

Voigt profile fitting and Ionisation modelling results

February 22, 2024

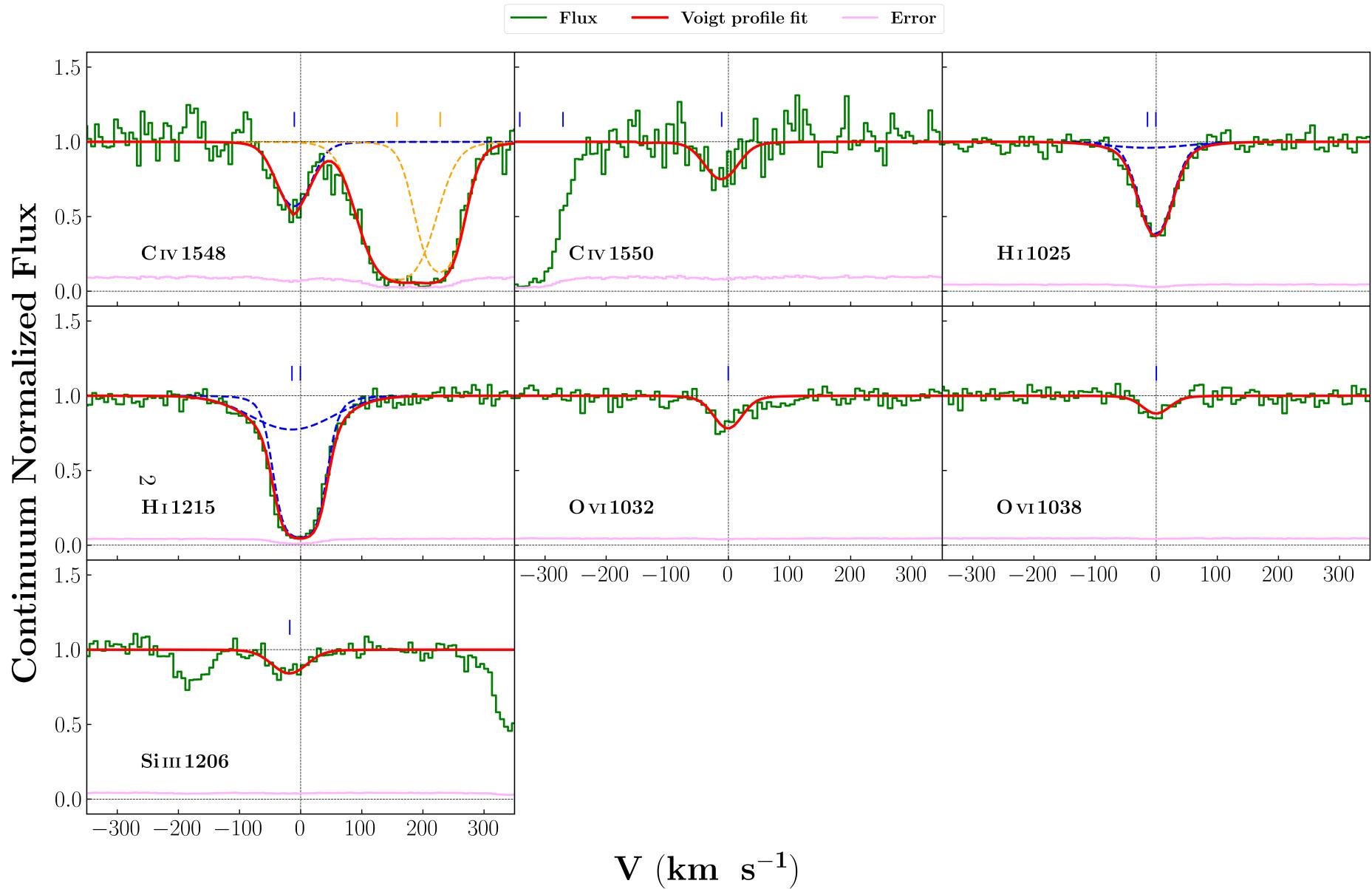
System plots

- 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 ($z_{\text{abs}} = 0.140756$)



Ion	v (km s⁻¹)	b (km s⁻¹)	log [N cm⁻²]
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 : $n_H = -4.45 \pm 0.01$	$Z = 1.30 \pm 0.05$

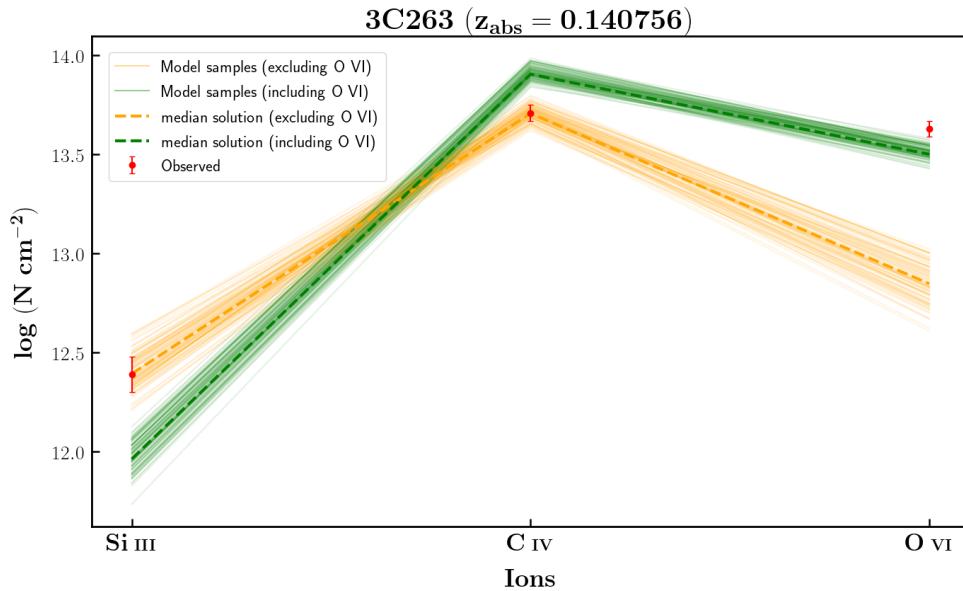


Figure 1: $N(\text{H I})=13.49$, $\log Z_{\text{ref}}=-1$

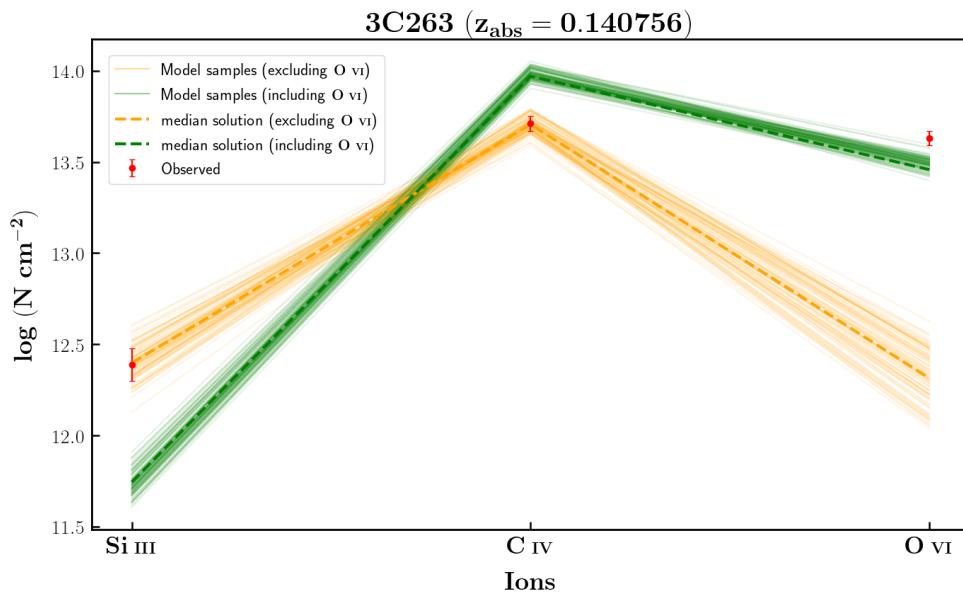
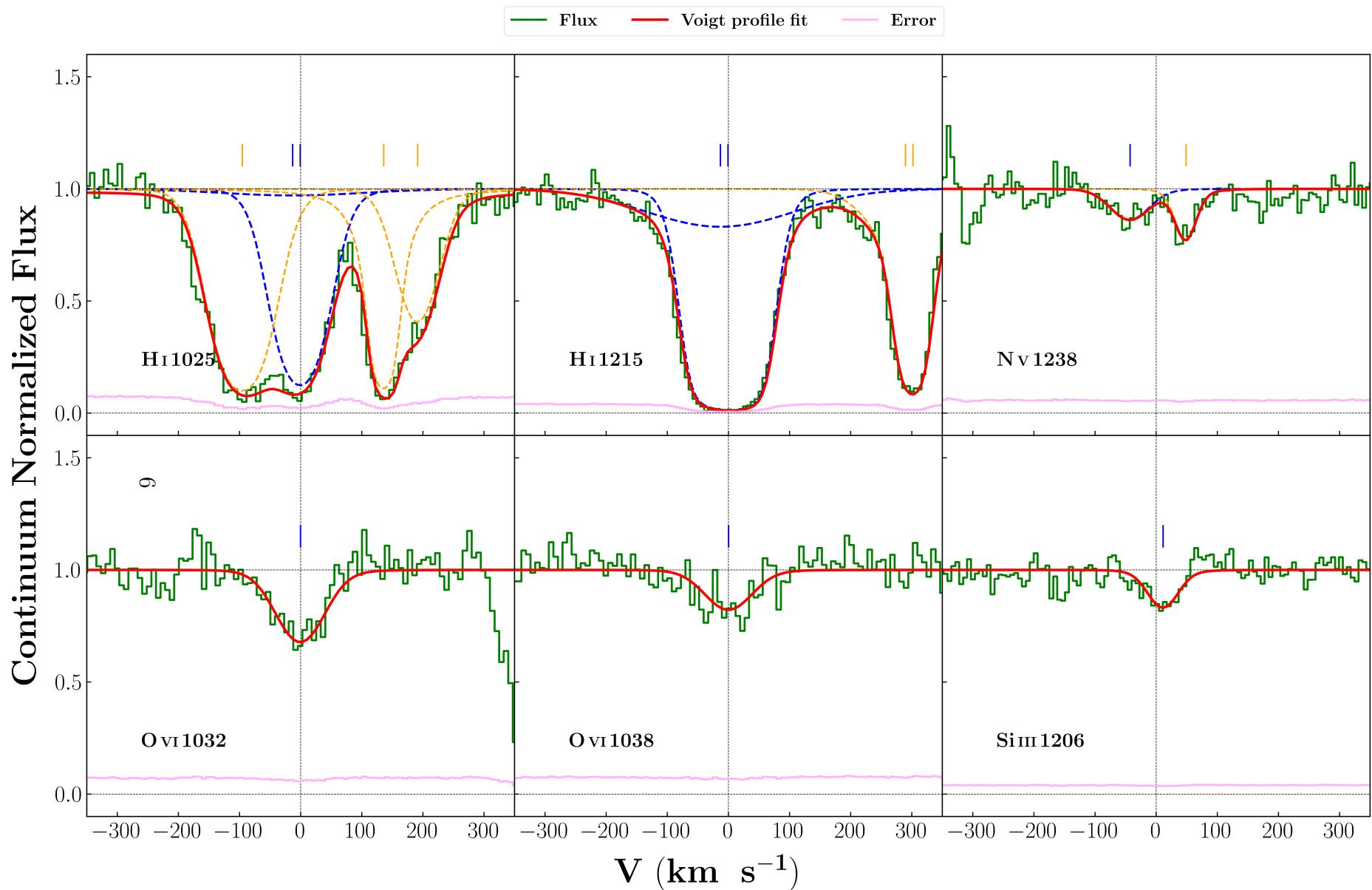


Figure 2: $N(\text{H I})=13.49$, $\log Z_{\text{ref}}=1$

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 ($z_{\text{abs}} = 0.161064$)



Ion	v (km s⁻¹)	b (km s⁻¹)	log [N cm⁻²]
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 : $n_H = -4.42 \pm 0.01$	$Z = 1.69 \pm 0.04$

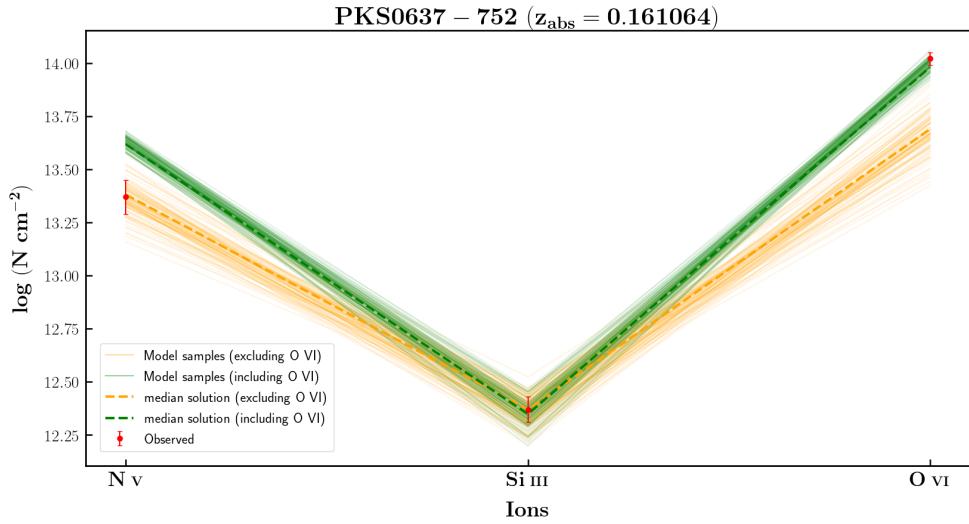


Figure 3: $\text{N(H I)}=13.60$, $\log Z_{\text{ref}}=-1$

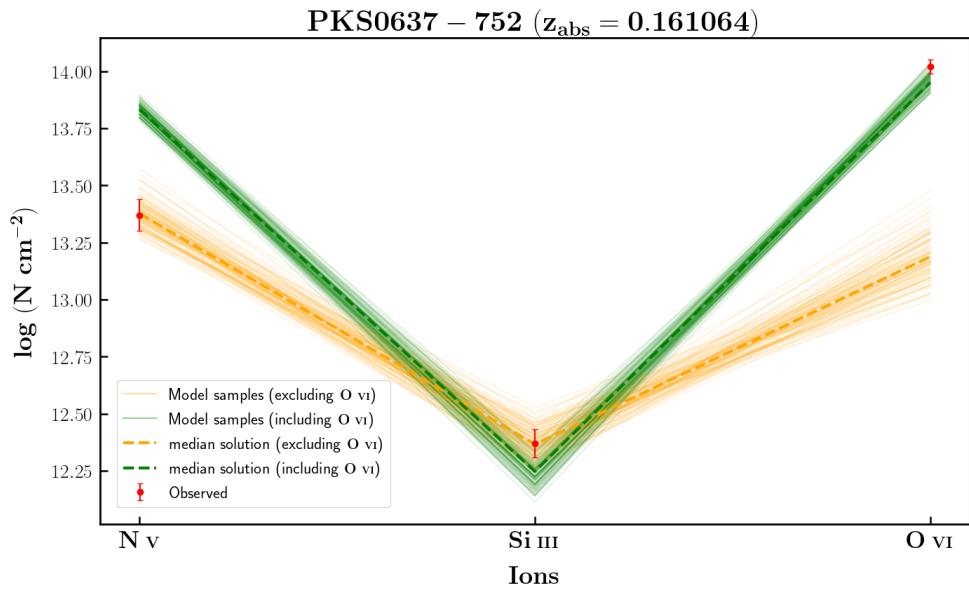
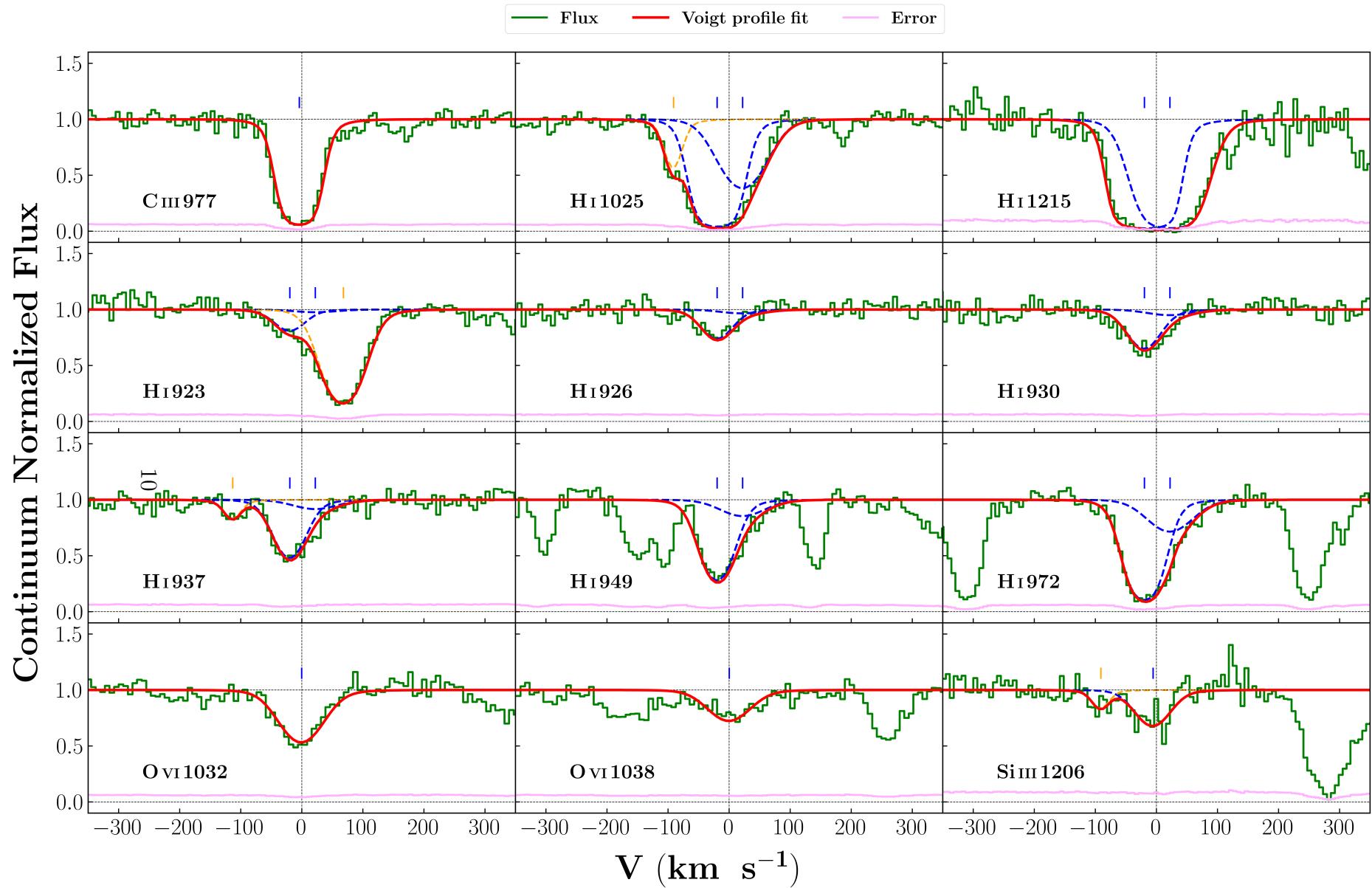


Figure 4: $\text{N(H I)}=13.60$, $\log Z_{\text{ref}}=1$

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 ($z_{\text{abs}} = 0.417539$)

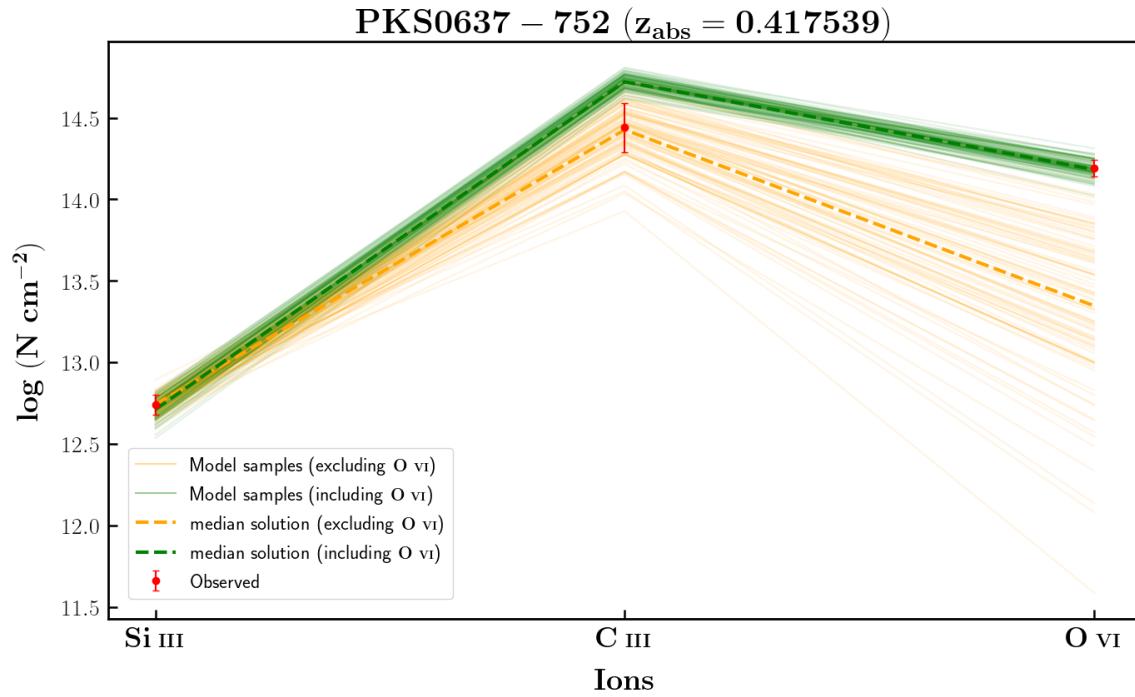


Ion	v (km s ⁻¹)	b (km s ⁻¹)	log [N cm ⁻²]
Si III	-5 ± 4	35 ± 7	12.74 ± 0.06
C III	-4 ± 1	24 ± 2	14.44 ± 0.15
O VI	0 ± 1	42 ± 6	14.19 ± 0.05
H I	-17 ± 1	30 ± 1	15.41 ± 0.03
H I	20 ± 1	46 ± 4	14.61 ± 0.07

$$N(HI) = 15.41$$

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

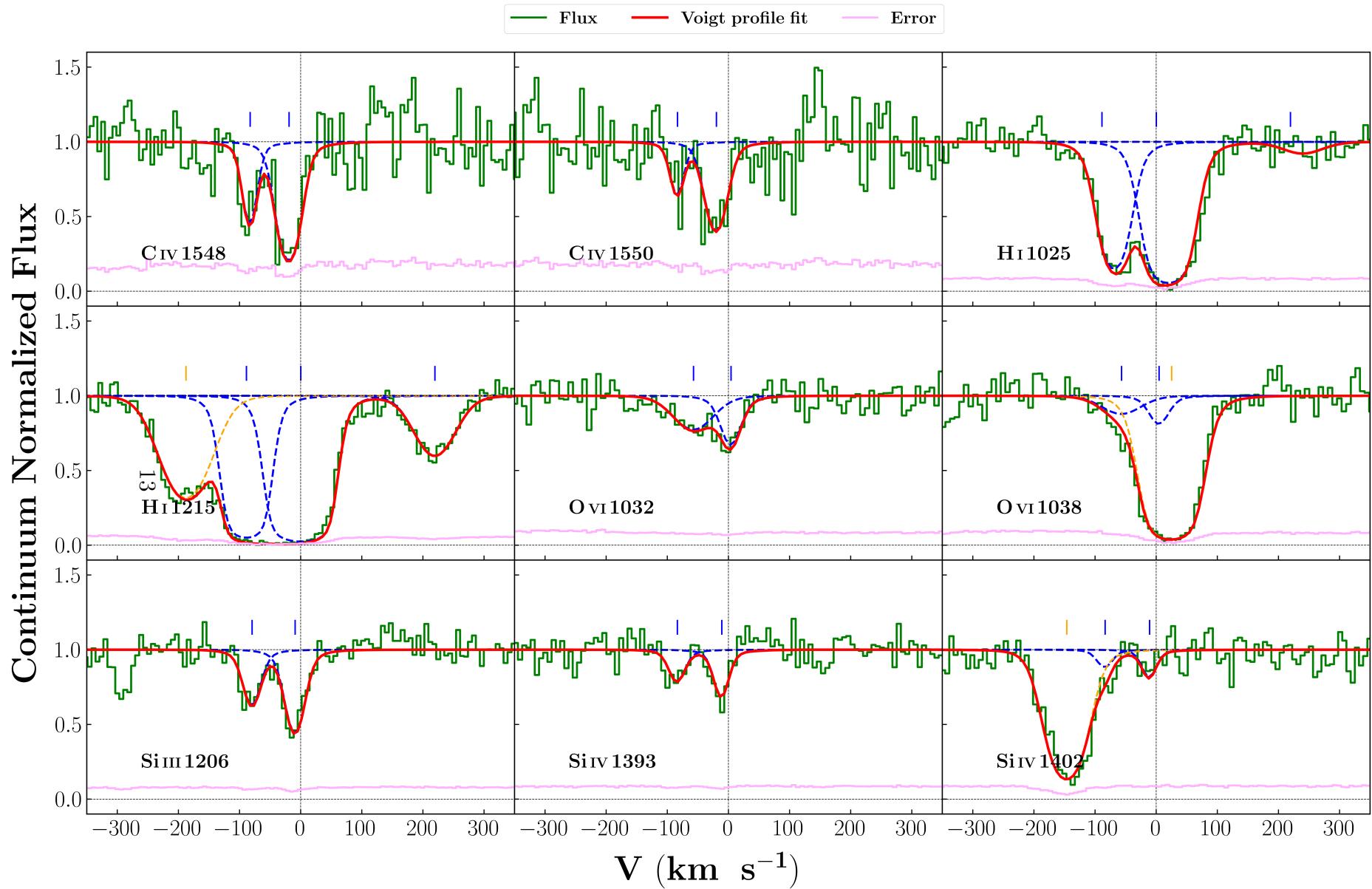
NOTE : MCMC walkers initialised near the solution for excluding O VI case.



Comments

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

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



Ion	v (km s⁻¹)	b (km s⁻¹)	log [N cm⁻²]
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 : $n_H = -3.96 \pm 0.03$	$Z = -0.07 \pm 0.04$

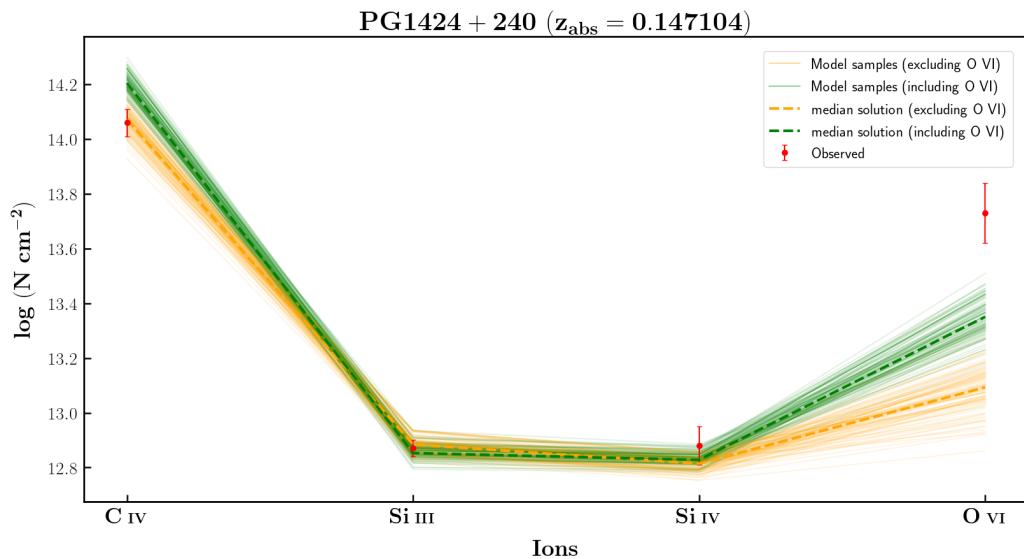


Figure 5: $N(\text{H I})=15.44$

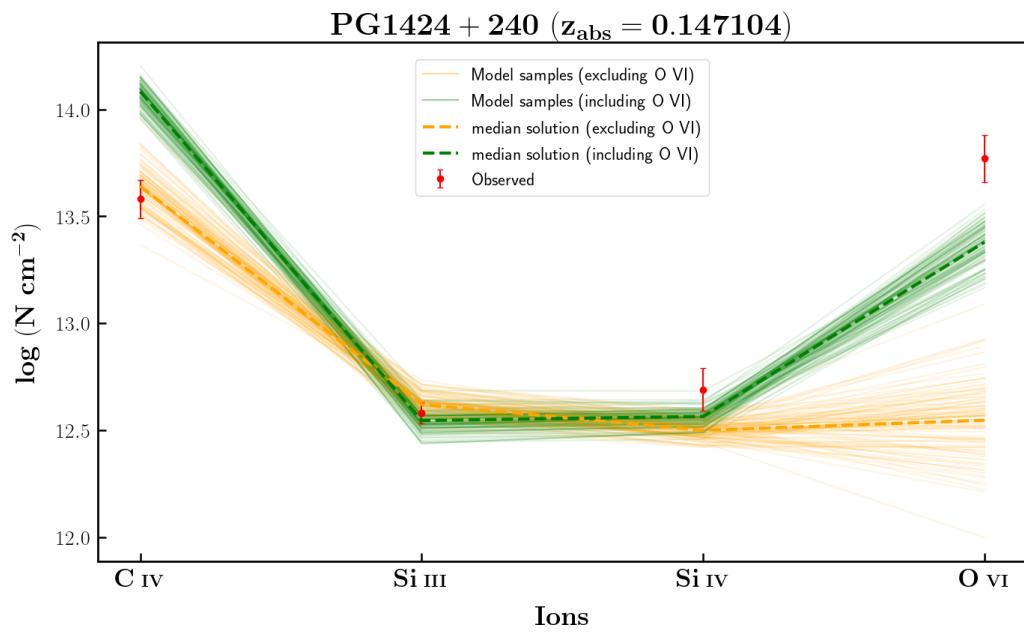
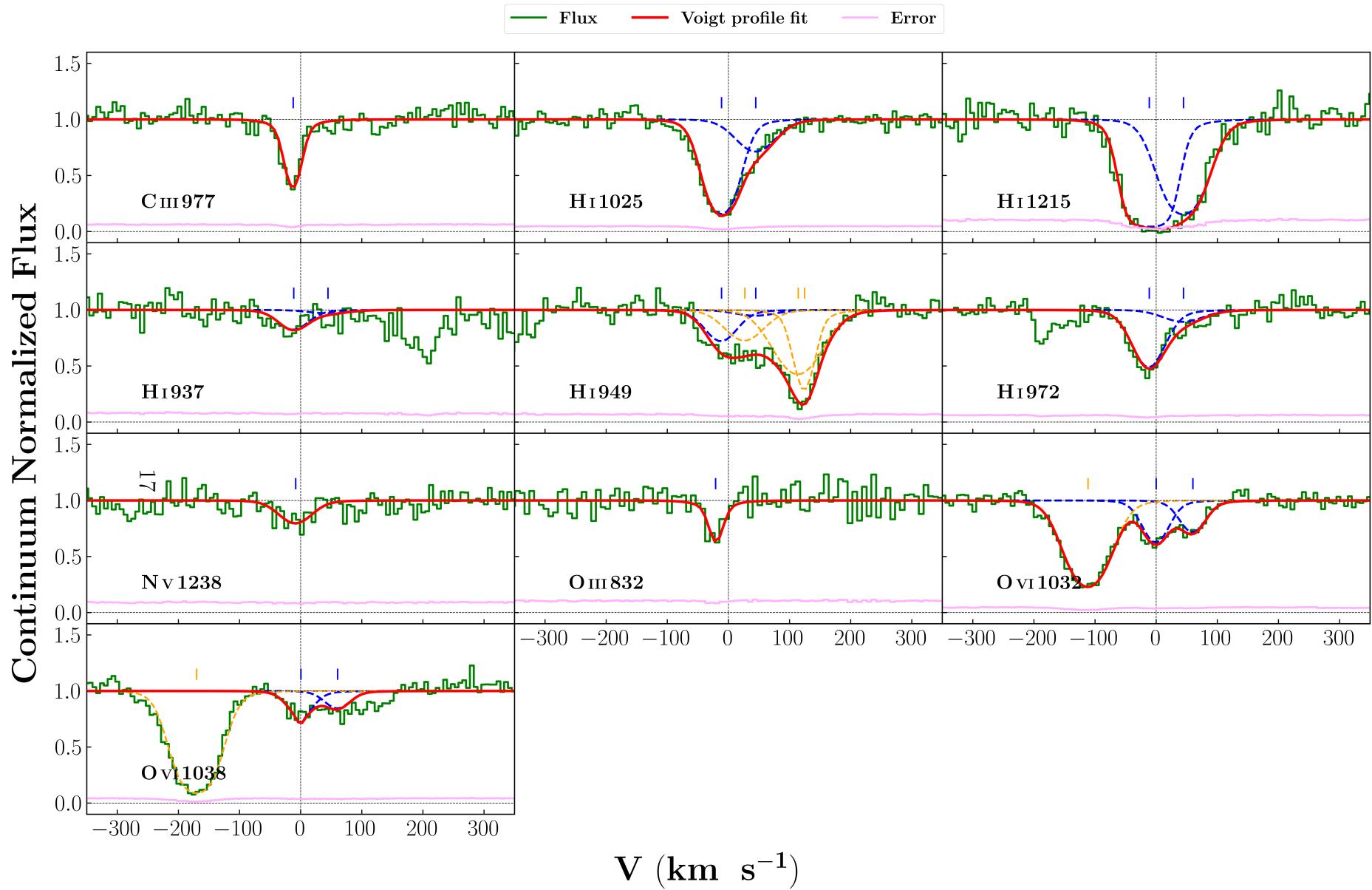


Figure 6: $N(\text{H I})=14.88$

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

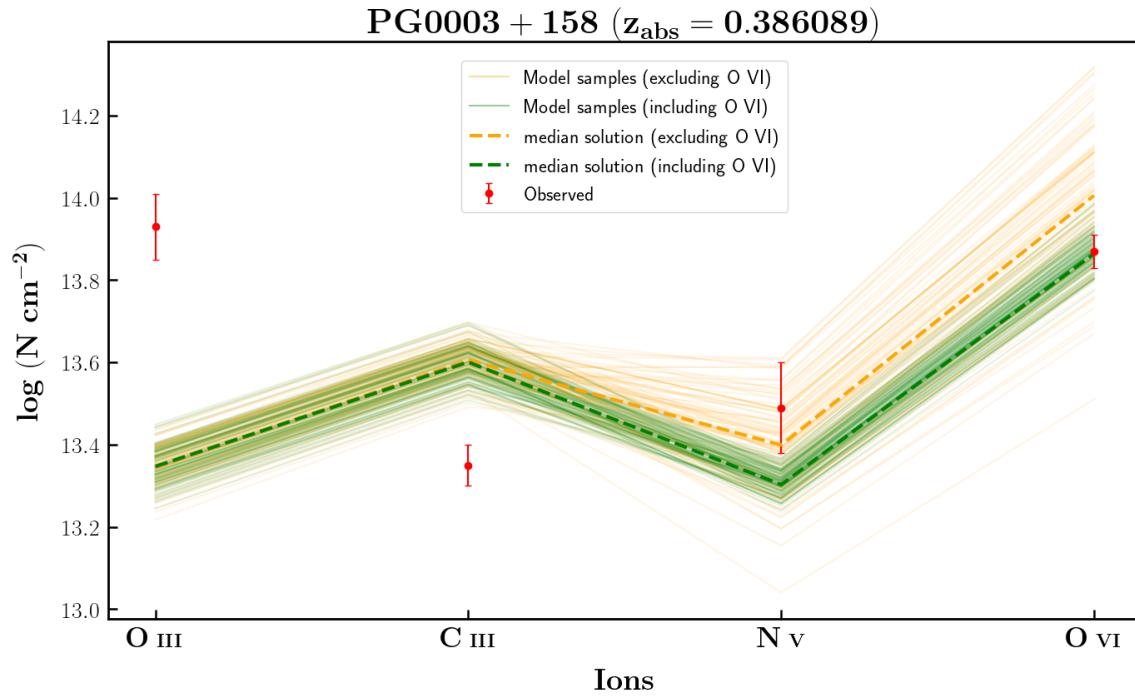
PG0003 + 158 ($z_{\text{abs}} = 0.386089$)



Ion	v (km s ⁻¹)	b (km s ⁻¹)	log [N cm ⁻²]
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

$$N(HI) = 14.81$$

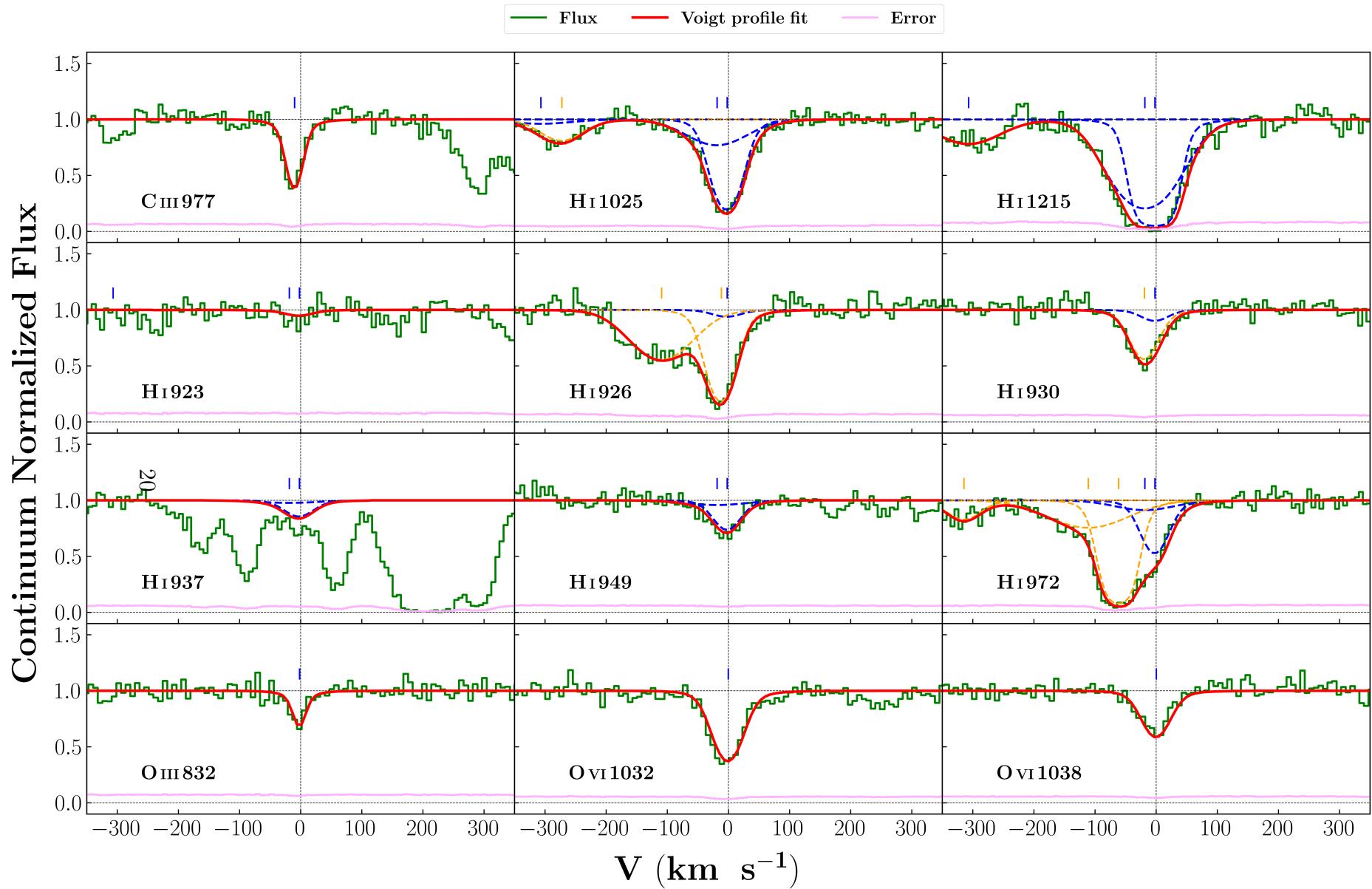
Excluding O VI : $n_H = -4.12 \pm 0.06$ $Z = -0.65 \pm 0.04$
 Including O VI : $n_H = -4.07 \pm 0.02$ $Z = -0.68 \pm 0.03$



Comments

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

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

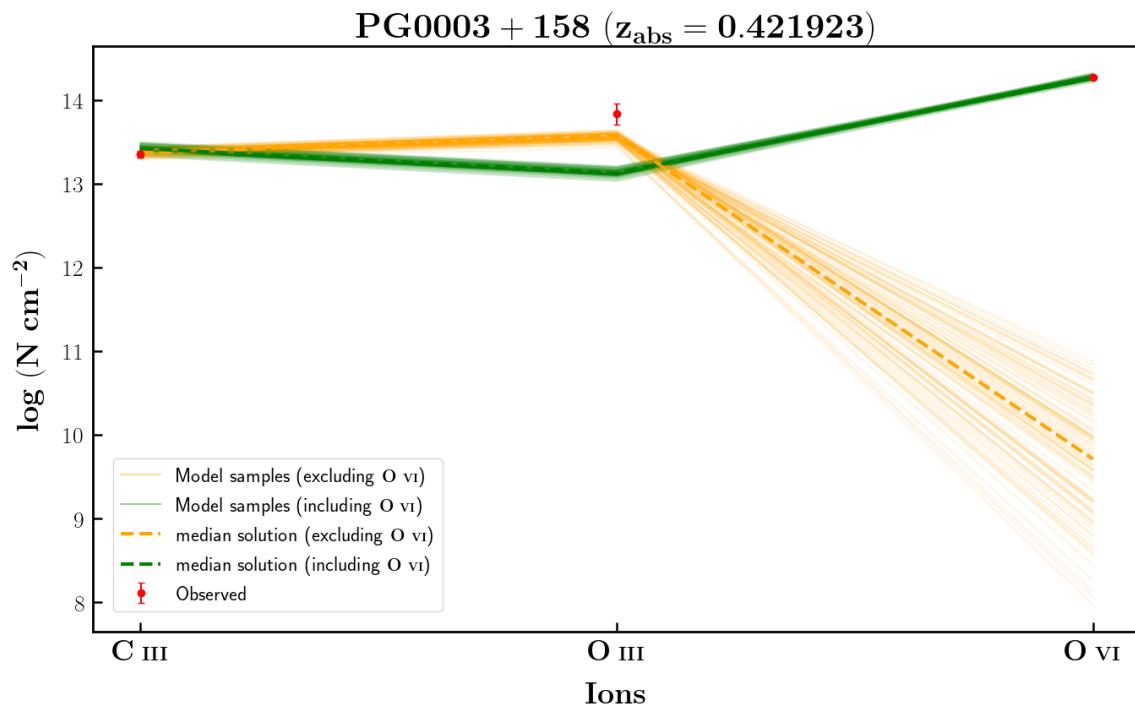


Ion	v (km s ⁻¹)	b (km s ⁻¹)	log [N cm ⁻²]
C III	-9 ± 1	13 ± 1	13.35 ± 0.04
O III	-1 ± 2	7 ± 5	13.83 ± 0.13
O VI	0 ± 1	27 ± 1	14.27 ± 0.02
H I	-272 ± 6	66 ± 10	13.37 ± 0.05
H I	-16 ± 1	64 ± 3	14.17 ± 0.04
H I	-2 ± 1	26 ± 1	14.71 ± 0.02

N(H I)=14.17

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

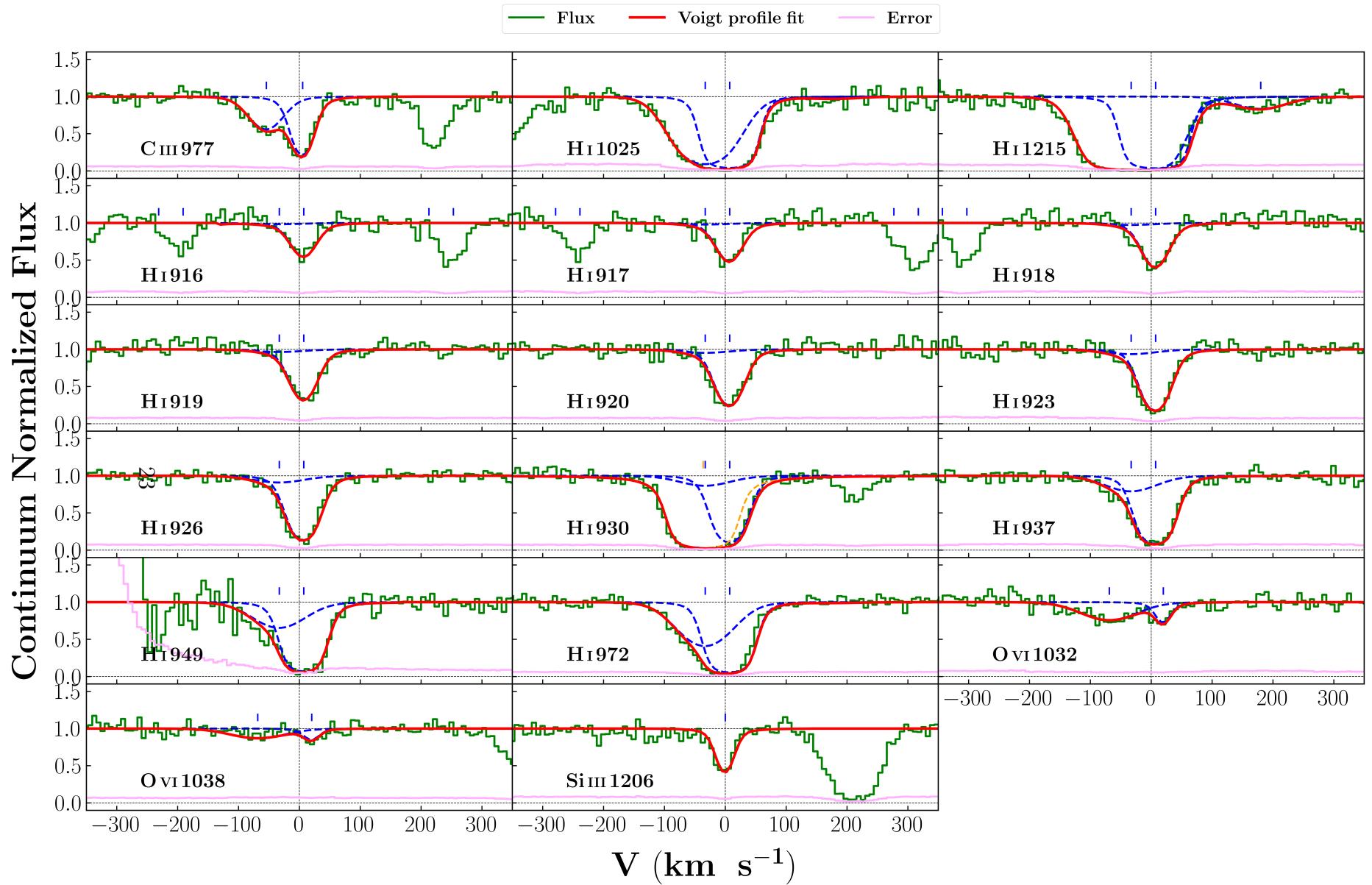
NOTE : Convergence is not good for excluding O VI case



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 ⁻¹)	b (km s ⁻¹)	log [N cm ⁻²]
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

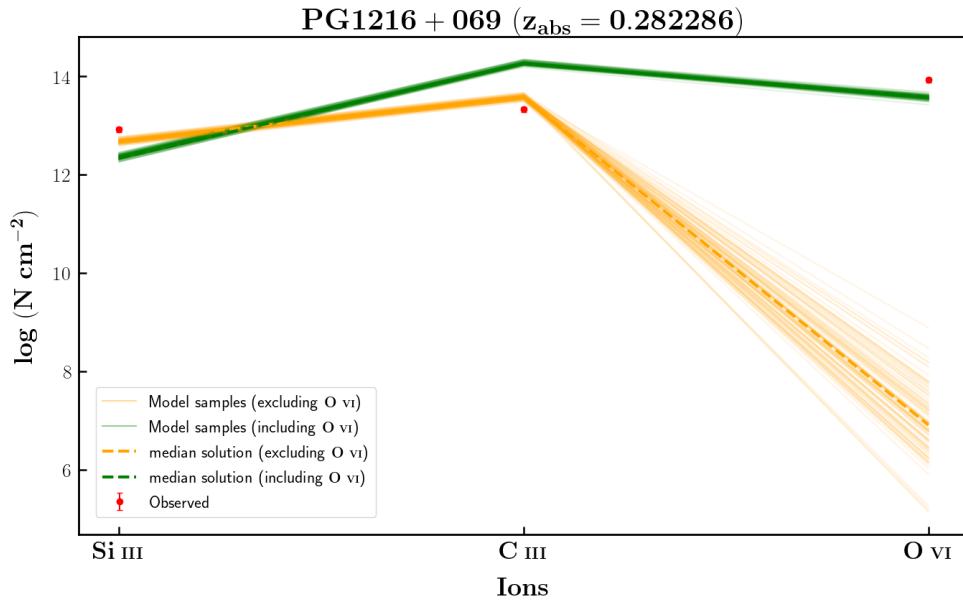


Figure 7: $N(\text{H I})=15.10$

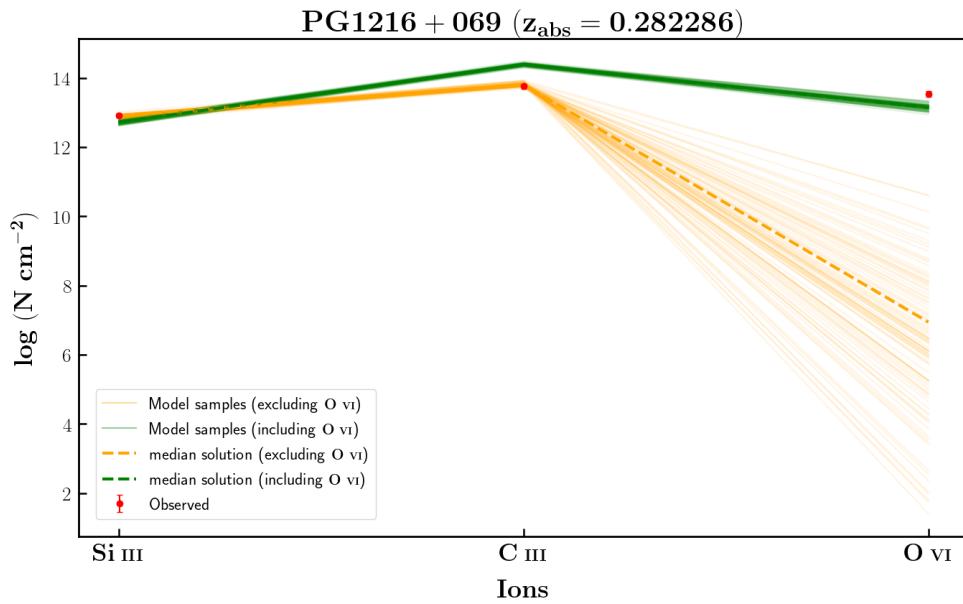
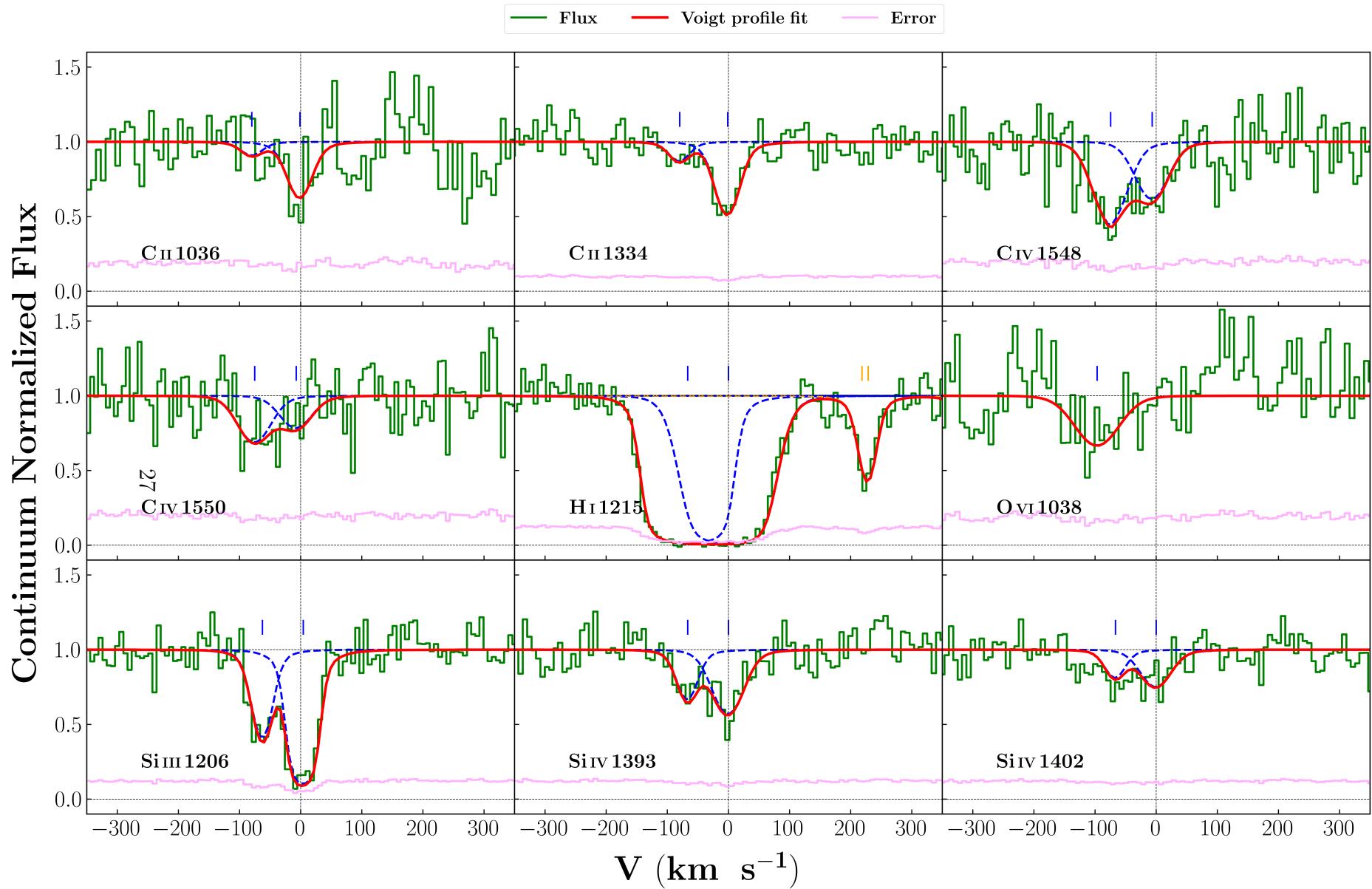


Figure 8: $N(\text{H I})=16.40$

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 ⁻¹)	b (km s ⁻¹)	log [N cm ⁻²]
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.

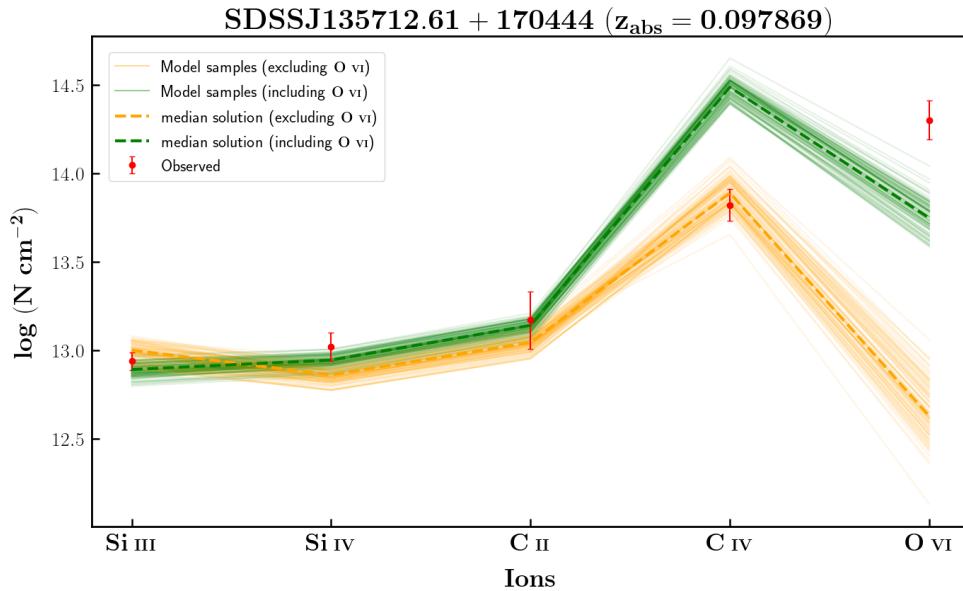


Figure 9: $N(\text{H I})=16.49$, $\log Z_{\text{ref}}=-1$

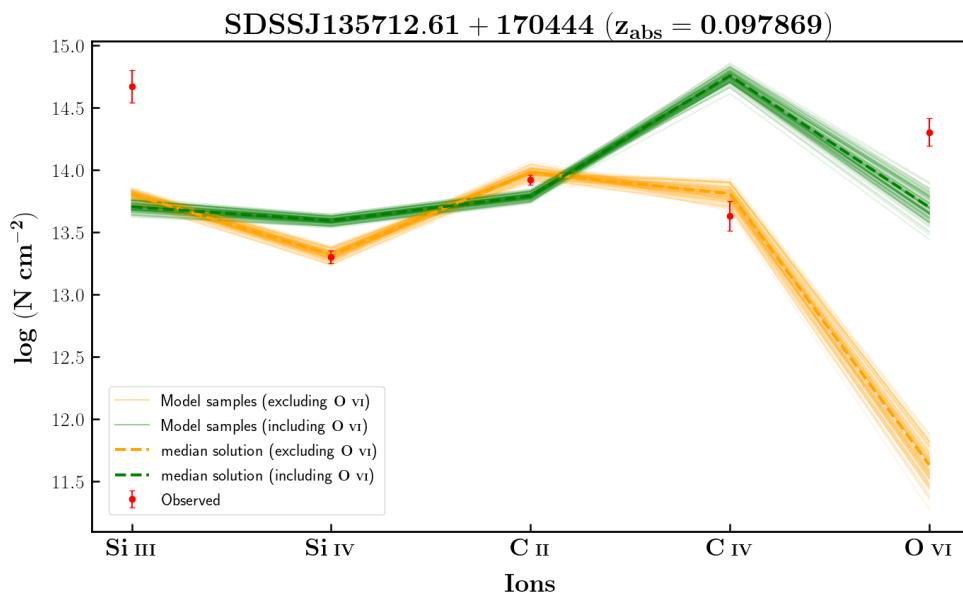


Figure 10: $N(\text{H I})=15.01$, $\log Z_{\text{ref}}=-1$

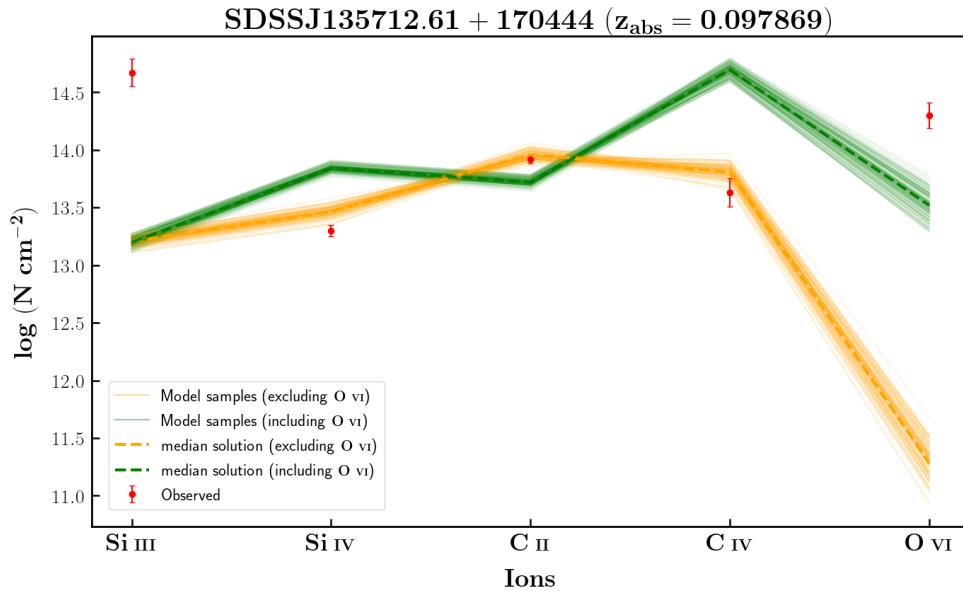
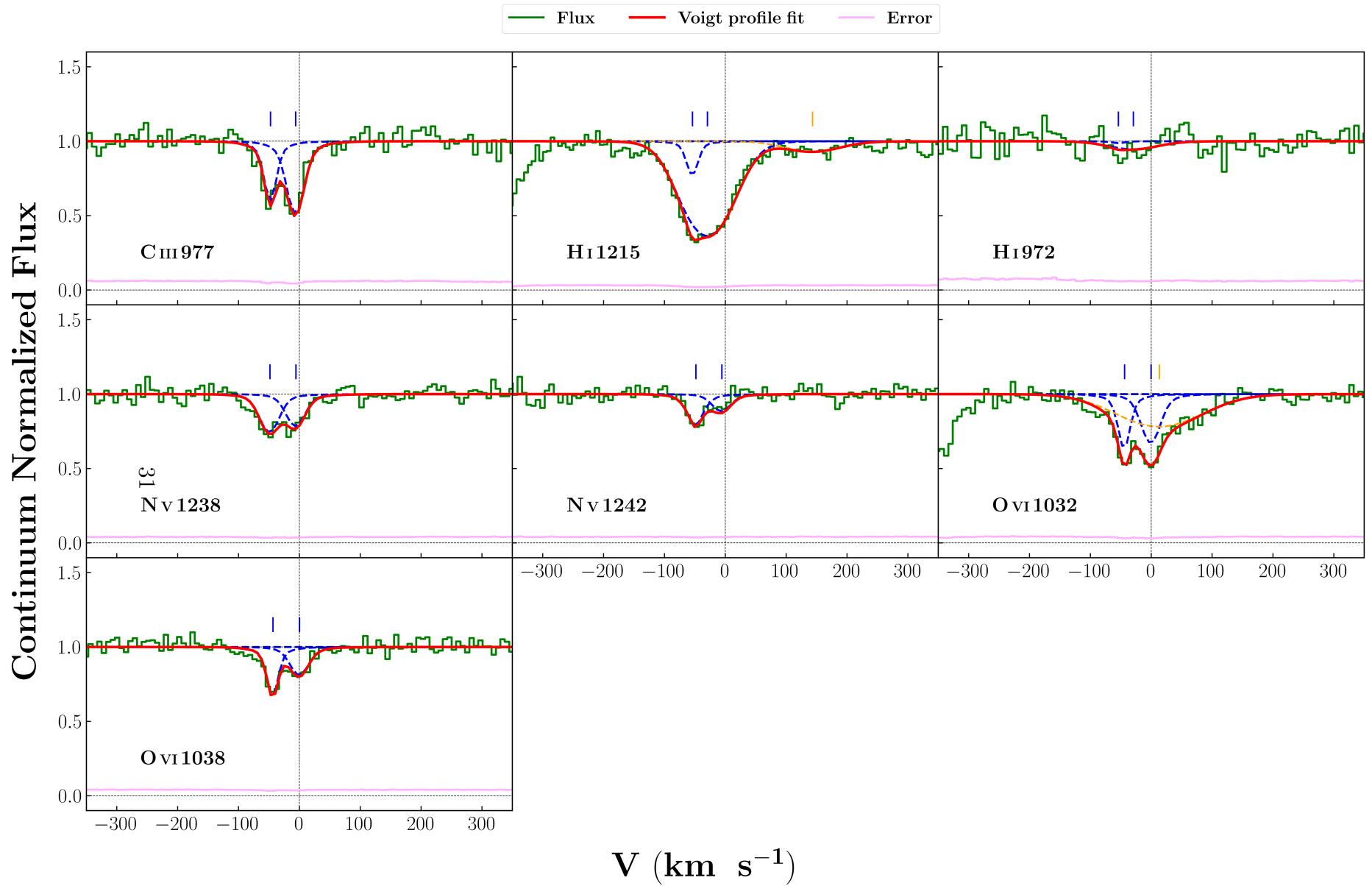


Figure 11: $N(\text{H I})=15.01$, $\log Z_{\text{ref}}=1$

Comments

- Good solution II component ($N(\text{H I})=16.49$) : 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 ($N(\text{H I})=15.01$), 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 ⁻¹)	b (km s ⁻¹)	log [N cm ⁻²]
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 χ^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 : $n_H = -4.44 \pm 0.02$ $Z = -0.06 \pm 0.02$

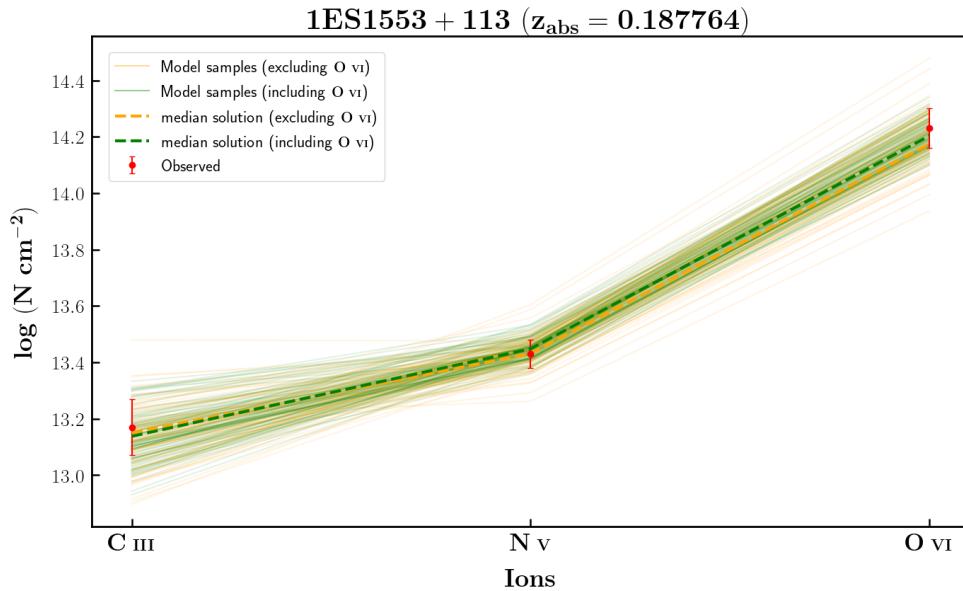


Figure 12: $\text{N(HI)}=12.76$

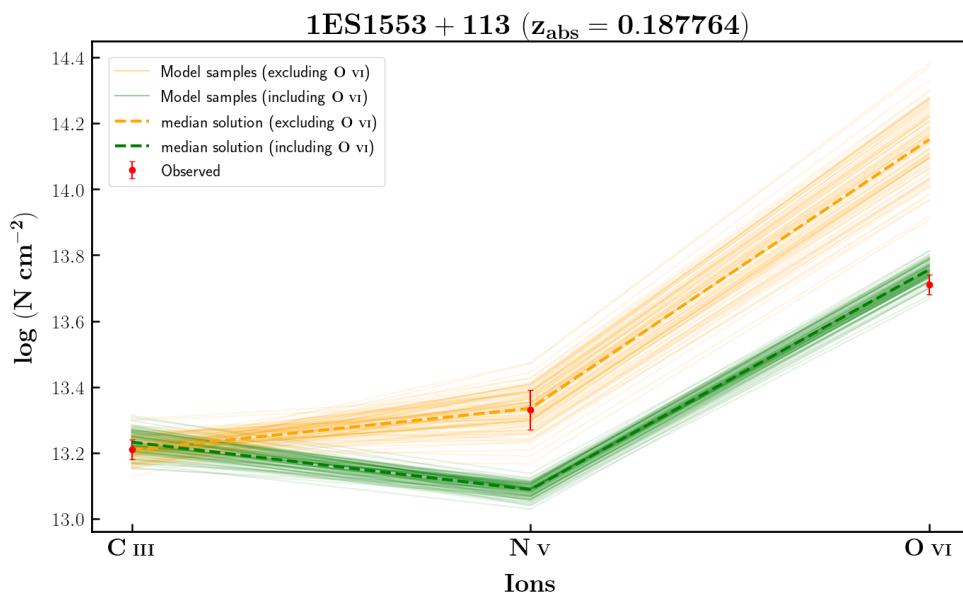
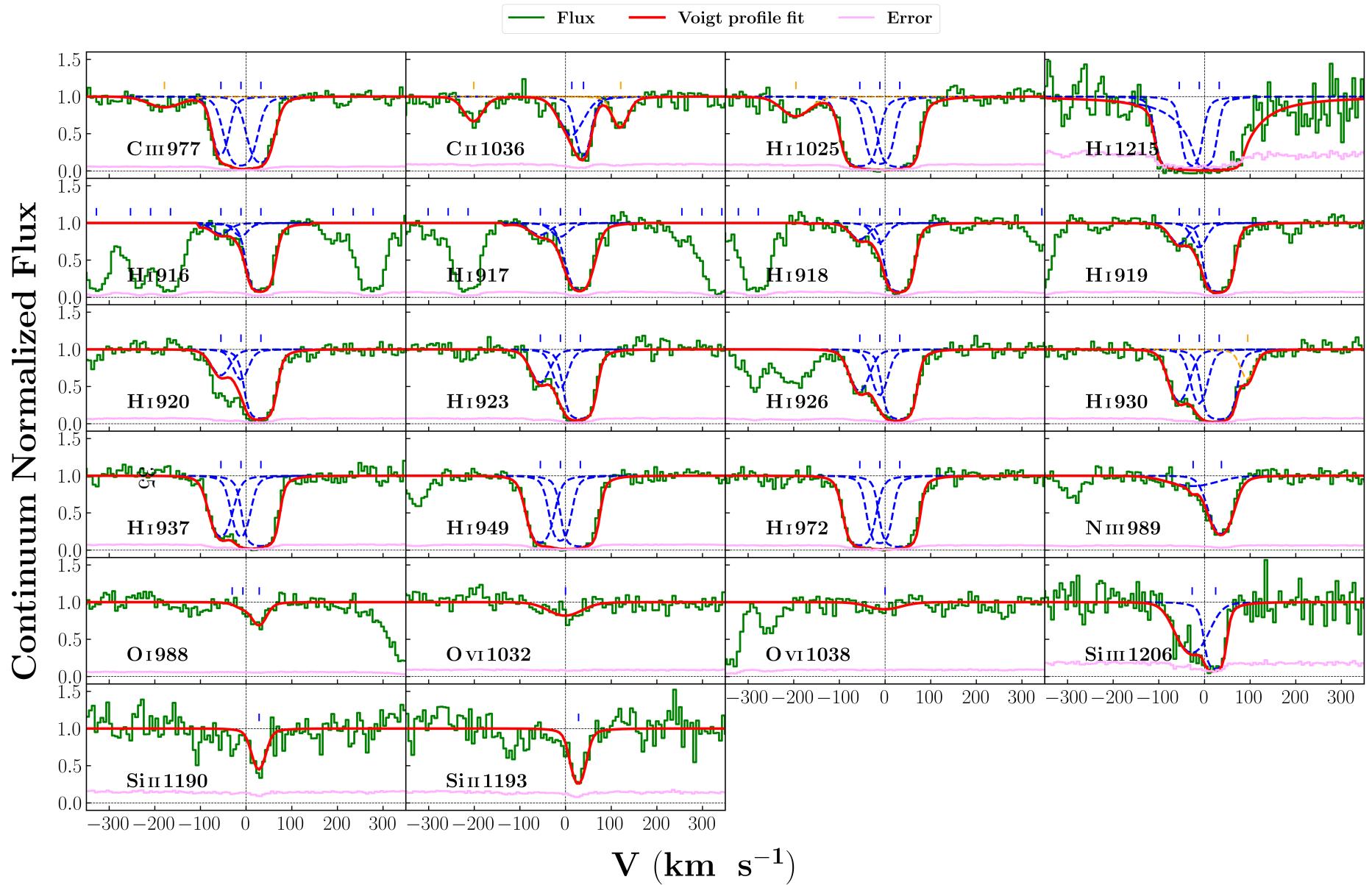


Figure 13: $\text{N(HI)}=13.88$

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 ⁻¹)	b (km s ⁻¹)	log [N cm ⁻²]
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 $Z_{ref} = 1$
 $N(HI) = 18.10$

$$\begin{array}{ll} \text{Excluding O VI : } n_H = -2.55 \pm 0.03 & Z = -0.83 \pm 0.04 \\ \text{Including O VI : } n_H = -3.49 \pm 0.01 & Z = -0.92 \pm 0.03 \end{array}$$

N(H I)=15.79

$$\begin{array}{ll} \text{Excluding O VI : } n_H = -3.33 \pm 0.10 & Z = -0.02 \pm 0.12 \\ \text{Including O VI : } n_H = -3.99 \pm 0.02 & Z = -0.44 \pm 0.05 \end{array}$$

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

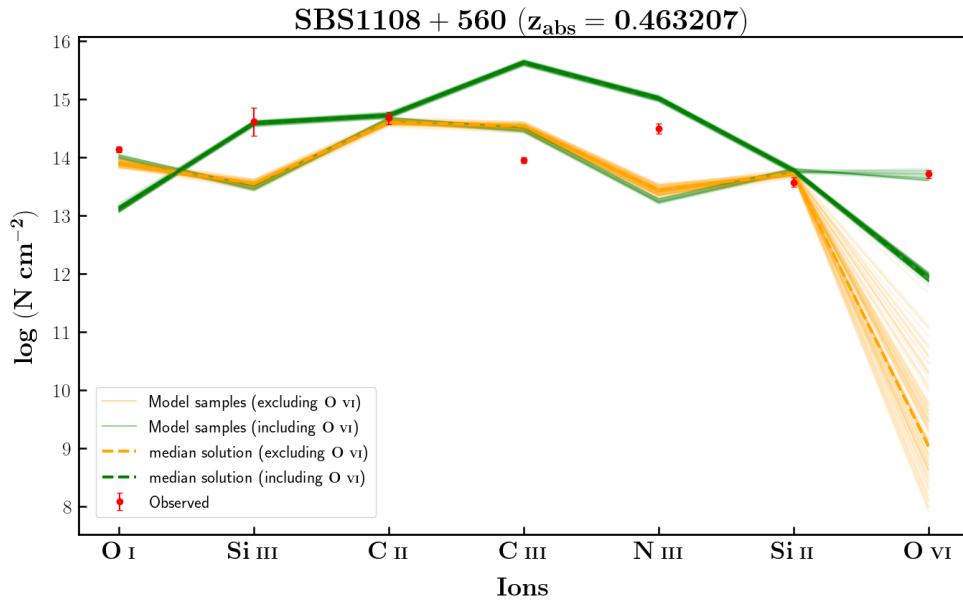


Figure 14: $\text{N(HI)}=18.10$, $\log Z_{\text{ref}}=-1$

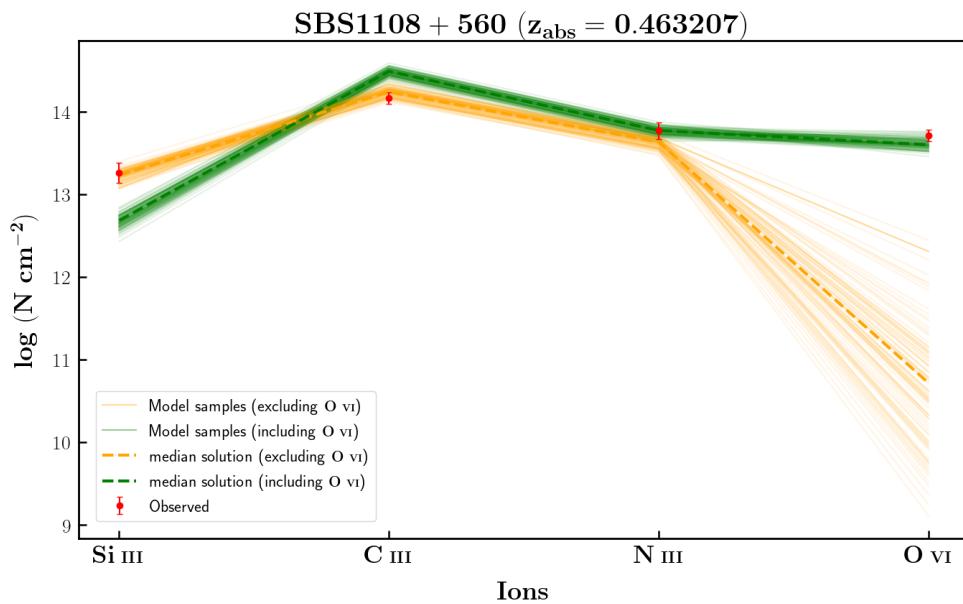


Figure 15: $\text{N(HI)}=15.79$, $\log Z_{\text{ref}}=-1$

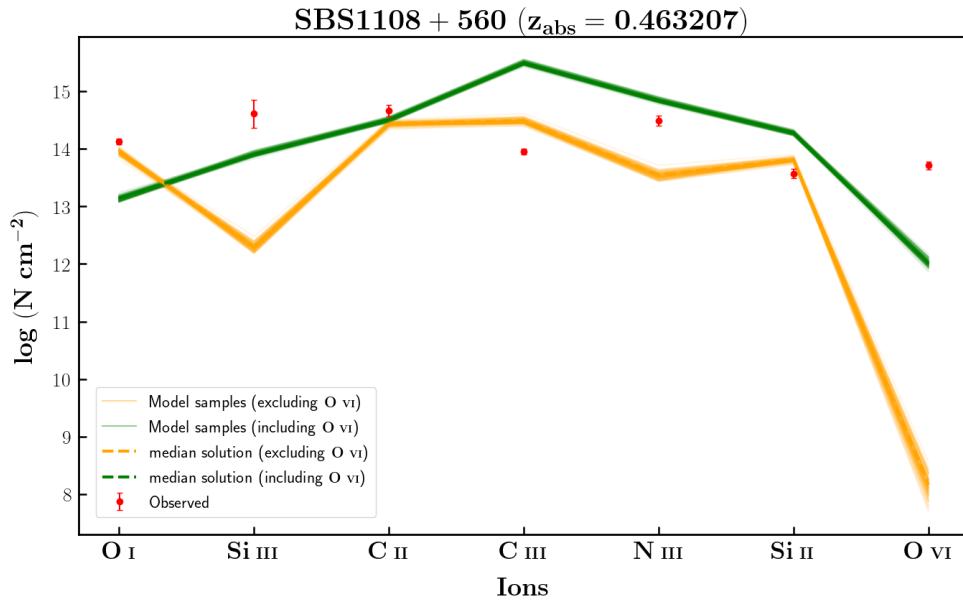


Figure 16: $\text{N(HI)}=18.10$, $\log Z_{\text{ref}}=1$

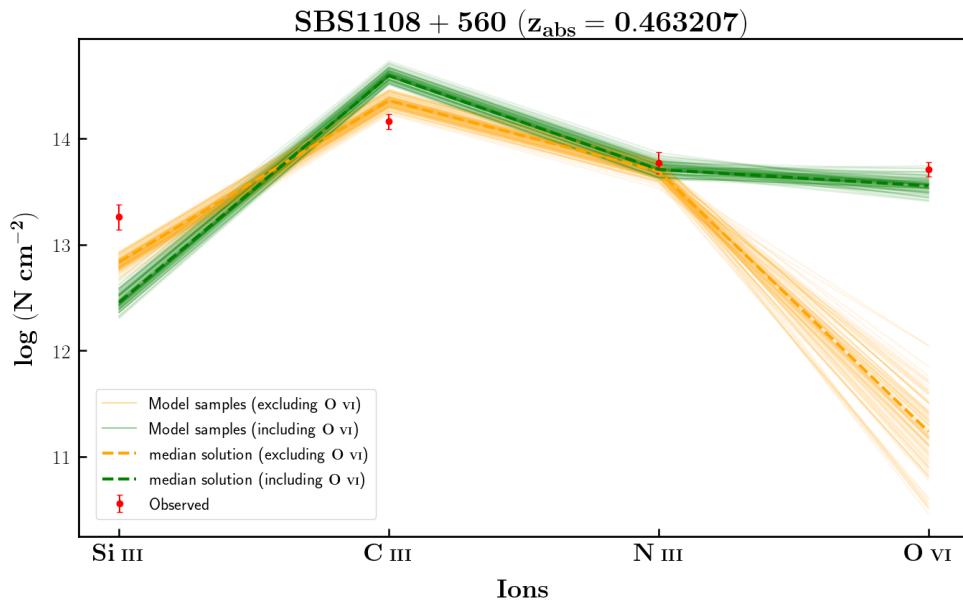
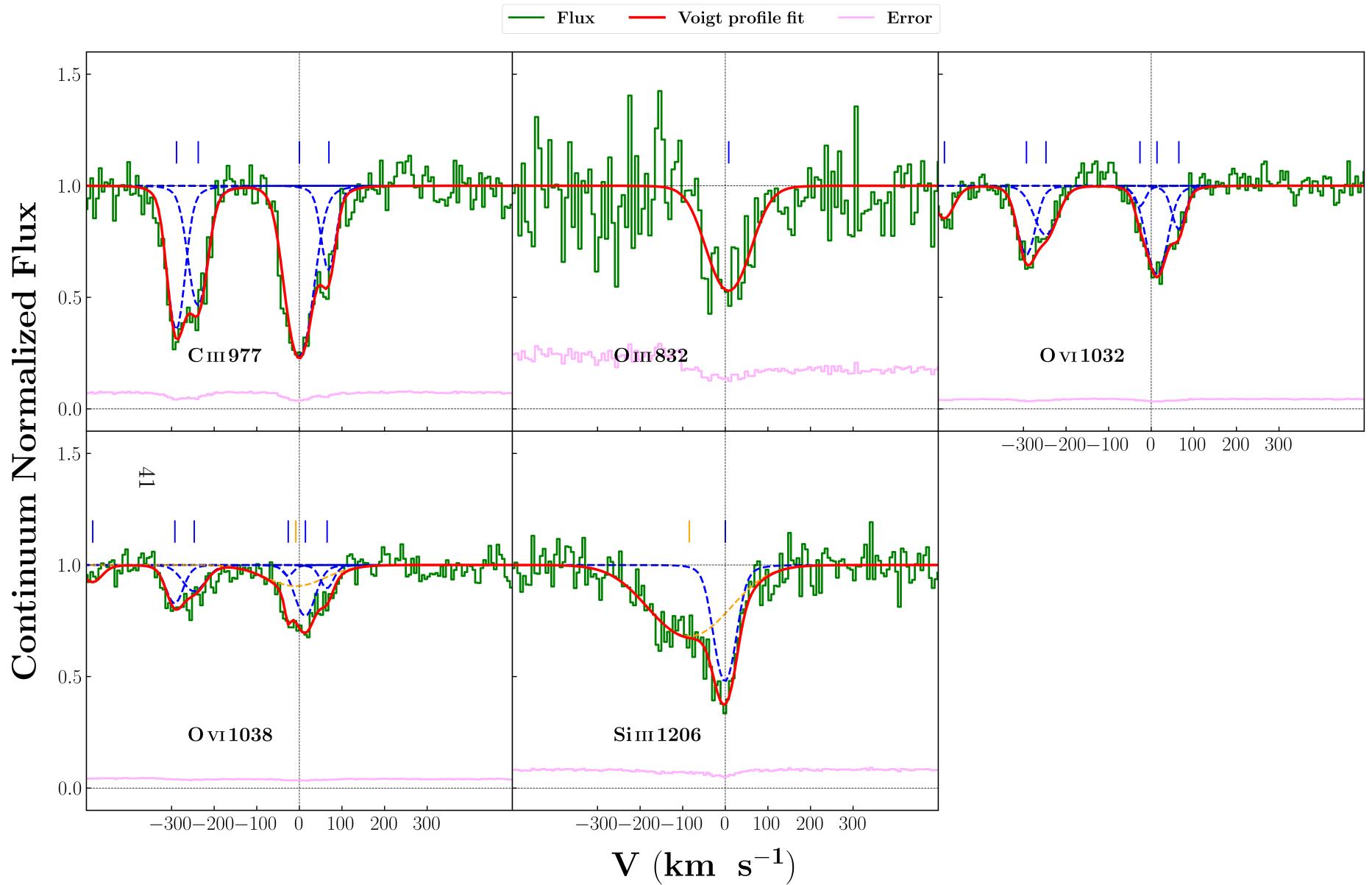


Figure 17: $\text{N(HI)}=15.79$, $\log Z_{\text{ref}}=1$

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

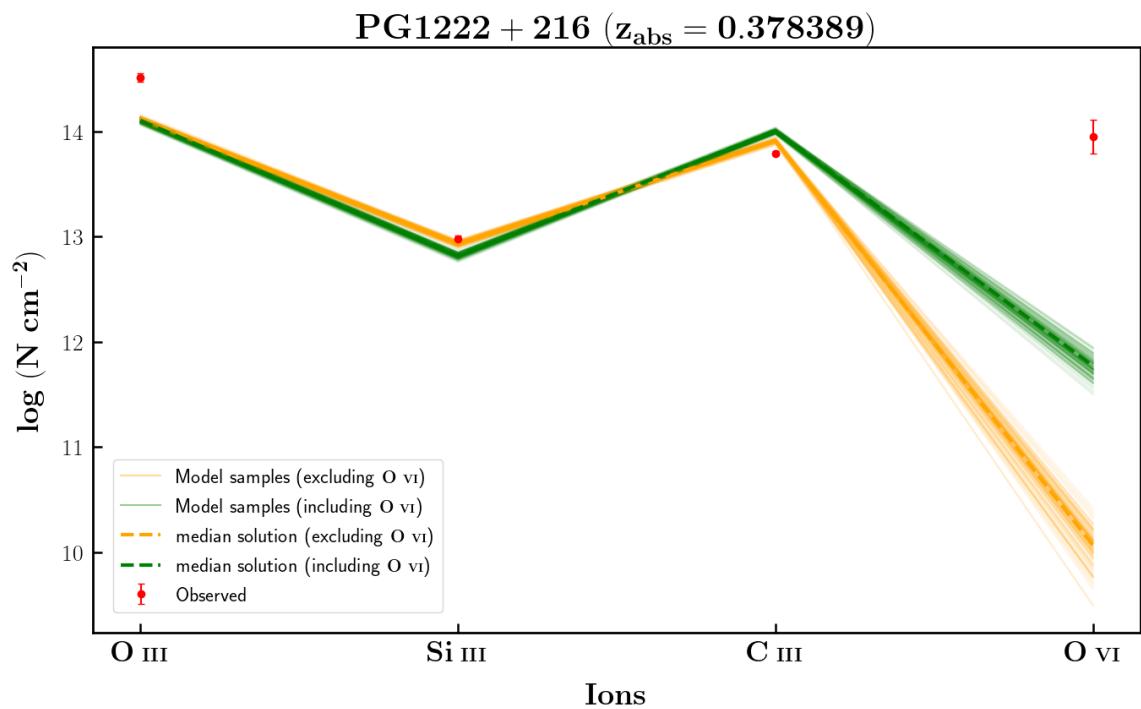
PG1222 + 216 ($z_{\text{abs}} = 0.378389$)



Ion	v (km s ⁻¹)	b (km s ⁻¹)	log [N cm ⁻²]
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

$$N(HI) = 15.43$$

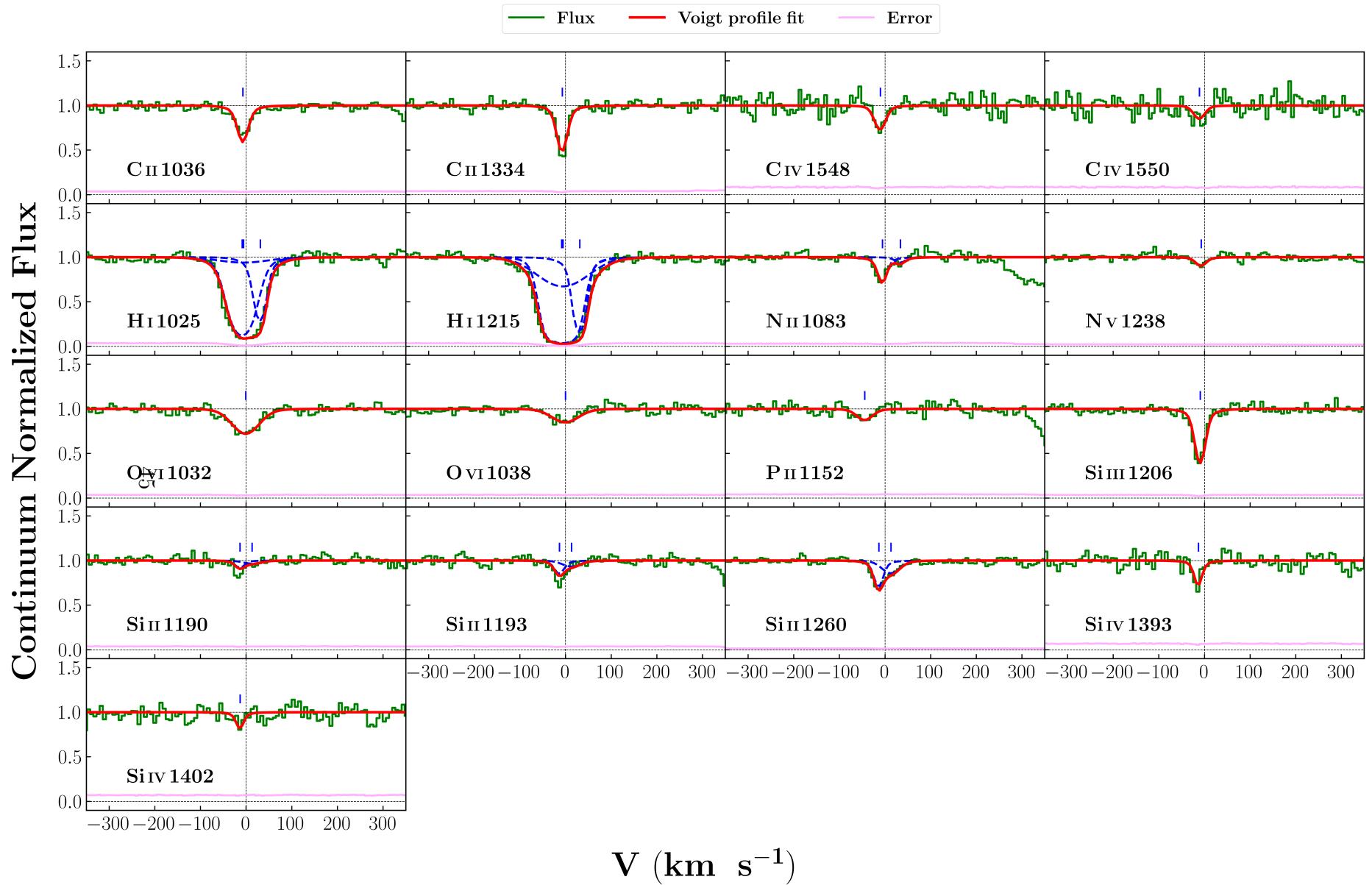
Excluding O VI : $n_H = -2.66 \pm 0.05$	Z = -0.25 ± 0.06
Including O VI : $n_H = -3.16 \pm 0.03$	Z = -0.66 ± 0.02



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 ⁻¹)	b (km s ⁻¹)	log [N cm ⁻²]
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

$$N(HI) = 13.60$$

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

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

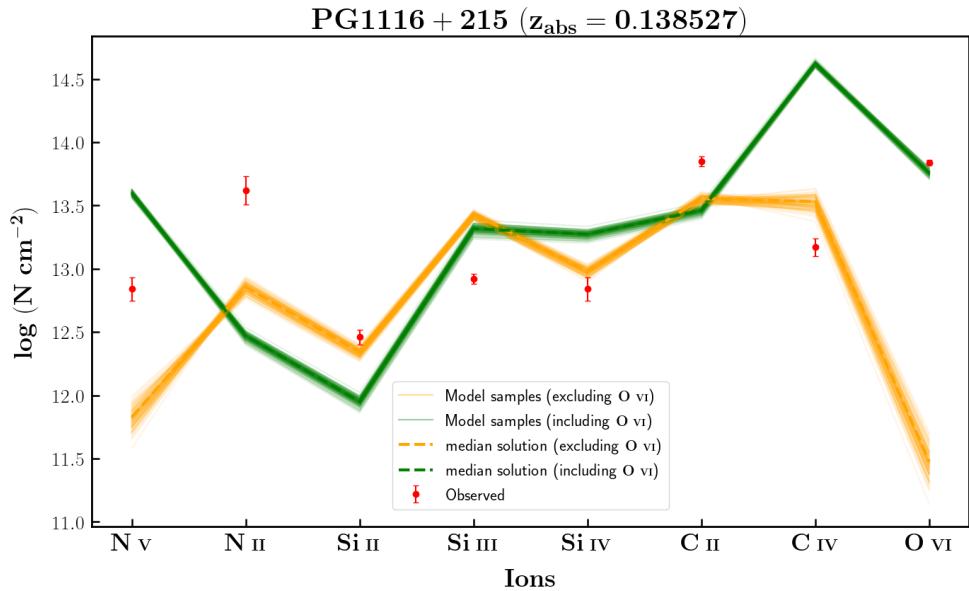


Figure 18: $\text{N(HI)}=13.60$, $\log Z_{\text{ref}} = -1$

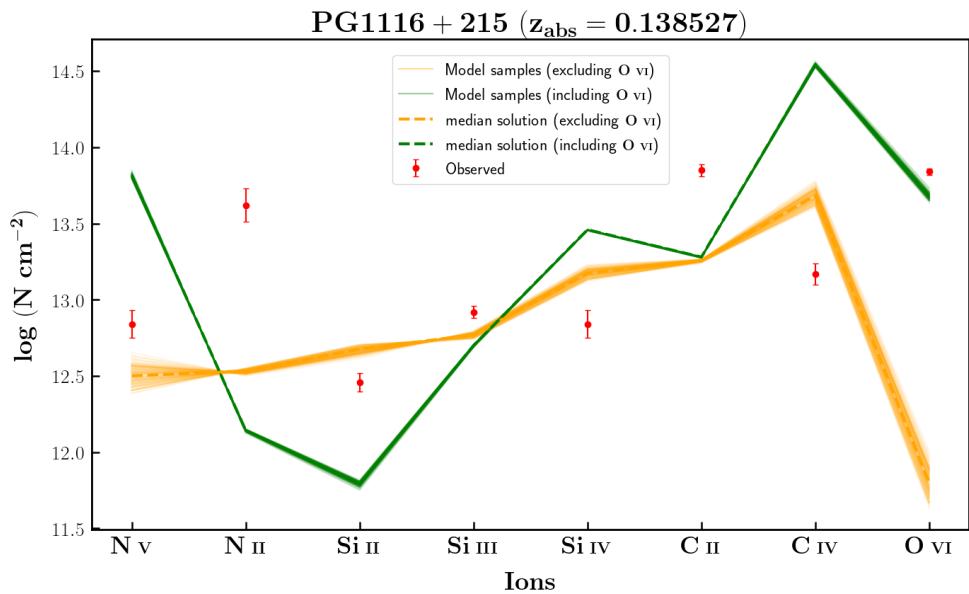
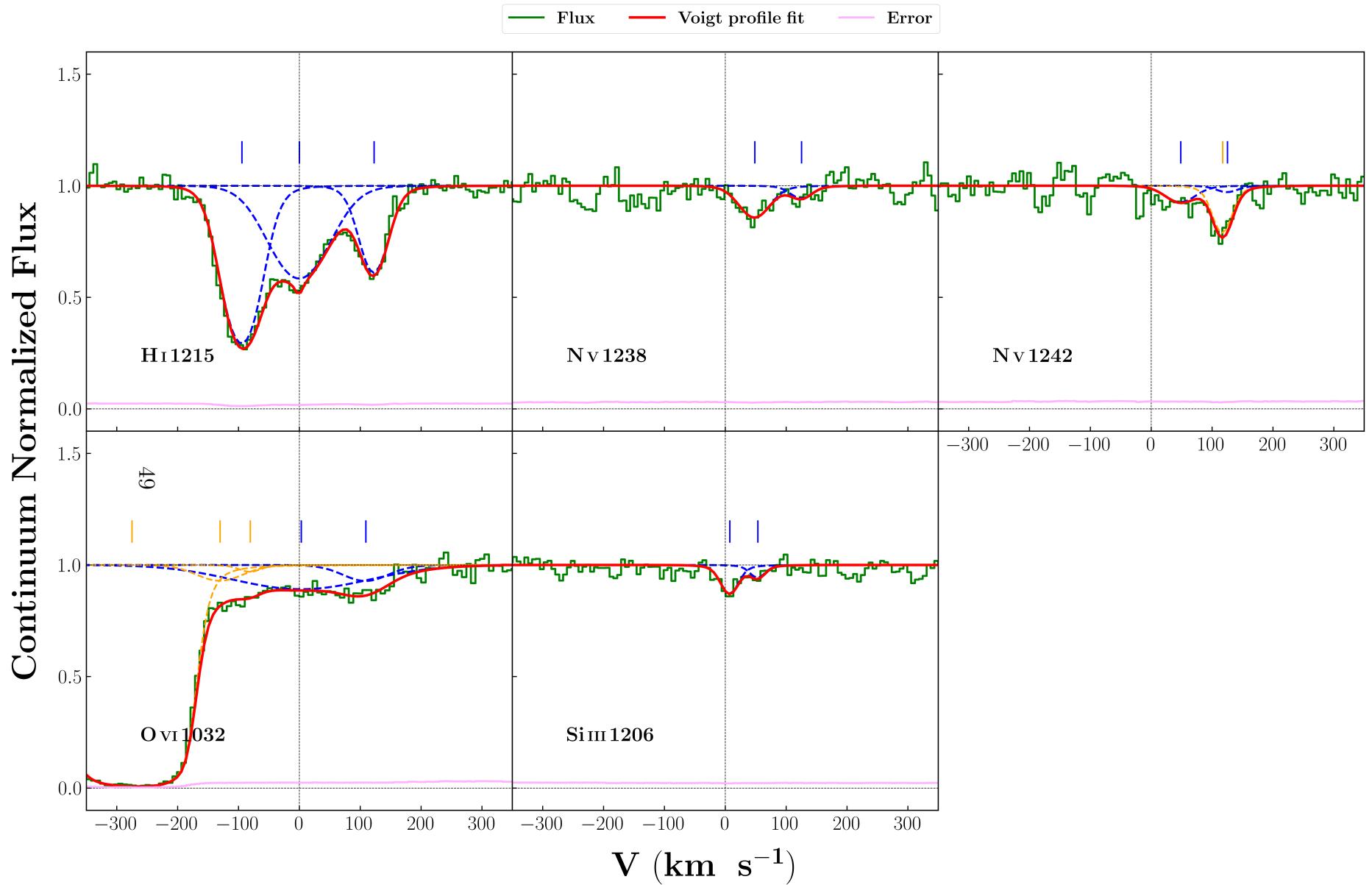


Figure 19: $\text{N(HI)}=13.60$, $\log Z_{\text{ref}} = 1$

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 ($z_{\text{abs}} = 0.170006$)



Ion	v (km s⁻¹)	b (km s⁻¹)	log [N cm⁻²]
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

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

$$N(HI) = 13.68$$

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

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

$$N(HI) = 13.35$$

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

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

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

$$N(HI) = 13.68$$

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

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

$$N(HI) = 13.35$$

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

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

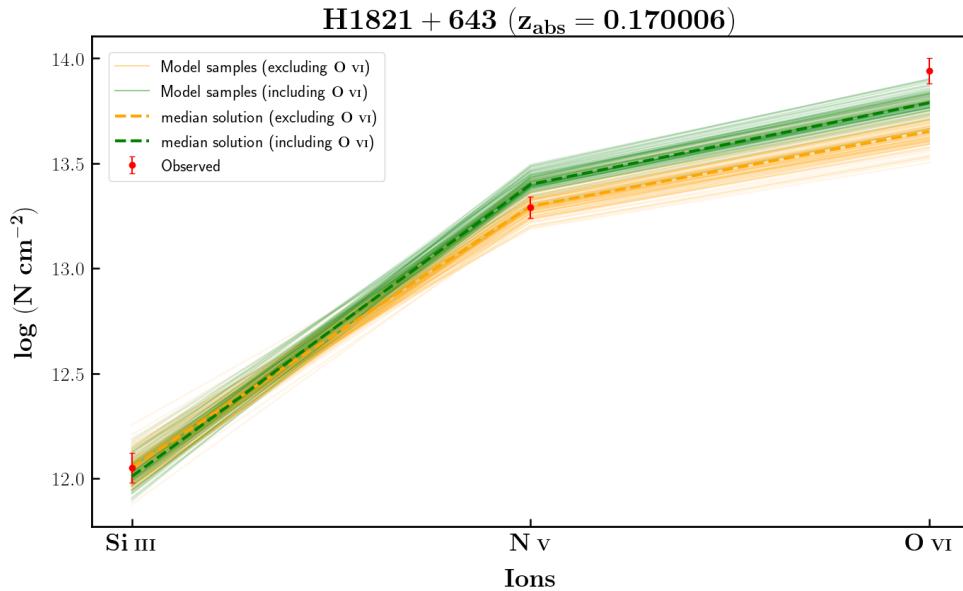


Figure 20: $\text{N(HI)}=13.68$, $\log Z_{\text{ref}} = -1$

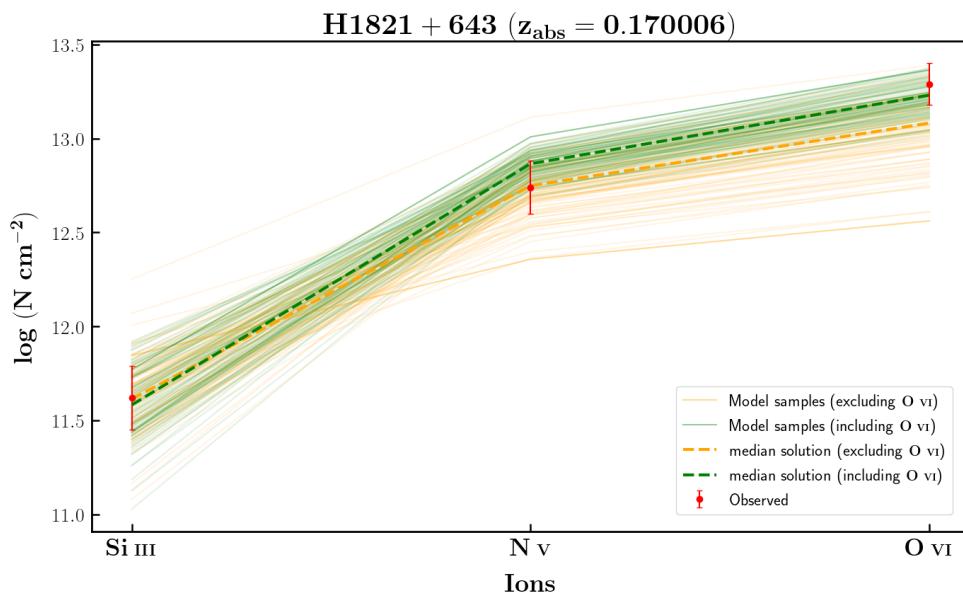


Figure 21: $\text{N(HI)}=13.35$, $\log Z_{\text{ref}} = -1$

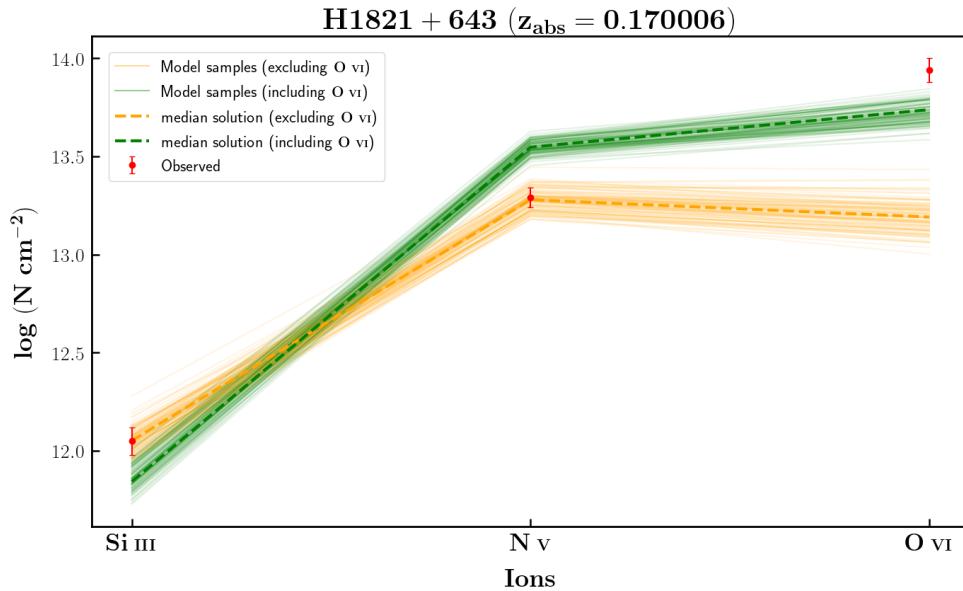


Figure 22: $N(\text{H I})=13.68$, $\log Z_{\text{ref}} = 1$

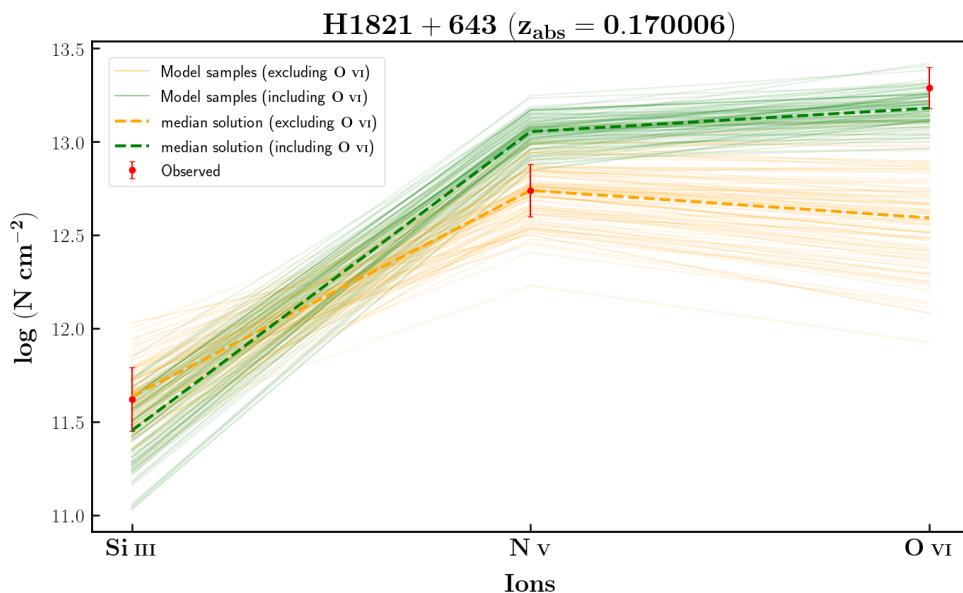
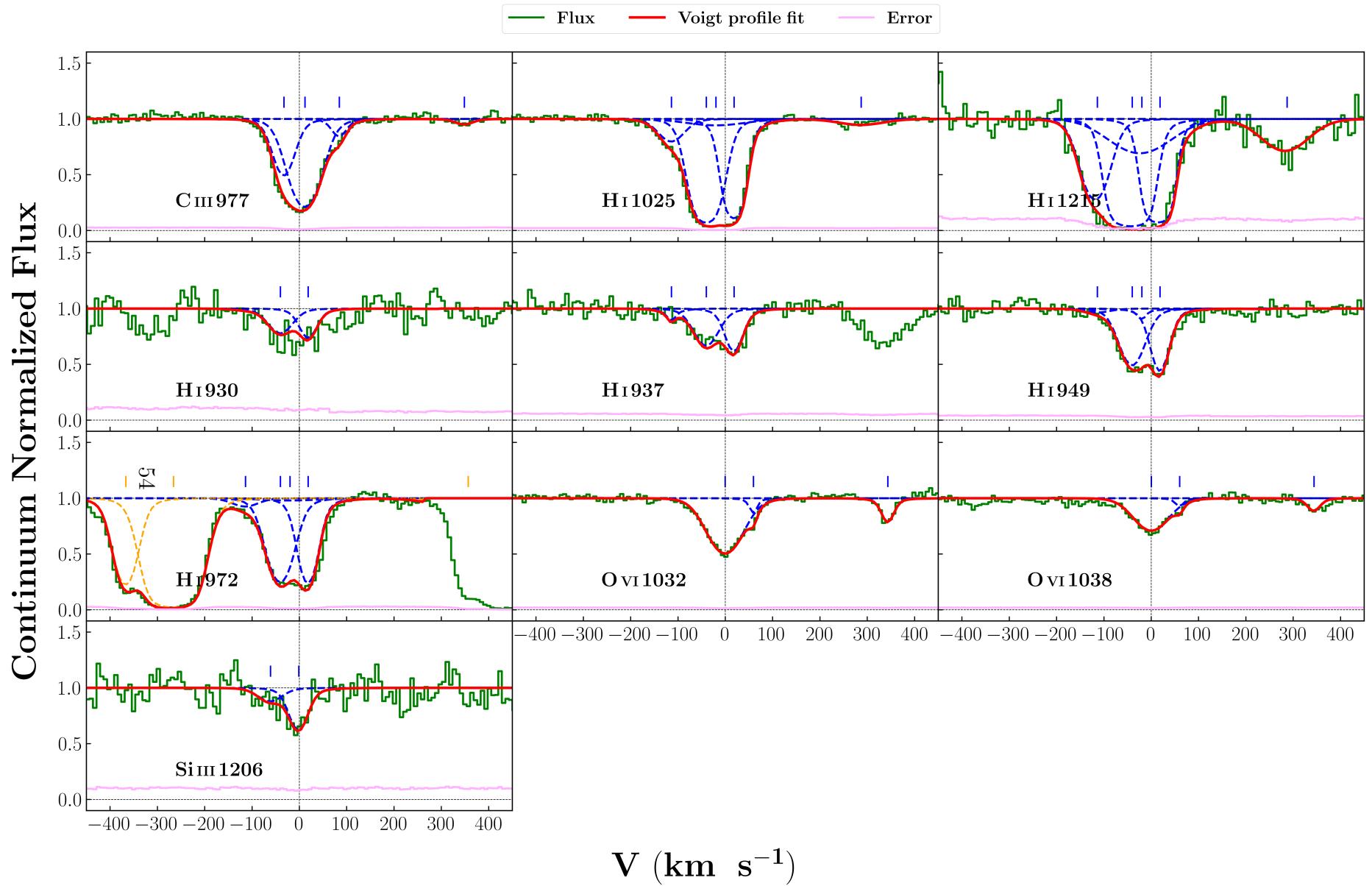


Figure 23: $N(\text{H I})=13.35$, $\log Z_{\text{ref}} = 1$

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 ⁻¹)	b (km s ⁻¹)	log [N cm ⁻²]
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 χ^2 , MCMC didn't converge good, shows hint of two solution, another solution with high density and metallicity for both the components

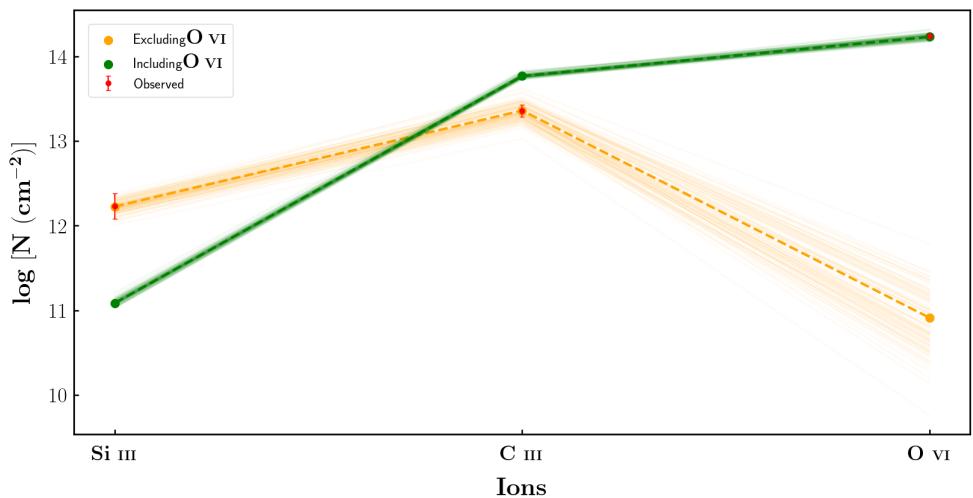


Figure 24: $N(\text{H I})=15.16$

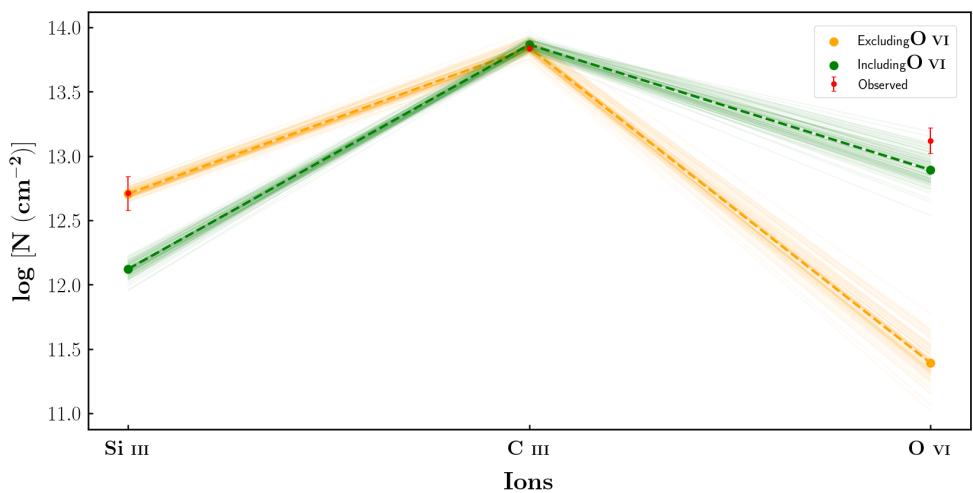
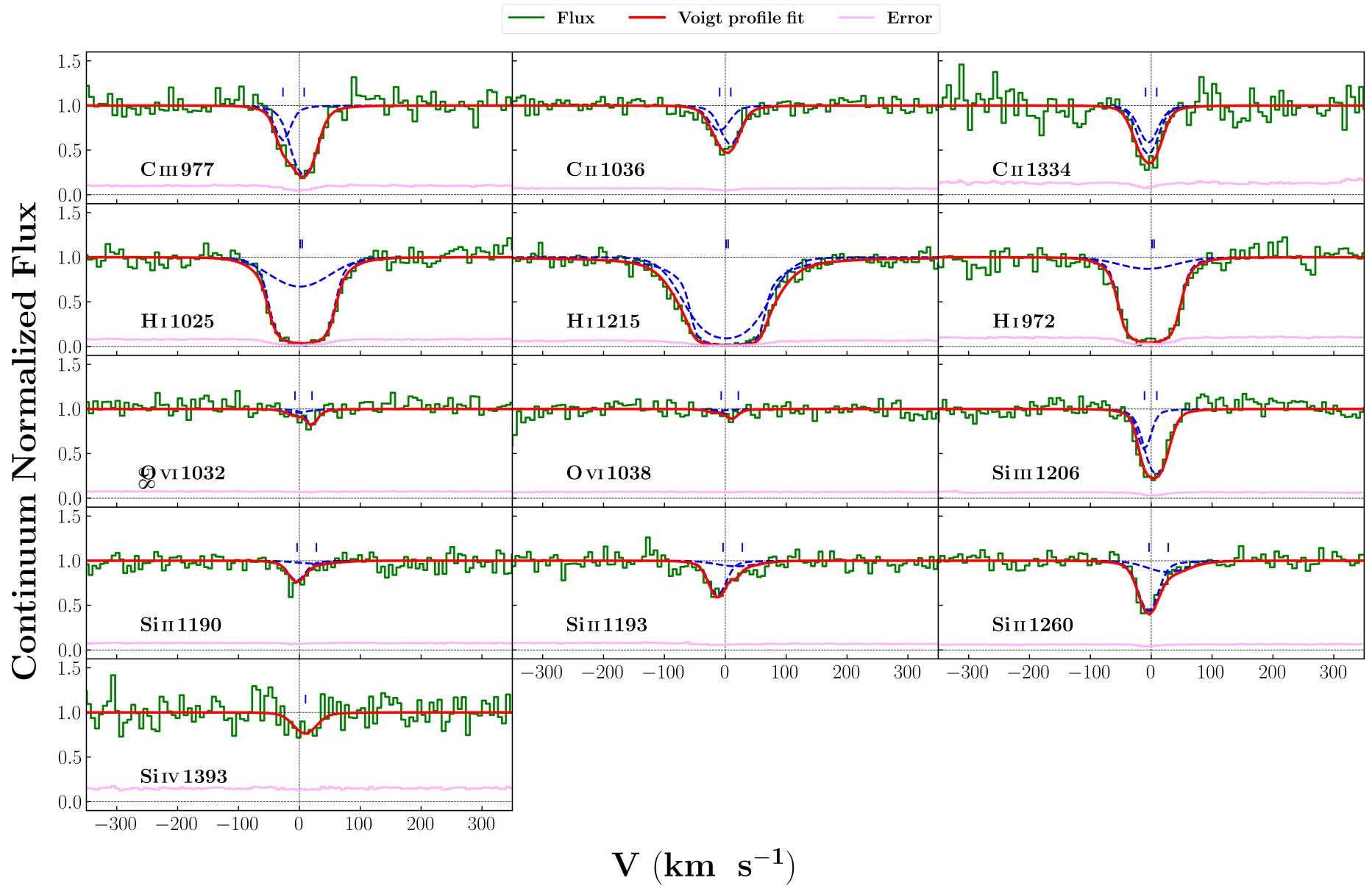


Figure 25: $N(\text{H I})=15.13$

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 ⁻¹)	b (km s ⁻¹)	log [N cm ⁻²]
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.

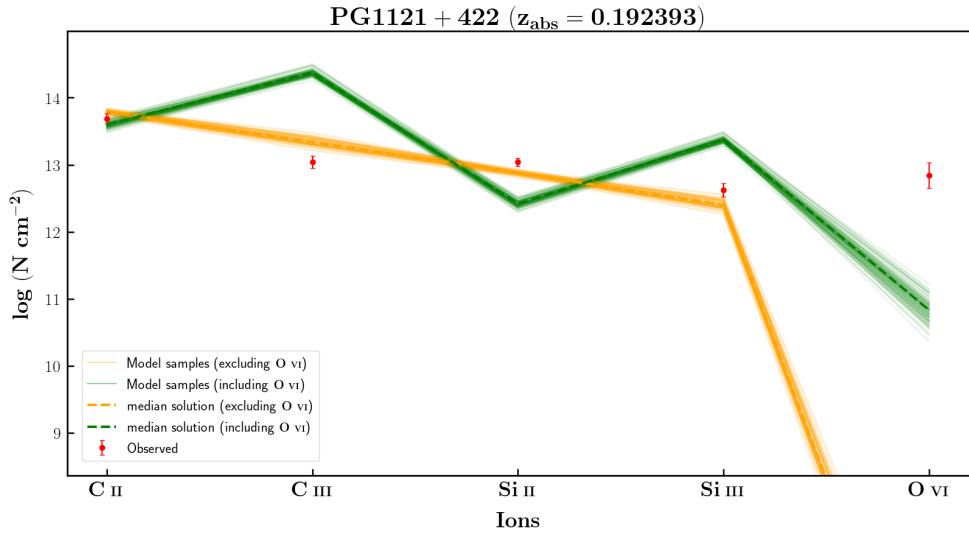


Figure 26: $N(\text{H I})=14.34$, $\log Z_{\text{ref}}=-1$

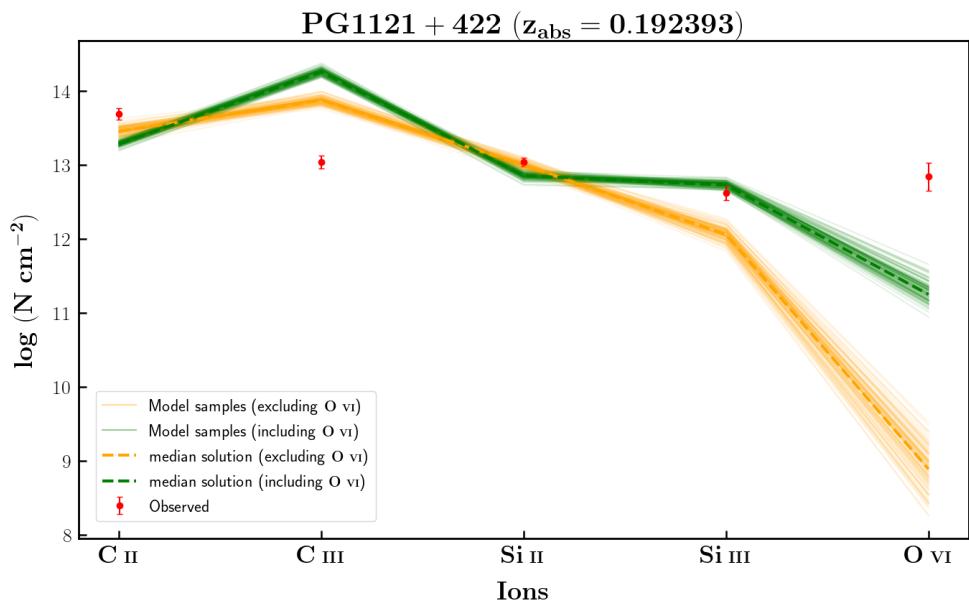


Figure 27: $N(\text{H I})=14.34$, $\log Z_{\text{ref}}=1$

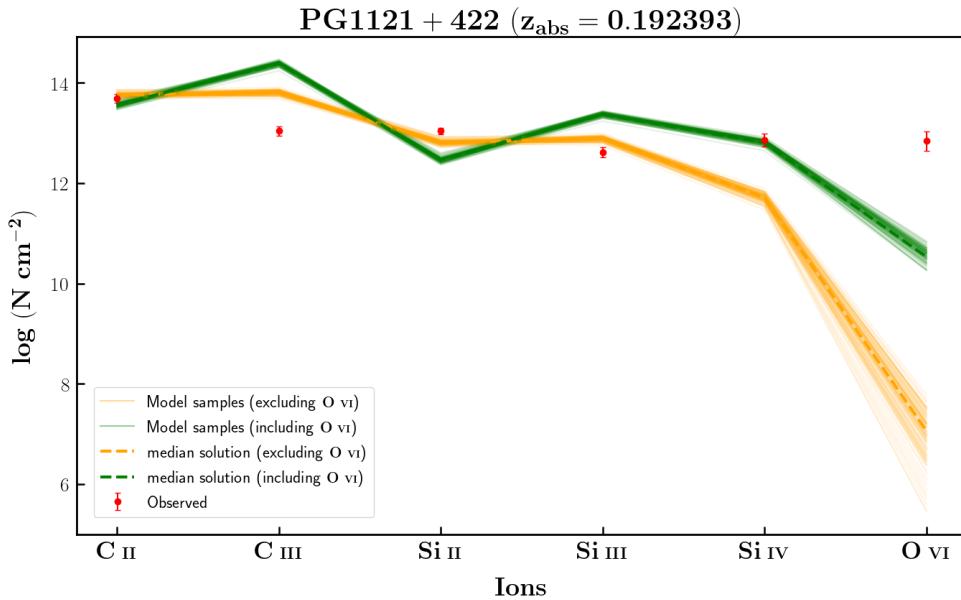
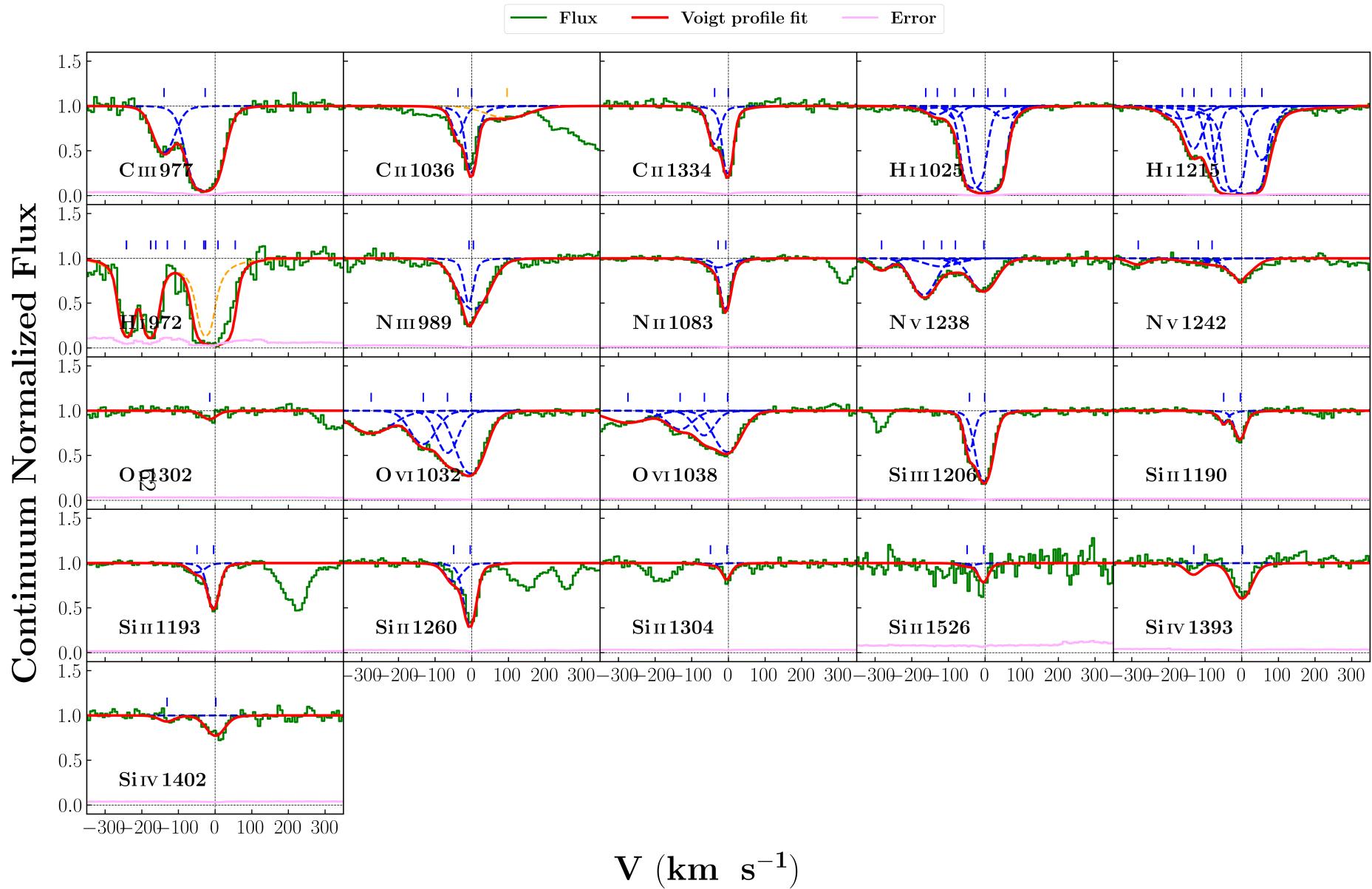


Figure 28: $N(\text{H I})=17.70$, $\log Z_{ref}=-1$

Comments

- For component I ($N(\text{H I})=14.34$), 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 ($N(\text{H I})=17.70$), no good solution is obtained, possibly due to more no. of ions.
- All the solutions underproduce O VI
- Ionisation : CI
- BLA : +ve

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



Ion	v (km s⁻¹)	b (km s⁻¹)	log [N cm⁻²]
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 : $n_H = -3.27 \pm 0.03$ $Z = -0.33 \pm 0.02$

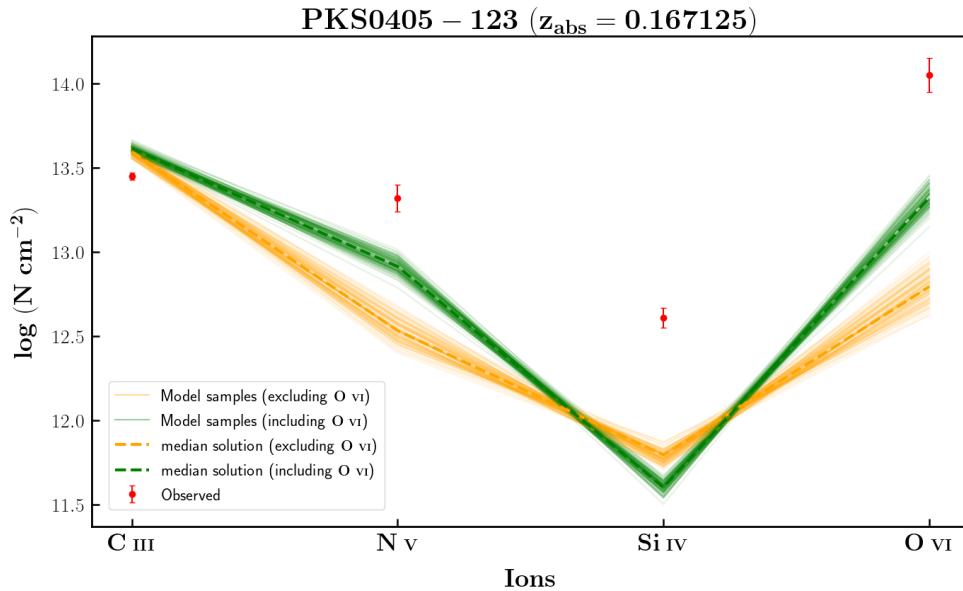


Figure 29: $\text{N}(\text{H I})=13.46$

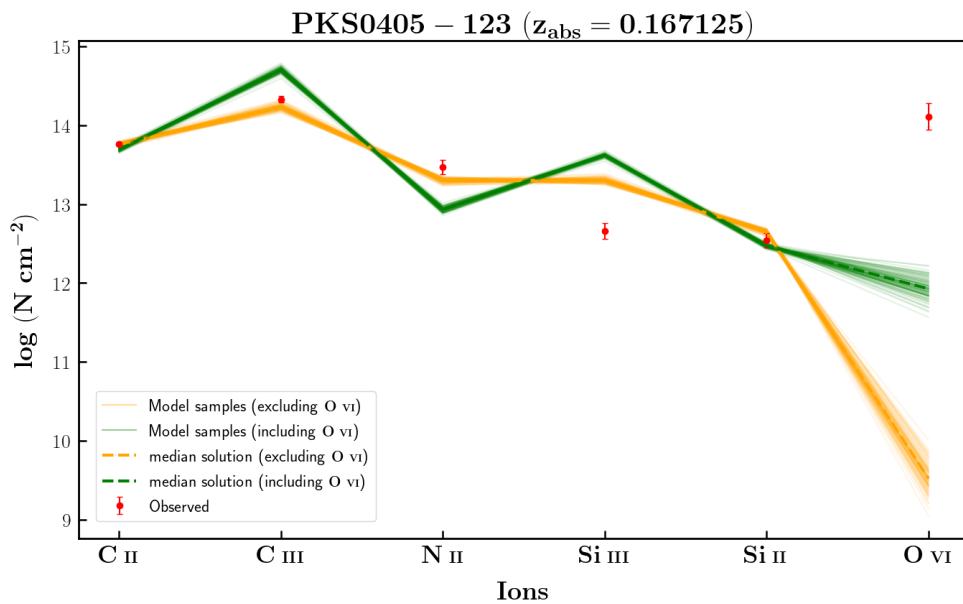


Figure 30: $\text{N}(\text{H I})=15.98$

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

Some statistics

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.

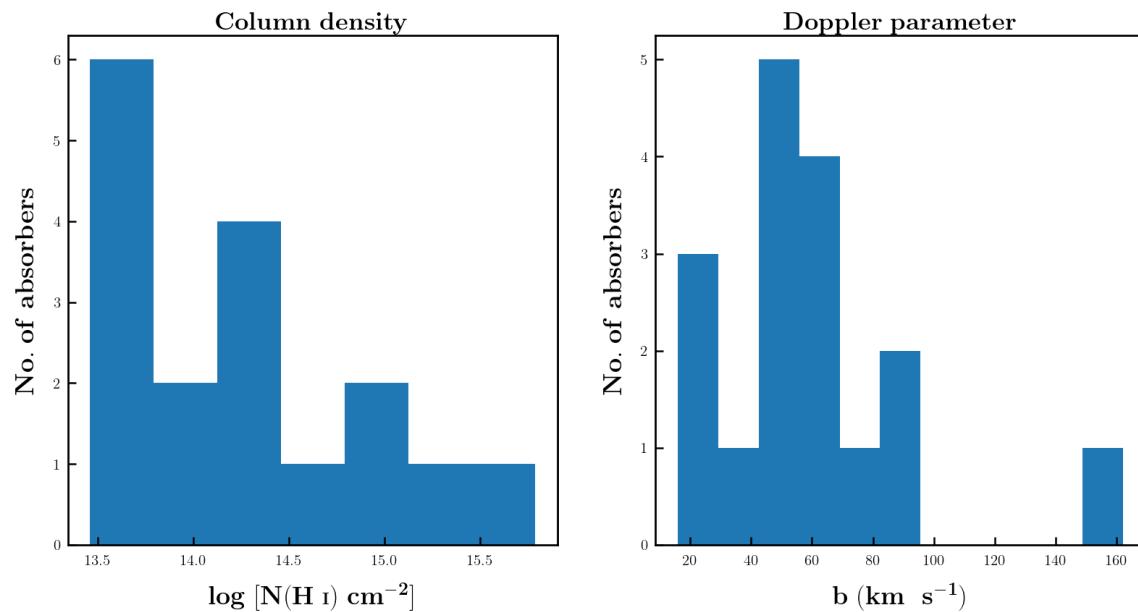


Figure 31: Distribution of column density and doppler parameters of the Lyman lines in the 17 absorbers

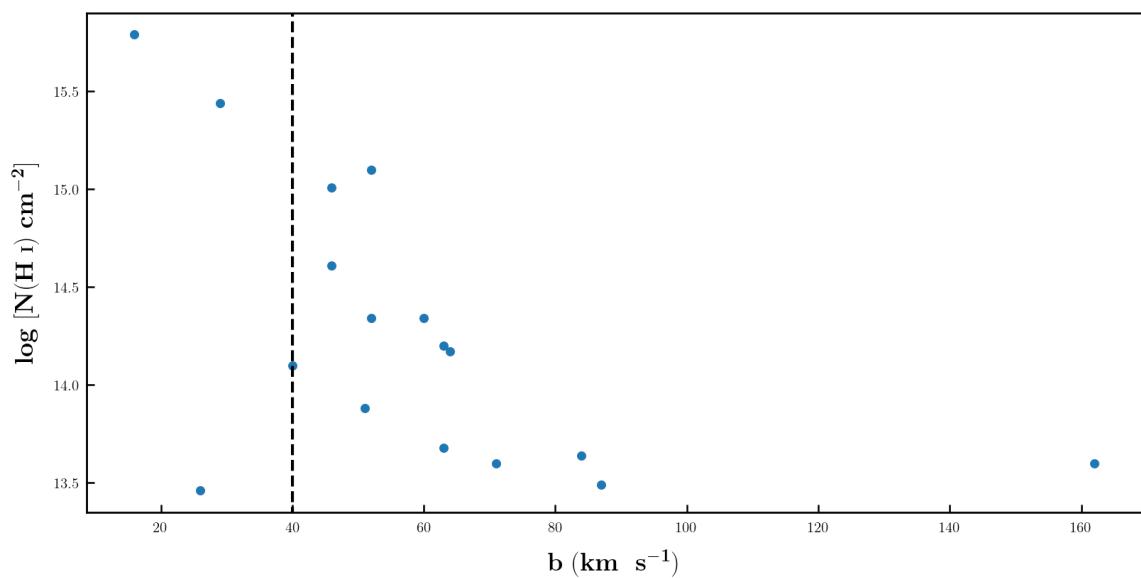


Figure 32: Column desnity v/s doppler parameter. Vertical black dashed line shows the doppler parameter of 40 km s^{-1}