Physical conditions in high-z CIII absorbers: origin and stability

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Cosmic Explosions, Cargèse 2019

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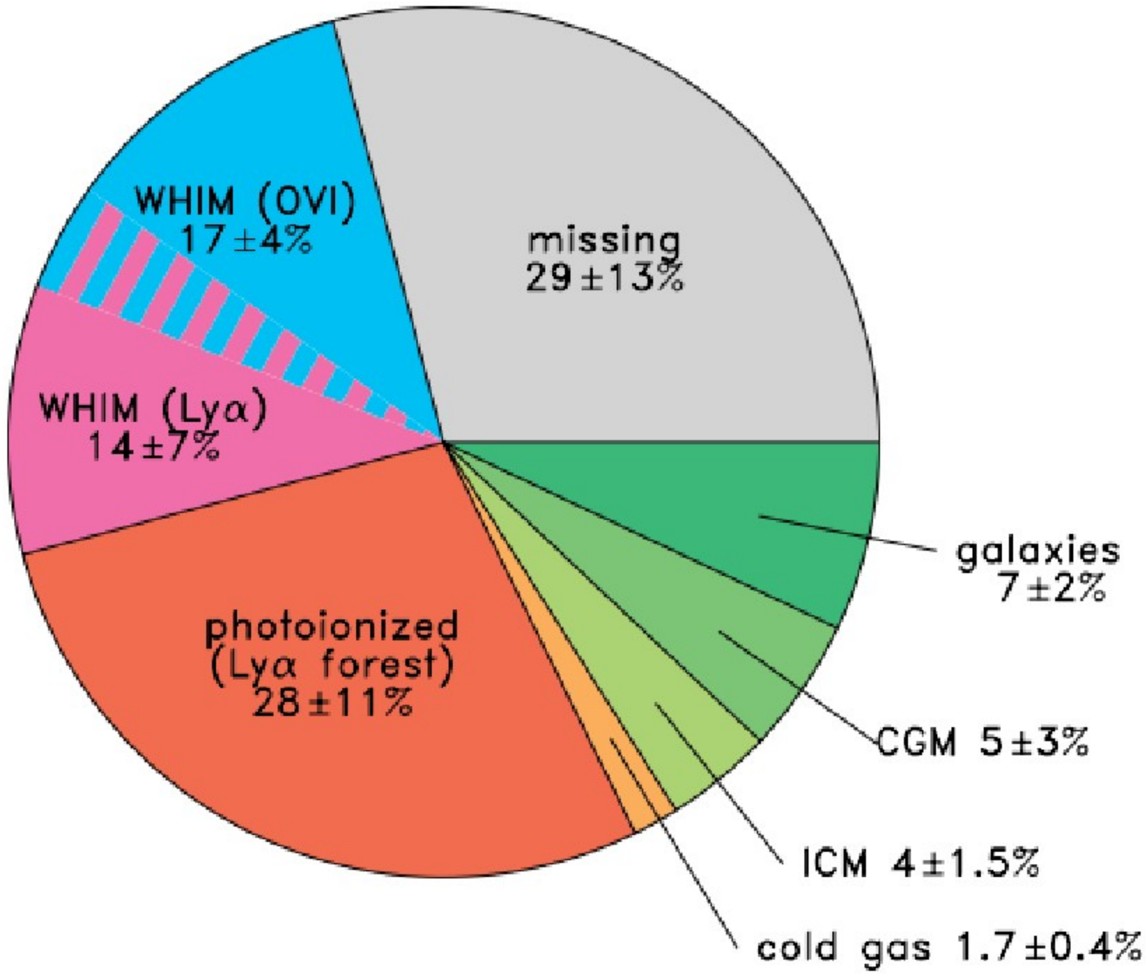
Introduction

Figure 1: **Reference:** HST Deep Field Survey

Where to find baryonic matter!

- 20% of the baryonic matter resides in the galaxies.

- Rest of the ordinary (baryonic) matter exists **OUTSIDE** – Intergalactic medium (IGM) or in the Circumgalactic medium (CGM).



Compilation of current observational measurements of the low redshift baryon

Enrich mechanism of empty space!!!!

Metals in the IGM/CGM

1. Metals are mostly transported by strong outflows from the nearby starforming galaxies.
2. From the supernova remnants.
3. Interaction between galaxies.

How Do we know!!!!!

One of many methods of detecting metals in the IGM/CGM is by absorption/emission lines seen in the spectra of a **background hot source**.

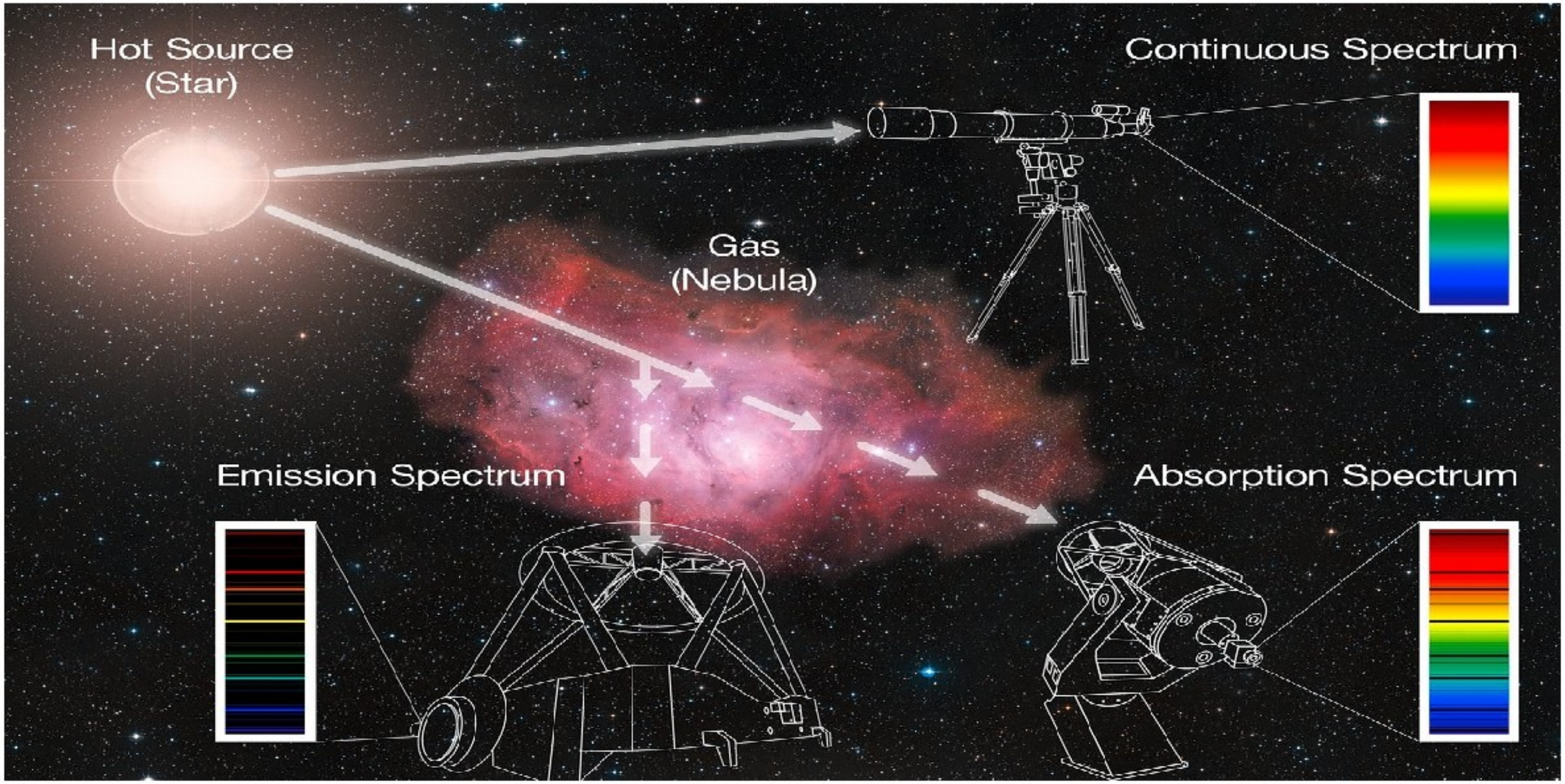


Figure 2: **Reference:**
http://astro.unl.edu/naap/hr/spectroscopy1.html

IONs	Wavelength	Absorption Strength	Energy (ev)	IONs	Wavelength	Absorption Strength	Energy (ev)
HI	1215.6701	4.16E-01	10.20	CIV	1550.77	9.52E-02	8.00
HI	1025.7223	7.90E-02	12.09	CIV	1548.195	1.90E-01	8.01
HI	972.5368	2.90E-02	12.75	CIV	312.453	6.78E-02	39.69
HI	949.7431	1.39E-02	13.06	CIV	312.422	1.35E-01	39.69
.	.	.	.	CIV	244.911	2.03E-02	50.63
.	.	.	.	CIV	244.907	4.07E-02	50.63
.	.	.	.	SiIII	1892.03	2.69E-05	6.55
HI	912.839	6.43E-05	13.58	SiIII	1206.5	1.68E+00	10.28
HI	912.768	5.81E-05	13.59	SiIII	566.613	1.55E-02	21.88
SiIV	1402.77	2.60E-01	8.84	CIII	1908.734	1.23E-07	6.50
SiIV	1393.755	5.24E-01	8.90	CIII	977.02	7.67E-01	12.69
SiIV	458.155	1.18E-02	27.07	CIII	386.2028	2.32E-01	32.11
SiIV	457.818	2.36E-02	27.08	CIII	322.5741	4.52E-02	38.44

Quasar Absorption Line

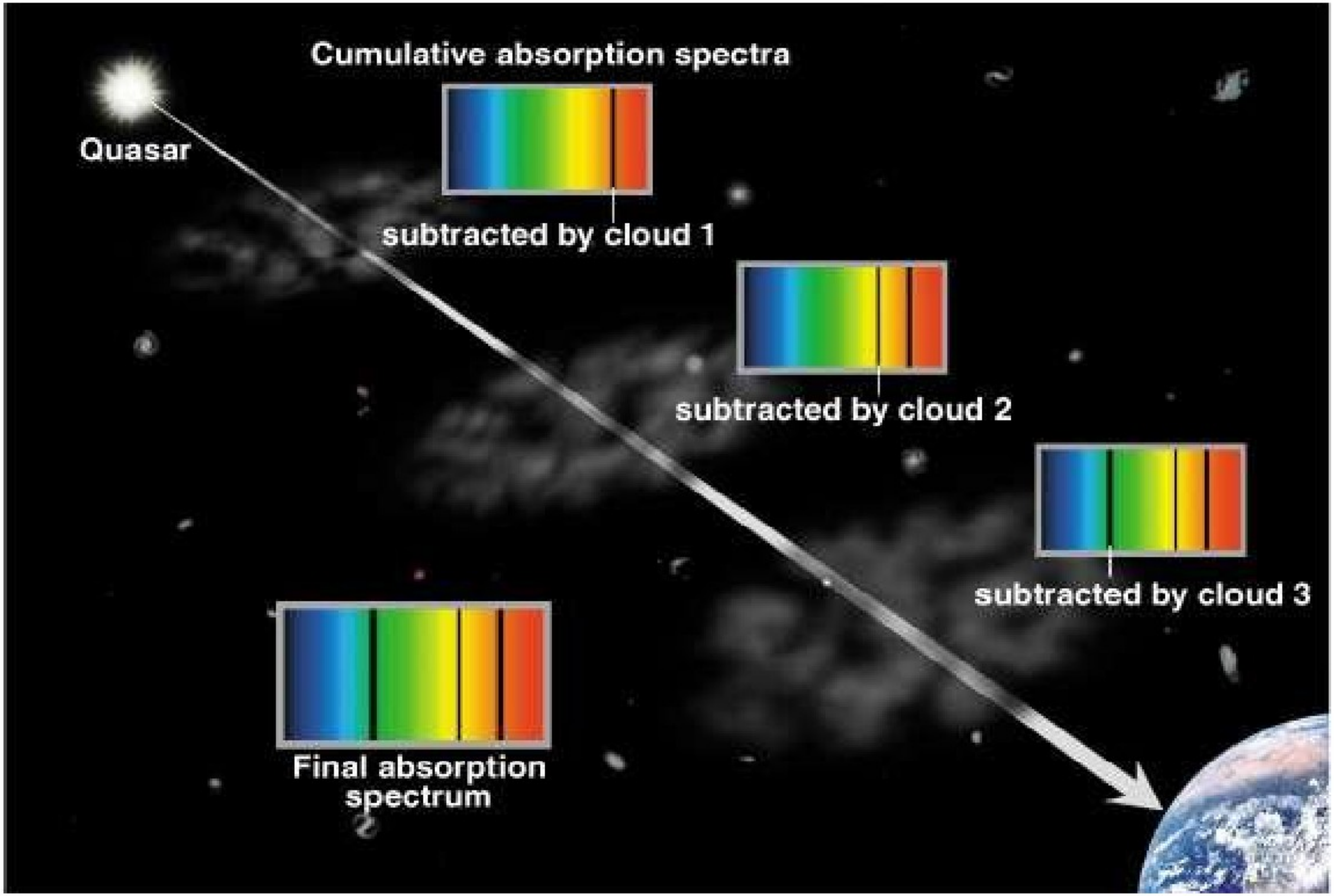


Figure 3: **Credits:** Addison Wesely

Quasar Spectrum

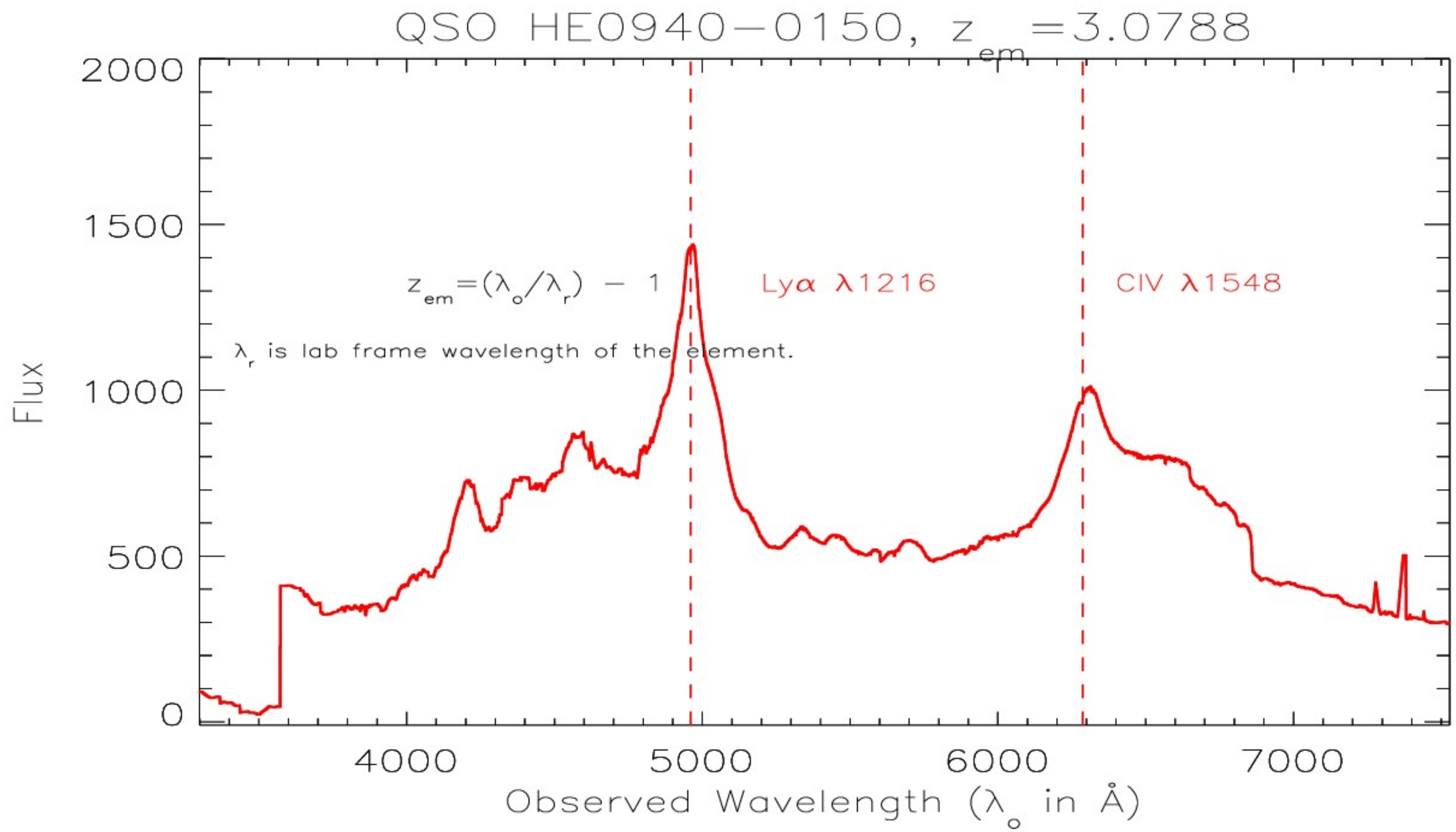


Figure 4: **QSO Spectrum HE0940-0150 assuming no intervening absorbers (VLT/UVES).**

Quasar Spectrum

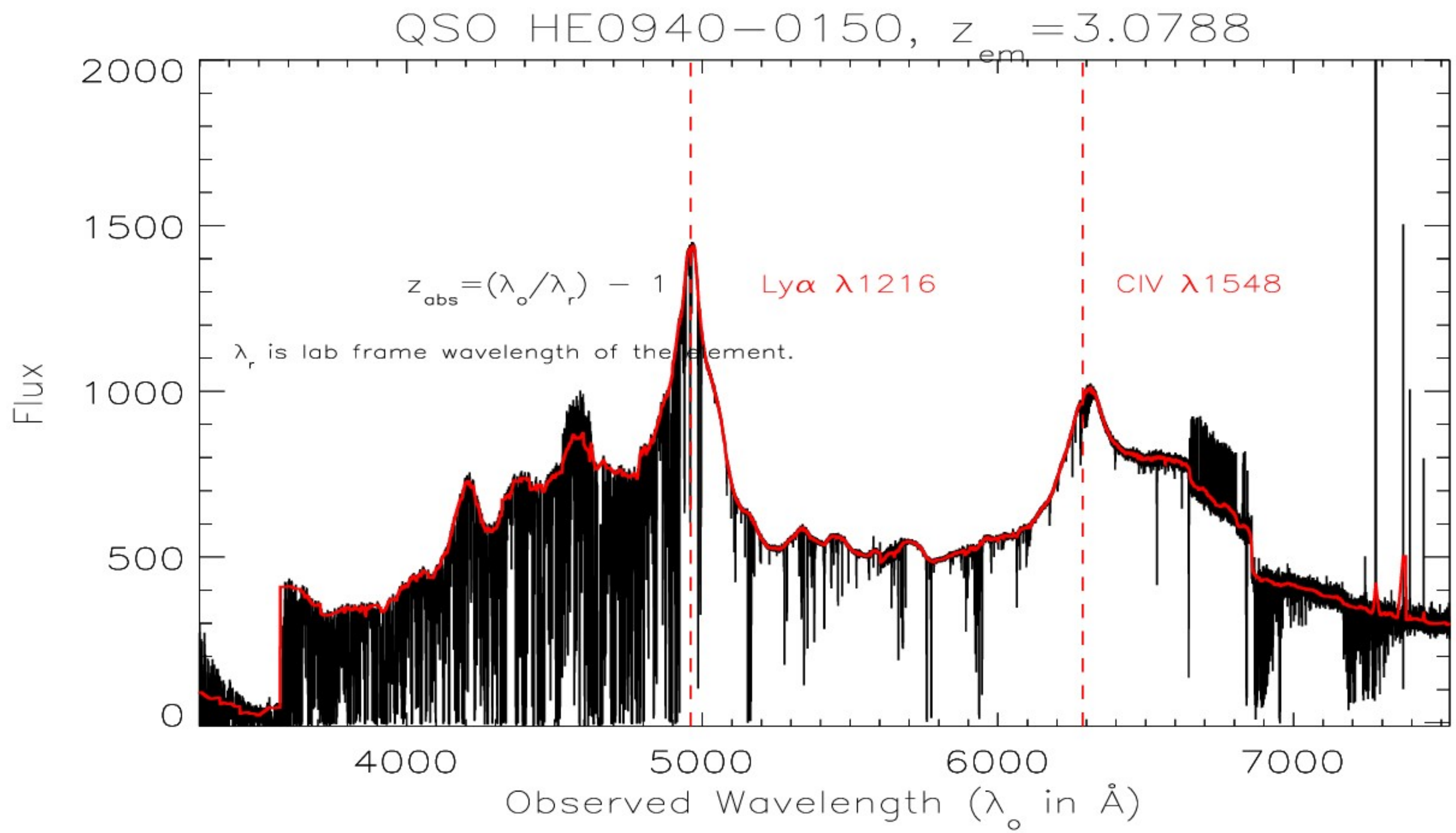


Figure 5: **Classification of intervening absorption systems (VLT/UVES).**

Intervening gas

Based on the neutral hydrogen content i.e., the column density of $N(\mathrm{H\,I})$:

- Lyα forest systems: $N(\mathrm{H\,I}) \leq 10^{17} cm^{-2}$
- Lyman limit systems (LLS): $N(\mathrm{H\,I})$ (cm^{-2}) of $10^{17.3} - 10^{20.3}$
- Damped Lyα systems (DLAs): $N(\mathrm{H\,I})$ $\geq 2 \times 10^{20} cm^{-2}$

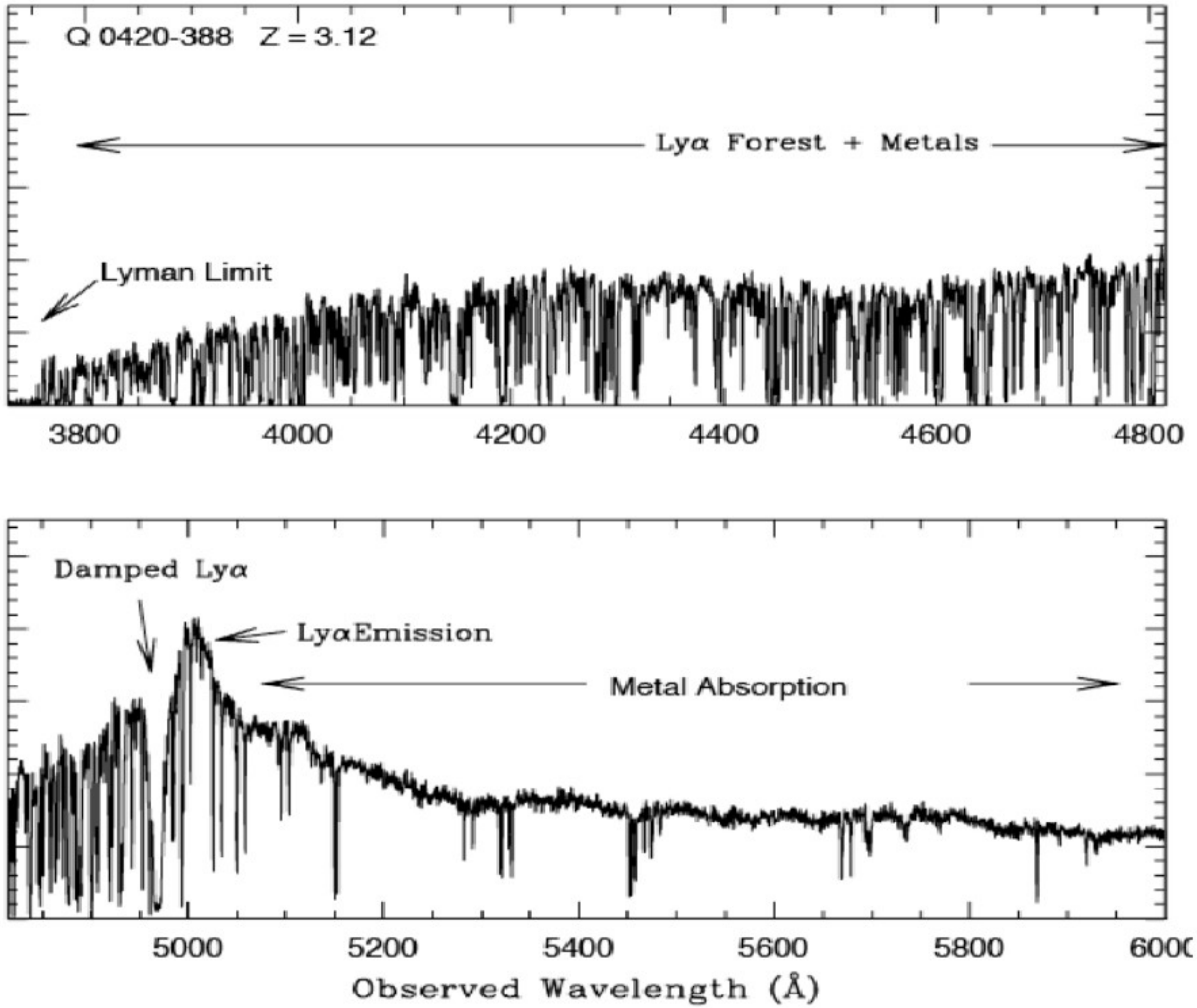


Figure 6: Types of QSO absorption systems. Credits: George Djorgovski

CDDF of $N(\mathrm{H\,I})$

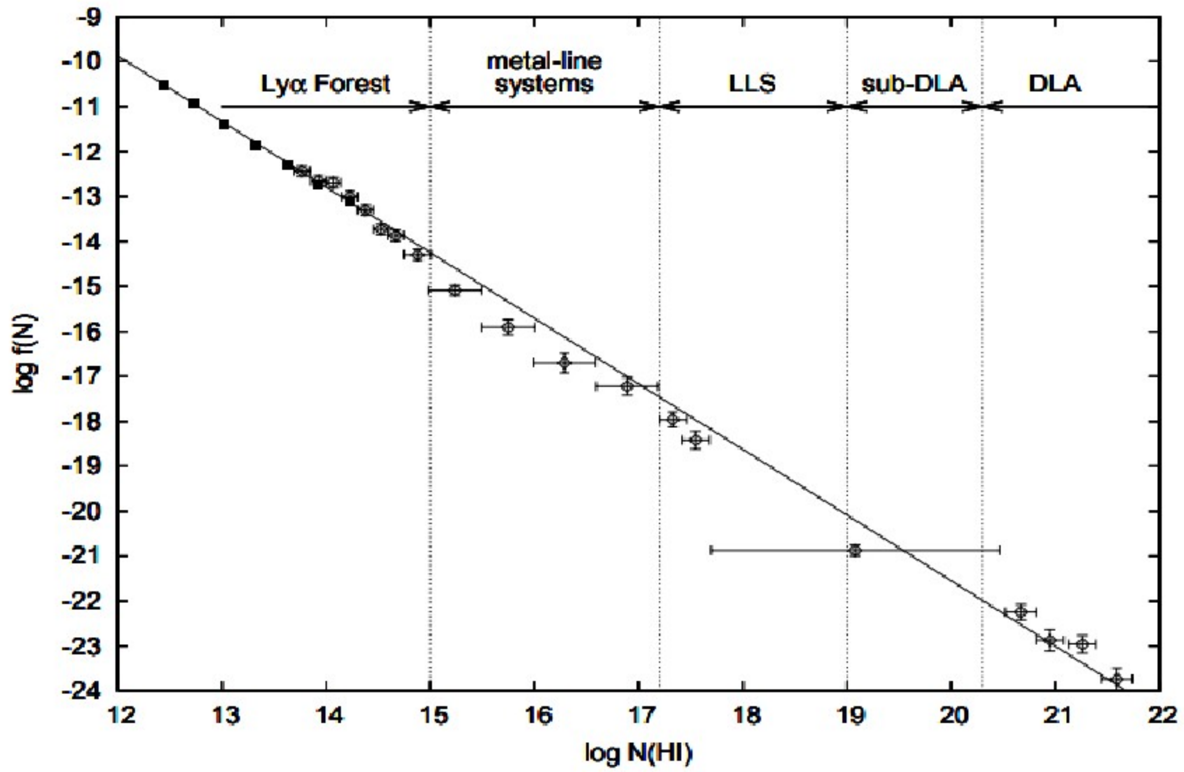


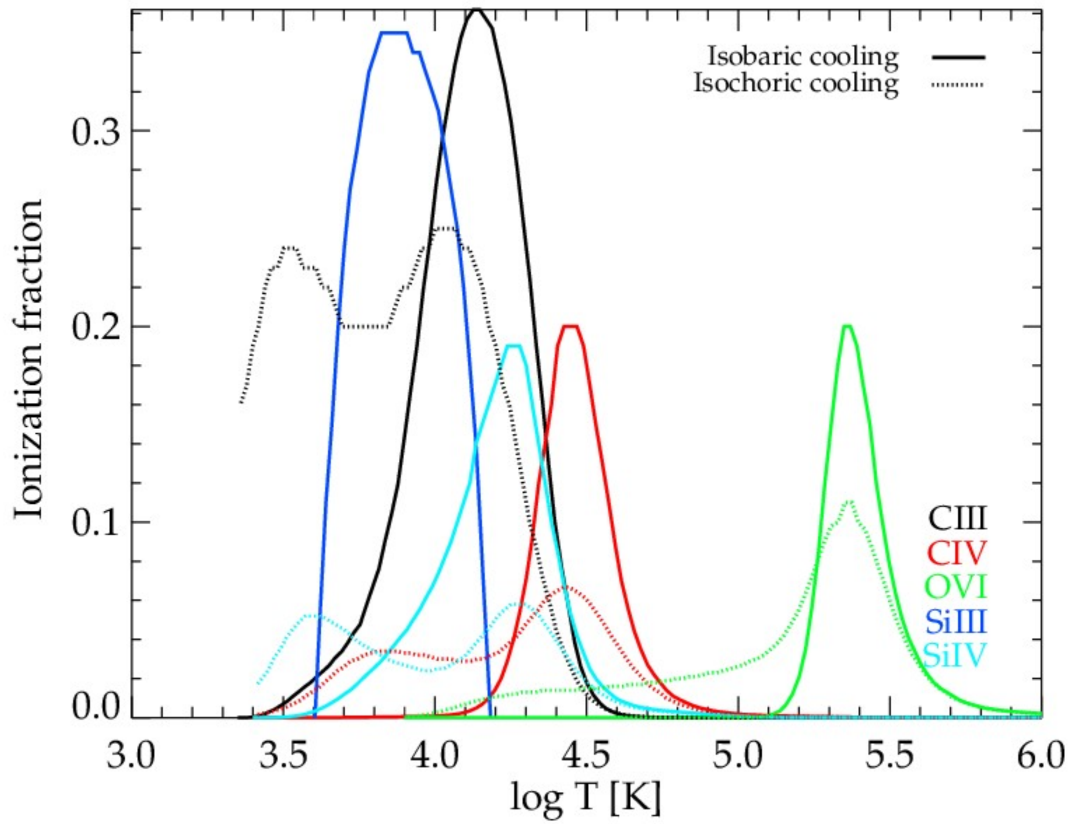
Figure 7: Column density distribution function (CDDF) of $N(\mathrm{H\,I})$ or in general denoted here as N. A single power law, $f(N) \propto N^{-\beta}$, with $\beta = -1.6$ fits the observed points ($f(N)$ is the number of absorber systems per unit N). **Credits:** Petitjean et. al (1993)

The Universe in absorption

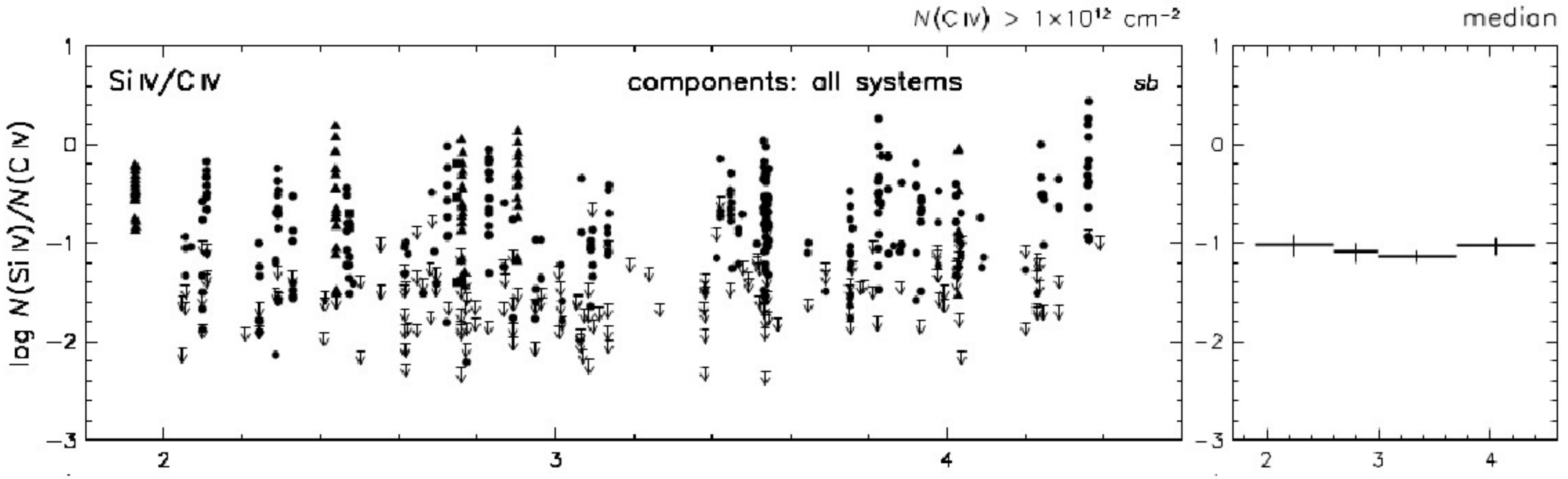
Property	Cosmic Web	WHIM	Dark Halos	Galaxy
Baryon & Structure Tracer	IGM, fuel	baryons, metals	CGM, infall, winds, metals	disk, SF, Bulge
Overdensity (Δ)	$1 - 100$	$1 - 100$	$10^2 - 10^5$	$> 10^6$
Size [Mpc]	$0.3 - 30$	$1 - 30$	$0.1 - 0.3$	$0.03 - 0.1$
T [K]	$10^4 - 10^5$	$10^5 - 10^7$	$10^4 - 10^6$	
Density (atmos/cm^3)	$10^{-6} - 10^{-4}$	$10^{-5} - 10^{-3}$	$10^{-4} - 10^{-2}$	~ 1
Ionization	Photons	Collisions	Photons + Collisions	Mostly collisions
QSO absorption	Lyα forest	O VI , broad Lyα	Lyα limit, Metal lines	Damped Lyα

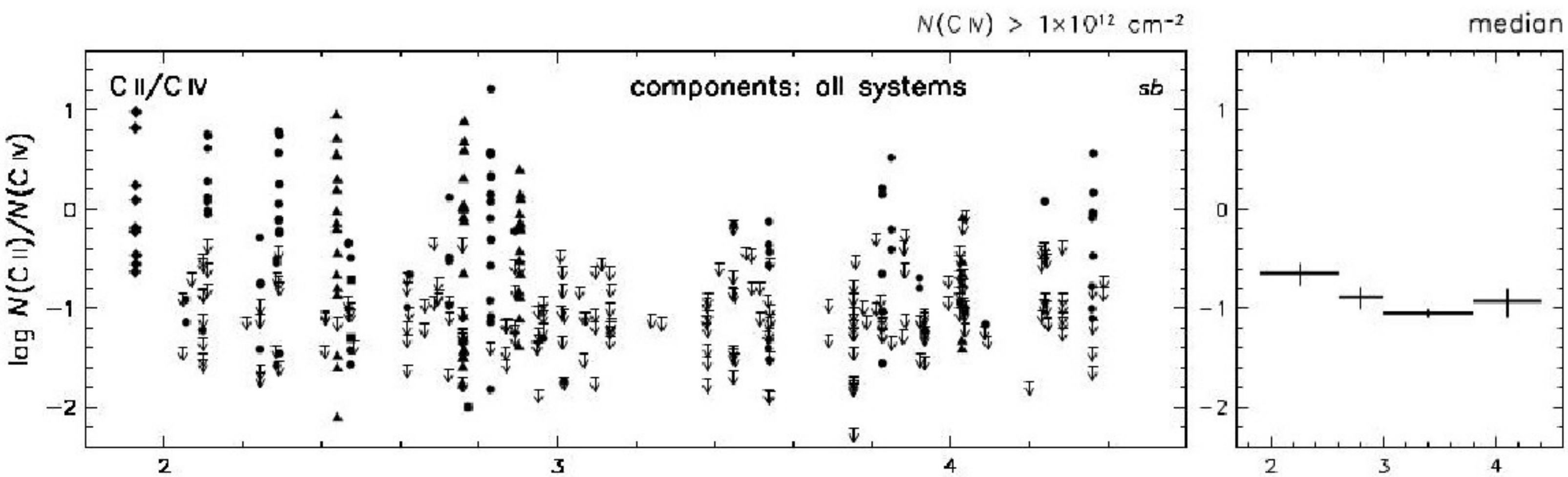
Figure 8: Components of the baryonic Univesre which are difficult to map in emissions.

- C IV: Third ionization state of carbon.
- Doublet transitions C IV $\lambda\lambda$ 1548, 1550 $\AA$ is easy to detect (falls well outside of the Lyα forest)
- Ionization fraction of C IV peaks at $T \sim 10^{4.5}$ K



Gnat & Sternberg 2007





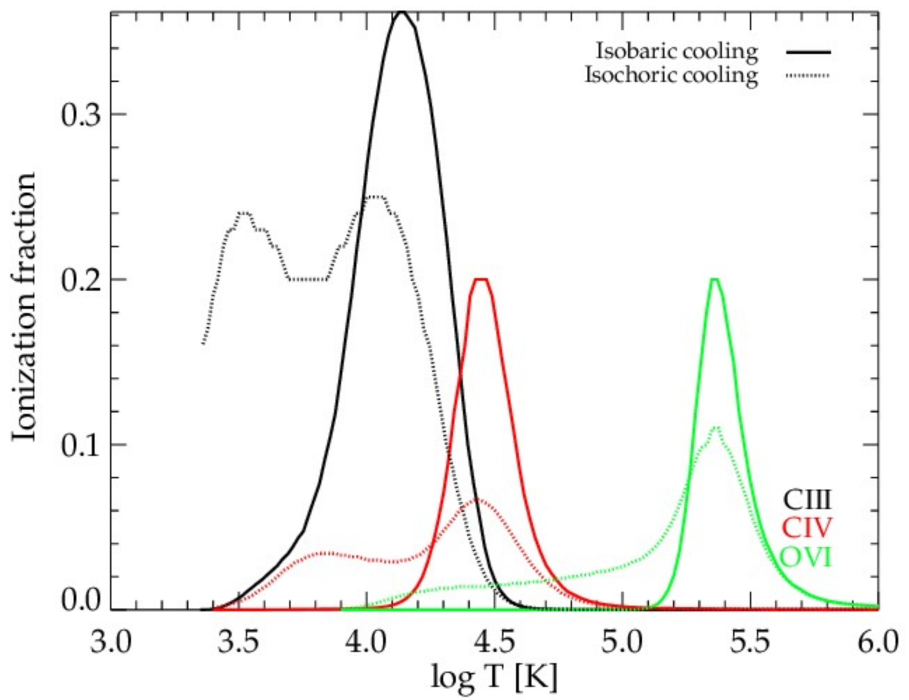
Boksenberg & Sargent 2015

C III selected C IV absorbers

- C III: Second ionization state of carbon, I. P $\sim$ 47.88778 ev
- Strongest transitions C III λ 977 Å falls inside of the Lyα forest
- Ionization fraction of C III peaks at T $\sim 10^4$ K

C III selected C IV is best species to use for:

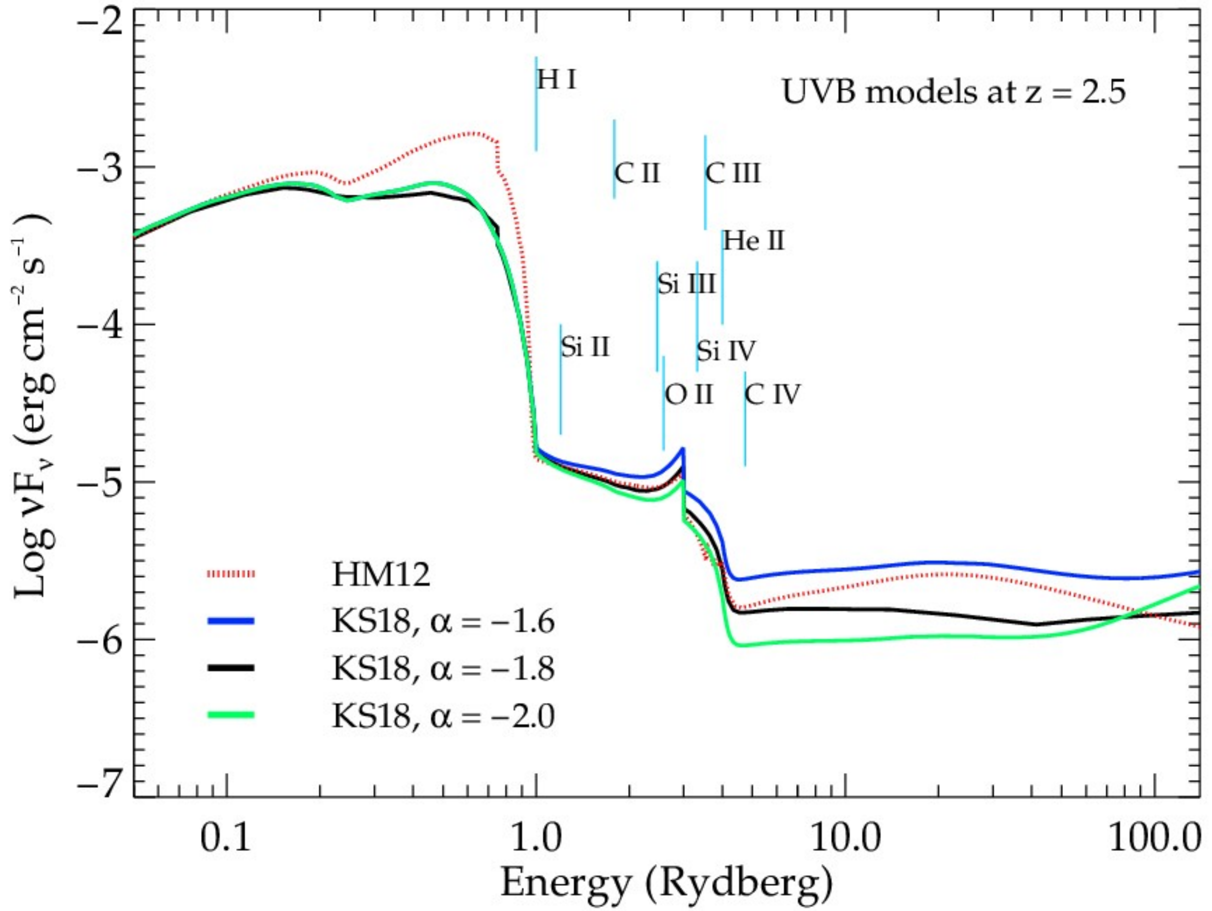
- Tracing intervening gas absorber photoionized by external UVB
- Constraint number density and metallicity of the gas absorbers
- Constraint the UVB



Gnat & Sternberg 2007

What we are interested in ?

- Effect of C III selected absorbers to the He II reionization around redshift 2.6 - 3 and the thermal history of the IGM ?



Different UVB models at $z \sim 2.5$.

What we are interested in ?

- Spatial distribution of C III absorbers hence the photoionized gas regions and/or regions affected by external UV ionizing photons.
- Physical properties of C III absorbers across the redshift. Is there any fundamental difference in the properties of what is seen in the other gas absorbers ? (Any Evolution ?).
- Large homogeneous sample collection of C III selected absorbers to relate the LOS properties to the global picture of the absorber.

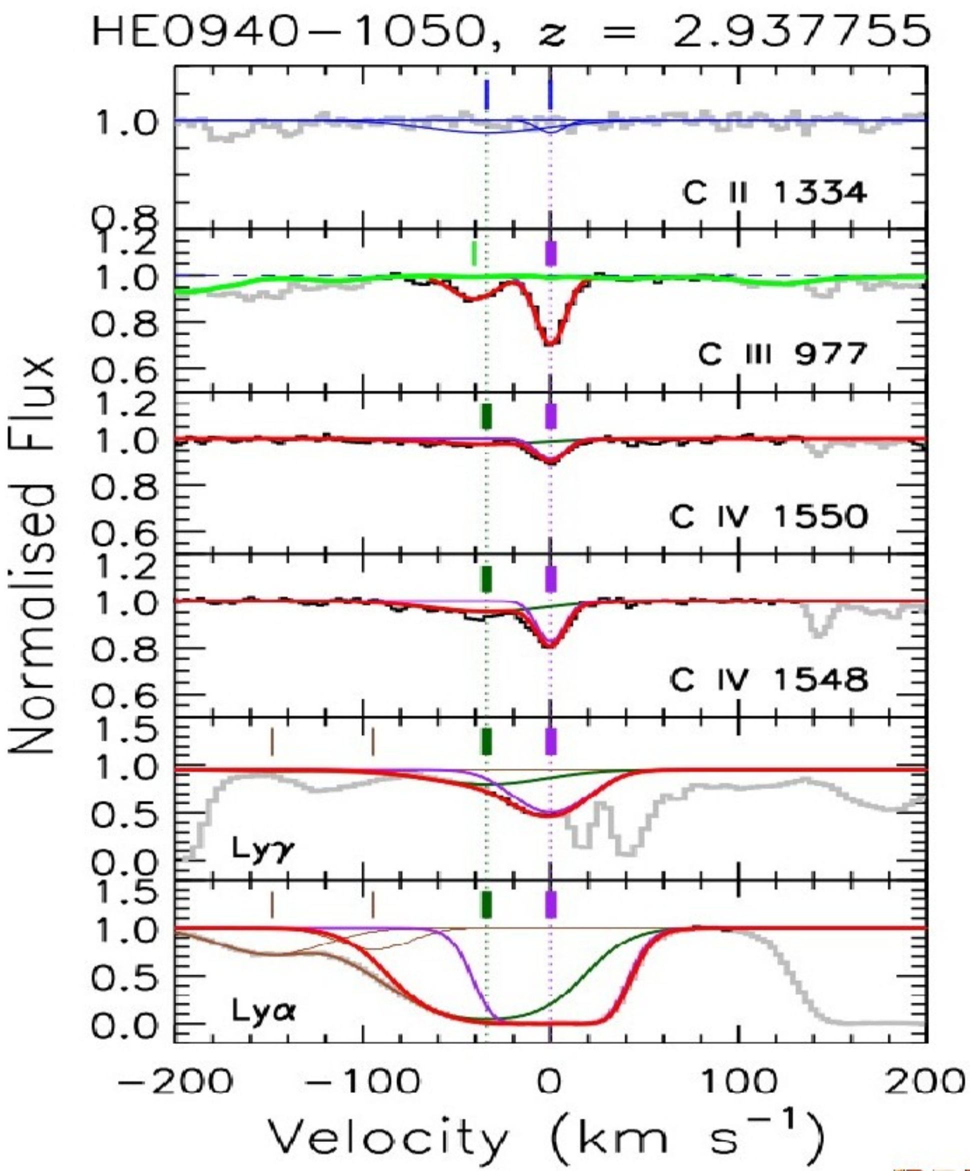
Data Sample

- Ooptical quasar spectra from VLT/UVES and KECK/HIRES and UV quasar spectra from HST/COS
- This provide a sample of QSO sight lines in the redshift range 0.2 - 4.5.
- Typical resolution $\sim$ 45,000 (6.6 km/s) and S/R $\sim$ 70/pixel for optical spectra and $\sim$ 18,000 for HST/COS spectra with S/R $\geq$ 10/pixel.
- Wave length coverage 3200 $\AA$ to 10,000 $\AA$ for optical data and 1150 $\AA$ to 1800 $\AA$ for HST/COS data.

C III selected gas absorbers

C III systems: using C IV doublets $\lambda\lambda$ 1548,1550 $\mathring{A}$.

- Total ~ 200 C III systems: 332 C III+C IV components
- S1: C III+C IV components with well-aligned H I components
- S2: C III+C IV components with moderately aligned H I components



Kim et. al 2106

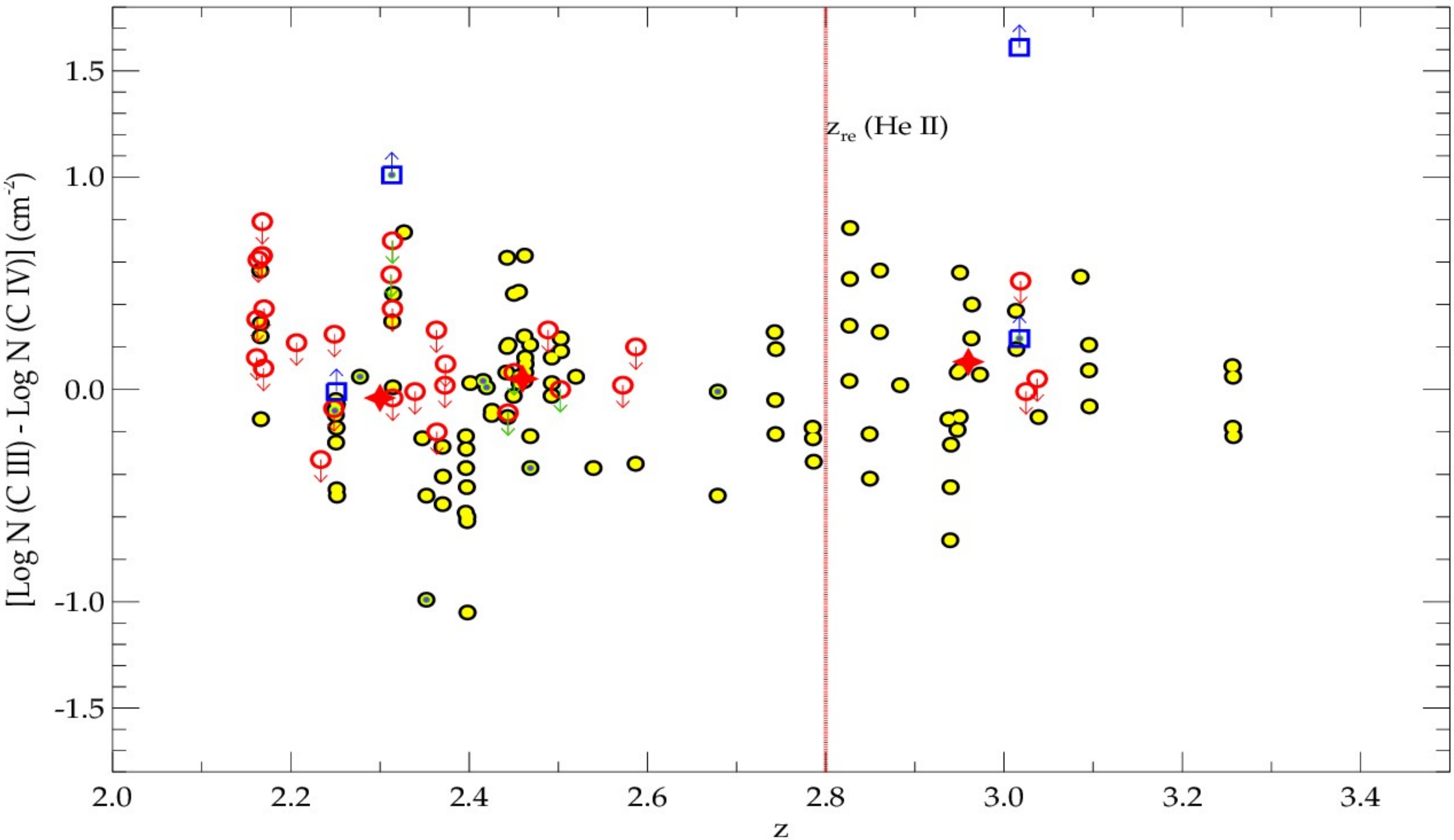
Photoionization Model

- CLOUDY v13.03 (Ferland et. al 2013) with KS18 (Khaire & Srianand 2018) and HM12 (Haardt & Madau 2012) UVBs

- Assumption : (a) cloud is optically thin and (b) cloud is in single phase !

- CLOUDY parameters : (i) Grids of $n_{\rm H}$ (ii) grids of metallicity ([C/H]) (iii) Stopping criteria : (a) N(H) using Jean's length (Schaye 2001) (b) N(HI)

Statistical Properties of C III absorbers



Redshift(z) vs. ratio of column density of carbon ions.

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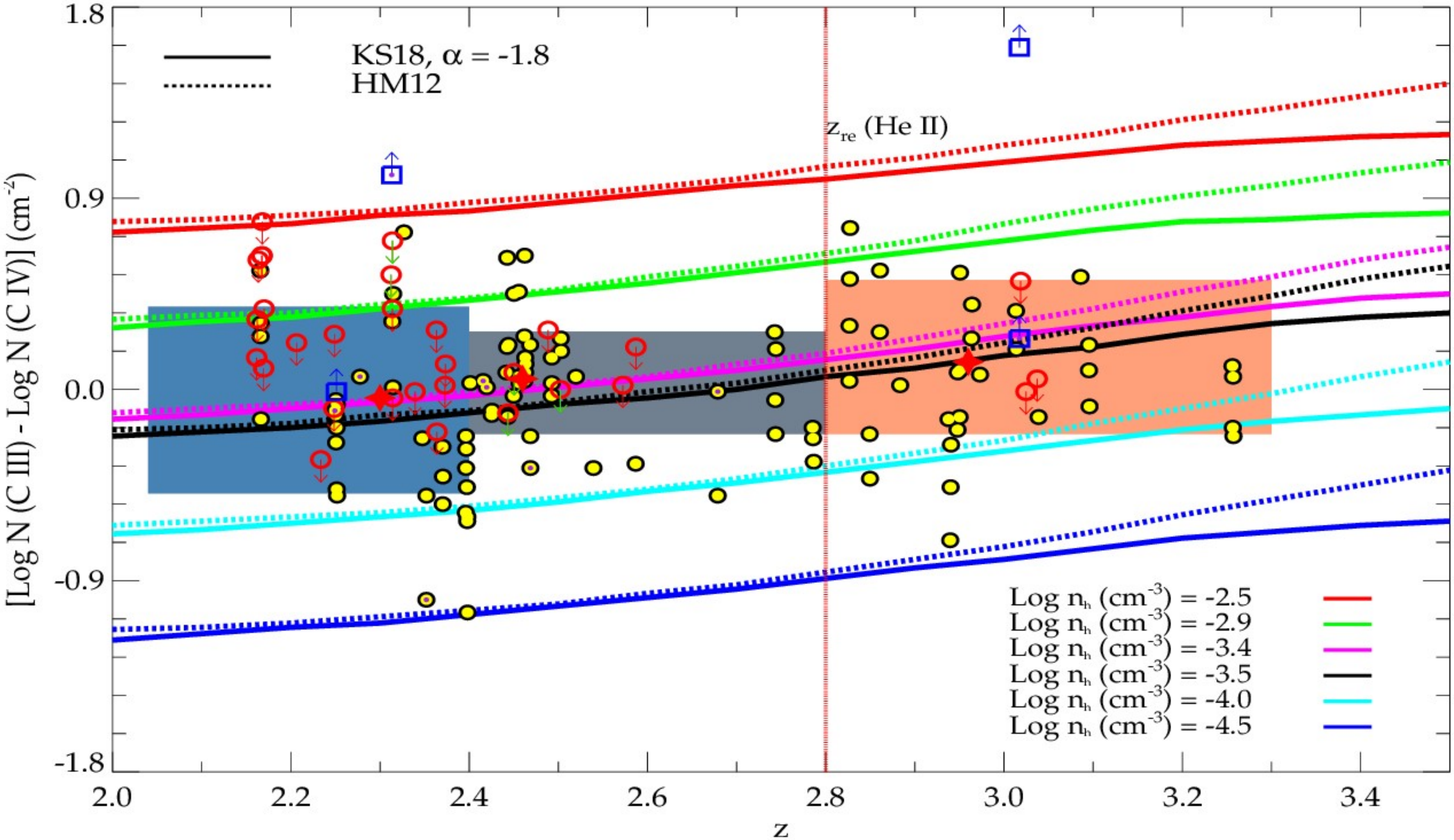
Statistical Properties of C III absorbers



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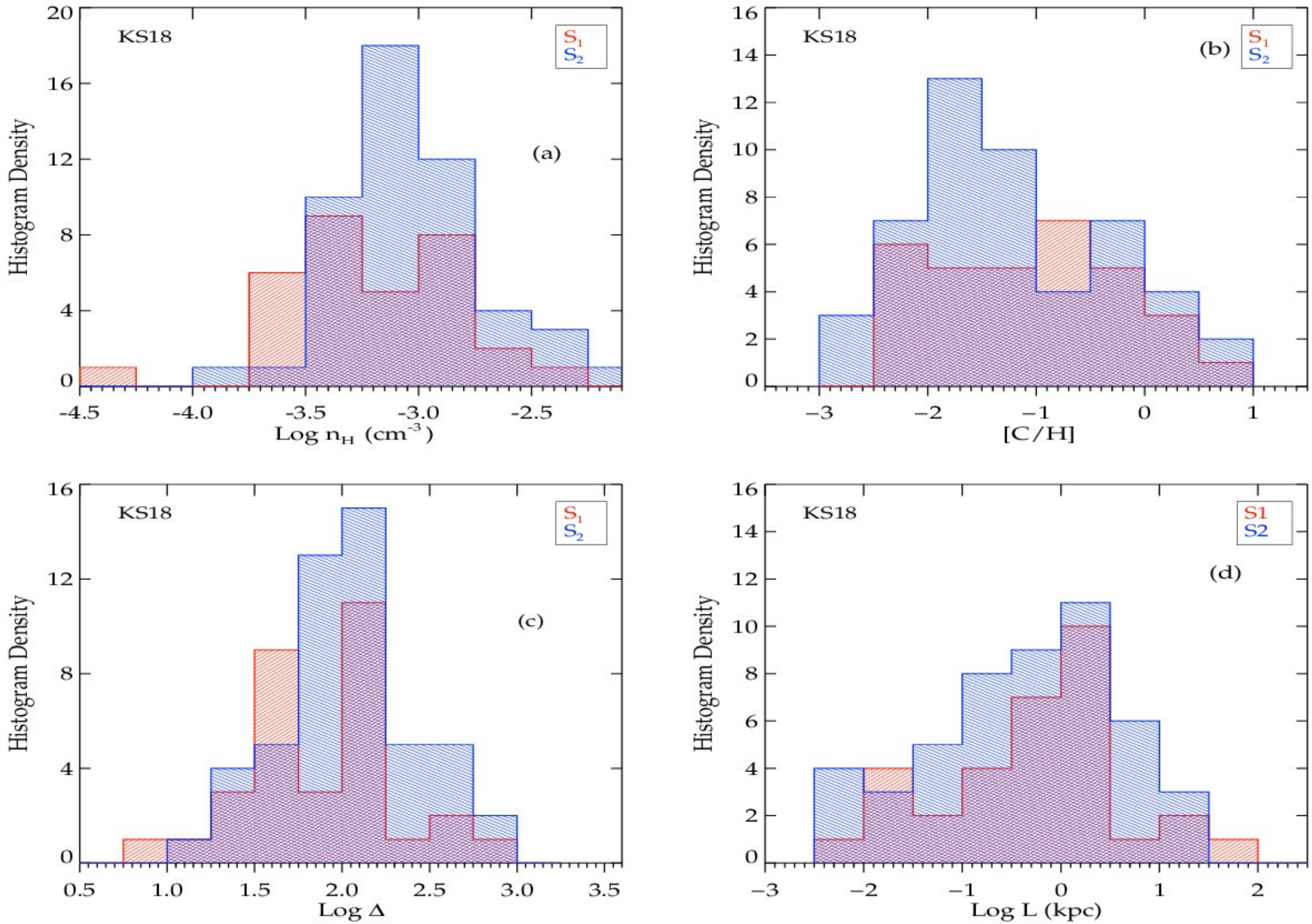
Mohapatra et al. 2019

Physical properties of C III absorbers



Derived parameters

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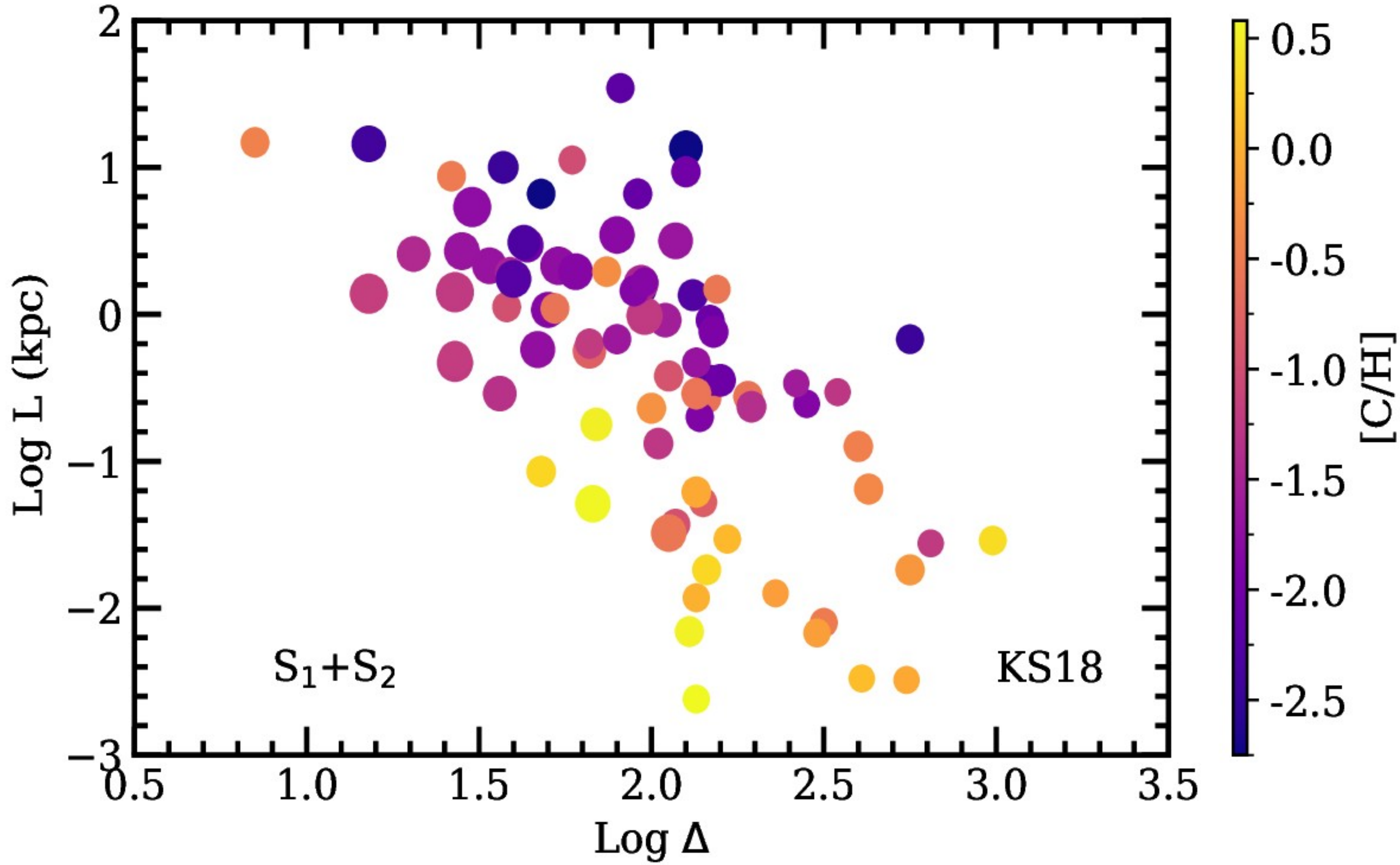
Physical properties of C III absorbers



Derived parameters of the intervening absorbers

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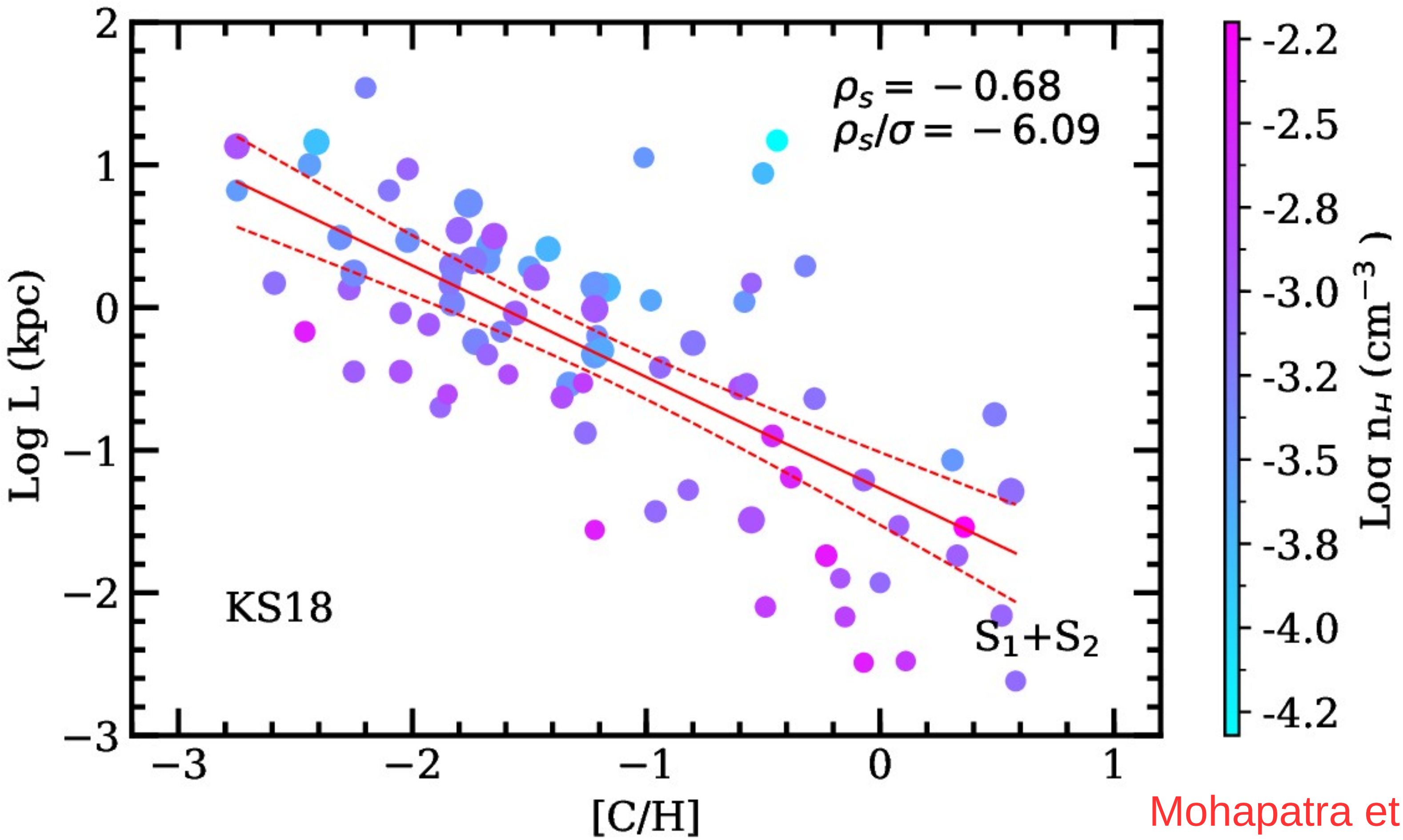
Confinement of the absorbers



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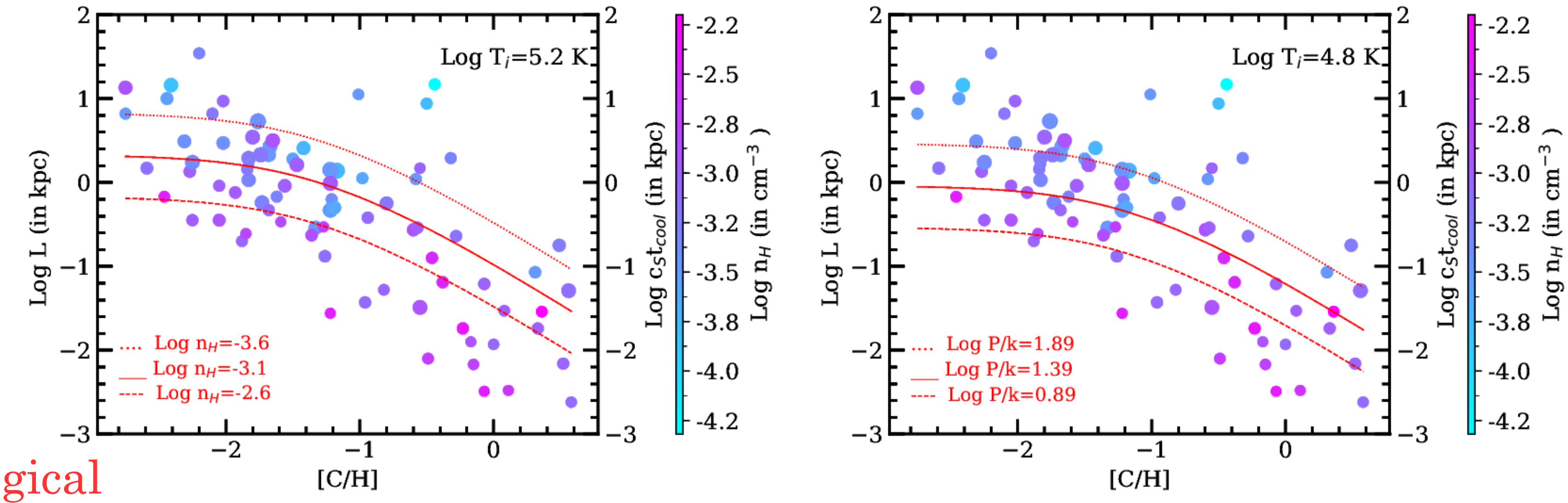
Correlation of [C/H] with L.The dashed solid line indicates linear regression fit to the data. The red dashed lines show the 1σ range allowed by the regression analysis.

Confinement of the absorbers



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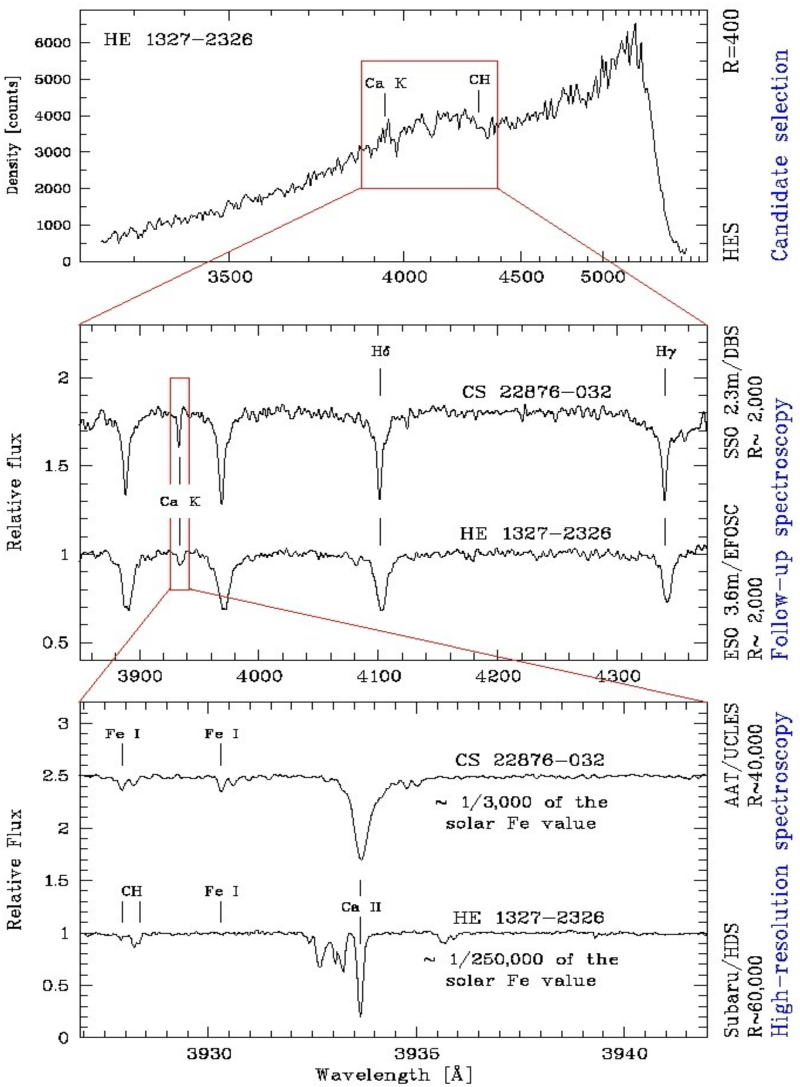
- Simple phenomenological model for thermal instabilities: allow the clouds to cool from an intial cloud temprature [parent cloud] to final temperature [T_f = 2 x 10^4 from observation].

  T_i for Isochoric: 2 x 10^5 and for Isobaric: 6.3 x 10^4
- Analogy with cloud fragmentaion and pressure confinement (McCourt et al. 2018)!

Summary

- Cold clouds formed in-situ at large distances and their frequency of occurrence may have some links to the star formation rate in the host galaxies.
- We take C III selected C IV absorbers over large redshift ranges and associate their evolution with the global star formation rate density (Mohapatra et al. in prep.).
- Optically thin C III components studied here are most probably associated with gas outside the galactic discs (outflows, inflows or galactic halo gas).
- Bielby et al. (2013) have searched for Lyman break galaxies and found no clear association of any galaxies around these quasar fields .
- It will be important to have deep imaging survey (like LSST) in these fields to confirm the galaxies associated.

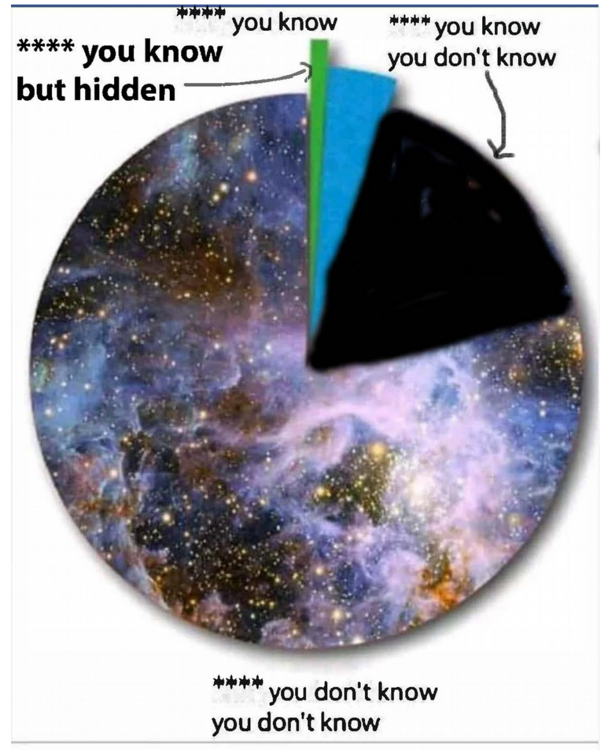
Future?



Credits: https://www.tmt.org/download/MediaFile/84/original

Thirty meter telescope (TMT) with R~75000:

- Metals hidden inside the Lyα forest.
- Resolve CIII inside the Lyα forest and aligned HI absorptionn line components: measure column densities and thermal width.
- Resolve structure within parsec scales.




Thank you