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Can we use the N2 index to derive metallicities?

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SUMMARY

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Introduction

Methods to derive metallicities:

- Analysis of the nebular spectra => best method to determine chemical abundances of elements that have optical emission lines.

  - *Direct method:* Determines O/H using the physical properties (Electron temperature, T_e).

    The direct method is: **simple**, **powerful** and provide **reasonable results**.

  - *Strong-line methods:* based on cooling properties of ionized nebulae => **relationship emission line ratios and O/H.**

    EXAMPLES: N2 index, R23 parameter, etc.

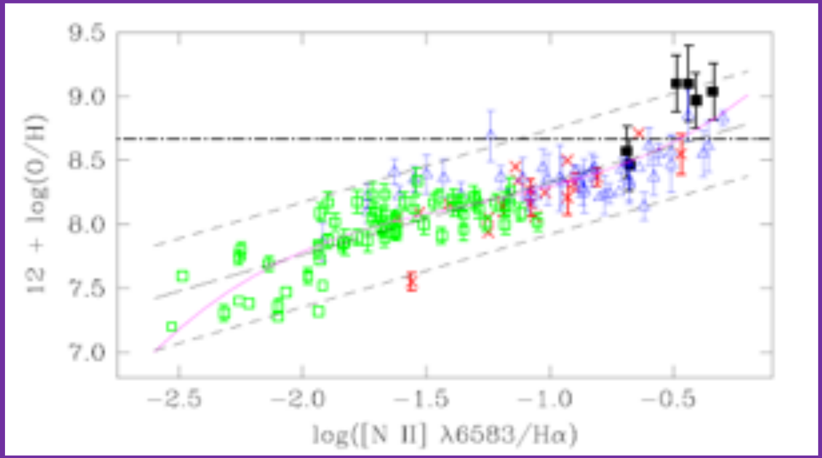
  - *Photoionization models:* Previous knowledge of the physical properties of the nebulae is required.
    - Commonly accepted: provides the most accurate abundances.

Introduction: N2 index

- The N2 index is defined (Denicolo, Terlevich & Terlevich (2002)):

$$N2=\log([NII]6583 / H\alpha)$$

[Pettini & Pagel (2004)]



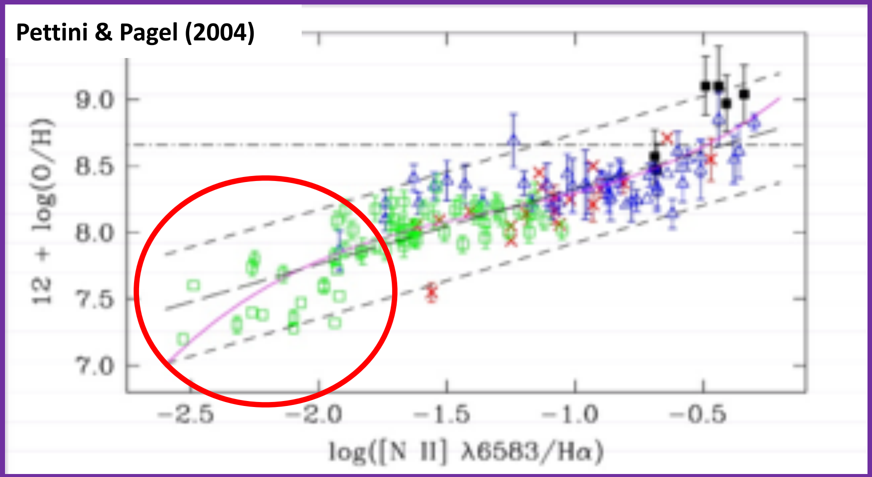
- Obtained using **only HII regions with values of (O/H) determined via the T_e method** or photoionization models.
- Used to obtain oxygen abundance when we do not have all the lines that we need.

- **Commonly used** to determine O/H.
- Independent of: reddening correction and flux calibration.
- **Single-valued.**
- Applied at high redshift.

OBJECTIVE: Calibration of N2 index

- The precise measure of oxygen abundance (the direct method) requires:
  - To measure a significant number of emission lines along a wide spectral range
  - The key is the measurement of auroral forbidden oxygen emission lines ([OIII]λ 4363 and [OIII]$\lambda\lambda$4959,5007)
- At 12+log(O/H)≃8.2 => [OIII]λ 4363 practically undetectable => strong-line method needed.
- Objective: To improve the N2 calibration at low-metallicities using the complete sample of XMPs compiled in Morales-Luis et al. (2011).

Previous N2 calibrations



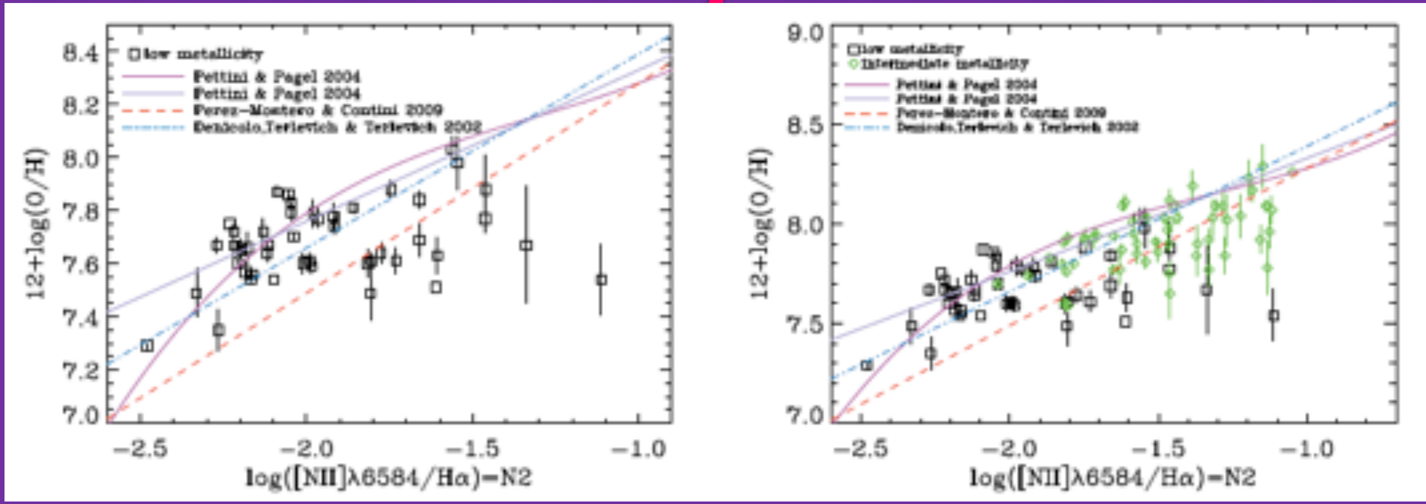
The sample

- We employ the sample of metal-poor galaxies compiled by Morales-Luis et al. (2011).
- We use the XMPs from the main search in SDSS/DR7 (11 galaxies) and the galaxies from the literature (129 XMPs) => only 79 galaxies with SDSS/DR7 spectra.
- Total: 46 galaxies with all the lines needed to determine oxygen abundance using the direct method.
- Second control sample ("intermediate-metallicity galaxies"): 65 galaxies with $7.65 \leq 12+\log(O/H) \leq 8.2$.

Determination of abundances

- We developed a tool to determine physical properties and chemical abundances using the **direct method**.
- The procedure was written in IDL.
- It is valid for HII regions and galaxies with emission lines.
- It uses the equations and fitting functions described in Hägele et al. (2008).

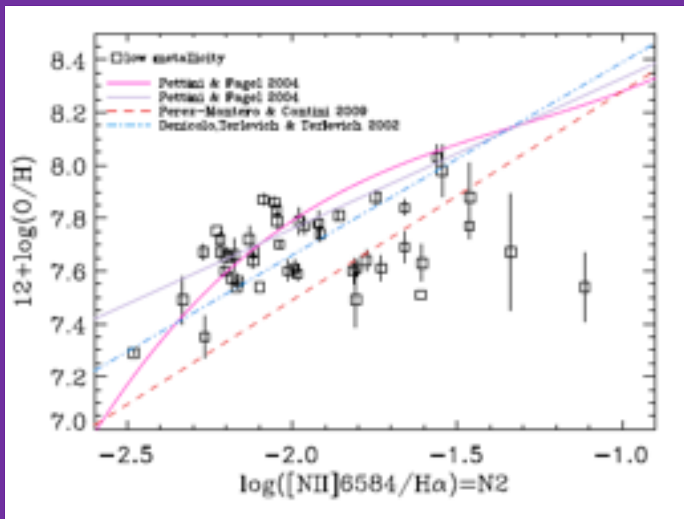
RESULTS: Metallicity and N2 index



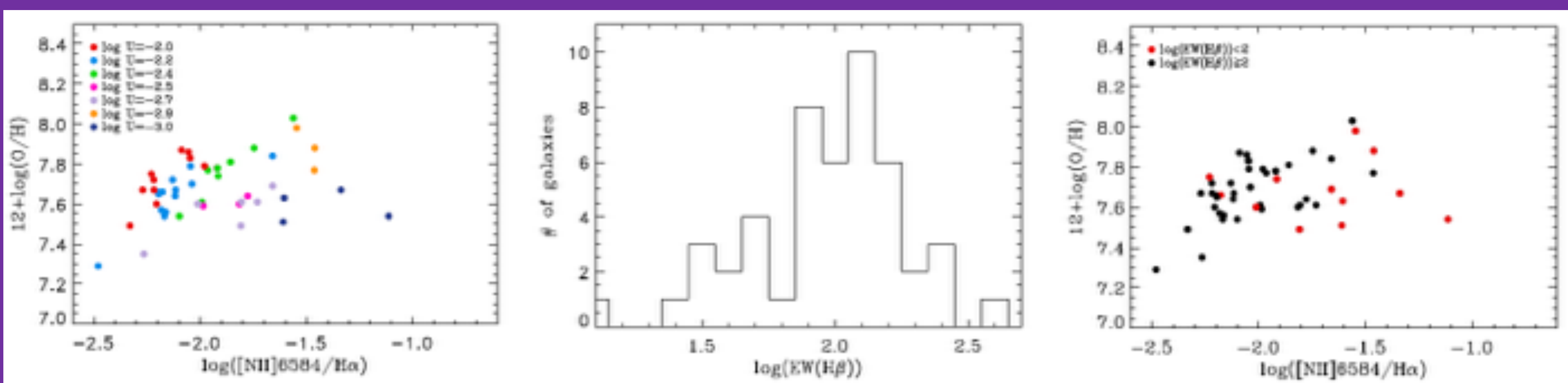
- The direct method confirms:
  - Low metallicity galaxies in Morales-Luis et al. (2011) are, indeed, XMPs.
  - There are not jumps => the sample is continuous.
- O/H tendency to be constant with N2 for XMPs => The scatter is very large.
  - Photoionization models to explain the scatter.
  - We study as a first possibility the dependence with the ionization parameter (U). (Denicolo et al. 2002)
- N2 can be used as an upper limit to the true metallicity in the low-metallicity range.
  - Third order polynomial calibration from Pettini & Pagel (2004) suffices for this objective.

$$12 + \log(O/H) \lesssim 9.37 + 2.03 \cdot N2 + 1.26 \cdot N2^2 + 0.32 \cdot N2^3$$
$$-2.5 \leq N2 \leq -1$$

RESULTS: Scatter in O/H versus N2

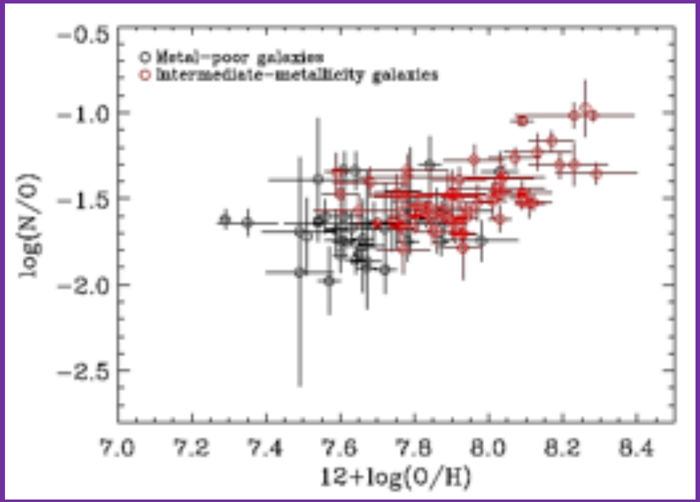


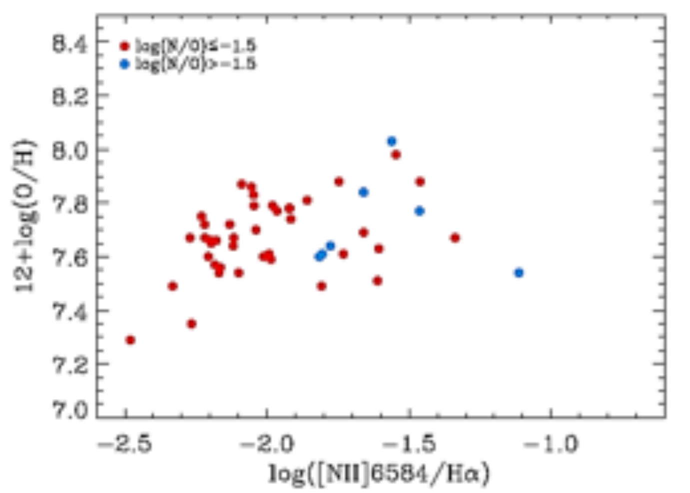
- Oxygen abundance presents a <u>tendency to be constant with N2</u> for metal-poor galaxy sample.
- We use [OIII]/Hβ and models to determine ionization parameter.
- <u>N2 decreases with U</u>. Scatter due to the degree of ionization.
- EW(Hβ) => qualitative idea of evolution state of our galaxies.
- Younger galaxies have EW(Hβ) larger.
- Galaxies with less ionization parameter are the most evolved.
- <u>Dispersion correlated also with the evolutionary state</u>.



RESULTS: Scatter in O/H versus N2

- N2 uses N lines to diagnose oxygen abundance, part of the uncertainty due to N/O (Pérez-Montero & Díaz 2005).
- Metal-poor galaxies is expected log(N/O)≈-1.6 => N primary origin (coming mainly from massive stars).
- We calculated N/O using N2S2 (Pérez-Montero & Contini 2009). We separe galaxies with log(N/O)≤-1.5 and with log(N/O)>-1.5.
- Part of the dispersion=> due to an excess of N/O.
- Possible reasons:
  - Extra production of primary nitrogen from low-metallicity and intermediate-mass stars. (Molla et al. 2006, Gavilán et al. 2006)
  - Combination of outflows and inflows of metal-poor gas => trigger star formation processes changing the metal content without changes in N/O (Amorín et al. 2010).





CONCLUSIONS

INITIAL AIM: To improve the calibration used in the literature to infer oxygen abundances from N2.

– We compare N2 and metallicity using direct method in the XMP galaxies worked out by Morales-Luis et al. (2011).

- *RESULTS:*

1. Direct method confirms galaxies classified as low-metallicity galaxies in Morales-Luis et al. (2011) are, indeed, metal-poor.
2. O/H presents a tendency to be constant with N2 => difficult to work out any calibration at low metallicity.
3. The calibration O/H vs N2 by Pettini & Pagel (2004) can be used at low metallicities to set an upper limit to the true metallicity.
4. O/H vs N2 presents a very large scatter. Using CLOUDY MODELS (Ferland et al. 1998):
   – N2 decreases with the ionization parameter for a given O/H.
   – Part of the dispersion is due to the evolutionary state of the galaxies.
   – Part of the scatter due to an excess of N/O in some of metal-poor galaxies => could due to extra production of primary nitrogen, or other processes including inflows of metal-poor gas.

CONCLUSIONS

Morales-Luis et al. (2014)

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ON THE USE OF THE INDEX N2 TO DERIVE THE METALLICITY IN METAL-POOR GALAXIES

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ABSTRACT

The N2 index ([N II] λ6584/Hα) is used to determine emission line galaxy metallicities at all redshifts, including high redshift, where galaxies tend to be metal-poor. The initial aim of this work was to improve the calibrations used to infer oxygen abundance from N2 by employing updated low-metallicity galaxy databases. We compare N2 and the metallicity determined using the direct method for the set of extremely metal-poor galaxies compiled by Morales-Luis et al. To our surprise, the oxygen abundance presents a tendency to be constant with N2, with a very large scatter. Consequently, we find that the existing N2 calibrators overestimate the oxygen abundance for most low-metallicity galaxies, and can therefore only be used to set upper limits to the true metallicity in low-metallicity galaxies. An explicit expression for this limit is given. In addition, we try to explain the observed scatter using photoionization models. It is mostly due to the different evolutionary state of the H II regions producing the emission lines, but it also arises due to differences in N/O among the galaxies.