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Latest Research Progress on the Size of Lyman Alpha Emitters

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Abstract: Research on the size of Lyman Alpha Emitters (LAEs) provides important clues for understanding the formation and structural characteristics of young galaxies. In recent years, with the accumulation of high-resolution imaging observations, significant progress has been made in understanding the size characteristics of LAEs. A large number of studies have shown that LAEs generally exhibit a compact galactic morphology, with their effective radii significantly smaller than those of typical star-forming galaxies, displaying characteristics of high stellar mass surface density and high specific star formation rate (sSFR). This compactness is believed to be closely related to their low dust content, strong feedback activities, and early assembly stage. Despite certain differences among different samples, current results generally support the compact size characteristics of LAEs. Overall, existing studies indicate that LAEs represent a class of compact young galactic systems, and their morphological characteristics provide important observational constraints for understanding the early stages of galaxy formation.

Keywords: Lyman Alpha Emitters (LAEs); High-redshift galaxies; Galaxy morphology

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1. Introduction

Lyman Alpha Emitters (LAEs) are a population of young, low-mass galaxies with high specific star formation rates (sSFR). Their intense Lyman alpha emission lines make them important observational windows for exploring early galaxy formation [1]. Since the widespread application of narrowband imaging and spectroscopic techniques [2-3], a large number of high-redshift LAE samples have been discovered, providing key data support for studying the physical mechanisms of galaxy formation, interstellar medium properties, and morphological structure evolution. Compared with aspects such as luminosity function, emission line properties, or ionization environment, the morphological characteristics of LAEs—especially their size structure—are equally significant in revealing the internal physical states of galaxies in the initial stages of formation [1].

In recent years, with the official launch of scientific observations by the James Webb Space Telescope (JWST)

[4], important progress has been made in detecting the structural characteristics of high-redshift Lyman alpha emitters (LAEs) [5-7]. Equipped with exceptional infrared imaging capabilities and high spatial resolution, JWST has provided unprecedented data support for the systematic study of the morphological properties of these distant celestial objects across a wide wavelength range. Observational studies have shown that LAEs typically exhibit significant spatial compactness, with their effective radii generally smaller than those of ordinary star-forming galaxies. This structural compactness is thought to be closely related to the high star formation surface density, low dust extinction, and intense galactic feedback activities within the galaxies. These physical conditions not only affect the efficiency of star formation but may also largely dominate the subsequent evolutionary paths of galaxies. Although several statistical studies have initially revealed the general rules regarding the size of LAEs, there are still certain differences among different observational samples. Factors such as imaging depth, sample selection methods, definition of continuum emission components, and measurement algorithms can all affect the estimation of structural parameters [8]. As JWST continues to conduct high-resolution, deep observations of LAEs, it is expected to resolve their morphological structures at finer scales, thereby further revealing the formation mechanisms and early evolutionary processes of LAEs and bringing new breakthroughs in understanding galaxy evolution.

This review aims to summarize the main research achievements on the morphological size of Lyman alpha emitters in recent years, sort out the current observational results and theoretical explanations, discuss the connection between size characteristics and galactic physical properties, and point out possible directions for future research. Through a systematic summary of existing literature, we hope to provide a more comprehensive perspective for understanding the structural nature of LAEs and their position in the framework of galaxy formation.

2. Definition of Galaxy Size

In observational astrophysics, the most commonly used and precise definition of galaxy size is the half-light radius r_e , obtained by fitting the two-dimensional surface brightness distribution of the galaxy with the Sérsic model. The mathematical form of this model is as follows:

$$I(r) = I_e \exp\{-b_n[(\frac{r}{r_e})^{\frac{1}{n}} - 1]\}$$

Where: I(r) is the surface brightness at radius r; I_e is the surface brightness at the half-light radius r_e; r_e (half-light radius) is the radius containing half of the galaxy's total luminosity, usually taken as the characteristic size of the galaxy; n is the Sérsic index, which describes the concentration of the galaxy's brightness distribution (when n=1, the profile decreases exponentially, corresponding to disk galaxies; when n=4, it conforms to the de Vaucouleurs law, corresponding to typical elliptical galaxies); b_n is a normalization constant related to n, ensuring that half of the total luminosity is contained within the radius r_e. Through this fitting, r_e provides a robust scale that excludes background noise and reflects the intrinsic structural characteristics of the galaxy.

3. JWST Observational Progress

The James Webb Space Telescope (JWST), with its exceptional infrared imaging and spectroscopic capabilities, has brought revolutionary progress to the morphological study of Lyman Alpha Emitters (LAEs), particularly achieving key breakthroughs in the structural resolution and radiation mechanism research of high-redshift sources [9-10]. Its Near-Infrared Camera (NIRCam) features high angular resolution and deep detection capabilities, enabling fine morphological decomposition of LAEs at redshifts z>3 on sub-kiloparsec scales. Meanwhile, the Mid-Infrared Instrument (MIRI) has further expanded the ability to detect Lyman alpha radiation in dust-obscured environments, providing a new window for understanding the radiation transfer processes in the early stages of galaxy formation.

In terms of size measurement, JWST's high-resolution images have advanced the study of LAE structures to a new stage. For example, Liu et al. used JWST/NIRCam to fit the Sérsic model to 10 spectroscopically confirmed LAEs at redshift z≈3.1 in the UDS field. The results showed that the median value of their typical half-light radii is 0.36 kpc, consistent with the characteristic of LAEs generally exhibiting compact structures on sub-kiloparsec scales [6]. This difference may stem from JWST's superior spatial resolution, which can more accurately distinguish between compact cores and extended components. Further supporting this trend, Ning et al. conducted a similar analysis on 14 spectroscopically confirmed LAEs at redshift z≈6 in the COSMOS field. The half-light radius obtained based on NIRCam data was further reduced to approximately 0.22 kpc, indicating a possible structural compactification trend in higher-redshift samples [7]. Additionally, Witten et al. found signs of merging in some LAEs, which are associated with the escape of Lyman alpha photons [5].

These observational results highlight JWST's unique advantage in resolving the morphological details of galaxies during the dawn of the nearby universe. Beyond the precise measurement of structural parameters, JWST's multi-wavelength joint observation capability allows researchers to compare the distribution of Lyman alpha radiation with the stellar mass distribution in the same galaxy, thereby revealing the interaction between photon transfer processes and the interstellar medium.

4. Conclusion

Systematic research on the size of Lyman Alpha Emitters (LAEs) provides a key observational window for understanding the formation and initial structure of galaxies in the early universe. This review summarizes the latest observational progress based on the James Webb Space Telescope (JWST), with the main conclusions as follows:

The launch of JWST has advanced LAE size research to new depths and precision. Its near-infrared high-resolution data not only confirms the compact nature of LAEs but also reveals a possible evolutionary trend: among samples from redshift z≈3 to z≈6, the measured half-light radii show a decreasing trend (e.g., from 0.36 kpc to 0.22 kpc). This may indicate that galaxies were structurally more compact at higher redshifts (earlier cosmic epochs). More importantly, JWST's multi-wavelength capability enables astronomers to compare the size of Lyman alpha emission with the size of the stellar mass distribution, opening up new avenues for directly studying radiation transfer processes (such as photon scattering) and gas distribution within galaxies.

In summary, observational studies have clearly shown that LAEs are a class of compact objects on sub-kiloparsec scales, and their structural characteristics are closely related to physical properties such as low dust content and high star formation rate. Leveraging JWST's powerful capabilities, the research paradigm is shifting from mere morphological description to in-depth analysis of physical mechanisms. In the future, conducting statistical research using JWST's growing larger samples and combining in-depth interpretation with radiative transfer models will be key to accurately revealing the origin of LAE sizes, understanding their star formation patterns on small scales, and determining their position in the galaxy evolution sequence.

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