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THE LYMAN ALPHA ESCAPE FRACTION ALONG THE HISTORY OF THE UNIVERSE

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RESUMEN

La emisión Lyα es especialmente útil a la hora de identificar galaxias a muy altos desplazmientos al rojo. Para poder caracterizar los procesos de formación estelar que tienen lugar en ellas es preciso calibrar el valor de su fracción de escape. En esta contribución resumimos los resultados que hemos obtenido estudiando galaxias a lo largo de la historia del Universo.

ABSTRACT

The Lyα emission line has repeatedly proven itself to be a powerful tool by which to identify and study evolving galaxies at the highest redshifts. In order to use Lyα as a probe of the physical properties of galaxies, it becomes vital to know the Lyα escape fraction ($f_{\rm esc}^{\rm Ly\alpha}$). Unfortunately, due to the resonant nature of Lyα, $f_{\rm esc}^{\rm Ly\alpha}$ may vary in an extraordinarily unpredictable manner. In this contribution we summarize the results we have achieved up to now in understanding and parameterizing the Lyα escape fraction at different evolutionary states of the Universe.

Key Words: cosmology: observations — galaxies: starburst — intergalactic medium

1. THE NEARBY UNIVERSE AND LARS

Lyα is in principle the strongest Hydrogen emission line, being around a factor 9 stronger than Hα in ionized regions. With a $W_{\rm Ly\alpha}$ up to 300 Å, it would be ideal to study the star formation processes at the primordial Universe. Moreover, Lyα enters the optical window at $z \sim 2$, being a good target for ground based telescopes up to very high redshifts. Nevertheless, our results on local star-forming galaxies have shown that Lyα is generally weaker than expected, and in some cases appears as damped absorptions instead of emission profiles. As discussed by Kunth et al. (1998),Mas-Hesse et al. (2003) and Östlin et al. (2009), the shape and intensity of the Lyα emission profile depends on the amount of HI and its kinematics, as well as on the amount of dust in the region surrounding the young, massive stellar clusters. The radiation transfer of Lyα photons has been modelled in detail by Verhamme et al. (2006), showing that it is a multiparametric process whose final results are difficult to predict based on the macroscopic properties of the galaxies. In order to get more empirical information of the Lyα emission in the Local Universe we have started the "Lyα Reference Sample - LARS" project, based on 14 galaxies selected from SDSS and GALEX, and which we are observing from the UV to the near infrared with several telescopes (HST:ACS-WFC3-COS, GTC, ESO-VLT,...). We show in Figure 1 an HST-ACS UV and a GTC-OSIRIS Hα image of LARS-6 (SDSS J154544.52+441551.8). The main observations of LARS will be finished along 2012 (COS spectroscopy will be completed in 2013). A final catalogue will be made public with all the results as soon as completed.

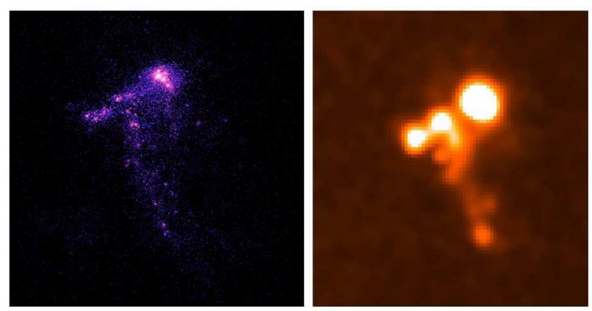

Fig. 1. HST-ACS UV continuum (left) and GTC-OSIRIS Hα (right) images of LARS-6.

2. THE LYMAN α ESCAPE FRACTION AT $Z \sim 2.2$

It is clear that to be able to characterize the evolution of the star formation along the history of the Universe, based on the measured intensity of the Lyα emission line, we need first to determine the average values of $f_{\rm esc}^{\rm Ly\alpha}$ in different scenarios. We started this by measuring simultaneously Lyα and Hα within the

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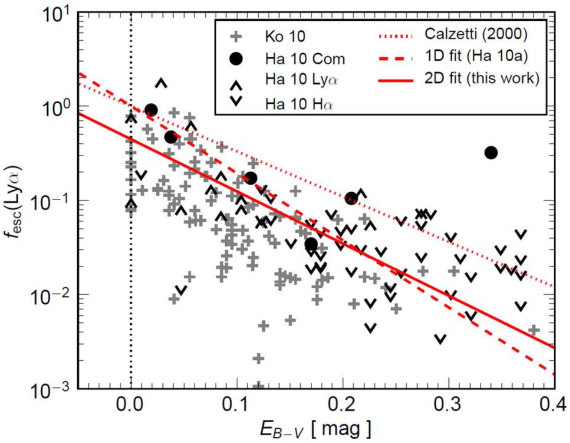

Fig. 2. Scatter diagram of $f_{\rm esc}^{\rm Ly\alpha}$ vs. the measured $E(B-V)$. References and details are discussed in Hayes et al. (2011).

same cosmological volume at $z \sim 2.2$, by observing a region of the GOODS field with the HAWK-I and FORS1 instruments of the VLTs. We defined a custom built filter for FORS1 giving us a similar volume than the available Hα filter at HAWK-I. We identified 55 Hα emitters, and 38 Lyα ones, but only 6 objects were identified simultaneously in both lines. The results, discussed in Hayes et al. (2010), showed that at this age of the Universe the mean value of $f_{\rm esc}^{\rm Ly\alpha}$ was around 0.05, but with a significant dispersion. The Lyα emitters identified were those objects with a high value of $f_{\rm esc}^{\rm Ly\alpha}$, so high that their corresponding Hα luminosity was below our detection limit. On the contrary, for most of the detected Hα emitters, their $f_{\rm esc}^{\rm Ly\alpha}$ values were low enough to inhibit their detection in Lyα. The comparison of both luminosity functions allowed us to derive the volumetric average value of $f_{\rm esc}^{\rm Ly\alpha}$ at this redshift.

3. LONG TERM EVOLUTION AND THE REIONIZATION ERA

In order to study the evolution of the average $f_{\rm esc}^{\rm Ly\alpha}$ values we applied the same method of comparing the luminosity functions of Lyα and Hα emission or UV continuum to different samples at various redshifts obtained from the literature. The results are described and discussed in detail in Hayes et al. (2011). We show first in Figure 2 the relation between $f_{\rm esc}^{\rm Ly\alpha}$ and the $E(B-V)$ values as derived from UV continuum, obtained from a compliation of observations at $z \sim 2$–3. We fitted a biparametric function, leaving free the slope and the ordinate at the origin. It can be seen in the figure that even for zero dust absorption we expect an average value of $f_{\rm esc}^{\rm Ly\alpha}$ value not higher than 0.5. This illustrates that

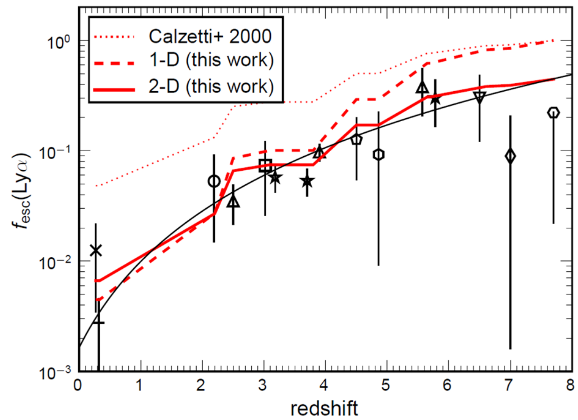

Fig. 3. Evolution of $f_{\rm esc}^{\rm Ly\alpha}$ as a function of redshift. References and details are discussed in Hayes et al. (2011).

while $f_{\rm esc}^{\rm Ly\alpha}$ and $E(B-V)$ are related, destruction of Lyα photons is not just a single function of the amount of dust, but the result of a complex process driven by the kinematics of the neutral gas.

In Figure 3 we show finally the evolution of the mean $f_{\rm esc}^{\rm Ly\alpha}$ values along the history of the Universe. It can be seen that there is a continuous and monotonic increase of $f_{\rm esc}^{\rm Ly\alpha}$ up to $z \sim 6.5$. If we plot the $f_{\rm esc}^{\rm Ly\alpha}$ values derived from the measured $E(B-V)$, applying the relation obtained at $z \sim 2$–3, the resulting curve fits very well the average observational one, showing that the relation between both parameters seems to apply at least until $z \sim 6.5$.

At higher redshifts, when the Universe was very young, $f_{\rm esc}^{\rm Ly\alpha}$ seems to decrease again and the relation between $f_{\rm esc}^{\rm Ly\alpha}$ and $E(B-V)$ breaks. We believe that this break is associated to the reionization of the young Universe: at $z > 6.5$ the intergalactic medium was not fully reionized, and the scattering of Lyα photons was enhanced. If these results are confirmed by additional studies at very high redshifts, we warn that care should be taken when using Lyα emission to derive the star formation rates of the very young Universe when it was less than 900 million years old.

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REFERENCES

Hayes, M., et al. 2010, Nature, 464, 562
Hayes, M., et al. 2011, ApJ, 730, 8
Kunth, D., et al. 1998, A&A, 334, 11
Mas-Hesse, et al. 2003, ApJ, 598, 858
Östlin, G., et al. 2009, AJ, 138, 923
Verhamme, A., Schaerer, D., & Maselli, A. 2006, A&A, 460, 397