Comparison of Different Detection Scenarios of Lyman-α

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Abstract. After the first galaxies formed in the universe, the energy they produced causes the cosmic reionization. Galaxies at high redshift are so faint that it will be extremely difficult to obtain their data. The Ly-α line becomes an excellent target for spectroscopic redshift determinations to gain the data because it is among the strongest lines emitted by high-redshift galaxies. This paper reviews recently observation and simulation relating to Ly-α: J2129.4 and the Sherwood simulations. Lyman-alpha line is a spectral line of hydrogen in the Lyman series among the strongest lines emitted by high-redshift galaxies. This review concludes the Keck DEIMOS and HST Grism Data. It indicates the gravitational lensing may be the most efficient method of galaxy detection, even in the era of the James Webb Space Telescope and conclude. This paper also summarizes the results of the Sherwood simulation, which shows that the simulations are perfectly corresponding to high resolution, high signal-to-noise observations of the Ly α forest over the redshift range $2 \leq z \leq 5$ although there are some discrepancies. This paper can help people have a picture of recent observation and simulations as well as shed light on guiding further exploration of Ly-α.

Keywords: Ly-α; High-redshift; Observation; Simulation.

1. Introduction

The Lyman alpha emission line of atomic hydrogen is one of the most luminous lines high-redshift galaxies [1]. For high-redshift galaxies, Lyman play an important role. For example, the Lyman α emission is important for confirming the highest redshift galaxies at $z > 5$ [2]. Because of its strength, it also helps scientists identifying the redshift of galaxies at $z \sim 2$–3 and at some extremely dusty galaxies [3]. In order to review recent observation and simulation, this paper summarize the information of J2129.4 and the results of Sherwood simulation.

To be specific, summarizing the data of J2129 gained from different ways and indicating the results and comparing the observation to the results of Sherwood simulation. The rest part of the paper will be presented following the organization as presented as follows. The Sec. 2 will briefly broadly descript the Ly-α. The Sec. 3 will introduce the detection facility. The Sec.4 will introduce the state-of-art results. The Sec.5 will talk about the limitation and prospects. The sec.6 will conclude this paper.

2. Descriptions of Lyman-alpha Line

2.1. Concept

Lyman-alpha line (Ly-α) is a spectral line of hydrogen in the Lyman series. It is produced by transitions of the electrons within hydrogen atom when the atomic electrons undergo the transitions from first excited state to the ground state. Lyman α is emitted from hydrogen, which is significantly produced in the universe. Its short wavelength(1216˚A) allows to locate the high-z objects very efficiently with more chances of dust attenuation in the process of resonant scattering caused by the physical nature of resonance line 1, which means it is an excellent probe of high-z objects near the observational redshift frontier [4].

2.2. Formation & Emitters

Typically, there are two ways to generate Ly-α including ionization and collision. After ionization, the hydrogen ion doesn’t have an electron. When the gas density is high enough and the temperature is not too high, the hydrogen ion can get an electron afterward. If this new electron goes to the first excited state, it will finally decay to the ground state. When collision happens between a neutral hydrogen atom and another particle, the electron is possible to reach the first excited state. Then, the electron immediately decays to the ground state, emitting a Lyman-alpha line. The galaxies which emitted Lyα, are so-called Lyα emitters which also called LAEs.

2.3. Sources of Emission in the Forming Galaxies

As mentioned above, Lyα is produced when electrons transit from first excited state to the ground state. Several processes in the forming of universe can contribute to this movement. Stars is one of sources. Stars going through the time when intense stars form, the most massive star (O and B stars) burn fast ionizing the neutral hydrogen atoms around them. Recombining of these hydrogen atoms emits bunches of Lyman-alpha lines [5]. Compared with the cooling, Lyα due to star formation will usually dominate. However, if the galaxy is very dusty, most of the "stellar" Lyα may be absorbed (since dust is close to the stars) while the cooling Lyα is typically emitted farther away from the dusty regions.

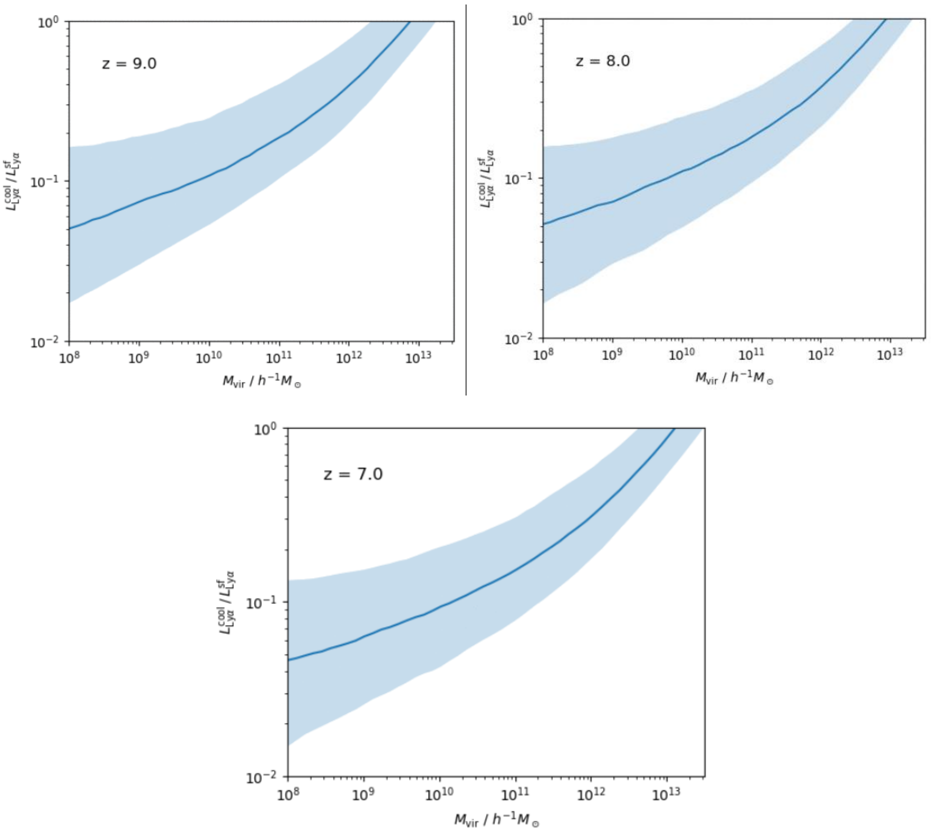

Fig. 1 Cooling-to-star formation Lyα ratio at z = 7, z = 8, and z = 9**:** Theoretical prediction of the ratio between Lyα due to cooling and Lyα due to star formation, as a function of the dark matter halo mass of the galaxy, and at various redshifts (z) / age of the Universe (t in "Gyr", i.e., billion years).

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3. Detection Facility

People can detect Lyα by using MOSFIRE [6]. As a matter of fact, it is a NIR multi-object spectrograph with a resolving power of R~3,500 for a 0.7" (0.508 mm) functionally as presented in Fig. 2. As sketch of the detector presented in Fig. 2, it is equipped with CSU as well as also has a large double filter wheel and a collimator. There is also a pupil mechanism with iris bladed [7].

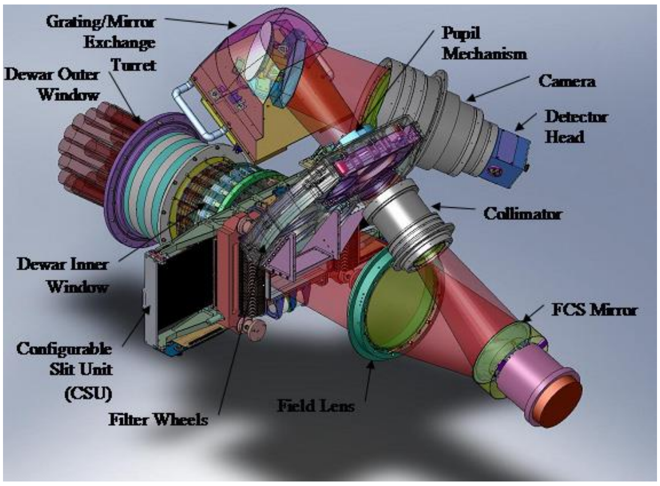

Fig. 2 The sketch of MOSFIRE

4. The State-of-art Results

4.1. J2129.4−0741

Some imaged galaxies are not directly observed and detected by spectroscopy but have strong constraints at redshifts up to ∼11 [8]. The highest imaged system spectrospically confirmed to date is the galaxy cluster MACS J2129.4−074. Researchers report the detection of Lyman-alpha from three sources [9].

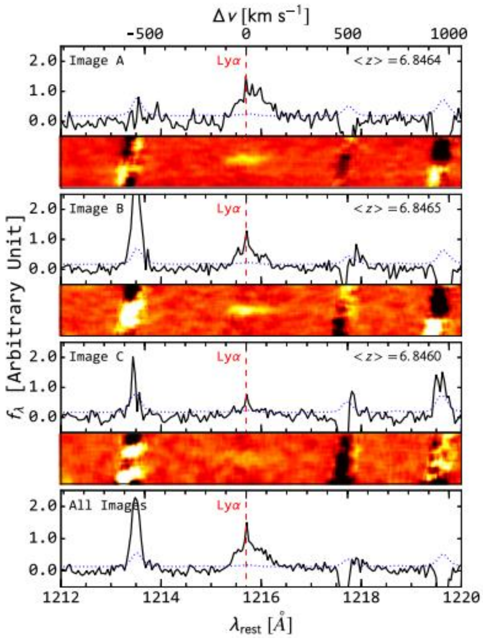

Fig. 3 The full-depth 1D and 2D Keck/DEIMOS spectra of different image.

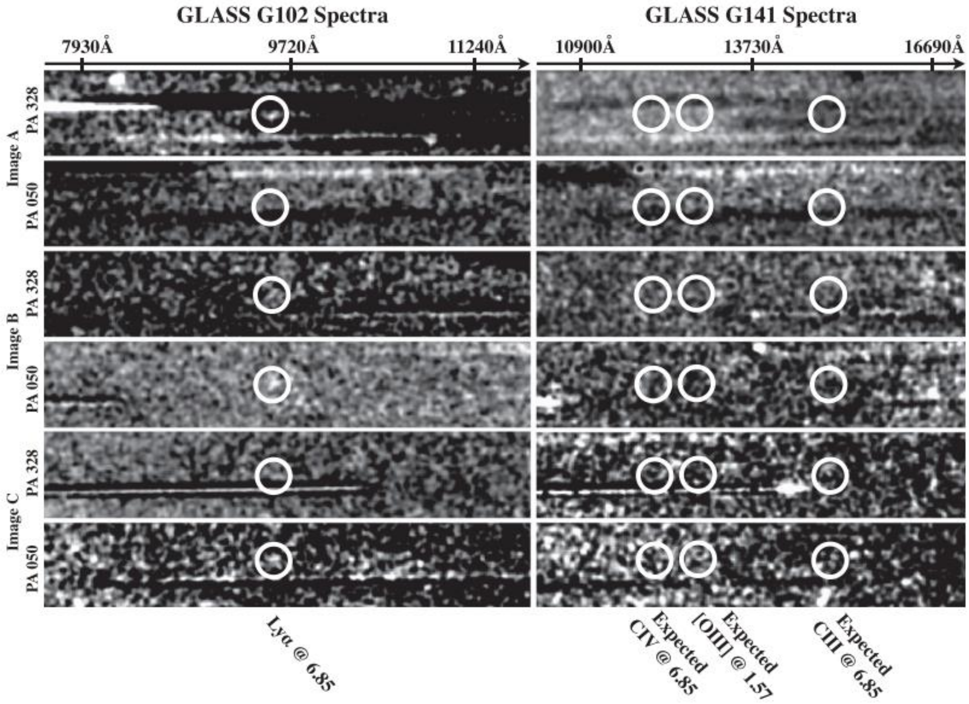

Fig. 4. Images A, B, and C's GLASS-obtained *HST* G102 and G141 GRISM spectra with contamination eliminated. The two position angles (PAs; 50° and 328°) at which the GRISM data were collected are shown separately. White circles indicate the wavelengths of the observed Ly-α line and the anticipated C_{IV} and C_{III} lines at z = 6.85. Additionally, one marks the $[O_{\text{III}}]$ line's anticipated sites at z = 1.57. The top limits on $[O_{\text{III}}]/[O_{\text{II}}]$ clearly support the z = 6.85 Ly-α interpretation. Besides, there is no observation of any appreciable flux at the predicted wavelength of the possible $[O_{\text{III}}]$ line.

As shown in Fig. 3, the observed results for A, B, and C are (9.9 ± 0.6)$\times 10^{-18}$, (5.7 ± 0.6´)$\times 10^{-18}$, and (3.7 ± 0.6´) $\times 10^{-18}$ erg $s^{-1}cm^{-2}$ around 9538 Å. They achieve 6.1s detection from the stacked 1D spectrum even for Image C. As shown in Fig.3., there are some data relating to slit loss corrected line fluxes and Lyα line luminosities. Also, the weighted average EW (equivalent width) of Ly-α is 74 ± 15 Å. In Figure 4, there is the extracted GRISM spectra for all three images. For HST GRISM data, researchers discovered that detecting the C_{IV} and C_{III} emission at z $\gtrsim$ 7 from available HST GRISM spectra is still difficult.

Lyα emission has recently been confirmed in several galaxies at z $\gtrsim$ 7 [10, 11]. Due to the depth of Spitzer image data available, the z $\gtrsim$ 7 galaxies identified in this way are mostly bright galaxies. [12]. The reside in dense regions within local HII bubbles [13]. In addition, all sub-L* galaxies at z $\gtrsim$ 7 are confirmed by Lyα emission [14,15]. By Lyα fraction in LBG (Pentericci et al. 2014). In some respects, the galaxy studied here resembles the galaxy z = 6.4 found behind MACS0717+3745 [16].

4.2. The Sherwood simulations

The Sherwood simulation suite is a new set of large-scale, high-resolution hydrodynamical simulations of the intergalactic medium. The simulations are perfectly corresponding to high resolution, high signal-to-noise observations of the Ly α forest over the over the redshift range 2 ≤ z ≤ 5. Base on the results, the recent ionizing background model must be increased Possibly because of the uncertain effect. At redshifts z < 2.5 star formation and galactic winds have the largest impact on the Ly α forest [17, 18]. The observed scatter in the mean transmitted flux corresponds reasonable [19]. The simulations suit the CDDF foresting proposed by other researchers [20]. Simulations also underpredict the incidence of saturated absorption lines with N_{HI} > $10^{14.5}$ cm^{-2}, though the problem is not resolved [21]. At z = 2.7 the simulations may be slightly too cold, which is possibly due to additional non-equilibrium heating not included in the simulations [22]. At z = 2.4, having a temperature at mean density of T_0 = 11 735 K, the lower cut-off in the b_{HI}–N_{HI} distribution for lines with $10^{12.5}$ cm^{-2} ≤ N_{HI} ≤ $10^{14.5}$ cm^{-2} measured by Rudie et al. [23] and re-analysed by Bolton et al. [24] broadly correspond with researchers' reference simulation while a slightly lower value (by $\Delta\gamma \cong 0.05 - 0.1$) [25].

5. Limitation & Prospects

Although Ly-α work well in many cases, there are some limitations. Due to they are resonant line, which happens if a photon's energy matches the ground state and the first excited state, when the atom de-excites, another photon with the same energy is emitted in another direction, which causes the diffusion in space. Thus, a Ly-α photon makes a random path before it can escape the galaxy and the direction where Ly-α is observed is not the direction from where it is emitted. Ly-α keep scattering, which is so-called radiative transfer process. It always takes a long distance, resulting the galaxy being surrounded by a Ly-α halo.

Because the galaxy is not perfectly spherical, depending on which direction people observe, the result may be bright or close to black. Moreover, there is diffusion in wavelength. The probability of a photon interacting with an atom is highly dependent on its exact wavelength. The probability is highest when the photon wavelength is exactly 1215.67 Å. However, as the atom moves away from the photon, the photon is Doppler-shifted in the atom's coordinate system. For example, if the photon has a wavelength of 1215.59 Å, it needs a velocity of about 20 km/s to redshift to 1215.67 Å, making it ten times more likely to be scattered. Therefore, Lyα's radiative transmission includes diffusion in both space and wavelength. Since the scattering probability decreases sharply with wavelength away from the central wavelength of 1215.67 Å, the typical spectrum of a Lyα-emitting galaxy has a double peak at about 1215.67 Å with zero intensity between the peaks. is. In addition, there is galactic outflows, if more photons are moving away from the source, blue peak is suppressed and the red peak is enhanced. These factors make it difficult for people to use Ly-α for detection. However, simulation can help scientists solve the problem. Fortunately, with the help of computers, scientists can still see how Lyα propagates through the interstellar medium of realistic galaxies and reaches telescopes then they can predict what they will observe and interpret what they observe.

6. Conclusion

In summary, this paper discusses the application of Ly-α based on the observation in a specific area and on a simulation. Specifically, the J2129.4-0741 and the Sherwood simulation. According ot the analysis, gravitational lensing may be the most efficient method of galaxy detection. Sherwood simulations are perfectly corresponding to high resolution, high signal-to-noise observations. Nevertheless, the diffusion in wavelength and in space and other properties of the universe may produce difficulties. In the future, people can solve the problem and gain more information. Overall, these results offer a guideline for the further exploration of Ly-α in universe.

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