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The discovery of the most UV–Ly α luminous star-forming galaxy: a young, dust- and metal-poor starburst with QSO-like luminosities

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ABSTRACT

We report the discovery of BOSS-EUVLG1 at $z = 2.469$, by far the most luminous, almost un-obscured star-forming galaxy known at any redshift. First classified as a QSO within the Baryon Oscillation Spectroscopic Survey, follow-up observations with the Gran Telescopio Canarias reveal that its large luminosity, $M_{\rm UV} \simeq -24.40$ and $\log(L_{{\rm Ly}\alpha}/{\rm erg\ s^{-1}}) \simeq 44.0$, is due to an intense burst of star formation, and not to an active galactic nucleus or gravitational lensing. BOSS-EUVLG1 is a compact ($r_{\rm eff} \simeq 1.2$ kpc), young (4–5 Myr) starburst with a stellar mass $\log(M_*/{\rm M_\odot}) = 10.0 \pm 0.1$ and a prodigious star formation rate of $\simeq$1000 ${\rm M_\odot\ yr^{-1}}$. However, it is metal- and dust-poor [$12 + \log({\rm O/H}) = 8.13 \pm 0.19$, $E(B-V) \simeq 0.07$, $\log(L_{\rm IR}/L_{\rm UV}) < -1.2$], indicating that we are witnessing the very early phase of an intense starburst that has had no time to enrich the ISM. BOSS-EUVLG1 might represent a short-lived (<100 Myr), yet important phase of star-forming galaxies at high redshift that has been missed in previous surveys. Within a galaxy evolutionary scheme, BOSS-EUVLG1 could likely represent the very initial phases in the evolution of massive quiescent galaxies, even before the dusty star-forming phase.

Key words: galaxies: formation – galaxies: high-redshift.

1 INTRODUCTION

Over the past decades, deep extragalactic surveys have been designed to identify star-forming galaxies (SFGs) at high redshift ($z > 2$), such as Lyman break galaxies (LBGs) and Lyman α emitters (LAEs), providing a wealth of information on their physical properties (e.g. Shapley et al. 2003) and investigating their space density as a function of luminosity through luminosity functions (LFs; e.g. Reddy & Steidel 2009; Sobral et al. 2018a). The bright-end of LFs of the UV and Ly α emission probes massive star formation, however, identifying such UV/Ly α-luminous SFGs is challenging due to their very low space density. The most efficient SFGs consume their gas faster, implying short time-scales of their luminous phases, thus low observable abundances. Furthermore, star formation produces dust, so that the most vigorous and intrinsically luminous SFGs are expected to have their emission at short wavelengths heavily obscured (e.g. dusty star-forming galaxies, DSFGs; Casey, Narayanan & Cooray 2014). Probing the bright-end of LFs requires thus very large area surveys and, in addition, spectroscopic follow-up to distinguish SFGs from the much more abundant active galactic nuclei (AGNs; e.g. Sobral et al. 2018b). However, the widest dedicated surveys at $z \simeq 2-3$ with a few deg^2 (e.g. Ouchi et al. 2008; Sobral et al. 2018b) have failed to discover SFGs more luminous than two times the typical luminosity (L^*) of UV and Ly α of LBGs/LAEs, implying maximal un-obscured luminosities by a starburst of $M_{\rm UV} = -21.5$ and $\log(L_{{\rm Ly}\alpha}/{\rm erg\ s^{-1}}) = 43.3$ (Sobral et al. 2018b).

In this Letter, we study SDSS J122040.72+084238.1, hereafter BOSS-EUVLG1, located at $(\alpha, \delta)_{\rm J2000} = (185.^\circ1697, 8.^\circ7106)$ with a redshift $z = 2.469$. It was discovered as part of our search for extremely UV-luminous galaxies (EUVLGs, $M_{\rm UV} < -23$) within the ∼9300 deg^2-wide extended Baryon Oscillation Spectroscopic Survey (eBOSS; Abolfathi et al. 2018) of the Sloan Digital Sky Survey (SDSS; Eisenstein et al. 2011). BOSS-EUVLG1 is the most luminous, un-obscured star-forming galaxy known in the Universe by far, with $M_{\rm UV} = -24.4$ and $\log(L_{{\rm Ly}\alpha}/{\rm erg\ s^{-1}}) = 44.0$. Throughout this work, we assume a Salpeter (1955) initial mass function (IMF) and a concordance cosmology with $\Omega_{\rm m} = 0.274$, $\Omega_\Lambda = 0.726$, and $H_0 = 70\ {\rm km\ s^{-1}\ Mpc^{-1}}$. All magnitudes are given in the AB system.

2 DISCOVERY AND FOLLOW-UP OBSERVATIONS

In our survey 'BOSS Extremely UV-Luminous Galaxies' (BOSS-EUVLG), we have identified a total of ∼70 SFGs at $2 < z < 4$ with $-24.5 < M_{\rm UV} < -23$, being BOSS-EUVLG1 the brightest and most luminous one, and the subject of this work. The sample and the

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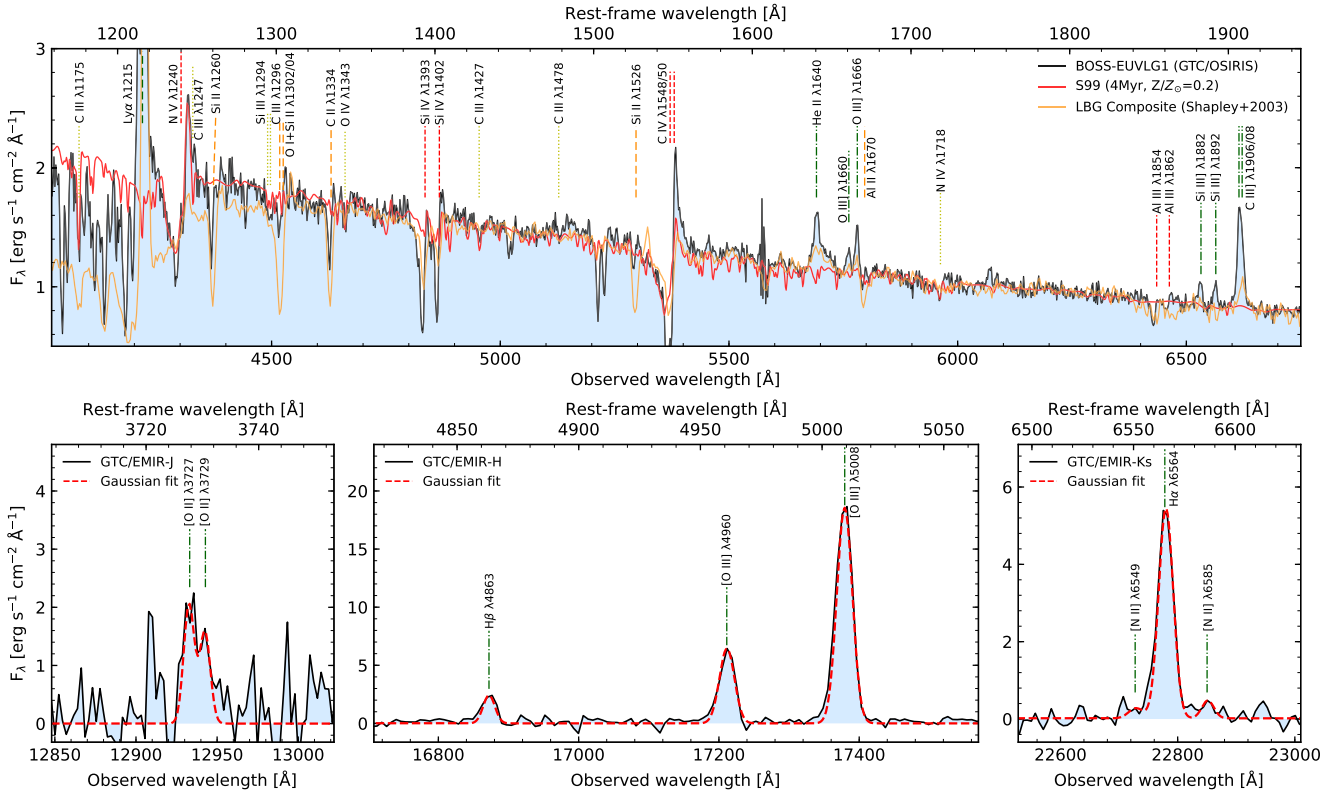


Figure 1. GTC rest-frame UV (up) and optical (down) spectra of BOSS-EUVLG1. Ticks mark the positions of main features associated with stellar P-Cygni wind lines (red) and photospheric absorption (yellow), nebular emission (green), and ISM absorption (orange). The best-fitting S99 model with age of 4 Myr and $Z/Z_{\odot} = 1/5$ is shown in red [$E(B-V) = 0.07$]. The $z \sim 3$ LBG composite at the redshift of BOSS-EUVLG1 is shown in orange (Shapley et al. 2003).

selection techniques will be presented in a future work (Marques-Chaves et al., in preparation). Its BOSS spectrum (plate-mjd-fiberid: 5397-55944-626) shows features characteristic of an un-obscured, luminous SFG without any evidence so far of a hidden AGN, showing narrow C III] emission (∼200 km s^{-1} full width at half-maximum, FWHM) and strong P-Cygni stellar profiles. The systemic redshift $z = 2.4694 \pm 0.0004$ is measured from the C III] doublet.

Optical and near-IR long-slit spectroscopy were obtained with the Gran Telescopio Canarias (GTC) OSIRIS and EMIR instruments, respectively, as part of the programmes GTC67-17A and GTCMULTIPLE2F-18A (PI: R. Marques-Chaves). OSIRIS observations were performed using the R1000B grism ($R \sim 700$) with a total integration time of 50 min. The data were reduced with standard IRAF tasks. Near-IR spectra were obtained using the J ($R \sim 3000$) and HK grisms ($R \sim 700$) with a total observing time of 27 and 43 min, respectively. Reduction was performed using the EMIR pipeline. Optical and near-IR spectra were flux calibrated using standards stars, and their fluxes matched those obtained from photometry. Optical and near-IR spectra of BOSS-EUVLG1 are shown in Fig. 1.

Broad-band imaging were also obtained in the near-IR with EMIR, using J, H, and K_s filters. These were flux calibrated against 2MASS stars in the field. We also used archival Canada–France–Hawaii Telescope (CFHT) optical images in U to Z bands processed with the MegaPipe image staking pipeline (Gwyn 2008). Both optical and near-IR images have sub-arcsec seeing conditions ≃0.55–0.9 arcsec FWHM). We use aperture photometry with a diameter of 2.5× FWHM. BOSS-EUVLG1 is also detected in the mid-IR in the sixth year NEOWISE 2020 data release (Meisner, Lang & Schlegel 2017) at 3.4 μm ($W1 = 20.60 \pm 0.11$), but not at 4.6 μm (3σ limit $W2 > 21.20$). Finally, we observed the dust continuum toward BOSS-EUVLG1 at 1.2 mm using the Atacama Large submillimeter/Millimeter Array (ALMA: project ID: 2018.1.00932.S; PI: R. Marques-Chaves) with a total on source time of 5.6 min. Data reduction was performed using version 5.4.0 of the Common Astronomy Software Applications (CASA) package. BOSS-EUVLG1 is not detected with a 3σ limit of 37 μJy (beam size of 0.62 arcsec × 0.61 arcsec).

3 RESULTS AND DISCUSSION

3.1 The nature of BOSS-EUVLG1

The most striking property of BOSS-EUVLG1 is its brightness, and corresponding large luminosities at $z \simeq 2.469$, in both the rest-frame UV continuum ($R \simeq 20.8$) and nebular emission (fluxes in Ly α and H α above 10^{-15} erg s^{-1} cm^{-2}, Table 1). Such apparent fluxes are much larger than those observed in typical SFGs (factors ≈30; e.g. Reddy & Steidel 2009; Sobral et al. 2018a) and are only comparable to those observed in highly magnified lensed systems (e.g. Shu et al. 2016; Marques-Chaves et al. 2020) or in QSOs (e.g. Pâris et al. 2014).

3.1.1 Neither lensed galaxy nor luminous AGN

The lack of lensing structures, such as multiple images or arc-like morphologies, and foreground galaxies in optical and near-IR images (Fig. 2a) make unlikely that BOSS-EUVLG1 is being magnified by gravitational lensing. It shows a compact morphology that is only barely resolved in images taken with very good seeing conditions.

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Table 1. Integrated fluxes and rest-frame equivalent widths (units of 10^{-17} erg s^{-1} cm^{-2} and Å, respectively) of main nebular emission lines in BOSS-EUVLG1. The values of He II 1640 Å refer to the narrow component.

Line	Ly α	He II	C III]	[O II]	H β	[O III]	[O III]	H α	[N II]
$\lambda_{\rm rest}^{\rm vac}$ (Å)	1215.57	1640.42	1906.68, 1908.68	3727.09, 3729.88	4862.68	4960.30	5008.24	6564.61	6585.27
Flux	194 ± 17	4.6 ± 0.4	17.3 ± 0.9	18 ± 4, 13 ± 3	61 ± 5	176 ± 6	562 ± 7	190 ± 5	$<12(3\sigma)$
EW$_0$	22 ± 3	1.0 ± 0.1	4.4 ± 0.2	–	115 ± 25	350 ± 70	1125 ± 225	685 ± 185	$<43(3\sigma)$

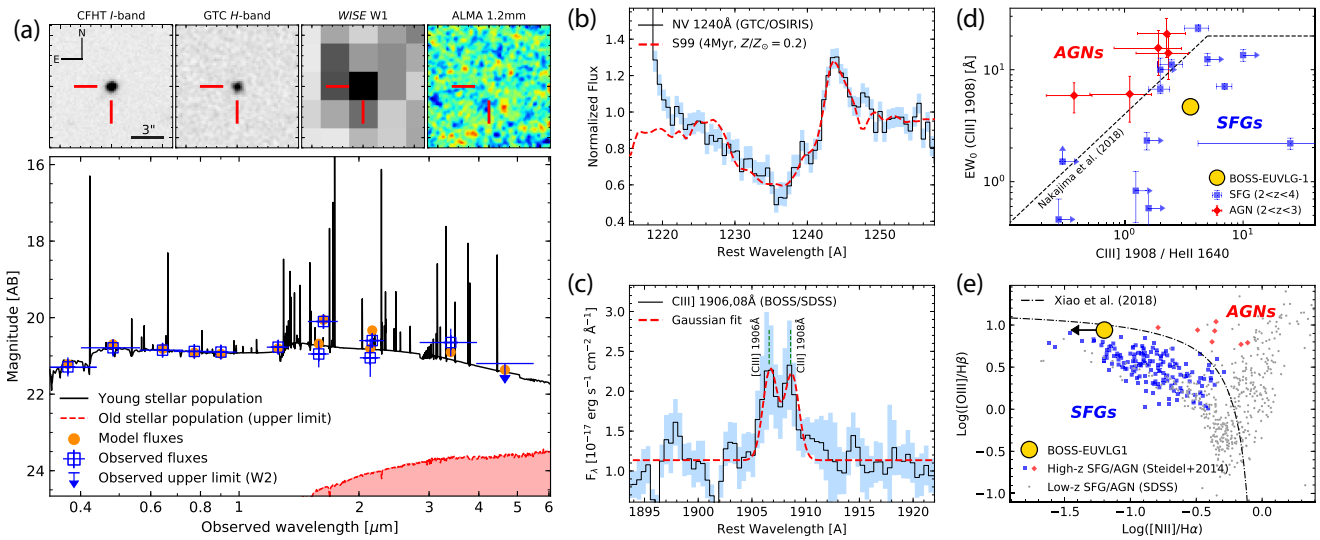


Figure 2. Summary of the main results. (a) Cutout images of BOSS-EUVLG1 (12 arcsec × 12 arcsec) in selected bands from optical to mm (top) and best-fitting SED of BOSS-EUVLG1, characterized by a young and intense burst of star formation (down); (b) comparison of the normalized GTC spectrum (black) with the best-fitting model (4 Myr and $Z/Z_\odot = 1/5$, dashed red) around the wind line N V; (c) [C III] nebular emission as seen in the BOSS spectrum (black). The resolved lines have widths of $\simeq$200 km s^{-1} FWHM; (d and e): BOSS-EUVLG1 (yellow circle) in the rest-frame UV and optical line diagnostics (Nakajima et al. 2018, panel d; and Xiao et al. 2018, BPT, panel e).

Using the CFHT *I* band (seeing $\simeq$0.55 arcsec FWHM) and GALFIT (Peng et al. 2002), the light distribution of BOSS-EUVLG1 is well modelled with a Sersic profile with an effective radius $r_{\rm eff} = 0.15 \pm 0.04$ arcsec (1.2 ± 0.3 kpc) and an index $n = 1.3 \pm 0.4$.

A strong contribution of an AGN is highly unlikely. The rest-frame UV and optical spectra (Fig. 1) show several spectral features that are common in SFGs. In particular, stellar wind P-Cygni profiles (N V 1240 Å or C IV 1550 Å) and photospheric absorption lines (e.g. C III 1427 Å or N IV 1718 Å) are clearly detected with high significance, indicating that the UV luminosity is dominated by stellar emission (at least >70 per cent) rather than AGN emission (Fig. 2b). Nebular emission also presents intrinsic narrow spectral profiles, e.g. $\simeq$200 km s^{-1} FWHM for C III] and [O II] 3726, 3729 Å in the BOSS and EMIR/J spectra, respectively (Figs 1 and 2c). The exception is the He II 1640 Å emission line, that shows two clearly distinguished components, one narrow from nebular emission and another one much broader ($\simeq$ 2600 km s^{-1} FWHM) likely associated with the presence of a large number of Wolf–Rayet stars (Schaerer & Vacca 1998). The mid-IR colour $W1 - W2 < -0.60$ also disfavours the presence of a strong AGN component, which typically shows $W1 - W2 > 0.2$ at $z \approx 2.5$ from the dust torus (Assef et al. 2013). We also use rest-frame UV and optical line diagnostics to investigate the contribution of an AGN to the nebular emission (Figs 2d and e). Following the star-formation and AGN models of Nakajima et al. (2018), the observed line ratio of C III]/He II = 3.6 ± 0.4 and the C III] rest-frame equivalent width 4.4 ± 0.2 Å (Table 1) place BOSS-EUVLG1 in the star formation region. The line ratios of log([O III]/H β) = 0.96 ± 0.03 and log([N II]/H α) < -1.20 (3σ) place it far away from the locus of low-z SFGs, but close to that expected for high-z SFGs (e.g. Steidel et al. 2014) with high ionizing parameters, U, and large electron density, $n_{\rm e}$ (Xiao, Stanway & Eldridge 2018). Indeed, the large [O III]/[O II] $\simeq$ 18 and [O II] 3729/3726 $\simeq$ 0.7 (Table 1) suggest such extreme properties [log(U) > −2 and log($n_{\rm e}$/cm^{-3}) > 10^3, Marques-Chaves, in preparation].

3.1.2 *BOSS-EUVLG1 as an extremely luminous starburst*

Our results indicate that the large luminosity is not arising from an AGN and that the effect of gravitational lensing is highly unlikely. Instead, the large luminosities arise from a large number of OB stars present in the first stages of an intense burst of star formation. We compare the wind line profiles of N V and C IV to those obtained with the spectral synthesis code STARBURST99 (S99; Leitherer et al. 1999) to infer the age and metallicity of the stellar population (details in Marques-Chaves et al. 2018, 2020). P-Cygni profiles are well modelled by a $Z/Z_\odot \simeq 1/5$ and $\simeq$4 Myr burst of star formation (Fig. 1). We infer a colour excess of the stellar continuum $E(B-V)_* = 0.07 \pm 0.02$ (Calzetti et al. 2000) by comparing the observed UV slope $\beta_{\rm UV}^{\rm obs} = -2.16 \pm 0.05$ with that from the best-fitting S99 model ($\beta_{\rm UV}^{\rm syn} = -2.44$).

BOSS-EUVLG1 shows a flat spectral energy distribution (SED) from optical to the mid-IR ($R - W2 < -0.35$), except in the near-IR H and $K_{\rm s}$ bands where a flux excess is clear identified (e.g. $J - H = 0.67 \pm 0.13$, Fig. 2a) due to the strong contribution of rest-frame optical H β + [O III] and H α emission to the H and $K_{\rm s}$ bands.

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We perform SED-fitting with CIGALE (Boquien et al. 2019) using the broad-band photometry (from *U* to *W2* bands), two synthetic bands generated from the collapsed EMIR spectra that sample the rest-frame optical continuum free from nebular emission, and the observed Hβ + [O III] and Hα line fluxes. The star formation history (SFH) is modelled using two components; (i) instantaneous SFH with ages ranging from 1 to 10 Myr, and (ii) a exponentially declining SFH with ages >1 Gyr. We adopted the stellar population models from Bruzual & Charlot (2003), and the Calzetti et al. (2000) dust attenuation law. The metallicity is fixed to $Z/Z_{\odot} = 1/5$. The best-fitting model, shown in Fig. 2(a), indicates that BOSS-EUVLG1 is dominated by a young stellar burst characterized by an SFR $= 1060 \pm 100$ M$_{\odot}$ yr^{-1}, an age of 5 ± 1 Myr, and a stellar mass of $\log(M_*/\mathrm{M}_{\odot}) = 10.0 \pm 0.1$. This yields to a high specific SFR (sSFR = SFR/M_*) of 106 ± 15 Gyr^{-1}. The old stellar population is not well constrained, yet it should be faint as the SED from *U* to *W2* (0.10−1.33 μm rest-frame) is dominated by the emission from the young burst, and should be less massive than $\log(M_*^{\mathrm{old}}/\mathrm{M}_{\odot}) < 10.2$ otherwise a >3σ detection at 4.6 μm would be expected (Fig. 2a).

Turning to the nebular emission, BOSS-EUVLG1 shows intense lines in the rest-frame UV and optical (Fig. 1 and Table 1). The detection of nebular He II emission and the large [O III]/[O II] $\simeq 18$ are indicative of a hard ionizing spectrum. The rest-frame equivalent widths EW$_0$(Hβ) $= 115 \pm 25$ Å and EW$_0$(Hα) $= 685 \pm 185$ Å are consistent with S99 burst models with age ≃4 Myr. Using the Hα flux, we measure a total SFR(Hα) $= 955 \pm 135$ M$_{\odot}$ yr^{-1} (Kennicutt 1998), after correction for dust obscuration using the observed line ratio Hα/Hβ $= 3.10 \pm 0.18$ [$E(B-V)_{\mathrm{neb}} = 0.07 \pm 0.05$, Calzetti et al. 2000]. The SFR(Hα) is significantly larger than that measured using the UV luminosity, SFR(UV) $= 680 \pm 125$ M$_{\odot}$ yr^{-1} (Kennicutt 1998), but expected for very young starbursts like BOSS-EUVLG1, as Hα and UV indicators trace different time-scales (∼10 and 100 Myr, respectively; e.g. Flores Velázquez et al. 2020). The Lyα emission is not spatially resolved (<0.8 arcsec FWHM). Its spectral profile shows two different velocity components. The main component (≃90 per cent of the total flux) appears redshifted relative to the rest velocity by 260 ± 60 km s^{-1} and shows an intrinsic FWHM of ≃480 km s^{-1}. A second and fainter component (10 per cent of the total flux) is found blueshifted by ≃−650 km s^{-1}. Assuming case-B recombination, we measure a total Lyα escape fraction $f_{\mathrm{esc}}(\mathrm{Ly}\,\alpha) = 0.10 \pm 0.2$, in line with the empirical relation derived by Sobral & Matthee (2019) considering the EW$_0$(Lyα) $= 22 \pm 3$ Å. We measure a dust-corrected line ratio $R23 = ([\mathrm{O\,II}] + [\mathrm{O\,III}])/\mathrm{H}\beta = 12.5 \pm 3.3$, yielding to a nebular metallicity $12 + \log(\mathrm{O/H}) = 8.13 \pm 0.19$ (Pilyugin & Thuan 2005), compatible with that measured for the young stellar population. The ISM of BOSS-EUVLG1 also appears mostly ionized, showing weak low-ionization ISM lines (e.g. EW$_0$ ≃ 0.66 Å for Si II 1260 Å), but strong high-ionization ones (e.g. ≃2.55 Å for Si IV 1393 Å). These lines have their centroids blueshifted by -320 ± 80 km s^{-1} relative to the systemic velocity, indicative of strong large-scale outflows.

The large SFR of BOSS-EUVLG1 (from Hα and SED) is only comparable to those measured in hyper-luminous DSFGs, and should be detected in the far-IR if large amounts of dust have been already formed. However, it is not detected in dust continuum in ALMA with a 3σ limit of 37 μJy at 1.2 mm (Band 6). Using the far-IR SED of ALESS galaxies ($T_{\mathrm{dust}} \simeq 43$ K; da Cunha et al. 2015), this limit yields to an integrated far-IR luminosity $\log(L_{\mathrm{IR}}/L_{\odot}) < 10.91$ (from 8 to 1000 μm) and a dust mass $M_{\mathrm{dust}}/\mathrm{M}_{\odot} < 1.9 \times 10^7$ (3σ), implying a $\log(L_{\mathrm{IR}}/L_{\mathrm{UV}}) < -1.2$. While a large T_{dust} would lead to larger upper limits on L_{IR} and M_{dust}, a low dust content is actually expected if a very young age of the burst is considered. Assuming a constant SFR $= 955 \pm 135$ M$_{\odot}$ yr^{-1} over 10 Myr, we would expect a $M_{\mathrm{dust}}/\mathrm{M}_{\odot} = (2.0 \pm 1.0) \times 10^7$ formed by supernovae (Gall & Hjorth 2018, assuming no dust destruction), still compatible with the non-detection of ALMA dust continuum. The non-detection of dust also suggests minor past starburst episodes, and that the bulk of stellar mass was formed in just few Myrs, in line with the results from SED fitting

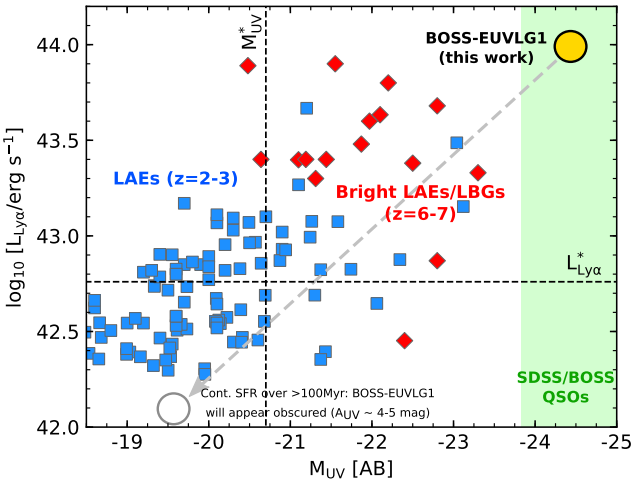


Figure 3. Lyα luminosity and UV absolute magnitude of BOSS-EUVLG1 (yellow) and other LAEs/LBGs at similar redshift (blue; Ouchi et al. 2008; Marques-Chaves et al. 2017, 2020; Sobral et al. 2018b) and at $z \sim 6-7$ (red; Sobral et al. 2015; Matthee et al. 2017; Matsuoka et al. 2018; Shibuya et al. 2018; Hashimoto et al. 2019). Horizontal and vertical dashed lines represent the typical Lyα and UV luminosities of $z \sim 2-3$ LAEs and LBGs (Reddy & Steidel 2009; Sobral et al. 2018a). If the SFR of BOSS-EUVLG1 is prolonged over ≳100 Myr, its UV and Lyα luminosity will likely become heavily obscured (empty circle).

3.2 BOSS-EUVLG1: the prototype of the first and intense bursts of star formation at high redshift

BOSS-EUVLG1 is by far the most luminous, dust-poor star-forming galaxy discovered at any redshift, with $M_{\mathrm{UV}} = -24.40 \pm 0.05$ and $\log(L_{\mathrm{Ly}\alpha}/\mathrm{erg\ s}^{-1}) = 44.0 \pm 0.1$. Fig. 3 compares the Ly$\alpha$ and UV luminosities of BOSS-EUVLG1 with those from other LAEs and LBGs, including the most luminous ones known at similar (Marques-Chaves et al. 2017, 2020) and higher redshifts (Sobral et al. 2015; Matsuoka et al. 2018; Shibuya et al. 2018). Our findings show that star formation alone can produce almost un-obscured luminosities comparable to QSOs, well above (by factors of ≃15) the proposed limit for star formation UV/Lyα luminosities at $z = 2-3$ (Sobral et al. 2018b).

The properties of BOSS-EUVLG1 are still intriguing and different from those observed in other galaxies. Its large luminosity and SFR (≃1000 M$_{\odot}$ yr^{-1}), yet residual dust attenuation [$E(B-V) \simeq 0.07$] and low metallicity ($Z/Z_{\odot} \simeq 1/5$), are clearly in contrast with those found in other samples, where the most luminous and vigorous SFGs are statistically more dusty and metal enriched (e.g. Bouwens et al. 2009; Casey et al. 2014). A natural explanation, supported by our results, is that we are witnessing the very early phase (≲10 Myr) of the formation of a massive galaxy that has had no time to enrich its ISM with metals and dust.

This phase should be, however, short lived. If the star formation is quenched, BOSS-EUVLG1 will appear redder and UV-faint in some tens Myrs (∼3 mag fainter in 30 Myr, according to S99), as

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the most luminous OB stars will no longer be present. It could thus represent the progenitors of compact ellipticals found at $z \sim 2$ ('red nuggets'; e.g. Dekel & Burkert 2014). On the other hand, if it lies in a gas-rich environment and the SFR is prolonged over a few hundreds Myrs, large amount of dust should be produced [$M_{\rm dust}/{\rm M}_\odot \sim (2-4) \times 10^8$ formed by supernovae Gall & Hjorth 2018], approaching those observed in ultra- and hyper-luminous DSFGs ($M_{\rm dust}/{\rm M}_\odot \sim 10^8-10^9$; e.g. Santini et al. 2010). In such case, BOSS-EUVLG1 could represent the very early phase (~10 Myr) of DSFGs, becoming a very bright source in the far-IR, but heavily obscured in the UV in just ~100 Myr ($A_{\rm UV} \simeq$ 4–5 mag, Fig. 3; e.g. da Cunha et al. 2015). Such rapid change from UV-bright to IR-bright is supported by simulations (Arata et al. 2019).

The gas content and the efficiency to keep the vigorous SFR over a prolonged period will definitively dictate different fates for BOSS-EUVLG1, but in any case its extremely, dust-poor luminous phase is likely short, <100 Myr. Moreover, such phase should be only visible during the first, major episodes of star formation, otherwise the dust produced in past SFHs would likely obscure the UV and nebular radiation. This implies a very low observable abundance of these luminous sources and might explain why such galaxies have not been discovered before. The sharp statistical transition between SFGs and AGNs at $z \sim 2-3$ around $M_{\rm UV} = -21.5$ and $\log(L_{{\rm Ly}\,\alpha}/{\rm erg\,s^{-1}}) = 43.3$ found by Sobral et al. (2018b) already suggests that extremely UV and Ly α luminous sources like BOSS-EUVLG1 should be very rare as AGNs are the norm at these luminosities. Considering the other ~70 EUVLGs at $z \sim 2-3$ identified in the ~9300 deg^2-wide eBOSS survey, we estimate a number density of $\sim 10^{-9}$ Mpc^{-3}, three orders of magnitude lower than that measured in QSOs at similar redshifts and $M_{\rm UV}$ (e.g. Palanque-Delabrouille et al. 2016). This, in turn, does not necessarily mean that luminous phases are intrinsically rare. SFGs at $z > 6$ are thought to have bursty SFHs, due to the high merger rate and accretion of primeval gas at such early times, thus expected to experience similar luminous phases in their first episodes of star formation. In fact, some exceptional luminous SFGs (both in the UV and Ly α), have already been discovered at $z > 6$ (e.g. Sobral et al. 2015; Matsuoka et al. 2018; Hashimoto et al. 2019; Fig. 3). Similar to BOSS-EUVLG1, their SEDs, intense nebular emission, high sSFRs, and large, still un-obscured UV luminosities highly suggest that they are undergoing their first, major bursts of star-formation.

4 SUMMARY AND FINAL REMARKS

This Letter reports the discovery of BOSS-EUVLG1 at $z = 2.4694 \pm 0.0004$, the most luminous, dust-poor star-forming galaxy known at any redshift by far. BOSS-EUVLG1 is a compact ($r_{\rm eff} \simeq$ 1.2 kpc), very young (4–5 Myr) starburst with $\log(M_*/M_\odot) = 10 \pm 0.1$ and a prodigious SFR = 955–1060 ${\rm M}_\odot\,{\rm yr}^{-1}$ (from H α and SED fitting, respectively) and sSFR $\simeq 100\,{\rm Gyr}^{-1}$. It exhibits QSO-like luminosities, $M_{\rm UV} \simeq -24.40$ and $\log(L_{{\rm Ly}\alpha}/{\rm erg\ s^{-1}}) \simeq 44.0$, likely arising from a large number of massive stars present in the first stages of the intense starburst. Its SED is dominated by the young starburst without a relevant old stellar component, yielding to intense nebular emission in the rest-frame UV (e.g. Ly α, He II, or C III]) and optical [EW_0(H β+[O III]) $\simeq$ 1600 Å and EW_0(H α) $\simeq$ 680 Å]. Despite the large luminosity and SFR, BOSS-EUVLG1 is metal poor [$12 + \log({\rm O/H}) = 8.13 \pm 0.19$] and almost un-obscured [$E(B-V) \simeq 0.07$] with no detection of dust continuum [$\log(L_{\rm IR}/L_{\rm UV}) < -1.2$], indicating that we are witnessing the very early phase of an intense starburst that has had no time to enrich the ISM with metals and dust. BOSS-EUVLG1 could be identified as a prototype of the first and intense episodes of star formation, likely representing a short, initial phase in the evolution of compact ellipticals or DSFGs found at $z \sim 2$. Such phase would imply a fast mode – almost instantaneous at cosmic scales – of the stellar mass build-up and chemical and dust enrichment histories of SFGs in the early Universe. In future works, we will investigate in more detail the physical condition and properties of BOSS-EUVLG1, as well as present a large sample of other ~70 EUVLGs discovered within the eBOSS survey.

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DATA AVAILABILITY

The data underlying this article will be shared on reasonable request to the corresponding author. SDSS data are available to the public at https://data.sdss.org/sas/dr14/eboss.

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