Chemical Abundances in Gaseous Nebulae:
Open problems in Nebular astrophysics
AAA Workshop Series 11, 2019
M. Cardaci, G. Hägele & E. Pérez-Montero, eds.

Poster

Metallicity Determination in Seyfert 2 AGNs

Monteiro, A. F.[1,2], Dors, O. L.[1], Cardaci, M. V.[3,4], Hägele, G. F.[3,4]

[1] *Universidade do Vale do Paraíba, Av. Shishima Hifumi 2911, 12244-000, São José dos Campos - SP, Brasil*
[2] *Instituto Federal do Maranhão - Campus Imperatriz, Av. Newton Bello s/n, Vila Maria, 65906-335, Imperatriz - MA, Brasil*
[3] *Instituto de Astrofísica de La Plata (CONICET-UNLP), Argentina*
[4] *Facultad de Ciencias Astronómicas y Geofísicas, Universidad Nacional de La Plata, Paseo del Bosque s/n, 1900 La Plata, Argentina*

Abstract. Aims: To study calibrations of line ratios that can estimates metallicities of galaxies even in large redshift where the measurement of faint emission lines is not easy to obtain. Methods: We use the Cloudy Code to build a grid of photoionization models with lines ratios from the UV and, we compare with a sample of 77 object AGNs Seyfert 2. Results: We build semi-empirical calibrations between the metallicity of studied objects and the rest-frame intensity of the line ratios N V λ1240 / He II λ1640, C43=log[(C IV λ1549 + C III] λ1909) / He II λ1640] and C III] λ1909 / C IV λ1549.

Key words: galaxies: abundances — galaxies: Seyfert — galaxies: active — galaxies: ISM

1. Introduction

Metalicity determination in Active Galactic Nuclei (AGN) is essential to understand the evolution of galaxies. In general, the method that is considered more reliable for estimations of metallicity (Z) of emission-line objects (e.g. AGNs, H II regions, and Planetary Nebulae) is the Te-method, which consists of using fluxes of collisionally-excited emission-lines from different ionic levels of a given element to estimate the electron temperature and the abundance in relation to the hydrogen abundance, usually O/H (e.g. Pérez-Montero, 2017; Peimbert et al., 2017). Unfortunately, some auroral line fluxes cannot be easily measured in distant objects or objects with low excitation (e.g. Bresolin et al., 1999) and estimates using the strong-line method can be used as an alternative. The main idea of this method is to calibrate the relationship between the abundance of an element in an ionized region and relatively strong emission lines in its spectrum (Maiolino & Mannucci, 2019). Most of the calibrations between AGN narrow-line ratio and the metallicity is purely theoretical. One that was proposed by Dors et al. (2014) is between the metallicity of the gas in the Narrow Line Regions (NLR) of AGN and the intensity of a ultraviolet (UV) emission-lines through the use of the C43=log[(C IV λ1549 + C III] λ1909)/He II λ1640] emission-lines ratio. This calibration is strongly dependent on the gas ionization degree which can be estimated from the CIII] λ1909/CIV λ1549 emission-lines ratio. To add observational constraints to produce better reliable metallicity calibrations and also to investigate the use of other strong UV line ratio as a metallicity indicator, in this case, the NV λ1240/HeII λ1640 ratio suggested by Ferland et al. (1996), have motivated this work. The objective is to form a computational method that we can apply to hundreds or thousands of spectra.

2. AGN Sample

To investigate the metallicity in NLR of AGN, we compiled from the literature AGN type 2 line ratios in the range $1000 < \lambda(\text{Å}) < 2000$. It was composed of 77 spectra (redshift, z < 4.0), that we took most part from Matsuoka et al. (2018) and we included some objects at low redshifts (z < 0.04). The criteria used for selection is the presence of fluxes of CIII] λ1909, CIV λ1549 and HeII λ1640. The flux of NV λ1240 is only available for 22 of the objects of our sample. We did not correct emission-lines reddening due to the small effect of dust extinction on determinations of metallicity and ionization degree obtained from the considered emission-line ratios (Nagao et al., 2006b).

3. Photoionization models

We use the Cloudy code version 17.01 (Ferland et al., 2017) to build a grid of photoionization models representing AGN for comparing the predicted UV emission-line intensity ratios with those measured for the type-2 AGNs. All models have the Spectral Energy Distribution (SED) composed by two parts: one representing the Big Blue Bump peaking at 1 Ryd, and the other a power law with spectral index alpha parameter of -1.4 representing the non-thermal X-ray radiation (Miller et al., 2011). The electronic density is set to be 500cm^{-3} as well for all models, an average value calculated for a sample of Seyfert 2 AGN by Dors et al. (2014). For the ionization parameter (U), we use values in the range $-4.0 \leq \log U \leq -1.0$, with a step of 0.5 dex, and the following values for the metallicity in relation to the solar one ($Z/Z_{\odot}$): 0.2, 0.5, 0.75, 1.0, 1.5, 2.0, 3.0 and 4.0. We adopt that all elements abundance, except nitrogen, scales linearly with the oxygen abundance, for that, we use the relation found by Hamann & Ferland (1993), $(\text{N/H}) = (Z/Z_{\odot})^2 \times (\text{N/H})_{\odot}$, where the value of $\log(\text{N/H})_{\odot} = -4.07$ was taken from Holweger (2001).
In Figure 1, on the left panel, the grid composed by log(CIII] λ1909/CIV λ1549) and C43 line ratios, and, on the right panel, other one composed by log(CIII] λ1909/CIV λ1549) and log(NV λ1240/HeII λ1640) line ratios. An important caveat is that a strong line metallicity diagnostics can degenerate when employing some indirect correlations, such as the correlation between metallicity and ionization parameter (Maiolino & Mannucci, 2019; Nagao et al., 2006a). In the grids, we do not found degenerescence in metallicity for the values considered for the C43 index, but one is present for the diagnostic with NV/HeII line ratio, and we do not consider values in range $0.2 < Z/Z_{\odot} < 0.5$ because values above 0.5 seems to be more realistic to AGN.

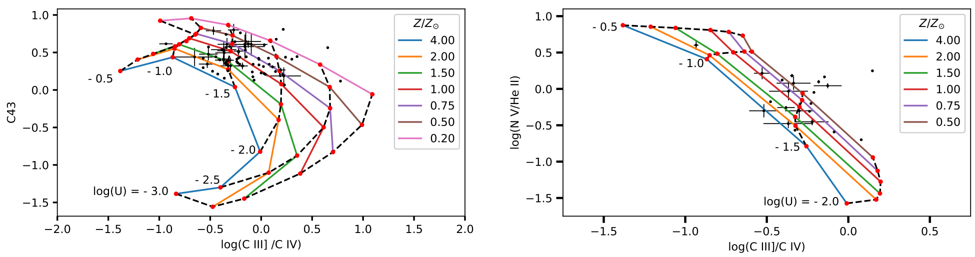

Figure 1. On the left panel, the grid composed by log(C III] λ1909/C IV λ1549) and C43 line ratios, and, on the right panel, it shows one with log(C III] λ1909/C IV λ1549) and log(N V λ1240/He II λ1640) line ratios.

4. Method

We used the same methodology of Castro et al. (2017) to obtain semi-empirical calibrations between metallicities and the indexes. For each point inside the grid shown in Figure 1, we found the value of Z by linear interpolation with line segments, which contain a point we are interested in estimating, bounded by the two nearest solid lines, the assumption is that a point over these line has the same metallicity indicated by the legend. We made an analogous process with the dashed lines for the values of the $\log U$. With the interpolated parameters and the observational line ratios of the sample, we have adjusted semi-empirical calibrations using the method of least squares.

5. Results

In Figure 2, the values of metallicity obtained with the grids shown in Figure 1. On the left panel, we plot the calibration found using the C43 line ratio, and, on the right panel, the calibration using the log(N V/He II) line ratio.

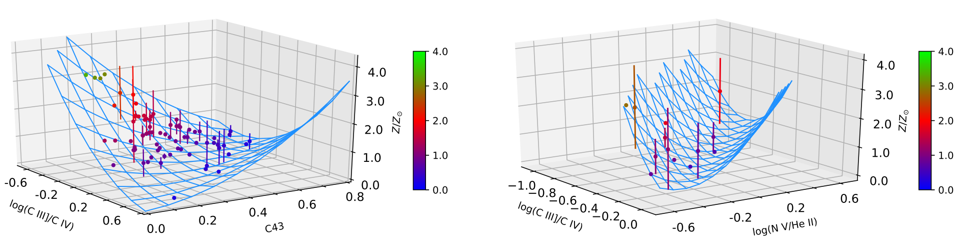

Figure 2. On the left panel, the calibration found using the C43 line ratio, and, on the right panel, the calibration using the log(N V/He II) line ratio.

We compared our results with the calibration between Z and $N2O2 = \log$([N II] λ6584 / [O II] λ3727) index on optical range proposed by Castro et al. (2017). We found only three objects in common in both samples, they are presented in Table 1, and it shows that the closest values were calculated by the calibration of the C43 line ratio.

Table 1. Metallicities ($Z/Z_{\odot}$) comparison of N V/He II and C43 line ratios obtained in this work and $N2O2$ line ratio obtained by Castro et al. (2017).

	$Z/Z_{\odot}$		
	N V/He II	C43	$N2O2$
NGC 5506	—	0.47	1.15
Mrk 3	2.47	1.00	1.16
Mrk 573	1.09	1.67	1.12

6. Conclusions

We compared the observational intensities of UV emission lines with results of photoionization models to obtain two semi-empirical calibrations between the metallicity of the Narrow Line Region of Seyfert type-2 Active Galactic Nuclei. The calibrations found seems to be more reliable than the results of Dors et al. (2014) once we use observational constraints.

Acknowledgments. A. F. Monteiro would like to thank Coordenação de Aperfeiçoamento de Pessoal de Nível Superior (CAPES).

References

Bresolin F., Kennicutt, Jr. R. C., Garnett D. R., 1999, *Astrophys. J.*, **510(1)**, 104
Castro C. S., Dors O. L., Cardaci M. V., Hägele G. F., 2017, *Mon. Not. R. Astron. Soc.*, **467(2)**, 1507
Dors O. L., Cardaci M. V., Hägele G. F., Krabbe Â. C., 2014, *Mon. Not. R. Astron. Soc.*, **443(2)**, 1291
Ferland G. J., Baldwin J. A., Korista K. T., Hamann F., Carswell R. F., Phillips M., Wilkes B., Williams R. E., 1996, *Astrophys. J.*, **461**, 683
Ferland G. J., Chatzikos M., Guzmán F., Lykins M. L., van Hoof P. A. M., Williams R. J. R., Abel N. P., Badnell N. R., Keenan F. P., Porter R. L., Stancil P. C., 2017, *Rev. Mex. Astron. y Astrofísica*, **53**, 385
Hamann F., Ferland G., 1993, *Astrophys. J.*, **418**, 11
Maiolino R., Mannucci F., 2019, *Astron. Astrophys. Rev.*, **27(1)**, 3
Matsuoka K., Nagao T., Marconi A., Maiolino R., Mannucci F., Cresci G., Terao K., Ikeda H., 2018, *Astron. Astrophys.*, **616**, L4
Miller B. P., Brandt W. N., Schneider D. P., Gibson R. R., Steffen A. T., Wu J., 2011, *Astrophys. J.*, **726(1)**, 20
Nagao T., Maiolino R., Marconi A., 2006a, *Astron. Astrophys.*, **459(1)**, 85
Nagao T., Maiolino R., Marconi A., 2006b, *Astron. Astrophys.*, **447(3)**, 863
Peimbert M., Peimbert A., Delgado-Inglada G., 2017, *Publ. Astron. Soc. Pacific*, **129(978)**, 082001
Pérez-Montero E., 2017, *Publ. Astron. Soc. Pacific*, **129(974)**, 043001