To model or not to model: nebular continuum in galaxy spectra

Henrique Miranda[1,2], Ciro Pappalardo[1,2], José Afonso[1,2], Polychronis Papaderos[1,2,3], Catarina Lobo[2,3], Ana Paulino-Afonso[1], Rodrigo Carvajal[1,2], Israel Matute[1,2], Patricio Lagos[1], and Davi Barbosa[1,2]

[1]Instituto de Astrofísica e Ciências do Espaço [2]Faculdade de Ciências da Universidade de Lisboa [3]Faculdade de Ciências da Universidade do Porto

Introduction

The neglect of modelling both stellar and nebular emission has been shown to have a significant impact on the derived physical properties of galaxies experiencing high levels of star formation. Although different studies have addressed this issue, a clear limit for the significant contribution of the nebular to the total optical emission has not been established. In this work, our aim is to establish such a threshold and explore its consequences at high redshifts.

Sample

From SDSS-DR7, we selected a sample of SF galaxies based on the BPT diagram and then divided it in different bins according to their EW(Hα), a commonly used tracer of the nebular contribution and star formation activity. Then, we selected an evenly distributed sample of 500 galaxies that adequately covered the EW(Hα) values of the SF sample.

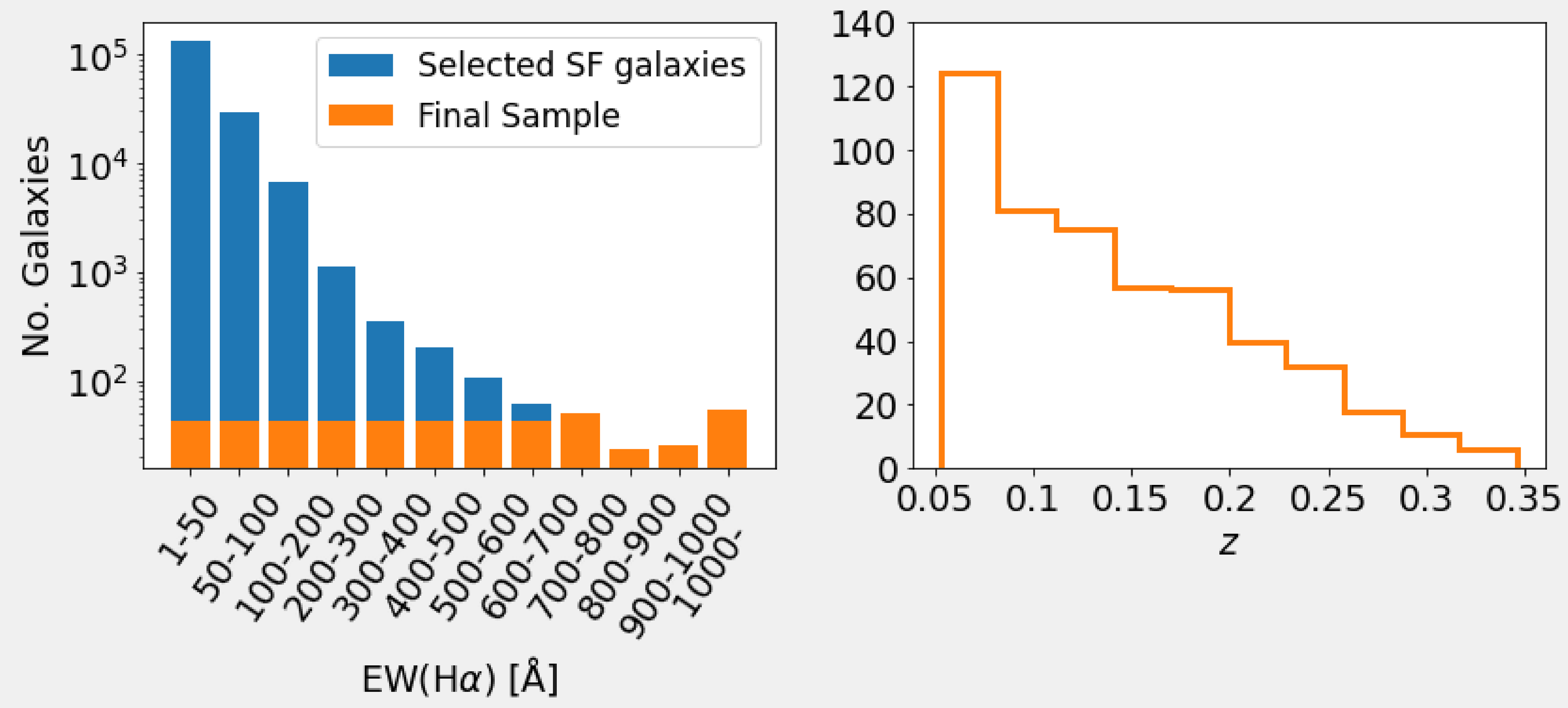

Figure 1. Left panel: EW(Hα) distribution for the selected SF galaxies, in blue, and for the final sample, in orange. Right panel: Redshift distribution of the final sample.

The nebular contribution and its tracers

We related the nebular contribution (X_{neb}) with different tracers used in the literature (EW of Hα and Hβ, the SFR and sSFR). To do so, we applied FADO to our sample, a spectral fitting tool that self-consistently fits the optical spectrum of galaxies, providing a way to obtain a stellar and nebular model that are consistent with each other. The EW of Hα and Hβ show a strong linear correlation with minor scatter, while the sSFR also correlates with X_{neb}, albeit with larger scatter.

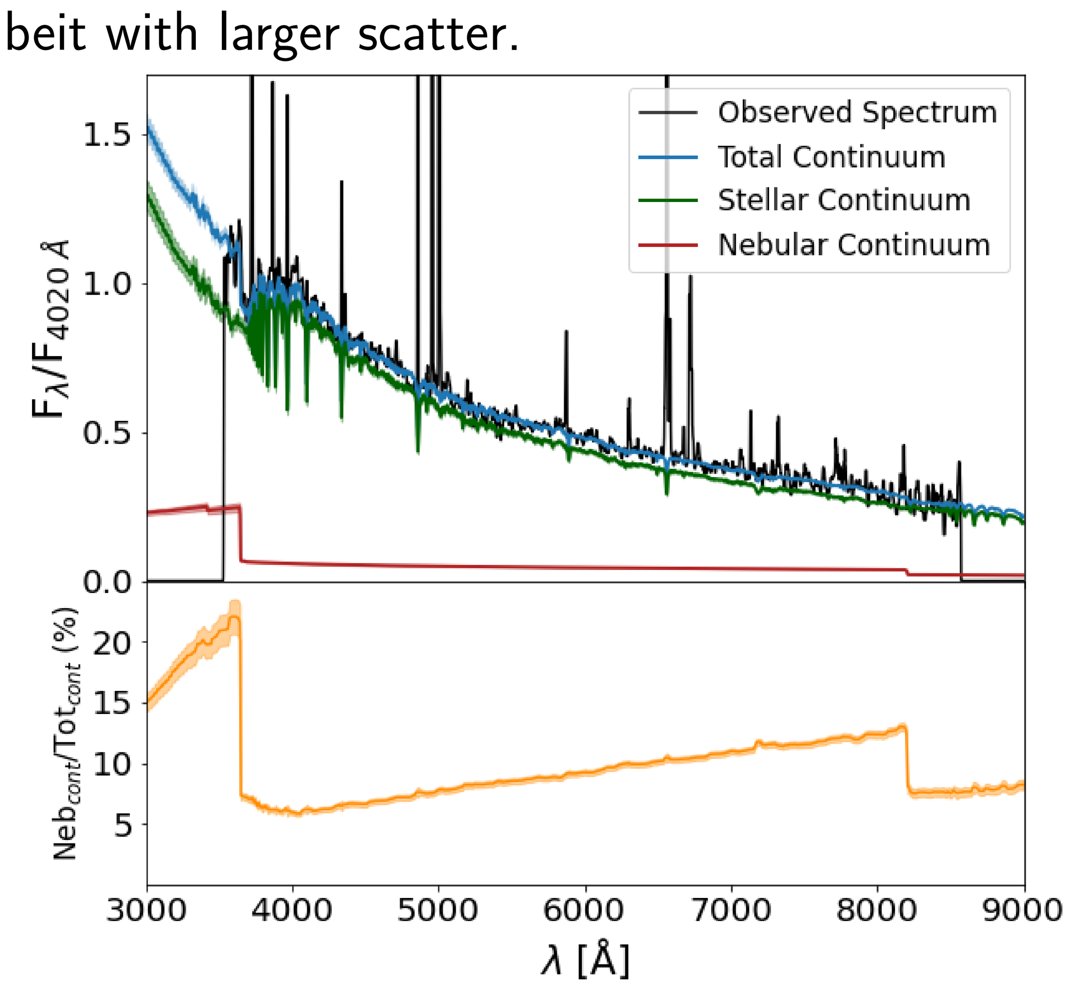

Figure 2. Upper Panel: FADO fit for an example galaxy in our sample with X_{neb}=10%. Bottom Panel: Ratio between the nebular and total continuum as a function of wavelength for the same galaxy.

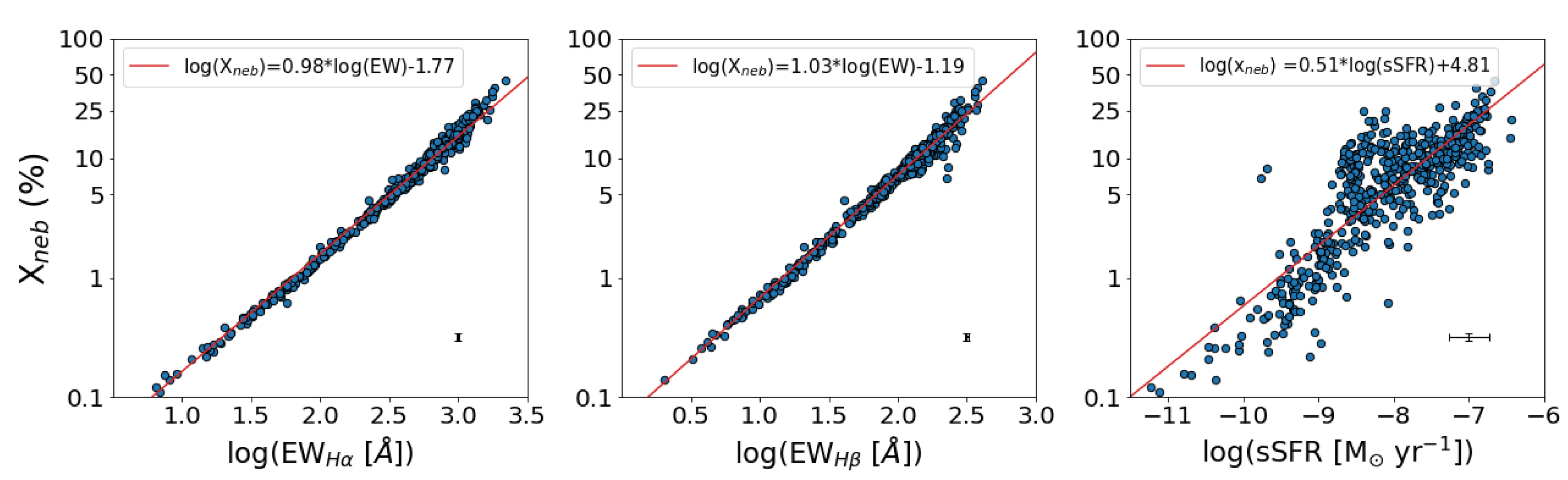

Figure 3. Relation between X_{neb} and EW of Hα (left panel) and Hβ (centre panel) and sSFR (right panel) in log-log scale. The red line is the derived best linear fit to the data.

Nebular component impact threshold

To study the impact on the estimated physical properties of galaxies due to modelling the nebular emission, we compared results between two spectral synthesis codes, FADO and STARLIGHT, a code that only models the stellar emission. We compared the difference between the stellar mass, age and metallicity estimates of these codes for different levels of X_{neb}.

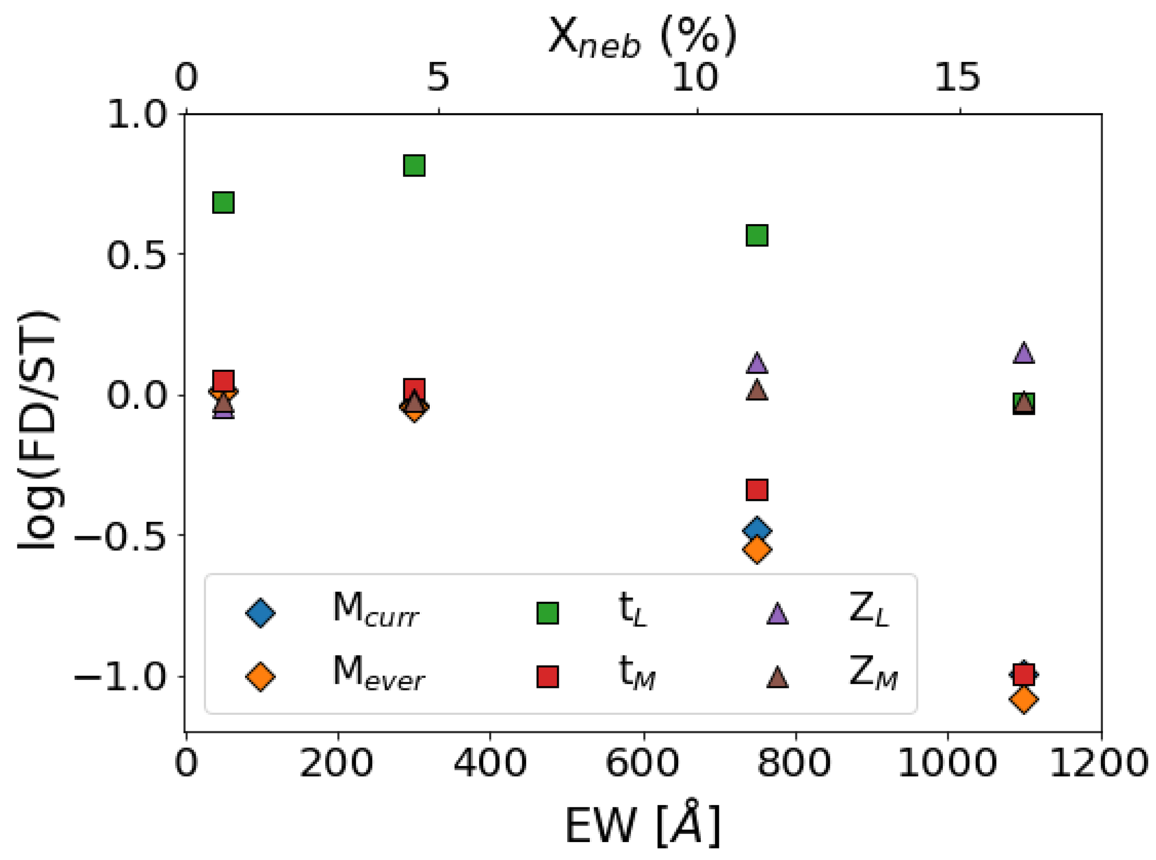

Figure 4. Logarithm of the median differences between FADO and STARLIGHT estimates of the stellar mass (diamonds), age (squares) and metallicity (triangles) for four bins: EW(Hα)<100 Å, 100≤EW(Hα)<500Å, 500≤EW(Hα)<1000 Å and EW(Hα)≥1000 Å.

Our results show increasing differences between the codes with rising X_{neb} and that modelling the nebular emission significantly impacts galaxy properties when X_{neb} ~8%. This corresponds to EW(Hα)≃500 Å, EW(Hβ)≃110 Å, and sSFR≃$10^{-7.8}$ yr^{-1}. At this level, neglecting nebular emission modelling overestimates the stellar mass by over 0.6 dex, altering the modelled stellar continuum and thus the physical and evolutionary properties of galaxies.

High redshift implications

The general level of star-forming activity in the Universe was higher in the past. Considering the evolution of EW(Hα) with redshift, we can infer how X_{neb} evolves with redshift. Using the relation derived in Faisst et al. (2016), we find that in the log(M_* [$M_\odot$])=7–11 range the threshold derived in this work is reached between z∼2–6. This means that on average, for galaxies in this stellar mass and redshfit range, the X_{neb} is so significant that it cannot be neglected when performing spectral fitting.

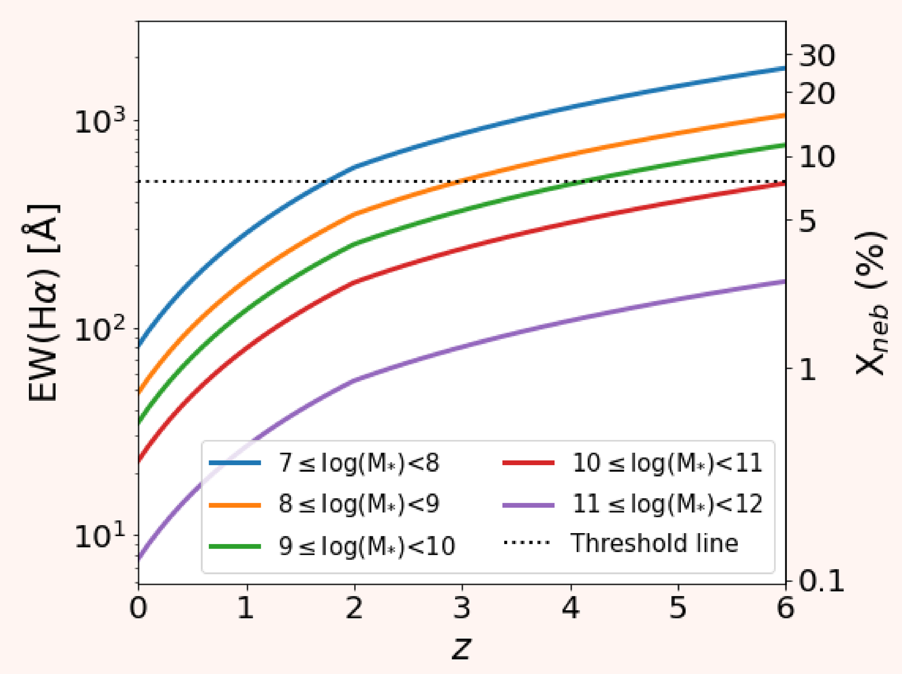

Figure 5. Evolution of the rest-frame EW(Hα) with redshift for different stellar mass intervals. The black dotted line is the EW(Hα)=500 Å threshold defined in this work.

Conclusions and future work

Our work shows that modelling both the optical stellar and nebular continuum is fundamental for extreme emission line galaxies at low redshifts and more generally for SF galaxies at high-redshifts, particularly at z>2. In light of recent JWST observations of high redshift galaxies and future instruments aimed at exploring the young Universe, such as MOONS, this arises as a crucial aspect to take into consideration when analysing the physical and evolutionary properties of galaxies.

Acknowledgements

This work was supported by Fundação para a Ciência e a Tecnologia (FCT) through the research grants UIDB/04434/2020 and UIDP/04434/2020. H.M. acknowledges support from FCT through the Fellowship 2022.12891.BD. C.P. acknowledges support from DL 57/2016 (P2460) from the 'Departamento de Física, Faculdade de Ciências da Universidade de Lisboa'.

COFINANCIAMENTO / COFINANCING