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A young star-forming galaxy at $z = 3.5$ with an extended Lyman α halo seen with MUSE

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Abstract. We present MUSE observations of a typical ($M_\star = 6 \times 10^9\ M_\odot$) young lensed galaxy at $z = 3.5$, for which we obtain 2D resolved spatial information of Ly α and, for the first time, of C III] emission. We also derive important physical properties from several UV emission and absorption lines, rarely seen at these redshifts. Stellar and gas-phase metallicities point towards a low metallicity object. We model the Ly α line and surface brightness profile using a radiative transfer code in an expanding gas shell, finding that this model provides a reasonable description of both observables.

Keywords. techniques: imaging spectroscopy; gravitational lensing: strong; galaxies: high-redshift; galaxies: abundances; galaxies: individual: SMACSJ2031.8-4036

1. Introduction

We combine gravitational lensing magnification with the efficiency of the MUSE (Multi Unit Spectroscopic Explorer) integral-field spectrograph to derive the 2D morphology and kinematics of a L* galaxy. This is a strongly-lensed system of 5 images at $z = 3.5$, previously reported by Christensen *et al.* (2012a) and firstly detected in the HST image of the massive cluster SMACSJ2031.8-4036 (MACS, Ebeling *et al.* 2001), from which we obtained new data with MUSE between April 30 and May 7 2014 during the second commissioning run, in a total of 10.4 hours with an average seeing of 0.72".

2. Results

From the spectrum of the central region we derive an electron temperature and density of 1500K and 300cm^{-3} combining the several line diagnostics. The analysis of low ionisation lines yields a maximum covering fraction of the neutral gas of 0.4. Using full spectral fitting, we derive a stellar mass of $6.7 \pm 0.2 \times 10^9$ $M_\odot$ and an extinction of $E(B - V) = 0.016 \pm 0.001$ for our best model, obtained with stellar populations of Z = $0.07Z_\odot$. We also derive a stellar metallicity of 0.0051$\pm$ 0.016 $Z_\odot$ from faint continuum features (Sommariva *et al.* (2012)) and measuring the equivalent width of absorptions lines we obtain a ISM metallicity of 0.065 to 0.16 $Z_\odot$ (Leitherer *et al.* (2011)). We conclude that this particular object is 2σ below the mass-metallicity relation, as it is seen in local mergers.

We spatially resolve the extended Ly α emission and the associated C III] kinematics in the central region. The Ly α emission has a very uniform profile across $\sim$ 10 kpc, showing only a small velocity shift that is unrelated to the intrinsic kinematics of the

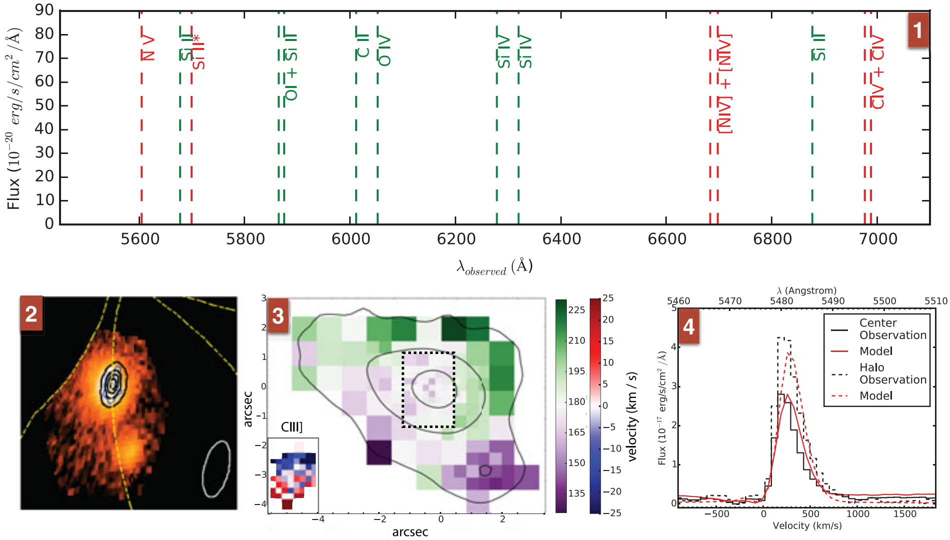

Figure 1. (1) Central region spectrum (in black) and pipeline propagated variance (grey). (2) Source plane reconstruction of the Ly α line image. Caustic lines in yellow, C III] in blue contours and continuum close to Ly α in black. (3) Ly α velocity map relative to systemic velocity. C III] velocity map in small insert on left bottom corner. (4) Observed and model Ly α in full lines (black and red, respectively) and observed halo and best model halo spectra, in dashed.

nebular emission. The Ly α emission is more extended than the continuum, with length scales of 1.51 kpc and 0.34 kpc respectively. Comparing this with the results of stacked images, this galaxy seems more compact than what is obtained for bigger and more massive galaxies at equivalent redshifts (e.g. Steidel *et al.* (2011)). Nevertheless, this object is comparable with the local LARS sample (Hayes *et al.* 2013).

The observed Ly α line is well-fit by synthetic spectra generated from a spherically expanding $\sim 2 \times 10^9$ $M_\odot$ gas shell model (Verhamme *et al.* (2006)). We further test this model by comparing the predicted surface brightness and predicted central and halo spectra and conclude that this simple model is compatible with the observations, although with some discrepancies.

3. Conclusions

Resolved data on individual galaxies pose new challenges to current models of Ly α radiative transfer, and also shows the need for further studies of resolved high-redshift individual and typical galaxies to improve our understanding their properties.

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