The first galaxies of the Universe: exploring the Epoch of Reionization with JWST

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INTRODUCTION

The James Webb Space Telescope (JWST [2]) is revolutionizing our understanding of star-forming galaxies and the growth of supermassive black holes (SMBHs) particularly during the so-called **Epoch of Reionization** (EoR, redshift, $z>6$). At these z, optical emission lines like Hβ and Hα are redshifted into the near-infrared, making them accessible to JWST.

High-z galaxy mergers are expected to play a key role in galaxy evolution, as the merger rate increases with redshift. Gravitational interactions can disturb galactic structures and kinematics, producing features such as tidal tails.
High-z quasars, powered by rapidly accreting supermassive black holes, represent some of the most extreme phenomena in the Universe and pose fundamental questions about the origin and growth of the first black holes.
In this work, we present **new JWST results** of a **merging system of galaxies** and two **quasars** at the EoR, providing key insights into the co-evolution of galaxies and SMBHs in the early Universe.

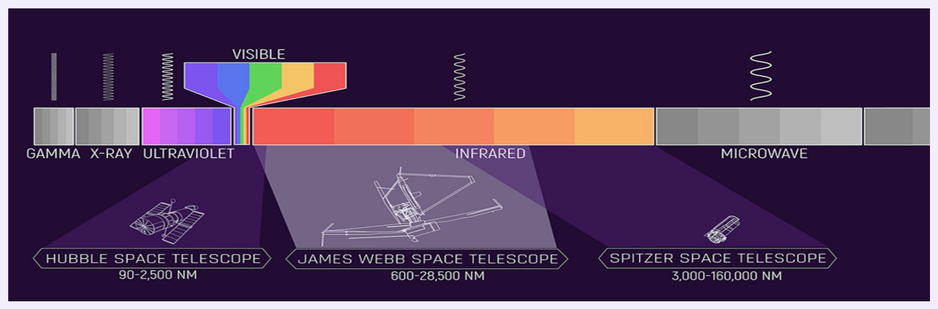

Figure 1. JWST wavelength range

OBSERVATIONS

ID #1
Name: B14-65666 (*Big Three Dragons*) [3]
Redshift: 7.15
(age Universe: 740 Myr)
Type of new data: Imaging + Spectroscopic [6]
Instrument of observation: Medium Infrared Spectrograph (MIRI/JWST)
Galaxy type: Star-forming
Special characteristics: Merging system

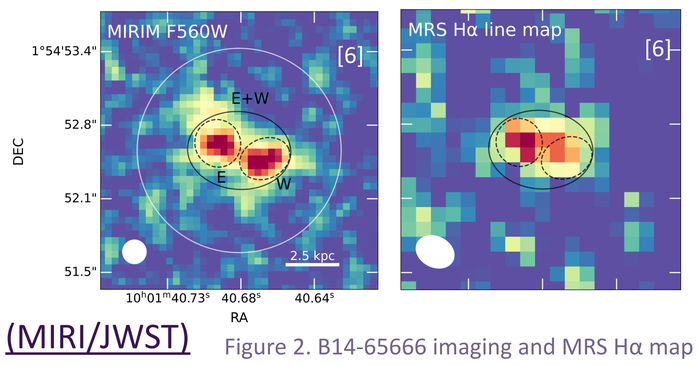

Figure 2. B14-65666 imaging and MRS Hα map

ID #2
Name: HSC J0859 +0022 [5]
Redshift: 6.39
(857 Myr)
Type of new data: Spectroscopic [*Prieto-Jiménez in prep.*]
Instrument of observation: Near Infrared Spectrograph (NIRSpec/JWST)
Galaxy type: Quasar (QSO)
Special characteristic: Low luminosity

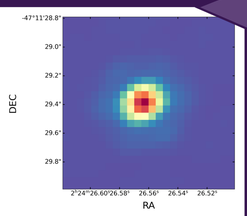

Figure 3. J0859 Hα map

ID #3
Name: VDES J0224 -4711 [7]
Redshift: 6.52
(835 Myr)
Type of new data: Spectroscopic [*Prieto-Jiménez in prep.*]
Instrument of observation: NIRSpec
Galaxy type: QSO
Special characteristic: Most X-ray luminous at z>6

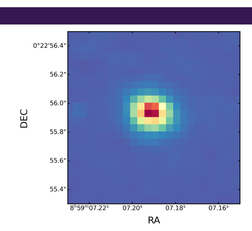

Figure 4. J0224 Hα map

ANALYSIS AND RESULTS

- The structure of the **Hα** emitting gas consists of **two galaxies** (E and W) with a relative velocity shift of 175 km s^{-1} (Fig. 5).
- The **SED fitting** of the galaxy, new data and combination of previous studies [3], reveals that the galaxy may have a **mature** stellar population and a **young** burst (Fig. 6).
- The two galaxies are experiencing an intense **starburst phase** (Fig. 7).

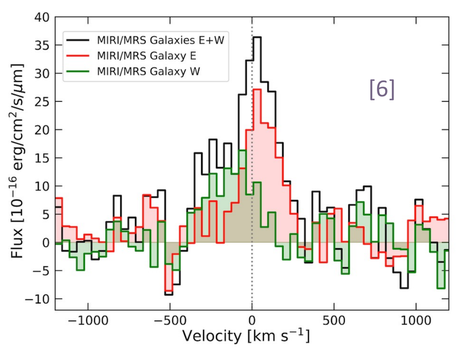

Figure 5. MIRI/MRS Hα emission line

- We identified galaxy E as an extremely **compact** source, characterized by a stellar-mass surface density close to that of the nuclei of low-z galaxies.
- Galaxy W shows a more elongated structure with four fainter clumps [8], reminiscent of star-forming regions along the tidal tails produced in **gas-rich interacting galaxies**.

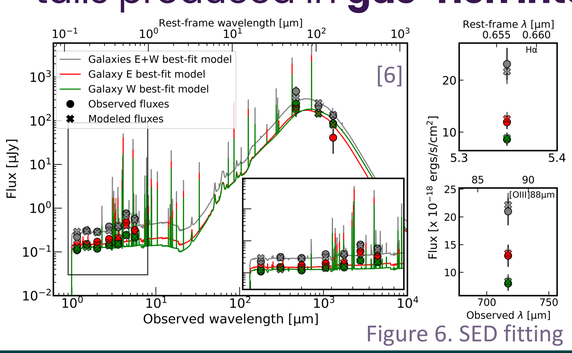

Figure 6. SED fitting

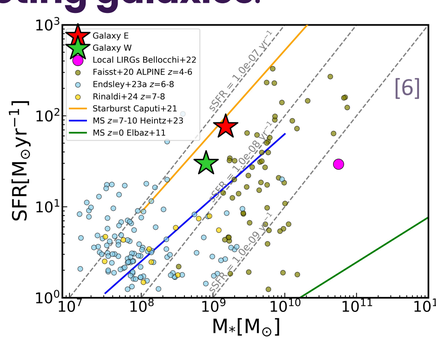

Figure 7. Star formation rate versus stellar mass

- The brightest nebular lines presented in the continuum-subtracted spectrum are **Hβ, [OIII]4959, 5007, Hα, [NII]6564, 6583**.
- We identify **narrow line region** and **broad line region** in both QSOs (Fig. 8, 9).
- With the Hα [1] we measure the **black hole mass** of both QSOs: $2x10^8$ and $5x10^9 M_\odot$ (respectively).

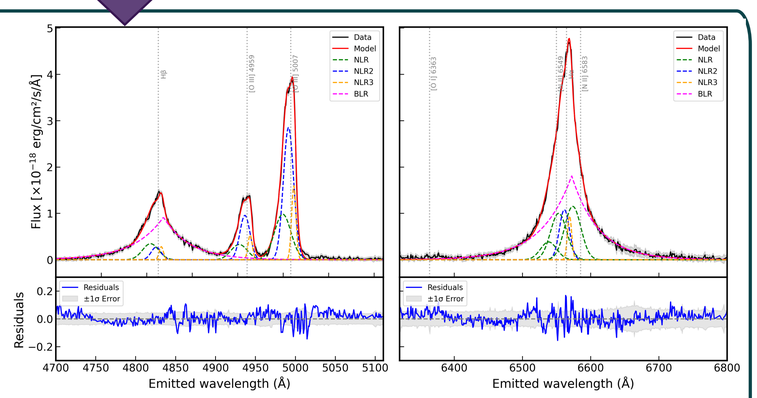

Figure 8. J0859 NIRSpec spectrum

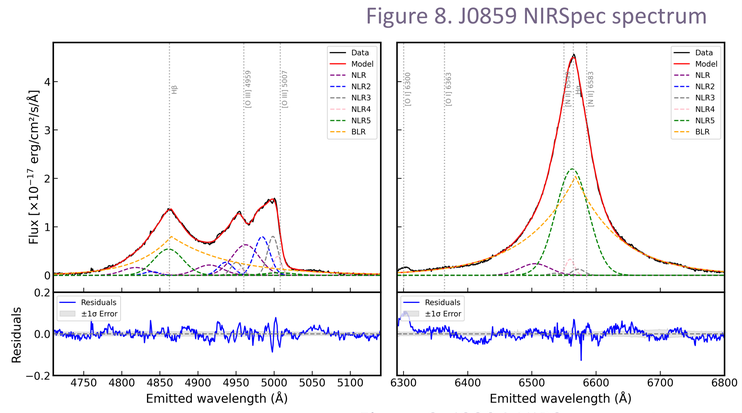

Figure 9. J0224 NIRSpec spectrum

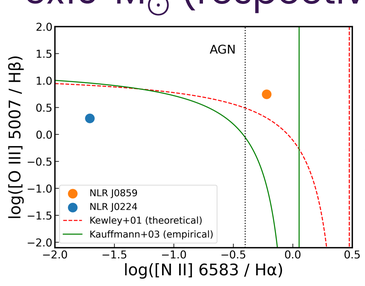

Figure 10. BPT diagram

- The classical "Baldwin, Phillips & Terlevich" (**BPT**) diagram [4] allows us to investigate the **dominant ionisation source** for the emitting gas across the quasars (Fig. 10).

CONCLUSIONS AND FUTURE WORK

We have studied for the **first time** the Hα emission line in the **merging system** B14-65666, and optical lines in the **QSOs** J0859 and J0224. The high resolution and sensitivity **of MIRI/JWST** and **NIRSpec/JWST** observations enable us to investigate the properties when the age of the Universe was only **740-860 Myr.**
The results obtained for **B14-65666** agree with cosmological simulations in the early Universe.
The results obtained for the **QSOs** give us the physical properties of the system. We aim to characterize the environment of both high-z quasars and look for satellites and companions.

REFERENCES

[1] Dalla Bontà, E., et al. 2025, A&A, 696, A48
[2] Gardener et al. 2023, PASP, 135, 068001
[3] Hashimoto et al. 2019, PASJ, 71, 71
[4] Kewley, L.J. et al. 2013, ApJ, 774L, 10K
[5] Matsuoka et al. 2016, ApJ, 828, 26
[6] Prieto-Jiménez, C. et al. 2025 A&A, 701, A31
[7] Reed, S. L et al. 2017, MNRAS, 468, 4702
[8] Sugahara et al. 2025, ApJ, 981, 135

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