Study of Relative Abundances of Gas Rich Galaxies to Constrain the Early Nucleosynthesis Model

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Abstract

Chemical properties of the medium is encoded in the spectra of the background Quasars.We decode the absorption features and find the chemical composition of the medium to track the chemical enrichment of the early universe. In this research,We took the quasar spectra from **SDSS Data** Release 17 for DLAs, with Hydrogen column densities of **log NHI ≥20.3** (cm^{-2}) in the lines of sight, which are rich in neutral gas for early star formation in the high red shift(**3 ≤Z ≤5)** universe. Absorption features of O I, C II , Si II , FeII , S II , and Al II etc. are observed and we estimate the column density, metallicity, and relative abundances e.g.**, Si/O , Fe/O, C/O, Si/C** and **Si/S**. Cosmic chemical evolution models predict the mean metallicity of galaxies to rise from low metallicities at high-z to a near-solar level at z=0. In this research, we compare our results from the low resolution SDSS data with the high-resolution observations in the literature. We also try to constrain the early Nucleosynthesis models through relative abundances.

1. Introduction

1.1 Quasars

- Supermassive black hole at the center of a distant galaxy
- Luminous because of thermal radiation due to gas feeding on.

Image Source: https://scholarcommons.sc.edu/cgi/viewcontent.cgi?article=4205&context=etd

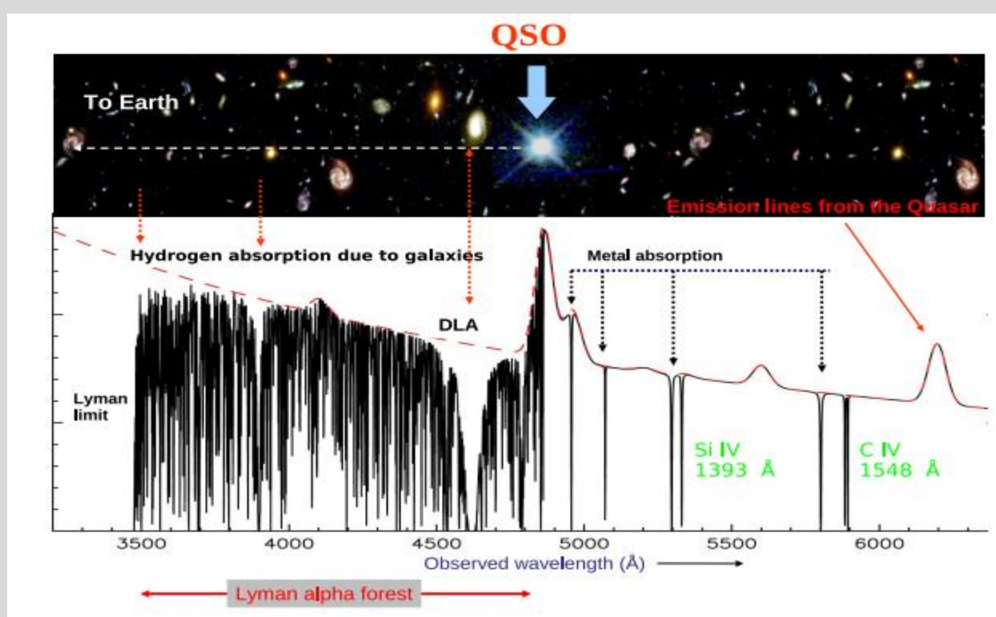


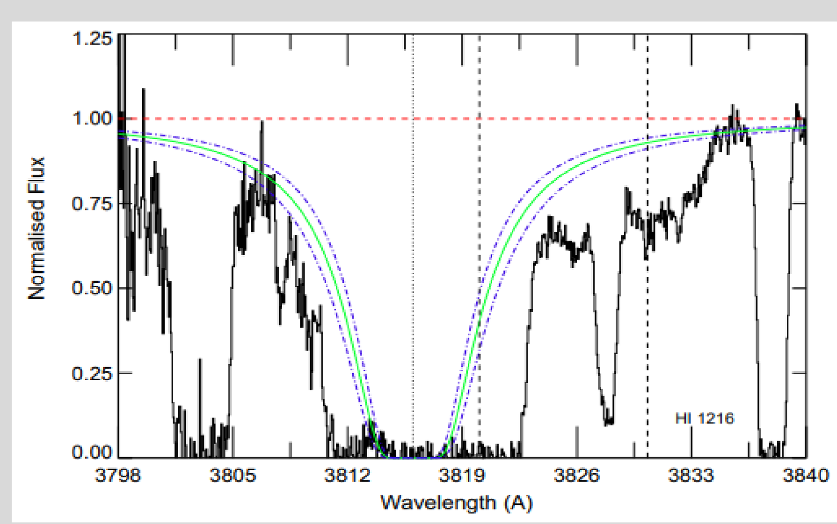
Fig 1.1 A schematic representation of the quasar absorption line technique. This representation is created from a version produced by John Webb and published in Pettini (2004).

1.2 Damped Lyman Alpha system

DLAs are concentrations of neutral hydrogen gas that are detected in the spectra of quasars. Generally column density more than 20.3 are called DLAs .

Fig1.2 : Lyman-α absorption feature. The red dashed line represents the normalized continuum while the black dotted line denotes the profile center.

Image Source : https://scholarcommons.sc.edu/cgi/viewcontent.cgi?article=3910&context=etd



1.8 BigBang Nucelosynthesis

The process of forming the Hydrogen and Helium and other trace constituents is often called "Big bang nucleosynthesis".

1.6 Metallicity

Besides Hydrogen and Helium each elements are said to be metal elements .The Abundance of metals with respect to hydrogen is known as metallicity.

2. Methodology

2.1 Radial Velocity Plot

Each plot are for different ion and each plot is centered on the rest wavelength of corresponding absorption feature.

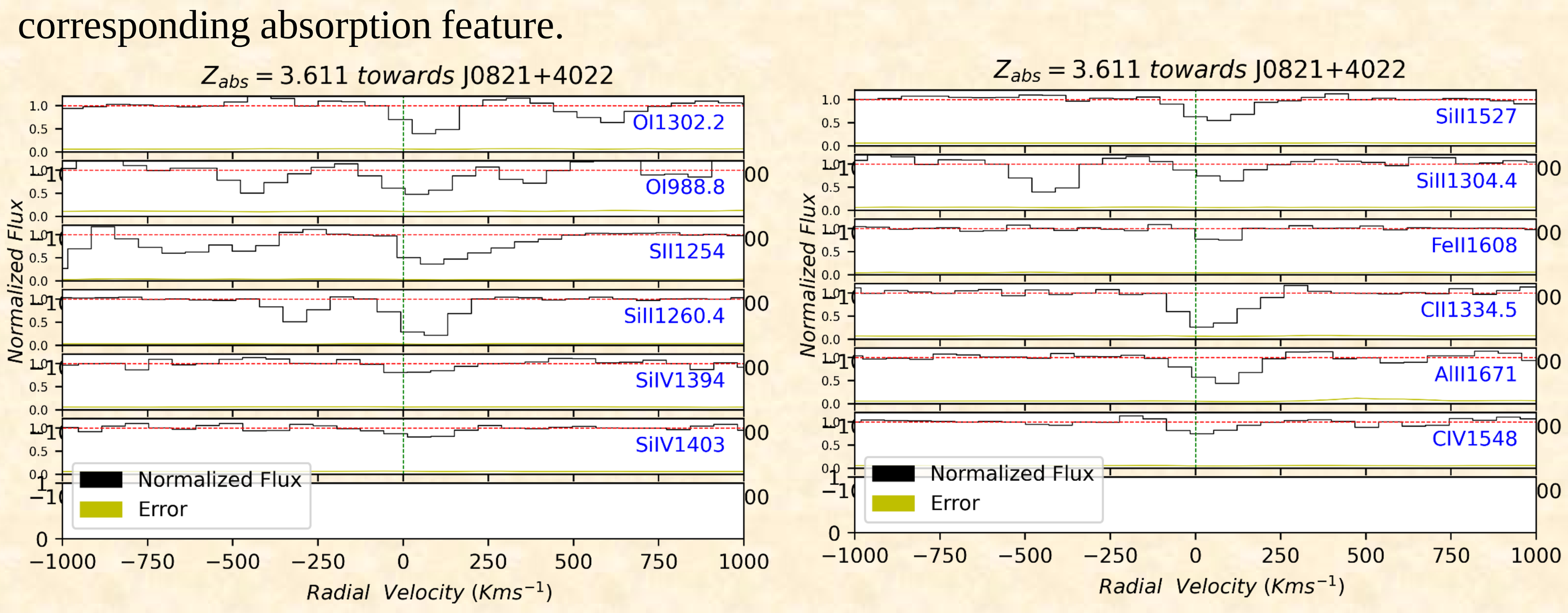


Fig: **2.1 a)** Velocity plots for several lines of interest in the a system Zabs=3.611 in the spectrum of a Quasar J0821+4022 . The solid green line indicates the theoretical profile fit to the spectrum, and the dashed red line is the continuum level.

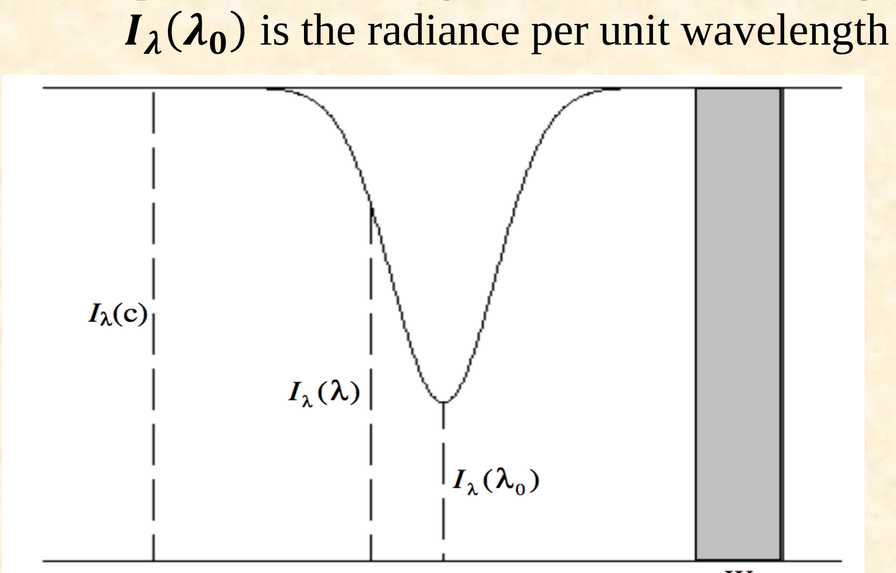
2.2 Equivalent Width

- Equivalent Width Gives the Strength of the Spectral Line

Area of fitted line profile given by :

$$WI_\lambda(c) = \int [I_\lambda(c) - I_\lambda(\lambda)] d\lambda \qquad (1.1)$$

$I_\lambda(\lambda)$ is the radiance per unit wavelength interval at some wavelength within the line profile . Radiance per unit wavelength interval of the background continuum source is $I_\lambda(\lambda)$ and $I_\lambda(\lambda_0)$ is the radiance per unit wavelength interval at the line center.



(Image Source : https://phys.libretexts.org/Bookshelves/Astronomy__Cosmology/Stellar_Atmospheres_(Tatum)/09%3A_Oscillator_Strengths_and_Related_Topics/9.01%3A_Introduction%2C_Radiance%2C_and_Equivalent_Width)

Fig **2.2** : different radiance intensity for equivalent width

2.3 Column Density

Column Density is the total number of particles which can absorbs the radiation in the line of sight in 1 cm^{-2} crossection .

$$N_u = \int n_u ds \qquad (1.2)$$

We can express the column density as the number of molecules n_u in energy level u integrated over the pathlength ds. (Mangum & Shirley,2015,pp. 3-4).

2.4 Relative Abundances

If N_x and $N_y$are the column densities of elements X and Y respectively, then the abundance of X relative to Y is given by

$$[X/Y] = log(N_X/N_Y) - log(X/Y)_\odot \qquad (1.3)$$

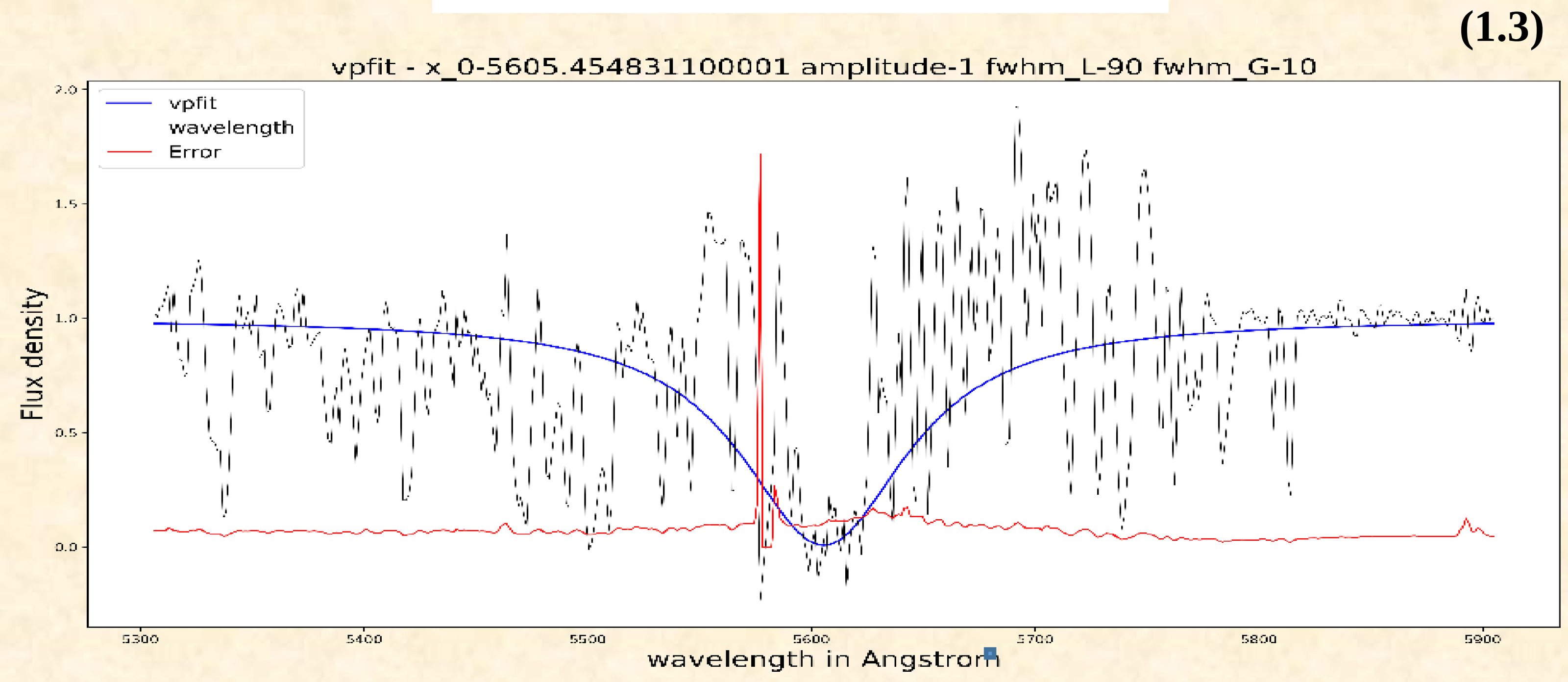


Fig2.3 (a) Voigt profile fit of system Zabs=3.611 towards **J0821+4022**

3. Result

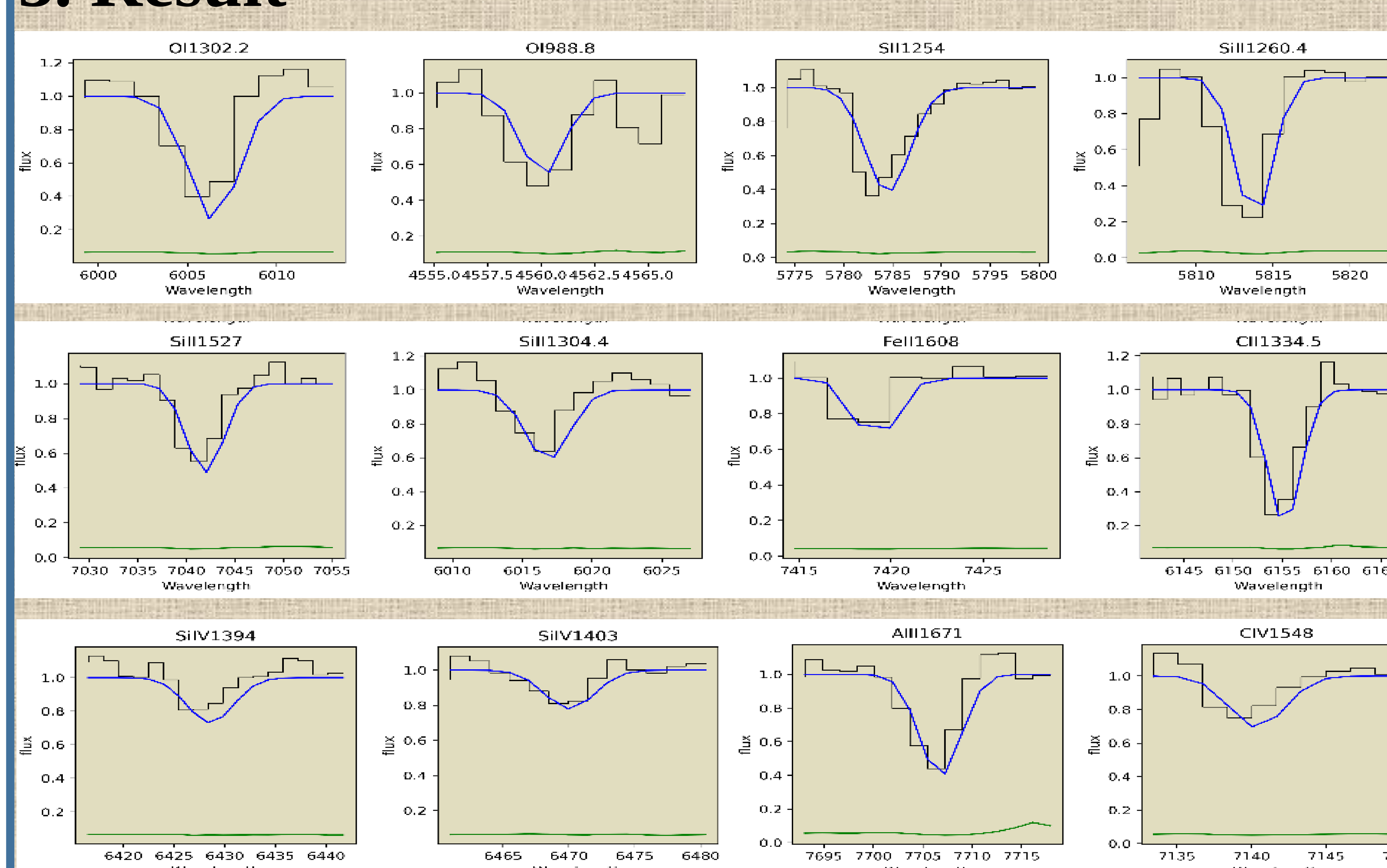


Fig 3 a) Gaussian fit (wavelength A° vs Normalized Flux) of different Ion of DLAs towards Quasar **J0821+4022**

Relative	J2311+0109	J0007+0224	J0948+4307	J1528+3254	J0821+4022	J2123-0053
Abundances	Zabs=3.413	Zabs=3.55	Zabs=3.487	Zabs=3.474	Zabs=3.611	Zabs=3.626
Si/O	0.693787687	1.446196174	1.318487277	1.47439017	1.239449906	1.186356787
Fe/O	0.768434022	1.169686478	-	1.262013441	0.995137553	1.039620742
C/O	-0.355041783	0.076632185	0.41614996	0.408591119	0.513478068	0.084952875
Si/C	1.048829471	1.36956399	0.902337318	1.065799051	0.725971838	1.101403912
Si/S	-0.649138778	-	0.003741843	-0.025658543	-0.444458776	-

Table 3.1 :Relative Abundances of 6 DLAs of interest

4. Conclusion

We have studied 6 DLAs using low resolution SDSS observations. We find a wide spread in the metallicities ranging from solar to 1/200 of the solar value. Some of the systems show dust depletion as evidence from the higher metallicity value for S in comparison to Si. Most of our measurements using O are seem to be saturated given the over-abundance reported for Si and C (refractory elements) than O (volatile element). While we suspect saturation for O, the over-abundant of Si in comparison to O might also be the effect of unusual Nucleosynthetic signatures of the early stars imprinted in the metal poor DLAs.

5. References

Mangum, J. G., & Shirley, Y. L. (2015). How to calculate molecular column density. *Publications of the Astronomical Society of the Pacific*, *127*(949), 266.