sup>-1</sup>)</b>	<b>log [N cm<sup>-2</sup>]</b>
N V	-42 ± 6	40 ± 9	13.37 ± 0.07
Si III	11 ± 4	30 ± 7	12.37 ± 0.06
O VI	0 ± 3	48 ± 5	14.02 ± 0.03
H I	-13 ± 2	162 ± 21	13.6 ± 0.06
H I	-1 ± 1	45 ± 1	15.01 ± 0.02

$$N(H\text{I})=13.60$$

$$\log Z_{ref} = -1$$

Excluding O VI : $n_H = -4.05 \pm 0.03$	$Z = 1.20 \pm 0.05$
Including O VI : $n_H = -4.12 \pm 0.01$	$Z = 1.30 \pm 0.04$

$$\log Z_{ref} = 1$$

Excluding O VI : $n_H = -4.29 \pm 0.02$	$Z = 1.64 \pm 0.05$
Including O VI : $n_H = -4.42 \pm 0.01$	$Z = 1.69 \pm 0.04$

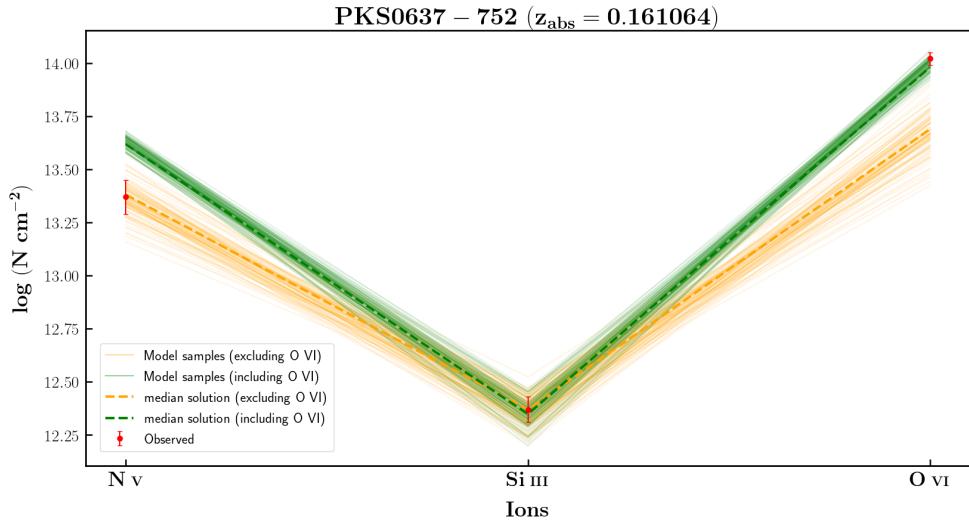


Figure 4:  $\text{N(H I)}=13.60$ ,  $\log Z_{\text{ref}}=-1$

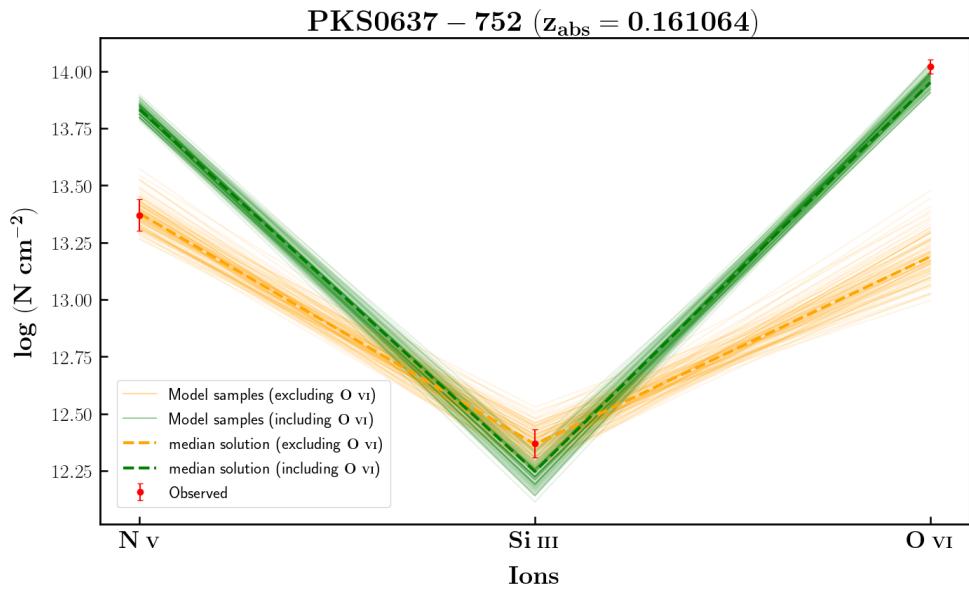


Figure 5:  $\text{N(H I)}=13.60$ ,  $\log Z_{\text{ref}}=1$

## Non-detections

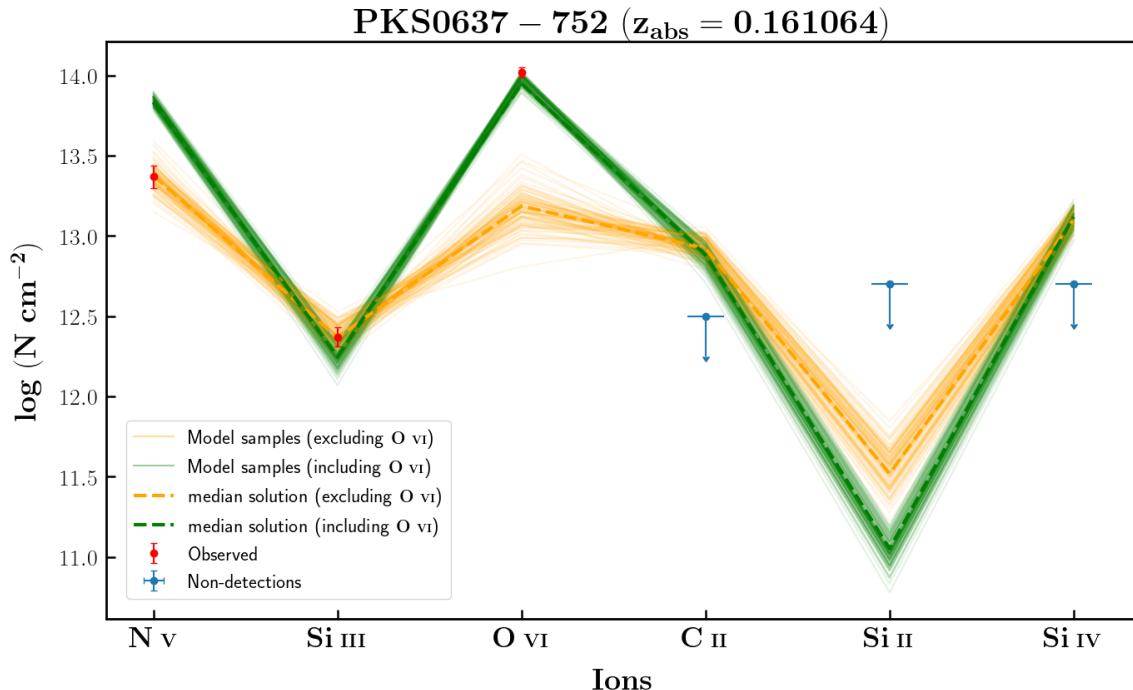
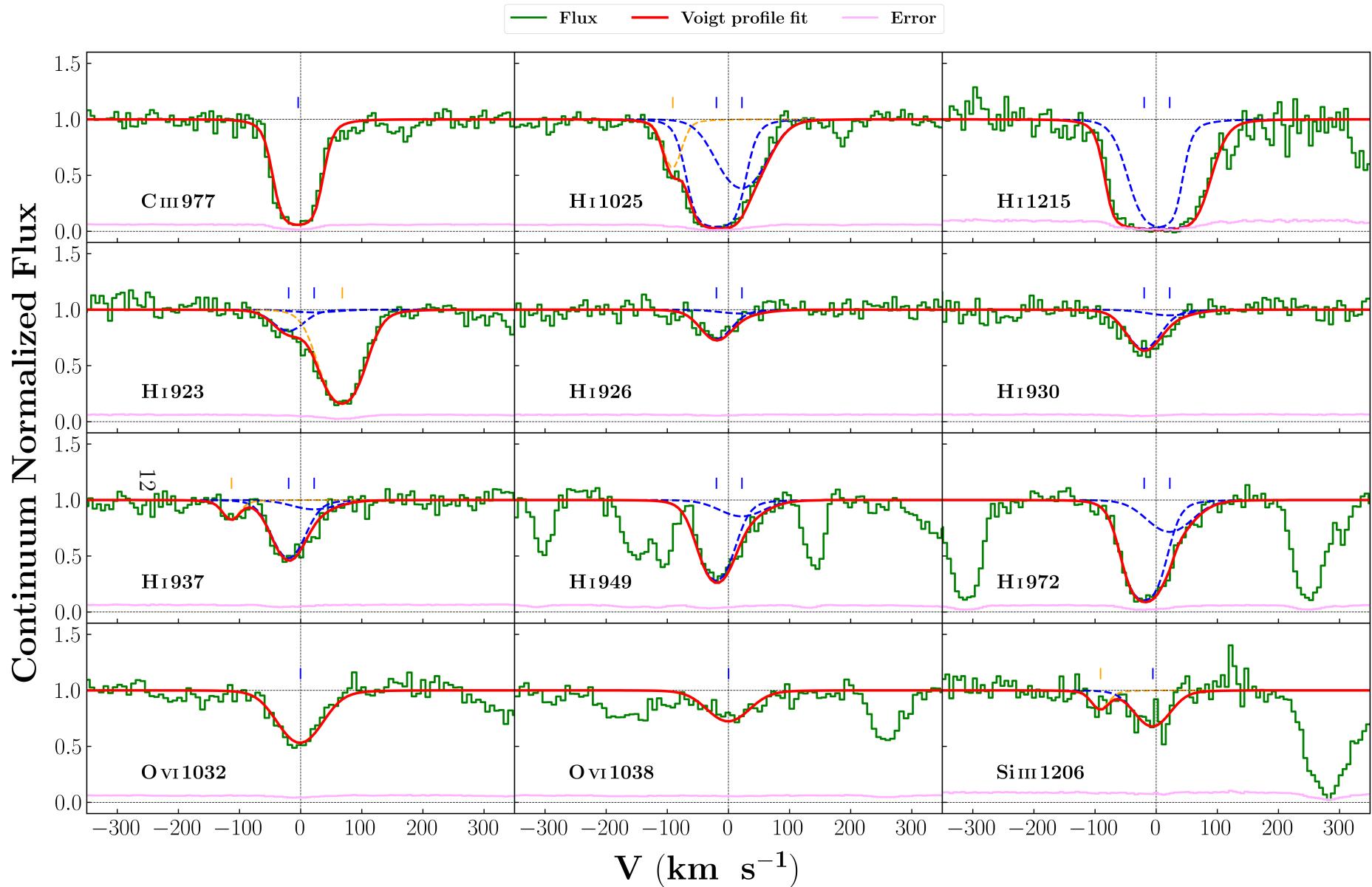


Figure 6:  $\text{N(H I)}=13.60$ ,  $\log Z_{\text{ref}}=1$

## Comments

- large  $b$  value
- All 3 ions couldn't be explained together
- When excluded O VI is underproduced, but not significantly less, about an order of magnitude
- Modelled using both logZ=1 and logZ=-1
- Ionisation : CI
- BLA : +ve

PKS0637 – 752 ( $z_{\text{abs}} = 0.417539$ )

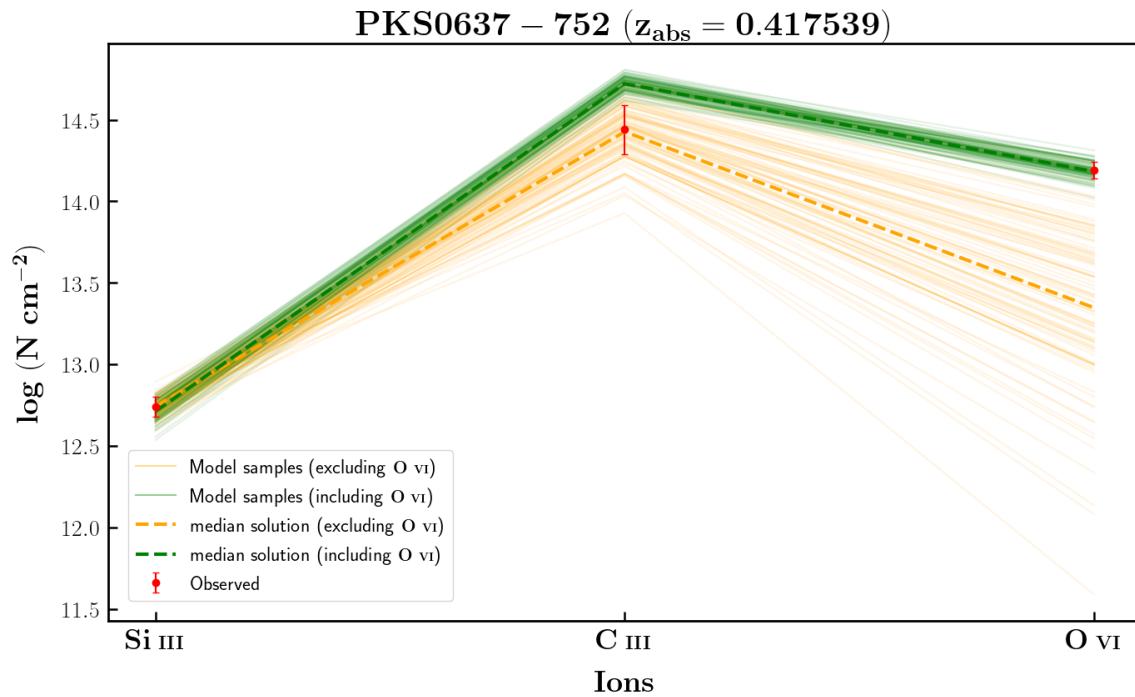


Ion	v (km s <sup>-1</sup> )	b (km s <sup>-1</sup> )	log [N cm <sup>-2</sup> ]
Si III	-5 ± 4	35 ± 7	12.74 ± 0.06
C III	-4 ± 1	24 ± 2	14.44 ± 0.15
O VI	0 ± 1	42 ± 6	14.19 ± 0.05
H I	-17 ± 1	30 ± 1	15.41 ± 0.03
H I	20 ± 1	46 ± 4	14.61 ± 0.07

$$N(HI) = 15.41$$

$$\begin{array}{ll} \text{Excluding O VI : } n_H = -3.54 \pm 0.11 & Z = -0.49 \pm 0.11 \\ \text{Including O VI : } n_H = -3.74 \pm 0.02 & Z = -0.23 \pm 0.04 \end{array}$$

NOTE : MCMC walkers initialised near the solution for excluding O VI case.



## Non-detections

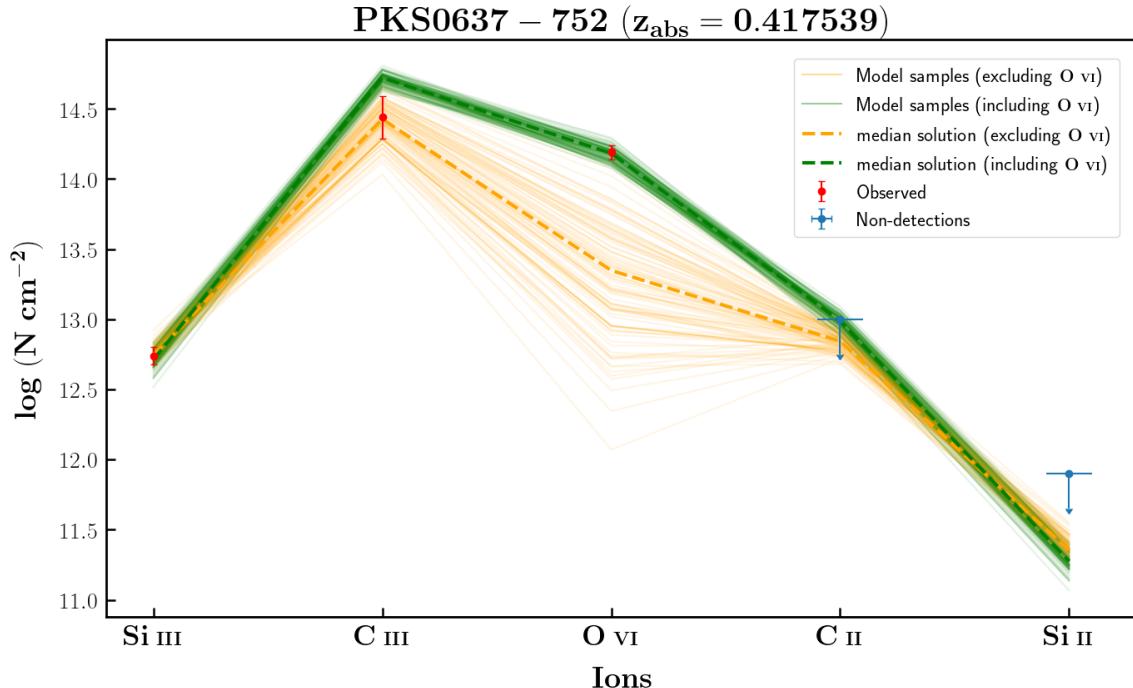
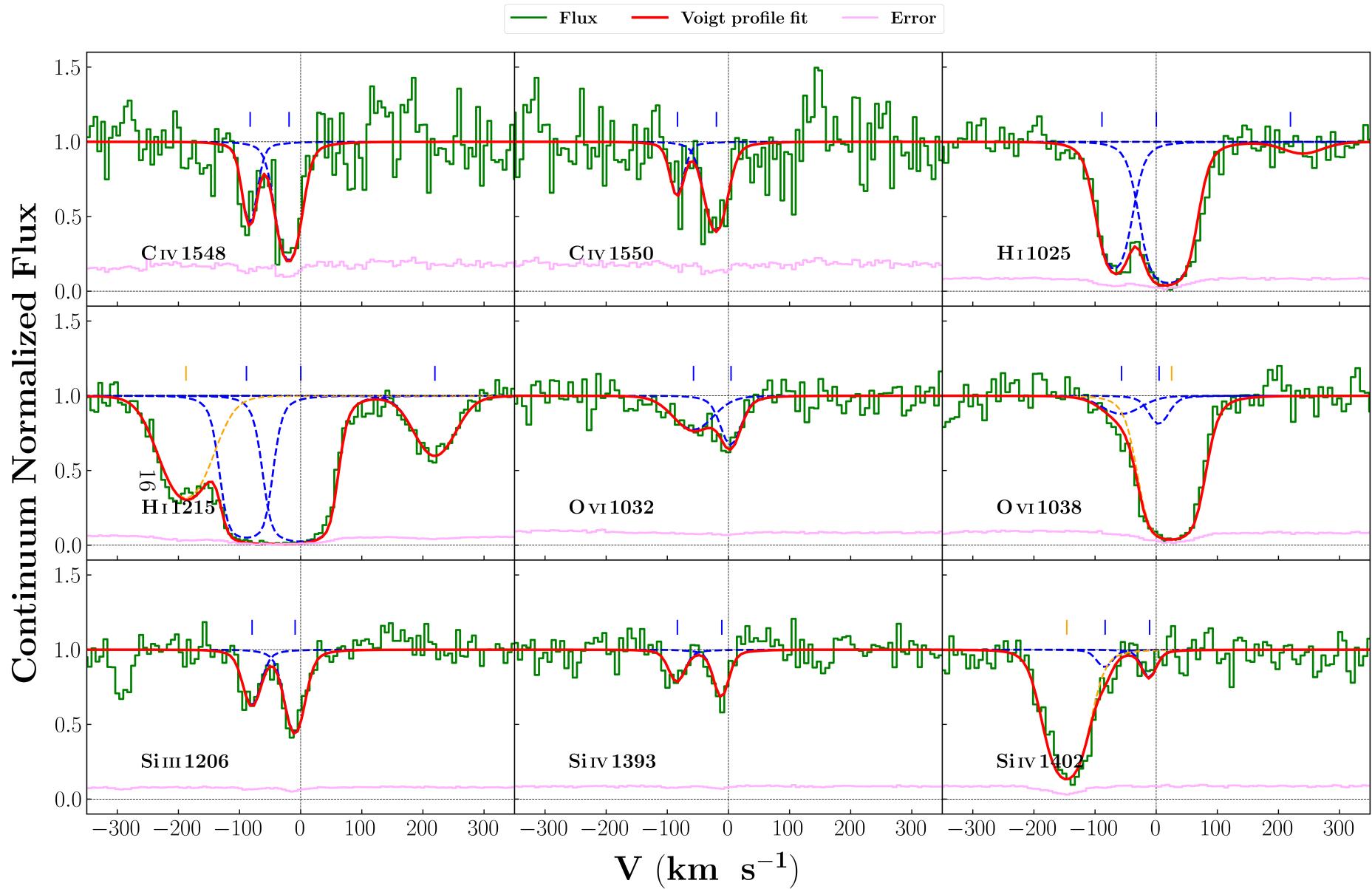


Figure 7:  $N(\text{H I})=15.41$  ,  $\log Z_{\text{ref}}=-1$

## **Comments**

- All 3 ions couldn't be explained together
- When excluded O VI is underproduced
- Ionisation : CI
- BLA : +ve

PG1424 + 240 ( $z_{\text{abs}} = 0.147104$ )



<b>Ion</b>	<b>v (km s<sup>-1</sup>)</b>	<b>b (km s<sup>-1</sup>)</b>	<b>log [N cm<sup>-2</sup>]</b>
C IV	-81 ± 2	11 ± 4	13.58 ± 0.09
C IV	-18 ± 2	20 ± 3	14.06 ± 0.05
Si III	-78 ± 2	15 ± 3	12.58 ± 0.05
Si III	-9 ± 1	16 ± 2	12.87 ± 0.03
Si IV	-82 ± 4	13 ± 7	12.69 ± 0.1
Si IV	-11 ± 2	11 ± 5	12.88 ± 0.07
O VI	-56 ± 9	39 ± 13	13.77 ± 0.11
O VI	4 ± 4	16 ± 6	13.73 ± 0.11
H I	-454 ± 3	27 ± 5	13.16 ± 0.05
H I	-87 ± 3	23 ± 2	14.88 ± 0.05
H I	0 ± 3	29 ± 2	15.44 ± 0.14
H I	216 ± 2	40 ± 3	13.49 ± 0.02

N(H I)=15.44

Excluding O VI : $n_H = -3.81 \pm 0.03$	$Z = -0.46 \pm 0.03$
Including O VI : $n_H = -3.88 \pm 0.02$	$Z = -0.42 \pm 0.02$

N(H I)=14.88

Excluding O VI : $n_H = -3.74 \pm 0.05$	$Z = -0.22 \pm 0.04$
Including O VI : $n_H = -3.96 \pm 0.03$	$Z = -0.07 \pm 0.04$

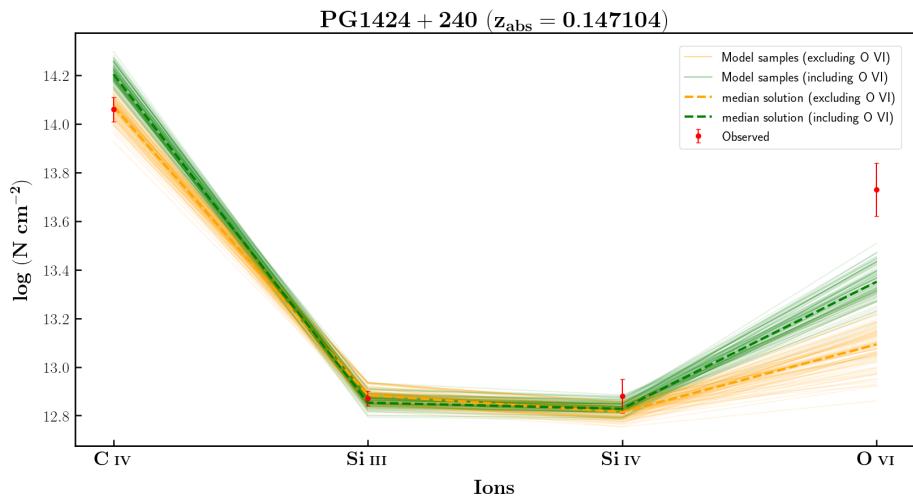


Figure 8:  $N(\text{H I})=15.44$

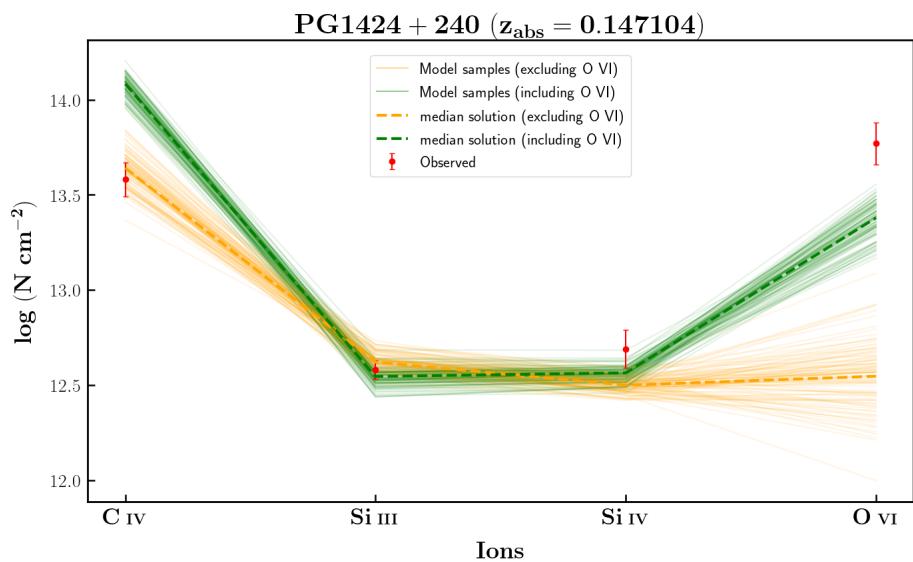


Figure 9:  $N(\text{H I})=14.88$

## Non-detections

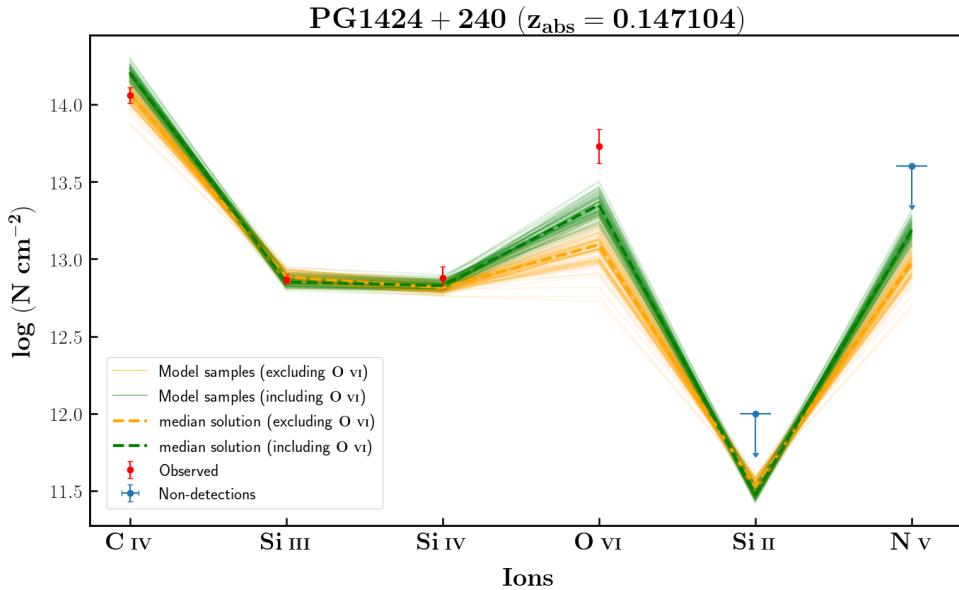


Figure 10:  $N(\text{H I}) = 15.44$ ,  $\log Z_{\text{ref}} = -1$

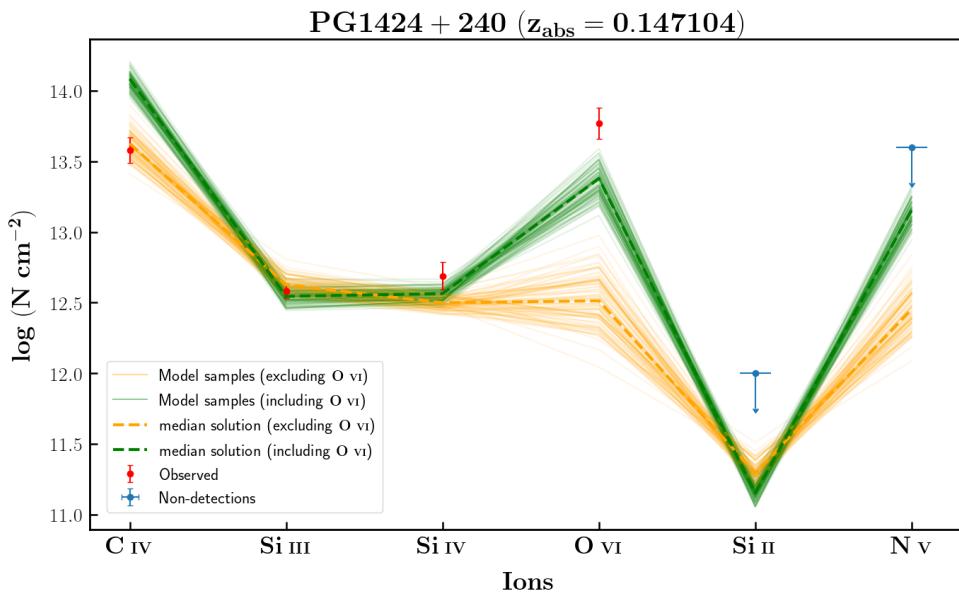
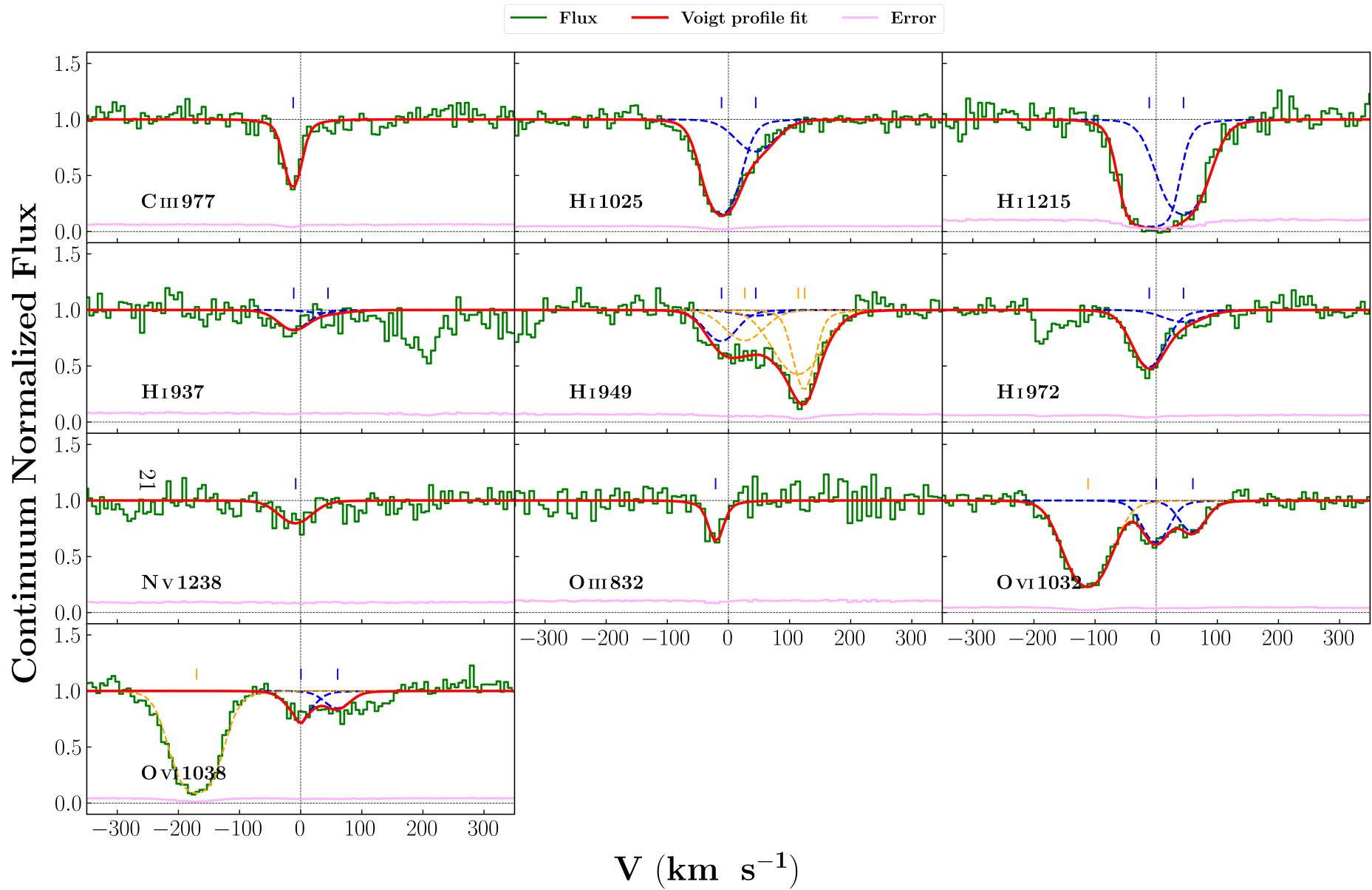


Figure 11:  $N(\text{H I}) = 14.88$ ,  $\log Z_{\text{ref}} = -1$

## Comments

- Smaller  $b$  values 23 and 29 km/s
- All 4 ions couldn't be explained together
- Ions excluding O VI could be explained together for both the components
- Ionisation : CI
- BLA : tentative - small b value but collisionally ionised

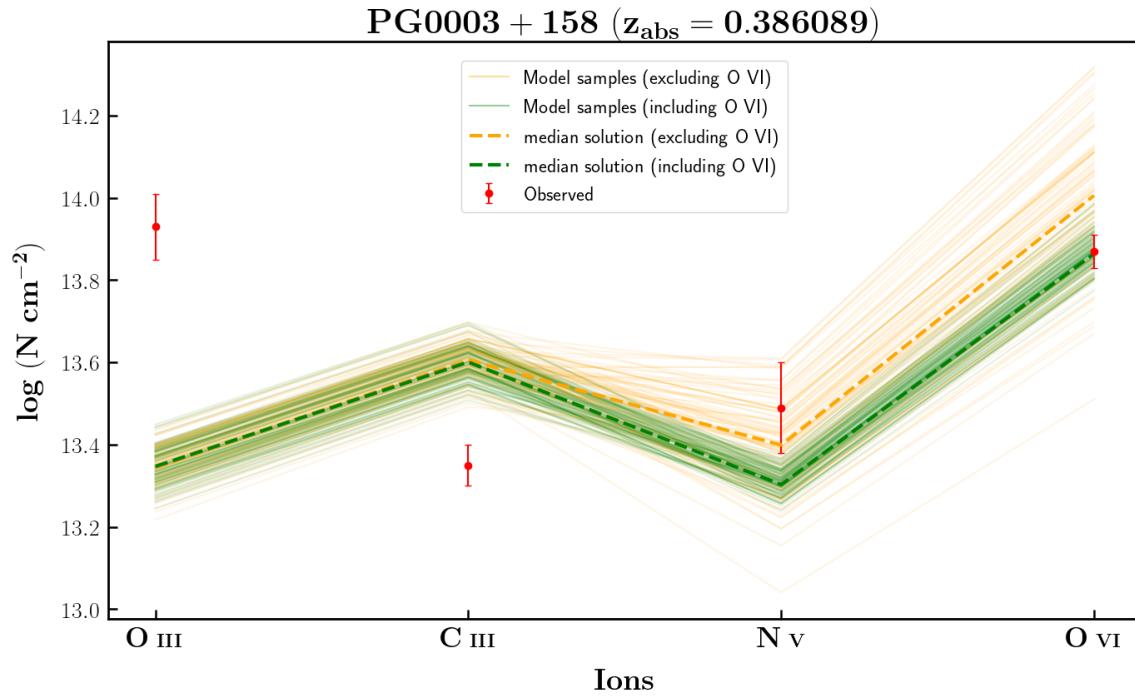
PG0003 + 158 ( $z_{\text{abs}} = 0.386089$ )



Ion	v (km s <sup>-1</sup> )	b (km s <sup>-1</sup> )	log [N cm <sup>-2</sup> ]
O III	-18 ± 2	9 ± 5	13.93 ± 0.08
C III	-11 ± 1	13 ± 2	13.35 ± 0.05
N V	-7 ± 1	33 ± 11	13.49 ± 0.11
O VI	0 ± 2	25 ± 3	13.87 ± 0.04
O VI	54 ± 3	25 ± 4	13.71 ± 0.06
H I	-10 ± 1	29 ± 0	14.81 ± 0.03
H I	40 ± 9	40 ± 4	14.1 ± 0.05

$$N(HI) = 14.81$$

Excluding O VI :  $n_H = -4.12 \pm 0.06$        $Z = -0.65 \pm 0.04$   
 Including O VI :  $n_H = -4.07 \pm 0.02$        $Z = -0.68 \pm 0.03$



## Non-detections

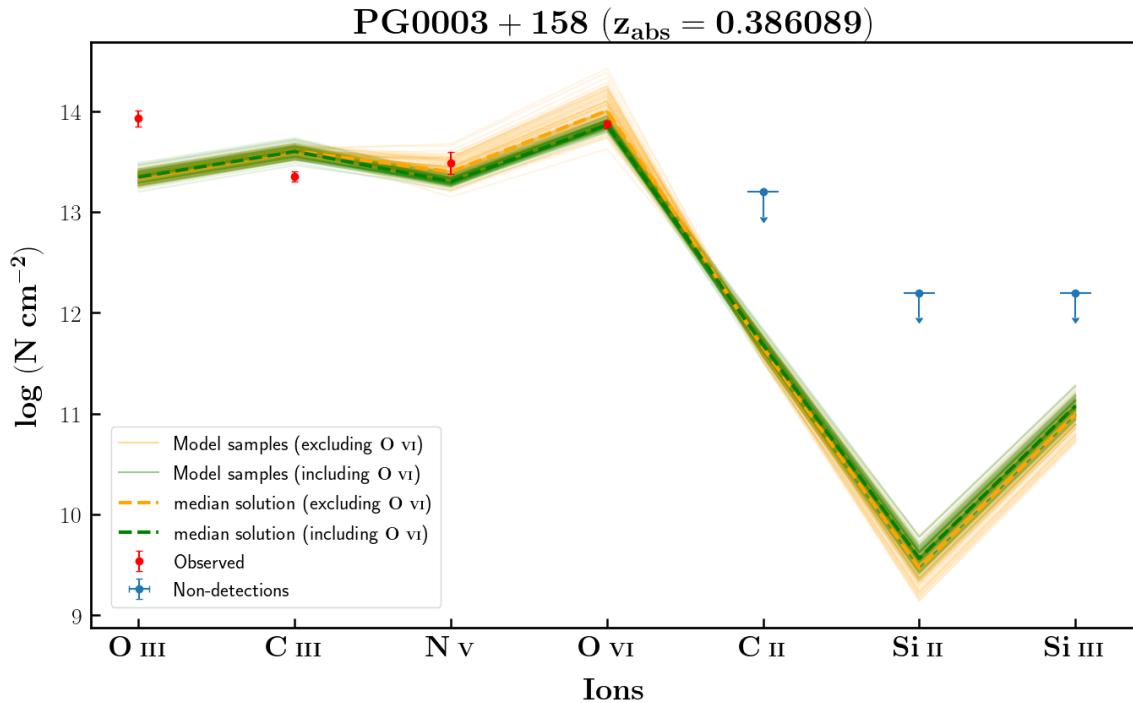
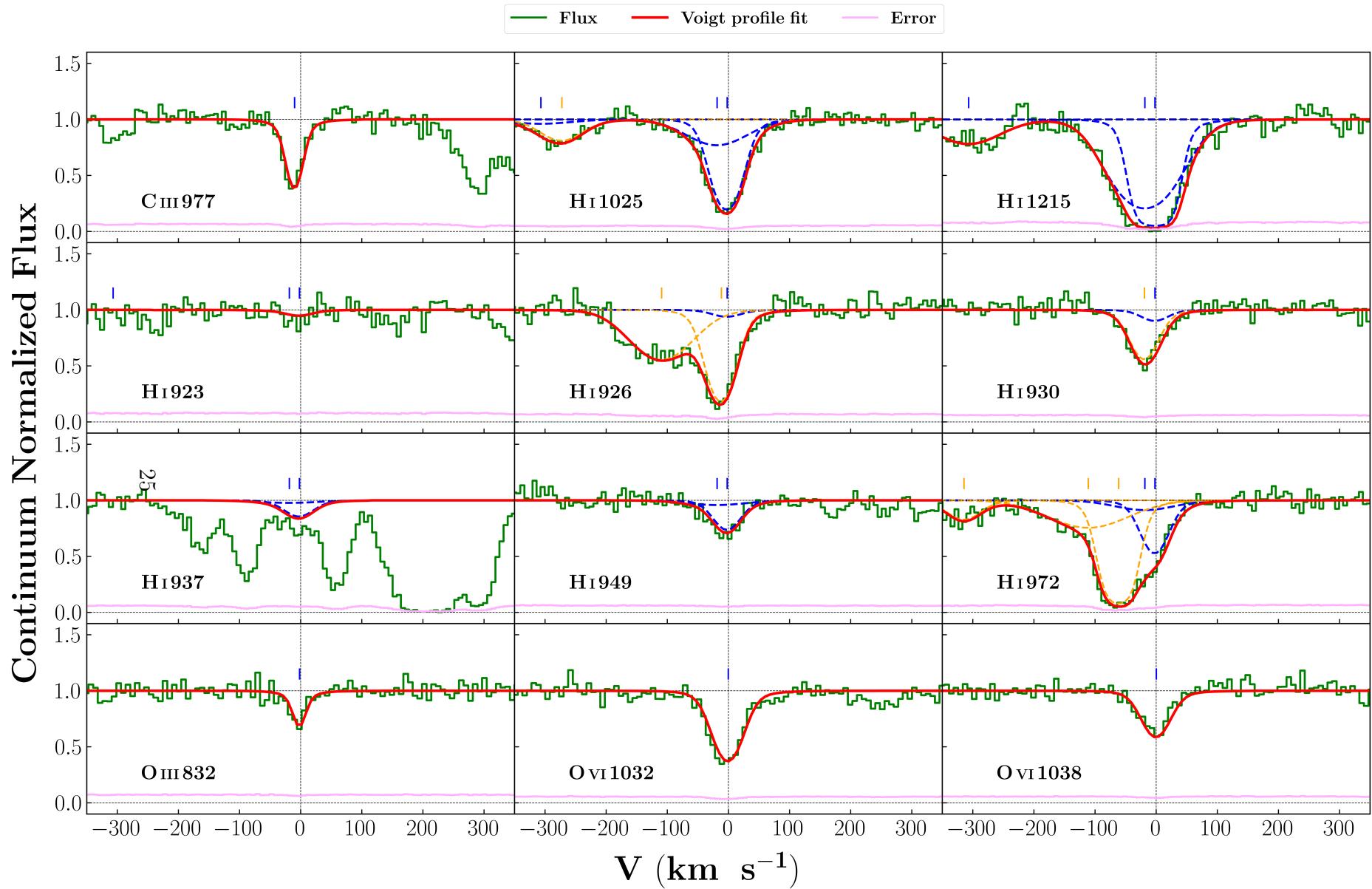


Figure 12:  $N(\text{H I})=14.81$ ,  $\log Z_{\text{ref}}=-1$

## **Comments**

- Not a good solution
- Ionisation : can't comment
- BLA : +ve

PG0003 + 158 ( $z_{\text{abs}} = 0.421923$ )

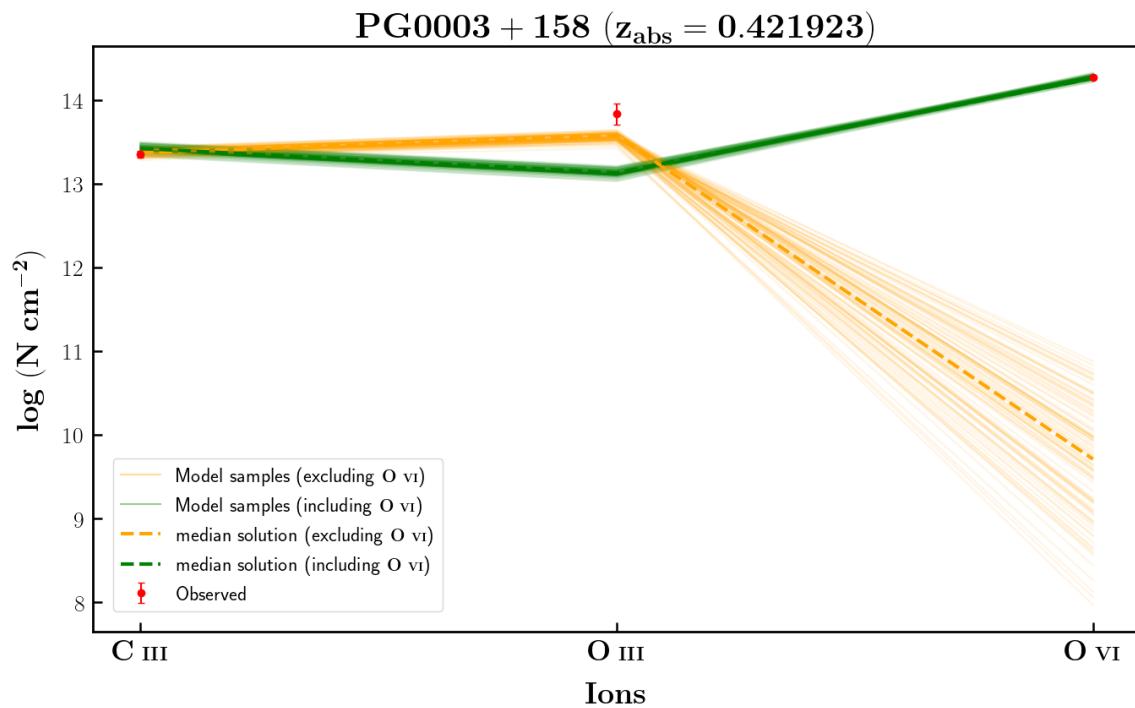


Ion	v (km s <sup>-1</sup> )	b (km s <sup>-1</sup> )	log [N cm <sup>-2</sup> ]
C III	-9 ± 1	13 ± 1	13.35 ± 0.04
O III	-1 ± 2	7 ± 5	13.83 ± 0.13
O VI	0 ± 1	27 ± 1	14.27 ± 0.02
H I	-272 ± 6	66 ± 10	13.37 ± 0.05
H I	-16 ± 1	64 ± 3	14.17 ± 0.04
H I	-2 ± 1	26 ± 1	14.71 ± 0.02

N(H I)=14.17

Excluding O VI :  $n_H = -2.66 \pm 0.22$        $Z = 0.42 \pm 0.23$   
 Including O VI :  $n_H = -4.24 \pm 0.02$        $Z = -0.09 \pm 0.03$

NOTE : Convergence is not good for excluding O VI case



## Non-detections

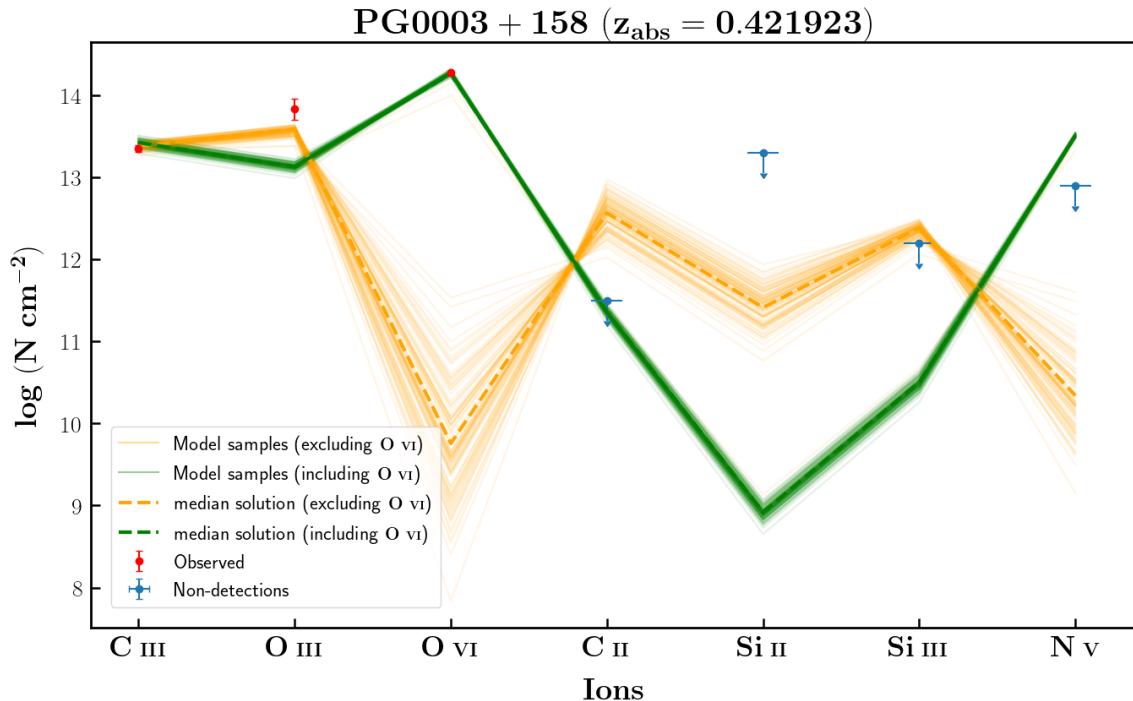
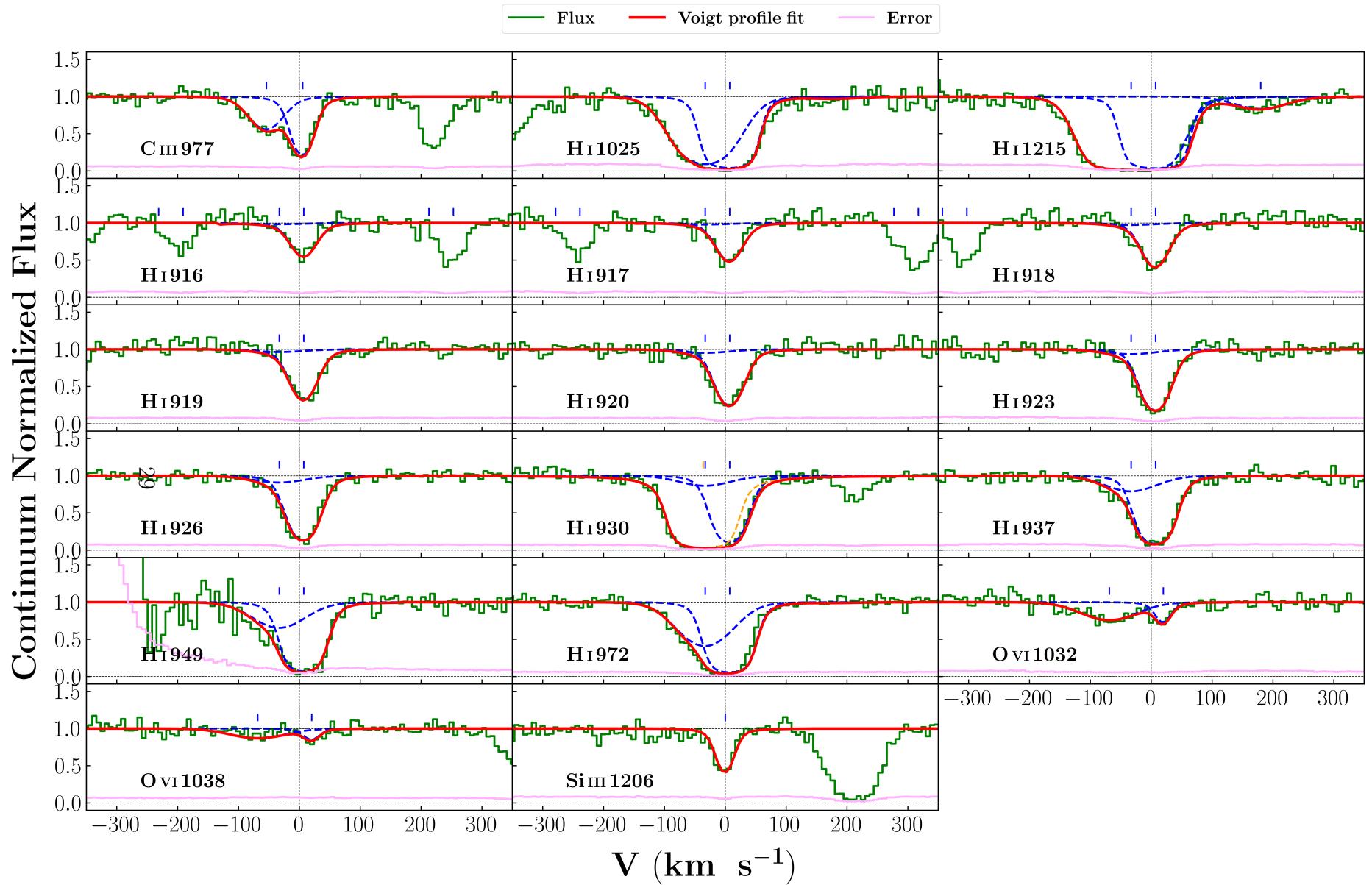


Figure 13:  $\text{N(HI)}=14.17$ ,  $\log Z_{\text{ref}}=-1$

## **Comments**

- All 3 ions couldn't be explained together
- When excluded O VI is heavily underproduced
- Convergence is not good for excluding O VI case
- Ionisation : CI
- BLA : +ve

PG1216 + 069 ( $z_{\text{abs}} = 0.282286$ )



Ion	v (km s <sup>-1</sup> )	b (km s <sup>-1</sup> )	log [N cm <sup>-2</sup> ]
Si III	0 ± 1	14 ± 3	12.92 ± 0.05
C III	-51 ± 3	32 ± 5	13.33 ± 0.05
C III	5 ± 1	16 ± 2	13.76 ± 0.07
O VI	-64 ± 6	58 ± 9	13.93 ± 0.05
O VI	19 ± 2	12 ± 5	13.54 ± 0.09
H I	-31 ± 1	52 ± 3	15.1 ± 0.05
H I	7 ± 1	22 ± 1	16.4 ± 0.03
H I	169 ± 22	53 ± 10	13.15 ± 0.18

N(H I)=15.10

Excluding O VI :  $n_H = -2.13 \pm 0.15$        $Z = 0.65 \pm 0.22$   
 Including O VI :  $n_H = -3.86 \pm 0.02$        $Z = -0.37 \pm 0.03$

NOTE : Convergence is not much good for excluding O VI case

N(H I)=16.40

Excluding O VI :  $n_H = -2.08 \pm 0.43$        $Z = -0.37 \pm 0.59$   
 Including O VI :  $n_H = -3.68 \pm 0.02$        $Z = -1.55 \pm 0.04$

NOTE : Convergence is not much good for excluding O VI case

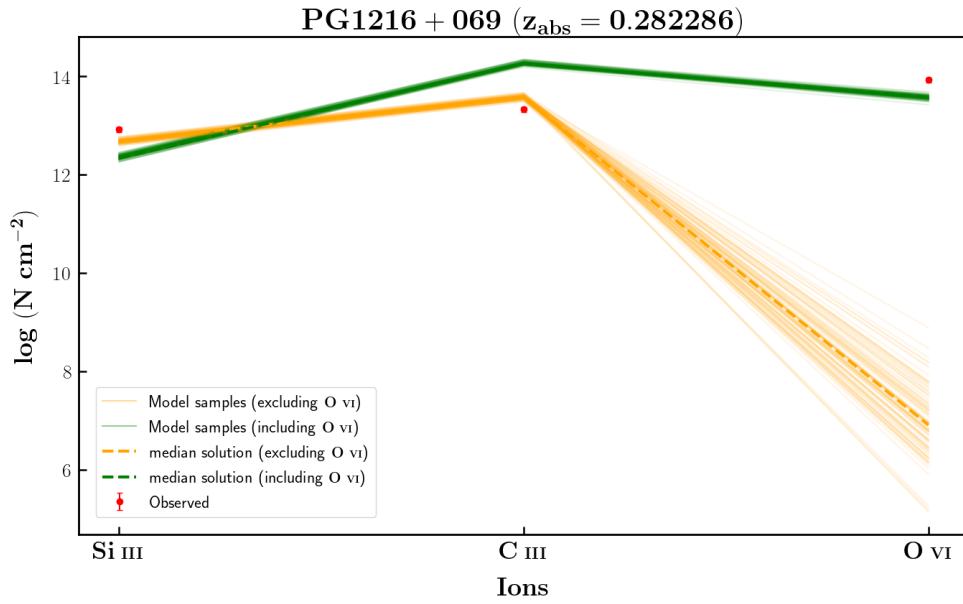


Figure 14:  $N(\text{H I})=15.10$

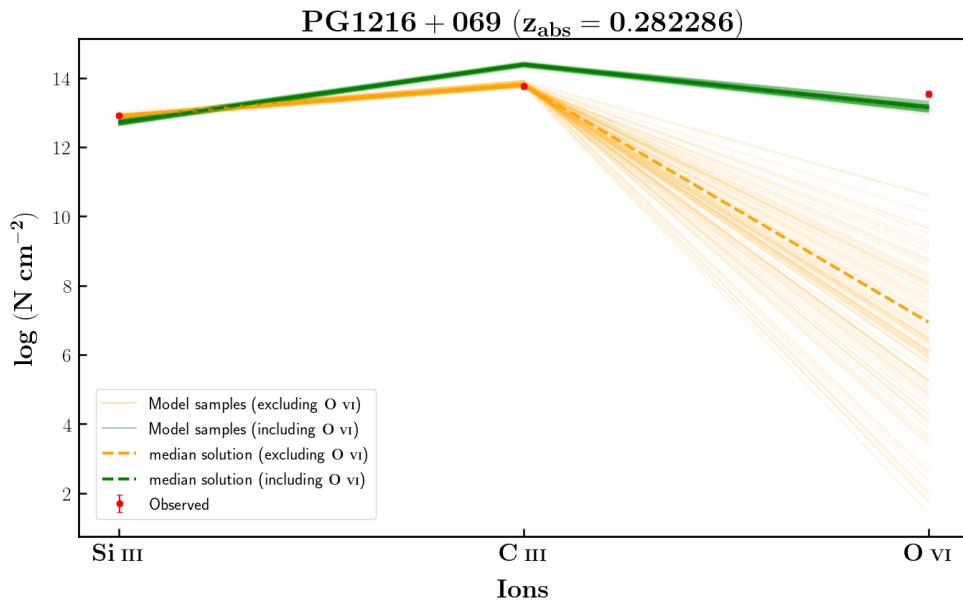


Figure 15:  $N(\text{H I})=16.40$

## Non-detections

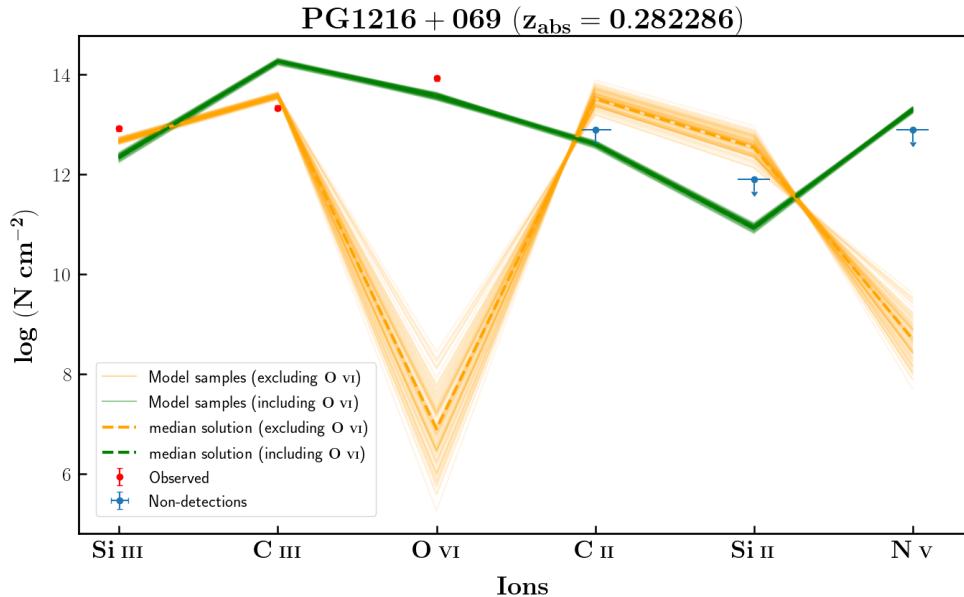


Figure 16:  $N(\text{H I})=15.10$ ,  $\log Z_{ref}=-1$

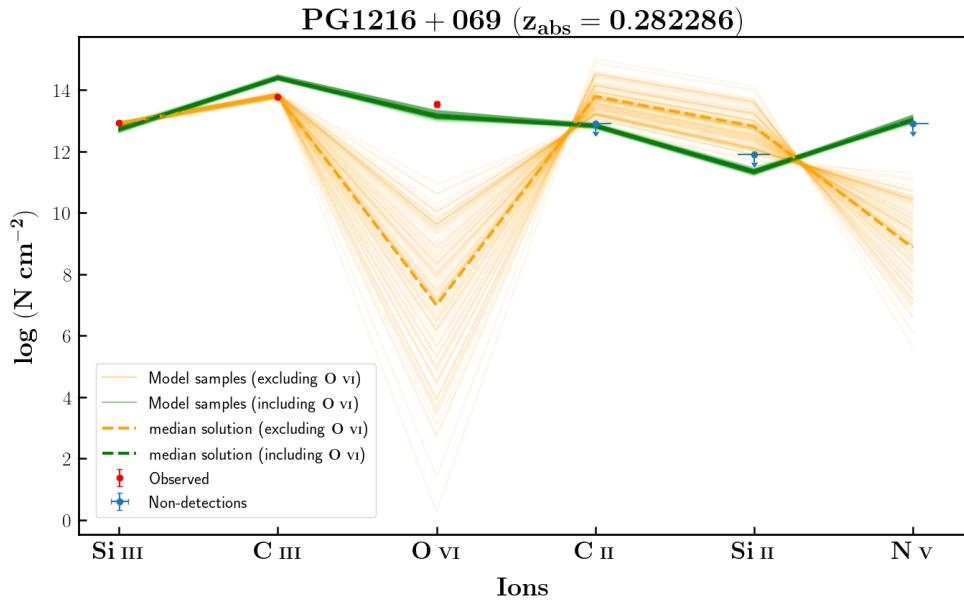
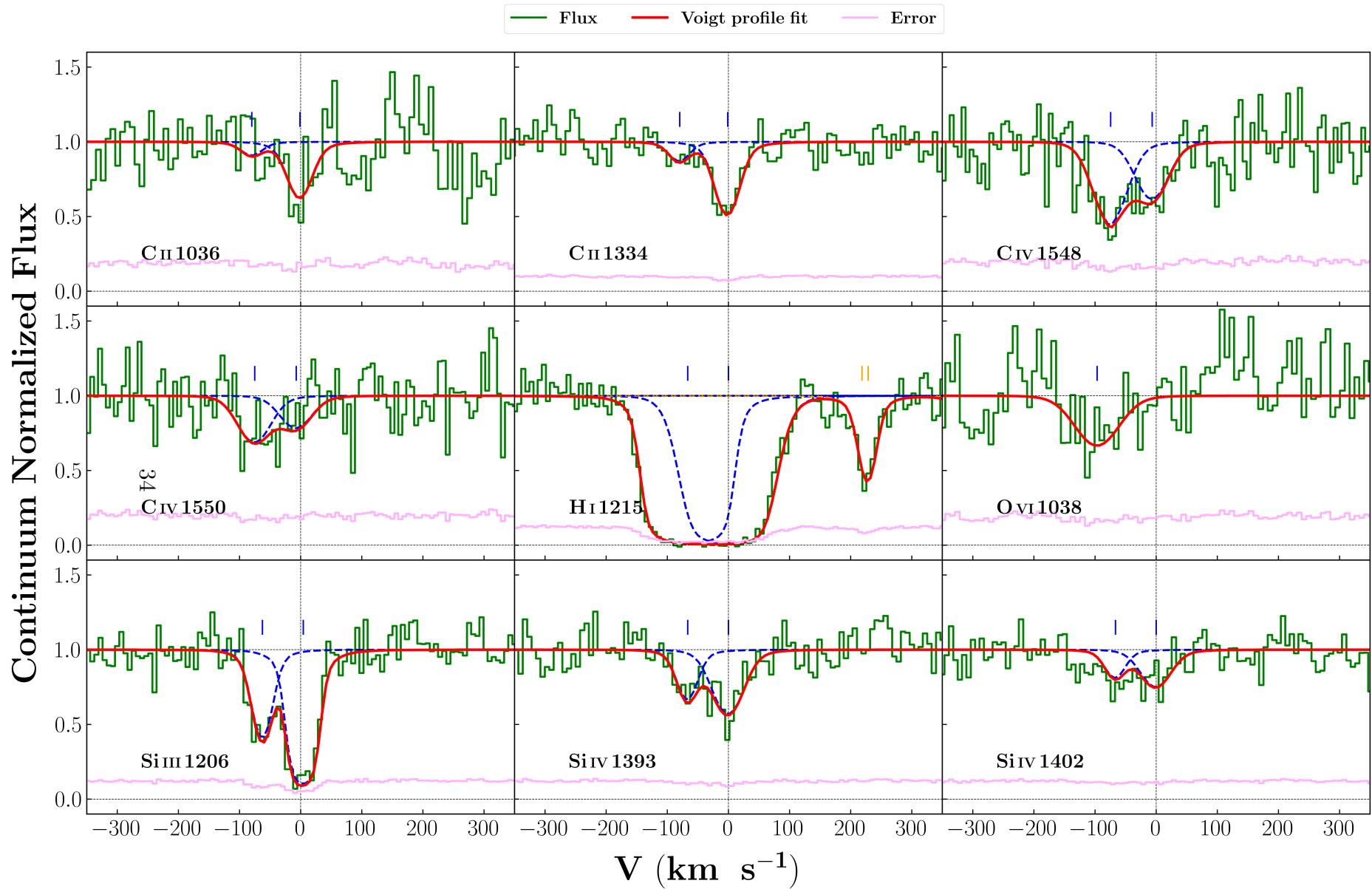


Figure 17:  $N(\text{H I})=16.40$ ,  $\log Z_{ref}=-1$

## Comments

- Results similar for both the components
- All 3 ions couldn't be explained together
- When excluded O VI is heavily underproduced
- Convergence is not much good for excluding O VI case
- Ionisation : CI
- BLA : +ve

SDSSJ135712.61 + 170444 ( $z_{\text{abs}} = 0.097869$ )



Ion	v (km s <sup>-1</sup> )	b (km s <sup>-1</sup> )	log [N cm <sup>-2</sup> ]
Si III	-62 ± 2	17 ± 3	12.94 ± 0.05
Si III	4 ± 1	13 ± 10	14.67 ± 2.87
C IV	-74 ± 6	33 ± 1	13.82 ± 0.09
C IV	-7 ± 8	32 ± 12	13.63 ± 0.12
Si IV	-66 ± 4	18 ± 6	13.02 ± 0.08
Si IV	0 ± 4	29 ± 5	13.3 ± 0.05
C II	-79 ± 8	19 ± 14	13.17 ± 0.16
C II	-1 ± 2	22 ± 3	13.92 ± 0.04
O VI	-96 ± 10	43 ± 16	14.3 ± 0.11
H I	-536 ± 3	29 ± 5	13.36 ± 0.05
H I	-66 ± 0	29 ± 8	16.49 ± 0.12
H I	0 ± 0	46 ± 4	15.01 ± 0.16
H I	424 ± 3	34 ± 4	13.52 ± 0.04

N(H I)=16.49 (log  $Z_{ref}=-1$ )

Excluding O VI : $n_H = -3.76 \pm 0.05$	$Z = -1.49 \pm 0.04$
Including O VI : $n_H = -4.06 \pm 0.02$	$Z = -1.32 \pm 0.04$

N(H I)=15.01

log $Z_{ref}=-1$	
Excluding O VI : $n_H = -3.25 \pm 0.04$	$Z = 0.93 \pm 0.04$
Including O VI : $n_H = -3.84 \pm 0.03$	$Z = 0.75 \pm 0.03$

log $Z_{ref}=1$	
Excluding O VI : $n_H = -3.7 \pm 0.03$	$Z = 1.35 \pm 0.04$
Including O VI : $n_H = -4.30 \pm 0.03$	$Z = 1.00 \pm 0.03$

NOTE : Using O VI column density from other component to compare.

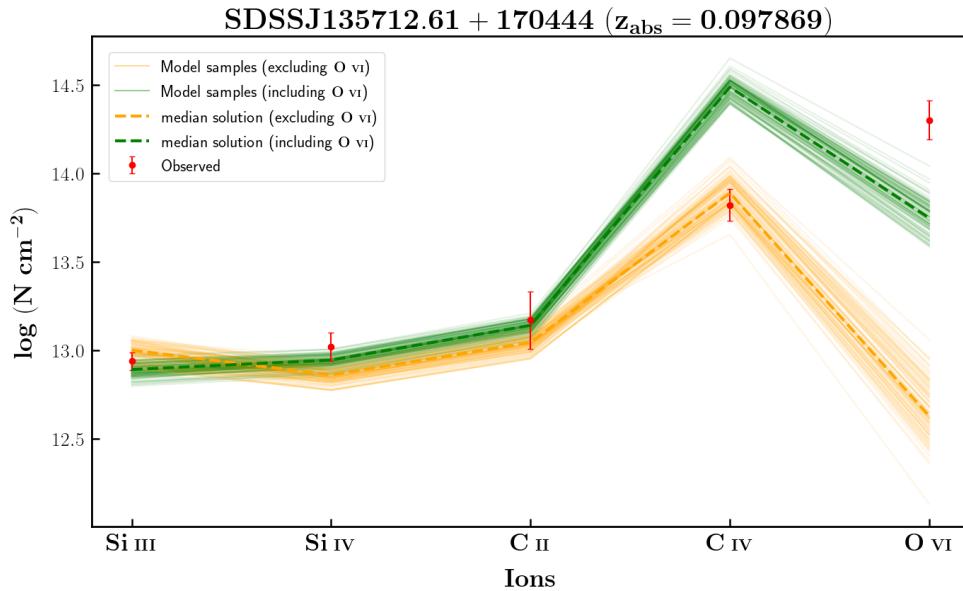


Figure 18:  $N(\text{H I})=16.49$ ,  $\log Z_{\text{ref}}=-1$

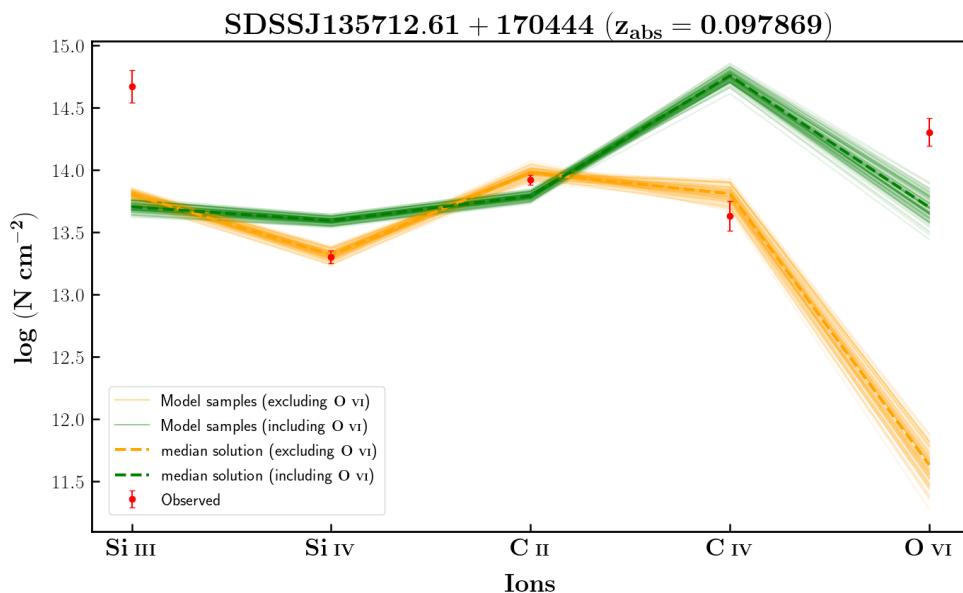


Figure 19:  $N(\text{H I})=15.01$ ,  $\log Z_{\text{ref}}=-1$

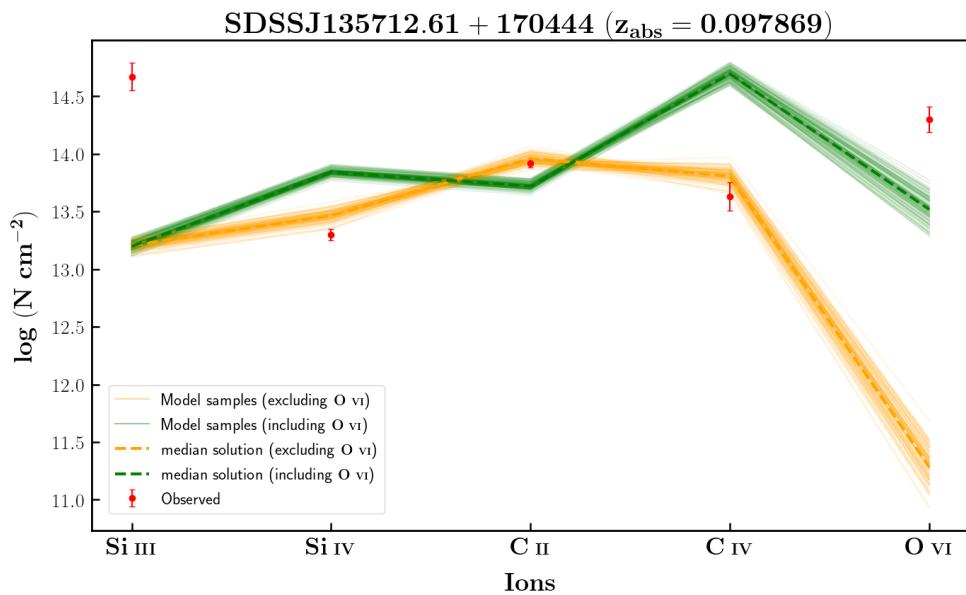


Figure 20:  $\text{N(H I)}=15.01$ ,  $\log Z_{\text{ref}}=1$

## Non-detections

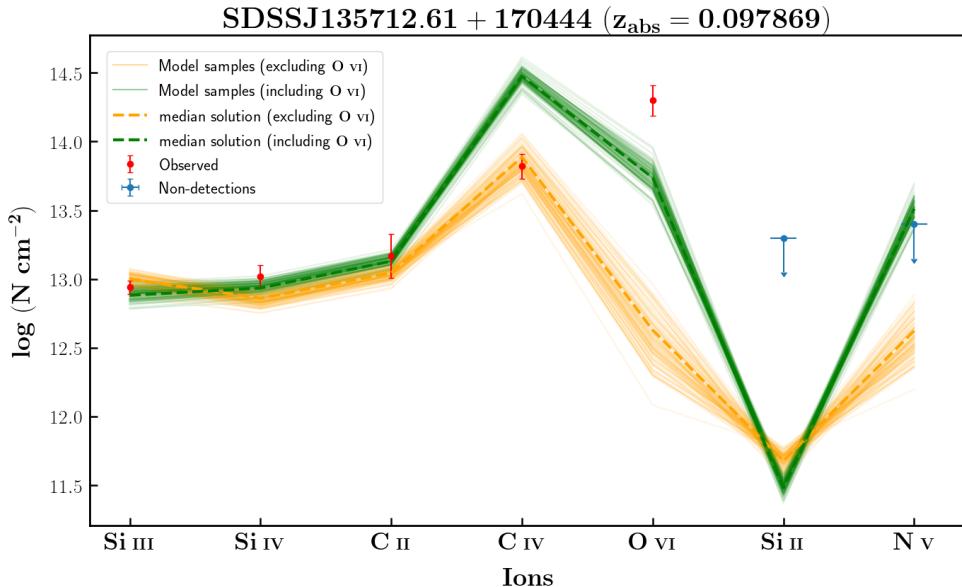


Figure 21:  $\text{N(H I)}=16.49$ ,  $\log Z_{\text{ref}}=-1$

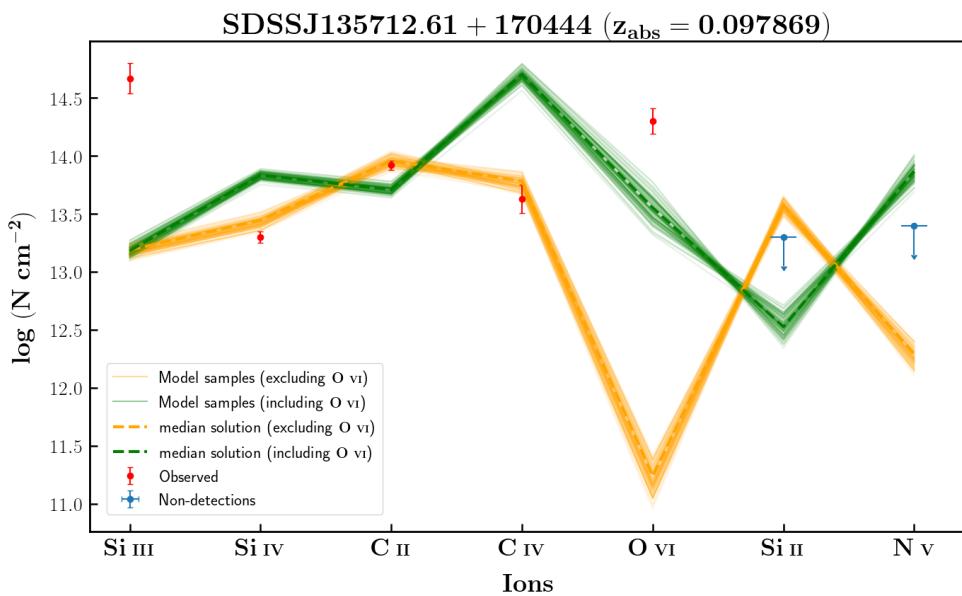
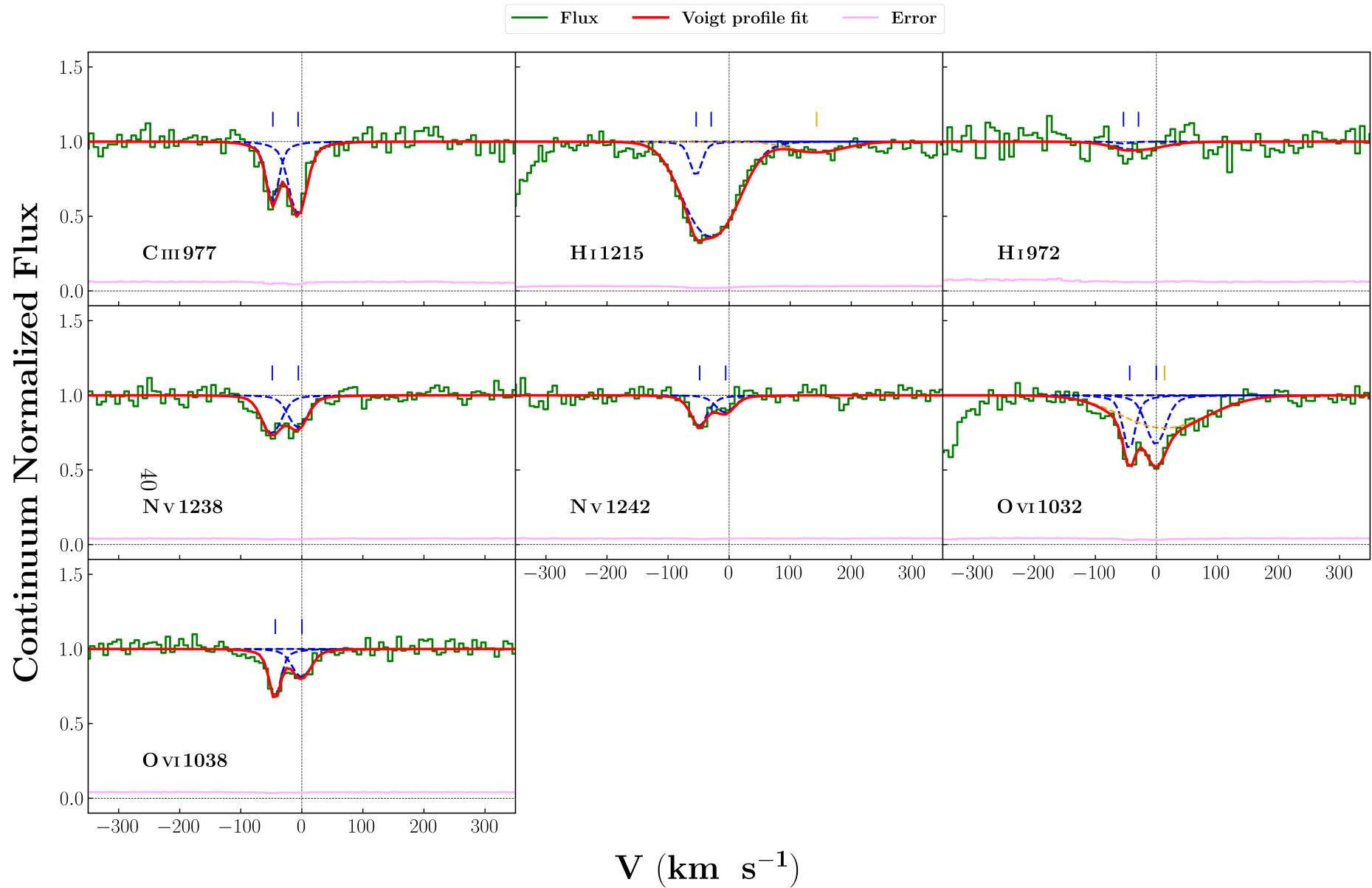


Figure 22:  $\text{N(H I)}=15.01$ ,  $\log Z_{\text{ref}}=1$

## Comments

- Good solution II component ( $N(H\ I)=16.49$ ) : small  $b$  value - 29 km/s
- All other 4 ions could be explained together except O VI
- When excluded O VI is heavily underproduced
- For III component ( $N(H\ I)=15.01$ ), model can't predict column density of Si III for the excluding O VI case.
- Ionisation : CI
- BLA : +ve

1ES1553 + 113 ( $z_{\text{abs}} = 0.187764$ )



Ion	v (km s <sup>-1</sup> )	b (km s <sup>-1</sup> )	log [N cm <sup>-2</sup> ]
C III	-46 ± 1	5 ± 4	13.17 ± 0.46
C III	-6 ± 1	13 ± 2	13.21 ± 0.03
N V	-47 ± 2	17 ± 0	13.43 ± 0.05
N V	-5 ± 2	16 ± 4	13.33 ± 0.06
O VI	-42 ± 1	3 ± 1	14.23 ± 0.33
O VI	0 ± 1	15 ± 3	13.71 ± 0.03
O VI	511 ± 3	28 ± 5	13.49 ± 0.05
H I	-52 ± 3	8 ± 6	12.76 ± 0.15
H I	-28 ± 1	51 ± 1	13.88 ± 0.01
H I	425 ± 3	25 ± 5	13.02 ± 0.07
H I	496 ± 2	37 ± 3	13.46 ± 0.03

N(H I)=12.76

Excluding O VI :  $n_H = -4.62 \pm 0.04$        $Z = 1.37 \pm 0.06$   
 Including O VI :  $n_H = -4.63 \pm 0.03$        $Z = 1.37 \pm 0.06$

NOTE : Reference metallicity at log Z = 1. Low N(H I), and error for column density for C III and O VI for component I were obtained from  $\chi^2$ , else they were large and convergence was not good. Nearly similar solution for both the cases.

N(H I)=13.88

Excluding O VI :  $n_H = -4.6 \pm 0.04$        $Z = 0.03 \pm 0.03$   
 Including O VI :  $n_H = -4.44 \pm 0.02$        $Z = -0.06 \pm 0.02$

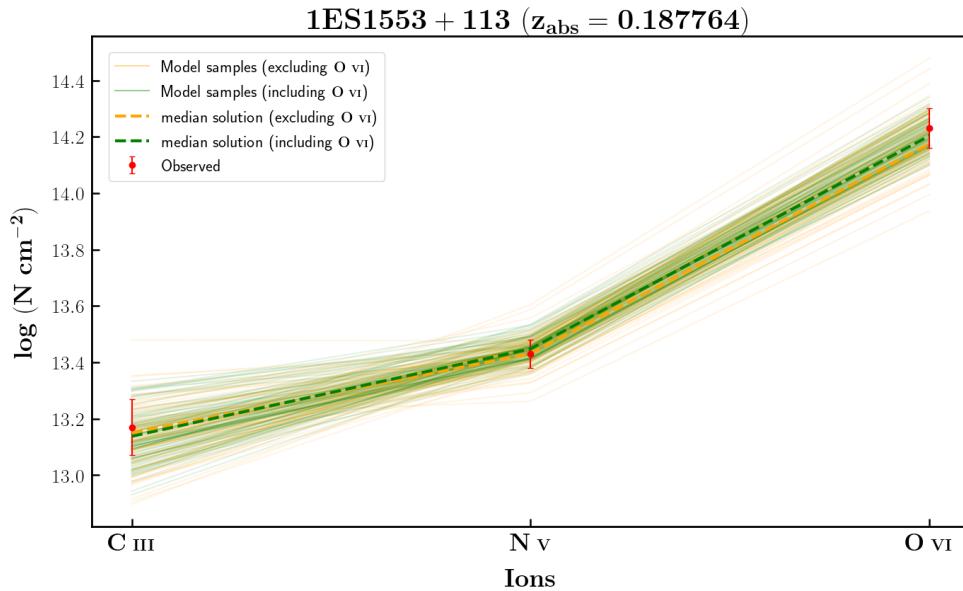


Figure 23:  $\text{N(HI)}=12.76$

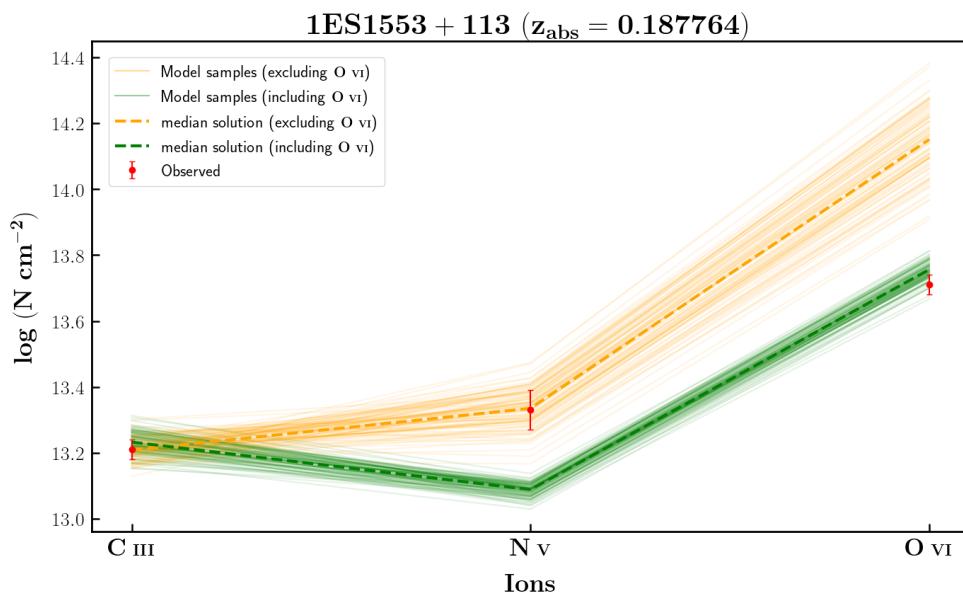


Figure 24:  $\text{N(HI)}=13.88$

## Non-detections

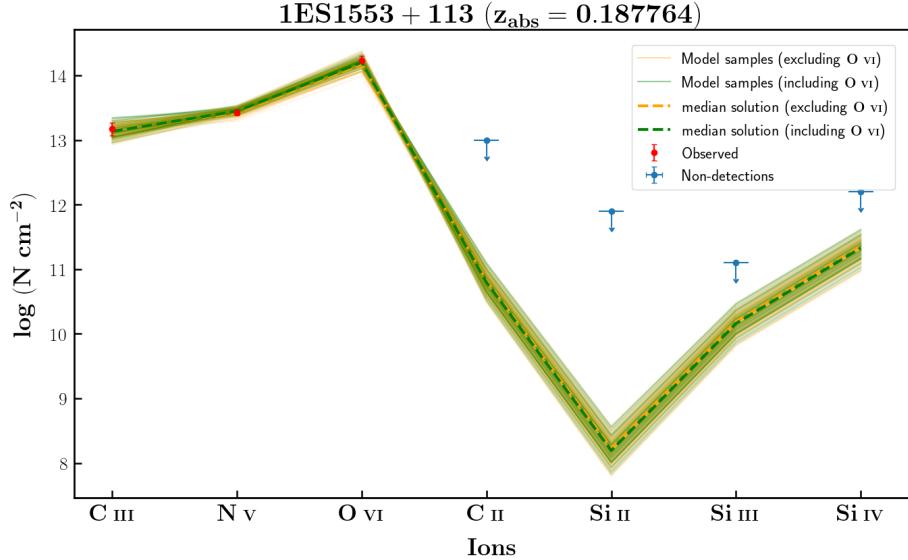


Figure 25:  $\text{N(H I)}=12.76$ ,  $\log Z_{\text{ref}}=1$

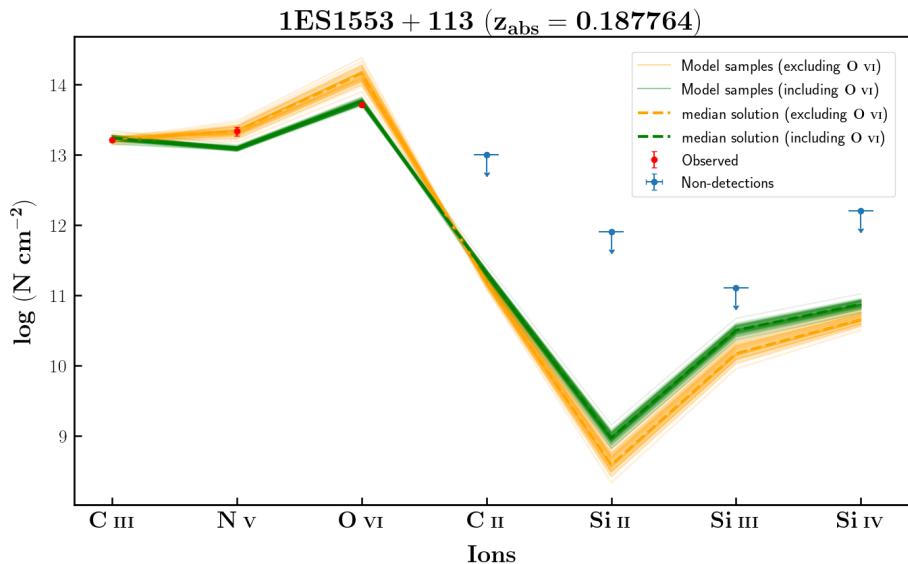
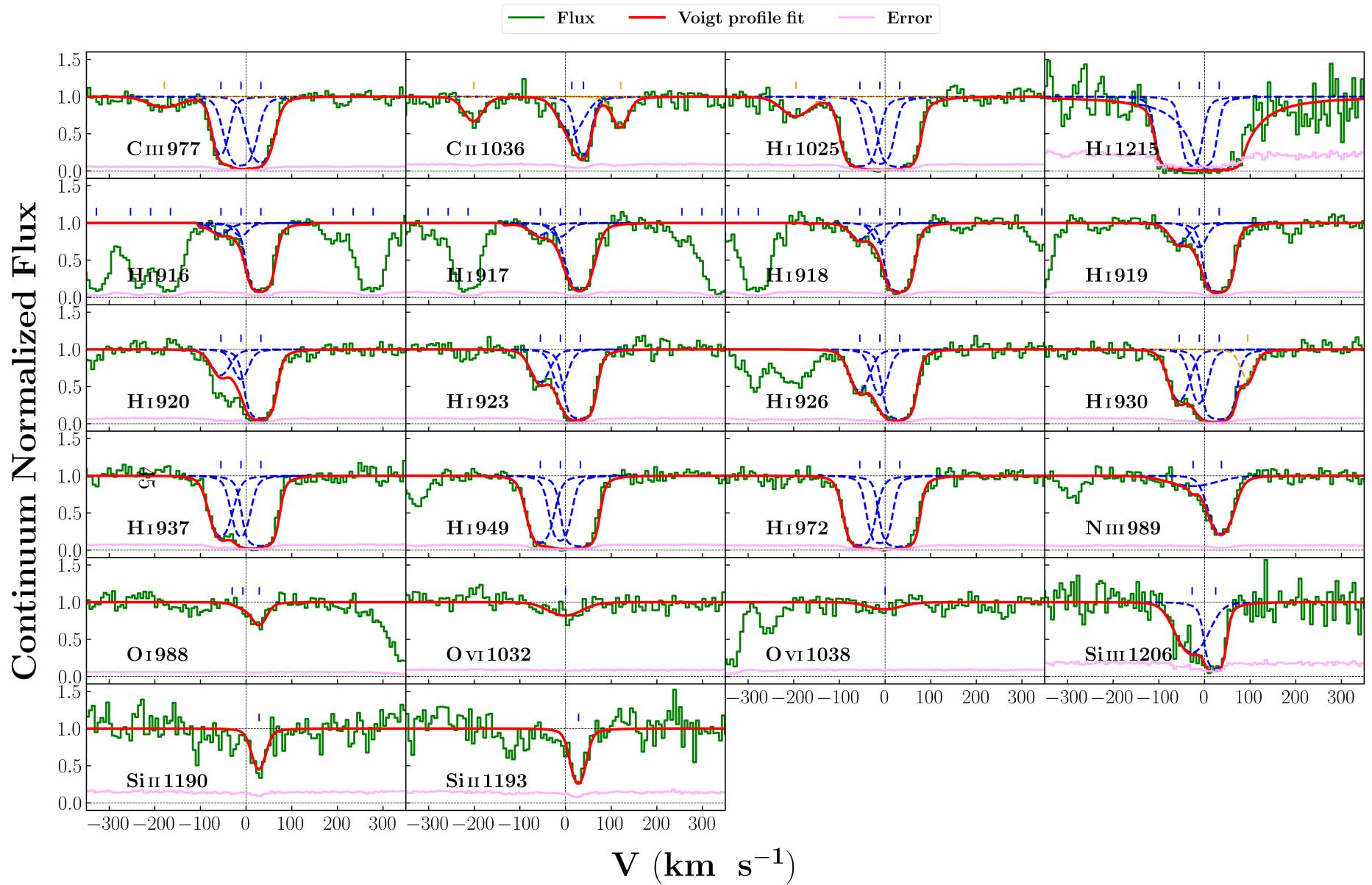


Figure 26:  $\text{N(H I)}=13.88$ ,  $\log Z_{\text{ref}}=-1$

## Comments

- Same solution for I component ( $N(H\ I)=12.76$ ) : all ions explained in both the cases : PI
- For II component ( $N(H\ I)=13.02$ ), all 3 ions couldn't be explained together, O VI is overproduced.
- Ionisation : PI in component I and CI for component II
- BLA : +ve

# SBS1108 + 560 ( $z_{\text{abs}} = 0.463207$ )



Ion	v (km s <sup>-1</sup> )	b (km s <sup>-1</sup> )	log [N cm <sup>-2</sup> ]
O I	25 ± 2	18 ± 4	14.13 ± 0.05
Si III	-23 ± 9	39 ± 12	13.26 ± 0.12
Si III	21 ± 2	13 ± 15	14.61 ± 0.24
C II	12 ± 9	31 ± 4	14.15 ± 0.05
C II	34 ± 2	12 ± 5	14.67 ± 0.1
C III	-48 ± 3	15 ± 1	13.66 ± 0.08
C III	-10 ± 3	26 ± 7	14.16 ± 0.07
C III	28 ± 3	24 ± 1	13.95 ± 0.05
N III	-22 ± 59	67 ± 61	13.77 ± 0.1
N III	32 ± 2	26 ± 4	14.49 ± 0.09
Si II	25 ± 1	15 ± 1	13.57 ± 0.08
O VI	0 ± 6	45 ± 10	13.71 ± 0.07
H I	-48 ± 0	22 ± 2	15.77 ± 0.02
H I	-10 ± 2	16 ± 0	15.79 ± 0.11
H I	28 ± 1	16 ± 1	18.1 ± 0.12

log  $Z_{ref} = -1$   
 $N(HI) = 18.10$

Excluding O VI :  $n_H = -1.88 \pm 0.03$        $Z = 1.07 \pm 0.04$   
 Including O VI :  $n_H = -2.83 \pm 0.02$        $Z = 0.89 \pm 0.03$

NOTE : Using O VI from other component to compare

$N(HI) = 15.79$

Excluding O VI :  $n_H = -2.65 \pm 0.22$        $Z = 1.6 \pm 0.22$   
 Including O VI :  $n_H = -3.56 \pm 0.03$        $Z = 1.16 \pm 0.05$

log  $Z_{ref} = 1$   
 $N(HI) = 18.10$

Excluding O VI :  $n_H = -2.55 \pm 0.03$        $Z = -0.83 \pm 0.04$   
Including O VI :  $n_H = -3.49 \pm 0.01$        $Z = -0.92 \pm 0.03$

N(H I)=15.79

Excluding O VI :  $n_H = -3.33 \pm 0.10$        $Z = -0.02 \pm 0.12$   
Including O VI :  $n_H = -3.99 \pm 0.02$        $Z = -0.44 \pm 0.05$

NOTE : With  $\log Z_{ref} = 1$ , logZ is coming -ve for both the components

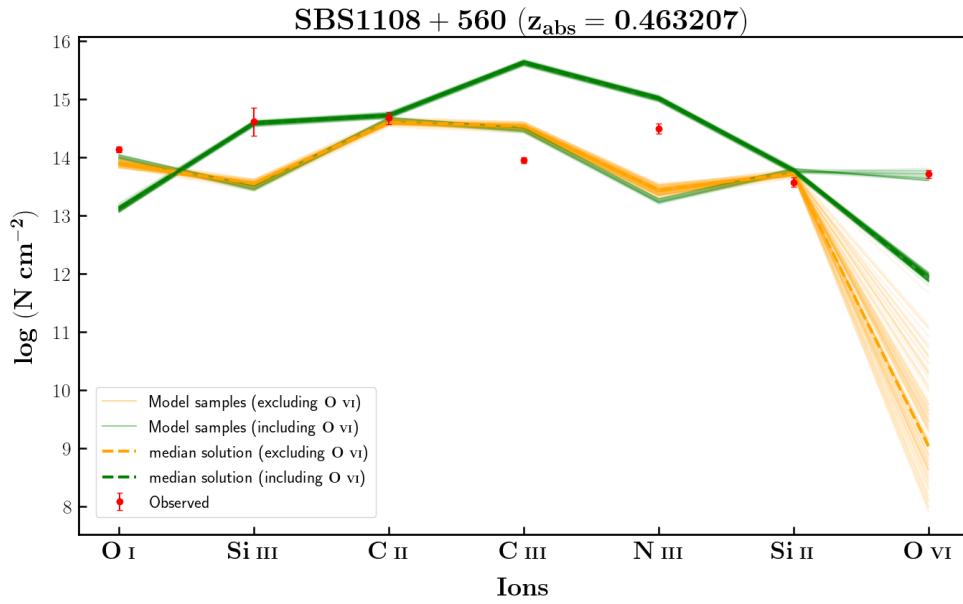


Figure 27:  $\text{N(HI)}=18.10$ ,  $\log Z_{\text{ref}}=-1$

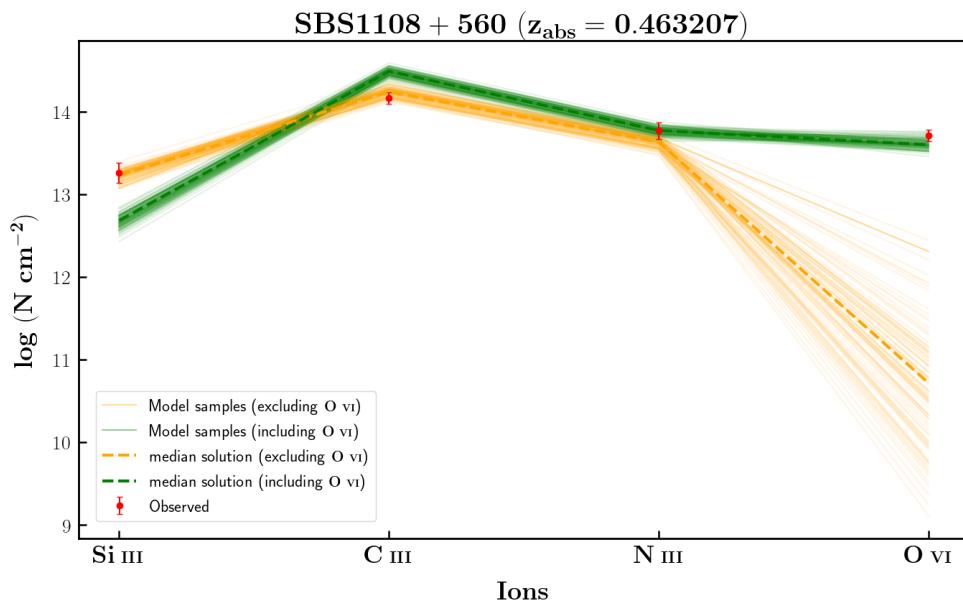


Figure 28:  $\text{N(HI)}=15.79$ ,  $\log Z_{\text{ref}}=-1$

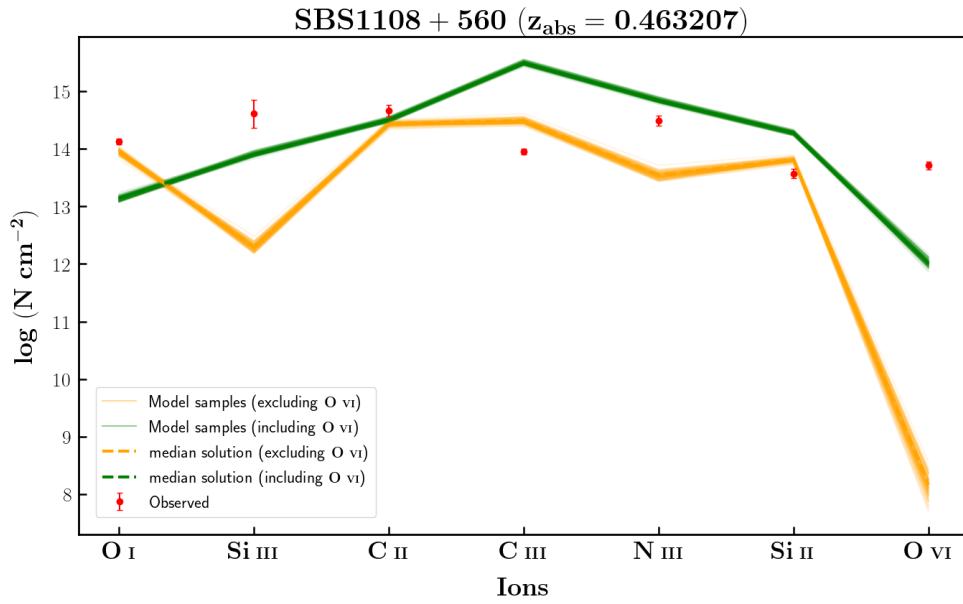


Figure 29:  $\text{N(HI)}=18.10$ ,  $\log Z_{\text{ref}}=1$

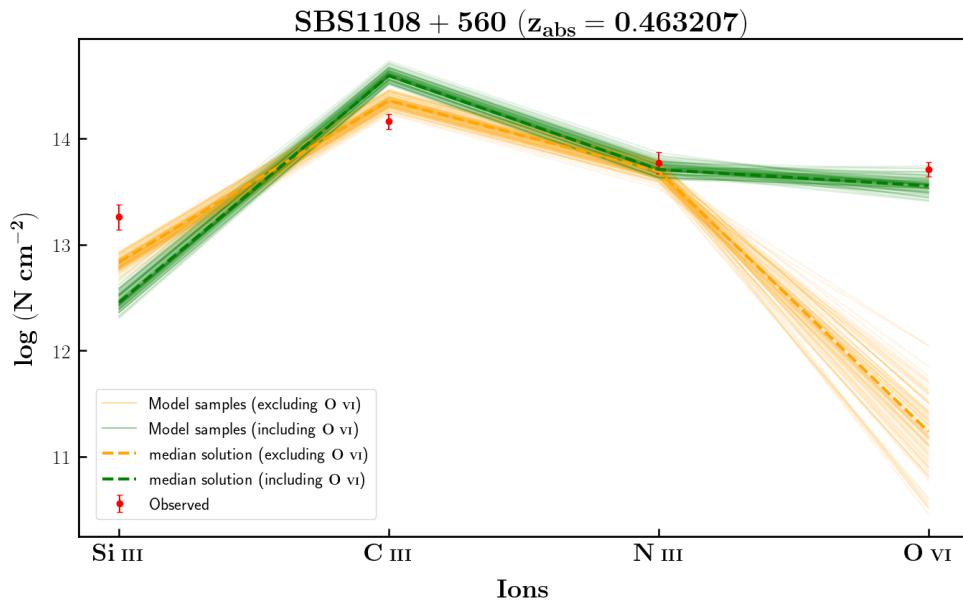
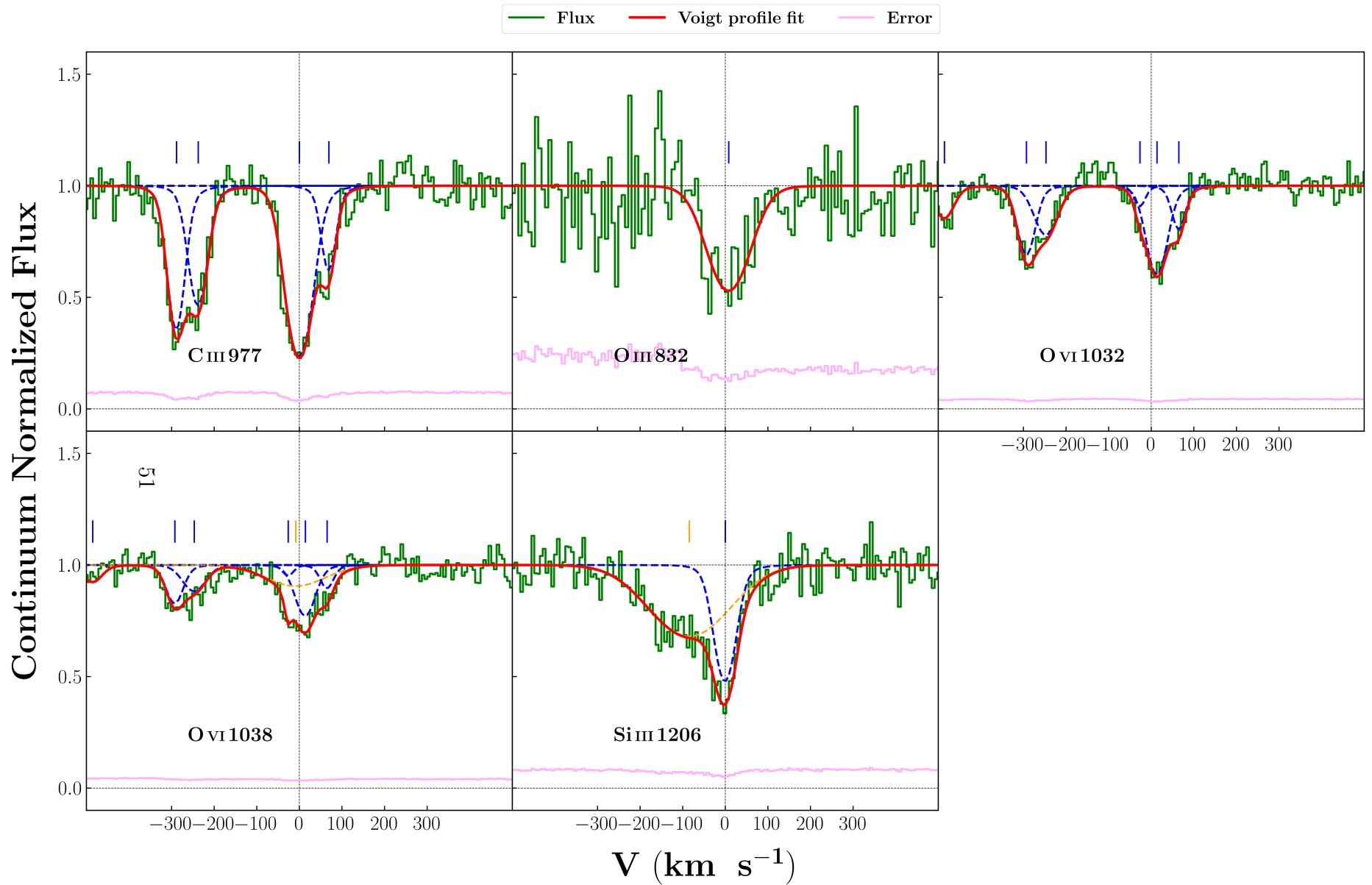


Figure 30:  $\text{N(HI)}=15.79$ ,  $\log Z_{\text{ref}}=1$

## Comments

- Smaller  $b$  values for all 3 components
- Not much good solution for component III ((N(H I)=18.10)), as there are many ions. Only few can be explained.
- Modelled using both logZ=-1 and logZ=1 for both the components
- For component II ((N(H I)=15.79)), when using logZ=1 model, the metallicity is coming -ve. And the solution is better when logZ=-1 model is used.
- Ionisation : CI
- BLA : tentative

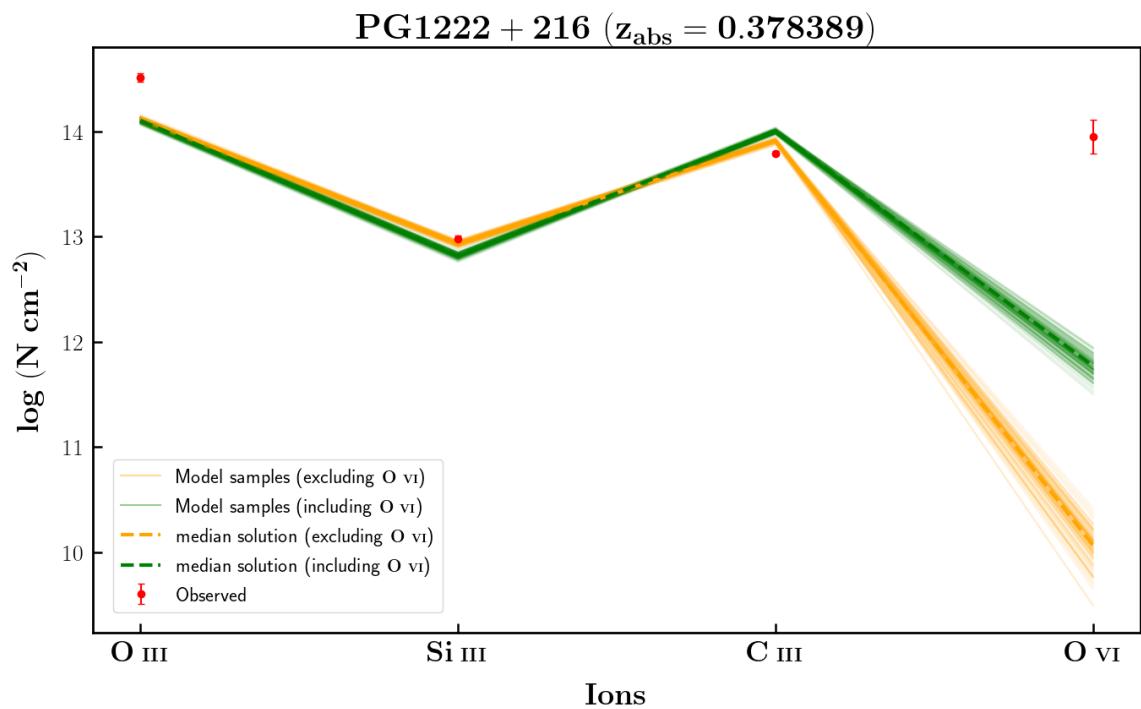
PG1222 + 216 ( $z_{\text{abs}} = 0.378389$ )



Ion	v (km s <sup>-1</sup> )	b (km s <sup>-1</sup> )	log [N cm <sup>-2</sup> ]
O III	7 ± 5	61 ± 8	14.51 ± 0.04
Si III	0 ± 2	30 ± 3	12.98 ± 0.03
C III	-261 ± 3	17 ± 5	13.54 ± 0.06
C III	-215 ± 5	22 ± 6	13.40 ± 0.08
C III	0 ± 2	32 ± 3	13.79 ± 0.02
C III	63 ± 3	13 ± 6	13.12 ± 0.07
O VI	-439 ± 3	28 ± 5	13.42 ± 0.06
O VI	-264 ± 6	24 ± 6	13.75 ± 0.2
O VI	-223 ± 14	34 ± 13	13.68 ± 0.24
O VI	-24 ± 12	14 ± 18	13.00 ± 0.11
O VI	13 ± 4	29 ± 13	13.95 ± 0.16
O VI	59 ± 6	18 ± 7	13.42 ± 0.23
H I	-455 ± 3	26 ± 4	13.40 ± 0.06
H I	-353 ± 9	64 ± 19	13.54 ± 0.11
H I	-268 ± 1	16 ± 6	13.70 ± 0.14
H I	-227 ± 5	52 ± 4	14.34 ± 0.05
H I	-27 ± 2	23 ± 1	14.73 ± 0.08
H I	31 ± 2	43 ± 1	15.43 ± 0.04

$$N(HI) = 15.43$$

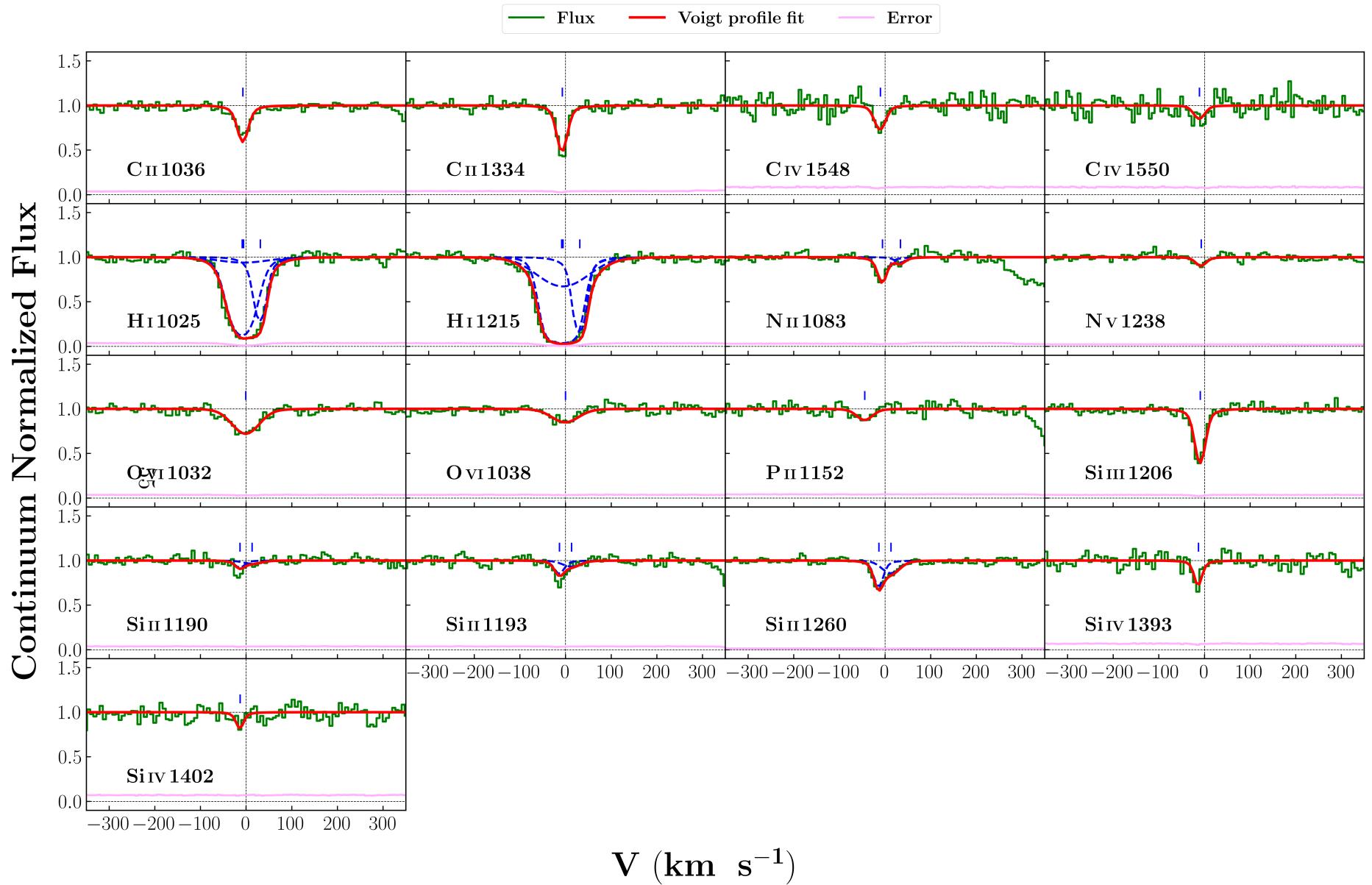
Excluding O VI : $n_H = -2.66 \pm 0.05$	Z = $-0.25 \pm 0.06$
Including O VI : $n_H = -3.16 \pm 0.03$	Z = $-0.66 \pm 0.02$



## Comments

- All ions couldn't be explained together
- When excluded, O VI is underproduced. However, column density of O III is also off by around 0.5 dex from predicted value
- Ionisation : CI
- BLA : +ve

PG1116 + 215 ( $z_{\text{abs}} = 0.138527$ )



Ion	v (km s <sup>-1</sup> )	b (km s <sup>-1</sup> )	log [N cm <sup>-2</sup> ]
N V	-7 ± 3	12 ± 6	12.84 ± 0.09
N II	-5 ± 1	6 ± 3	13.62 ± 0.11
N II	33 ± 6	8 ± 13	12.85 ± 0.15
P II	-44 ± 5	19 ± 8	12.94 ± 0.09
Si II	-13 ± 1	9 ± 1	12.46 ± 0.06
Si II	13 ± 1	23 ± 3	12.31 ± 0.04
Si III	-9 ± 1	10 ± 1	12.92 ± 0.04
Si IV	-13 ± 2	4 ± 3	12.84 ± 0.09
O VI	-1 ± 1	35 ± 3	13.84 ± 0.02
C IV	-10 ± 3	13 ± 4	13.17 ± 0.07
C II	-7 ± 1	9 ± 1	13.85 ± 0.04
H I	-8 ± 3	27 ± 2	14.97 ± 0.05
H I	-5 ± 9	71 ± 14	13.6 ± 0.23
H I	31 ± 2	6 ± 2	16.04 ± 1.77

N(H I)=13.60

$\log Z_{ref} = -1$

Excluding O VI : $n_H = -3.24 \pm 0.03$	$Z = 1.92 \pm 0.03$
Including O VI : $n_H = -3.88 \pm 0.01$	$Z = 1.87 \pm 0.02$

$\log Z_{ref} = 1$

Excluding O VI : $n_H = -3.92 \pm 0.02$	$Z = 2.0 \pm 0.0$
Including O VI : $n_H = -4.35 \pm 0.0$	$Z = 2.0 \pm 0.0$

NOTE : logZ coming near 2 for both the cases and for logZ=1 also, P II is not included

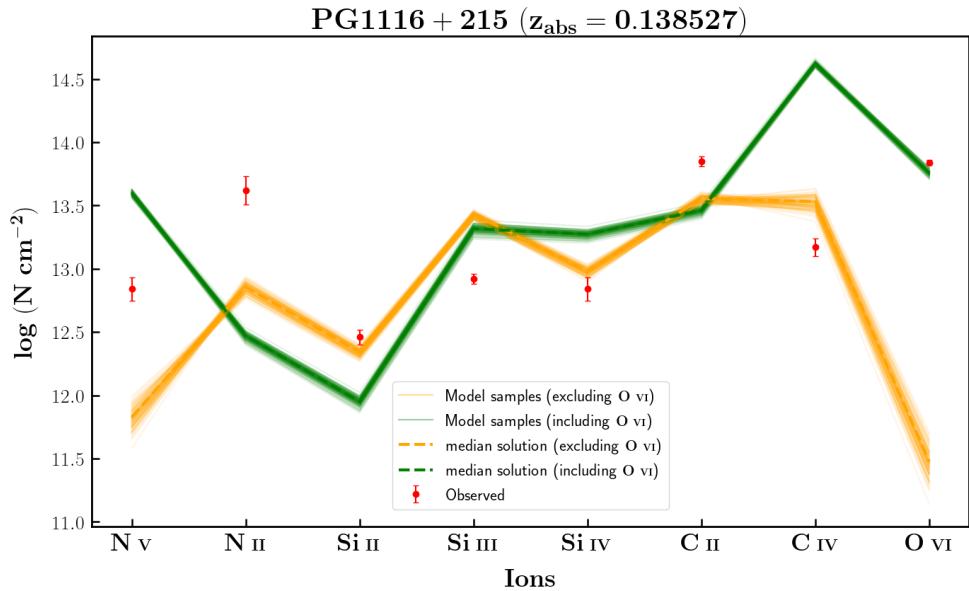


Figure 31:  $\text{N(HI)}=13.60$ ,  $\log Z_{\text{ref}} = -1$

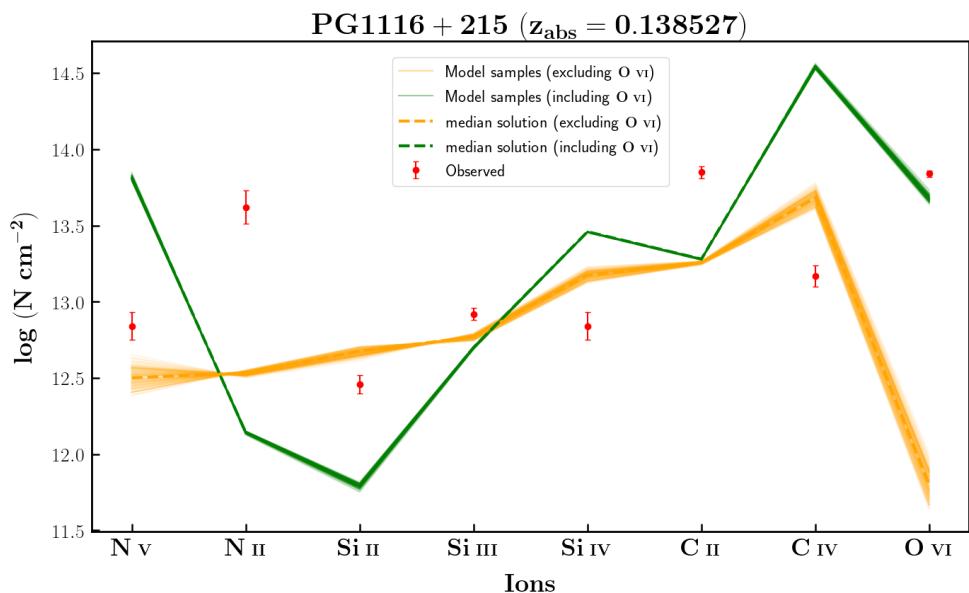
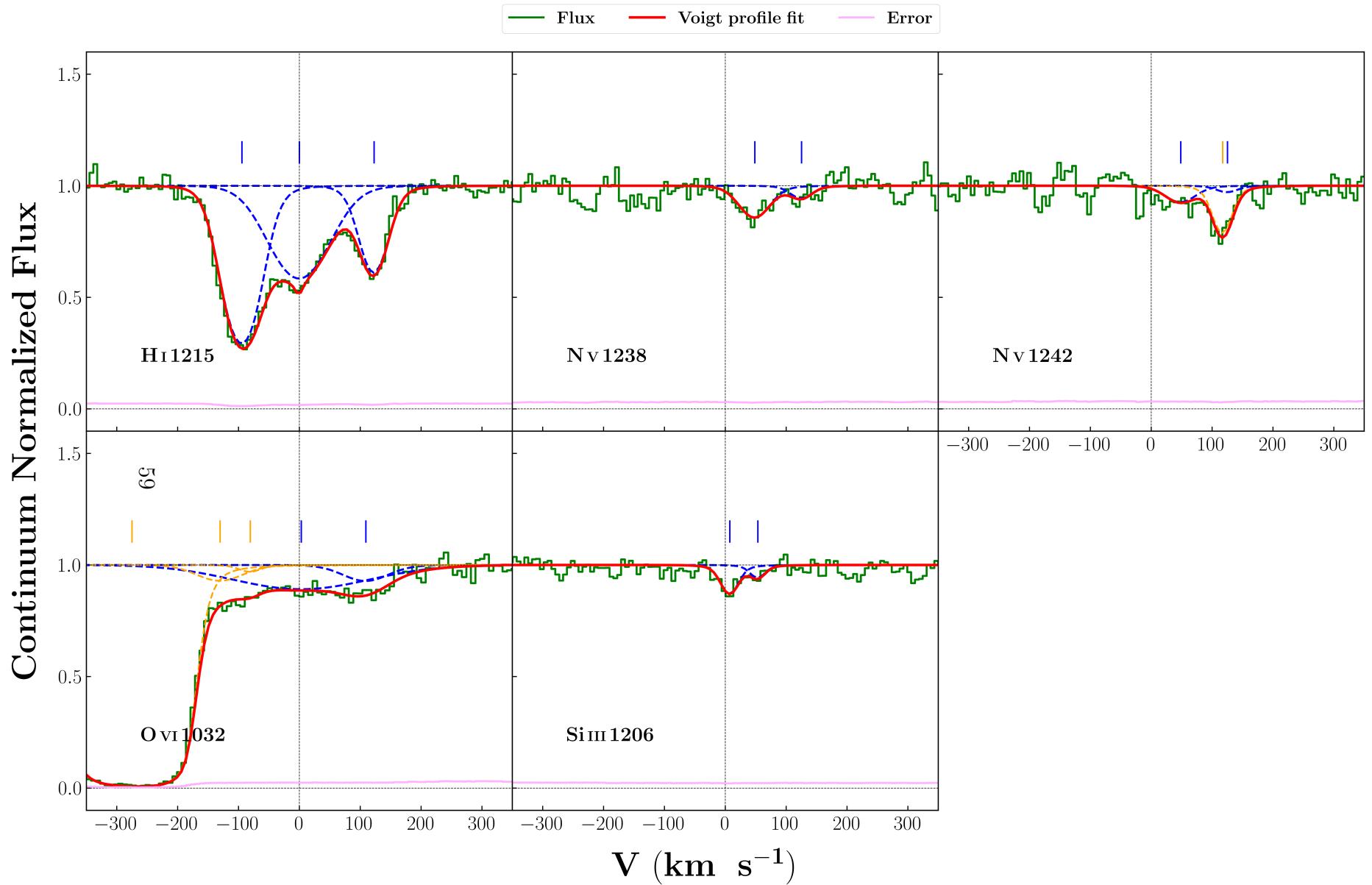


Figure 32:  $\text{N(HI)}=13.60$ ,  $\log Z_{\text{ref}} = 1$

## Comments

- Not good solution as there are many ions.
- metallicity is coming 2, which is the upper bound taken in flat priors
- Ionisation : tentative CI (since O VI can't be explained, even though the solution is not good)
- BLA : +ve

H1821 + 643 ( $z_{\text{abs}} = 0.170006$ )



<b>Ion</b>	<b>v (km s<sup>-1</sup>)</b>	<b>b (km s<sup>-1</sup>)</b>	<b>log [N cm<sup>-2</sup>]</b>
Si III	7 ± 3	17 ± 5	12.05 ± 0.07
Si III	52 ± 6	14 ± 10	11.62 ± 0.17
N V	47 ± 3	31 ± 5	13.29 ± 0.05
N V	122 ± 7	21 ± 11	12.74 ± 0.14
O VI	3 ± 28	152 ± 20	13.94 ± 0.06
O VI	107 ± 9	48 ± 12	13.29 ± 0.11
H I	-92 ± 1	36 ± 1	13.85 ± 0.02
H I	0 ± 2	63 ± 3	13.68 ± 0.02
H I	120 ± 1	28 ± 1	13.35 ± 0.02

$$\log Z_{ref} = -1$$

$$N(HI) = 13.68$$

$$\text{Excluding O VI : } n_H = -4.10 \pm 0.02 \quad Z = 0.91 \pm 0.04$$

$$\text{Including O VI : } n_H = -4.14 \pm 0.02 \quad Z = 0.94 \pm 0.04$$

$$N(HI) = 13.35$$

$$\text{Excluding O VI : } n_H = -4.07 \pm 0.06 \quad Z = 0.75 \pm 0.11$$

$$\text{Including O VI : } n_H = -4.11 \pm 0.05 \quad Z = 0.79 \pm 0.10$$

$$\log Z_{ref} = 1$$

$$N(HI) = 13.68$$

$$\text{Excluding O VI : } n_H = -4.33 \pm 0.02 \quad Z = 1.30 \pm 0.05$$

$$\text{Including O VI : } n_H = -4.43 \pm 0.01 \quad Z = 1.25 \pm 0.05$$

$$N(HI) = 13.35$$

$$\text{Excluding O VI : } n_H = -4.30 \pm 0.05 \quad Z = 1.18 \pm 0.13$$

$$\text{Including O VI : } n_H = -4.41 \pm 0.02 \quad Z = 1.15 \pm 0.12$$

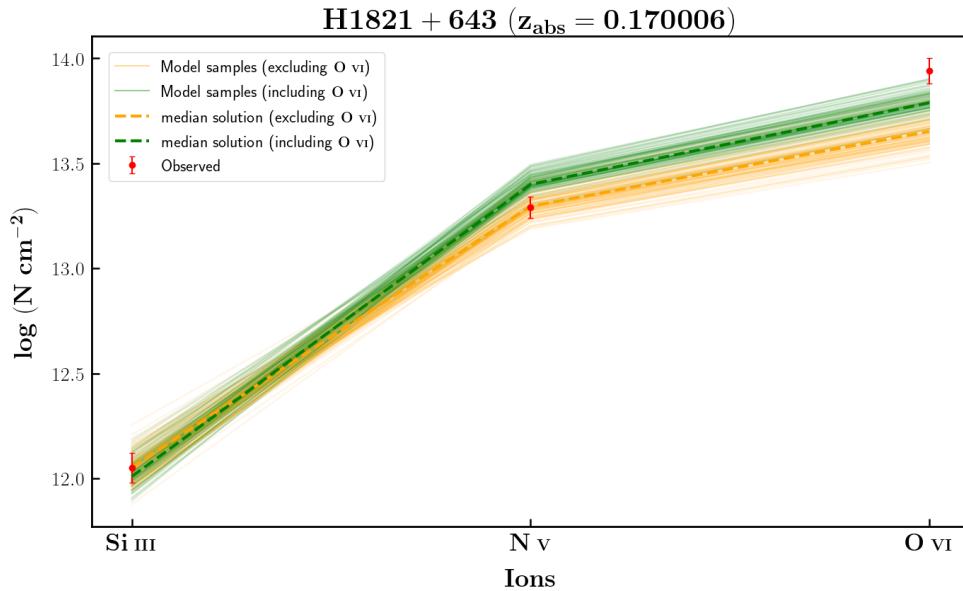


Figure 33:  $\text{N(HI)}=13.68$ ,  $\log Z_{\text{ref}} = -1$

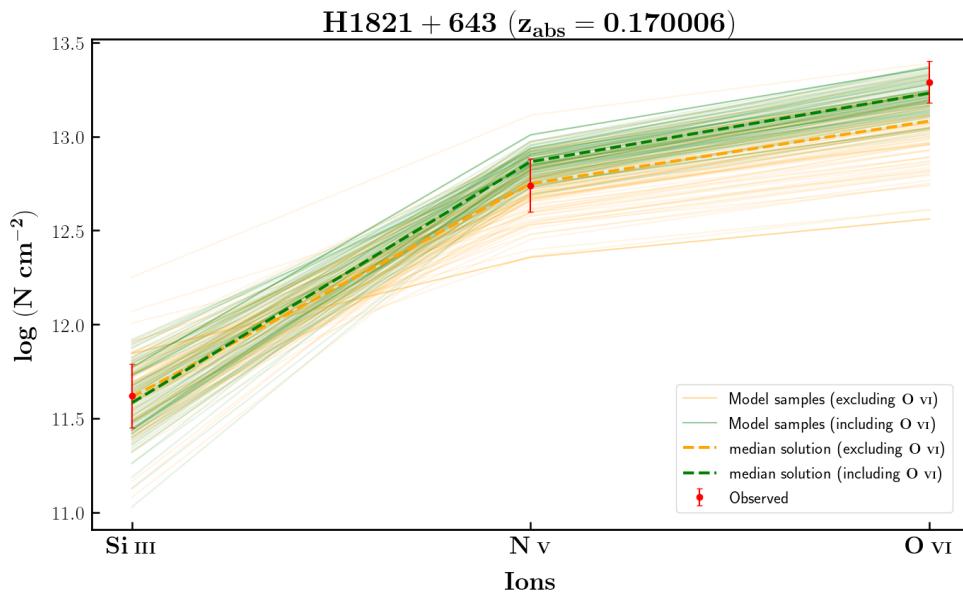


Figure 34:  $\text{N(HI)}=13.35$ ,  $\log Z_{\text{ref}} = -1$

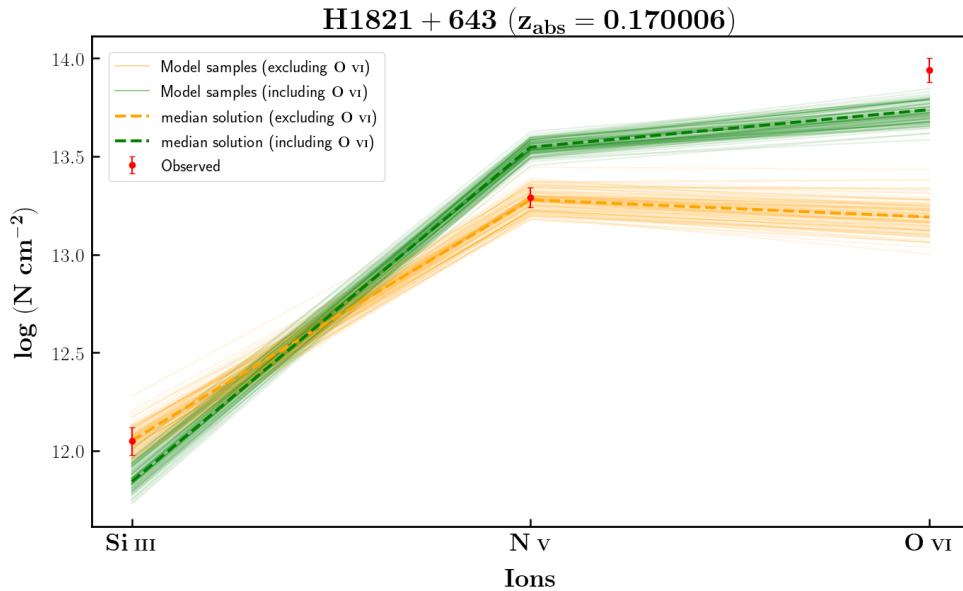


Figure 35:  $\text{N(HI)}=13.68$ ,  $\log Z_{\text{ref}} = 1$

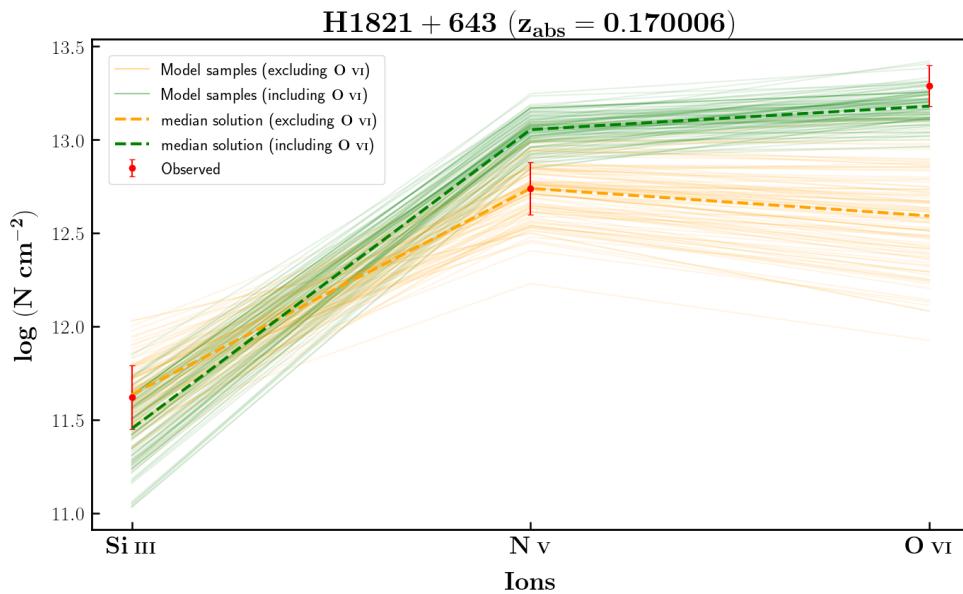


Figure 36:  $\text{N(HI)}=13.35$ ,  $\log Z_{\text{ref}} = 1$

## Non-detections

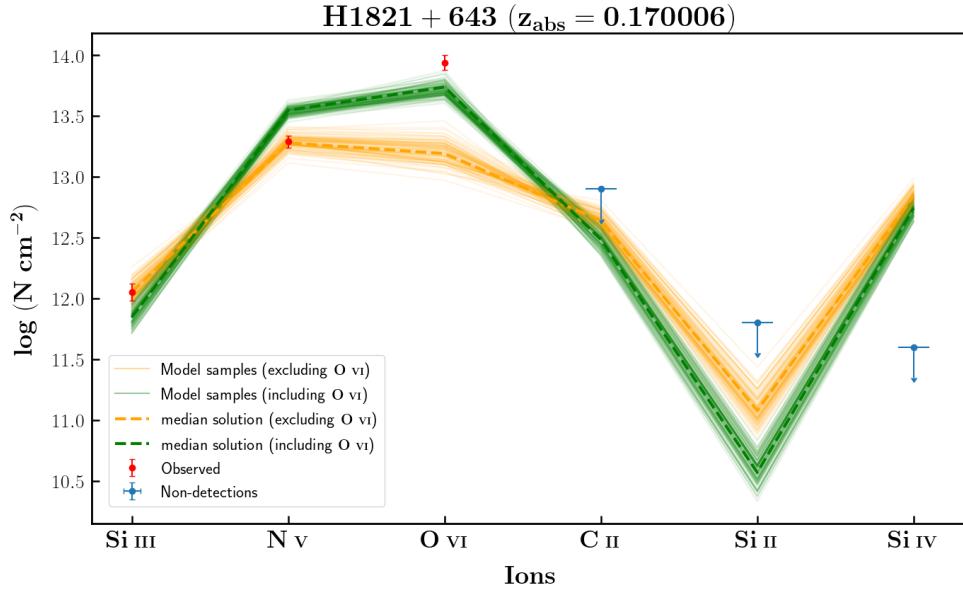


Figure 37:  $\text{N(HI)}=13.68$ ,  $\log Z_{\text{ref}}=1$

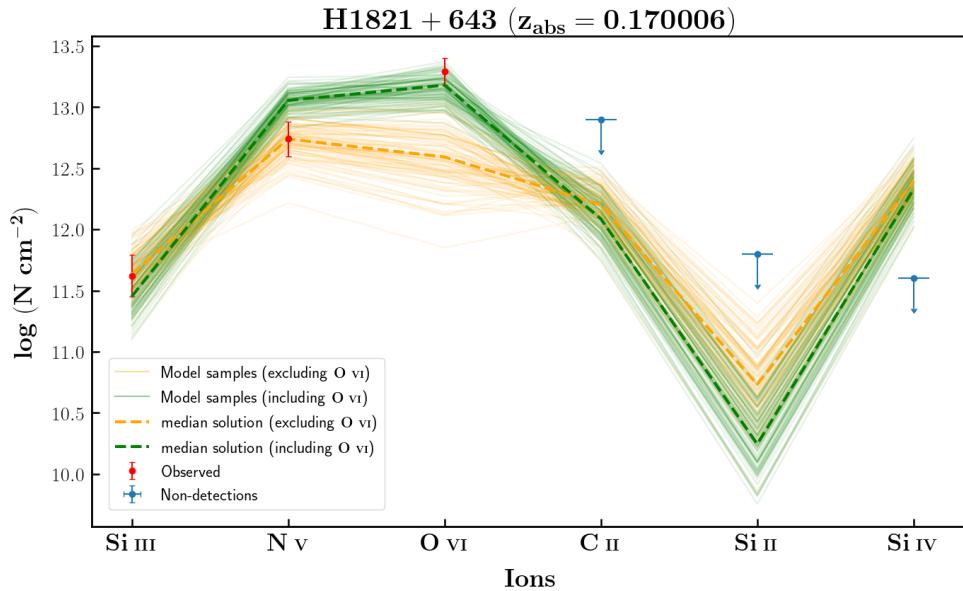
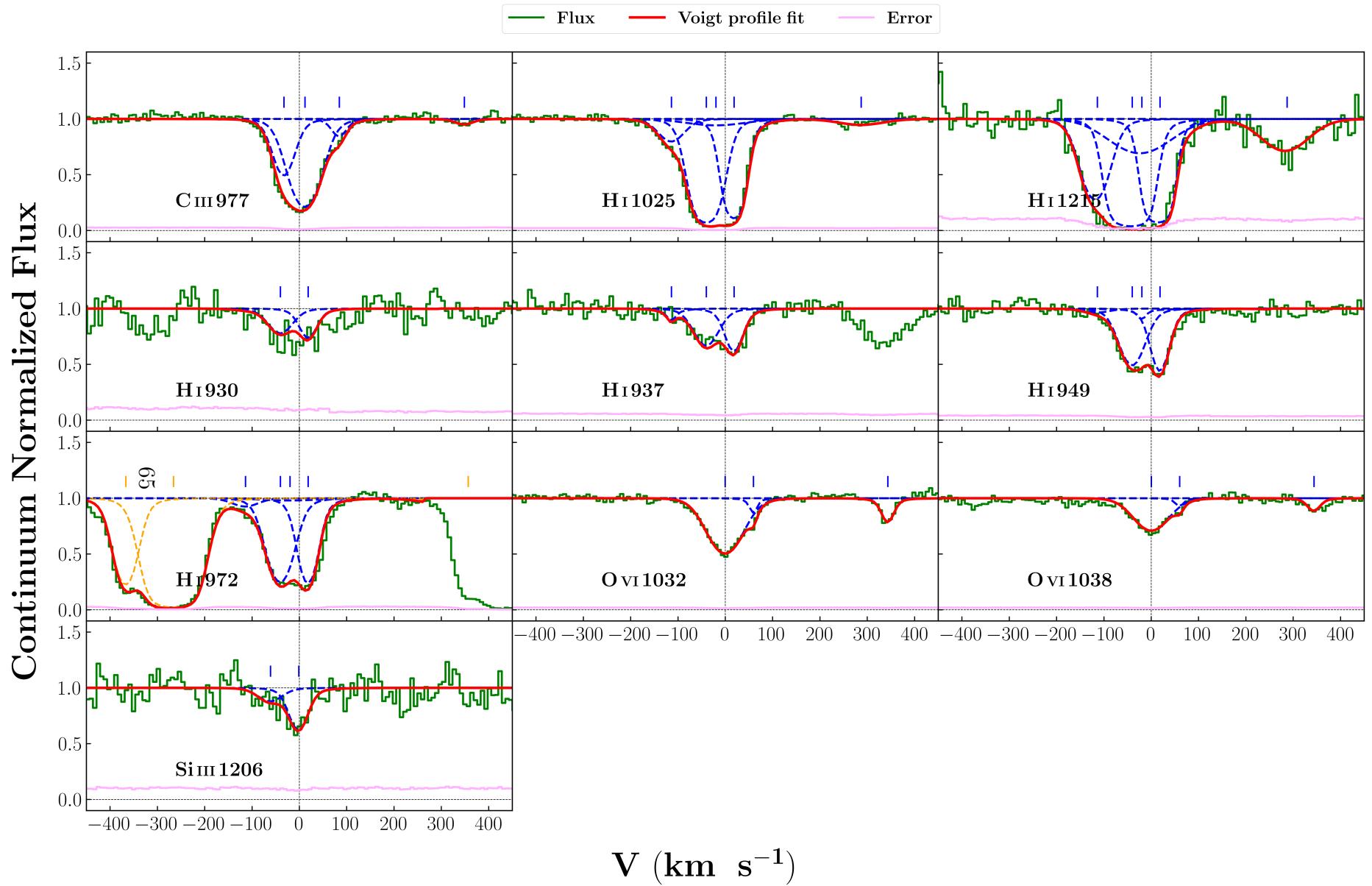


Figure 38:  $\text{N(HI)}=13.35$ ,  $\log Z_{\text{ref}}=1$

## Comments

- For component II ( $N(H\ I)=13.68$ ), solution very close to explaining all 3 ions but not exactly when using  $\log Z=-1$  models, but clearly, can't explain the 3 ions together when  $\log Z=1$  models are used.
- Similarly, for component III ( $N(H\ I)=13.68$ ), all 3 ions can be explained when using  $\log Z=-1$  models, but not with  $\log Z=1$  models.
- Ionisation : CI
- BLA : +ve

H1821 + 643 ( $z_{\text{abs}} = 0.224981$ )



Ion	v (km s <sup>-1</sup> )	b (km s <sup>-1</sup> )	log [N cm <sup>-2</sup> ]
Si III	-59 ± 13	31 ± 18	12.23 ± 0.15
Si III	-1 ± 6	22 ± 9	12.71 ± 0.13
C III	-31 ± 1	24 ± 2	13.36 ± 0.07
C III	12 ± 1	36 ± 2	13.84 ± 0.02
C III	81 ± 3	15 ± 5	12.6 ± 0.09
C III	335 ± 7	20 ± 10	12.13 ± 0.11
O VI	0 ± 1	45 ± 1	14.24 ± 0.01
O VI	57 ± 2	3 ± 3	13.12 ± 0.1
O VI	330 ± 1	13 ± 2	13.42 ± 0.03
H I	-109 ± 3	33 ± 0	13.87 ± 0.09
H I	-38 ± 1	30 ± 1	15.16 ± 0.02
H I	-19 ± 10	84 ± 13	13.64 ± 0.11
H I	18 ± 1	19 ± 1	15.13 ± 0.03
H I	276 ± 7	62 ± 11	13.48 ± 0.06

N(H I)= 15.16

Excluding O VI :  $n_H = -3.29 \pm 0.08$        $Z = -0.95 \pm 0.07$   
 Including O VI :  $n_H = -4.36 \pm 0.02$        $Z = -0.81 \pm 0.04$

N(H I)= 15.13

Excluding O VI :  $n_H = -3.29 \pm 0.03$        $Z = -0.44 \pm 0.03$   
 Including O VI :  $n_H = -3.83 \pm 0.04$        $Z = -0.77 \pm 0.03$

NOTE : Solution using  $\chi^2$ , MCMC didn't converge good, shows hint of two solution, another solution with high density and metallicity for both the components

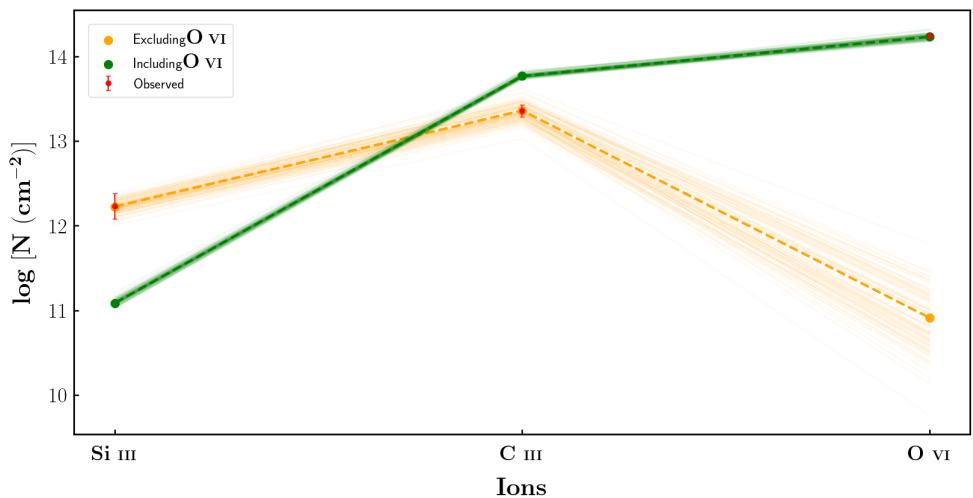


Figure 39:  $N(\text{H I})=15.16$

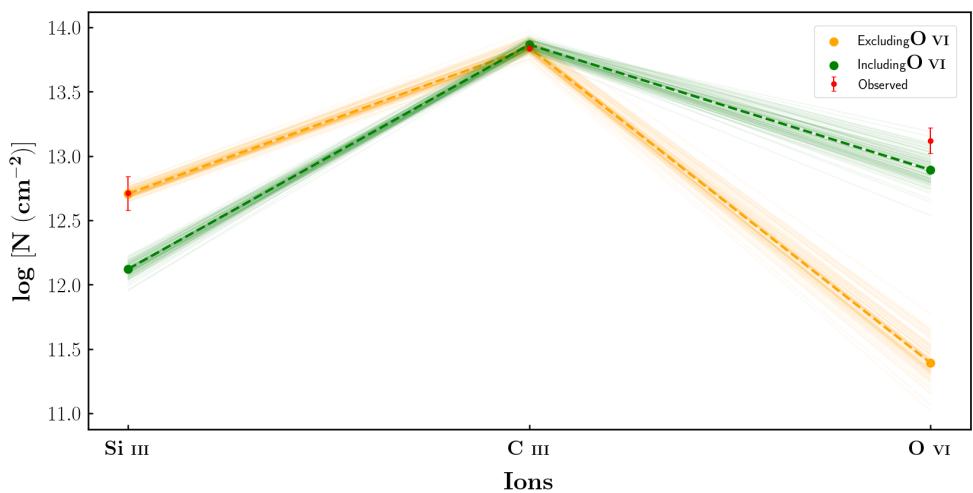


Figure 40:  $N(\text{H I})=15.13$

## Non-detections

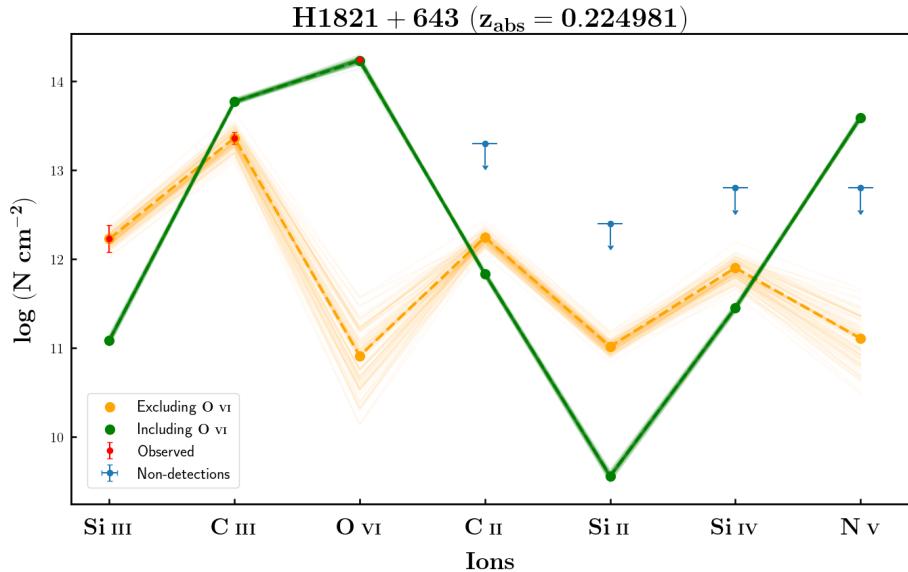


Figure 41:  $N(\text{H I})=15.16$ ,  $\log Z_{\text{ref}}=-1$

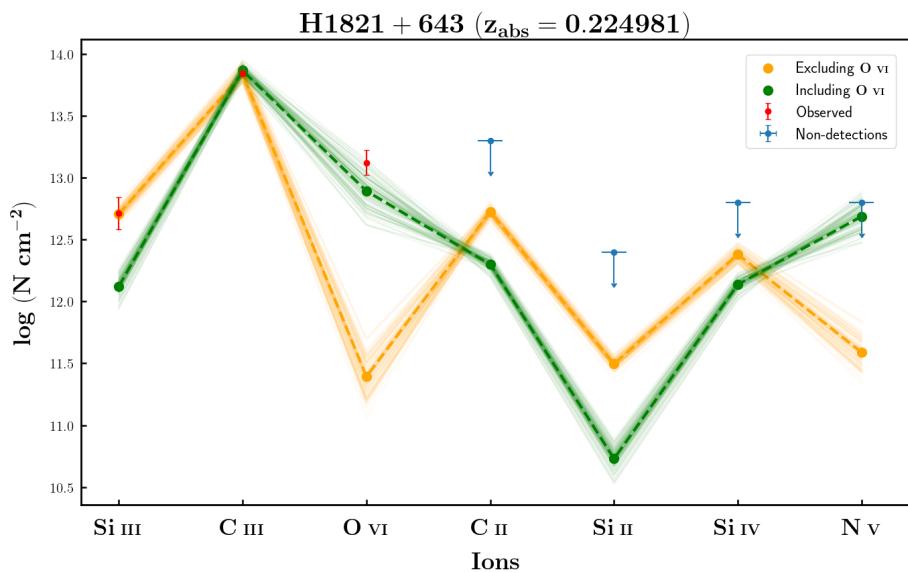
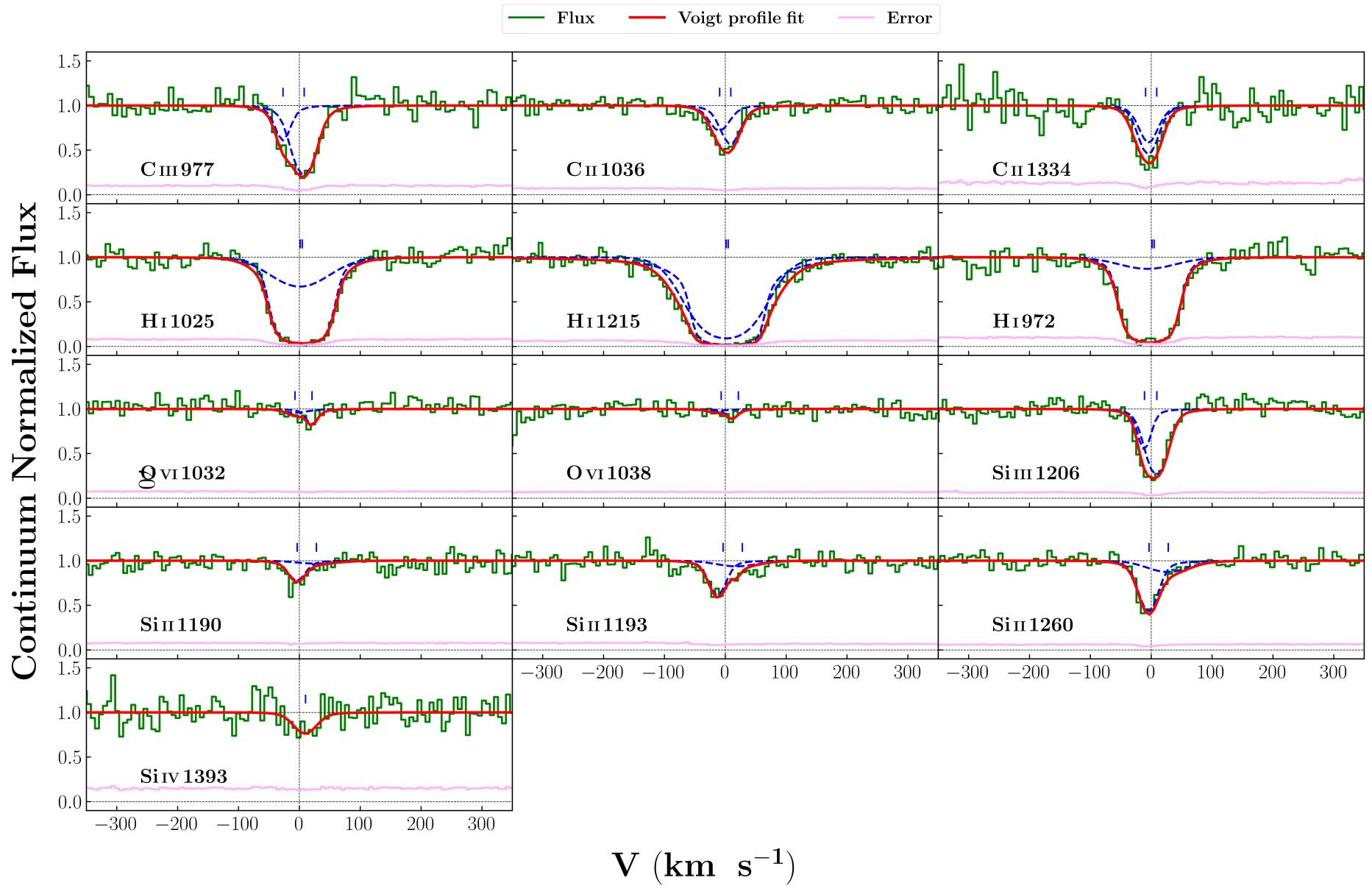


Figure 42:  $N(\text{H I})=15.13$ ,  $\log Z_{\text{ref}}=-1$

## **Comments**

- All 3 ions couldn't be explained for both component II ( $N(H\ I)=15.16$ ) and IV ( $N(H\ I)=15.13$ )
- Ionisation : CI
- BLA : +ve

PG1121 + 422 ( $z_{\text{abs}} = 0.192393$ )



Ion	v (km s <sup>-1</sup> )	b (km s <sup>-1</sup> )	log [N cm <sup>-2</sup> ]
Si III	-11 ± 13	10 ± 3	12.62 ± 0.10
Si III	9 ± 13	18 ± 4	13.14 ± 0.04
C III	-26 ± 10	10 ± 7	13.04 ± 0.09
C III	8 ± 5	18 ± 6	13.74 ± 0.11
C II	-9 ± 3	17 ± 5	13.69 ± 0.08
C II	9 ± 2	16 ± 3	13.93 ± 0.05
Si IV	10 ± 7	22 ± 11	12.86 ± 0.13
Si II	-3 ± 1	15 ± 2	13.04 ± 0.06
Si II	27 ± 19	42 ± 1	12.48 ± 0.23
O VI	-7 ± 13	11 ± 16	12.84 ± 0.19
O VI	20 ± 3	3 ± 4	13.37 ± 0.12
H I	1 ± 2	60 ± 6	14.34 ± 0.09
H I	5 ± 1	19 ± 1	17.7 ± 0.11

N(H I)=14.34

$\log Z_{ref} = -1$

Excluding O VI :  $n_H = -1.78 \pm 0.05$        $Z = 1.97 \pm 0.04$

Including O VI :  $n_H = -3.00 \pm 0.04$        $Z = 1.25 \pm 0.04$

$\log Z_{ref} = 1$

Excluding O VI :  $n_H = -3.12 \pm 0.07$        $Z = 1.62 \pm 0.07$

Including O VI :  $n_H = -3.7 \pm 0.03$        $Z = 1.33 \pm 0.04$

N(H I)= 17.70

Excluding O VI :  $n_H = -2.35 \pm 0.05$        $Z = -1.66 \pm 0.06$

Including O VI :  $n_H = -3.08 \pm 0.04$        $Z = -2.08 \pm 0.05$

NOTE : Since very high N(H I), so low metallicity. And solutions aren't much good.

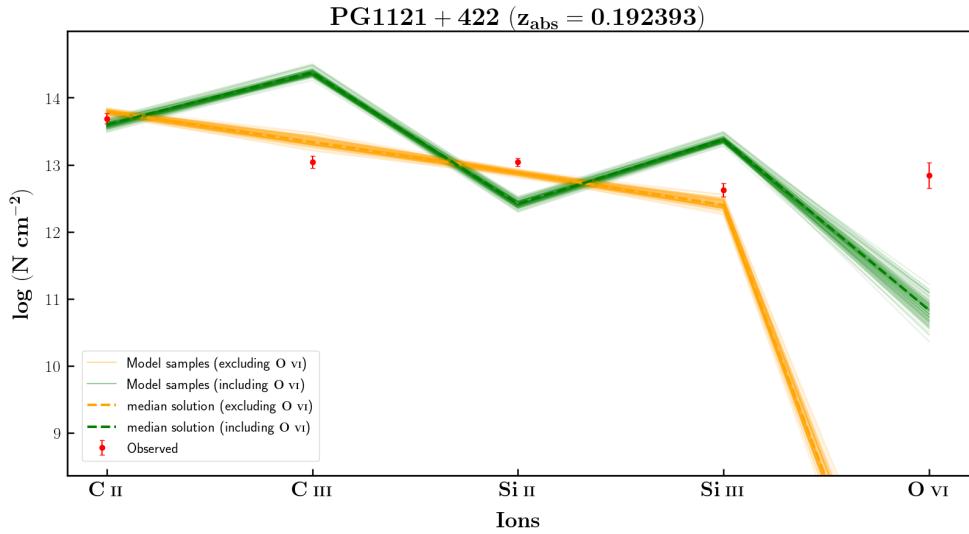


Figure 43:  $N(\text{H I})=14.34$ ,  $\log Z_{\text{ref}}=-1$

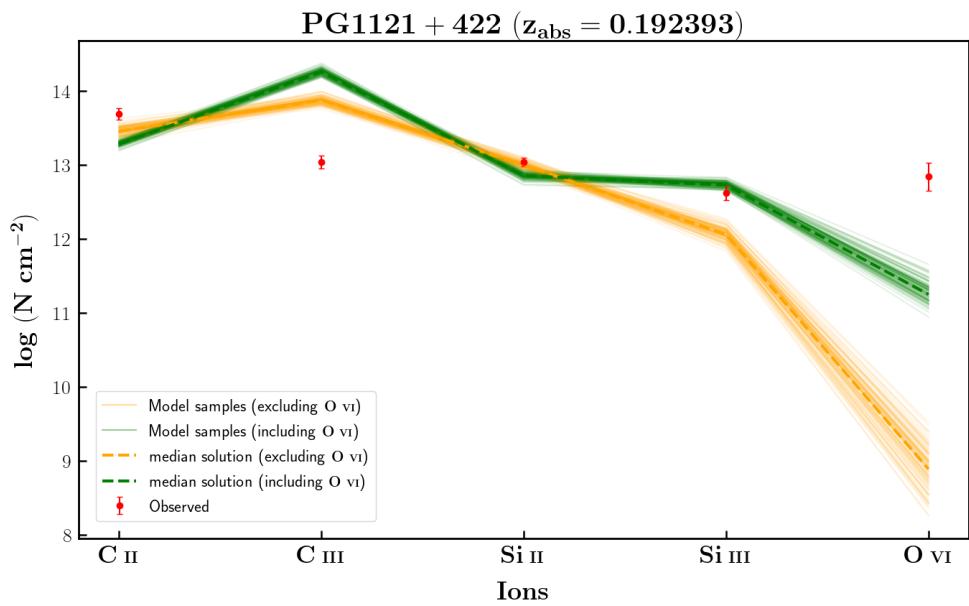


Figure 44:  $N(\text{H I})=14.34$ ,  $\log Z_{\text{ref}}=1$

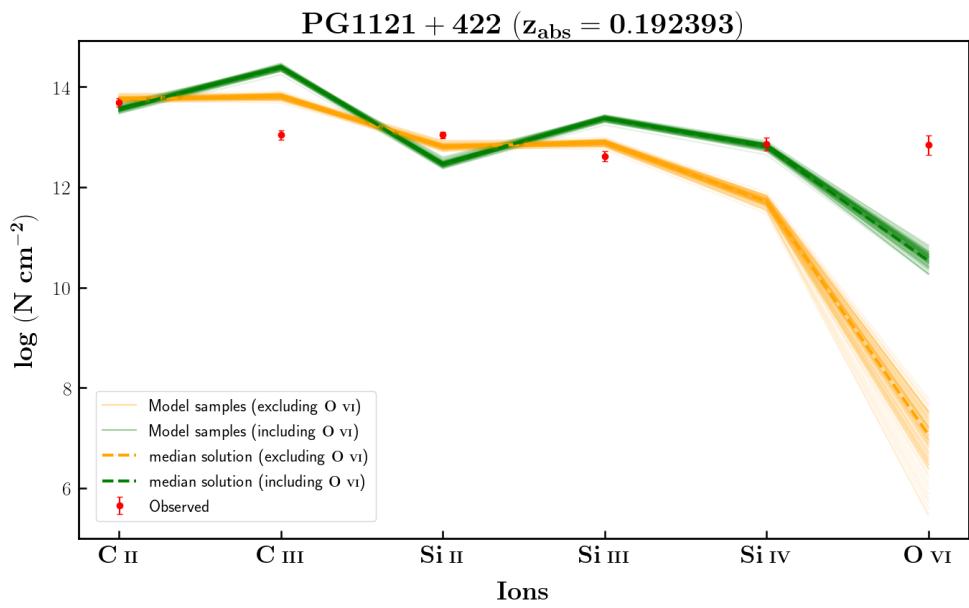


Figure 45:  $N(\text{H I})=17.70$ ,  $\log Z_{\text{ref}}=-1$

## Non-detections

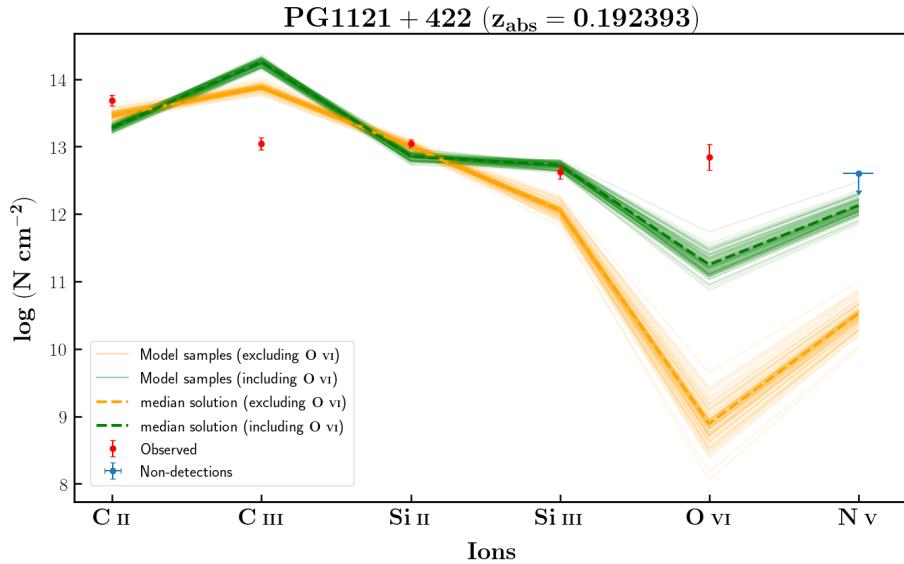


Figure 46:  $N(\text{H I})=14.34$ ,  $\log Z_{\text{ref}}=1$

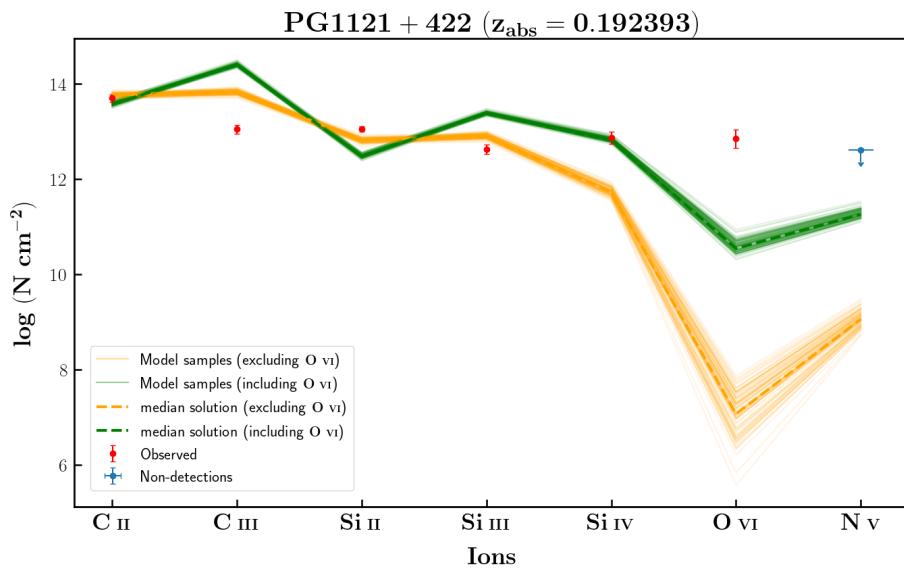
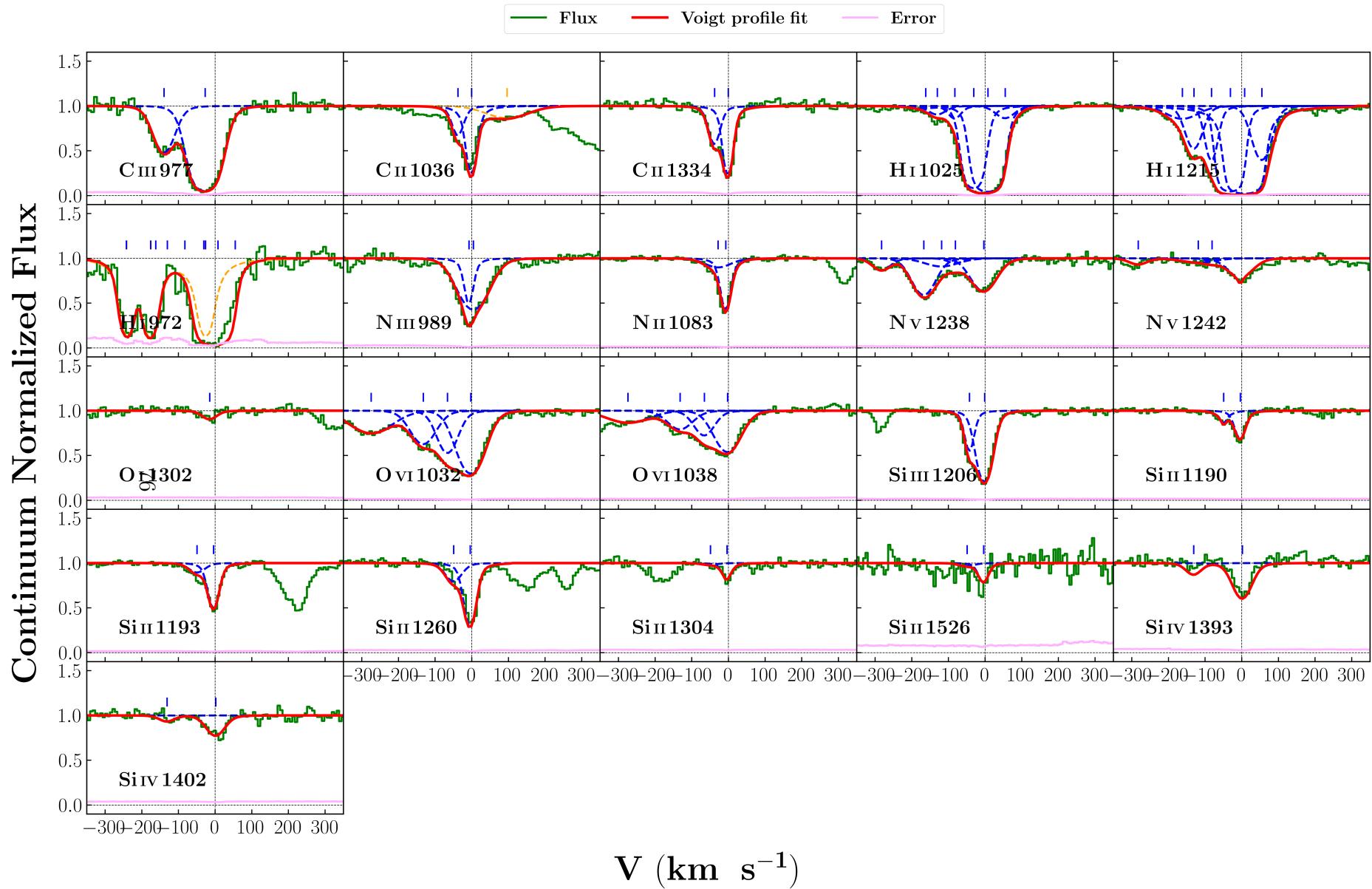


Figure 47:  $N(\text{H I})=17.70$ ,  $\log Z_{\text{ref}}=-1$

## Comments

- For component I ( $N(H\ I)=14.34$ ), solution is little better when  $\log Z=-1$  model is used, where other ions than O VI could be explained upto some level. And solution is not good in case of  $\log Z=1$  model
- For component II ( $N(H\ I)=17.70$ ), no good solution is obtained, possibly due to more no. of ions.
- All the solutions underproduce O VI
- Ionisation : CI
- BLA : +ve

PKS0405 – 123 ( $z_{\text{abs}} = 0.167125$ )



<b>Ion</b>	<b>v (km s<sup>-1</sup>)</b>	<b>b (km s<sup>-1</sup>)</b>	<b>log [N cm<sup>-2</sup>]</b>
O I	-14 ± 5	23 ± 7	13.52 ± 0.08
C II	-37 ± 2	16 ± 2	13.76 ± 0.02
C II	-1 ± 1	6 ± 1	16.27 ± 0.12
C III	-136 ± 2	32 ± 2	13.45 ± 0.02
C III	-26 ± 0	37 ± 2	14.33 ± 0.04
N II	-27 ± 6	44 ± 5	13.47 ± 0.09
N II	-7 ± 1	12 ± 1	14.11 ± 0.02
N III	-7 ± 0	9 ± 4	14.06 ± 0.08
N III	5 ± 0	50 ± 2	14.43 ± 0.02
N V	-276 ± 3	30 ± 0	13.25 ± 0.05
N V	-116 ± 0	59 ± 9	13.32 ± 0.08
N V	-79 ± 13	24 ± 12	12.77 ± 0.19
N V	-3 ± 2	43 ± 3	13.89 ± 0.03
Si III	-41 ± 3	13 ± 4	12.66 ± 0.10
Si III	-1 ± 2	22 ± 2	13.28 ± 0.03
Si IV	-128 ± 0	25 ± 5	12.61 ± 0.06
Si IV	2 ± 1	31 ± 2	13.25 ± 0.02
Si II	-48 ± 5	26 ± 8	12.54 ± 0.09
Si II	-4 ± 1	15 ± 0	13.24 ± 0.02
O VI	-268 ± 0	74 ± 5	14.05 ± 0.02
O VI	-129 ± 8	41 ± 3	14.05 ± 0.10
O VI	-64 ± 5	32 ± 2	14.11 ± 0.17
O VI	-2 ± 4	43 ± 3	14.49 ± 0.05
H I	-158 ± 0	56 ± 9	13.09 ± 0.06
H I	-127 ± 4	26 ± 3	13.46 ± 0.04
H I	-80 ± 1	18 ± 2	13.54 ± 0.04
H I	-30 ± 0	18 ± 2	15.98 ± 0.34
H I	8 ± 49	19 ± 0	17.53 ± 0.07
H I	54 ± 90	30 ± 2	13.66 ± 0.04

N(H I)= 13.46

Excluding O VI :  $n_H = -3.98 \pm 0.03$        $Z = 0.62 \pm 0.02$   
Including O VI :  $n_H = -4.17 \pm 0.02$        $Z = 0.63 \pm 0.02$

N(H I)= 15.98

Excluding O VI :  $n_H = -2.73 \pm 0.04$        $Z = -0.18 \pm 0.02$   
Including O VI :  $n_H = -3.27 \pm 0.03$        $Z = -0.33 \pm 0.02$

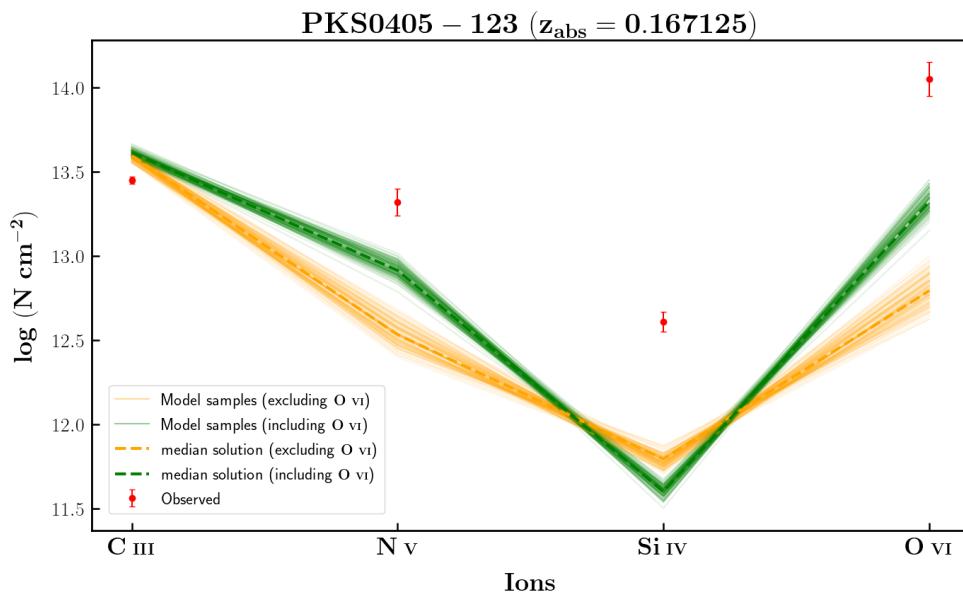


Figure 48:  $N(\text{H I})=13.46$

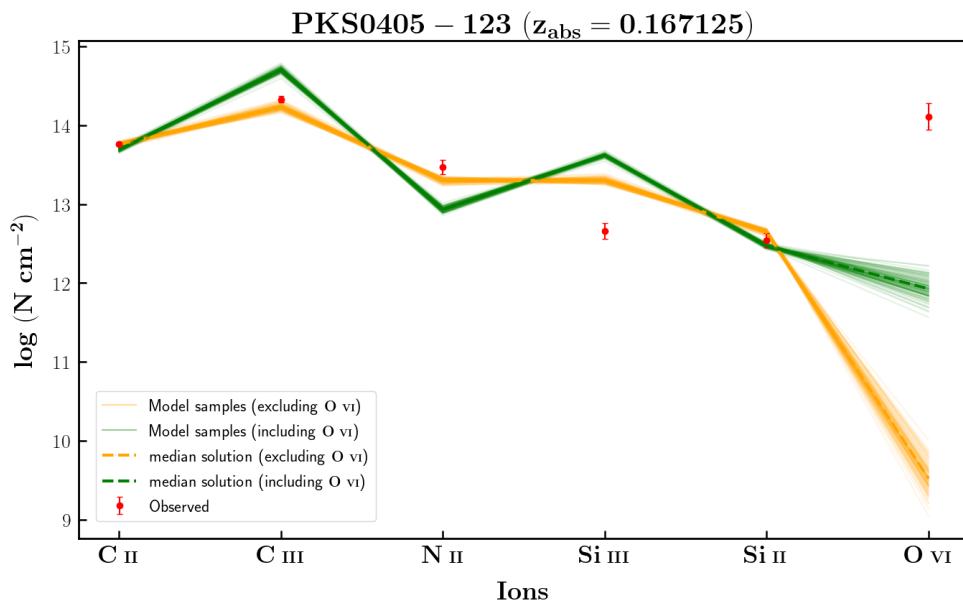


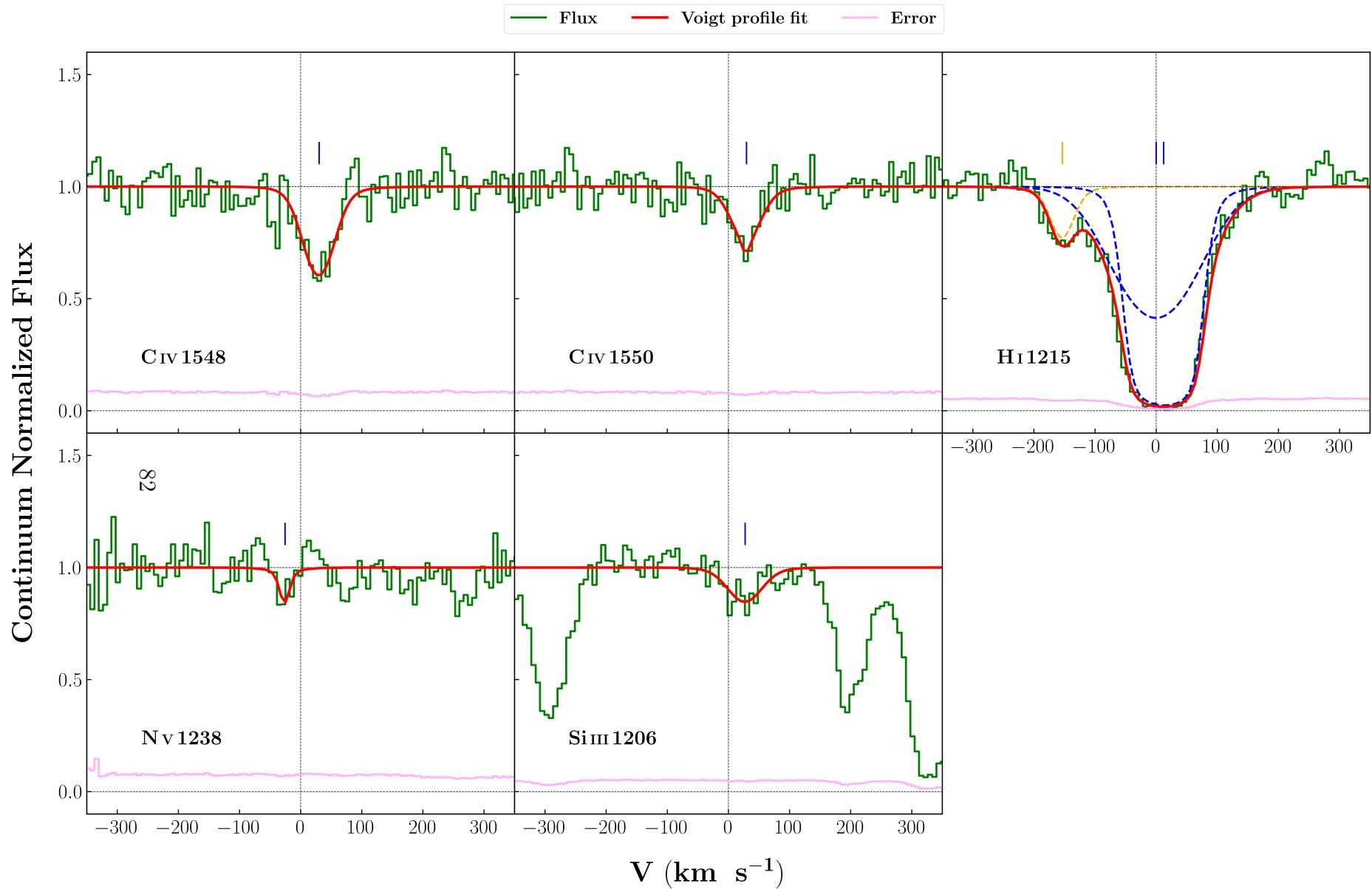
Figure 49:  $N(\text{H I})=15.98$

## Comments

- Not a good solution for component II ( $N(H\ I)=13.46$ )
- For component IV ( $N(H\ I)=15.98$ ), excluding O VI case explains all ions except Si III and O VI is underproduced in this case.
- Ionisation : CI
- BLA : +ve

## **Non O<sub>VI</sub> absorbers**

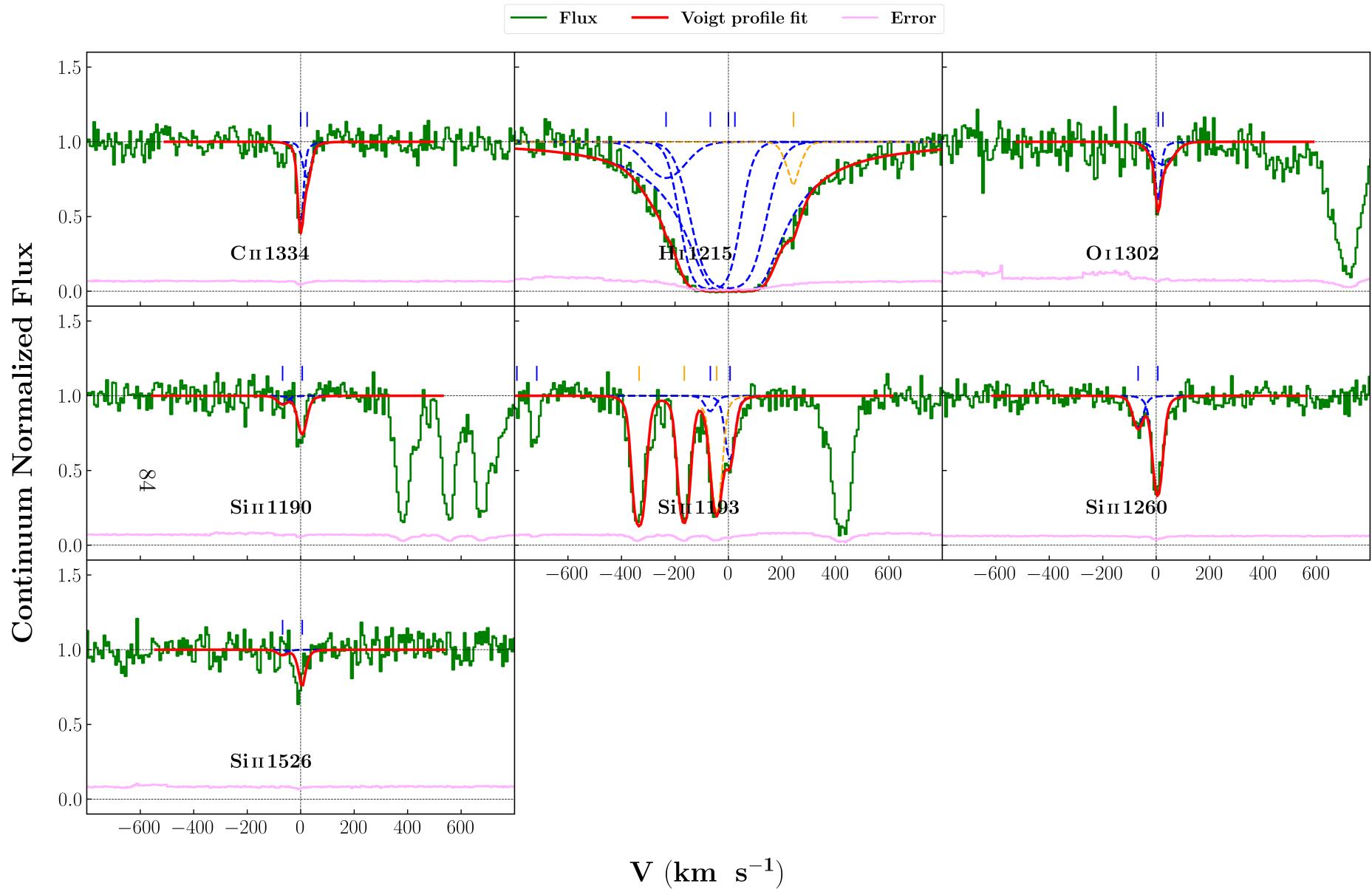
HE0056 – 3622 ( $z_{\text{abs}} = 0.043265$ )



<b>Ion</b>	<b>v (km s<sup>-1</sup>)</b>	<b>b (km s<sup>-1</sup>)</b>	<b>log [N cm<sup>-2</sup>]</b>
Si III	27 ± 6	34 ± 9	12.37 ± 0.07
N V	-26 ± 4	1 ± 8	13.42 ± 0.46
C IV	30 ± 2	31 ± 0	13.64 ± 0.03
H I	0 ± 3	85 ± 6	14.02 ± 0.07
H I	12 ± 1	32 ± 4	15.3 ± 0.1

Ionisation modelling to be done.

PG1216 + 069 ( $z_{\text{abs}} = 0.006328$ )



Ion	v (km s <sup>-1</sup> )	b (km s <sup>-1</sup> )	log [N cm <sup>-2</sup> ]
O I	8 ± 2	7 ± 5	14.07 ± 0.16
O I	25 ± 12	50 ± 13	14.0 ± 0.11
C II	0 ± 3	7 ± 5	13.98 ± 0.08
C II	24 ± 19	17 ± 6	13.43 ± 0.09
Si II	-68 ± 4	21 ± 6	12.51 ± 0.06
Si II	6 ± 1	18 ± 0	13.2 ± 0.02
H I	-233 ± 110	95 ± 15	13.56 ± 0.06
H I	-68 ± 0	81 ± 8	14.76 ± 0.12
H I	0 ± 0	106 ± 15	14.79 ± 0.08
H I	24 ± 0	20 ± 12	19.09 ± 0.03

$$N(H I) = 14.79$$

$$\text{Solution : } n_H = -1.90 \pm 0.07 \quad Z = 1.97 \pm 0.05$$

NOTE : logZ near 2

Tried excluding O I also, still not good solution.

$$\begin{aligned} \text{Excluding O I : } n_H &= -2.10 \pm 0.25 & Z &= 1.84 \pm 0.14 \\ \text{Including O I : } n_H &= -1.90 \pm 0.07 & Z &= 1.97 \pm 0.05 \\ \log Z_{ref} &= 1 \end{aligned}$$

$$\text{Solution : } n_H = -2.69 \pm 0.05 \quad Z = 1.97 \pm 0.04$$

$$\begin{aligned} \text{Excluding O I : } n_H &= -2.87 \pm 1.32 & Z &= 1.82 \pm 0.29 \\ \text{Including O I : } n_H &= -2.69 \pm 0.05 & Z &= 1.97 \pm 0.04 \end{aligned}$$

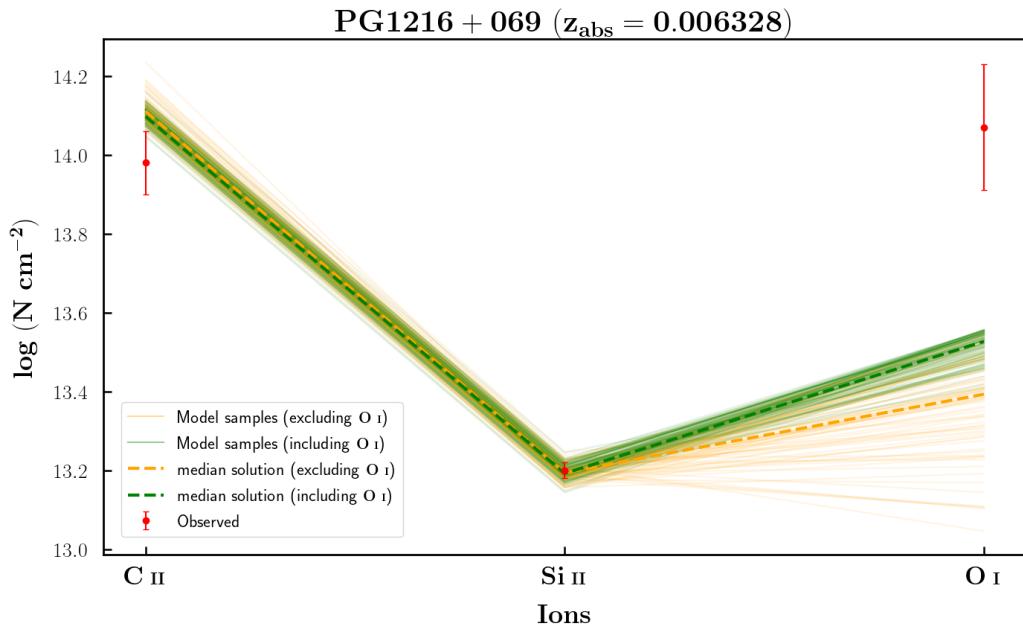


Figure 50:  $\text{N(HI)}=14.79$ , shows solution excluding O I,  $\log Z_{\text{ref}}=-1$

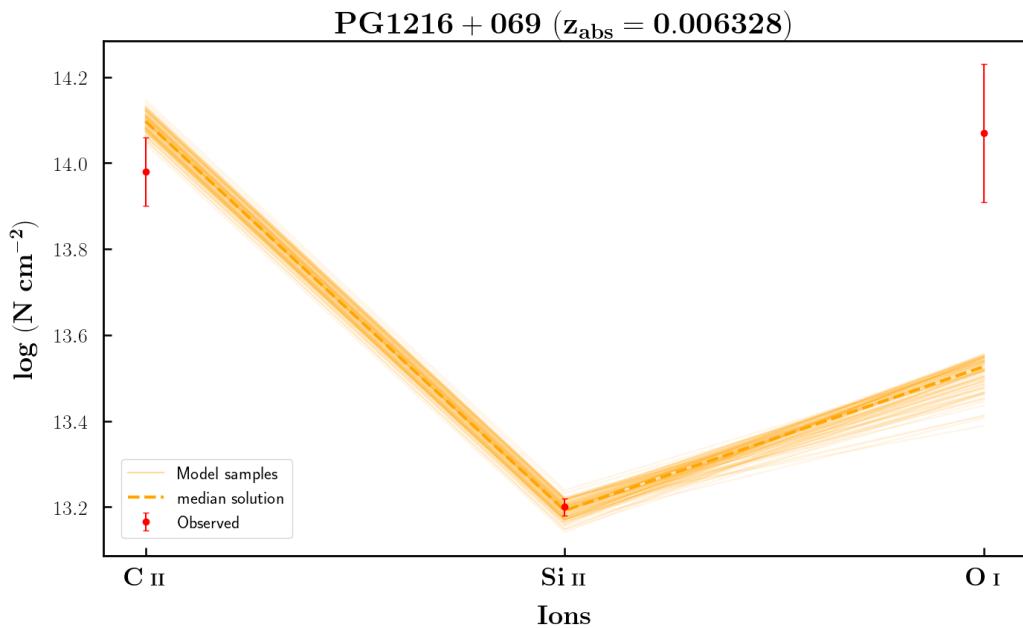


Figure 51:  $\text{N(HI)}=14.79$ ,  $\log Z_{\text{ref}}=-1$

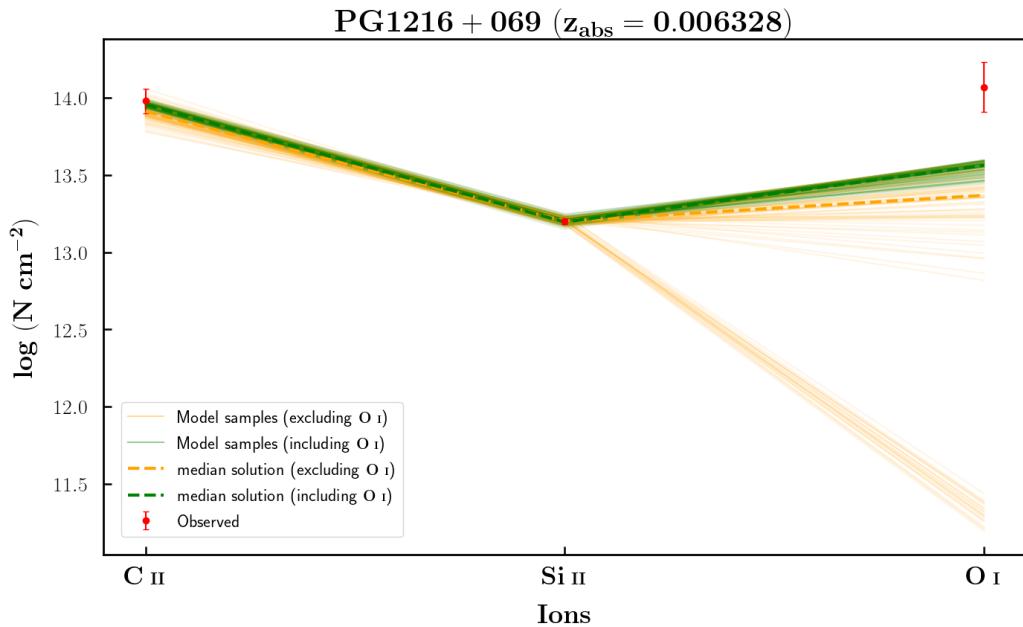


Figure 52:  $\text{N(HI)}=14.79$ , shows solution excluding O I,  $\log Z_{\text{ref}}=1$

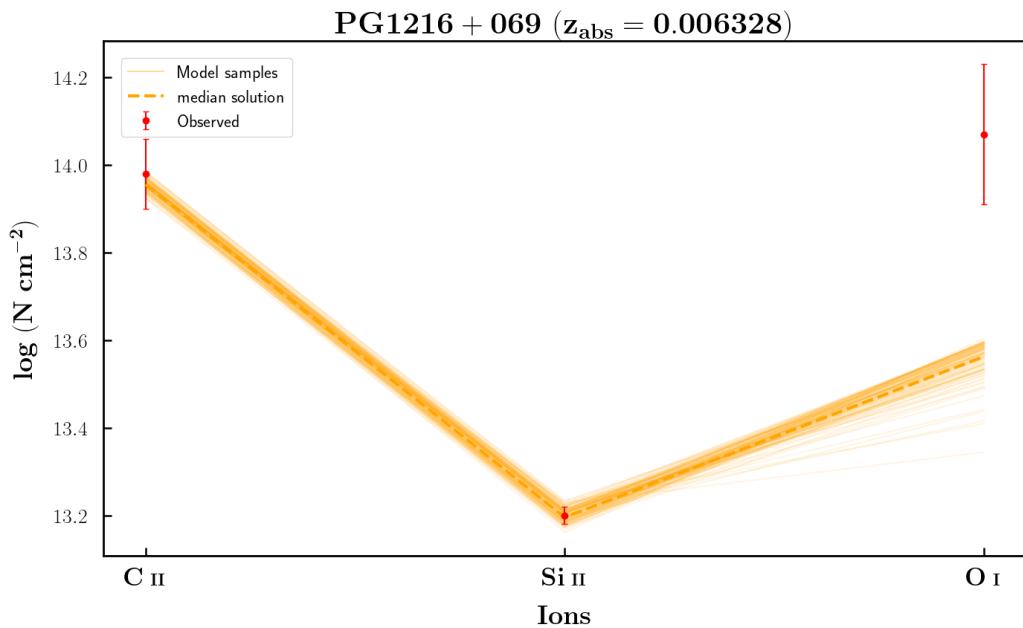
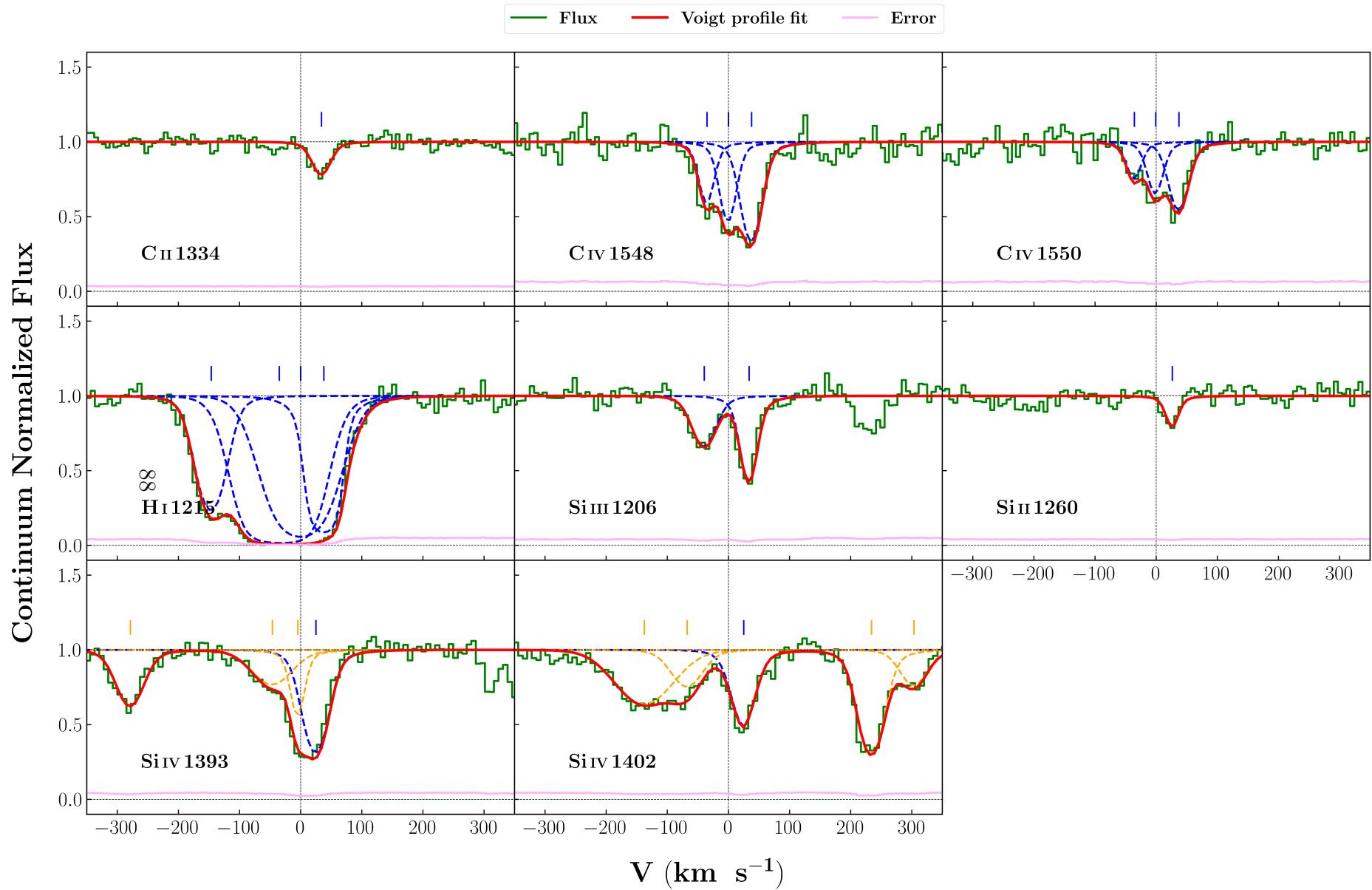


Figure 53:  $\text{N(HI)}=14.79$ ,  $\log Z_{\text{ref}}=1$

### 3C263 ( $z_{\text{abs}} = 0.063397$ )



Ion	v (km s <sup>-1</sup> )	b (km s <sup>-1</sup> )	log [N cm <sup>-2</sup> ]
Si II	26 ± 2	8 ± 4	12.29 ± 0.06
Si III	-39 ± 1	21 ± 2	12.64 ± 0.03
Si III	34 ± 1	12 ± 1	12.91 ± 0.04
Si IV	25 ± 1	22 ± 0	13.57 ± 0.02
C IV	-35 ± 1	12 ± 3	13.42 ± 0.06
C IV	0 ± 2	13 ± 3	13.63 ± 0.06
C IV	38 ± 2	17 ± 2	13.86 ± 0.04
C II	34 ± 2	17 ± 3	13.37 ± 0.04
H I	-146 ± 2	25 ± 2	13.87 ± 0.04
H I	-35 ± 0	50 ± 6	14.88 ± 0.12
H I	0 ± 0	54 ± 6	14.42 ± 0.2
H I	38 ± 0	12 ± 3	16.46 ± 0.13

$$N(HI) = 16.46$$

$$\text{Solution : } n_H = -3.72 \pm 0.02 \quad Z = -0.99 \pm 0.02$$

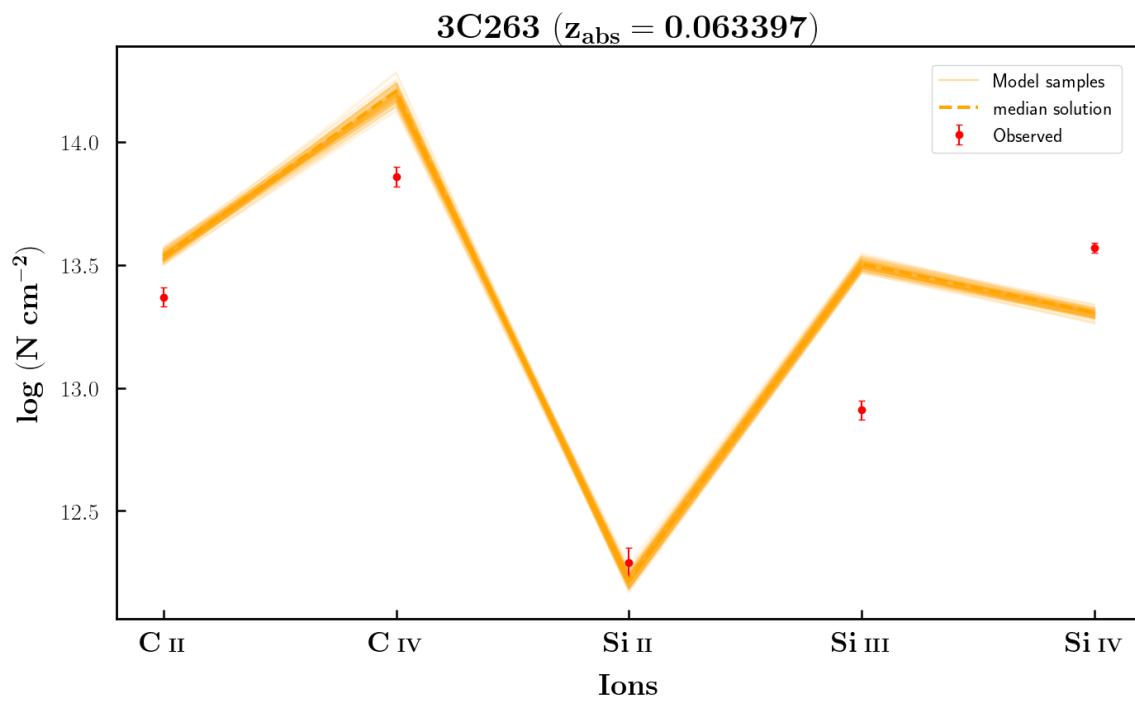
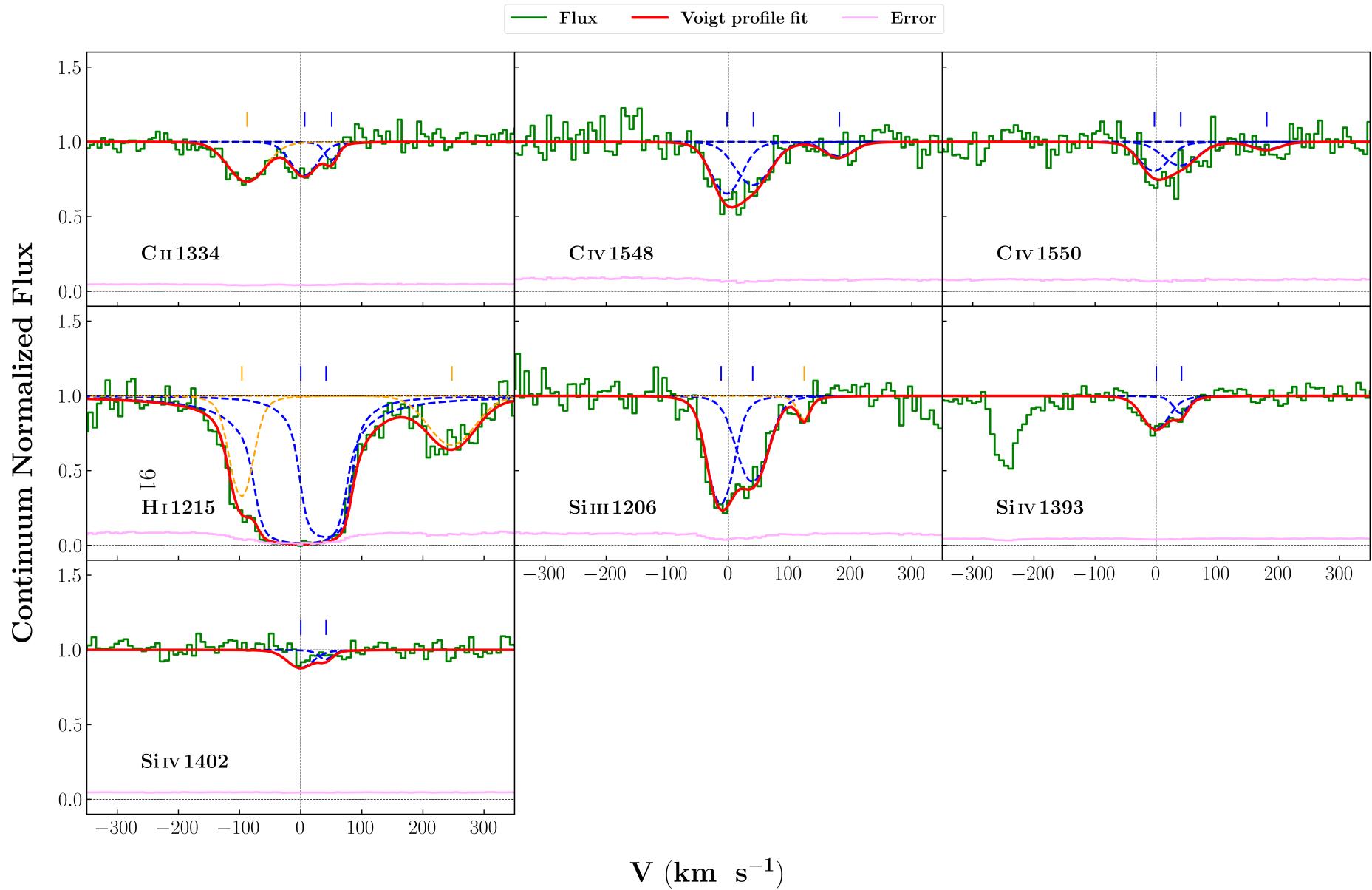


Figure 54:  $N(\text{H I})=16.46$ ,  $\log Z_{ref}=-1$

PG1222 + 216 ( $z_{\text{abs}} = 0.054479$ )



Ion	v (km s <sup>-1</sup> )	b (km s <sup>-1</sup> )	log [N cm <sup>-2</sup> ]
Si III	-12 ± 3	20 ± 3	13.19 ± 0.05
Si III	40 ± 5	27 ± 5	13.04 ± 0.07
Si IV	0 ± 1	25 ± 8	12.89 ± 0.08
Si IV	41 ± 4	10 ± 7	12.39 ± 0.13
C IV	-2 ± 1	29 ± 6	13.55 ± 0.1
C IV	41 ± 8	34 ± 6	13.5 ± 0.11
C IV	182 ± 10	26 ± 15	12.86 ± 0.15
C II	7 ± 4	26 ± 6	13.51 ± 0.07
C II	51 ± 4	10 ± 6	12.98 ± 0.09
H I	-12 ± 23	74 ± 11	14.08 ± 0.15
H I	5 ± 4	24 ± 3	17.91 ± 0.15
H I	0 ± 0	23 ± 1	17.9 ± 0.14
H I	41 ± 0	13 ± 2	17.22 ± 0.19

In table last two rows are from fits without BLA (fixed redshift).

$$N(HI) = 14.08$$

$$\text{Solution : } n_H = -3.45 \pm 0.06 \quad Z = 1.25 \pm 0.05$$

$$\log Z_{ref} = 1 :$$

$$\text{Solution : } n_H = -3.85 \pm 0.04 \quad Z = 1.92 \pm 0.06$$

$$N(HI) = 17.91$$

$$\text{Solution : } n_H = -3.86 \pm 0.08 \quad Z = -2.91 \pm 0.07$$

With Non-BLA fits :

$$N(HI) = 17.90$$

$$\text{Solution : } n_H = -3.62 \pm 0.06 \quad Z = -2.47 \pm 0.06$$

$$N(H_I) = 17.91$$

Solution :  $n_H = -3.73 \pm 0.08$        $Z = -2.36 \pm 0.06$

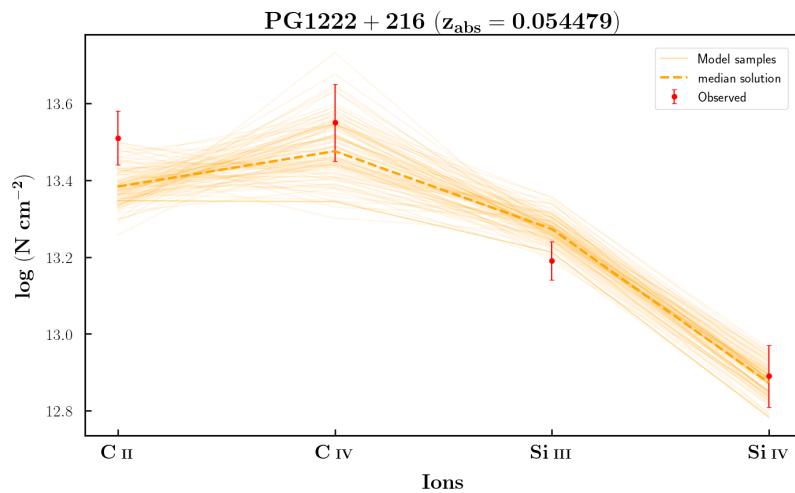


Figure 55:  $N(H_I)=14.08$ ,  $\log Z_{ref}=-1$

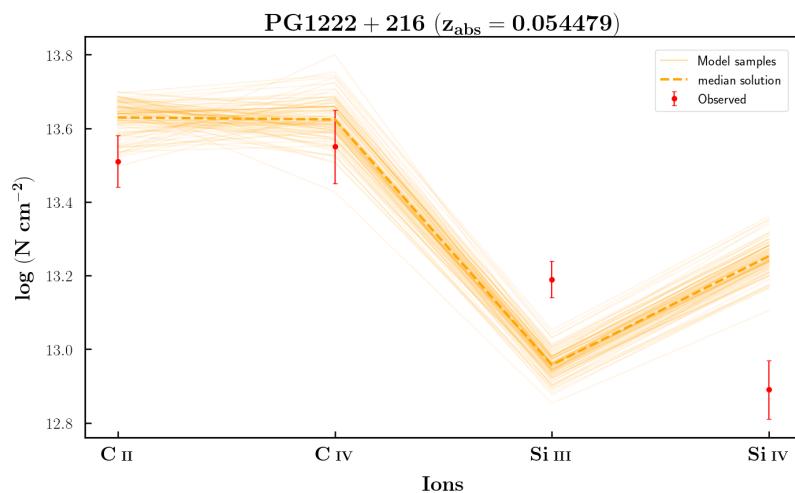


Figure 56:  $N(H_I)=14.08$ ,  $\log Z_{ref}=1$

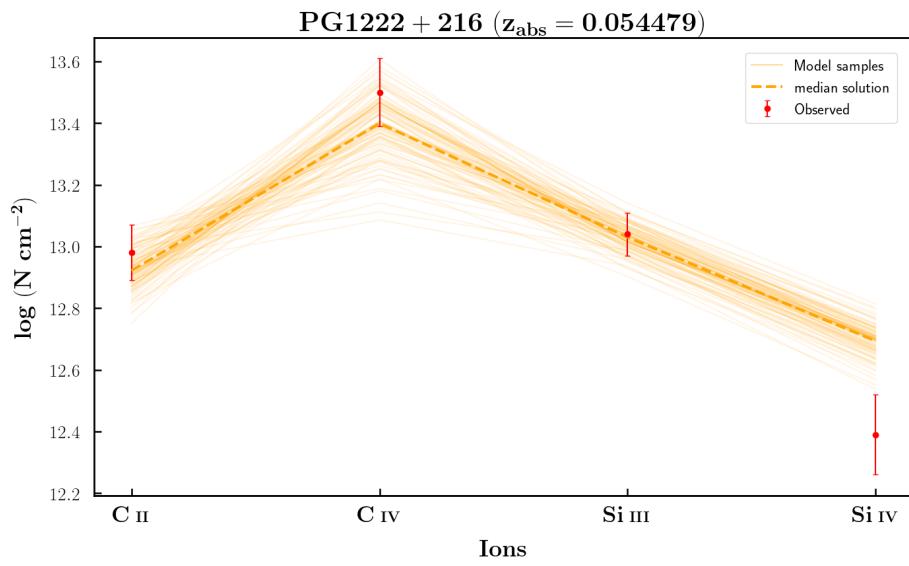


Figure 57:  $\text{N(HI)}=17.91$ ,  $\log Z_{\text{ref}}=-1$

With non-BLA fits

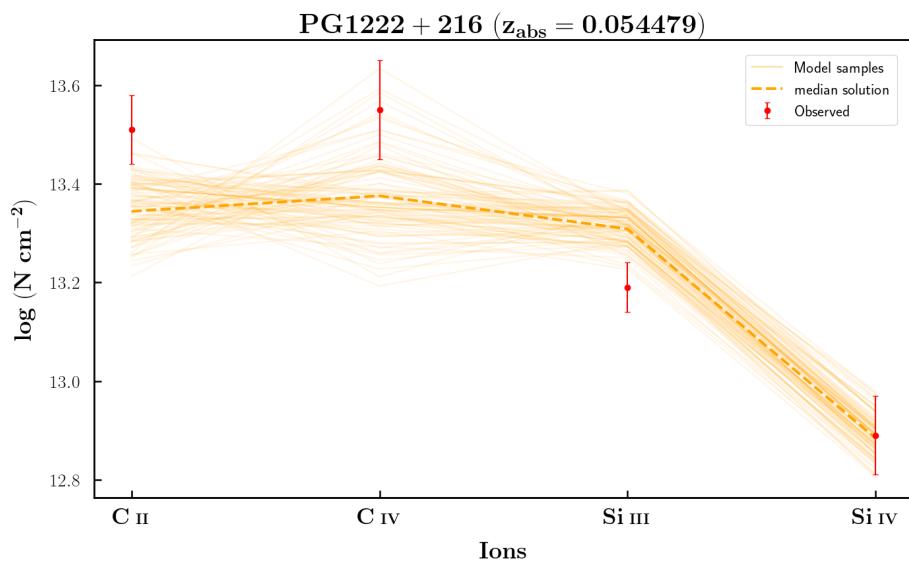


Figure 58:  $\text{N(HI)}=17.90$ ,  $\log Z_{\text{ref}}=-1$

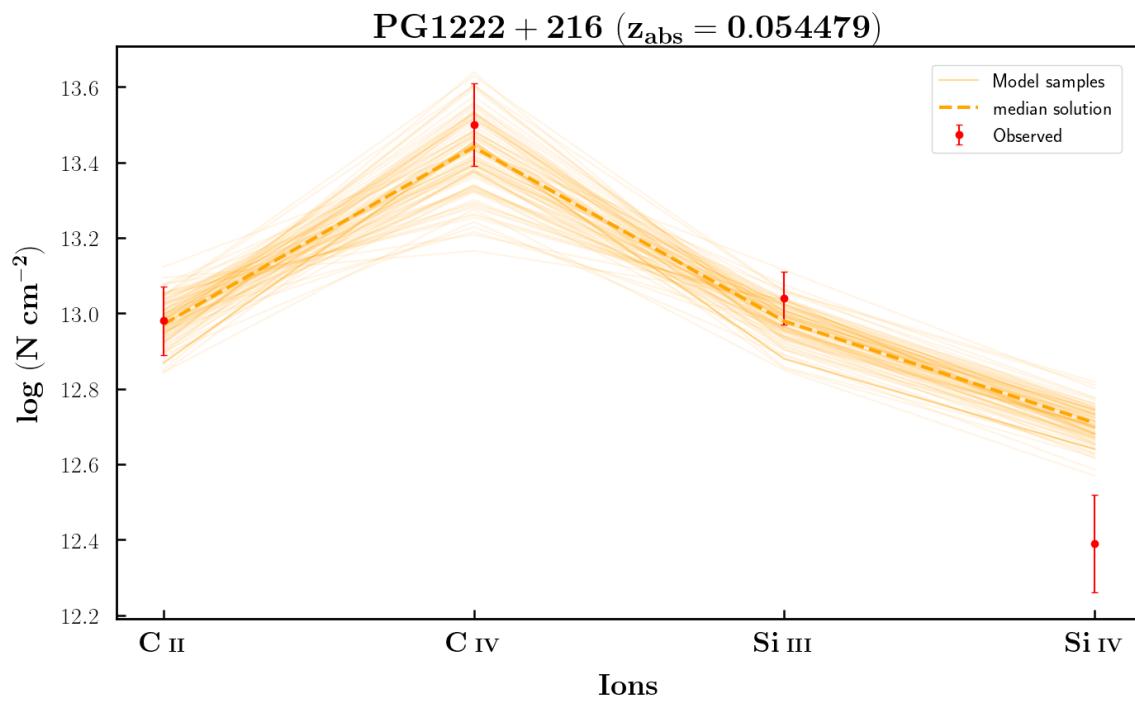
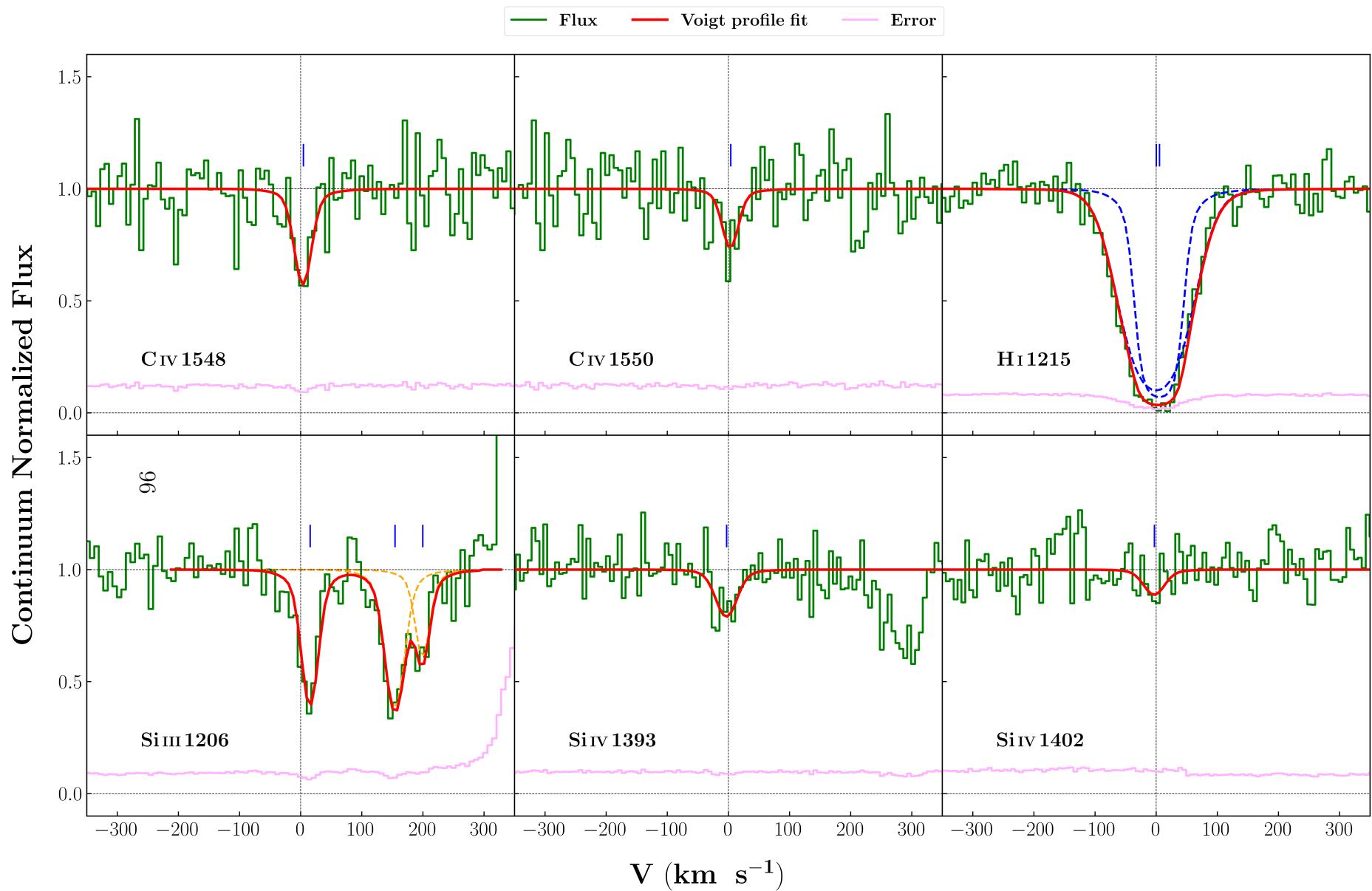


Figure 59:  $N(\text{H I})=17.91$ ,  $\log Z_{ref}=-1$

RXJ0439.6 – 5311 ( $z_{\text{abs}} = 0.005568$ )



Ion	v (km s <sup>-1</sup> )	b (km s <sup>-1</sup> )	log [N cm <sup>-2</sup> ]
Si III	16 ± 1	11 ± 3	13.01 ± 0.12
Si IV	-3 ± 4	20 ± 6	12.77 ± 0.08
C IV	4 ± 3	13 ± 5	13.5 ± 0.07
H I	0 ± 2	53 ± 6	14.3 ± 0.09
H I	5 ± 3	15 ± 6	16.11 ± 0.26

$$N(HI) = 16.11$$

$$\text{Solution : } n_H = -3.69 \pm 0.07 \quad Z = -1.07 \pm 0.1$$

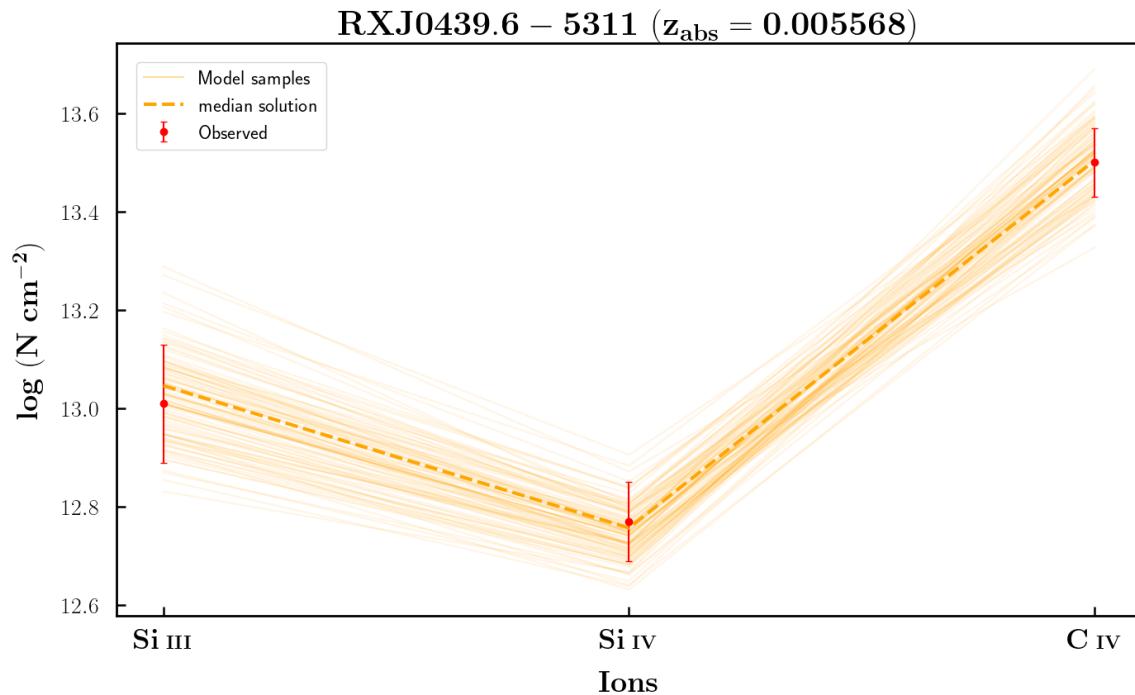
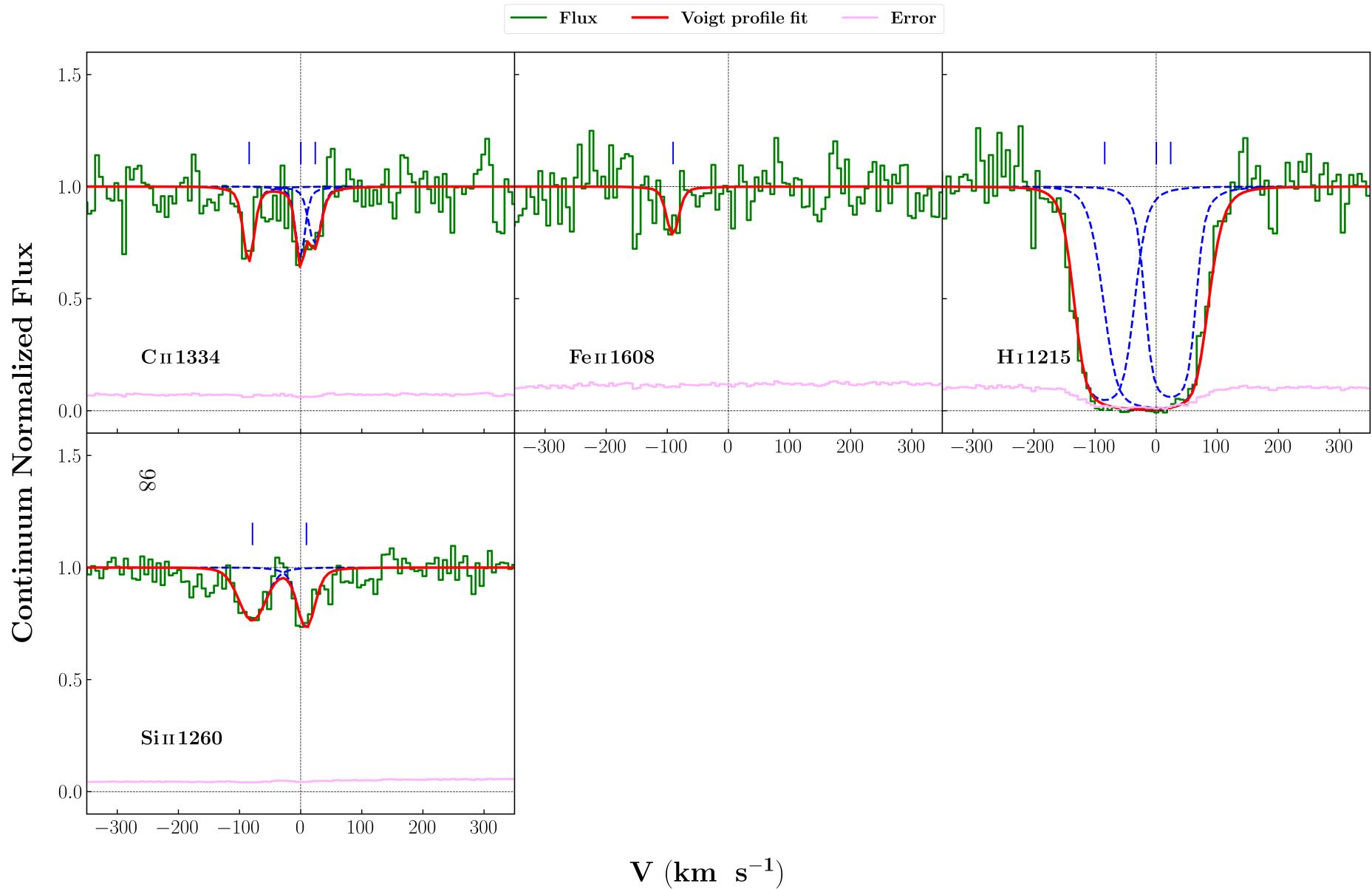


Figure 60:  $N(HI)=16.11$ ,  $\log Z_{ref}=-1$

UKS0242 – 724 ( $z_{\text{abs}} = 0.063850$ )



<b>Ion</b>	<b>v (km s<sup>-1</sup>)</b>	<b>b (km s<sup>-1</sup>)</b>	<b>log [N cm<sup>-2</sup>]</b>
Fe II	-90 ± 4	9 ± 9	13.49 ± 0.14
C II	-84 ± 2	7 ± 5	13.46 ± 0.11
C II	0 ± 3	3 ± 7	13.55 ± 0.16
C II	24 ± 5	9 ± 6	13.32 ± 0.1
Si II	-78 ± 3	25 ± 5	12.6 ± 0.05
Si II	10 ± 2	15 ± 4	12.52 ± 0.06
H I	-84 ± 0	30 ± 5	14.61 ± 0.06
H I	0 ± 0	46 ± 6	15.17 ± 0.1
H I	24 ± 0	19 ± 6	15.34 ± 1.33

$$N(H I) = 14.61$$

$$\text{Solution : } n_H = -1.28 \pm 0.12 \quad Z = 1.96 \pm 0.06$$

NOTE : logZ near 2 and density also coming higher than usual.

Tried with excluding Fe II also

$$\text{Excluding Fe II : } n_H = -1.8 \pm 0.55 \quad Z = 1.54 \pm 0.32$$

$$\text{Including Fe II : } n_H = -1.28 \pm 0.11 \quad Z = 1.96 \pm 0.07$$

NOTE : Excluding Fe II MCMC hints towards 2 sol. Didn't converge satisfactorily.

$$\log Z_{ref} = 1 :$$

$$\text{Solution : } n_H = -2.23 \pm 0.13 \quad Z = 1.92 \pm 0.10$$

$$\text{Excluding Fe II : } n_H = -2.42 \pm 0.58 \quad Z = 1.69 \pm 0.42$$

$$\text{Including Fe II : } n_H = -2.23 \pm 0.13 \quad Z = 1.92 \pm 0.10$$

NOTE : Same note as above.

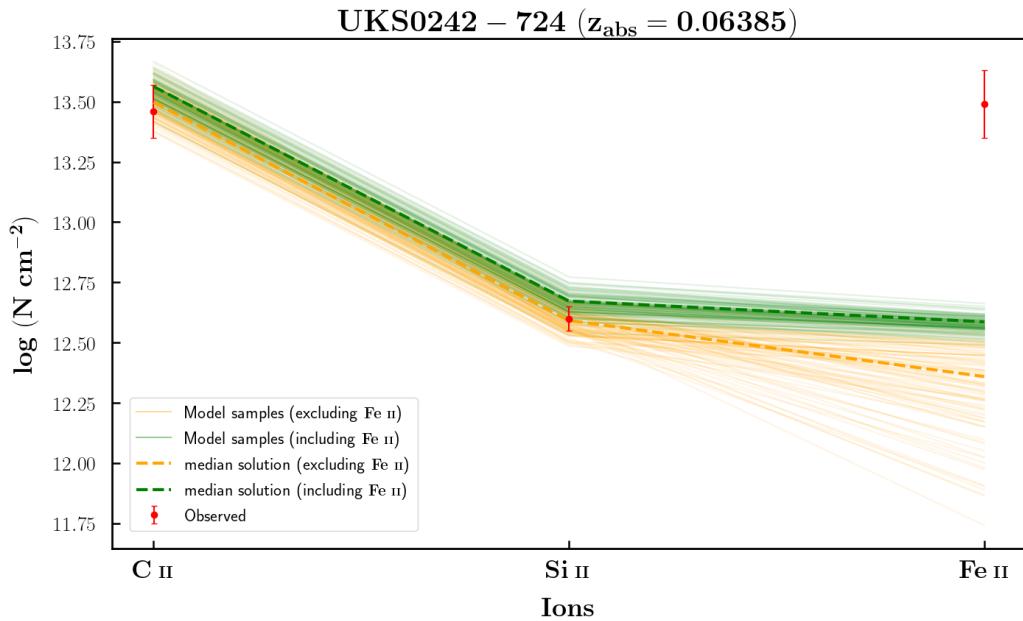


Figure 61:  $N(\text{H I})=14.61$ , shows solution with excluding Fe II,  $\log Z_{\text{ref}}=-1$

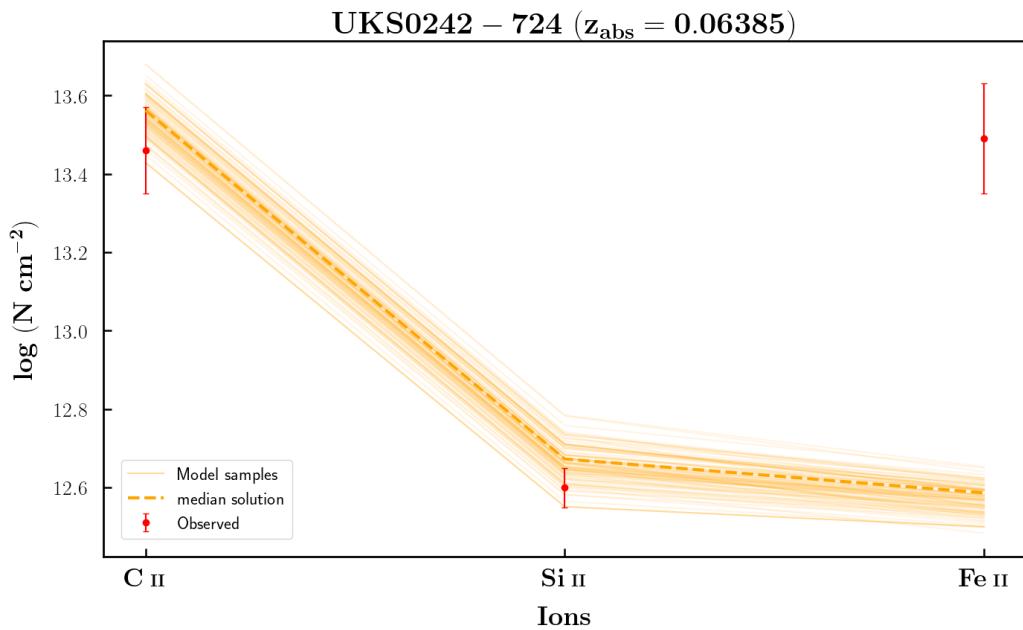


Figure 62:  $N(\text{H I})=14.61$ ,  $\log Z_{\text{ref}}=-1$

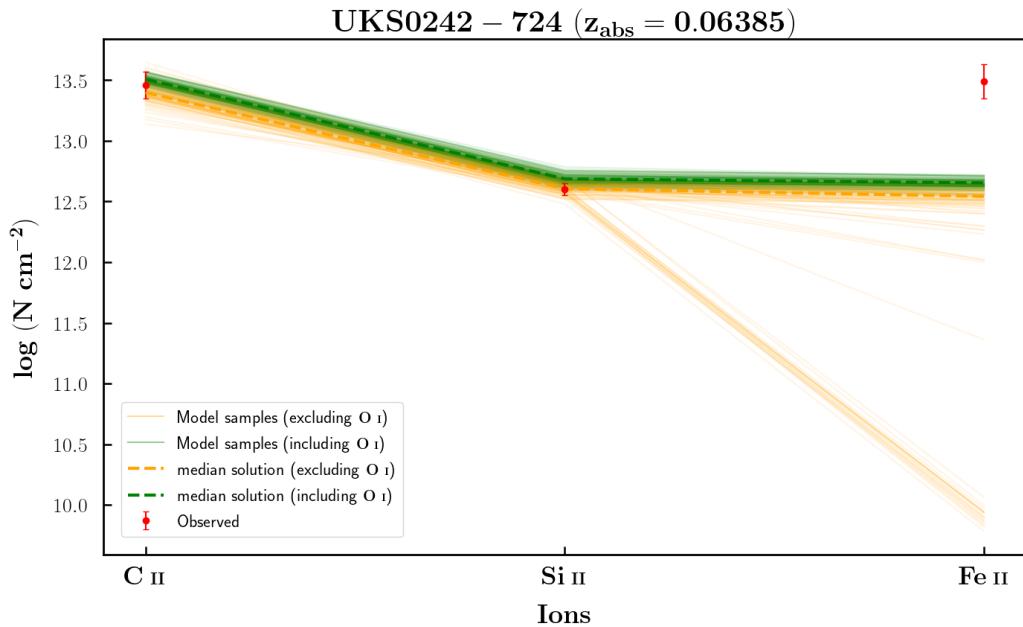


Figure 63:  $\text{N(H I)}=14.61$ , shows solution with excluding  $\text{Fe II}$ ,  $\log Z_{\text{ref}}=1$

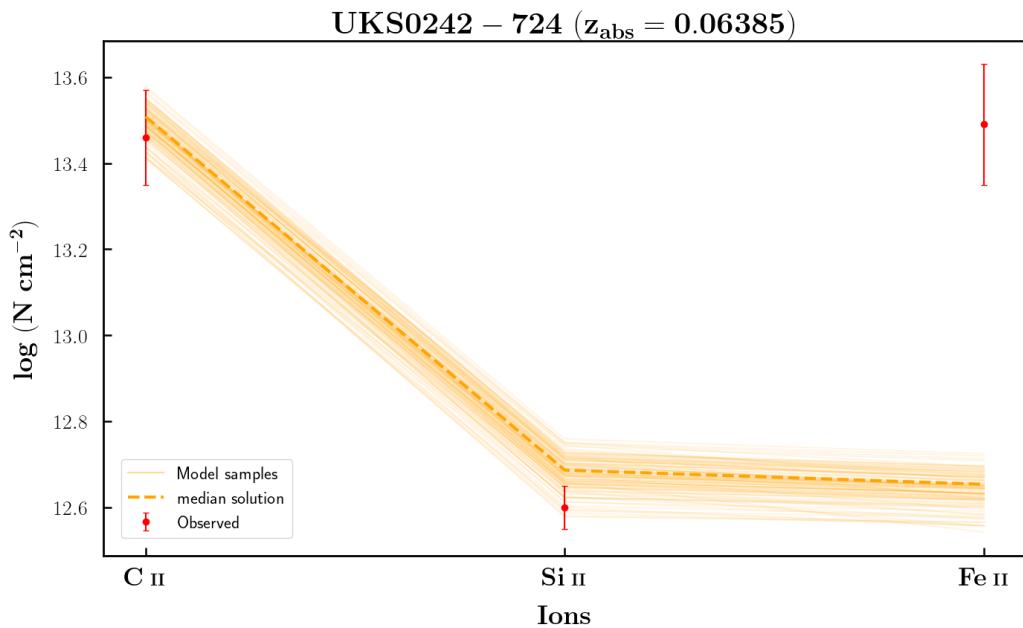
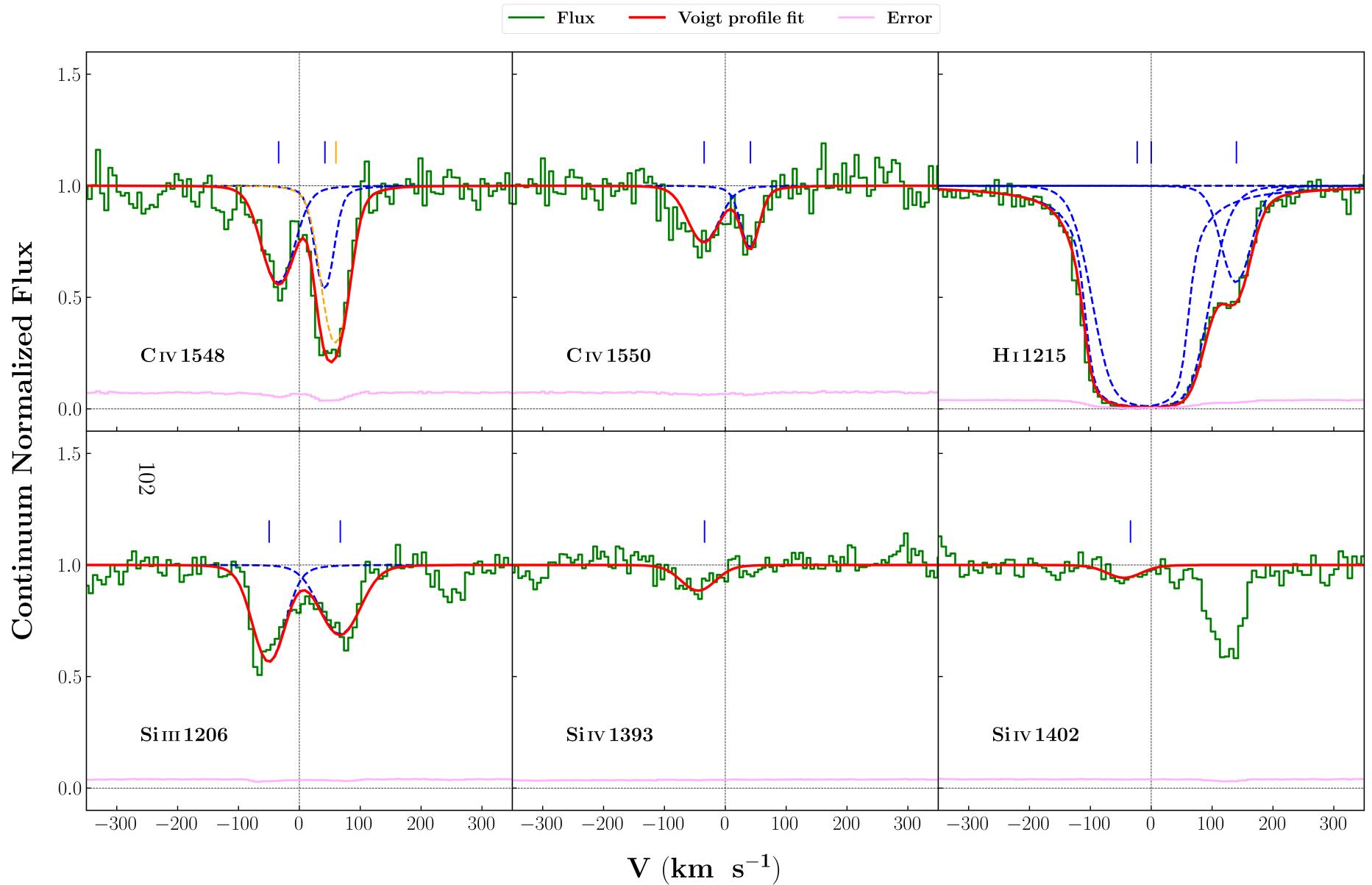


Figure 64:  $\text{N(H I)}=14.61$ ,  $\log Z_{\text{ref}}=1$

PG1259 + 593 ( $z_{\text{abs}} = 0.046284$ )



Ion	v (km s <sup>-1</sup> )	b (km s <sup>-1</sup> )	log [N cm <sup>-2</sup> ]
C IV	-34 ± 2	31 ± 3	13.7 ± 0.03
C IV	42 ± 2	16 ± 3	13.56 ± 0.05
Si IV	-43 ± 4	35 ± 6	12.67 ± 0.05
Si III	-50 ± 2	29 ± 3	12.87 ± 0.03
Si III	67 ± 3	40 ± 5	12.78 ± 0.04
H I	-590 ± 8	47 ± 12	12.79 ± 0.08
H I	-23 ± 7	26 ± 3	17.79 ± 0.07
H I	0 ± 5	61 ± 7	14.86 ± 0.06
H I	140 ± 3	27 ± 4	13.43 ± 0.07

$$N(HI) = 17.79$$

$$\text{Solution : } n_H = -4.23 \pm 0.04 \quad Z = -3.18 \pm 0.04$$

NOTE : Used logZ range from -4 because of low Z

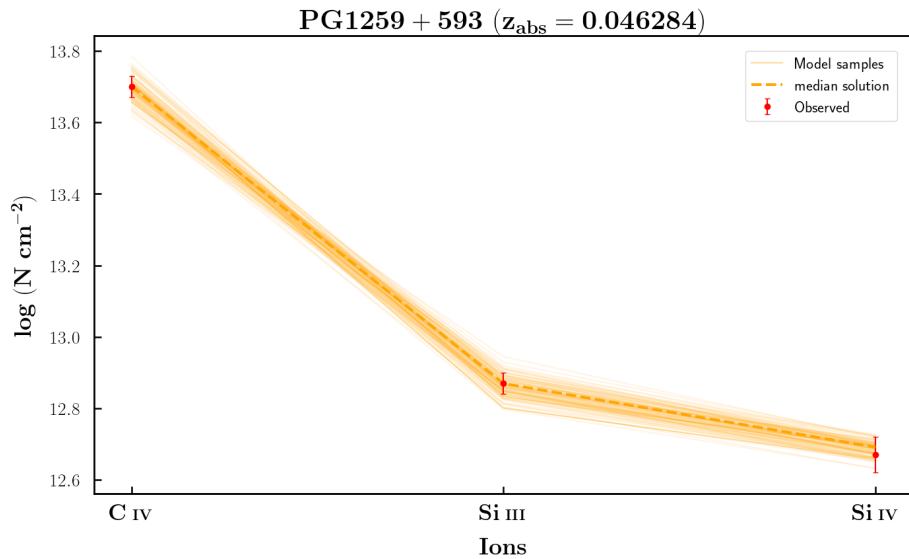
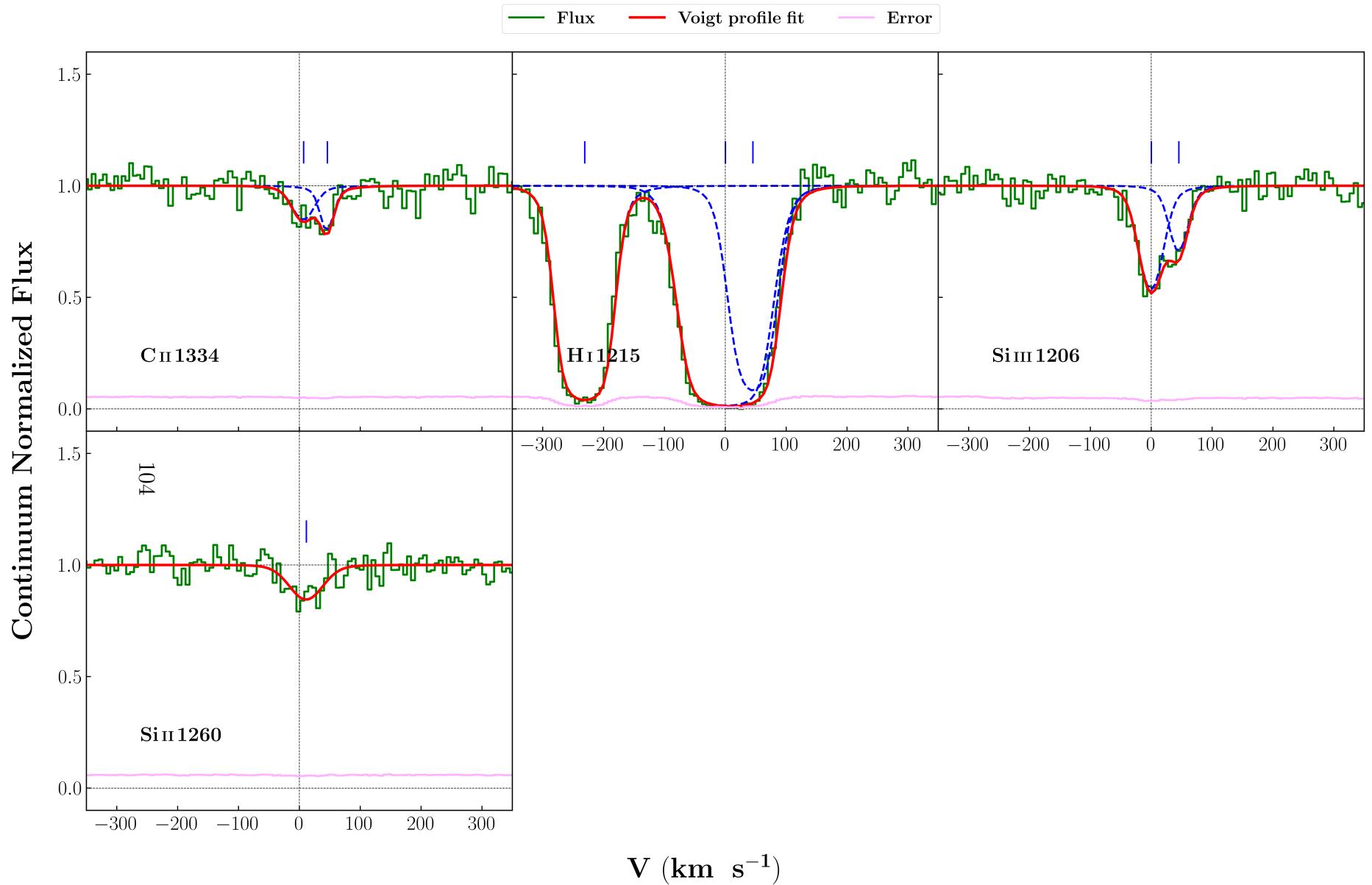


Figure 65:  $N(HI)=17.79$ ,  $\log Z_{ref}=-1$

PKS1302 – 102 ( $z_{\text{abs}} = 0.094839$ )



<b>Ion</b>	<b>v (km s<sup>-1</sup>)</b>	<b>b (km s<sup>-1</sup>)</b>	<b>log [N cm<sup>-2</sup>]</b>
Si III	0 ± 2	22 ± 3	12.82 ± 0.04
Si III	45 ± 3	16 ± 4	12.48 ± 0.08
Si II	11 ± 5	34 ± 7	12.48 ± 0.06
C II	7 ± 8	21 ± 8	13.27 ± 0.09
C II	46 ± 4	10 ± 5	13.25 ± 0.09
H I	-229 ± 1	29 ± 2	14.81 ± 0.14
H I	0 ± 0	46 ± 2	14.96 ± 0.1
H I	45 ± 0	31 ± 4	14.25 ± 0.14

$$N(HI) = 14.96$$

$$\text{Solution : } n_H = -2.65 \pm 0.06 \quad Z = 0.62 \pm 0.06$$

$$\log Z_{ref} = 1$$

$$\text{Solution : } n_H = -4.14 \pm 0.04 \quad Z = 0.64 \pm 0.03$$

NOTE : Density changed considerably in the two cases.

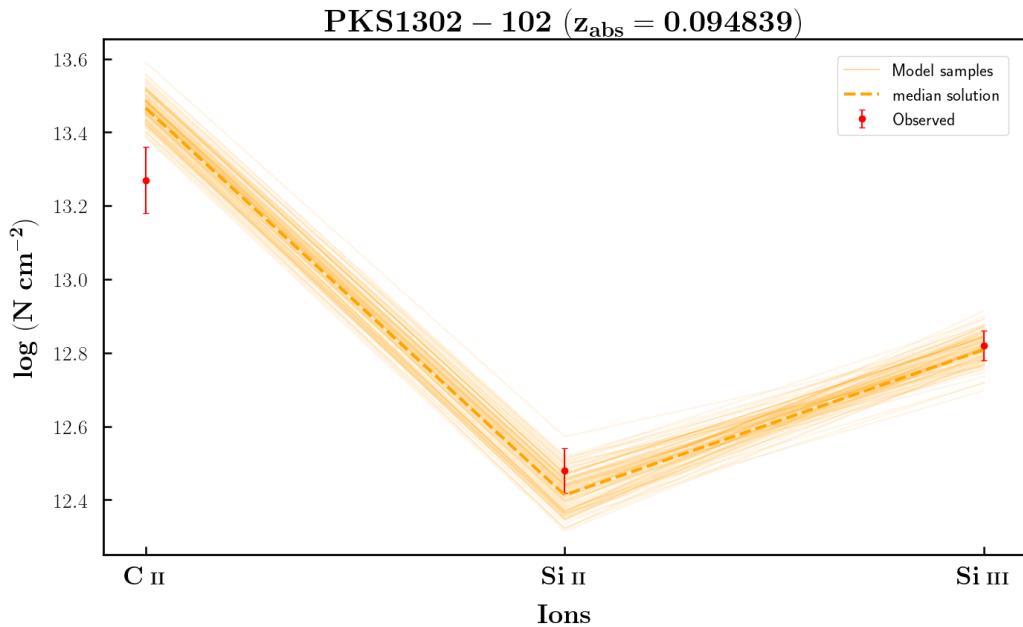


Figure 66:  $N(\text{H I})=14.96$ ,  $\log Z_{\text{ref}}=-1$

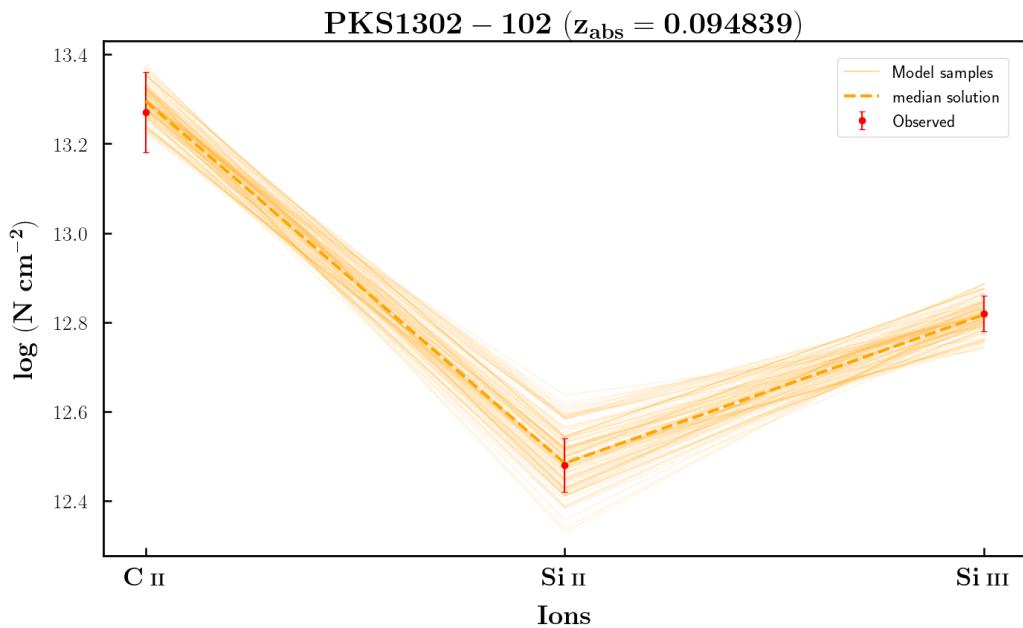
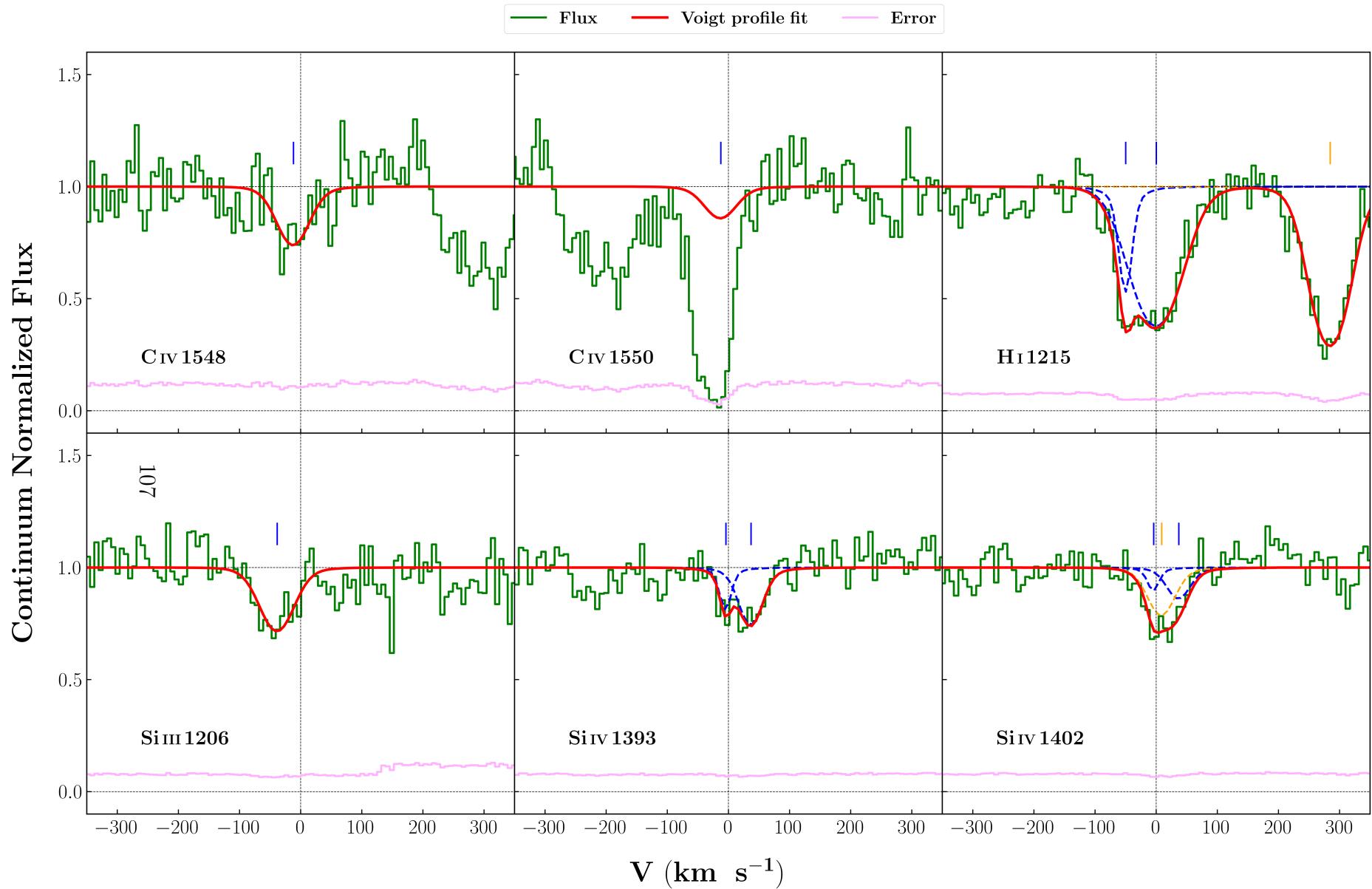


Figure 67:  $N(\text{H I})=14.96$ ,  $\log Z_{\text{ref}}=1$

### 3C57 ( $z_{\text{abs}} = 0.077430$ )



Ion	v (km s <sup>-1</sup> )	b (km s <sup>-1</sup> )	log [N cm <sup>-2</sup> ]
C IV	-12 ± 6	32 ± 9	13.43 ± 0.08
Si IV	-4 ± 4	7 ± 6	12.54 ± 0.09
Si IV	37 ± 4	22 ± 6	12.92 ± 0.07
Si III	-38 ± 5	34 ± 7	12.67 ± 0.06
H I	-50 ± 2	8 ± 4	13.3 ± 0.08
H I	0 ± 4	50 ± 4	13.86 ± 0.04

$$N(HI) = 13.30$$

$$\text{Solution : } n_H = -3.73 \pm 0.05 \quad Z = 1.38 \pm 0.05$$

$$\log Z_{ref} = 1$$

$$\text{Solution : } n_H = -4.04 \pm 0.04 \quad Z = 1.98 \pm 0.03$$

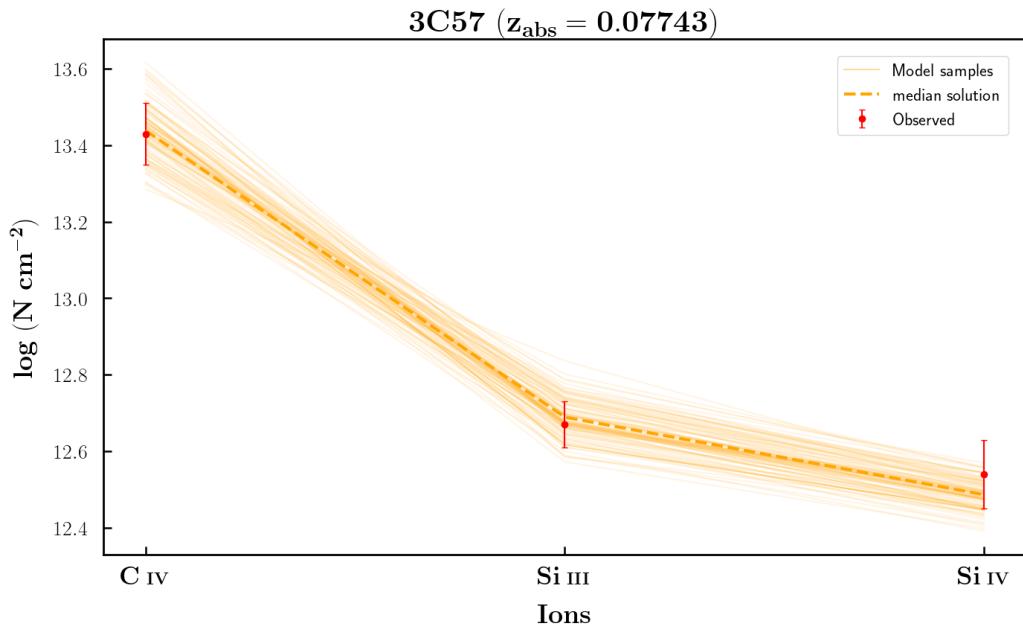


Figure 68:  $N(\text{H I})=13.30$ ,  $\log Z_{ref}=-1$

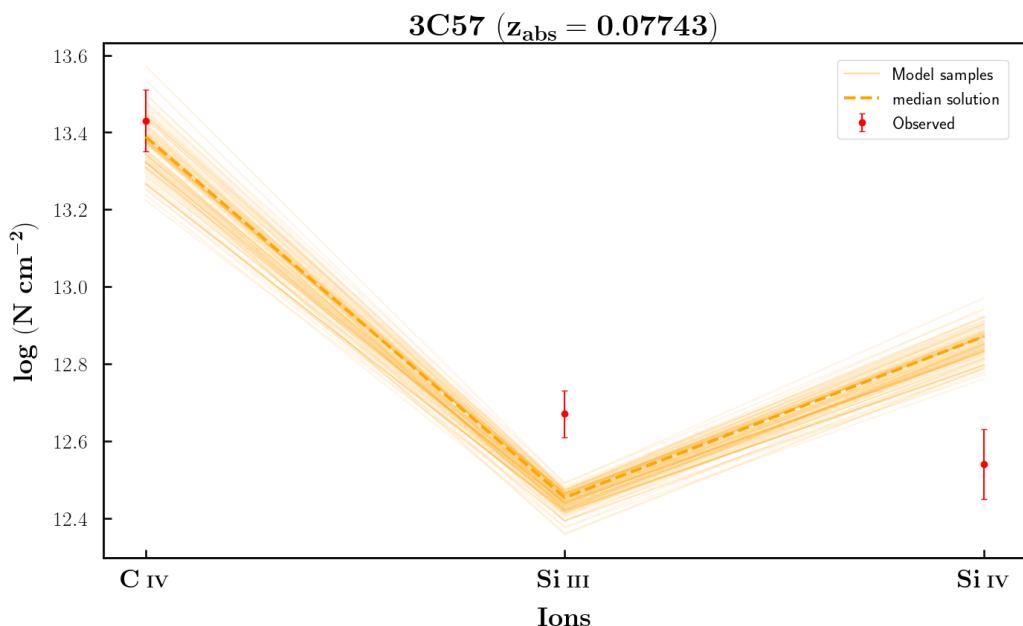
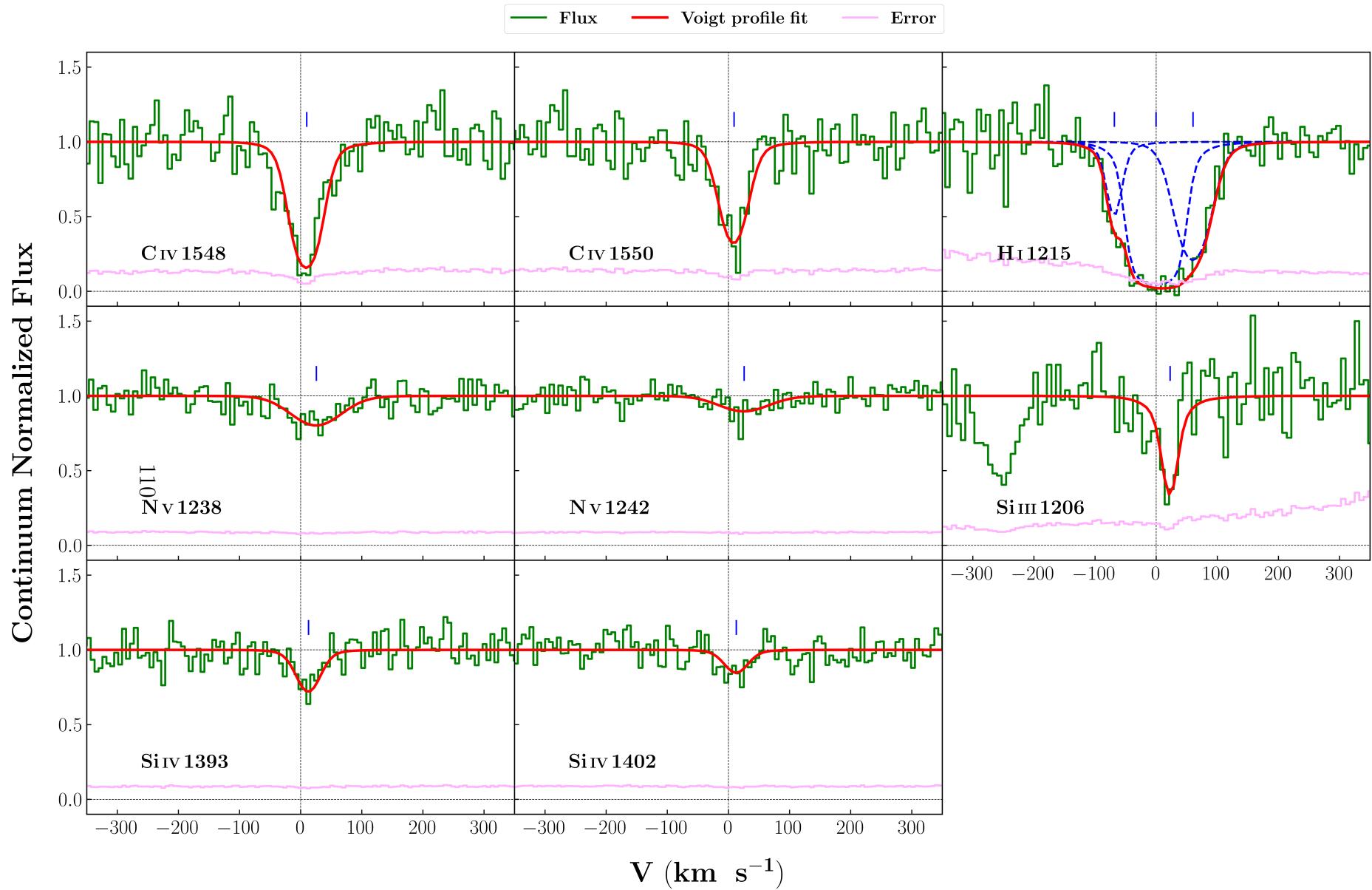


Figure 69:  $N(HI) = 13.3$ ,  $\log Z_{ref} = 1$

PMNJ1103 – 2329 ( $z_{\text{abs}} = 0.003934$ )



Ion	v (km s <sup>-1</sup> )	b (km s <sup>-1</sup> )	log [N cm <sup>-2</sup> ]
Si III	23 ± 3	4 ± 3	15.02 ± 0.22
Si IV	13 ± 3	23 ± 5	12.96 ± 0.06
N V	22 ± 5	52 ± 8	13.65 ± 0.05
C IV	10 ± 1	24 ± 2	14.26 ± 0.04
H I	-68 ± 6	10 ± 7	13.37 ± 0.09
H I	0 ± 12	19 ± 2	16.29 ± 0.19
H I	60 ± 27	28 ± 4	13.95 ± 0.05

$$N(HI) = 16.29$$

$$\text{Solution : } n_H = -4.17 \pm 0.03 \quad Z = -1.08 \pm 0.04$$

Tried excluding Si III also

$$\begin{aligned} \text{Excluding Si III : } n_H &= -4.24 \pm 0.03 & Z &= -1.19 \pm 0.04 \\ \text{Including Si III : } n_H &= -4.17 \pm 0.03 & Z &= -1.08 \pm 0.04 \end{aligned}$$

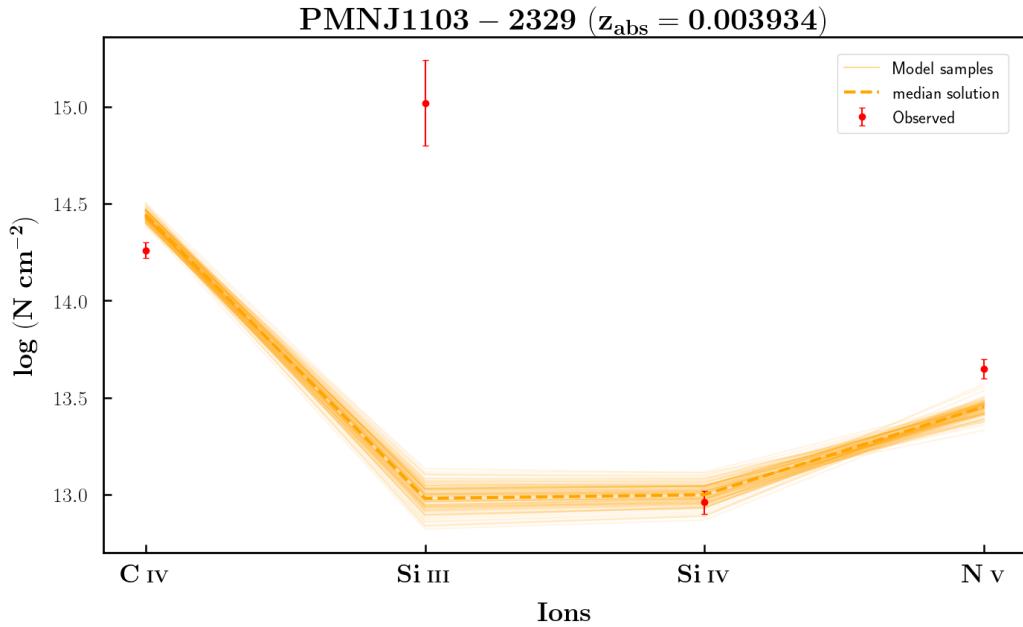


Figure 70:  $\text{N(HI)}=16.29$ ,  $\log Z_{ref}=-1$

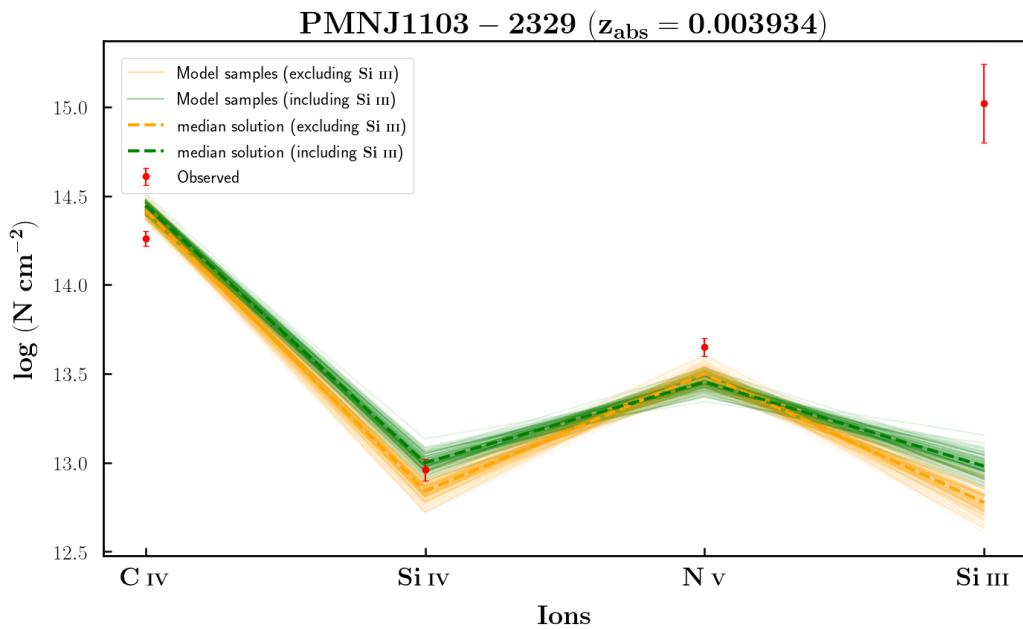
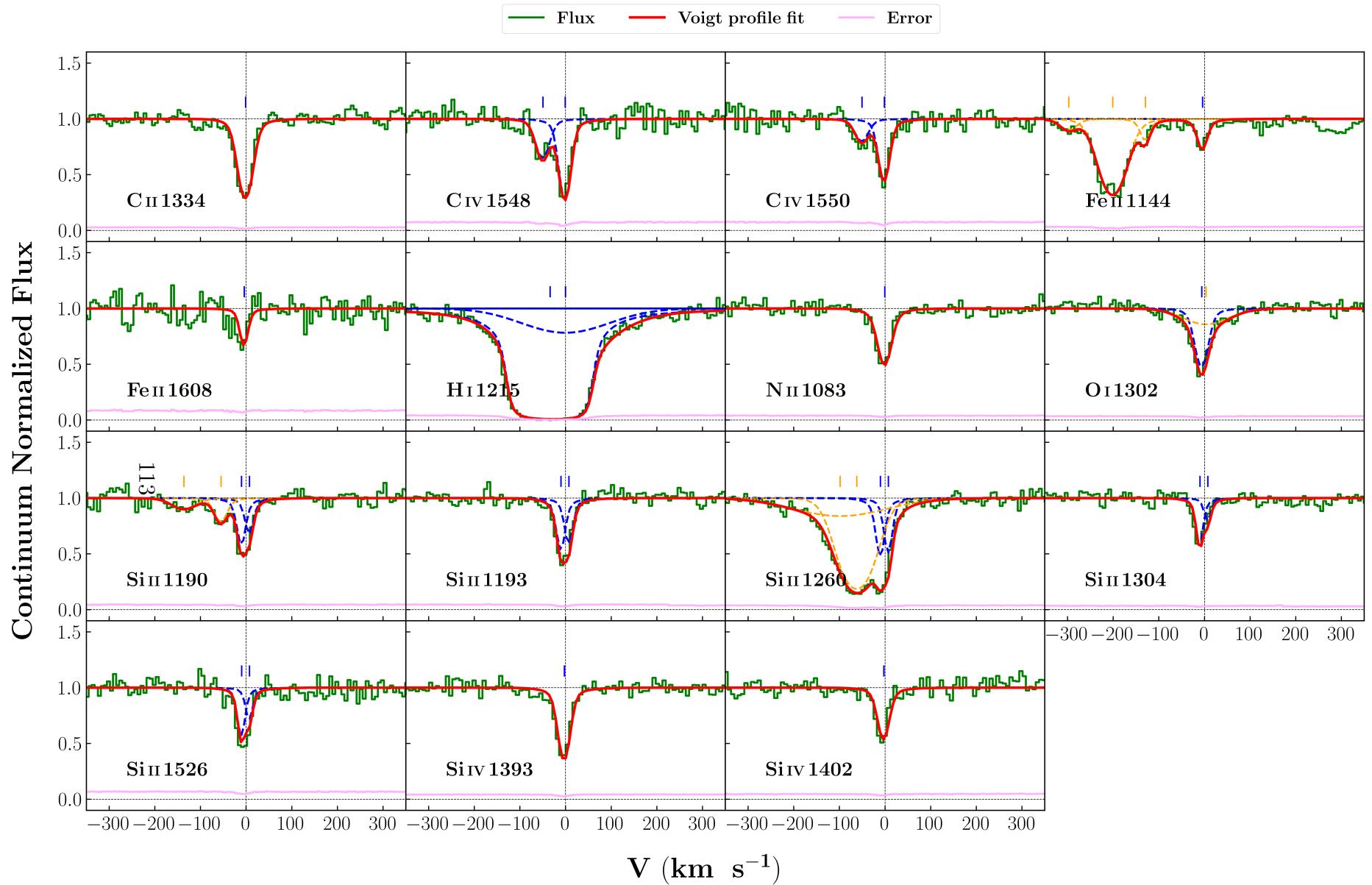


Figure 71:  $\text{N(HI)}=16.29$ , shows excluding Si III case,  $\log Z_{ref}=-1$

PHL1811 ( $z_{\text{abs}} = 0.080928$ )



Ion	v (km s <sup>-1</sup> )	b (km s <sup>-1</sup> )	log [N cm <sup>-2</sup> ]
O I	-6 ± 1	15 ± 2	14.29 ± 0.05
C II	-1 ± 1	16 ± 1	14.15 ± 0.02
N II	-1 ± 1	13 ± 1	14.06 ± 0.03
C IV	-49 ± 2	16 ± 3	13.38 ± 0.04
C IV	-1 ± 1	11 ± 1	13.93 ± 0.04
Si IV	-2 ± 1	11 ± 1	13.46 ± 0.03
Fe II	-4 ± 1	7 ± 3	13.7 ± 0.07
Si II	-10 ± 1	3 ± 1	14.24 ± 0.07
Si II	7 ± 1	4 ± 1	13.33 ± 0.08
H I	-875 ± 1	32 ± 1	14.6 ± 0.06
H I	-528 ± 0	30 ± 2	15.38 ± 0.05
H I	-34 ± 1	29 ± 1	18.02 ± 0.11
H I	0 ± 19	126 ± 23	13.62 ± 0.07

$$N(H I) = 18.02$$

Using all ions :

$$\text{Solution : } n_H = -3.11 \pm 0.01 \quad Z = -1.28 \pm 0.01$$

Using C II, C IV, Si II and Si IV :

$$\text{Solution : } n_H = -3.44 \pm 0.02 \quad Z = -1.7 \pm 0.02$$

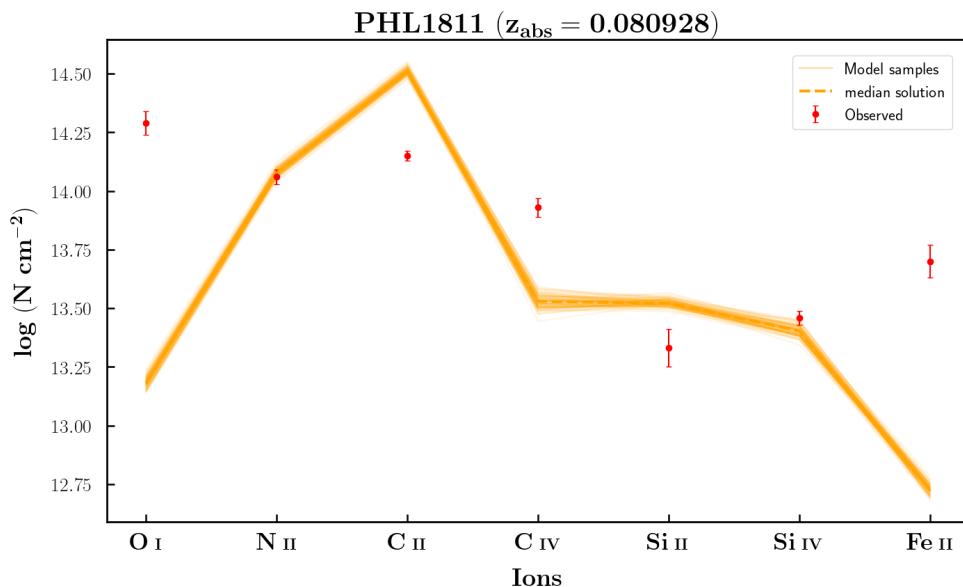


Figure 72:  $N(\text{H I})=18.02$ , all ions,  $\log Z_{\text{ref}}=-1$

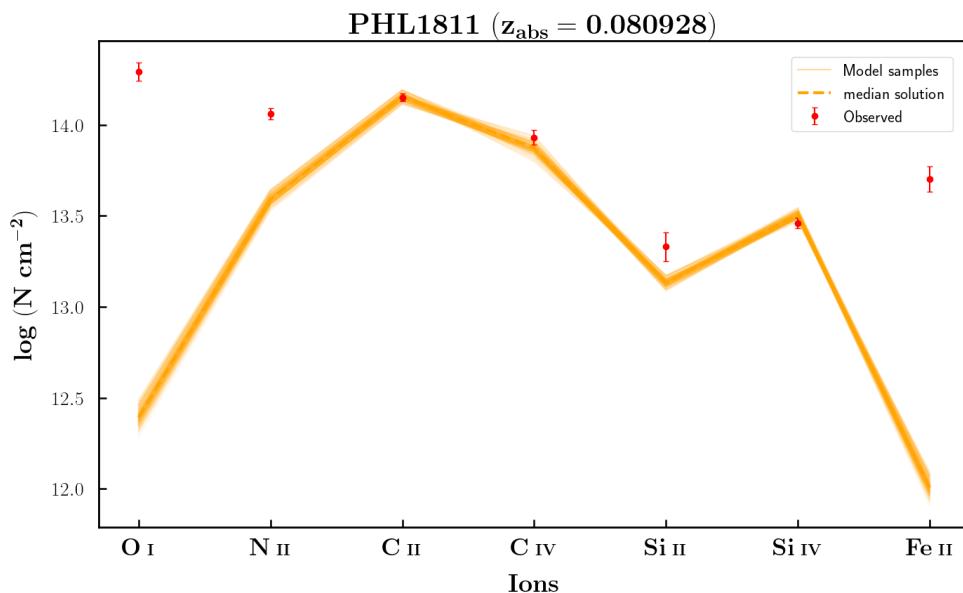
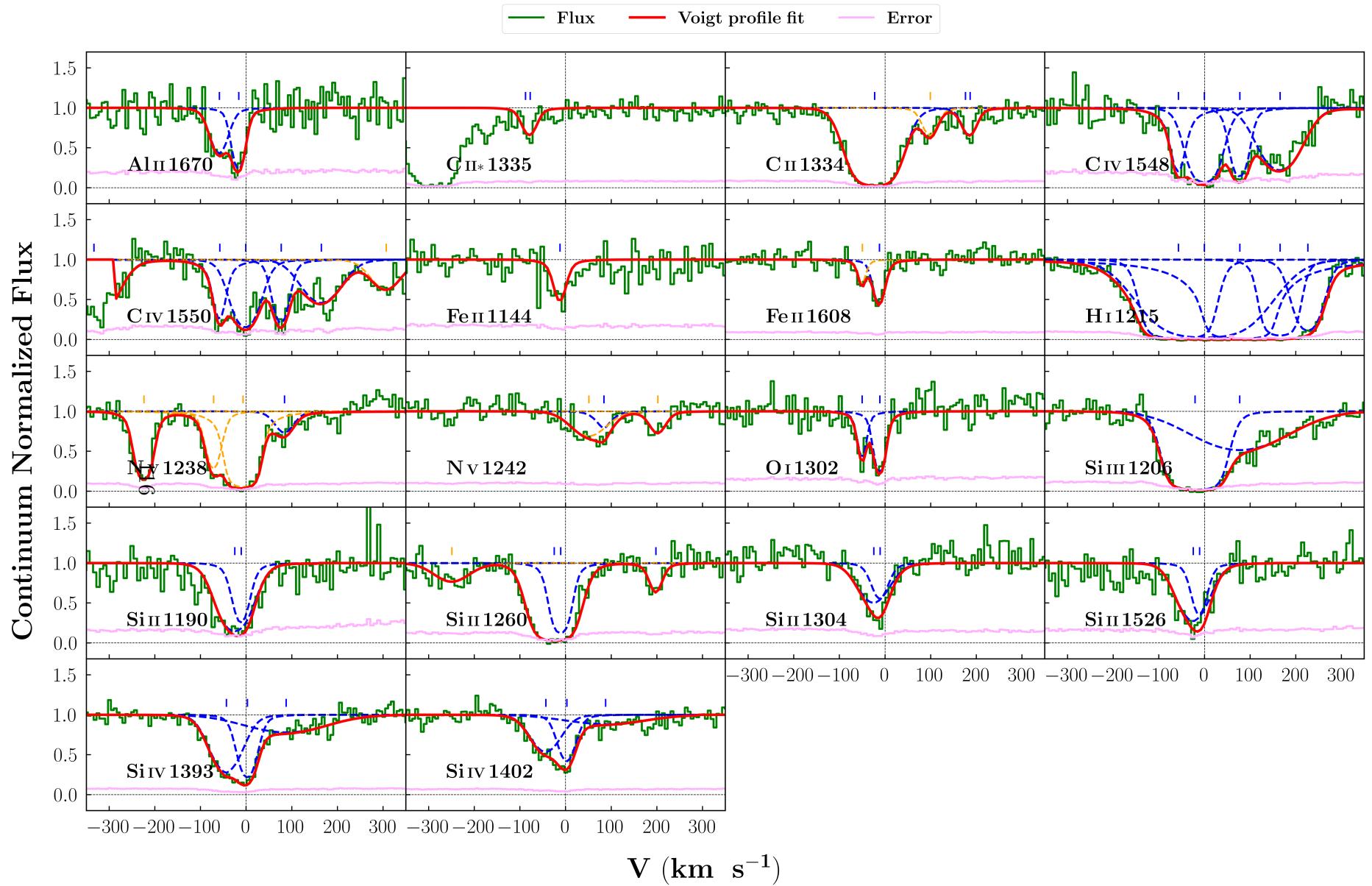


Figure 73:  $N(\text{H I})=18.02$ , C II, C IV, Si II and Si IV,  $\log Z_{\text{ref}}=-1$

PG0832 + 251 ( $z_{\text{abs}} = 0.017505$ )



Ion	v (km s <sup>-1</sup> )	b (km s <sup>-1</sup> )	log [N cm <sup>-2</sup> ]
Al II	-58 ± 7	21 ± 6	12.76 ± 0.08
Al II	-16 ± 4	12 ± 4	13.04 ± 0.11
O I	-50 ± 2	4 ± 2	15.28 ± 0.41
O I	-11 ± 1	7 ± 3	15.76 ± 0.28
Fe II	-12 ± 1	12 ± 3	14.16 ± 0.07
Si IV	-43 ± 8	39 ± 6	13.72 ± 0.1
Si IV	3 ± 3	21 ± 3	13.68 ± 0.11
Si IV	88 ± 1	120 ± 15	13.46 ± 0.05
C IV	-57 ± 2	4 ± 1	17.26 ± 0.12
C IV	0 ± 3	31 ± 3	14.59 ± 0.08
C IV	78 ± 1	15 ± 3	14.45 ± 0.07
C IV	166 ± 3	51 ± 4	14.31 ± 0.03
Si II	-25 ± 1	38 ± 2	14.29 ± 0.06
Si II	-11 ± 4	15 ± 2	14.02 ± 0.13
Si II	198 ± 4	13 ± 7	12.7 ± 0.09
Si III	-21 ± 2	38 ± 7	14.67 ± 0.06
Si III	77 ± 17	130 ± 14	13.48 ± 0.07
N V	84 ± 6	23 ± 7	13.53 ± 0.08
C II	-23 ± 1	43 ± 3	15.2 ± 0.1
C II*	-78 ± 3	10 ± 0	13.7 ± 0.08
H I	-57 ± 0	38 ± 6	15.82 ± 0.17
H I	0 ± 0	115 ± 26	14.79 ± 0.07
H I	78 ± 0	24 ± 5	18.22 ± 0.11
H I	166 ± 0	20 ± 6	15.83 ± 0.98
H I	227 ± 0	29 ± 4	14.18 ± 0.09

C II\* : it's a line not contamination.

N(H I) = 15.82

Solution :  $n_H = -4.09 \pm 0.05$        $Z = 1.4 \pm 0.07$

Excluding O I :

Solution :  $-4.20 \pm 0.05$        $Z = 1.42 \pm 0.07$

Excluding Al II :

$n_H = -4.93 \pm 0.05$        $Z = 1.70 \pm 0.11$

NOTE : MCMC samples going below  $\log n_H < 5$ , not good solution  
 $\log Z_{ref}=1$

Solution :  $n_H = -4.21 \pm 0.05$        $Z = 1.67 \pm 0.06$

Excluding O I :

Solution :  $n_H = -4.35 \pm 0.05$        $Z = 1.61 \pm 0.06$

Excluding Al II :

Solution :  $n_H = -4.93 \pm 0.04$        $Z = 1.33 \pm 0.09$

NOTE : MCMC samples going below  $\log n_H < 5$ , not good solution  
 $N(HI) = 14.79$

Solution :  $n_H = -3.09 \pm 0.02$        $Z = 2.0 \pm 0.0$

Excluding O I, Fe II and Al II

Solution :  $n_H = -3.34 \pm 0.03$        $Z = 1.99 \pm 0.02$

$\log Z_{ref}=1$

Solution :  $n_H = -3.74 \pm 0.02$        $Z = 2.0 \pm 0.0$

Excluding O I, Fe II and Al II

Solution :  $n_H = -4.11 \pm 0.02$        $Z = 2.0 \pm 0.01$

NOTE : log Z coming 2

$N(HI) = 18.22$

Solution :  $n_H = -4.68 \pm 0.07$        $Z = -2.97 \pm 0.08$

NOTE : Used logZ range from -4 because of low Z

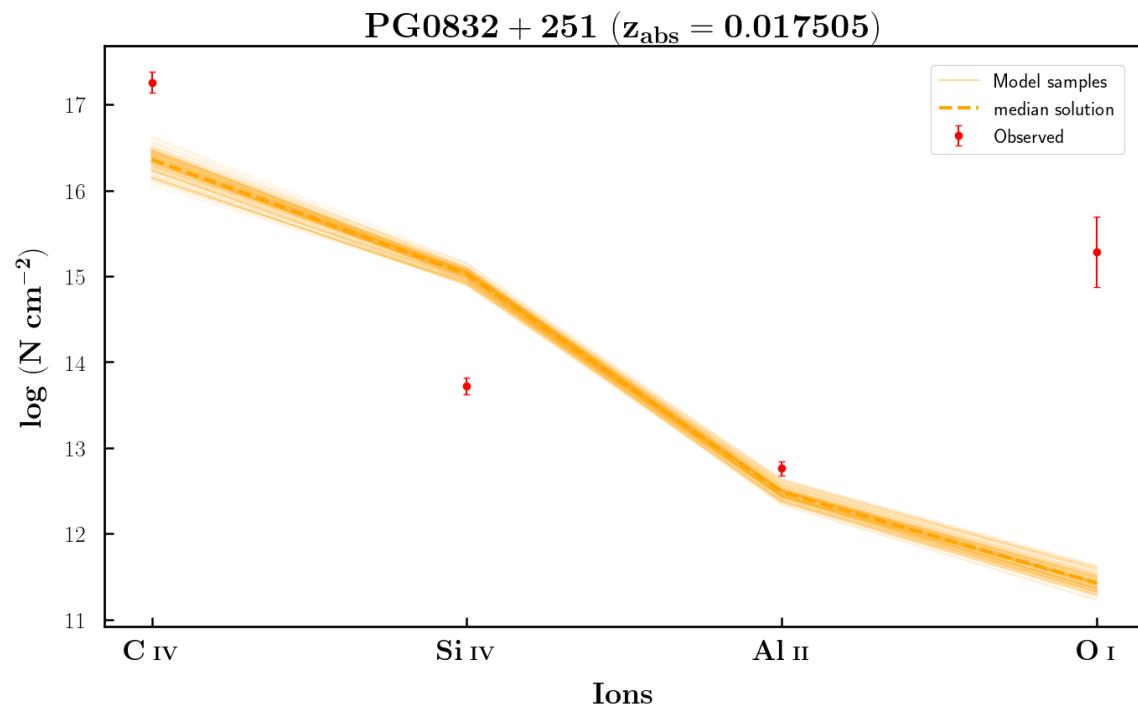


Figure 74:  $N(\text{H I})=15.82$ ,  $\log Z_{\text{ref}}=-1$

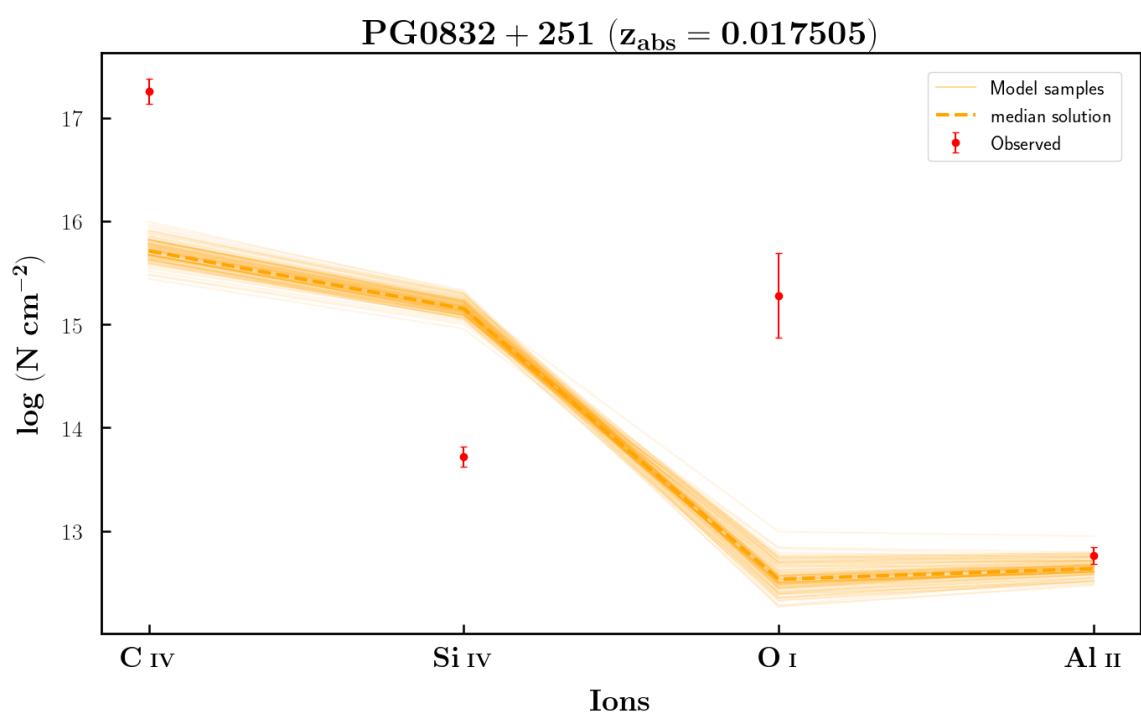


Figure 75:  $\text{N}(\text{H I})=15.82$ ,  $\log Z_{\text{ref}}=1$

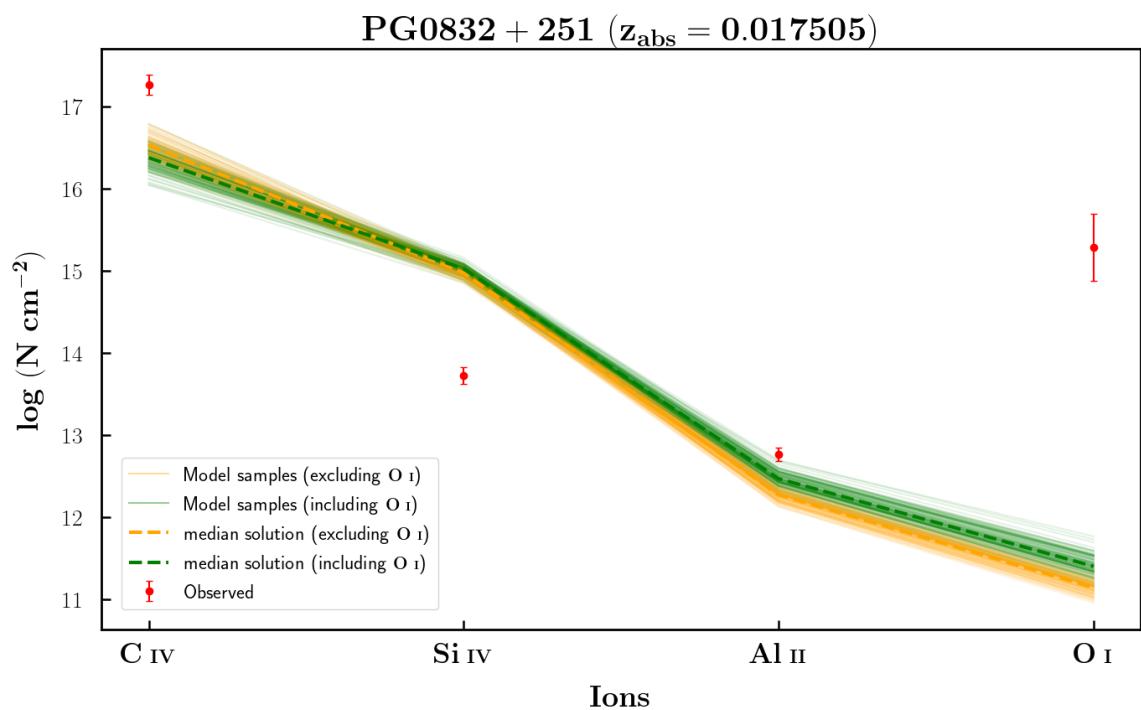


Figure 76:  $N(\text{H I})=15.82$ , excluding O I  $\log Z_{\text{ref}}=-1$

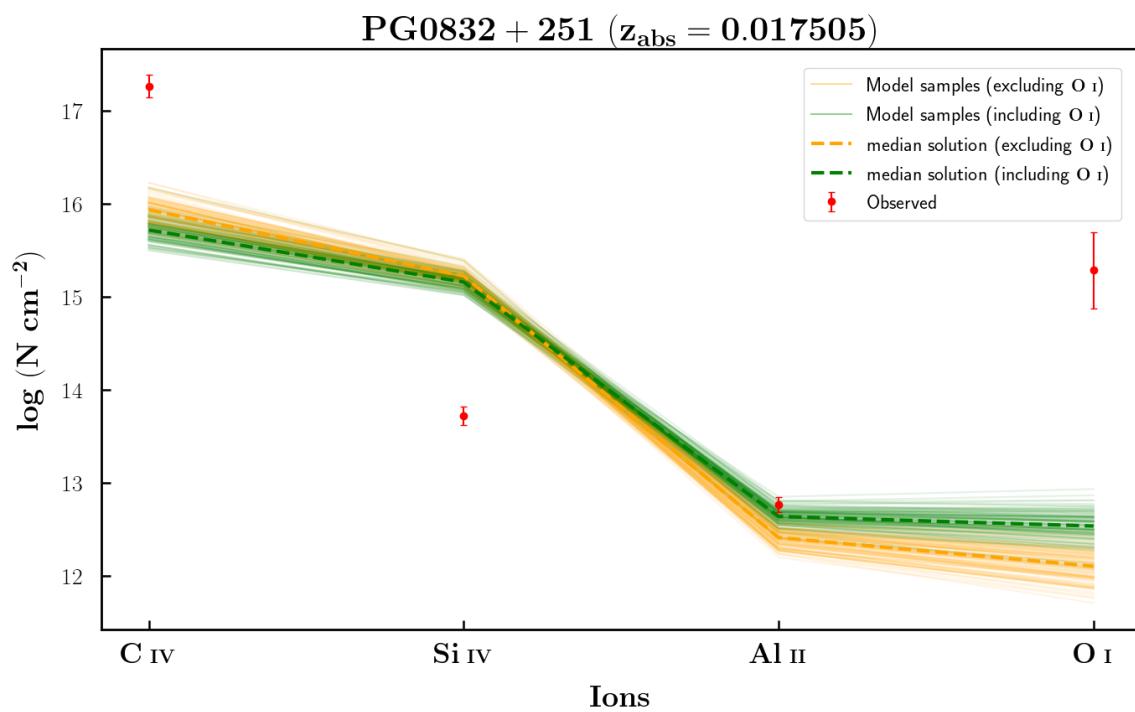


Figure 77:  $N(\text{H I})=15.82$ , excluding O I  $\log Z_{\text{ref}}=1$

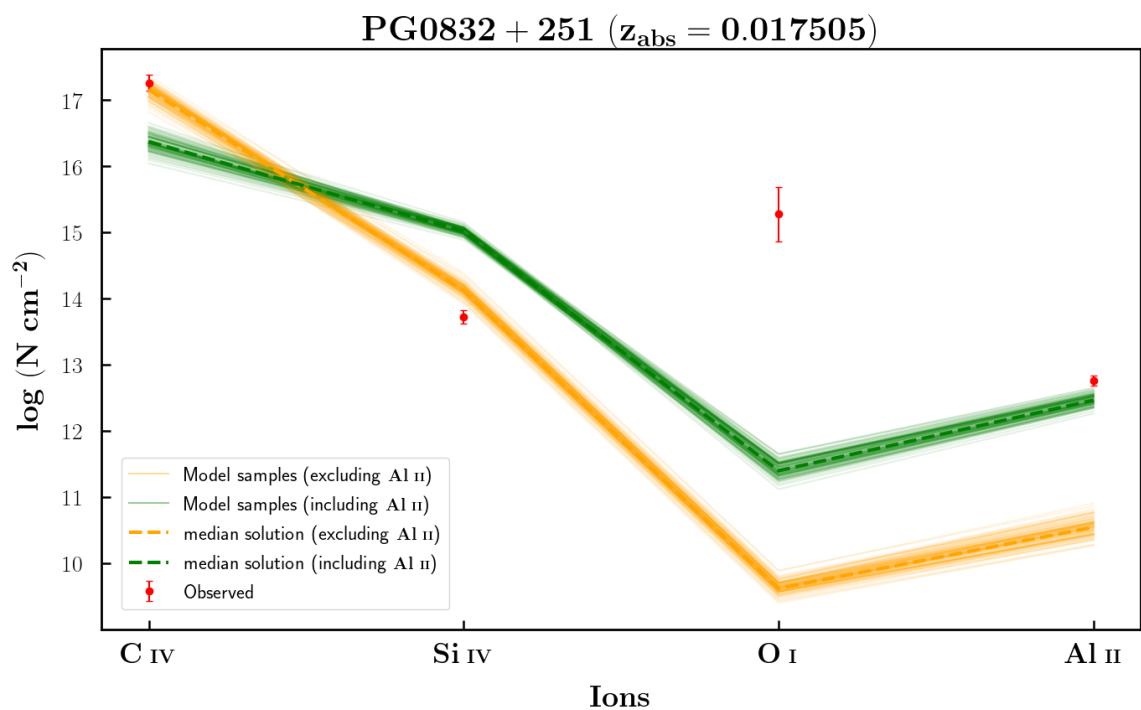


Figure 78:  $N(\text{H I})=15.82$ , excluding Al II  $\log Z_{ref}=-1$

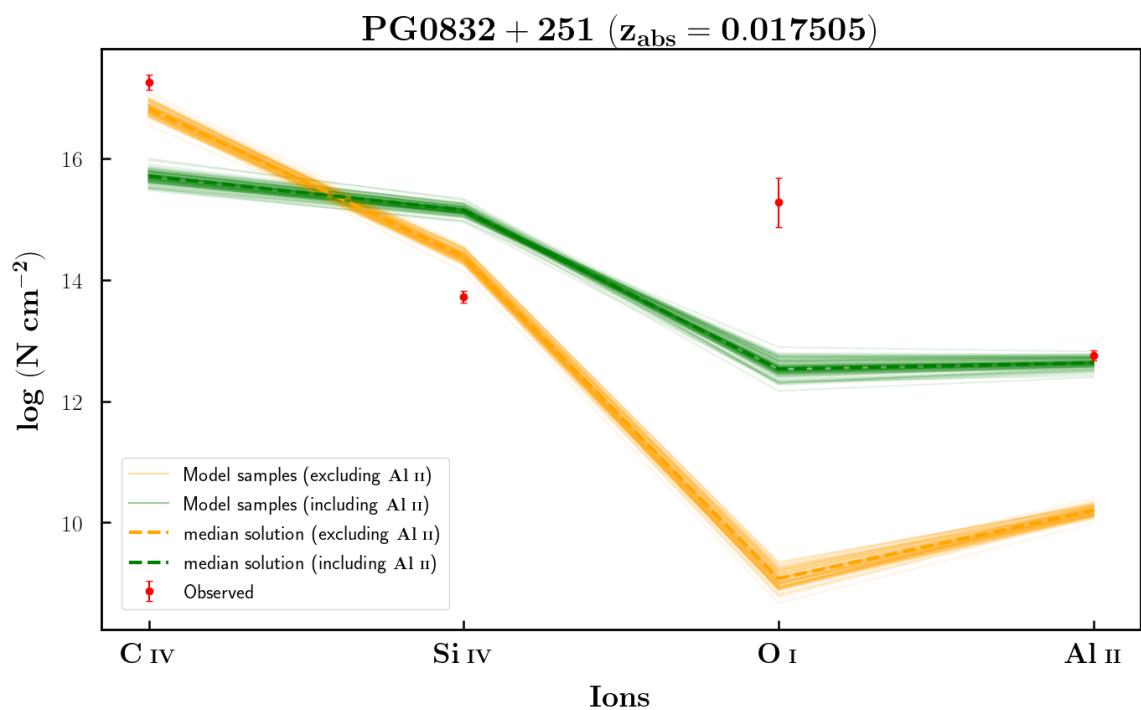


Figure 79:  $N(\text{H I})=15.82$ , excluding Al II  $\log Z_{\text{ref}}=1$

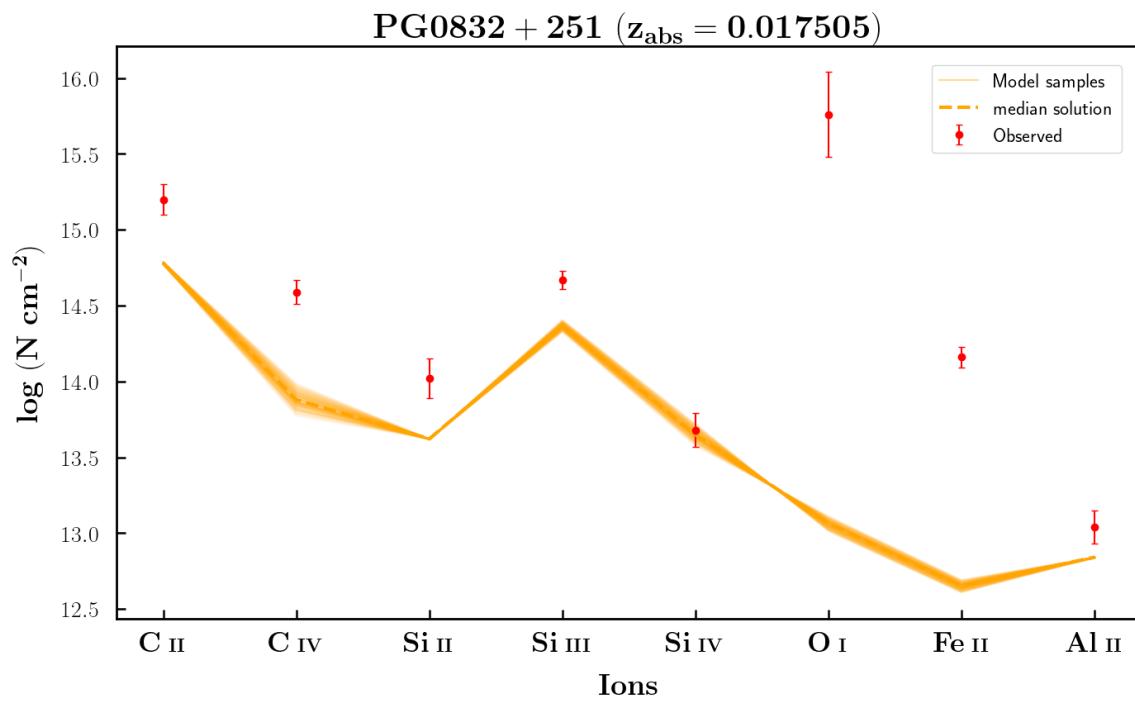


Figure 80:  $N(\text{H I})=14.79$ ,  $\log Z_{\text{ref}}=-1$

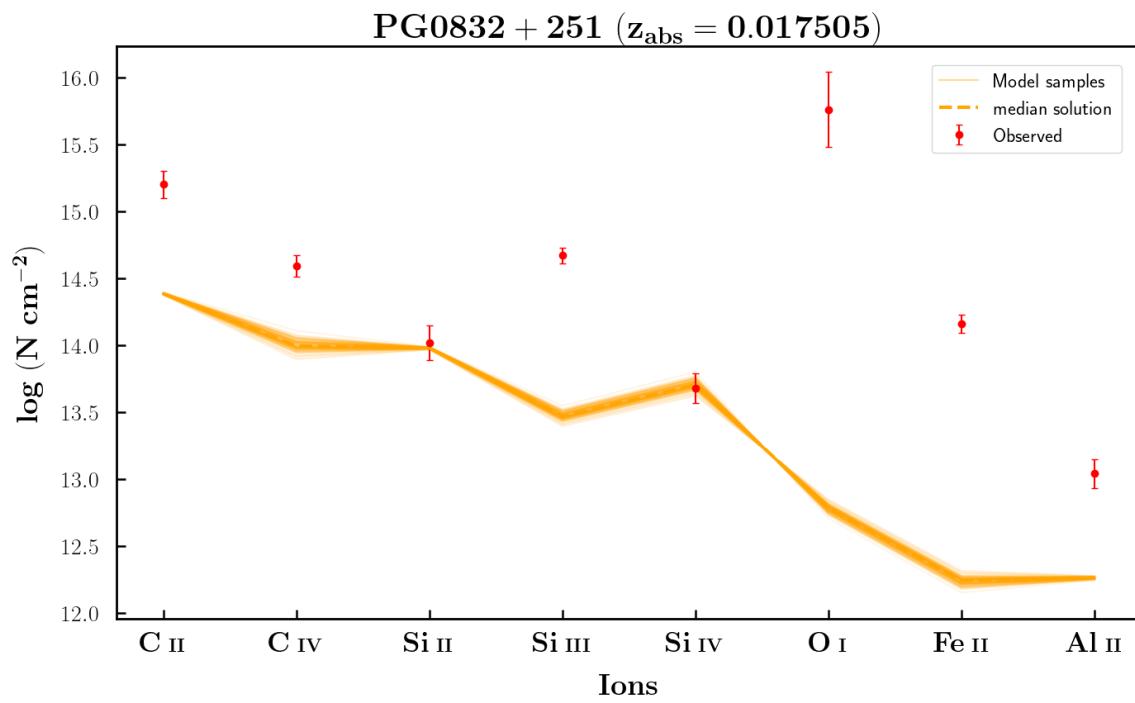


Figure 81:  $N(\text{H I})=14.79$ ,  $\log Z_{ref}=1$

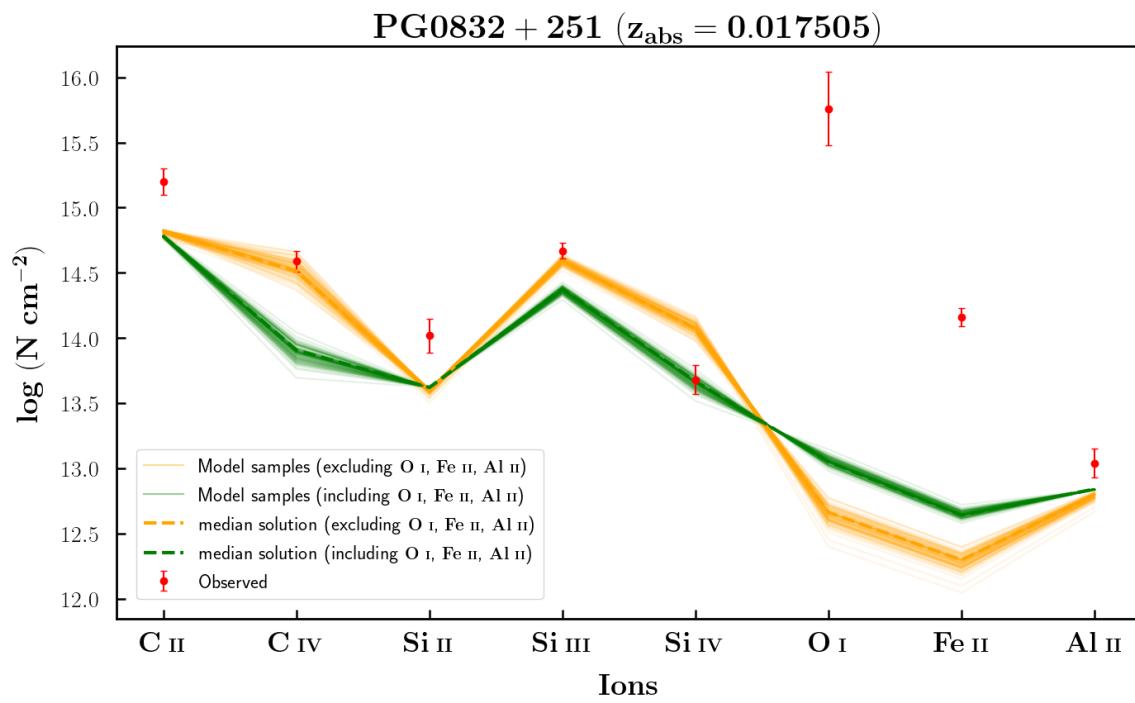


Figure 82:  $N(\text{H I})=14.79$ , excluding O I, Fe II and Al II,  $\log Z_{ref}=-1$

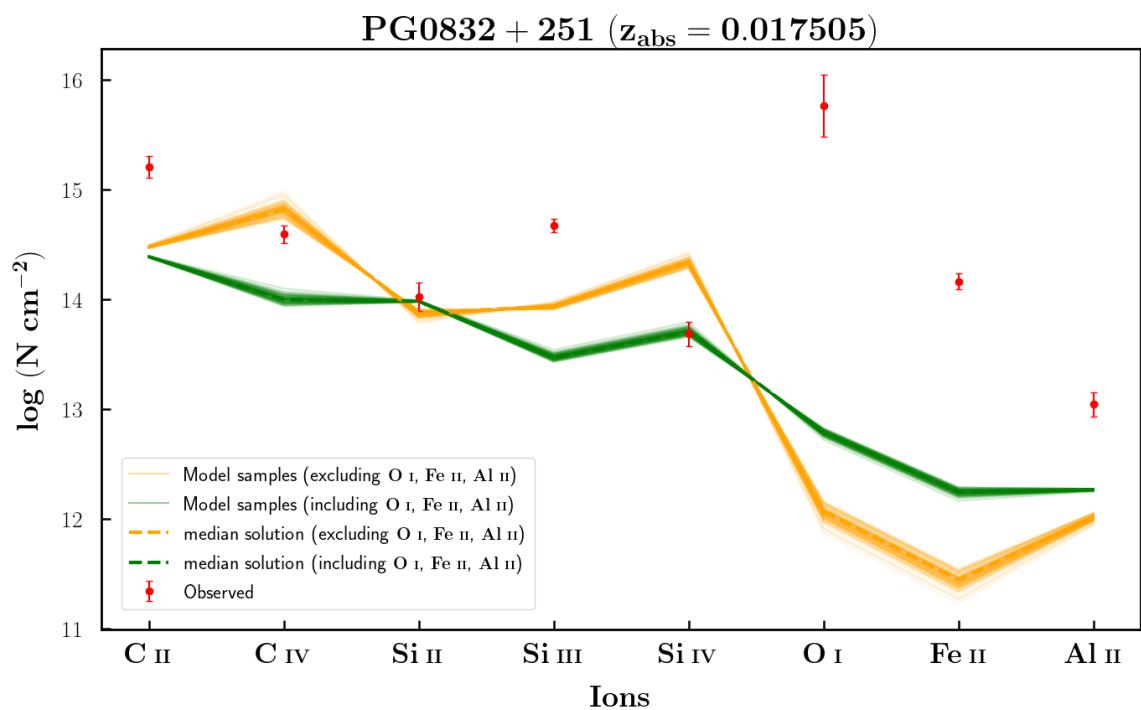


Figure 83:  $\text{N(H I)}=14.79$ , excluding O I, Fe II and Al II,  $\log Z_{\text{ref}}=1$

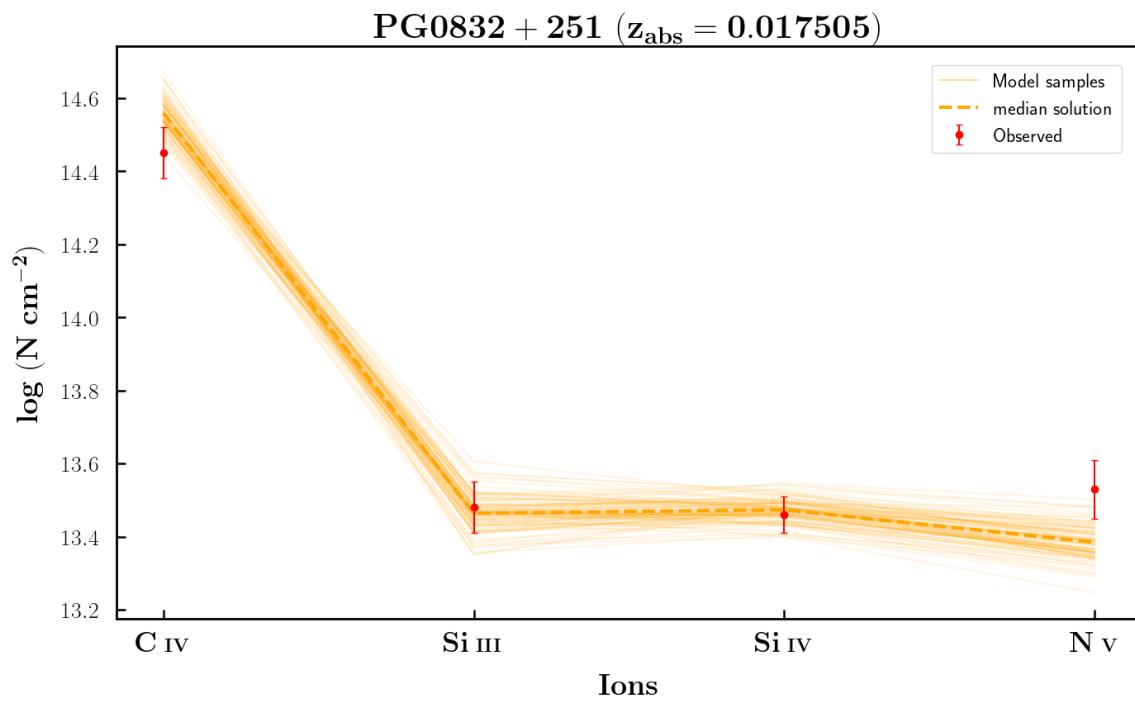


Figure 84:  $N(\text{H I})=18.22$ ,  $\log Z_{ref}=-1$

## Some statistics

O VI absorbers

Total no. of absorbers : 16

CI : 14 + 1 tentative

PI : 1 (one component is PI and other is CI, so this is included in above 14 CI absorbers)

BLA +ve : 14

BLA -ve or tentative : 2 - one has  $b$  values of 23, 9 and other absorber has 22,16,16

For, one absorber ionisation state (PG0003  $z_{abs}=0.386089$ ) couldn't be inferred.

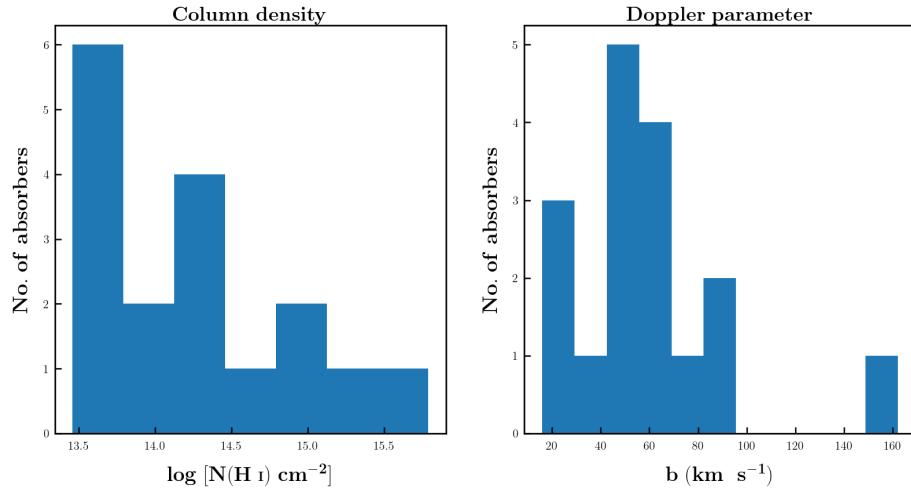


Figure 85: Distribution of column density and doppler parameters of the Lyman lines in the 17 absorbers

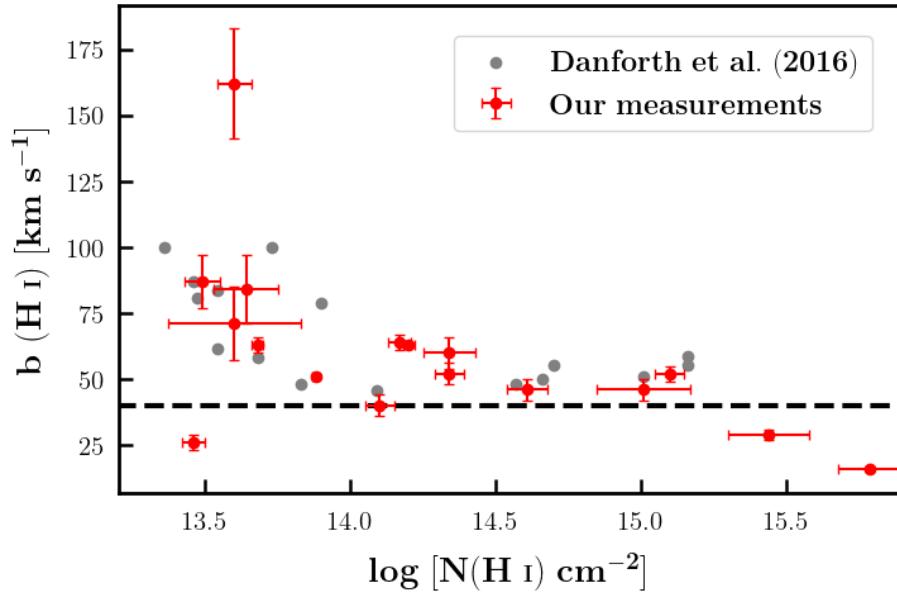


Figure 86: Doppler parameter vs. Column density. Horizontal black dashed line shows the doppler parameter of  $40 \text{ km s}^{-1}$

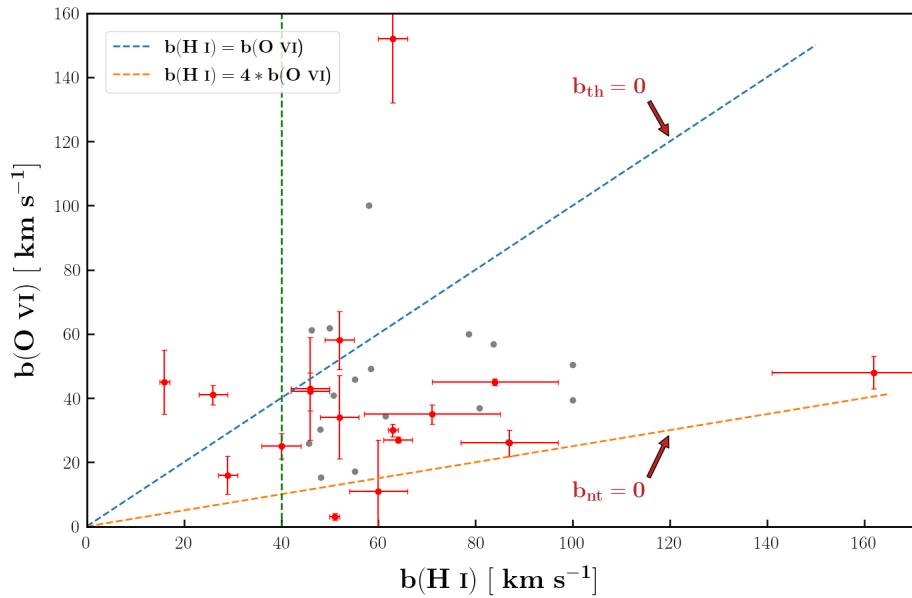


Figure 87:  $b(\text{O VI})$  vs.  $b(\text{H I})$ . Grey filled circles are measurements from Danforth et al. (2016).

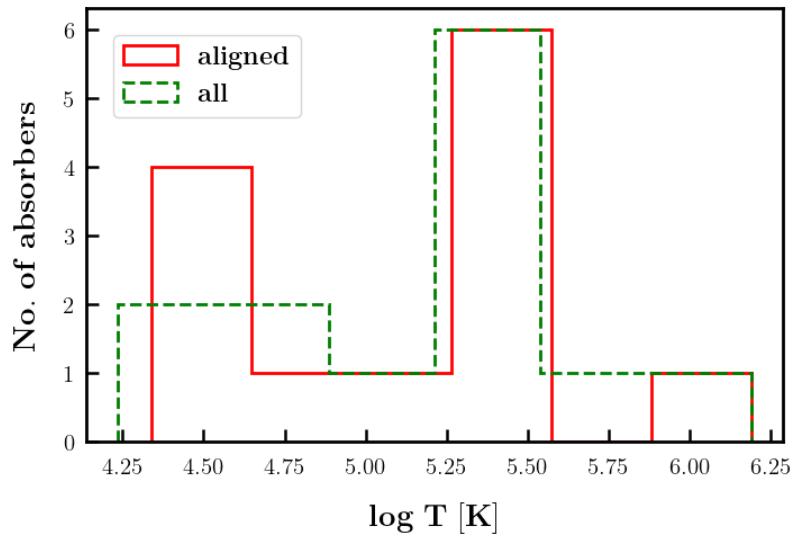


Figure 88: Distribution of temperature calculated from Doppler parameters of H I and O VI lines.

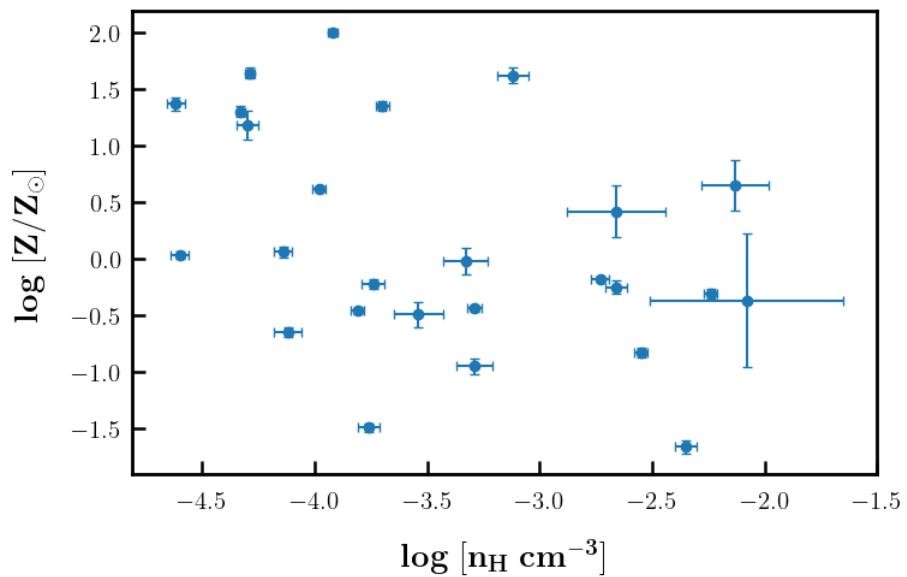


Figure 89: Ionisation modelling solutions ( $n_H, Z$ ) for all 26 components of O VI absorbers.

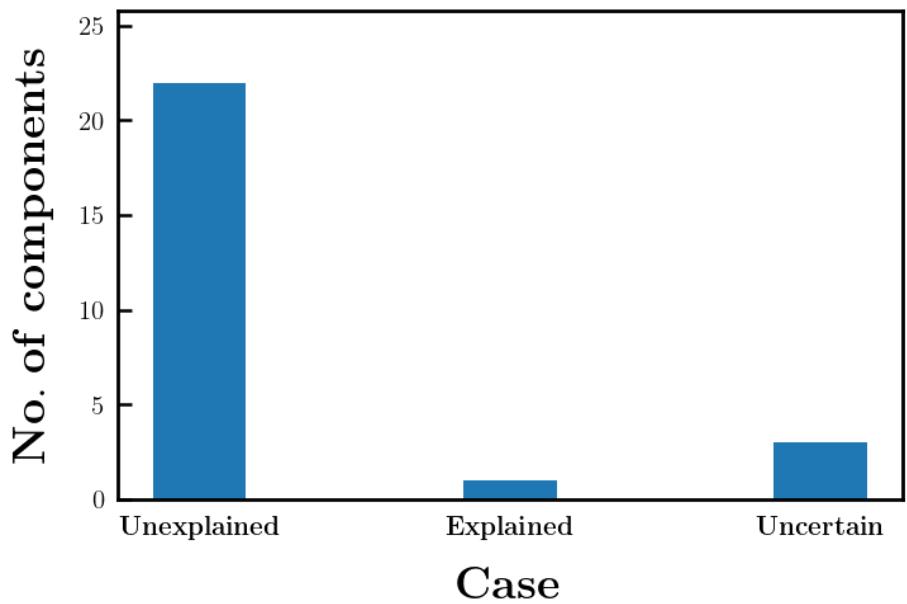


Figure 90: O VI column density predictions.

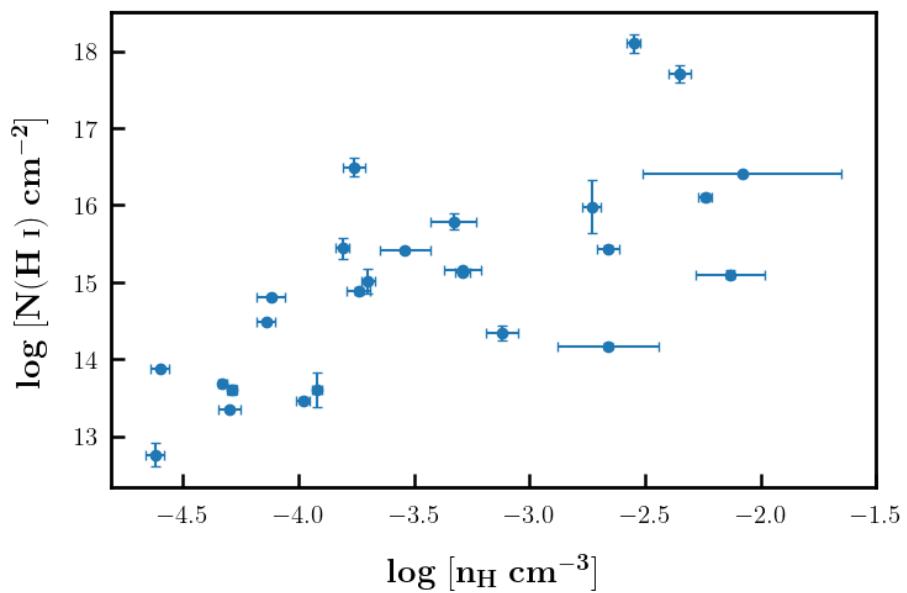


Figure 91: Variation of  $N(\text{H I})$  with  $n_{\text{H}}$

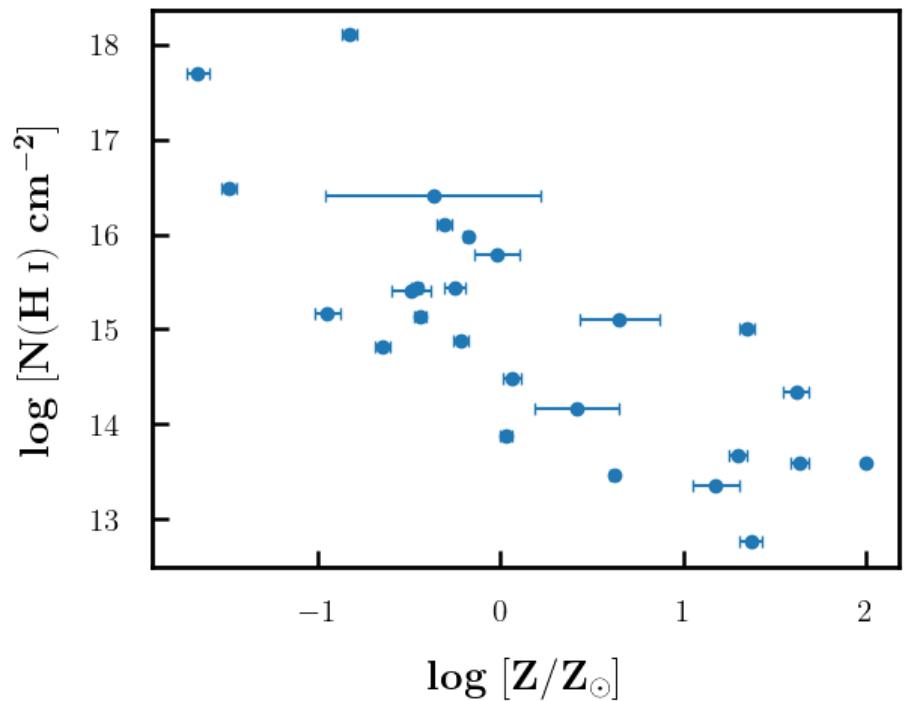


Figure 92: Variation of  $N(\text{H I})$  with  $Z$