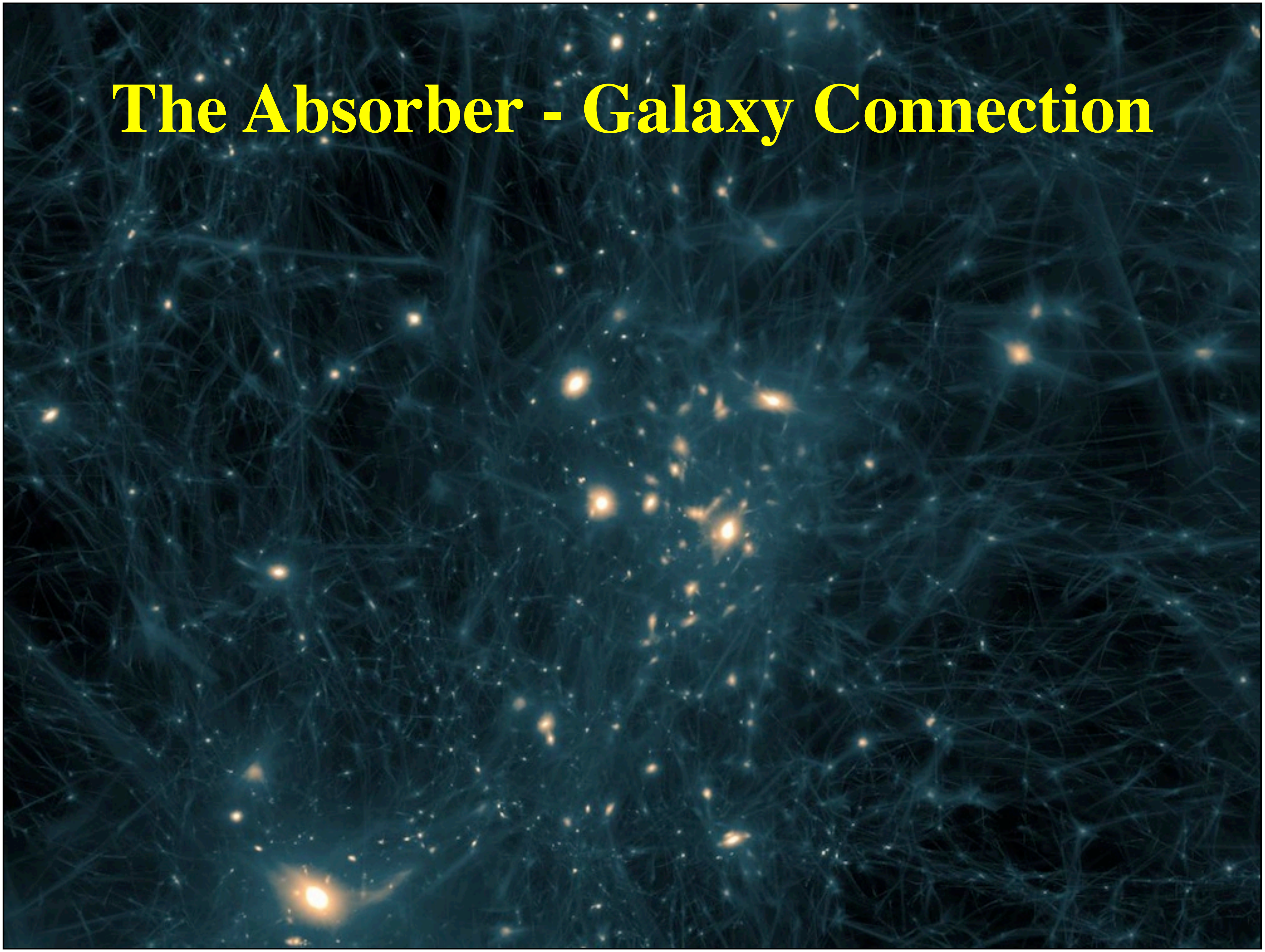
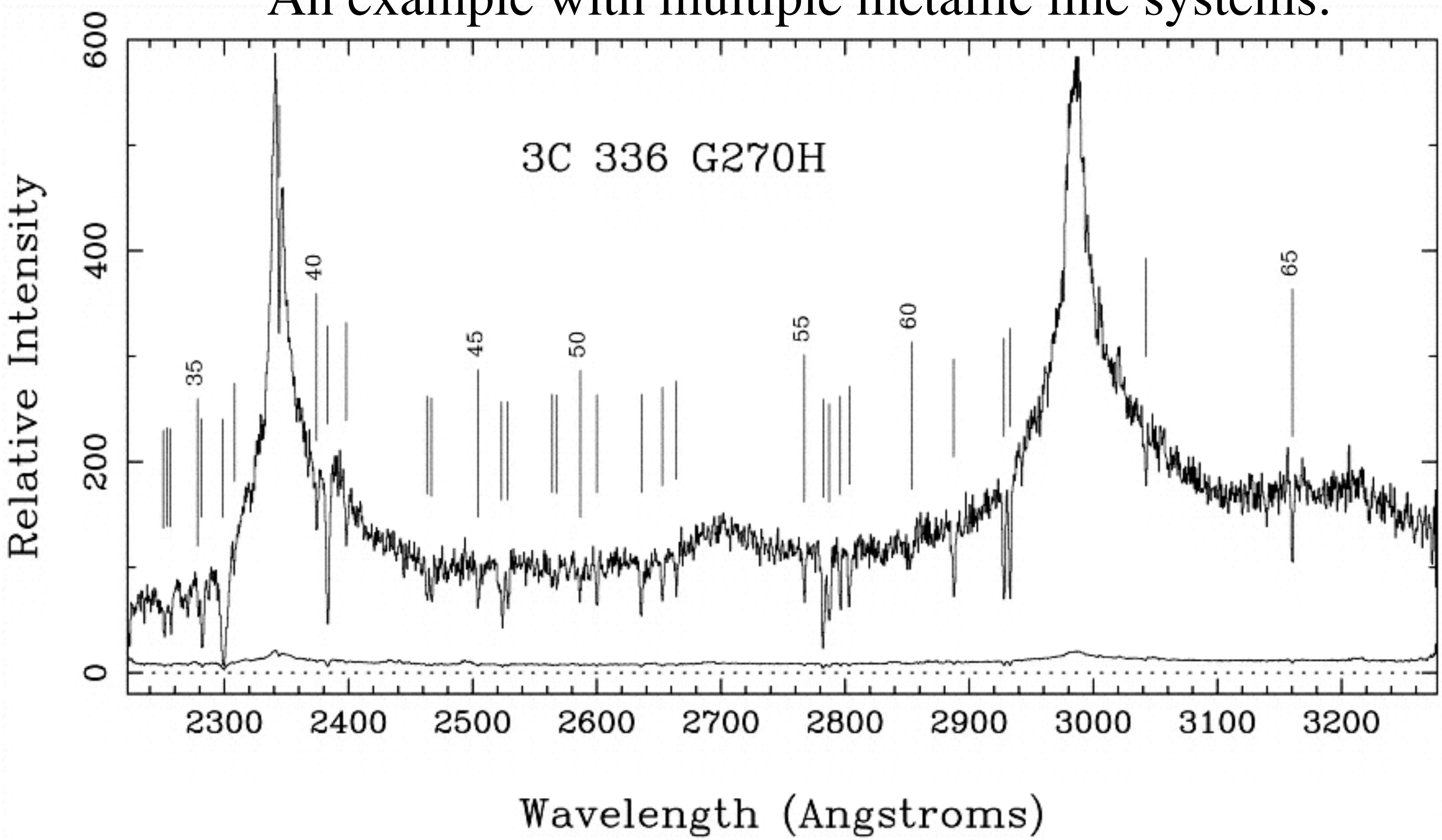
# The Absorber - Galaxy Connection



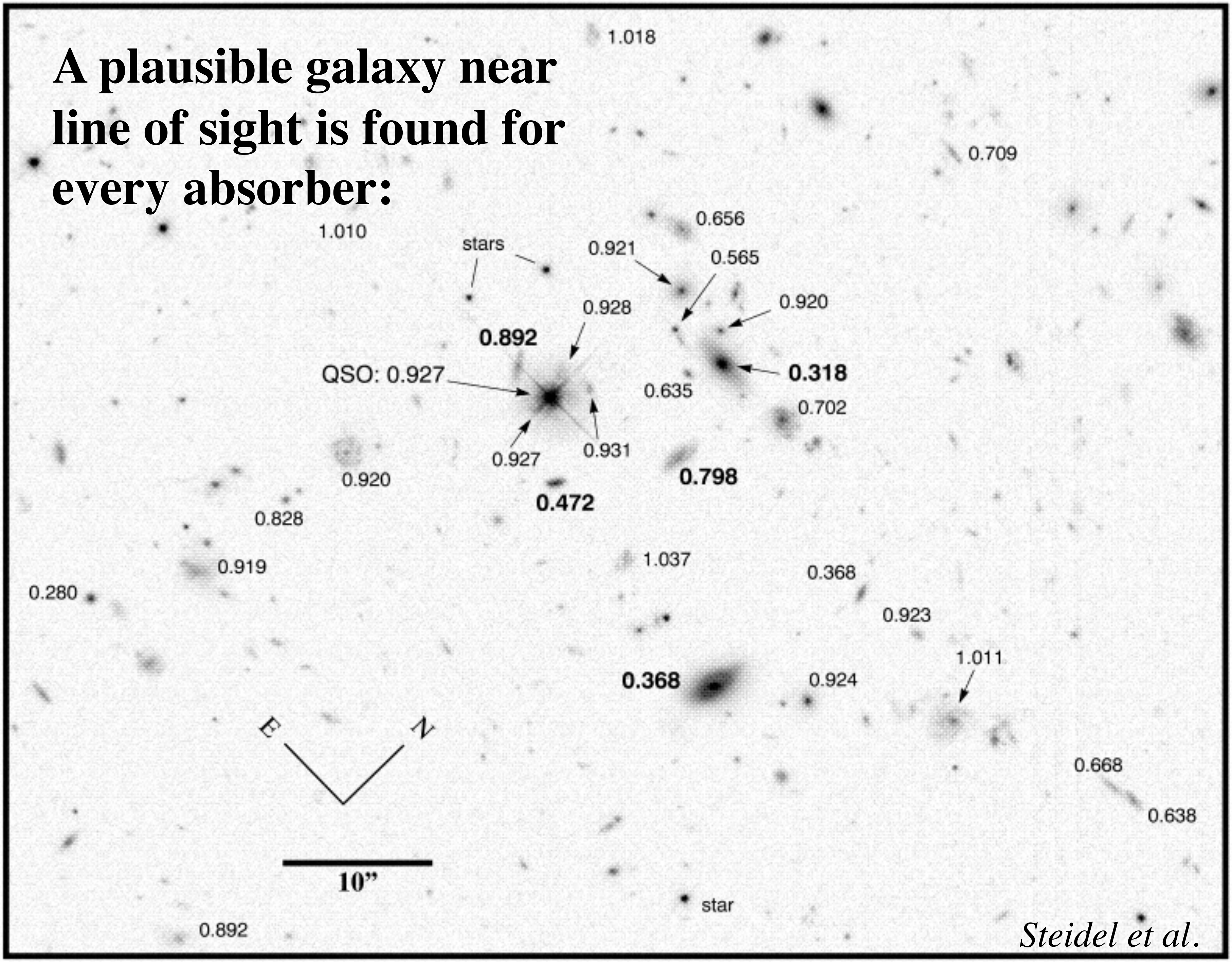
# The Absorber - Galaxy Connection

- Metallic line absorbers are generally believed to be associated with galaxies (after all, stars must have made the metals)

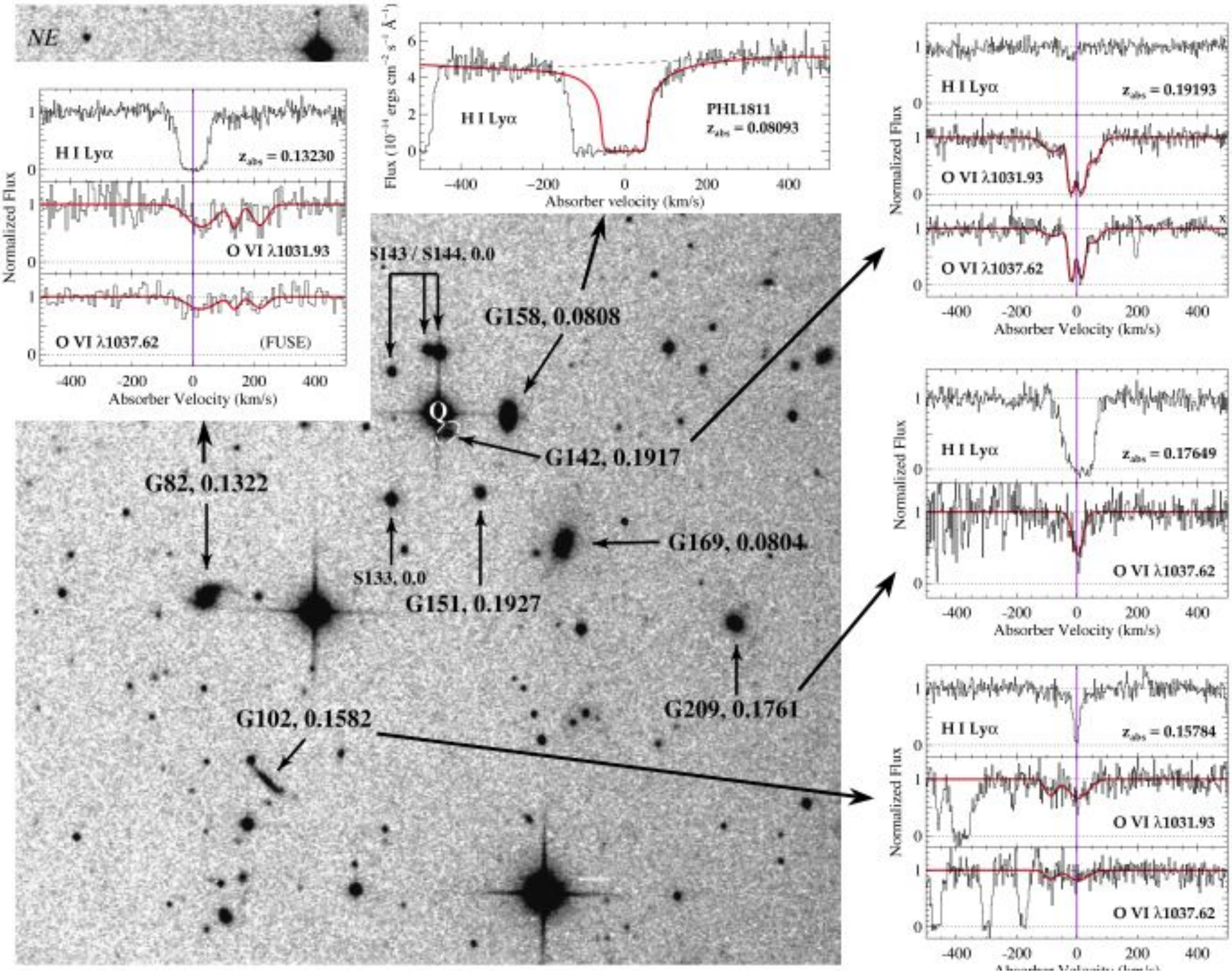
An example with multiple metallic line systems:



**A plausible galaxy near line of sight is found for every absorber:**



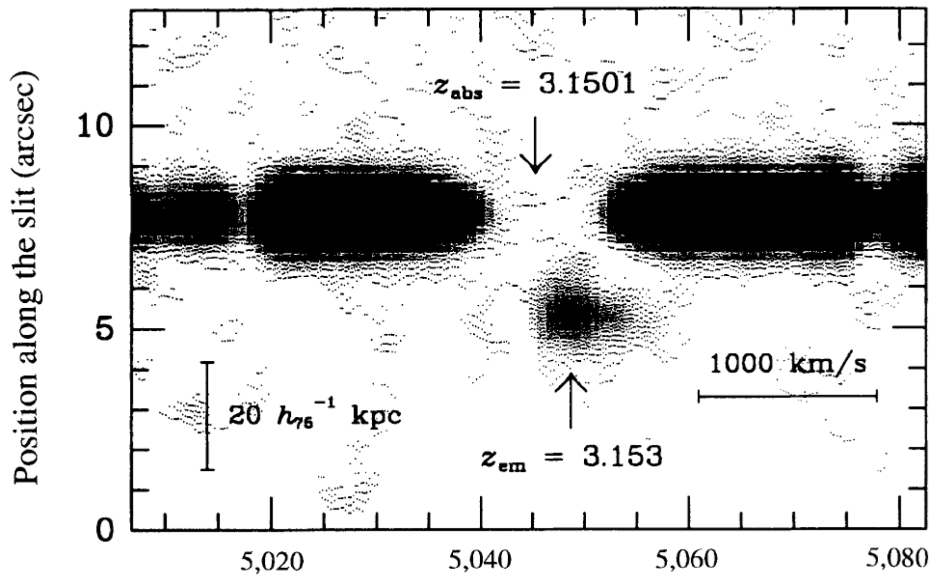

*Steidel et al.*

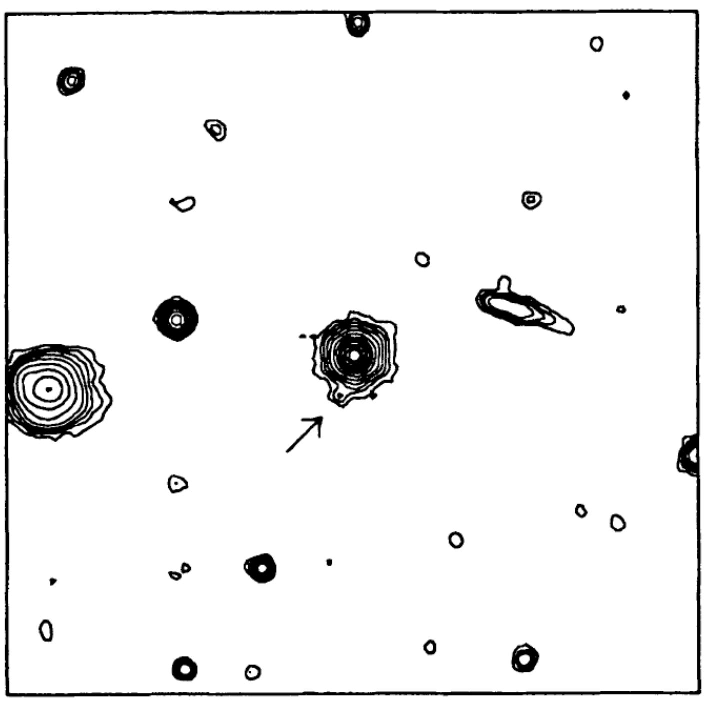


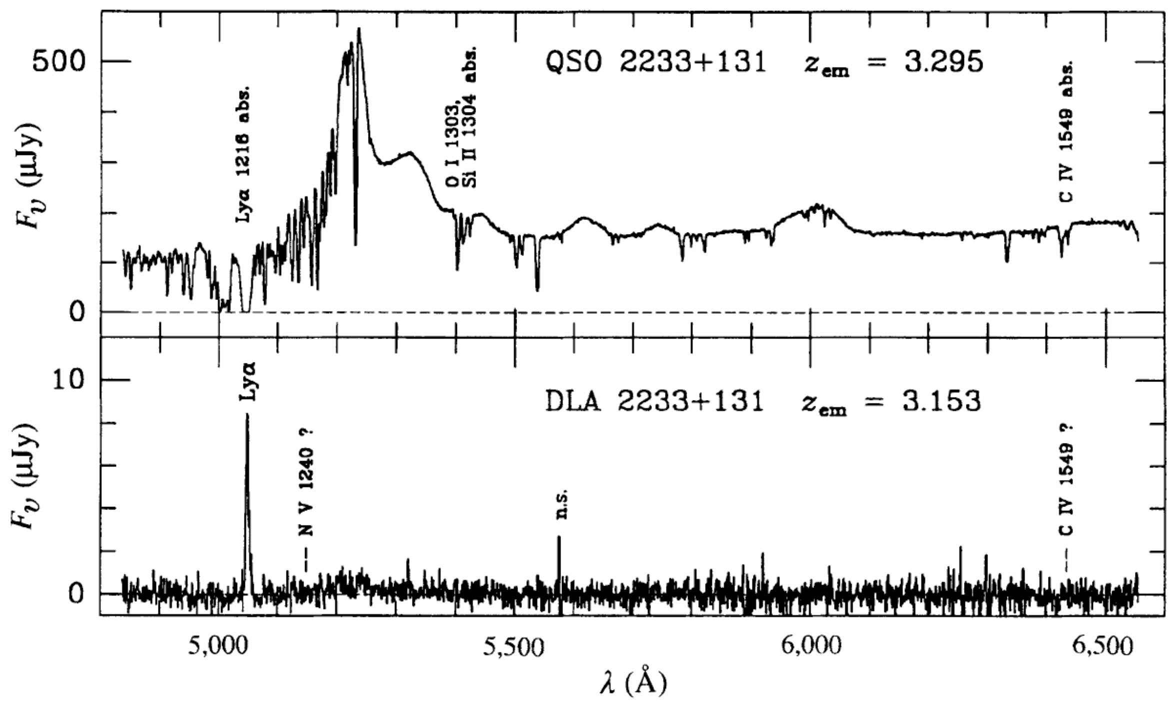
NE
H I Lyα
$z_{abs}$ = 0.13230
O VI λ1031.93
O VI λ1037.62
(FUSE)
Normalized Flux
Absorber Velocity (km/s)
Flux ($10^{-14}$ ergs cm$^{-2}$ s$^{-1}$ Å$^{-1}$)
PHL1811
$z_{abs}$ = 0.08093
Absorber velocity (km/s)
$z_{abs}$ = 0.19193
$z_{abs}$ = 0.17649
$z_{abs}$ = 0.15784
S143 / S144, 0.0
G158, 0.0808
G142, 0.1917
G82, 0.1322
S133, 0.0
G151, 0.1927
G169, 0.0804
G209, 0.1761
G102, 0.1582
Q

# Galaxy Counterparts of DLA Systems

- Several examples are known with Lyα line emission
- Properties (size, luminosity, SFR) are typical of field galaxies at such redshifts, and consistent with being progenitors of $z \sim 0$ disks

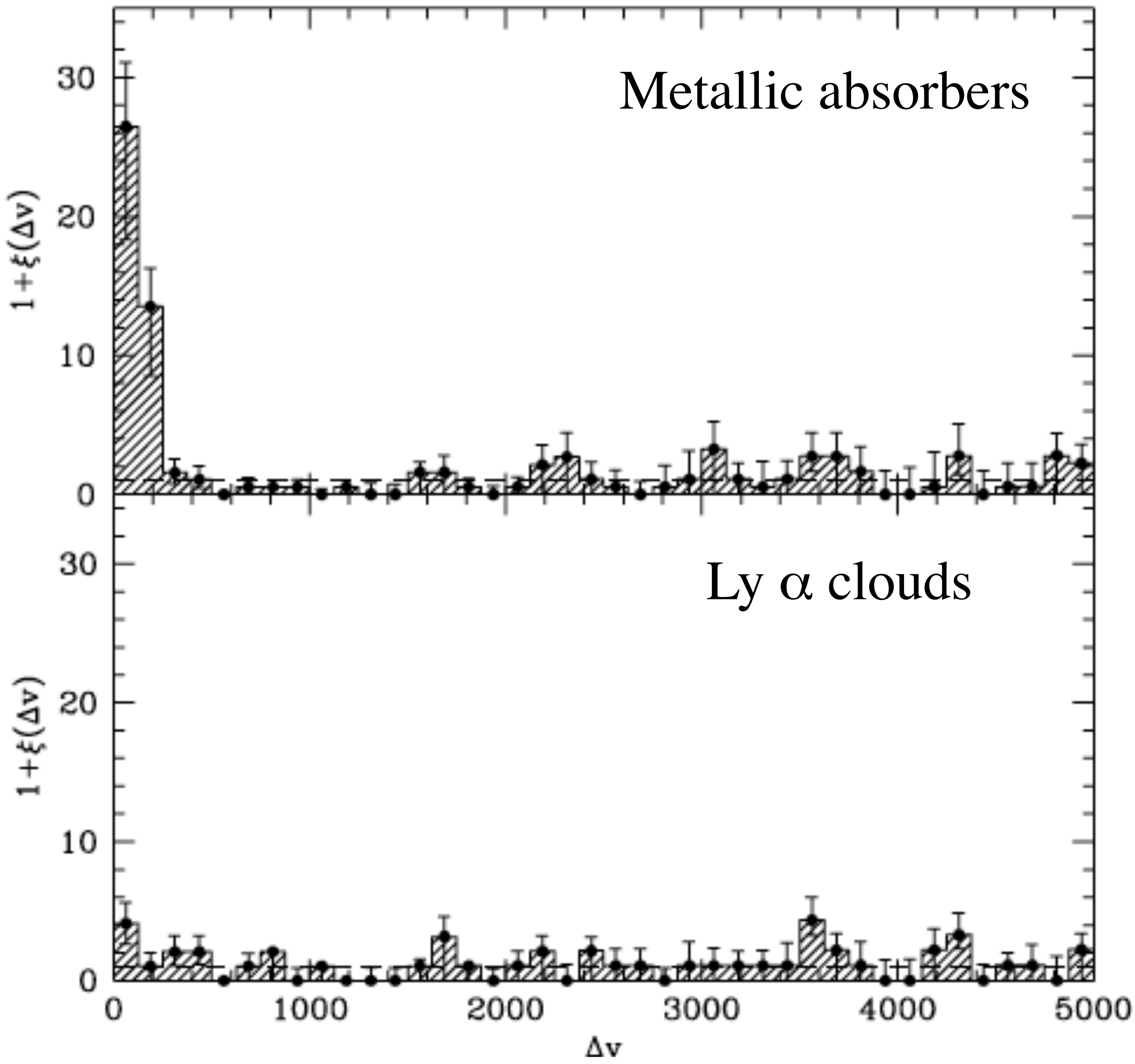




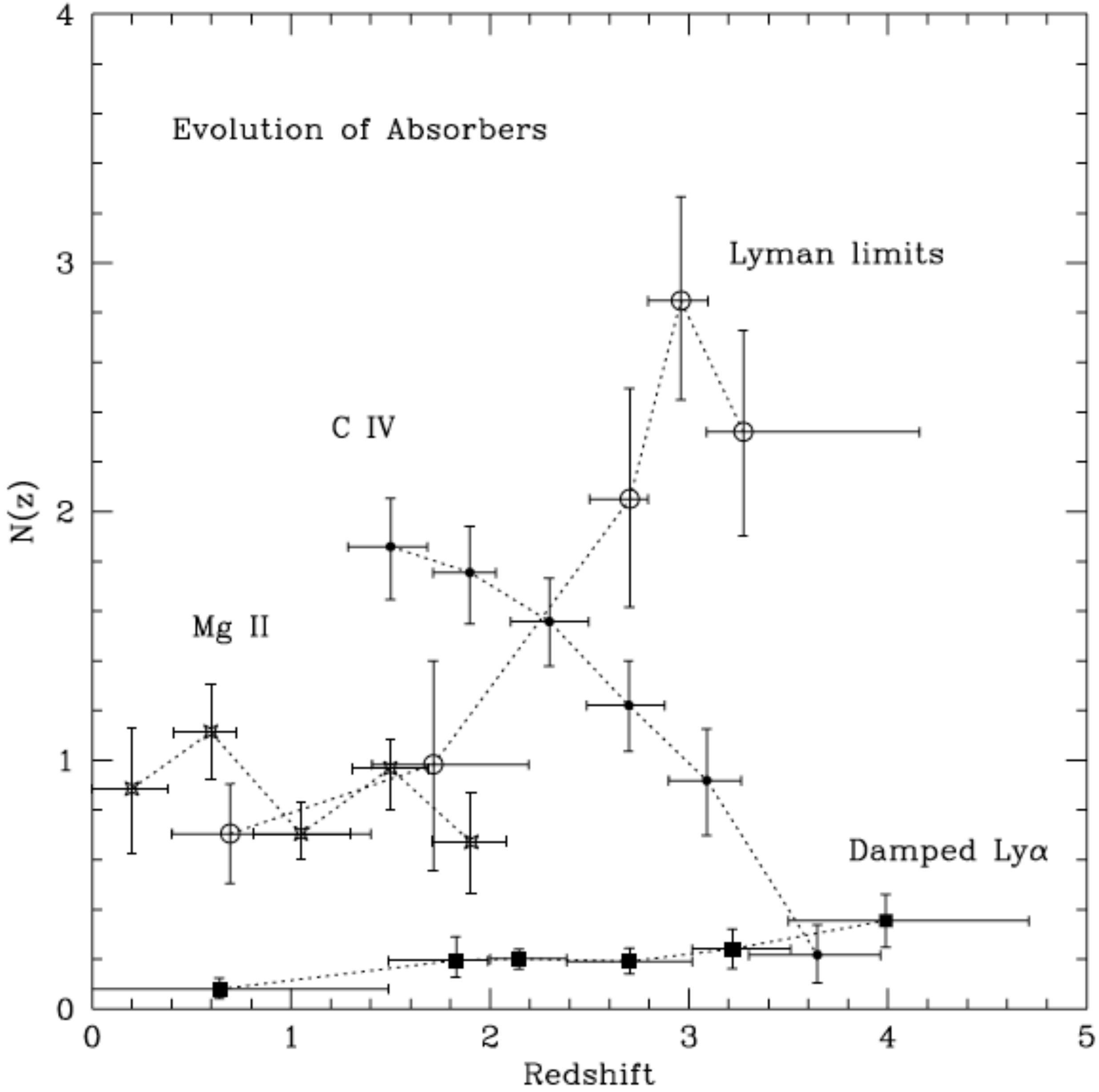
# Clustering of Metallic Absorbers

Metallic absorbers are found to cluster in redshift space, even at high *z*'s, while Ly α clouds do not. This further strengthens their association with galaxies

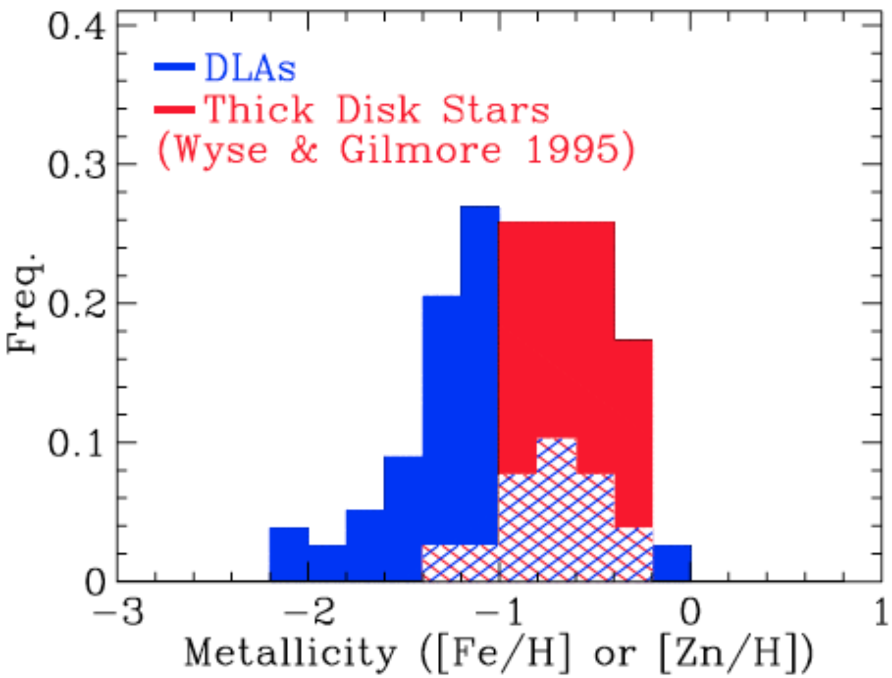


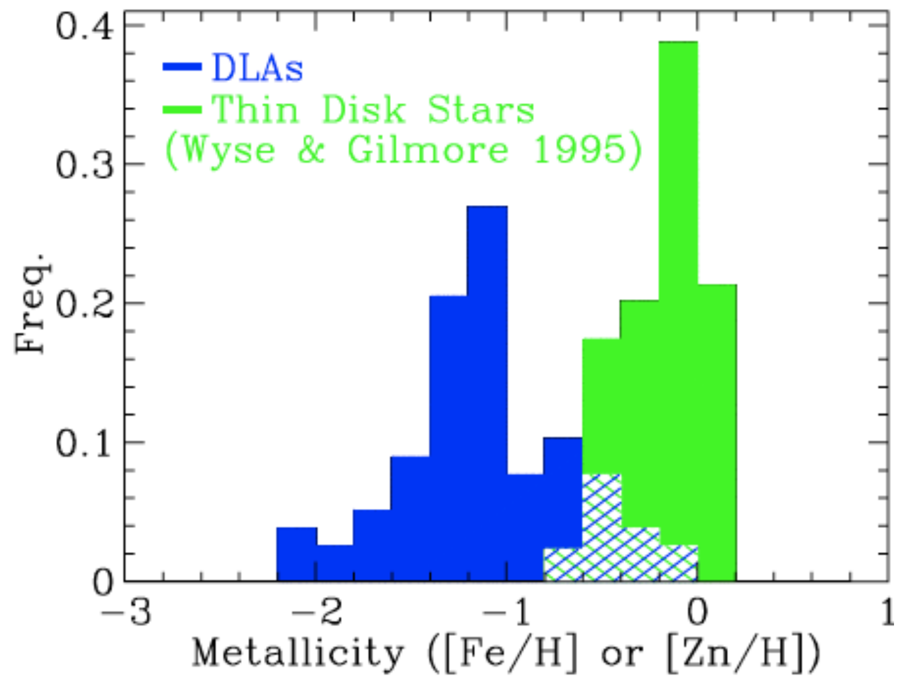
# Number Density Evolution of Absorbers

While the H I seems to decline in time (being burned out in stars?), the density of metals seems to be increasing, as one may expect



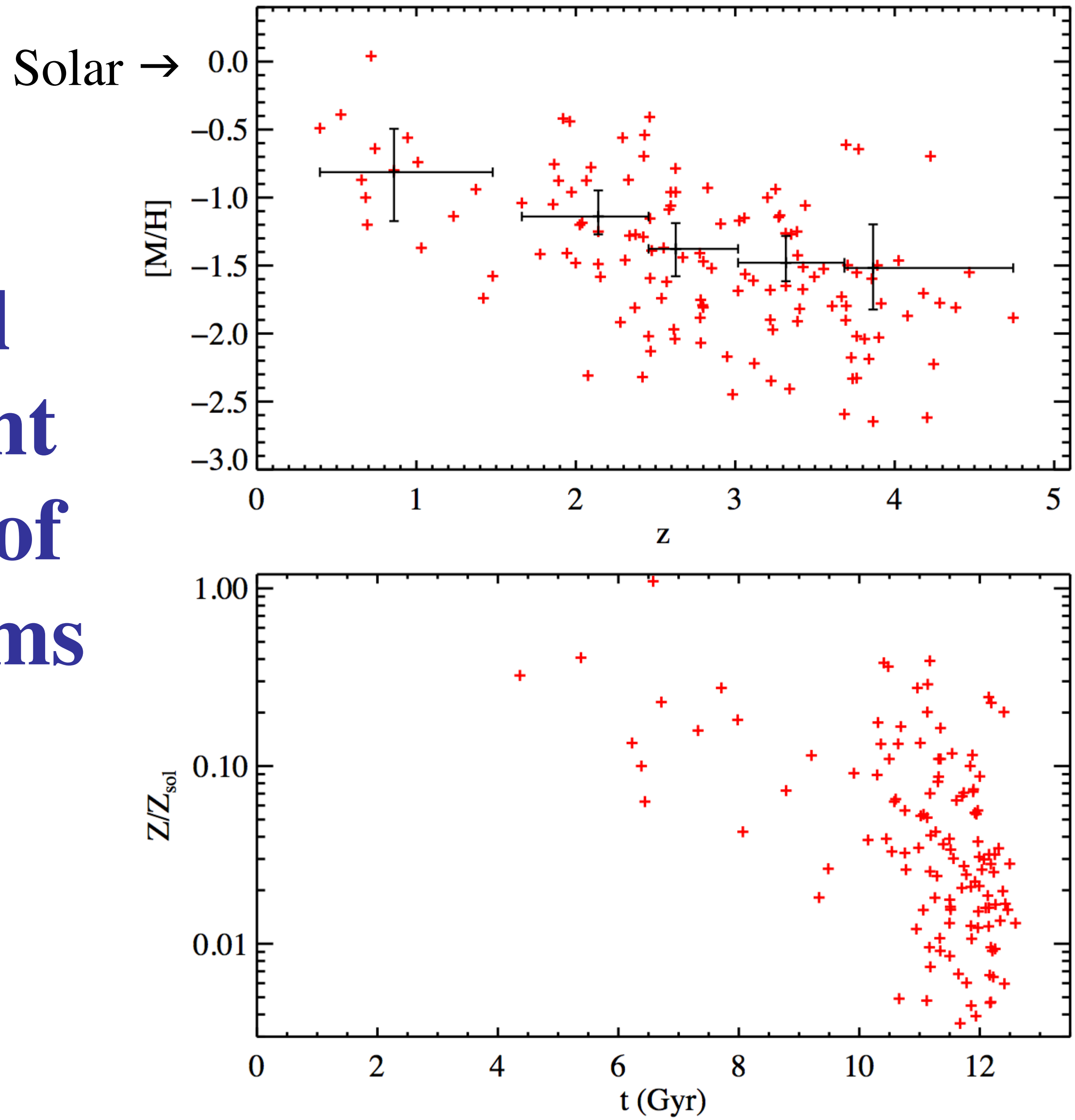
# Abundances in DLA Systems and Disks



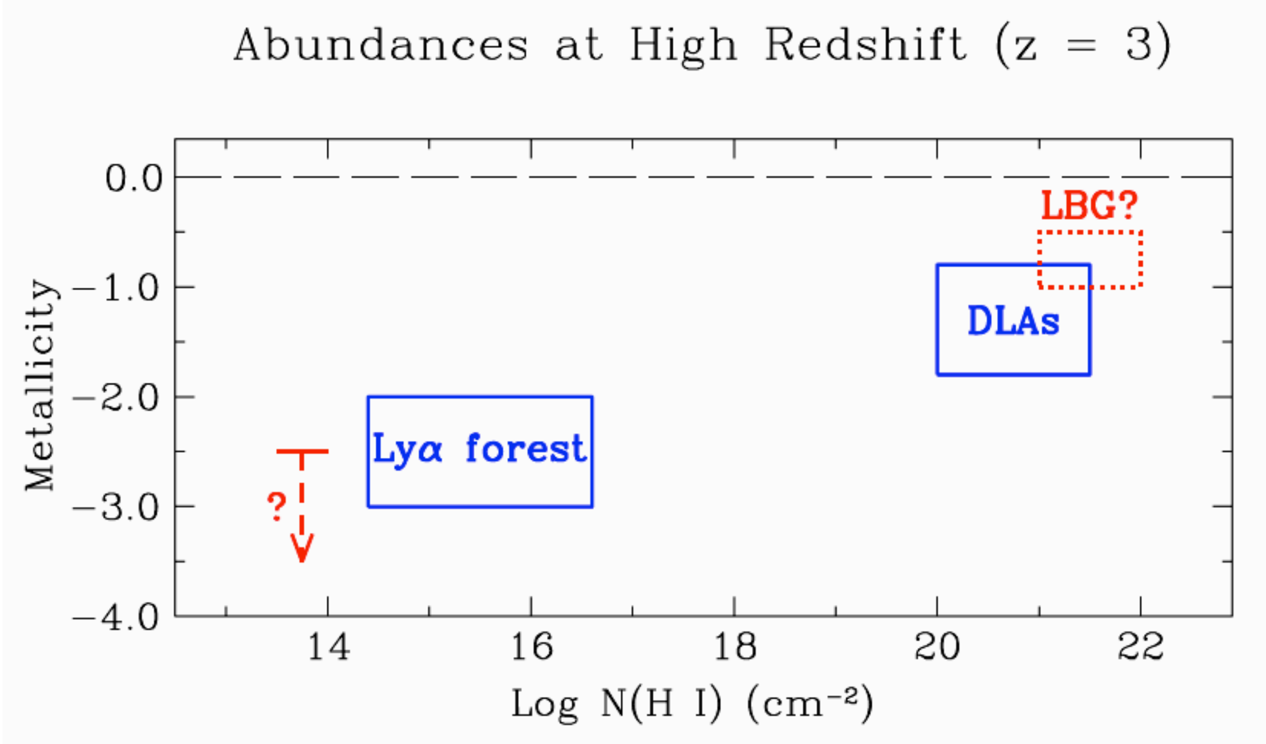



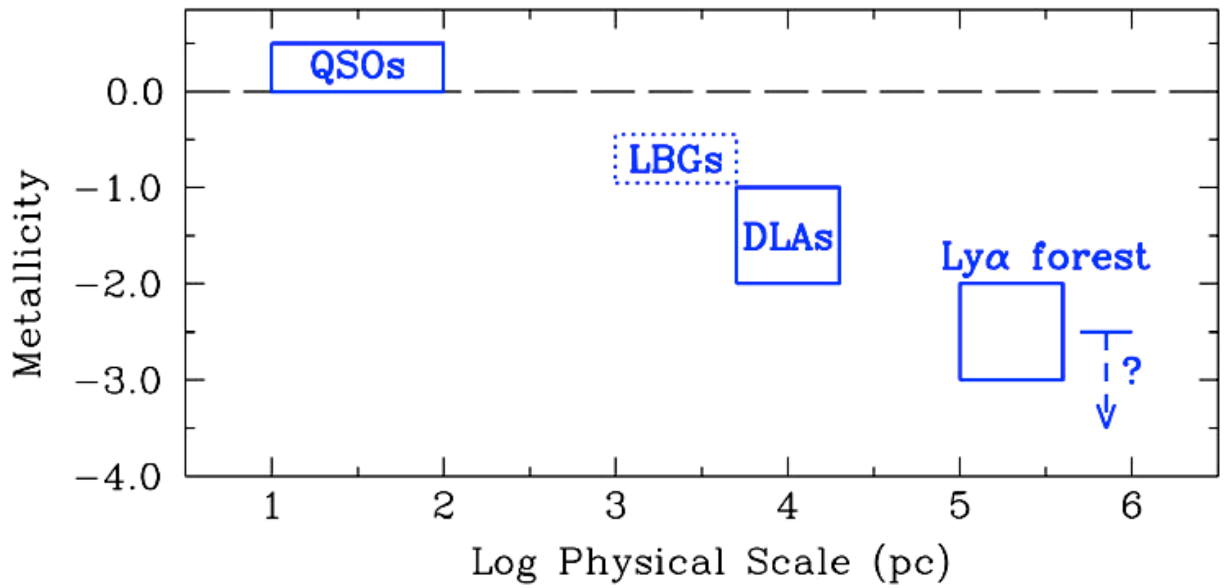
# Chemical Enrichment Evolution of DLA Systems

*(Wolfe et al.)*



But different types of systems may be evolving in different ways …




*(from M. Pettini)*

# Estimating the Evolution of Gas Density

(from Wolfe et al. 2005, ARAA, 43, 861)

To estimate $\Omega_g(z)$ we first derive an expression for the column-density distribution, $f(N, X)$. Let the number of absorbers per sightline with H I column densities and redshifts in the intervals $(N, N + dN)$ and $(z, z + dz)$ be given by

$$d\mathcal{N}(N, z) = n_{co}(N, z)A(N, z)(1 + z)^3|c\, dt/dz|dN\, dz, \tag{1}$$

where $n_{co}(N, z)\, dN$ is the comoving density of absorbers within $(N, N + dN)$ at $z$ and $A(N, z)$ is the absorption cross-section at $(N, z)$. Defining $dX \equiv (H_0/c)(1 + z)^3|c\, dt/dz|dz$ (Bahcall & Peebles 1969) we have

$$\frac{d\mathcal{N}(X)}{dX} = \int_{N_{min}}^{N_{max}} dN f(X, N), \tag{2}$$

$$f(N, X) \equiv (c/H_0)n_{co}(N, X)A(N, X), \tag{3}$$

and $N_{min}$ and $N_{max}$ are minimum and maximum column densities, respectively.[1]

$$\Omega_g = \frac{H_0}{c}\frac{\mu m_H}{\rho_{crit}}\int_{N_{min}}^{N_{max}} dN\, N f(N, X), \tag{4}$$

# Evolution of Neutral Gas

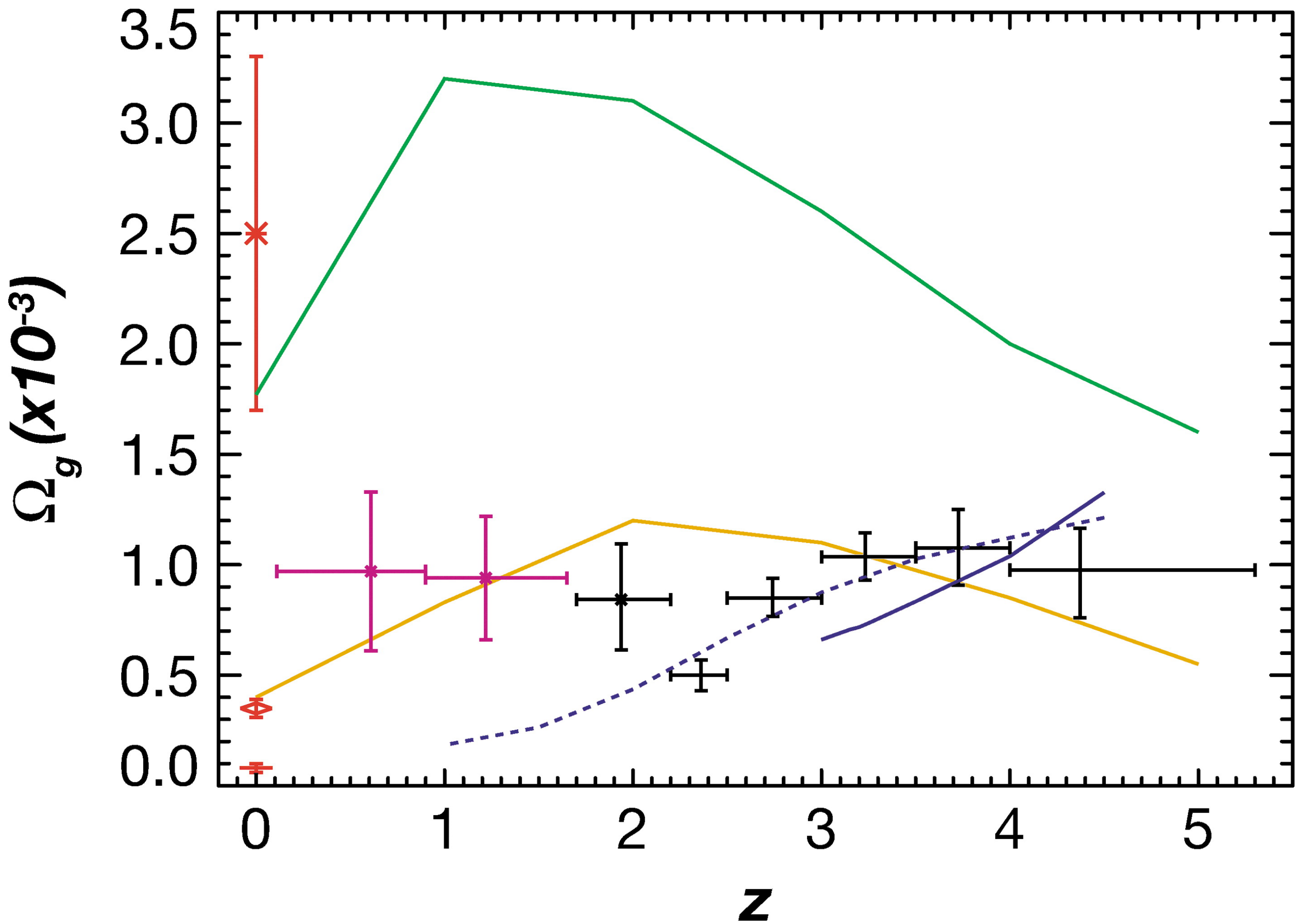



**Figure 5** Neutral gas mass density versus $z$ from Prochaska et al. (2005). H I data at (*a*) $z \geq 2.2$ from SDSS-DR3_4 survey, (*b*) $0<z<1.6$ from the MgII survey of S.M. Rao, D.A. Turnshek & D.B. Nestor (private communication), and (*c*) at $z$=0 (*red diamond*) from Fukugita et al. (1998). Stellar mass density at $z$=0 (*red star*) from Cole et al. (2001) and stellar mass density of Irr galaxies (*red plus sign*) from Fukugita et al. (1998). Theoretical curves from Cen et al. (2003) (*green*), Somerville et al. (2001) (*yellow*), and Nagamine et al. (2004a) (*blue*; *dotted* is D5 model and *solid* is Q5 model).

# Summary

- Intergalactic medium (IGM) is the gas associated with the large scale structure, rather than galaxies themselves; e.g., along the still collapsing filaments, thus the “cosmic web”
  - However, large column density hydrogen systems, and strong metallic absorbers are always associated with galaxies
- It is condensed into clouds, the smallest of which form the “Ly $\alpha$ forest”
- It is ionized by the UV radiation from star forming galaxies and quasars
- It is metal-enriched by the galactic winds, which expel the gas already processed through stars; thus, it tracks the chemical evolution of galaxies
- Studied through absorption spectra against background continuum sources, e.g., quasars or GRB afterglows


Next:
Galaxy Formation and Reionization