Metal-Line System Survey: Characterizing the Low-z IGM

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28 May 2007

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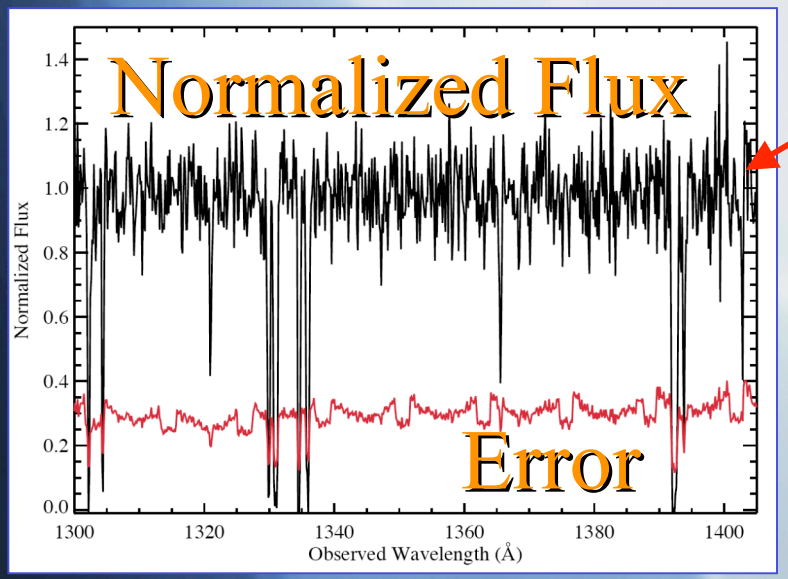
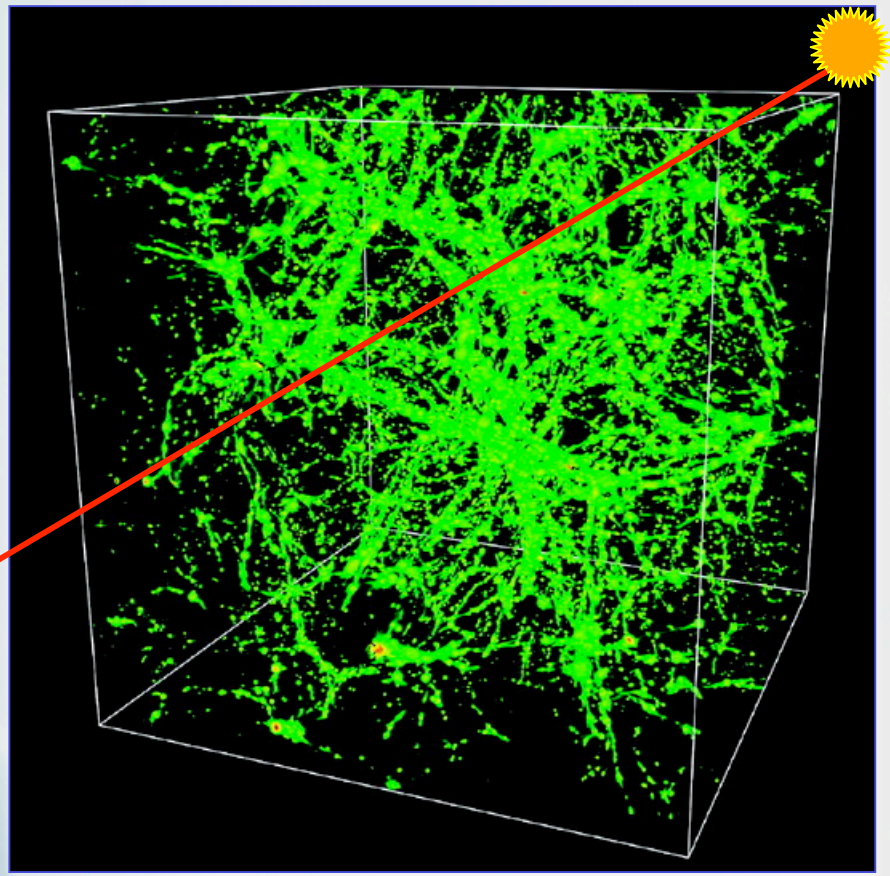
Outline

- Quasar absorption line spectroscopy
  - Some hot topics
- PKS1302-102 ($z_{qso} = 0.2784$)
  - Focus on OVI
  - Multi-phase IGM
  - Absorbers associated with galaxy groups
- *HST*/STIS archive survey (in progress)
  - More metal lines (CIV, SiIV)

Quasar Absorption Line Spectroscopy

- Probe low-density, large-scale structure
- Composition of IGM
  - Including evolution

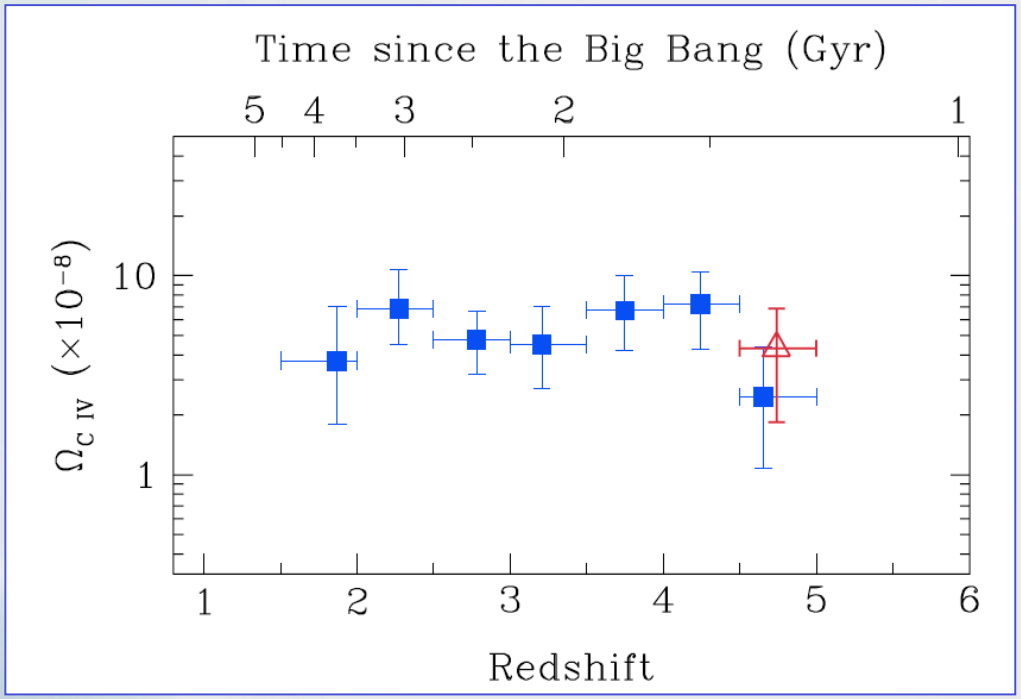




Cen & Ostriker (2005)

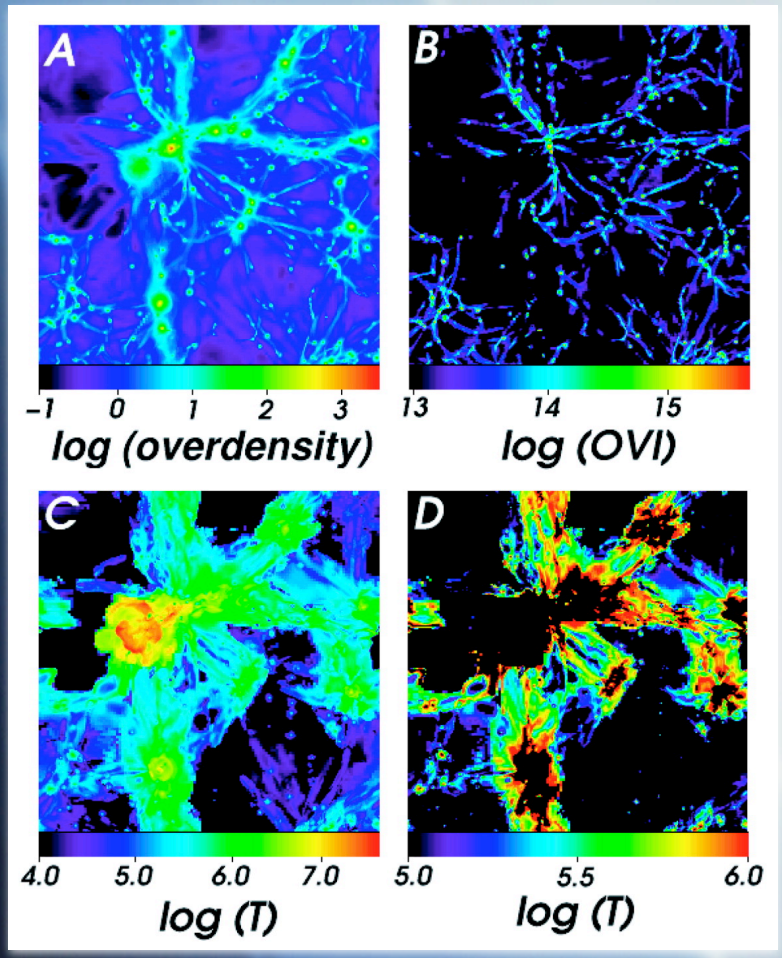
Chemical Evolution of IGM

- Universe enriched early
- Enriched even at low densities
- Ω_{CIV} constant from $1.5 < z < 5$
- What's happening at $z < 1.5$?
  - Return to this *question* later



Pettini et al. (2003)

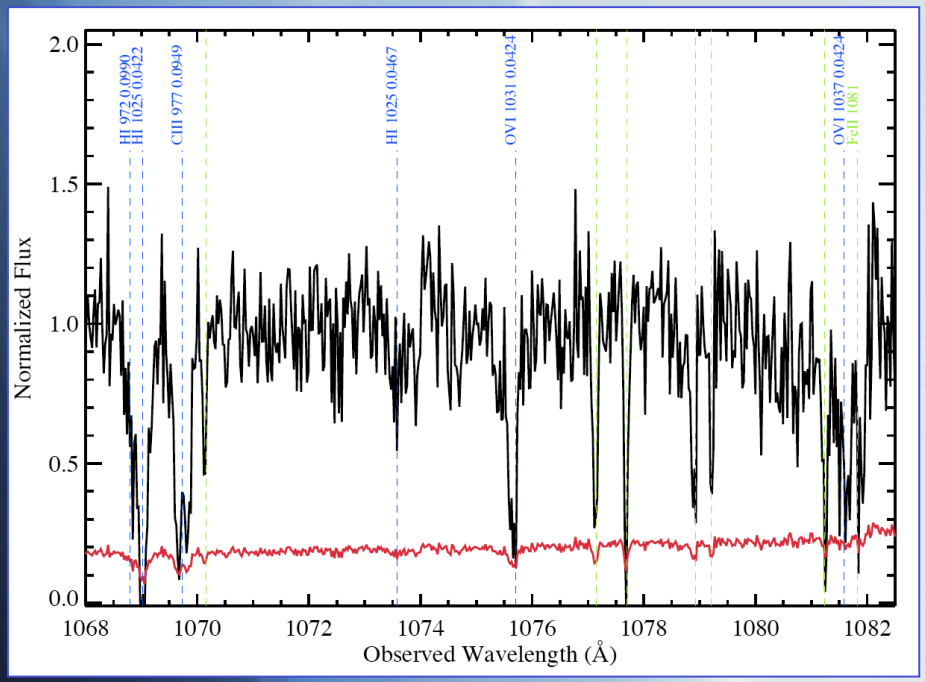
"Missing" Baryons



Fang and Bryan (2001)

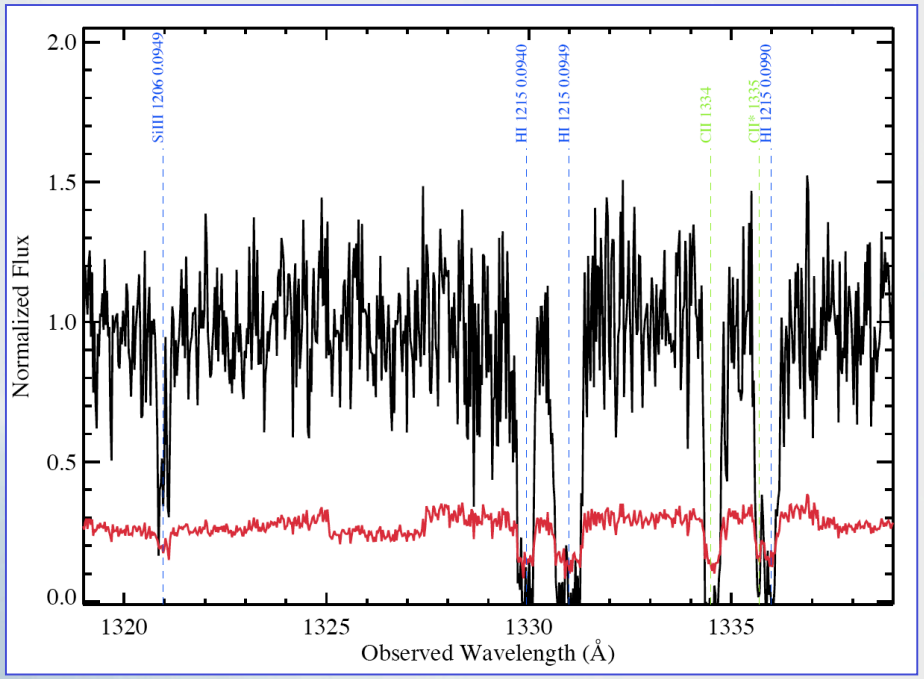
- Warm-hot intergalactic medium (WHIM)
- From simulations
  - Collisionally ionized
  - Shock heated: $10^5 < T < 10^7$ K
  - Overdensity: $10 < \delta < 30$
  - 10-40% Ω_b at $z \sim 1$
- Trace 3×10^5 K WHIM with OVI λλ1031,1037
- How well do observations agree with simulations?
  - Test on one sightline

PKS1302-102: Search for OVI

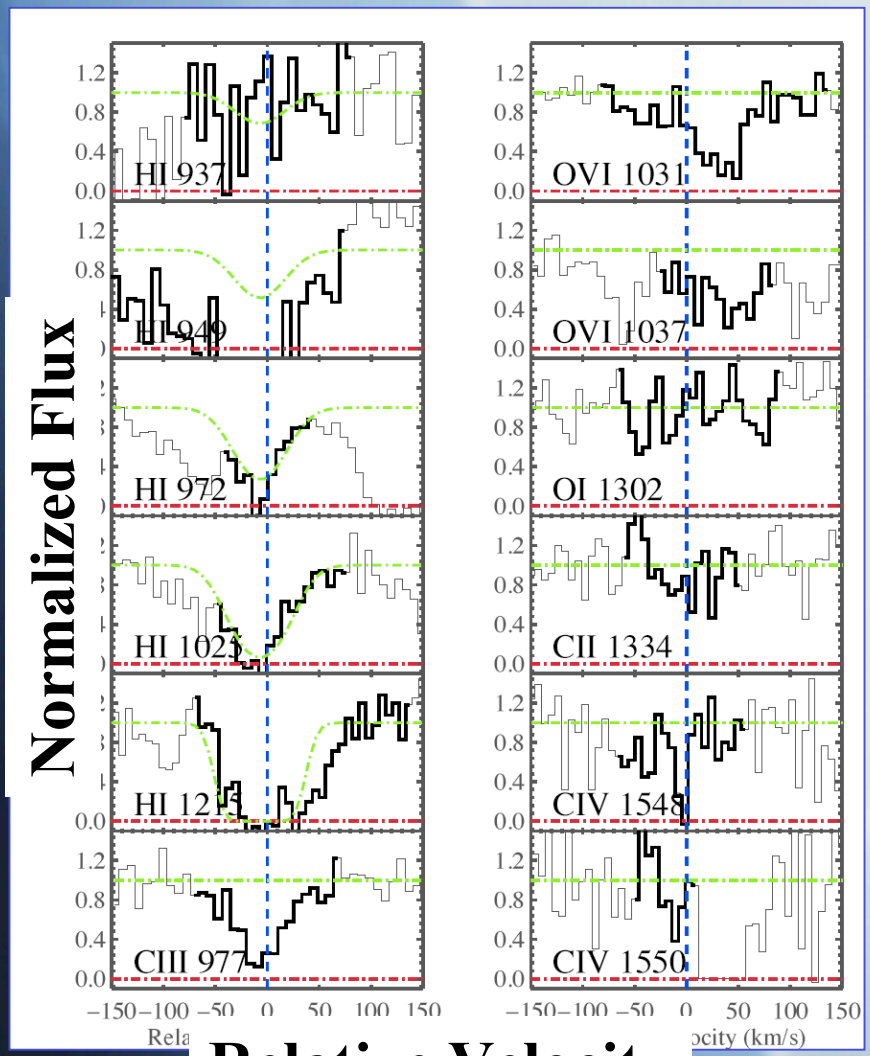


- $z_{qso} = 0.2784$
- 150ks *FUSE*
- 22ks STIS E140M
- S/N ~3-5/pix

- Lyα (23, log $N_{HI} > 14$)
- CIII (6, log $C^{++} > 13$)
- OVI (2+1, log $O^{+5} > 14$)



OVI at $z_{abs} = 0.04231$

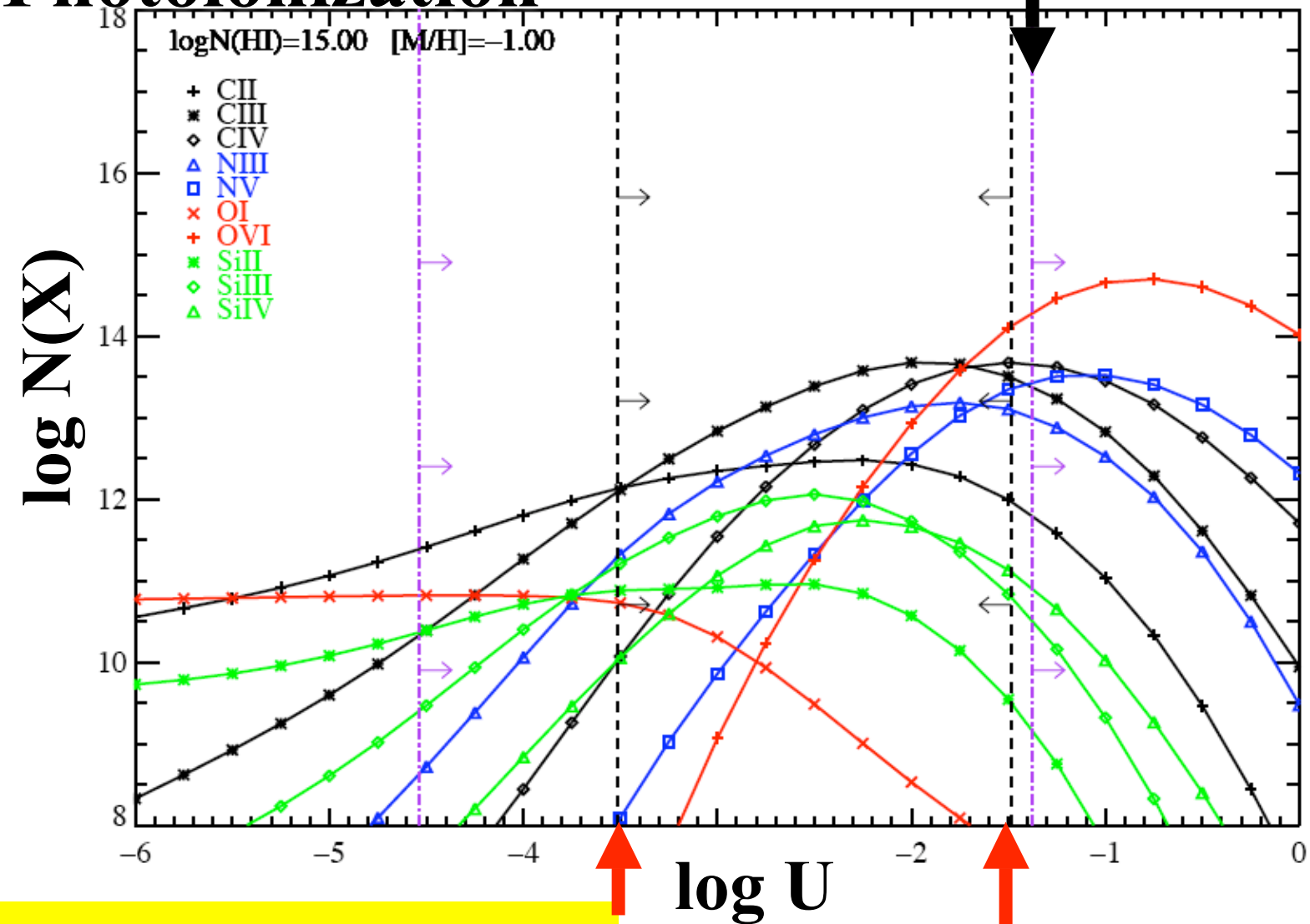


- log N_{HI} = 15.1, b = 22 km/s
  - Multi-component
- log (O^{+5}) = 14.5
  - $\delta v_\gamma > +50$ km/s
- log (C^{++}) = 13.7
  - No offset
- log (C^{+3}) < 13.9
- *Kinematically* different phases

What about ionization mechanism(s)?

Photoionization

$\log N(C^{+3})/N(O^{+5}) = -0.6$

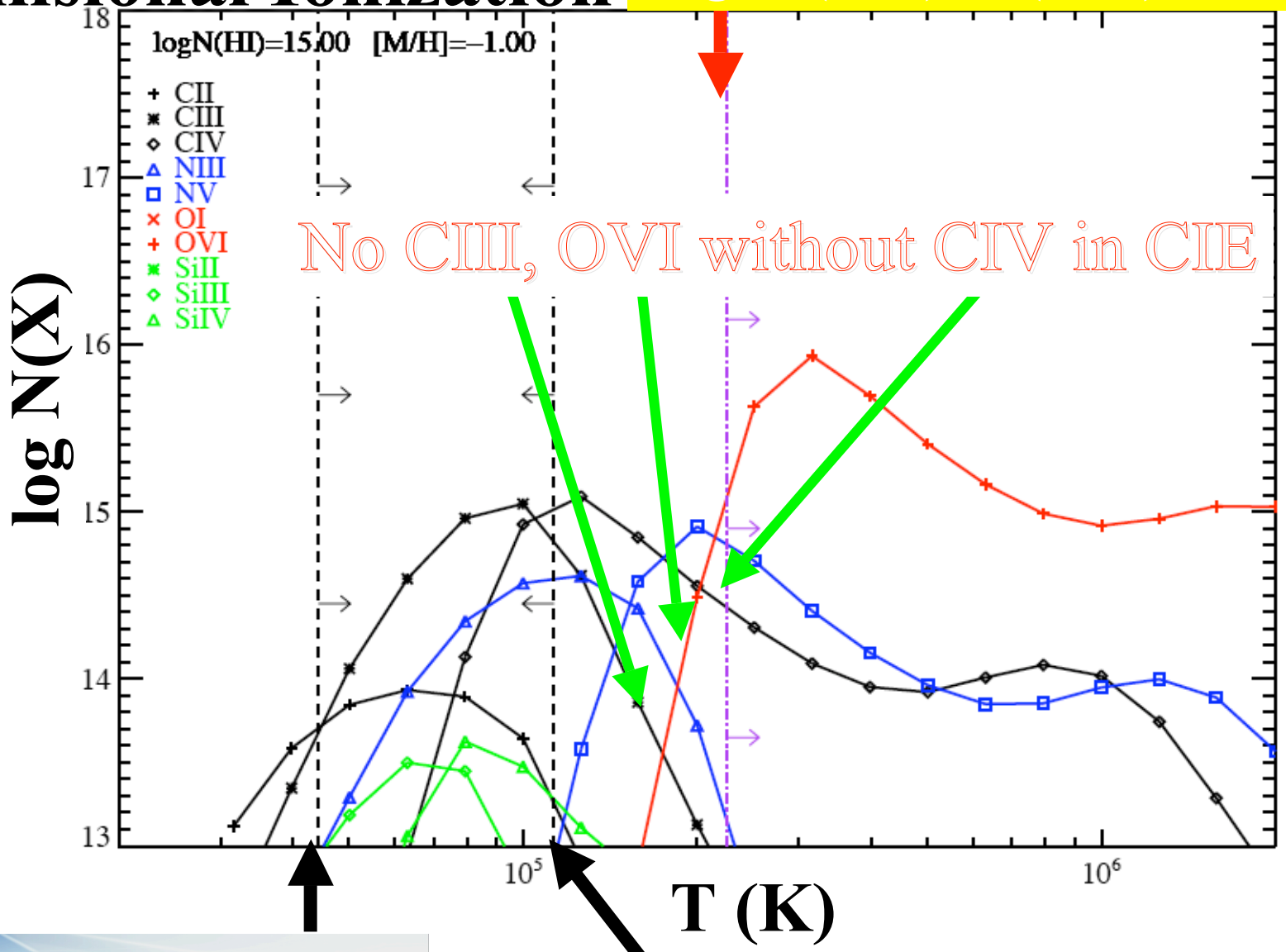


$\log N(C^{+})/N(C^{++}) = 0.04$

$\log N(C^{++})/N(C^{+3}) = -0.2$

Collisional Ionization

$\log N(C^{+3})/N(O^{+5}) = -0.6$



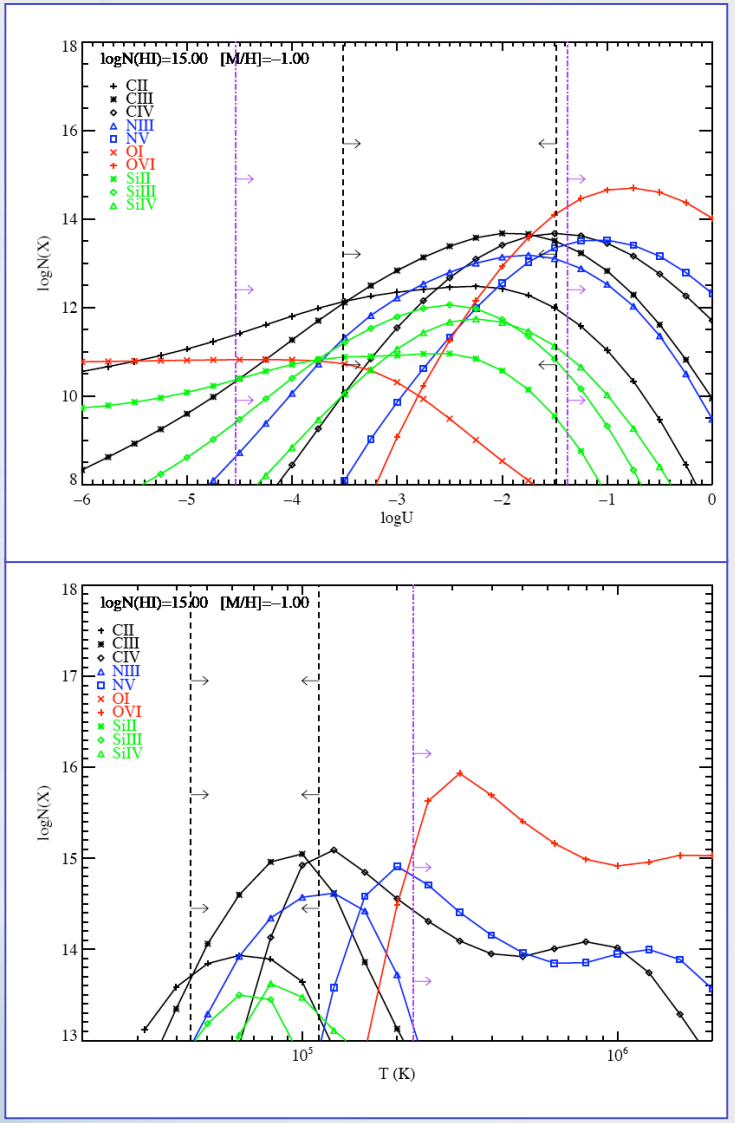
No CIII, OVI without CIV in CIE

$\log N(C^{+})/N(C^{++}) = 0.04$

$\log N(C^{++})/N(C^{+3}) = -0.2$

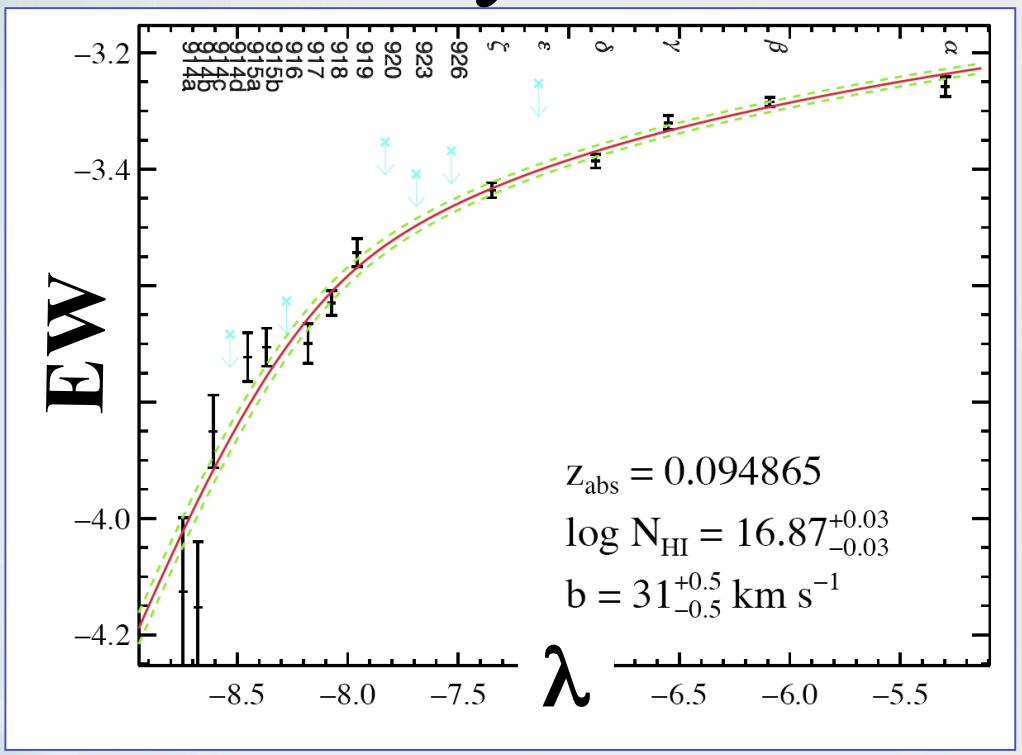
Two-phase Medium

- For photoionized
  - log U = -1.5
  - [C/H] = -0.9
  - [O/H] = -0.7
- For collisionally ionized
  - T = 2.3×10^5 K
  - [O/H] = -1.8
  - No CIII since no CIV
- Two phases
  - Supported by kinematics
  - Two photoionized phases?
  - HI, CIII photoionized + OVI collisionally ionized?



$z_{abs} = 0.09487$
Partial Lyman Limit System

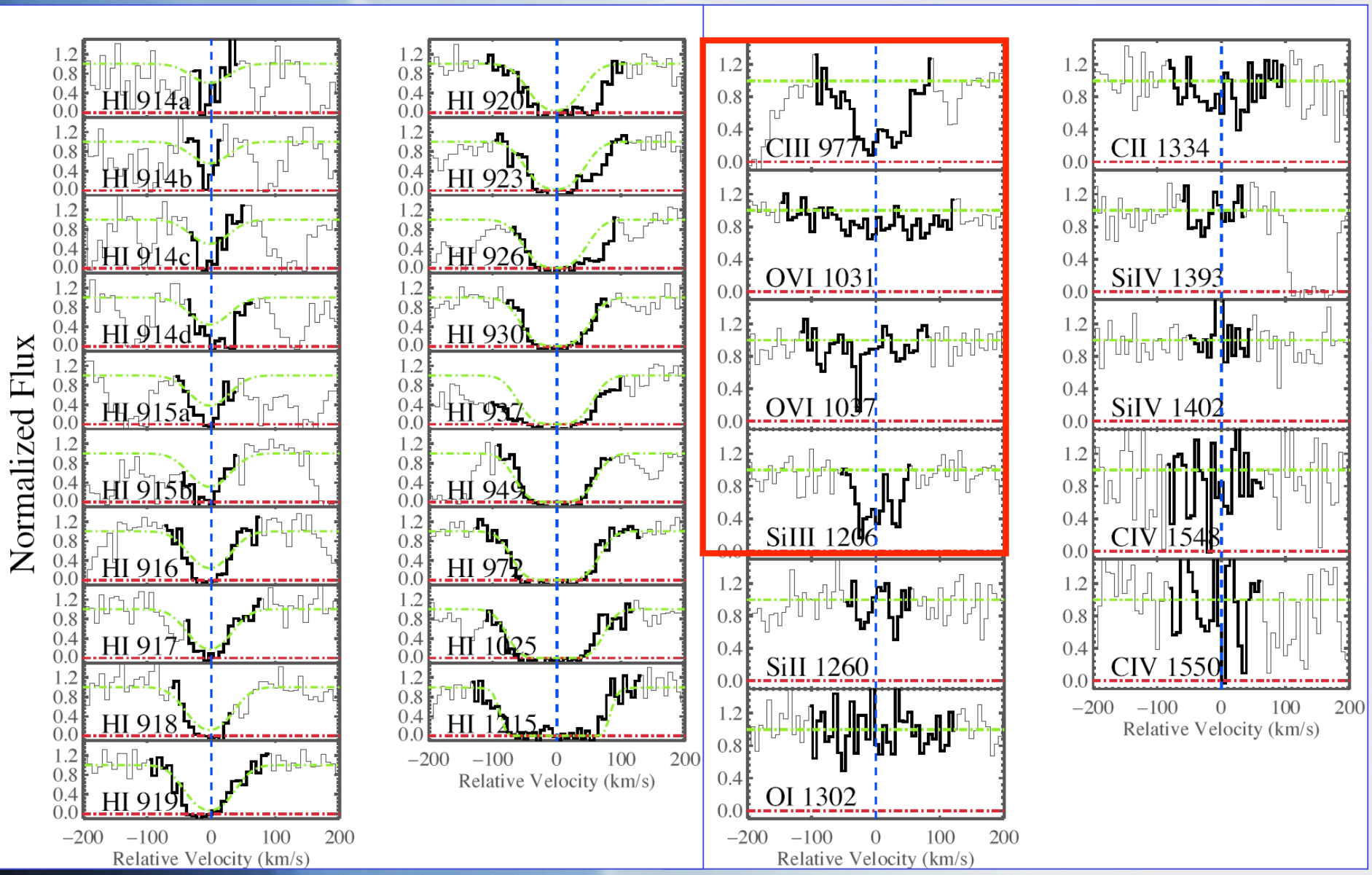
- log N_{HI} ~ 16.9, b = 31 km/s
  - Multi-component
- log (O^{+5}) = 14
  - Broad
- log (C^{++}) > 13.9, log (Si^{++}) = 13.1
  - Similar line profiles
- Kinematically different phases (again)



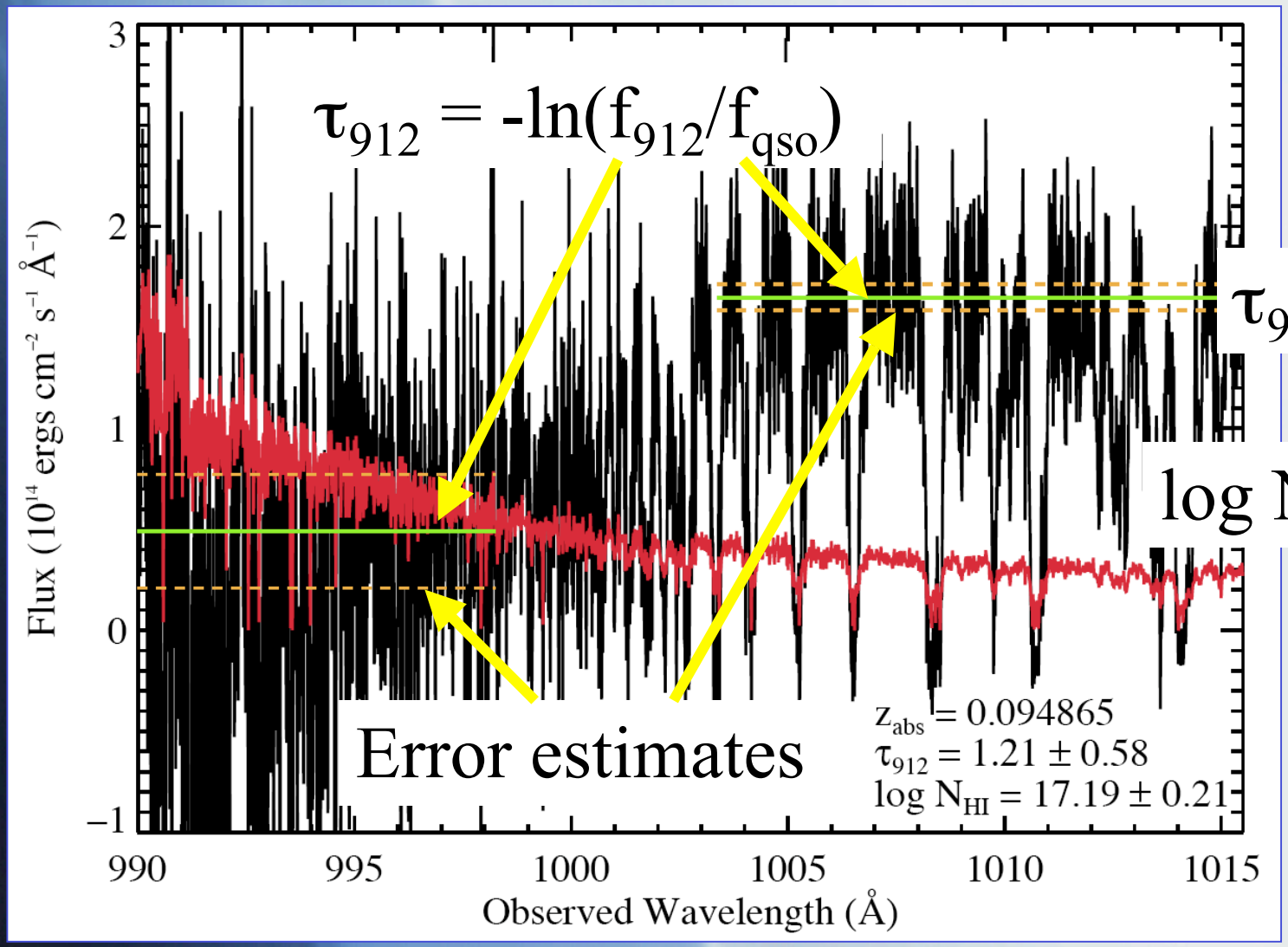
log U = -2.8:
-2 < [C/H] < -1.4
[Si/H] = -1.7

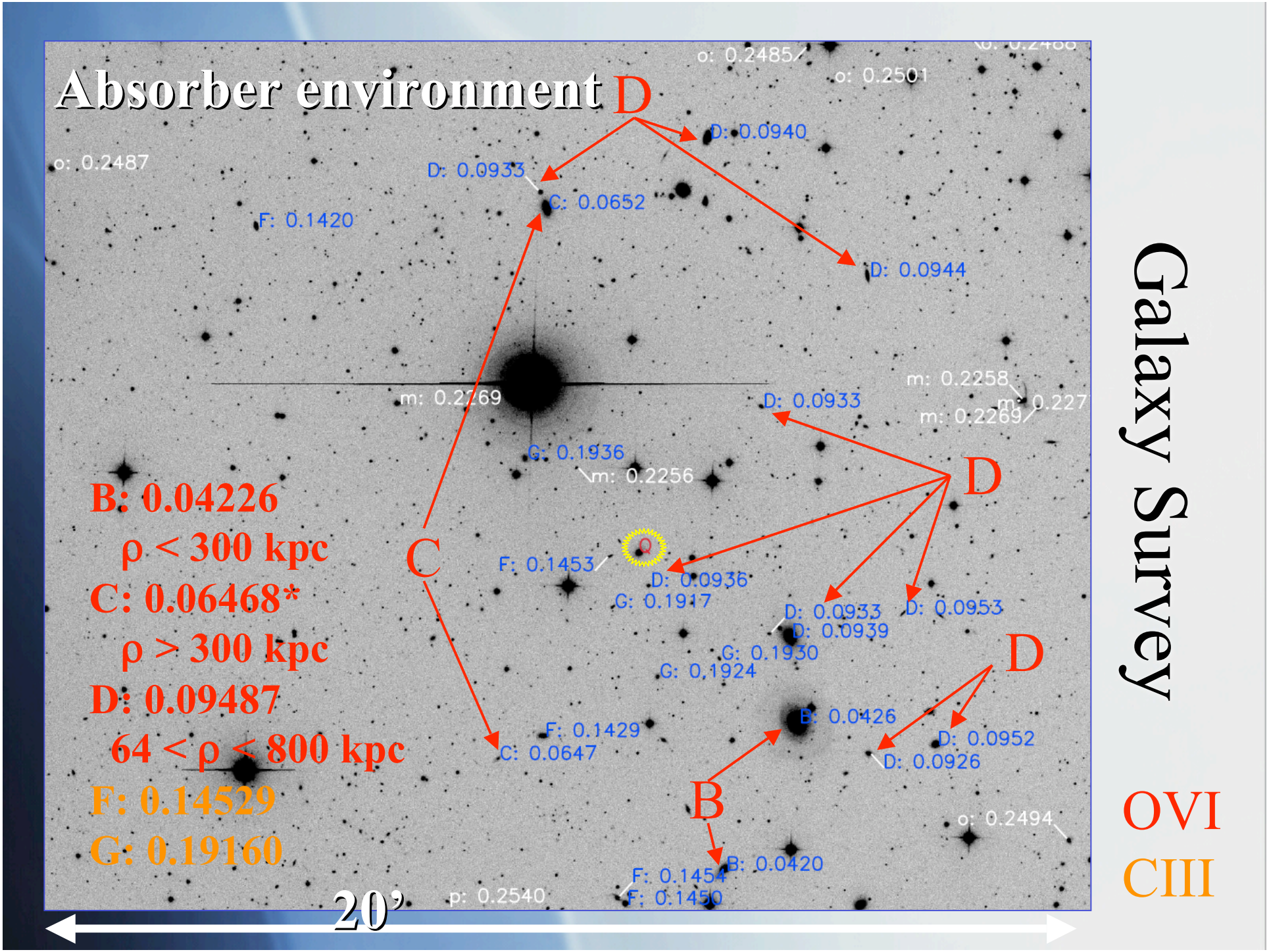
T = 1.8×10^5:
[O/H] = -2.6

Line Profiles

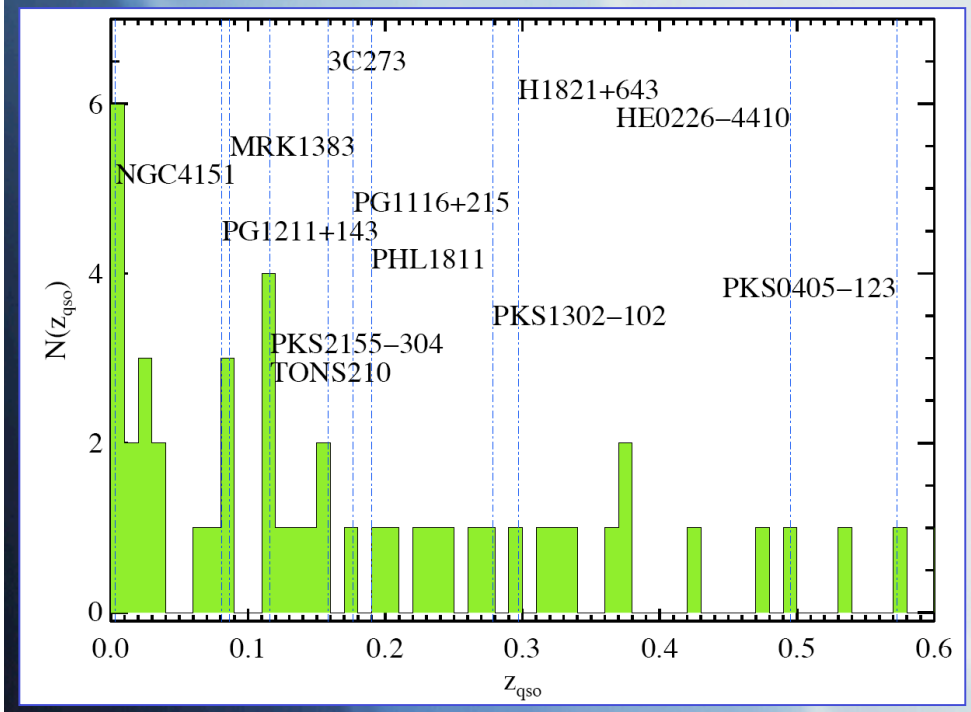


Lyman Limit Optical Depth




Absorber environment
B: 0.04226
ρ < 300 kpc
C: 0.06468*
ρ > 300 kpc
D: 0.09487
64 < ρ < 800 kpc
F: 0.14529
G: 0.19160
20’
Galaxy Survey
OVI
CIII
D
C
B
o: 0.2485
o: 0.2501
o: 0.2487
D: 0.0940
D: 0.0933
C: 0.0652
F: 0.1420
D: 0.0944
m: 0.2258
m: 0.2269
m: 0.227
D: 0.0933
G: 0.1936
m: 0.2256
F: 0.1453
D: 0.0936
G: 0.1917
D: 0.0933
D: 0.0939
D: 0.0953
G: 0.1930
G: 0,1924
B: 0.0426
F: 0.1429
C: 0.0647
D: 0.0952
D: 0.0926
o: 0.2494
B: 0.0420
F: 0.1454
F: 0.1450
p: 0.2540

HST/STIS Archive Survey



- Search for OVI, CIV, SiIV
- ~60 QSOs, $0 < z_{qso} < 2$
- Galaxy survey for ~12 sightlines
- Simulations and pixel optical depth
  - CIV of $z \sim 1$, $\delta \sim 1$ IGM
  - Add to Pettini et al. (2003) Ω_{CIV} plot
  - Aguirre et al. (2004)

How many absorbers will we find?

- Including only 12 objects of ~60
  - Δz will increase
- Have not adjusted for e.g. Galactic lines
  - Δz will increase
- If no CIV, dN/dz < 3

	Δz	**dN/dz**	**$N_{exp.}$**
OVI	2.5	15	37
SiIV	1.7	1-2 ?	2-3
CIV	0.9	1-3 ?	1-3
CIII	2.5	>12 ?	>30
Lyα	2.3	>100	>230

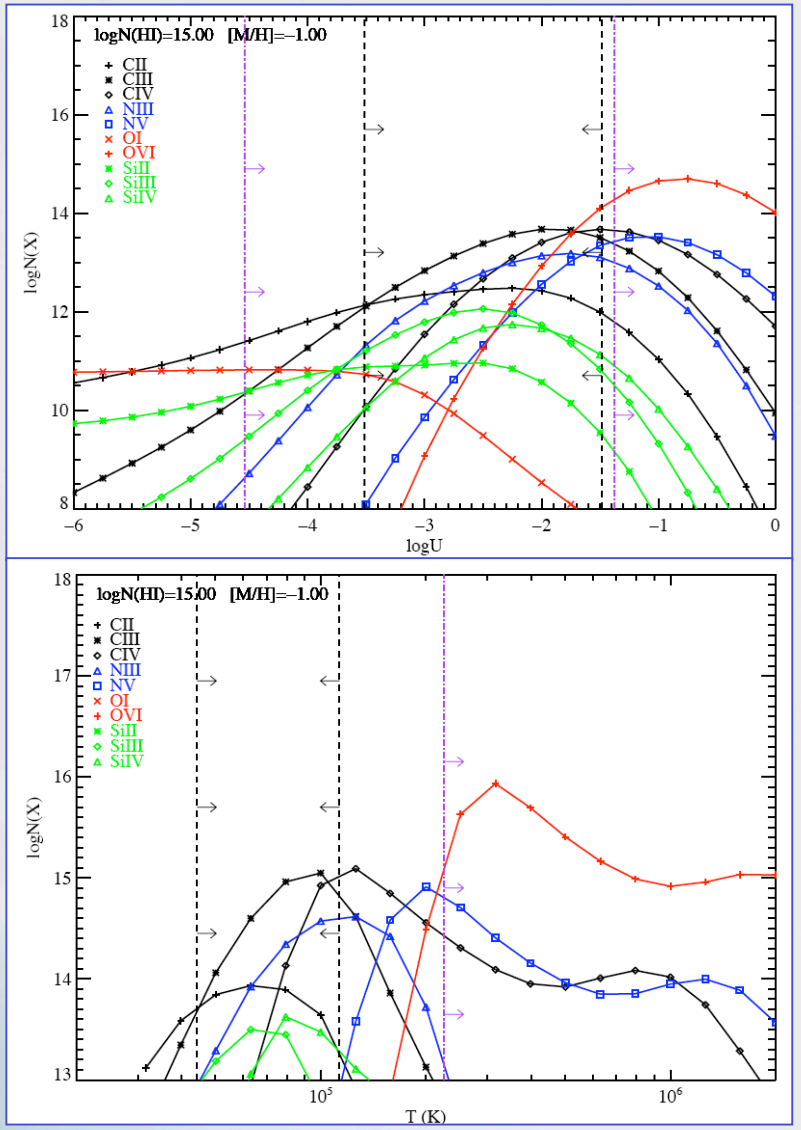
Summary

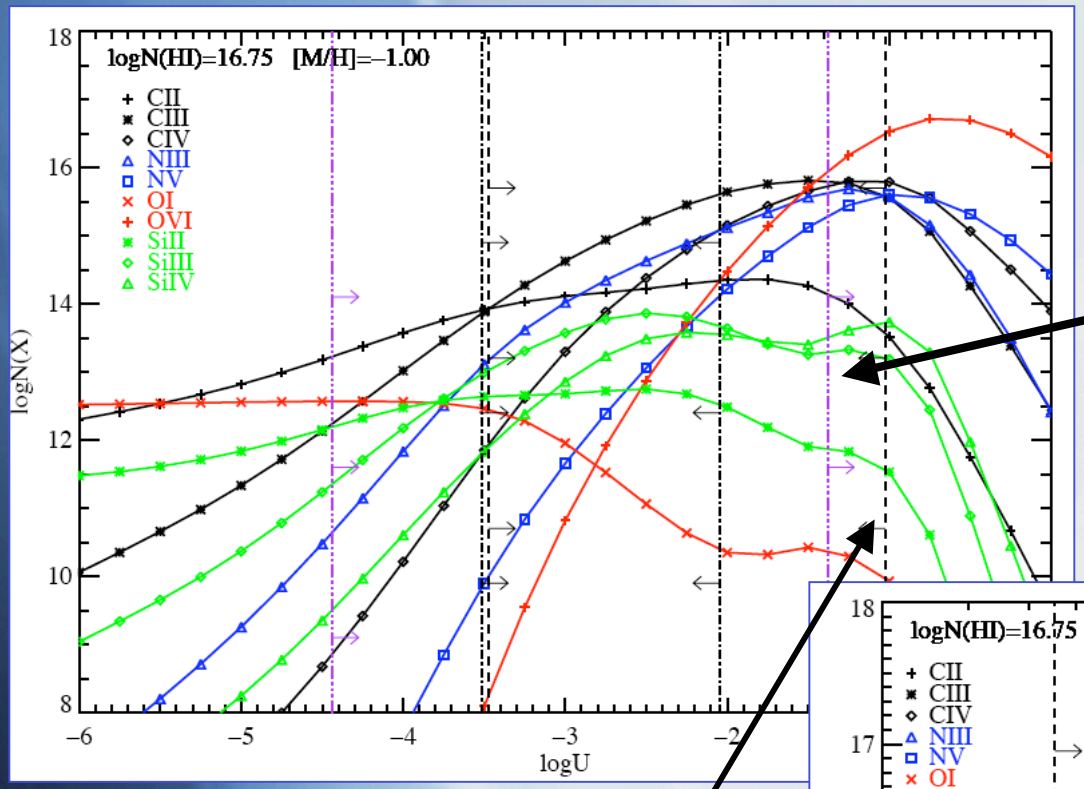
- Power in quasar absorption line spectroscopy
  - Composition, evolution, structure
- PKS1302-102
  - Consistent with multi-phase IGM (OVI, CIII)
    - As concluded by similar studies on other sightlines
  - Metal absorbers associated with galaxy groups
- Future STIS and *FUSE* archive survey
  - Characterize metallicity and distribution of metals at low redshift

Thank you. Gracias. Merci. Tack. 감사합니다.

Ionization Mechanism

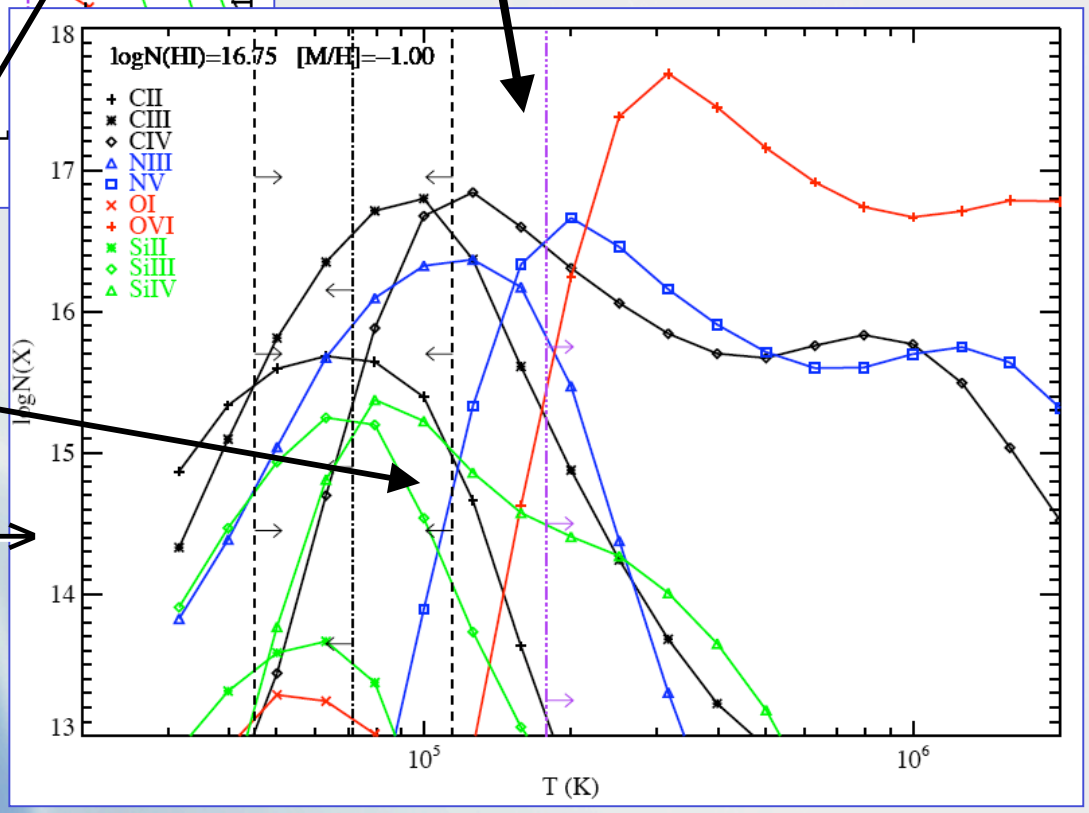
- Relative abundances
  - *e.g.*, $N(C^{+})/N(C^{++})$
- CLOUDY models
  - Photoionization
    - Ionization parameter log U
  - Collisional ionization equilibrium
    - Temperature
- Multi-phase?





← Photoionization

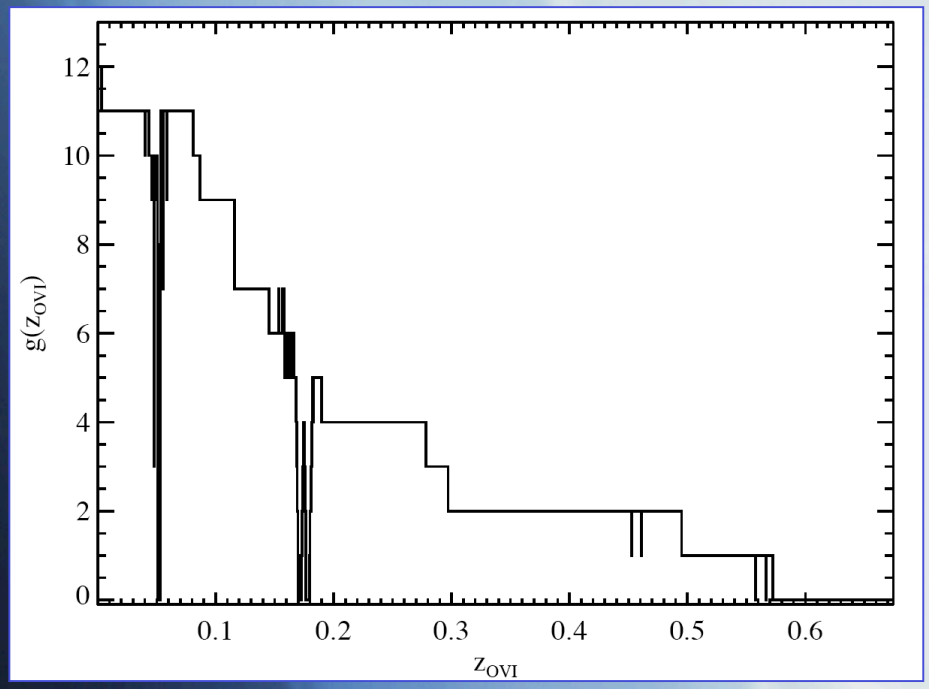
$N(C^{+3})/N(O^{+5})$



$N(C^{++})/N(C^{+3})$

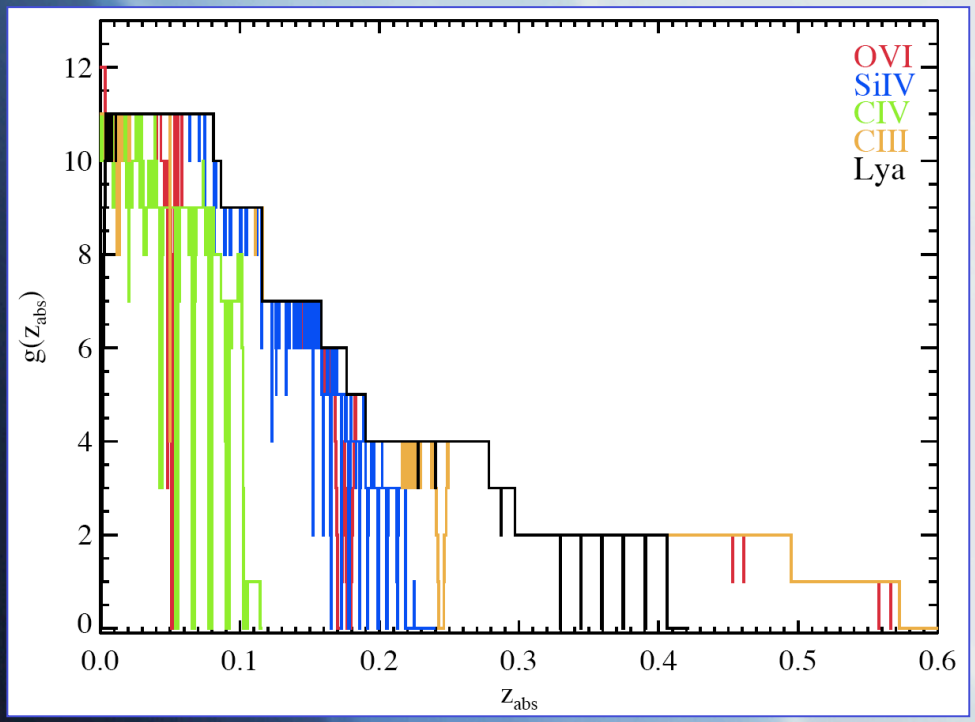
Collisional ionization →

How many OVI absorbers?



- $\Delta z = 2.5$
  - 12 objects with STIS and *FUSE* spectra
- dN/dz(OVI) = 15
  - EW > 30 mÅ
- $N_{exp.} \sim 37$

How many **metals** absorbers?



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