On the Reliability of Lyman-alpha Emission Line as a Cosmological Tool

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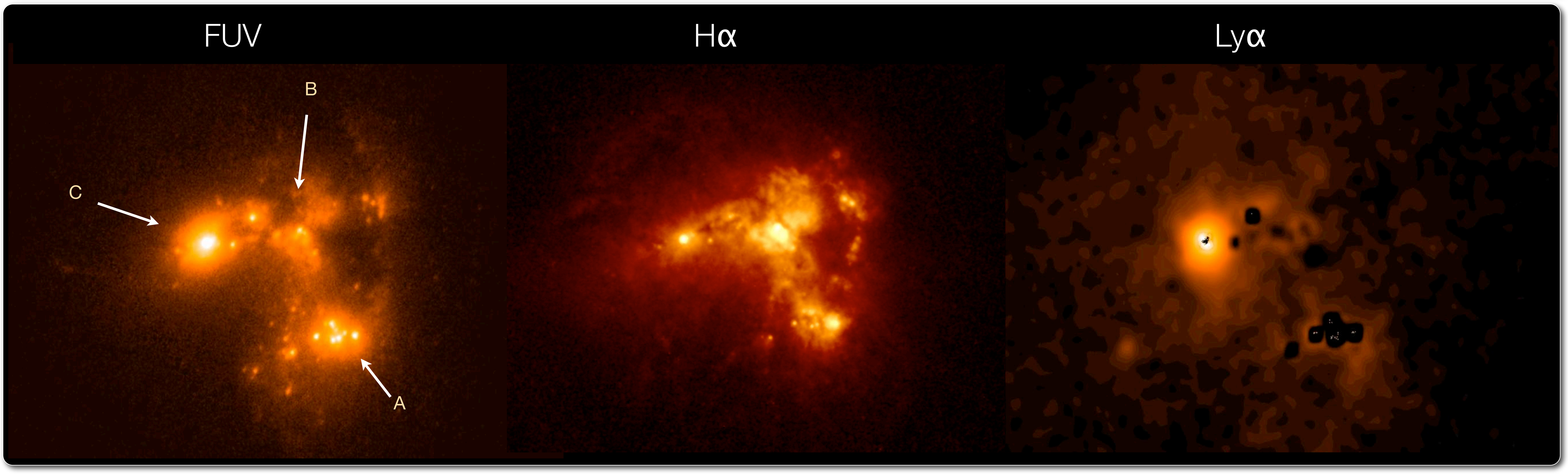

Haro 11 as seen by HST -- A complex emission structure is observed in the far UV and Hα, whereas only one knot shows Lyα in emission. The resonant scattering of Lyα photons on hydrogen atoms makes their escape more complex and less predictable than non-resonant radiation. This effect also produces the low surface brightness emission observed across the galaxy body.

Scientific Context:

Lyman-alpha (Lyα) has become the most powerful diagnostic tool of star formation at high-redshift since it becomes the strongest emission line in the optical-NIR window at z>2.1. It can be used, in principle, to derive star-formation rates, study galaxy clustering, and put constaints on the final stage of the reionisation epoch. However, the resonant nature of this line makes the above studies far from trivial. The dust, as well as ISM kinematics or geometry may regulate the Lyα escape. Therefore, without a rigorous understanding of the different and complex escape processes, all cosmological interpretations based on Lyα alone remain questionable, and could be seriously at

The Escape Process of Lyα Emission

To investigate the role of dust in the regulation of Lyα emission, we produced extinction and continuum-subtracted Lyα maps:

✔ In Fig. 1 we see Lyα in emission from knot C with E(B −V) ~ 0.48 whereas absorption is seen in knots A and B with E(B −V) ~ 0.2 and 0.41 respectively. The dust content is not always the main regulator of Lyα photons escape.

✔ In a classical view, considering only the selective extinction at the two wavelengths, and a case B intrinsic ratio of 8.7, we expect to have an exponential decline of Lyα/Hα ratio represented by the dark curve (Fig. 2). However, we observe a high dispersion for the diffuse emission (cyan crosses) and an emission from knot C (red triangles) above the predicted curve at high extinction, which supports the view of a scattering in inhomogeneous ISM that favors preferentially the escape of Lyα photons (Neufeld 1991).

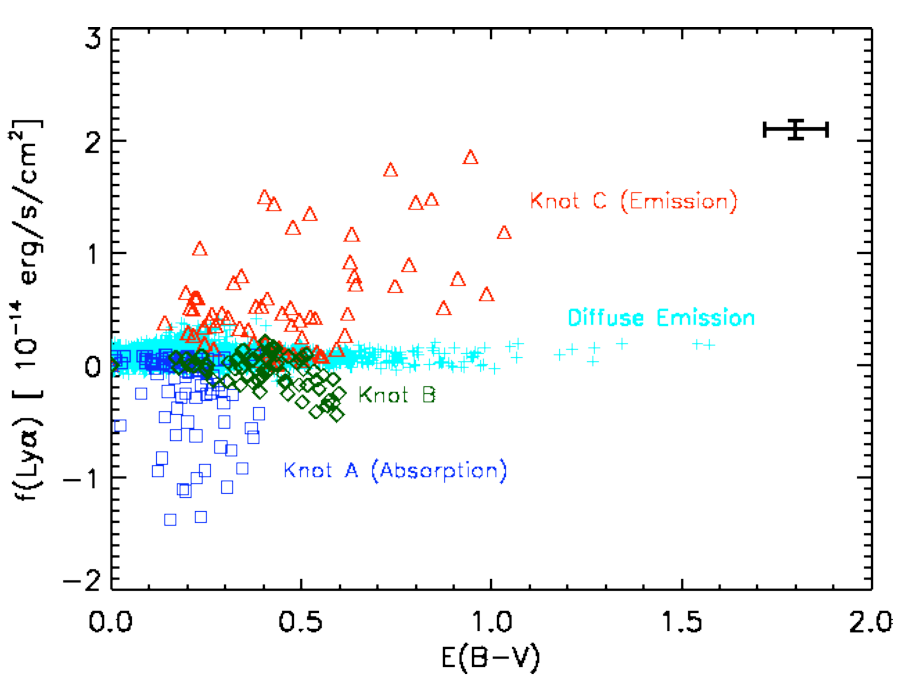

Fig. 1

Pixel-to-pixel correlation between the Lyα emission and the extinction determined from the Balmer decrement tracing the dust in the gas phase.

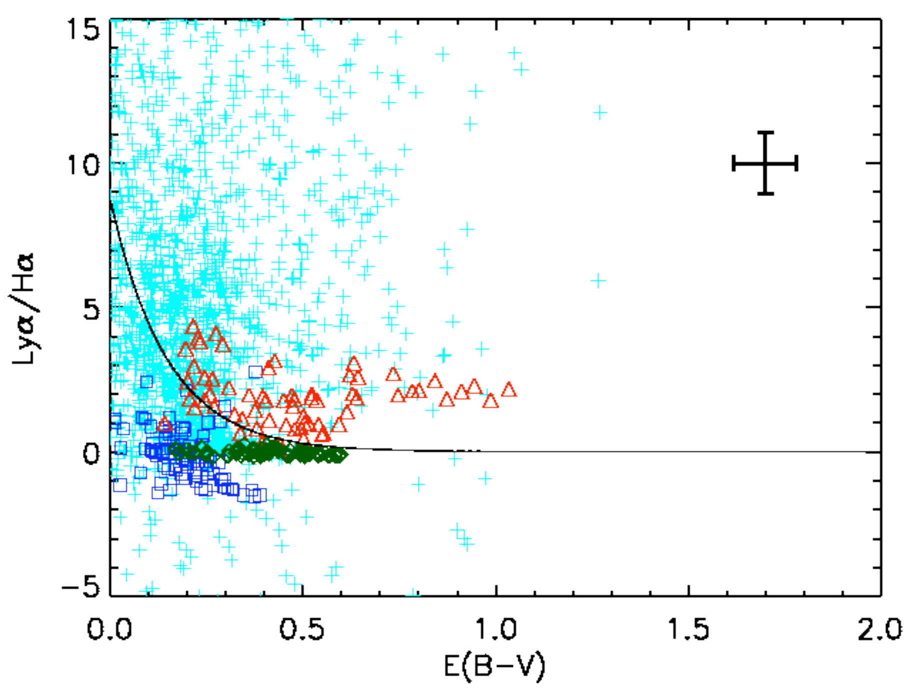

Fig. 2

Evolution of the Lyα/Hα ratio as a function of the extinction. The dark curve represents the theoretical ratio corrected for extinction.

Calibration of High-z Lyα Observations

✔ In Fig. 3 the Lyα escape fraction appears to be possibly correlated with E(B −V), although in a purely dust regulated model, this correlation would have been more striking.

✔ The rate of escaping Lyα photons does not exceed 10% in this sample while the diffuse emission represents the bulk of Lyα which is very likely to remain undetectable in high redshift observations.

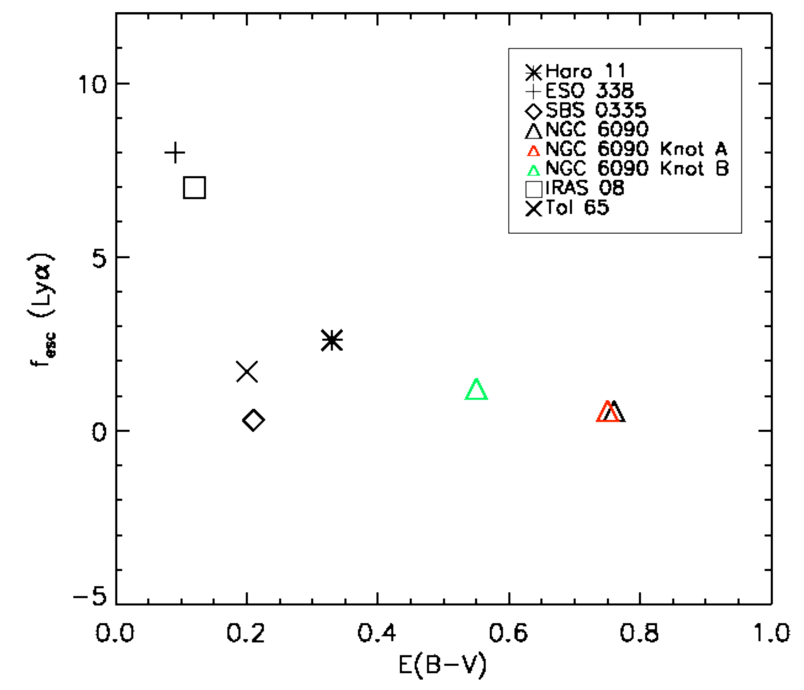

Fig. 3 Escape fraction of Lyα photons (in percent) as a function of extinction E(B-V) in the gas phase

The star formation rate derived from Lyα is systematically underestimated (by a factor between 2 to 6) with respect to that derived from UV. This discrepancy, usually observed in high-z galaxies, emphazises the highest attenuation of Lyα emission line with respect to UV continuum.

✔ The correction for dust attenuation, does not completely reconcile these two indicators (Fig. 4).

✔ The different results found when deriving SFR from Lyα and others indicators such as Hα or UV, and in particular the failure of Lyα indicator to recover the total SFR (UV + IR) even when corrected for reddening, are indicative of the difficulty to use this line as a reliable star formation indicator.

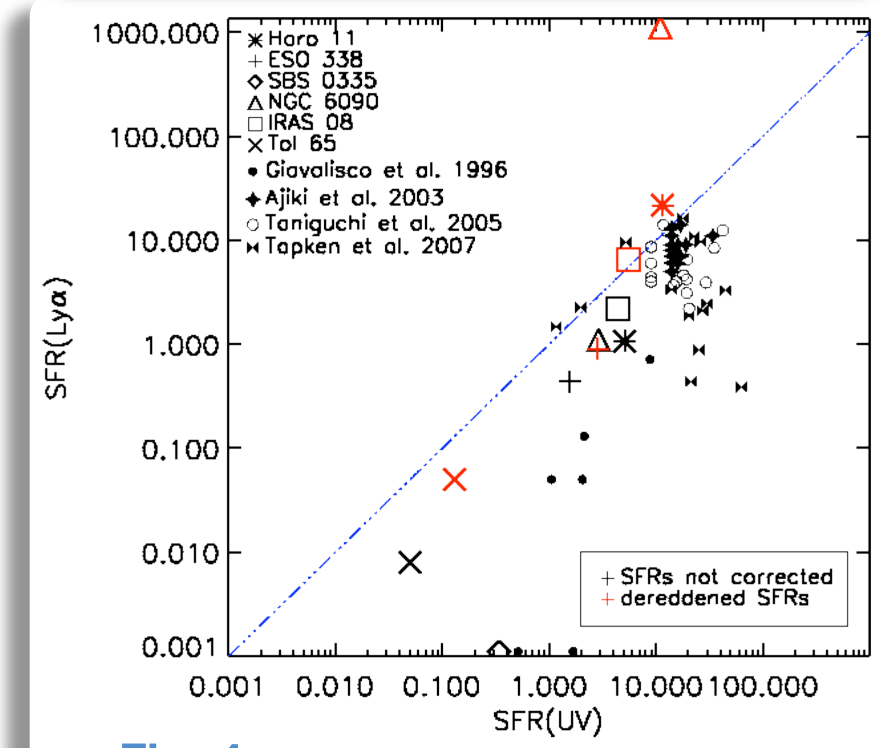

Fig. 4 SFR derived from nebular emission line Lyα vesus SFR derived from UV continuum. The dark points represent undereddened SFRs, the red points represent SFR(Lyα) dereddened using E(B−V)gas and SFR(UV) corrected using E(B −V)stars. The dashed line is for SFR(Lyα) = SFR(UV)

Conclusion :

Combining space (HST) and ground-based (ESO) observations we have mapped the Lyα emission and the dust content in six nearby star forming galaxies. We pointed out the role of the ISM distribution, where in the case of clumpiness morphology, Lyα photons escape preferentially to Hα ones, which produces an observed Lyα/Hα ratio higher than the theoretical level corrected for extinction. Simple dust extinction correction fails to recover the intrinsic Lyα/Hα ratio, where the role of dust is, in some cases underestimated because of the resonant scattering, and in other cases overestimated because of the clumpiness distribution of the ISM.
Because of the radiative transfer complexity of the Lyα line, cosmological quantities, such as star fomation rate based on Lyα alone are prone to large uncertainties. We are aiming to produce a reliable Lyα escape fraction as a remedy for the above estimation errors.

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