Damped Lyman Alpha Systems

Observing the Cosmic Dawn 2023
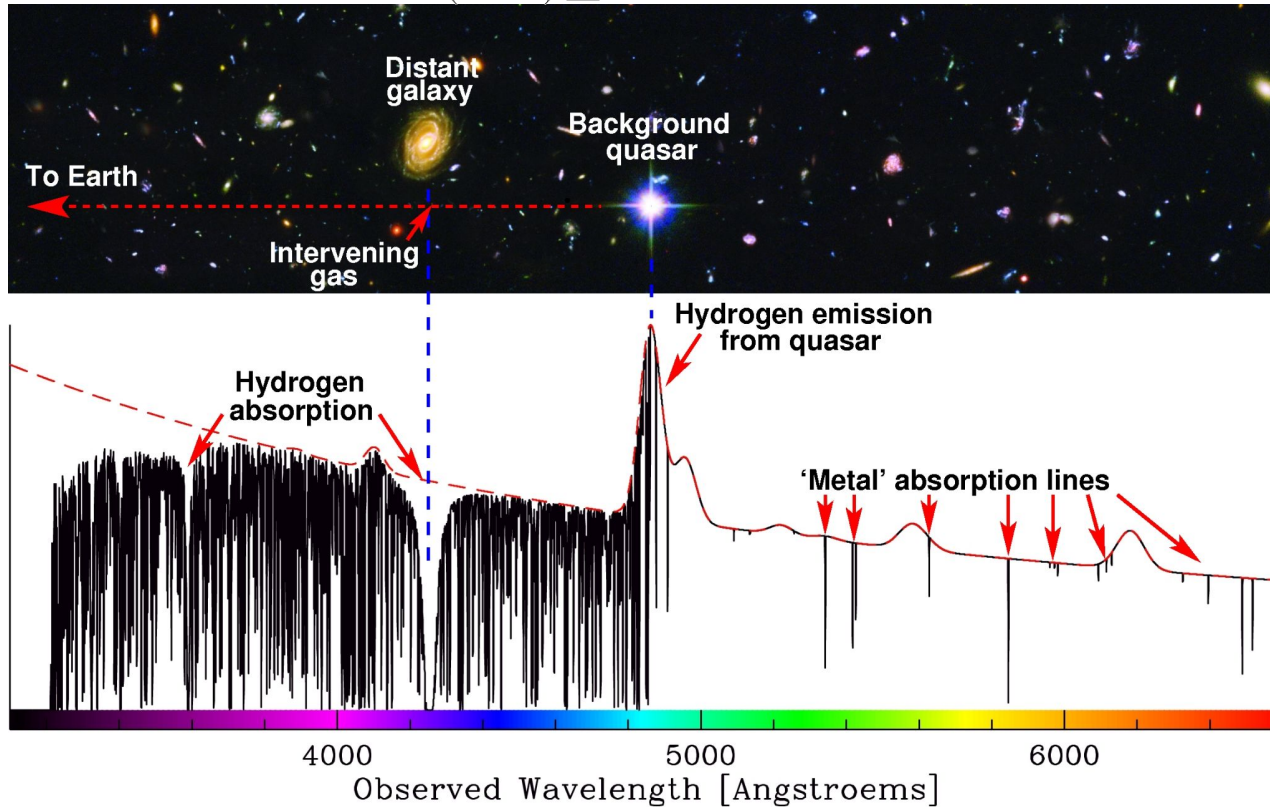
Shreyam Parth Krishna

Summary

- What are Damped Lyman Alpha (DLA) Systems?
- How are they found?
- Formlism for Measuring Neutral Gas Content of the Universe
- Measurement of the Neutral Hydrogen Cosmological Mass density at z =5
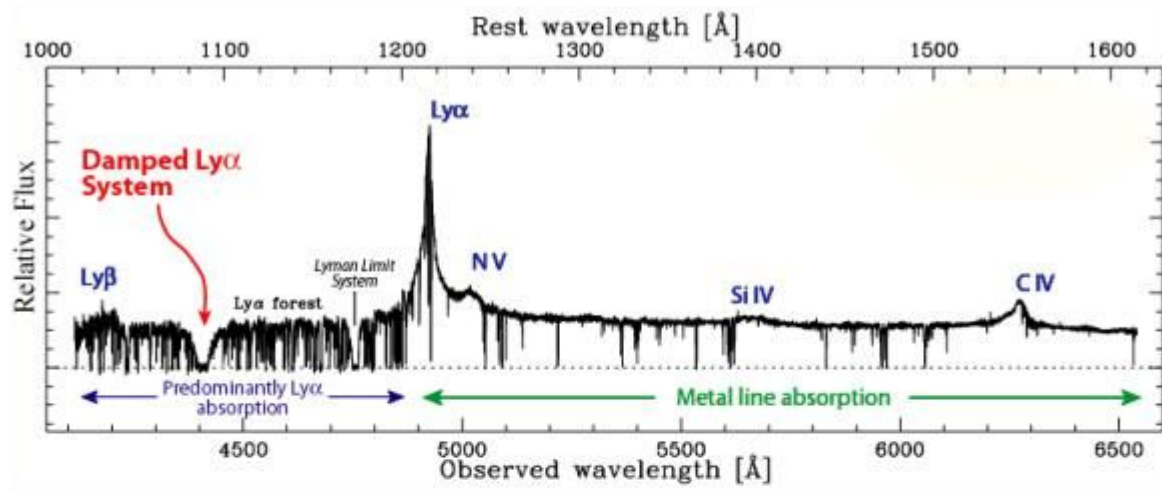
What are Damped Lyman Alpha Systems?

$$N(HI) \geq 2 \times 10^{20} cm^{-2}$$

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1: Wolfe et. al. 2005

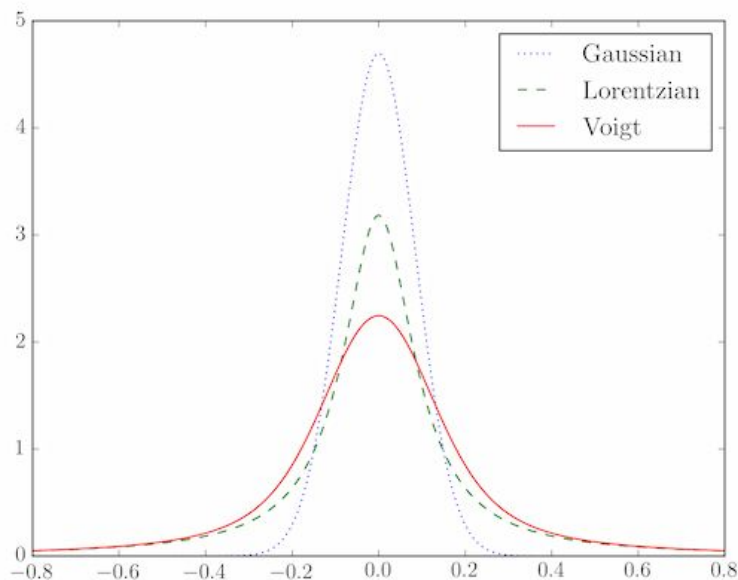# Voigt Profile

$$V(x;\sigma,\gamma) \equiv \int_{-\infty}^{\infty} G(x';\sigma)L(x-x';\gamma)\,dx'$$

$$G(x;\sigma) \equiv \frac{e^{-x^2/(2\sigma^2)}}{\sigma\sqrt{2\pi}} \qquad L(x;\gamma) \equiv \frac{\gamma}{\pi(x^2+\gamma^2)}$$

Most atomic transitions :
τ_ν >>1 core and τ_ν <<1 wings -
correspond to velocity & N(HI)

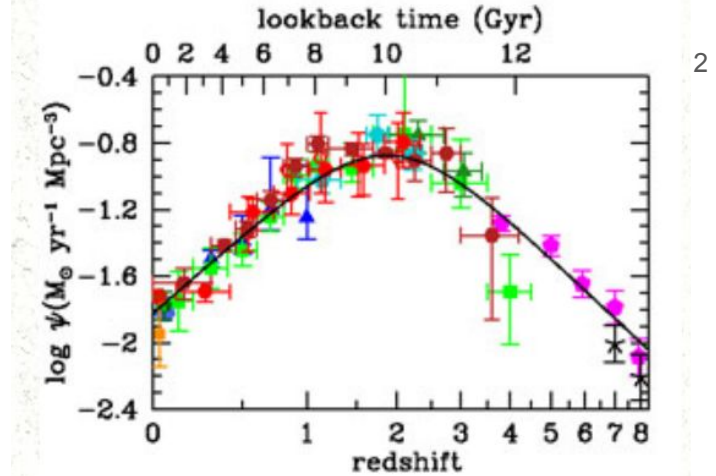$$\Delta\nu_{\tau=1} \propto \Delta v_D \times [ln N(X^j)]^{1/2}$$

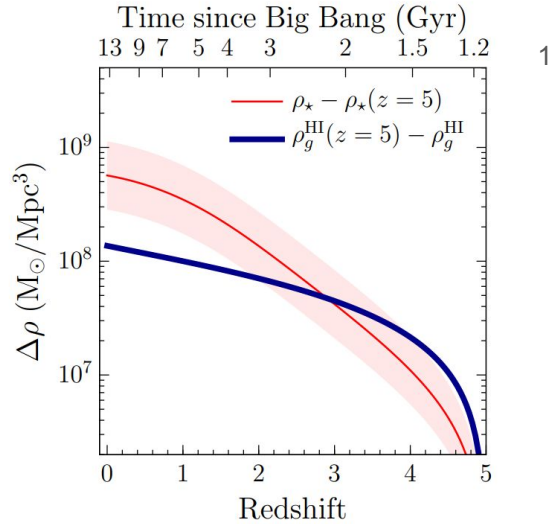DLA wings:
τ_ν ~ 1
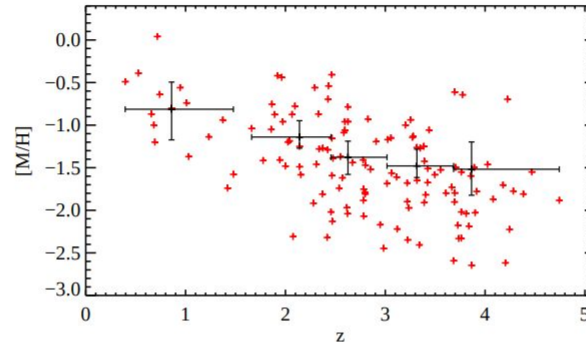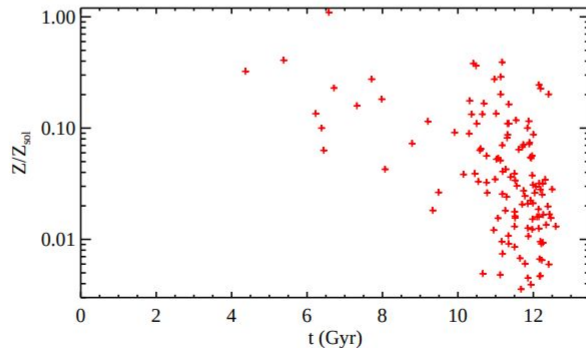Prominent wings irrespective of velocity

$$\Delta\nu_{\tau=1} \propto [A_{21} f 21 \times N(HI)]^{1/2}$$

Probe of Gas in Early Universe

1: Crighton et. al. 2015 2: Madau et. al. 2014

Properties of DLAs

- Mostly consist of neutral or singly ionized gas.
- Metal poor, but floor in metallicity
- Ionised and neutral gas not well mixed.
- Low fraction of molecular gas due to low dust content.

How are they found?

1) Take Quasar spectrum
2) Fit continuum blueward of Lyman Alpha line
3) Absorption feature with $W_r > 5$ Å between z_{min} and z_{max} determined by spectra quality and QSO redshift
4) Fit Voigt profile for N(HI)
5) Metal lines (outside Lyman α forest) for redshift determination where possible.

1: Wolfe et. al. 2005
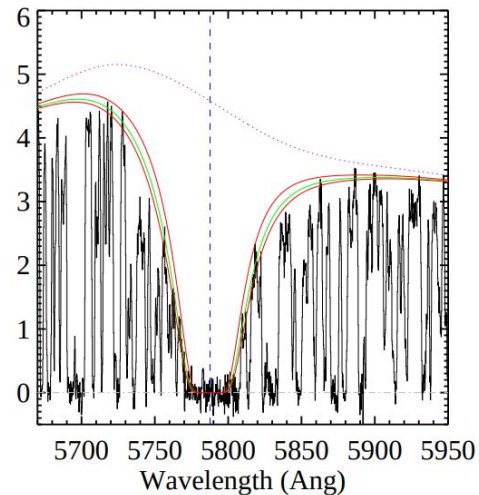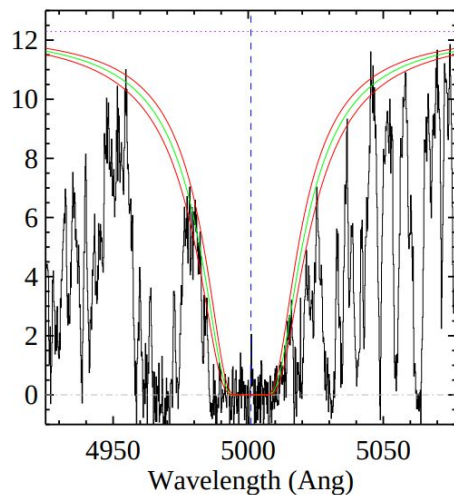
Formalism for Measuring the Neutral Gas Content of the Universe
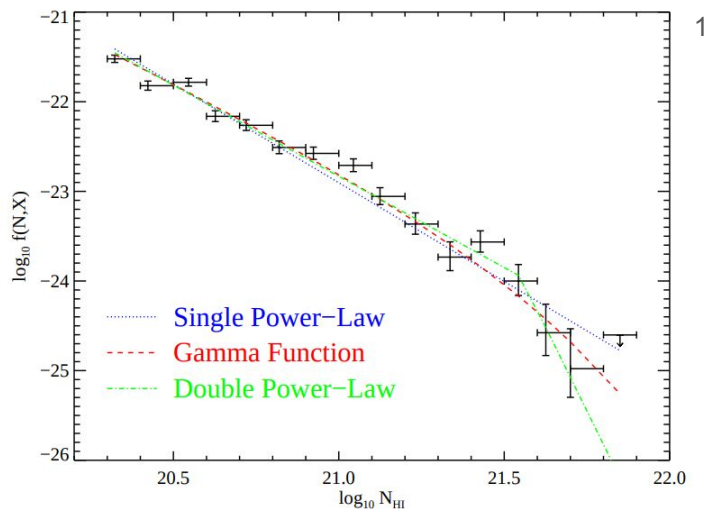
Cosmic column density distribution:

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

Density of the neutral gas in the universe:

$$\Omega_g \equiv \frac{H_0}{c} \frac{\mu m_h}{\rho_{crit}} \int_{N_{min}}^{N_{max}} dN N f(N, X)$$

1: Prochaska et. al. 2005
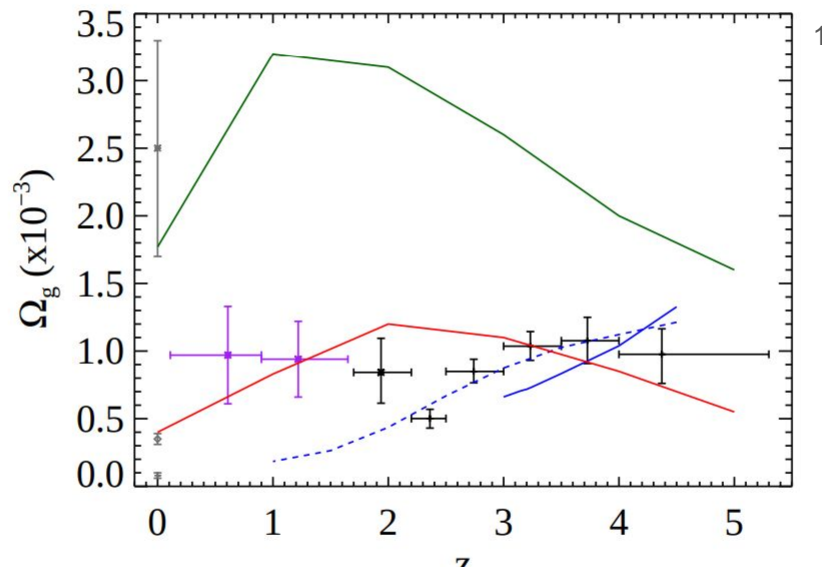
Measurement of the Neutral Hydrogen Cosmological Mass density at z =5 (Crighton et. al. 2015)

- 163 QSOs from the Giant Gemini GMOS (GGG) survey, z_{emis} b/w 4.4 and 5.4
- 59 with higher resolution spectroscopy - true noise sample & Mocks - true properties sample
- DLA = $N(HI) > 10^{20.3}$ cm^{-2}
- f^{DLA}_{HI} measured and corrected $\qquad f_{DLA} = f_{meas} \times k(N_{HI}) = f_{meas} \times \frac{k_{real}}{k_{found}}$
- f^{DLA}_{HI} converted to Ω^{DLA}_{HI}, further converted to Ω_{HI}
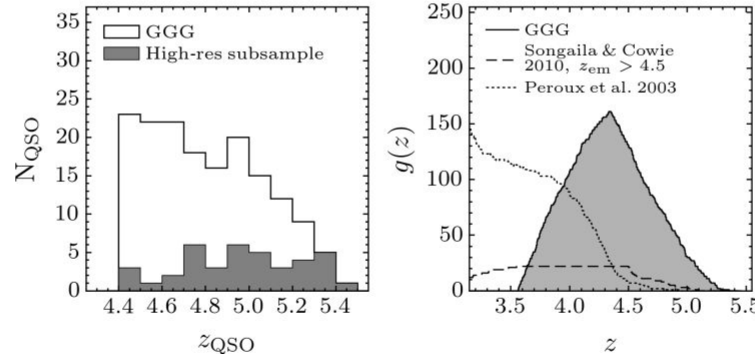
ID of DLAs:

1) Fit Continuum
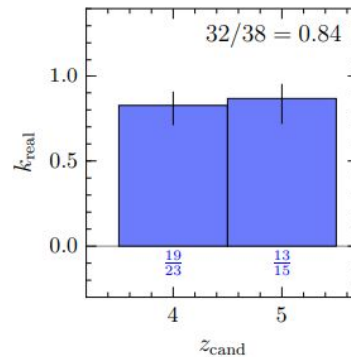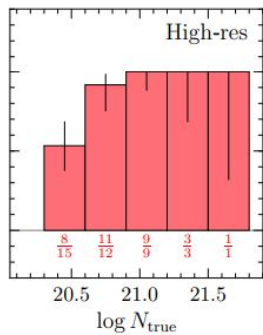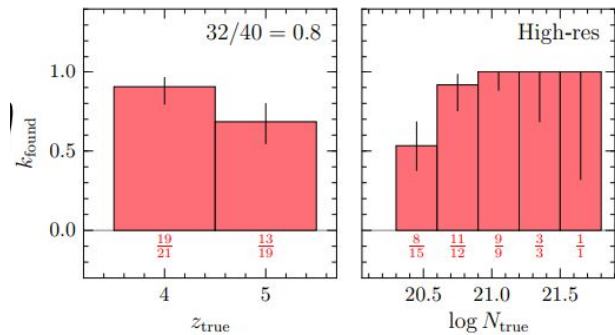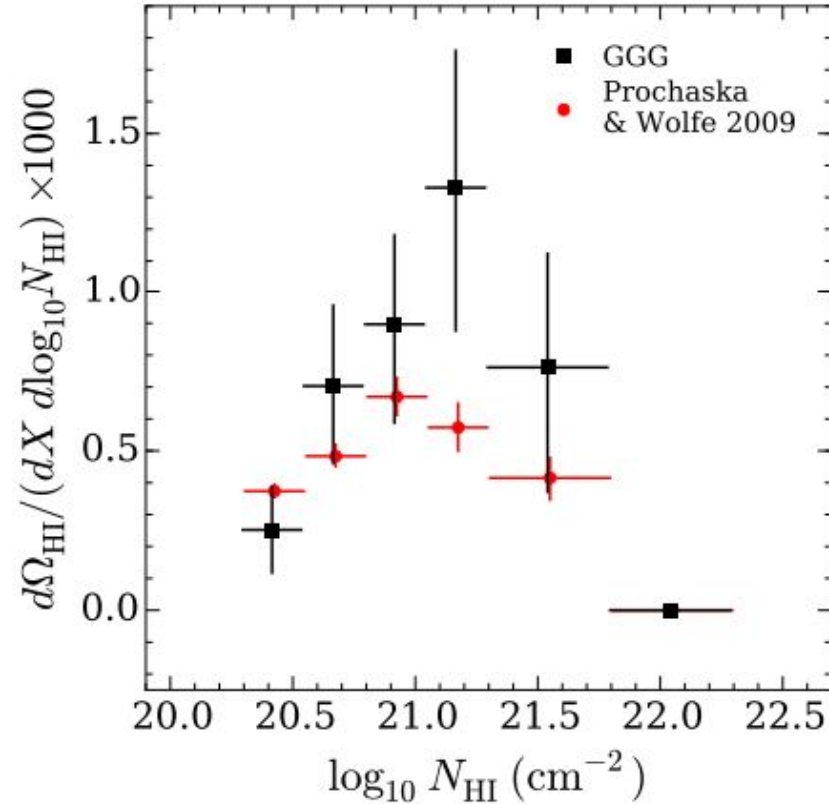2) Identify DLA region between Lyman α and Lyman β lines
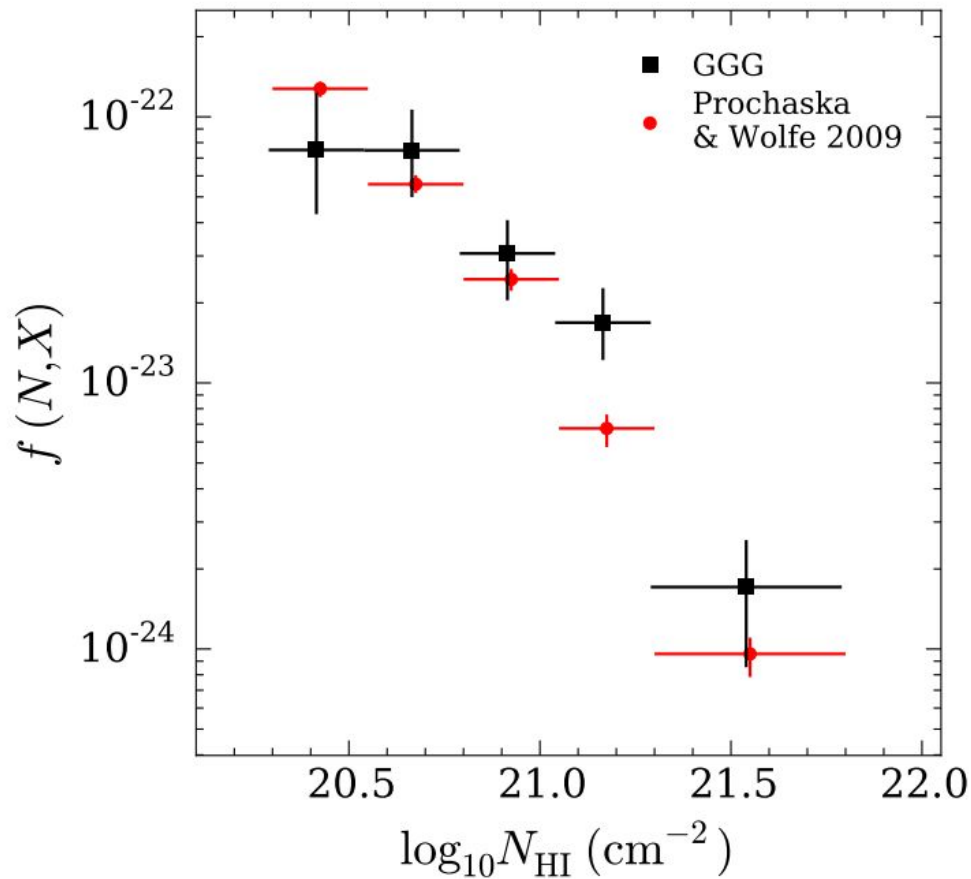3) Use higher order Lyman lines to refine z, N_{HI}
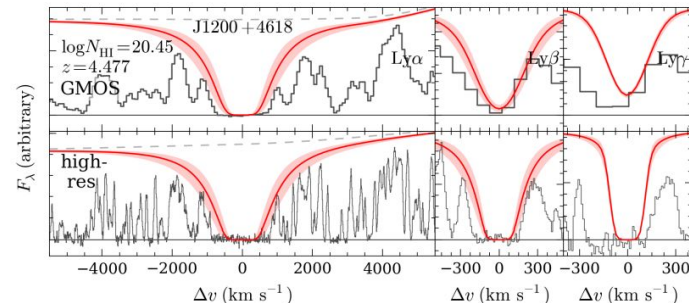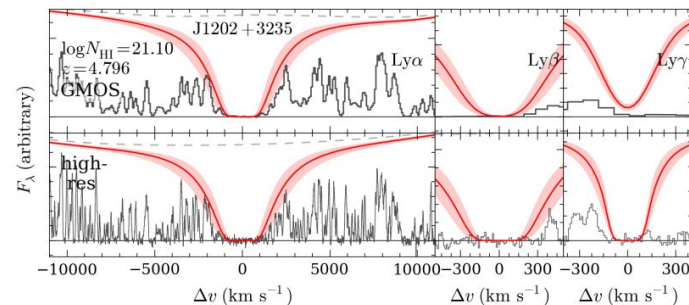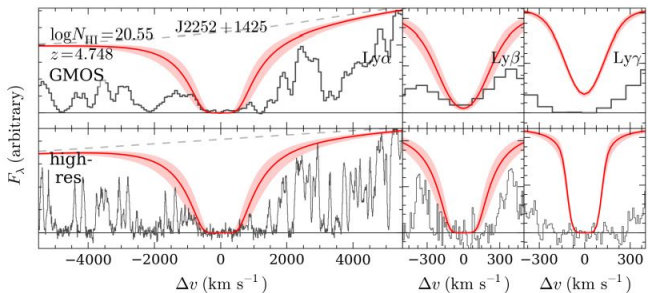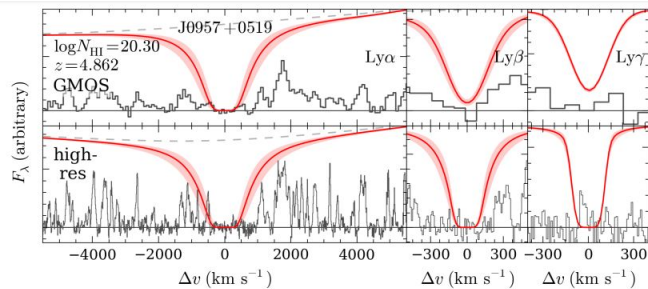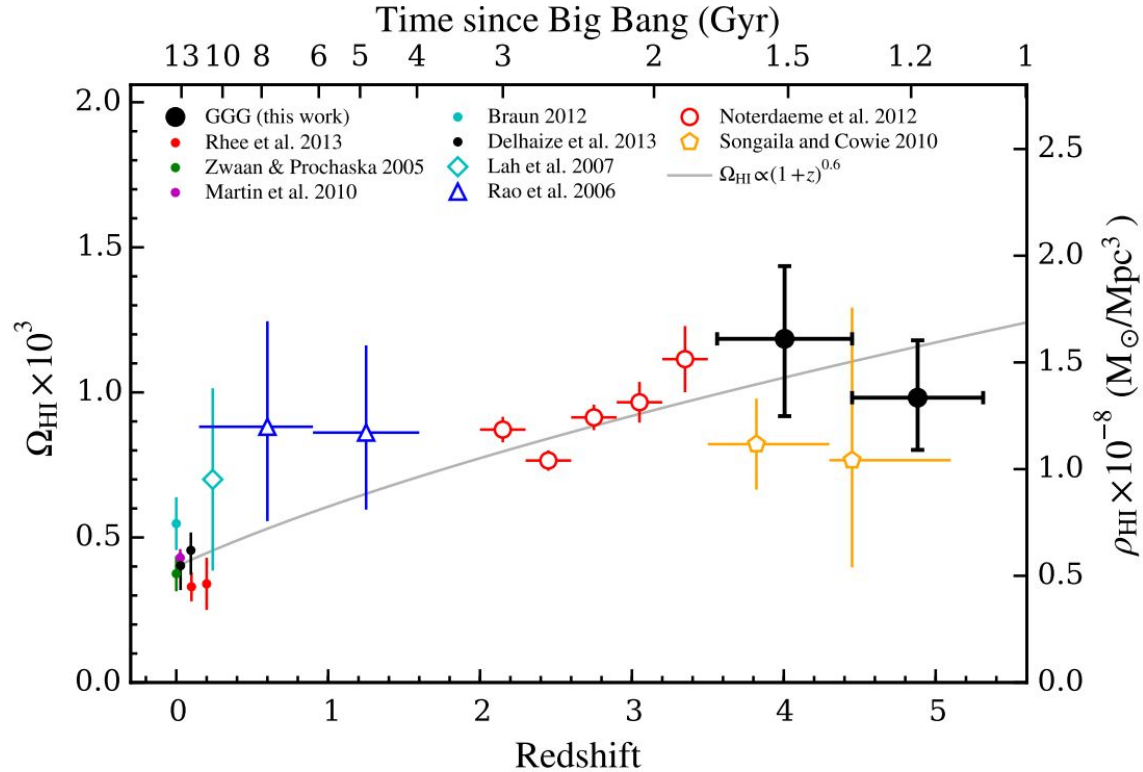
Completeness and purity
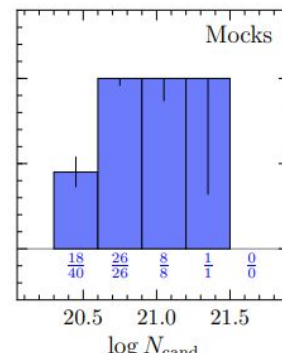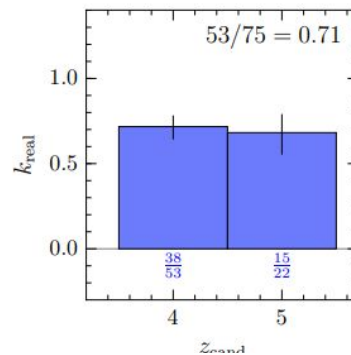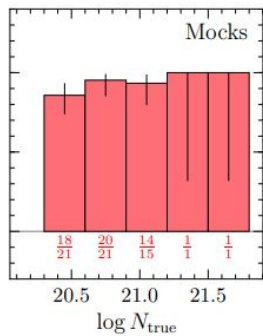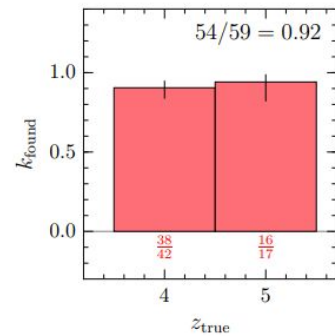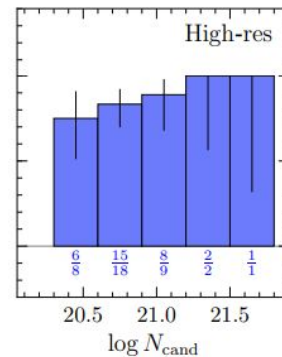
Biased results wrt low N(HI)

HI Column density distribution

Cosmic HI Density

Predictions by Theory