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Nitrogen-to-oxygen as a tracer of the chemical evolution of the Local and young Universe

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Abstract

Oxygen optical emission-lines are used exhaustively as tracers of the metal content in gaseous nebulae ionized during different episodes of massive star formation. The high luminosity of these lines make them to be detected from the Local Universe up to starbursts at high redshift. Occasionally, in those cases where these lines cannot be measured due to the spectral coverage or to the redshift, nitrogen emission-lines are used instead. However, both nitrogen and oxygen have different nucleosynthetic origins, so the study of chemical abundances from nitrogen emission-lines introduces variables depending on the star formation history of each galaxy that must be taken into account. This contribution summarizes those risks involved in using metallicity tracers based on optical nitrogen emission lines and also describes the advantages of using instead the nitrogen-to-oxygen ratio as a tracer itself, based mainly on its independence on star formation rate, avoiding selection effects at high redshift.

1 Introduction

Nitrogen (N) is one of the most abundant metals present in the interstellar medium (ISM). Although its relative abundance is not as high as those of oxygen, carbon, or neon it represents one of the main coolants of the gas, so some of their emission-lines appear very bright in the optical spectrum. The importance of the study of its relative abundance with oxygen (N/O) is motivated because N is ejected to the ISM mainly by low- and intermediate-mass stars, while O is ejected by massive stars. Therefore, the study of this ratio gives important clues to the study of the star formation history (SFH) in galaxies [5].

In Fig. 1 is shown the relation between N/O and O/H for a sample of objects with good determinations of the metal content of their ISM ([10], hereafter PMC09). This relation is characterized by the presence of two regimes: i) one at low metallicity with a production of primary N, independent of O/H and ii) another one at high metallicity for secondary N, which grows with metallicity. Nevertheless these two regimes are not universally predicted by chemical evolution models and present very high dispersion owing to different SFH and the influence of chemodynamical deviations from the closed-box approximation.

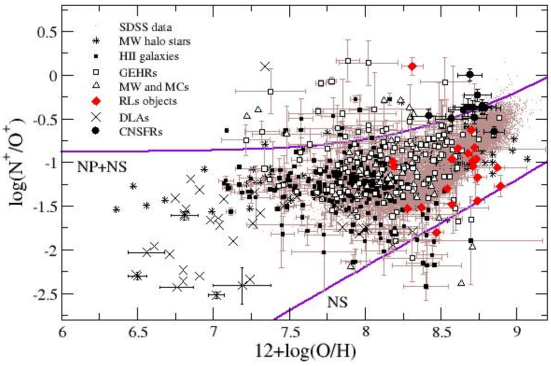

Figure 1: Relation between oxygen and nitrogen-to-oxygen ratio for different ionized gaseous nebulae. Solid lines represent the prediction from chemical evolution models with the relative production of primary and secondary nitrogen.

Therefore, when using tracers of the metal content of a galaxy based on nitrogen emission-lines they must be used carefully in order to take into account the effects due to the possible variations of the N/O.

2 Tracers of metallicity based on nitrogen lines

Among the most widely used strong-line methods to derive metallicities based on N emission-lines is the $N2$ parameter. This is defined as the logarithm of the ratio of [Nii] λ6584 and Hα. Due to the narrow wavelength baseline between the two involved emission lines this parameter is unaffected by reddening or flux calibrations uncertainties. Besides, unlike other strong-line methods based on O emission-lines, it has a monotonic relation with O/H up to solar metallicities [4]. However, it must be used carefully due to different sources of uncertainty such as its dependence on the ionization parameter or on the N/O ratio [11]. In Fig. 2, taken from PMC09, it can be seen how the linear relation between $N2$ and O/H changes for samples of objects with different values of N/O.

The relation between strong-line methods based on [Nii] emission-lines and the N/O ratio is especially high in the case of the $N2O2$ parameter. This parameter was defined by [6] as the logarithm of the ratio between the emission-line fluxes of [Nii] λ6584 and [Oii] $\lambda\lambda$3727,3729. According to these authors this ratio is almost independent on ionization parameter, so it can be even more attractive than $N2$. Unfortunately, according to PMC09, this parameter has indeed a linear relation with N/O so it only works to derive O/H when there is a linear relation between these two abundance ratios. This is the case of the regime

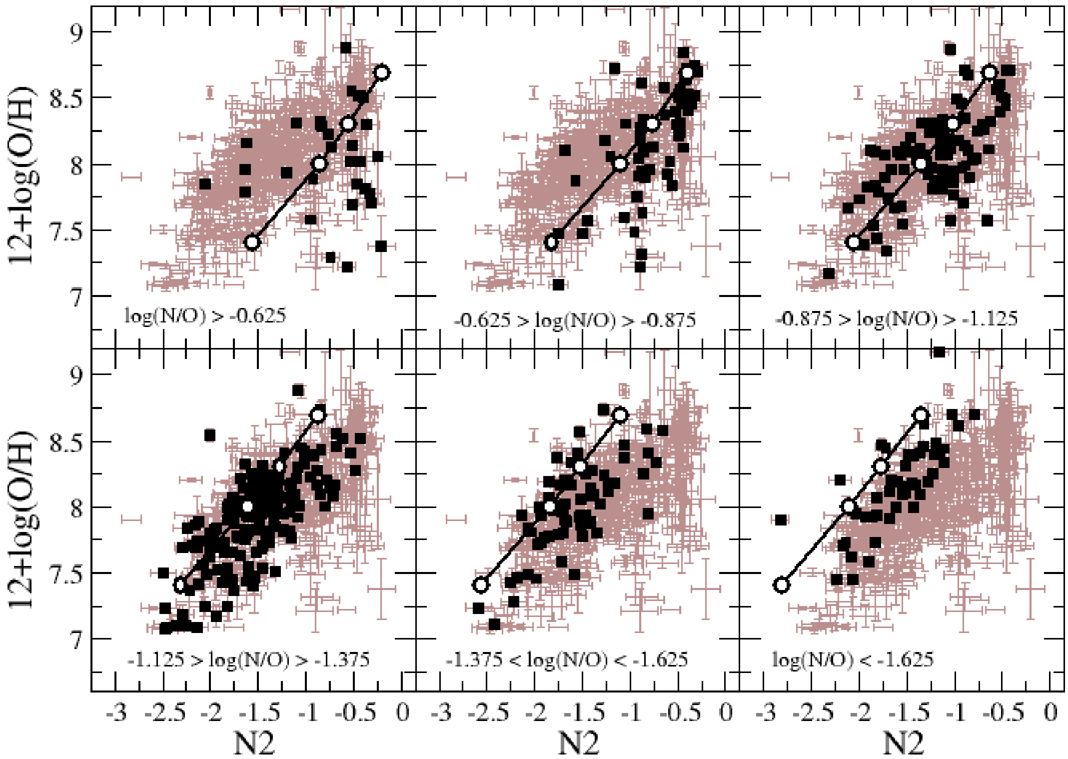

Figure 2: Relation between the $N2$ parameter and the oxygen abundance for a sample of objects and a grid of photoionization models described in PMC09 for different values of the N/O ratio.

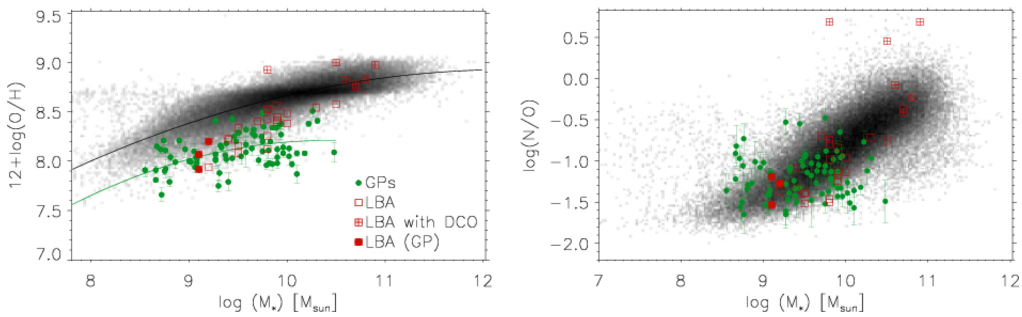

Figure 3: Relation between O/H (at left) and N/O (at right) with the stellar mass for a sample of star-forming galaxies in the SDSS-DR7. Green points represent the sample of GPs studied in Amorín et al. (2010)

of secondary nitrogen production, but as already explained above, even in this case there is a large dispersion owing to the different SFH in different objects and to the deviations from the closed-box chemical evolution assumption.

The bad usage of this parameter to derive metallicities is well illustrated with the case of the *green pea* galaxies (GPs, [3]). These objects are characterized by their compact aspect (about 2–3 kpc diameter) and very high specific star formation rates (i.e. the ratio between star formation rate (SFR) and the stellar mass) ranging between 10^{-8} and 10^{-9} yr^{-1}. This implies that their optical luminosities are dominated by very bright emission lines. In fact, these objects have been considered by some authors as Lyman-break analogs in the Local Universe [9]. Although the usage of the $N2O2$ parameter in this sample of objects yielded metallicities close to the solar value, a more thorough analysis made by [1] based on the determination of electron temperatures, cleared that the GPs are mostly metal-poor galaxies whose N/O is higher than the value expected for the single production of primary N. This was later confirmed by the analysis of the deep optical spectroscopy of three GPs observed with OSIRIS-GTC [2], for which accurate chemical abundances were derived and the presence of a very old underlying stellar population, responsible for the production of secondary nitrogen, was also found.

The relation between stellar mass and metallicity, the so-called mass-metallicity relation (MZR) is a powerful tool to study the evolution of galaxies because it shows how the change of the effective yield for different galaxy masses. In Fig. 3, at left, it can be seen the position of the GPs in this plot in relation to other star-forming galaxies selected from the Sloan Digital Sky Survey DR7 catalogue (see [1]). The GPs present systematically lower oxygen abundances than other star-forming galaxies with their same stellar mass. On the contrary, in the same figure at right, it can be seen that the GPs do not show a lower N/O ratio as compared with the other galaxies with their same stellar mass. According to [1], this different behaviour could be related with different chemo-dynamical processes, such as the infall of metal-poor gas, responsible for the very high SFRs found in these objects and the decrease of the metallicity. On the contrary the abundance ratio of a primary and a secondary element, such as N/O, is unaffected under this kind of processes.

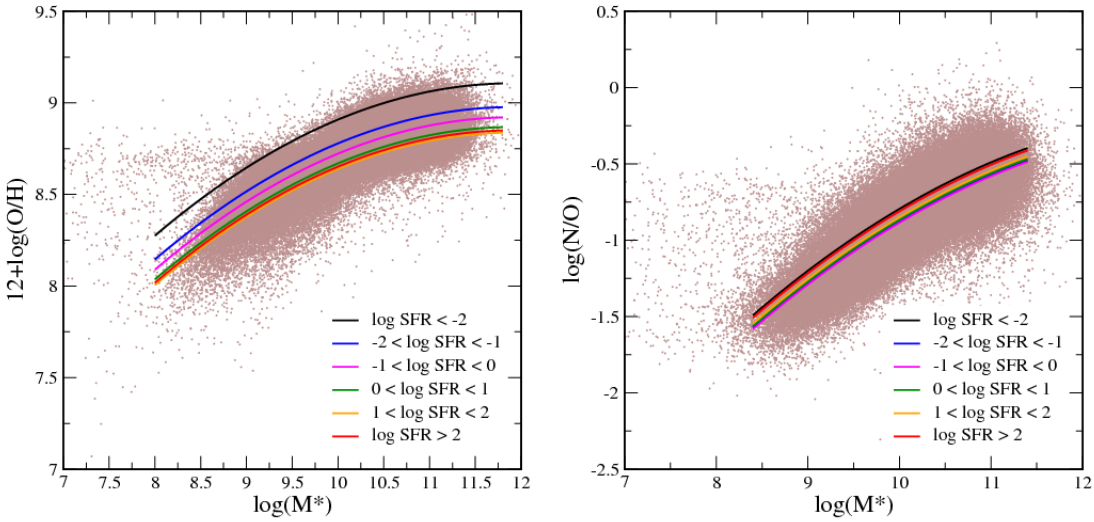

Figure 4: Relation between O/H (at left) and N/O (at right) with the stellar mass for a sample of star-forming galaxies in the SDSS-DR7. The solid lines of different colours represent quadratical fittings for subsamples with different SFR

3 Nitrogen-to-oxygen ratio as cosmic tracer of the metal evolution

The above example of GPs illustrates very well one of the fundamental relations between the integrated properties of star-forming galaxies, as it is the case of the relation between metallicity and SFR. In this case, the increase of SFR is related with a decrease of the average metallicity. Therefore, several authors (e.g. [8, 7]) have suggested that this relation could be used to reduce the dispersion of the MZR. The resulting relation was named as the Fundamental Metallicity Relation (FMR) and it is just the lowest-dispersion projection of the 3D relation between stellar mass, SFR and metallicity. However, N/O is also a very solid indicator of the chemical status of a galaxy and presents the advantage that it has no dependence on the SFR. In Fig. 4 it can be seen the MZR (at left) and the relation between mass and N/O (MNOR) for a sample of star-forming galaxies selected from the SDSS DR7. The solid lines represent different quadratical fittings to the subsamples with different bin values of the SFR. Only in the case of the O/H this is varied as a function of SFR, while N/O is unaffected by this change. This makes the relation between N/O and mass much more solid than the MZR to study the average cosmic evolution of the metallicity in the Universe, avoiding the always present selection effects towards very high SFR objects in samples of galaxies at high redshift.

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