High-z Lyman break galaxies with JWST: parallel observations of dwarf satellites

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The upcoming advent of the James Webb Space Telescope (JWST) will revolutionise our understanding of the distant Universe, allowing us to unveil the properties of the faintest galaxies during the Epoch of Reionization ($z > 6$). Among the numerous new sources that will be discovered, we are particularly interested in dwarf galaxies ($M_\star < 10^9 \mathrm{M}_\odot$). These objects are indeed fundamental in cosmic history since they are the first galaxies to form in the Universe and they represent the basic building blocks responsible for the build-up, through merger events, of the massive galaxies we see today. Dwarf galaxies have been observed and studied in great details in the Local Universe, where dozens of them live as *satellites* of more massive galaxies like our Milky Way [1]. At high-z we do expect an analogous situation, i.e. the presence of not only *isolated* dwarf galaxies in the field [2], but also of *satellite* dwarf galaxies dwelling around massive systems like Lyman Break Galaxies (LBG). I investigated for the first time high-z dwarf satellite galaxies in order to answer some fundamental questions: what are the expected physical properties of this distinct population of dwarf galaxies living in dense environments around massive LBGs? Will JWST be able to detect them for the first time?

To address these questions I used a state-of-art cosmological simulation, described in [3]. It is an high-resolution ($\Delta x \approx 10\,\mathrm{pc}$) simulation that follows the evolution of a massive LBG ($M_\star \simeq 10^{10} \mathrm{M}_\odot$) up to $z \sim 6$, reproducing the typical observed properties. I inspected the surrounding regions of the LBG, finding that five dwarf galaxies and one proto-globular cluster live within its virial halo. In the following, I first describe their main evolutionary and stellar properties (as detailed in [4]), and then I take a step further studying their expected stellar emission and predicting their detectability with JWST [5].

Dwarf satellites of high-z LBGs

My analysis [4] demonstrated that the evolutionary and chemical properties of high-z dwarf galaxy satellites are independent of their orbits, while they are regulated by their mass. This is illustrated in Figure 1, where the age-metallicity relation, star formation rate and metallicity distribution function are shown, for satellites pertaining to different categories. Low-mass dwarf satellites ($M_\star < 5 \times 10^8 \mathrm{M}_\odot$, upper panel) experience short and intense bursts of star formation ($< 50\,\mathrm{Myr}$) and are then completely quenched by internal *SN feedback*. On the other hand, high-mass satellites ($M_\star > 5 \times 10^8 \mathrm{M}_\odot$, lower panel) have much longer star formation histories, fueled by the numerous *merger events* characterising the dense environment surrounding the massive LBG. We note that both types of satellites are highly enriched in metals with respect to typical isolated dwarf galaxies, reflecting an interstellar medium that by $z \sim 6$ has already been significantly polluted with heavy elements by the central LBG. In this scenario, high-mass dwarf satellites typically form at earlier times ($z > 9$) in a still pristine environment. However, despite their initial higher metallicities, low-mass systems contain a larger amount ($> 50\%$) of metal-poor stars ($\log Z_\star/\mathrm{Z}_\odot < -0.5$), due to their shorter star formation histories.

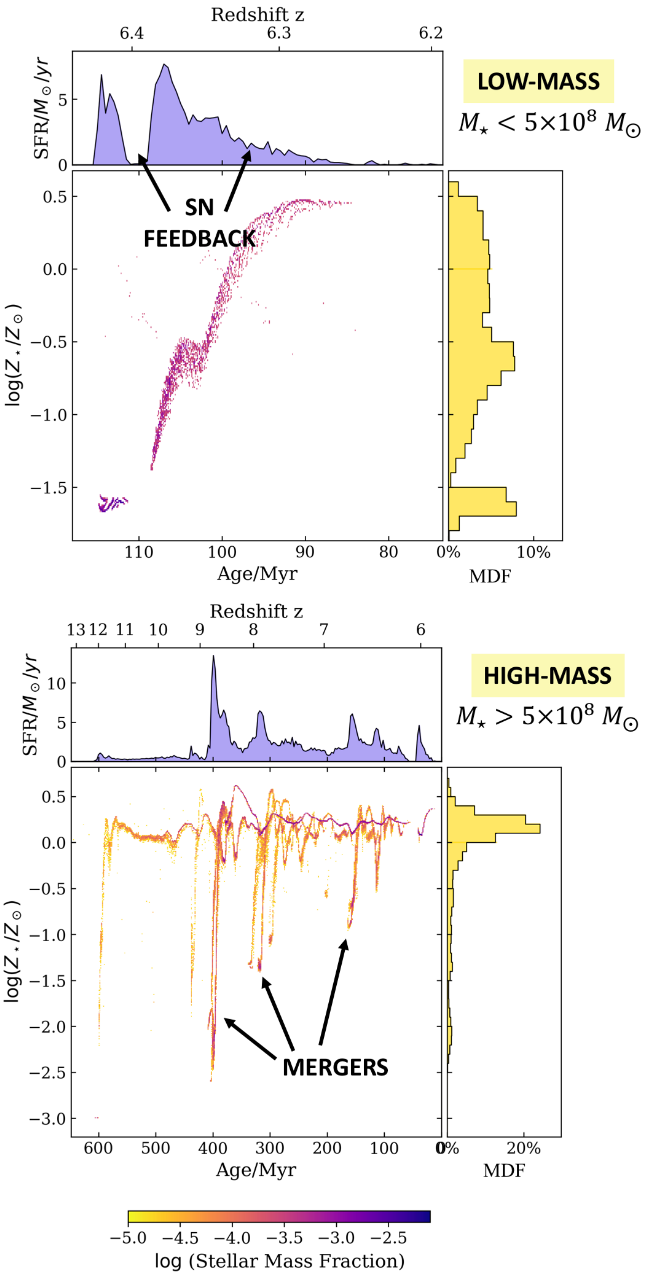

Figure 1: Examples of stellar age - metallicity relation (centre), star formation rate (top) and metallicity distribution function (right) for the two types of satellite dwarf galaxies.

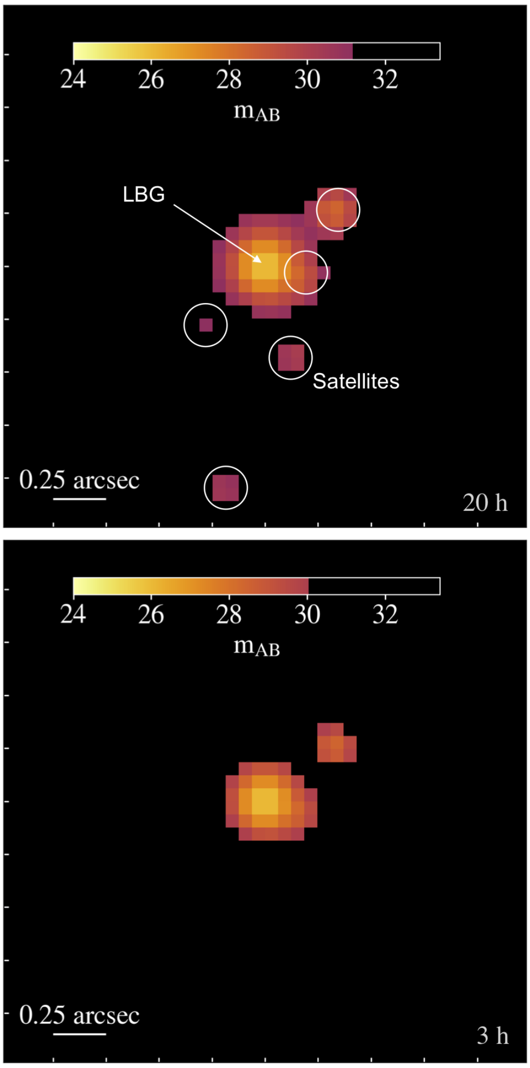

Figure 2: Synthetic images of the central LBG and its dwarf satellites in the filter F356W, for 20h (top) and 3h (bottom).

Can we detect high-z satellites?

In order to understand if the detection of high-z satellites will be feasible through imaging and photometry already during the first deep surveys with JWST (e.g., JADES), I reconstructed their expected spectra [5].

I used STARBURST99 [6] to model their stellar emission at all stages of their evolution up to $z \sim 6$, and I also took into account the attenuation of dust [7]. I then produced synthetic images of the system of LBG and its dwarf satellites in order to understand if these can be spatially resolved by JWST and their emission disentangled from that of the highly luminous central galaxy. In Figure 2, I show as an example the results at $z \sim 6$ in the filter F356W of the NIRCam instrument. The coloured pixels show the flux above the S/N~ 3 sensitivity threshold for different exposure times. Noticeably the emission of all five dwarf galaxies is detectable in 20 hours, despite most satellites being at the faintest level of their evolution at the displayed stage, having been quenched by SNe feedback (Figure 1). Moreover, the flux of the two most massive satellites can be detected in just 3 hours. The images reveal that we can disentangle the emission of the satellites from the one of the central LBG if they are located at a distance of at least $> 0.25''$ from its centre, requirement achieved by all our galaxies except for one. Having demonstrated that JWST/NIRCam will indeed be able to catch the stellar emission of satellites of LBGs, I also derived color-magnitude diagrams of all the systems during their evolution. I found that the color F200W-F356W will represent a powerful diagnostic tool that can be used to identify star-bursting, low-mass, metal poor systems.

Already during the first planned campaigns, as for instance with the deep JADES survey, NIRCam will provide observations of dozens of LBGs. As a consequence, we expect to obtain *for free* and *for the first time* the detection of hundreds of satellite dwarf galaxies: a free lunch for JWST.

References

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