The flux ratio of the \([\text{N II}] \lambda \lambda 6548, 6583 \text{ Å} \) lines in sample of Active Galactic Nuclei Type 2

Ivan Dojčinović\textsuperscript{a}, Jelena Kovačević-Dojčinović\textsuperscript{b}, Luka Č. Popović\textsuperscript{b,c}

\textsuperscript{a}Faculty of Physics, University of Belgrade, Studentski Trg 12, Belgrade, Serbia
\textsuperscript{b}Astronomical Observatory, Volgina 7, 11060 Belgrade, Serbia
\textsuperscript{c}Faculty of Mathematics, University of Belgrade, Studentski Trg 16, Belgrade, Serbia

Abstract

In spectra of the Active Galactic Nuclei (AGNs), the \([\text{N II}] \lambda \lambda 6548, 6583 \text{ Å} \) lines are commonly fitted using the fixed intensity ratio of these two lines (\( R_{[\text{N II}]} = I_{6583}/I_{6548} \)). However, the used values for fixed intensity ratio are slightly different through literature. There are several theoretical calculations of the transition probabilities which can be used for the line ratio estimation, but there are no experimental measurements of this ratio, since the \([\text{N II}] \) lines are extremely weak in laboratory plasma. Therefore, the intensity ratio of \([\text{N II}] \) lines can be measured only in the spectra of astrophysical objects. However, precise and systematic measurements have not been done so far, because of difficulties in measurement of the \([\text{N II}] \) ratio in various spectra (overlapping with \( \text{H} \alpha \), weak intensity of \([\text{N II}] \), influence of the continuum noise and outflow contribution, etc.). Here we present the measurements of the flux ratio of the \([\text{N II}] \lambda \lambda 6548, 6583 \text{ Å} \) emission lines for a sample of 250 Type 2 AGNs spectra taken form Sloan Digital Sky Survey (SDSS) data base. The spectra are chosen to have high signal-to-noise ratio and to \([\text{N II}] \) and \( \text{H} \alpha \) lines do not overlap. The obtained mean flux ratio from measurements is 3.049 ± 0.021. Our result is in agreement with theoretical result obtained by taking into account the relativistic corrections to the magnetic dipole operator.

Keywords: galaxies: active; galaxies: emission lines; atomic data

1. Introduction

Nitrogen (N) is the seventh most abundant element in the Universe and it can be observed in the spectra of different astrophysical objects. The forbidden emission lines \([\text{N II}] \lambda \lambda 6548, 6583 \text{ Å} \) were first time detected in optical spectra of gaseous planetary nebulae in our Galaxy (Bowen, 1927, 1928; Boyce, 1933). Bowen (1927) found that strong emission lines observed in spectra of gaseous nebulae, which have not been seen in any terrestrial source, originate by spontaneously emission from metastable level, which is possible only in extremely low density medium. In this way, he identified several forbidden emission lines, among them \([\text{N II}] \lambda \lambda 6548, 6583 \text{ Å} \).

The development of astronomical observations has led to the frequent observation of these lines in spectra of various astrophysical objects. They are among the most prominent narrow emission lines in spectra of the Active Galactic Nuclei - AGNs, HII regions/starburst galaxies, planetary nebulae, nova shells of gas and supernova remnants (Osterbrock & Ferland, 2006). In AGNs, they arise in low density (<10\(^5\) cm\(^{-3}\)) photoionized gas, called Narrow Line Region (NLR), which has lower velocity dispersion (up to 500 km s\(^{-1}\)) comparing the velocity of the gas in the Broad Line Region (BLR), which is closer to the super massive black hole in the center of an AGN (see Osterbrock & Ferland, 2006). The \([\text{N II}] \) lines could also arise in outflows, the large-scale phenomena, which are commonly seen in AGNs (Woo et al., 2016; Kovačević-Dojčinović et al., 2022).

The \([\text{N II}] \lambda \lambda 6548, 6583 \text{ Å} \) lines have the similar term struc-
ture as [O III] λ5007, 4959 Å, which are the most prominent narrow emission lines in low-density photoionized gas. Similarly as [O III] lines, [N II] lines originate from the same upper and slightly different lower energy level and have a negligible optical depth since the transitions are strongly forbidden. Therefore [N II] λ6548 Å and [N II] λ6583 Å lines may be scaled to exactly the same emission line profile, as it is shown for [O III] lines (Dimitrijević et al., 2007).

Because of observational and physical circumstances, these two pairs of lines ([N II] and [O III]) are suitable for diagnostics of astrophysical objects (Osterbrock & Ferland, 2006). They can be used for investigation of the gas kinematics in the Narrow Line Region of AGNs (Eum et al., 2017) and AGN outflow dynamics (Freitas et al., 2018). The line intensity ratio of [N II] λ6583/Hα is used in BPT (Baldwin, Phillips, Terlevich) diagnostic diagram (Baldwin et al., 1981) for classification of extragalactic objects. The BPT diagram consists of emission-line intensity ratios [N II] λ5007/Hβ, supplemented by separation curves of Kewley et al. (2001) and Kauffmann et al. (2003). Using this diagram one can identify the nature of the gas ionization source (Veilleux & Osterbrock, 1987; Smirnova et al., 2007), and separate extragalactic objects to AGNs, starburst galaxies or LINERs (Low Ionization Nuclear Emission-line Region galaxies). In some cases, separation between starburst galaxies and AGN-type objects is made only by [N III]/Hα ratio (Bae et al., 2017). Also, the [N II]/Hα ratio is commonly used as metallicity indicator (see Groves et al., 2006; Martens et al., 2019).

Since the Hα line is positioned between the [N II] λ6548 Å and [N II] λ6583 Å lines and there are small wavelength differences between these lines, [N II] and Hα lines are often blended in spectra of AGNs, which sometimes makes difficult to use these lines in diagnostics purposes. To reduce the number of fitting parameters in decomposition of the complex [N II] + Hα wavelength band it is necessary to fix the intensity ratio of [N II] λλ6583, 6548 Å lines (R\textsubscript{[NII]} = I\textsubscript{6583}/I\textsubscript{6548}). Since these two lines have the same upper level of the transition, it is expected that their intensity ratio is fixed in spectra, as it is the case for the [O III] λλ5007, 4959 Å lines (Dimitrijević et al., 2007).

However, the used values for R\textsubscript{[NII]} are slightly different through literature and there is a need for accurate measurement of this ratio. The obtained theoretical values for [N II] λλ6548.45 Å/[N II] λλ6548.05 Å transition probability ratio (A\textsubscript{6583}/A\textsubscript{6548}) are between 2.93-3.07 (see Table I). Acker et al. (1989) measured the flux ratio of [N II] lines for 267 planetary nebulae of our Galaxy. They found the line ratio of R\textsubscript{[NII]} = 2.92±0.32. However, there is lack of the systematic experimental measurements of [N II] lines from AGN spectra. These measurements are done only for several particular objects (see Nazarova et al., 1996; Dietrich et al., 2005).

The aim of this work is to do systematic and accurate measurements of [N II] lines ratio in large sample of AGNs Type 2 spectra and to compare the obtained value with various theoretical values. In Section 2 we give some basic properties of the N+ ion and the review of the different theoretical results for [N II] lines ratio. In Section 3 we described the properties of the [N II] lines in AGN spectra and we gave some measured values of [N II] ratio for particular objects from literature. The procedure of the sample selection and spectral analysis are presented in Section 4. In Section 5 we give our result of [N II] ratio and compare it with theoretically obtained values, and in Section 6 we outline some conclusions.

2. Theoretical values of the [N II] λ6548/[N II] λ6583 ratio

Ionization energy, necessary for ion N+ forming, is 14.5 eV. Ion N+ is carbon-like, as well as O+2 ion, with electron configuration of ground state 2s22p2. Allowed terms for p2 equivalent electrons are 3P, 1D and 1S. Ground level in [N II] spectra is 3P0. Another levels of 3P term are 3P1 (with energy 0.00604 eV), and 3P2 (0.01622 eV) (data taken from the National Institute of Standards and Technology (NIST) database, see Kramida et al., 2020). First excited level is metastable 1D2, with 1.89897 eV energy. The 1D state have low excitation potentials, high statistical weights and long lifetime of about 300 s (Bowen, 1936).

There are three possible transitions between metastable 1D2 and 1P terms (1P0, 1P1, 1P2). Two transitions, which are observed in astrophysical spectra are:

1. 2s22p2 1D2 - 2s22p2 3P2 ([N II] λλ6548.05 Å),
2. 2s22p2 1D2 - 2s22p2 3P1 ([N II] λλ6548.45 Å).

The radiative transitions within 1D and 1P terms are forbidden in electric dipole radiation, because they all have the same parity, i.e. they violate ΔS = 0 rule (intercombination transitions). Although they occur with small transition probabilities, the [N II] λλ6548 Å and [N II] λλ6583 Å lines are observed in optical spectra of different astronomical sources as strong emission lines, because of very low densities and a huge amount (volume) of photoionized gas where they arise. Their transition probabilities, calculated with different theoretical models, are given in the first and second column of Table I.

The third possible transition, [N II] λλ6527.23 Å (2s22p2 1D2 - 2s22p2 3P0), is additionally forbidden by selection rule ΔJ = 0, ± 1 and therefore it has the smallest transition probability (10−7 s−1). That line is not visible in the spectra.

The critical density of [N II] 1D2 for collisional deexcitation is 6.6 · 104 cm−3 (Osterbrock & Ferland, 2006). In medium with higher electron densities, metastable excited level 1D2 is depopulated by electron impact rather than radiation transition, and [N II] λλ6548, 6583 Å lines do not occur in spectrum.

2.1. The comparison of the theoretical values

Here we review some theoretical works which try to explain the 3P1 - 1D2 and 3P2 - 1D2 transitions ([N II] λλ6548, 6583 Å). Since these singlet-triplet transitions are forbidden in electric dipole approximation, they are possible by the breakdown of Russell-Saunders coupling. The wave function of the 1D2 level is a linear combination of 1D2 and 3P2 levels, so the transition to a triplet state can occur through this small part of the triplet in the singlet dominant wave function. Therefore, the mixing of different multiplicity states occurs through the spin-orbit interaction, which is very important for occurrence of the [N II] lines (Condon & Shortley, 1959). While [N II] λλ6548, 6583 Å
lines are essentially due to magnetic dipole radiation, the third line [N II]λ6527 Å, which is not visible in spectra, is made due to electric quadrupole only, and its transition probability is of the order of $10^{-7}$ s$^{-1}$ (Kramida et al., 2020). Contribution of the electric quadrupole in [N II]λ6548 and [N II]λ6583 lines intensity is about 0.1 per cent. One can see that the electric quadrupole radiation for these lines is of the order of $10^{-6}$ s$^{-1}$ (Galavis et al., 1997).

Some theoretical results of [N II]λλ 6548, 6583 Å radiative forbidden transition probabilities and their ratio are given in Table 1. Stevenson (1932) took basic perturbation calculations and found that transition probability [N II] lines ratio $(A_{6583}/A_{6548})$ is exactly 3:1, with mean life of 1D$_2$ state of 3.1 minutes. Several authors obtained $A_{6583}/A_{6548}$ ratio of 2.96 (Condon, 1934; Mendoza, 1983; Galavis et al., 1997; Tachiev & Fischer, 2001), while Pasternack (1940) obtained value of 2.93.

Condon (1934) considered the radiation field produced by an oscillating magnetic dipole. Single-triplet transition occurs because of the magnetic spin-orbit interaction, where the levels 1D$_2$ and 3P$_2$ interact, corresponding to J = 2, and forming upper level with dominant single and small contribution of the triplet state. In order to calculate $A_{6583}/A_{6548}$ ratio, Pasternack (1940) used Condon and Shortley theory of atomic spectra (Condon & Shortley, 1959, first printed in 1935). Mendoza (1983) included Breit-Pauli relativistic corrections to the magnetic dipole operator. Their relativistic corrections include all the one-body and two-body magnetic fine-structure interactions, spin-orbit, spin-spin etc. The electric quadrupole operator result is taken from Galavis et al. (1997). Finally, Storey & Zeippen (2000) obtained the $A_{6583}/A_{6548}$ ratio of 3.07, that is slightly larger value than values calculated by other authors.

3. The [N II]λλ 6548, 6583 Å lines in AGN spectra

The velocity dispersion of the [N II] lines in Type 2 AGN spectra approximately follows one-to-one relationship with stellar velocity dispersion which indicates that these lines partly arise in the gravitationally bounded gas (see Eun et al., 2017; Kovačević-Dojčinović et al., 2022). Therefore, they are commonly modelled with a single Gaussian, dominantly broaden by Doppler effect, which velocity dispersion (following stellar velocity dispersion) rarely exceed the $\sim 200$ km s$^{-1}$ (Kovačević-Dojčinović et al., 2022). If an outflow is present in an AGN structure, it contributes to the narrow emission line profile in the line wings. In these spectra, [N II] emission lines are commonly modelled with double Gaussian model: one Gaussian which fits the core of the line (core component), and represents emission from gravitationally bounded gas, and a second, broader Gaussian which fits the wings of the line (wing component), and represents the simplified model for an outflow emission (see diverse theoretical models of outflow emission shape in Bae & Woo, 2016). The wing Gaussian is commonly shifted to the blue or to the red comparing the core component, representing emission from an approaching or receding outflow cones, while centered wing component probably indicates superposed emission from both (Kovačević-Dojčinović et al., 2022).

It is commonly assumed that [N II] λ6583 Å and [N II] λ6548 Å lines arise in the same emission region, so it is expected to both lines have the same widths and shifts of the core components (Popović et al., 2004), and the same widths and shifts of the wing components (if they exist).

Kovačević-Dojčinović et al. (2022) analyzed the sample of 577 spectra typically classified as Type 2 AGNs, and found that in $\sim 40\%$ of the cases, the [N II] and Hø lines are blended, mostly due to strong outflow contribution in wing components. On the other hand, in the spectra of AGNs Type 1 (also Type...
1.8 and 1.9), the narrow [N II] and Hα emission lines are additionally overlapped with broad Hα line, which originate from the BLR of an AGN. In some cases, broad Hα line is so strong that narrow [N II] lines cannot be seen at all. Therefore, the lack of the systematic measurement of the [N II] flux ratio in a large sample of AGN spectra, could be partly explained by difficulties to precisely extract the profiles of the [N II] λλ 6548, 6583 Å lines from AGN Type 1 spectra and from large amount of the AGN Type 2 spectra, and to measure their flux ratio.

In order to decompose complex [N II]+Hα wavelength band in AGN Type 1/Type 2 spectra, and to reduce the number of fitting parameters, different values were used through literature to fix the flux ratio of [N II] λλ 6583 and [N II] λλ 6548 lines. The most frequently, this flux ratio is fixed as 3:1, without giving any particular reference (see e.g. Zakamska et al., 2003; Mullane et al., 2013; Faissel et al., 2018; Fischer et al., 2019; Manzano-King et al., 2019; Marasco et al., 2020; Davies et al., 2020). However, in some papers, the flux ratio has been fixed at the theoretically obtained value of transition probability ratio 2.96 (see e.g. Popović et al., 2004; Greene & Ho, 2004; Reines et al., 2013; Woo et al., 2014; Kawasaki et al., 2017). Also, other values have been used, as e.g. Zakamska et al. (2016) used value of the ratio 2.94, Martens et al. (2019) value of 3.077, Nazarova et al. (1996) reported theoretical value of 2.88, etc.

Despite the fact that spectra of Seyfert galaxies and quasars have not been used to explicitly check the theoretical flux ratio of the [N II] λ6548, 6583 Å lines, there are examples where such ratios were obtained as a by-product or could be derived from published results (Nazarova et al., 1996; Cooke et al., 2000; Barcons et al., 2003; Dietrich et al., 2005). Nazarova et al. (1996) investigated the Seyfert 1.2 galaxy Mrk 79 with long-slit spectroscopy. Using their measured data it could be derived that $R_{NII}$ in nucleus is 3.00, while in the different parts of the extended NLR, the ratios are in the range of 2.52-3.69, which might be caused by different signal-to-noise ratio (SNR) in long-slit spectra.

Dietrich et al. (2005) measured the NLR emission line flux for 12 Narrow Line Seyfert 1 (NLSy1) galaxies. The derived $R_{NII}$ for these objects are in the range of 2.92-3.26. From measurements of the line intensities given in Cooke et al. (2000) for Seyfert 2 galaxy NGC 3393, one may obtain $R_{NII} = 2.96$, while in Barcons et al. (2003) for Seyfert 1.8/1.9 galaxy H1320+551, the measured [N II] flux ratio is 2.95. Note that [N II] lines are strongly blended by broad Hα in Nazarova et al. (1996), Dietrich et al. (2005) and Barcons et al. (2003) and by strong wing components in Cooke et al. (2000), which makes the precise measurements of the [N II] λλ 6548, 6583 Å line intensities very difficult.

On the other hand, Acker et al. (1989) performed the measurements of the [N II] line intensities in large number of the planetary nebulae spectra (267), but with low spectral resolution (1 nm), which affects the accuracy of measurements. The obtained result in Acker et al. (1989) is $R_{NII} = 2.92 \pm 0.32$.

4. The sample selection and fitting procedure

Diverse types of emission line galaxy spectra can be used for $R_{NII}$ measurements (Type 2 AGNs, starburst galaxies, LINERs, etc.). Disadvantage of the Type 2 AGN and LINERs spectra is that [N II] and Hα lines could have multi-component shapes which overlap. On the other hand, in starburst galaxies, [N II] line intensity is smaller relative to Hα, comparing the same in the Type 2 AGNs. In this research, we use only Type 2 AGN spectra, since the idea is to find the $R_{NII}$ that can be used for decomposition of the Type 1 (Sy 1) AGNs with broad lines, where the $R_{NII}$ is usually "apriori" assumed. We expect that NLR physical properties are the same (or quite similar) for all AGNs.

The spectra were chosen from Sloan Digital Sky Survey (SDSS) Data Release 14 (DR14) (Abolfathi et al., 2018), using Structural Query Language (SQL) with following requests: to be classified as Type 2 AGNs in SDSS spectral classification, median SNR over all good pixels in spectrum to be $> 20$, and to have strong emission lines ([O III], Hβ, [S II], [N II] and Hα EWs to be larger than 5 Å). In this way, we obtained 588 spectra. The spectra were corrected for the Galactic reddening and for the cosmological redshift. For correction of the Galactic reddening we used standard extinction law from Howarth (1983) and extinction coefficients from Schlafly & Finkbeiner (2011). We applied the spectral principal component analysis (SPCA) in order to decompose the spectra to the host-galaxy and AGN contribution (for details of the SPCA procedure see Kovačević-Dojčinović et al., 2022). After we obtained the host-galaxy spectra (with masked emission lines), we subtracted them from the observed spectra. In this way we obtained the AGN contribution which is not affected with stellar absorption features.

From the initial sample, through several steps, we selected the subsample which is optimal for precise measurements of the [N II] flux ratio. It is the subsample where Hα and [N II] lines could be fitted with a single-Gaussian model, i.e. they do not have wing components. Presence of the wing components in these lines import additional degrees of freedom in fitting process, and cause overlapping Hα+[N II].

First, we rejected all spectra where Hα and [N II] lines are strongly blended, as shown in Figure 1. We kept in sample only the spectra in which the emission line flux at ~ 6575 Å ($F_{6575}$), which is minimum between Hα and [N II] 6583 Å line, is close to the continuum level ($F_{6575}/N < 3$). This criterium left 346 spectra in sample. Then, we fitted simultaneously the continuum level within the range $\lambda \lambda 6550-6630$ Å with a linear function, and [N II]+Hα lines with a single-Gaussian or a double-Gaussian model. For fitting process we used nonlinear least-squares (NLLS) Marquardt-Levenberg algorithm. The Hα line is fitted with all free parameters. The widths and shifts of Gaussians which fit [N II]+Hα 6548, 6583 Å lines were forced to be the same (Popović et al., 2004), while their intensities were left to be the free parameters.

To distinguish whether a single or a double-Gaussian model should be applied on [N II]+Hα, we used the criterium of the extra-sum-of-squares F-test (Lupton, 1993). This test compares...
The histogram of distribution of obtained $R_{\text{best fit}}$, we calculated their intensity ratio all three lines are well resolved (as in Figure 1d). Overlapped (as shown in Figure 1c), while in 25% of the sample errors of the $[\text{N II}]$ $\lambda 6548$ Å and $H\alpha$ lines cannot be fitted well with single-Gaussian model (Figure 1b), i.e. where F-test P-value is $< 0.05$. Finally, our sample contains 250 spectra of AGNs Type 2, where $[\text{N II}]$ and $H\alpha$ lines can be fitted well with single Gaussian function for each line (Figures 1c,d). We found that in 75% of the final sample $[\text{N II}]$ $\lambda 6548$ Å and $H\alpha$ lines are slightly overlapped (as shown in Figure 1c), while in 25% of the sample all three lines are well resolved (as in Figure 1d).

### 5. Results and discussion

After we obtained the intensities of the $[\text{N II}]$ lines from the best fit, we calculated their intensity ratio $R_{[\text{N II}]}$ for each object. The histogram of distribution of obtained $R_{[\text{N II}]}$ in sample of 250 AGNs is shown in Figure 2.

#### 5.1. The uncertainty analysis

The nonlinear least-square fitting method gives asymptotic standard errors for obtained fitting parameters. The standard errors of the $[\text{N II}]$$\lambda 6548$ Å and $[\text{N II}]$$\lambda 6583$ Å intensity parameters were used to estimate the uncertainty of the $[\text{N II}]$ line ratio caused by fitting procedure ($\Delta R_{\text{FIT}}$). We found that the $\Delta R_{\text{FIT}}$ shows strong correlation with the widths of the $H\alpha$ and $[\text{N II}]$ lines. As widths of these lines increase, the lines more overlap (as in Figure 2b), which makes larger uncertainty in determination of the $[\text{N II}]$$\lambda 6548$ Å intensity parameter. The correlation is shown in Figure 3 (Spearman coefficient of correlation is $r = 0.51$, and P-value = 0). In order to examine the influence of the noise to the results, we measured SNR in continuum near $[\text{N II}]+H\alpha$ ($\lambda \lambda 6610-6630$ Å) as the ratio of mean value of the flux continuum to standard deviation of the flux in the same range. We found that $\Delta R_{\text{FIT}}$ is not strongly affected by the noise, since we found only negative trend between $\Delta R_{\text{FIT}}$ and SNR measured near $[\text{N II}]+H\alpha$.

However, the role of the noise in $[\text{N II}]$ intensity measurements is important, since it could affect significantly the shape of the smaller $[\text{N II}]$$\lambda 6548$ Å line, and also it contributes to the uncertainty of the continuum subtraction. Even a small difference in the determined continuum level and the slope due to noise could affect measured line intensities. Therefore, in order to additionally estimate the uncertainty in result due to noise, we applied Monte Carlo method for each spectrum. First, we constructed the spectrum model for every object, using obtained values from the fit of emission lines and continuum level. We made 100 mock spectra for each source by adding the random noise to model spectra. The random noise is limited to have Gaussian distribution. Similarly as for observed spectra, we simultaneously fitted the continuum and emission lines in mock spectra. After we obtained the fitting parameters of the mock spectra, we took the $1\sigma$ dispersion of the parameters as the parameter uncertainty and we estimated uncertainty of the $[\text{N II}]$$\lambda 6548$/[$\text{N II}]$$\lambda 6583$ ratio ($\Delta R_{\text{MC}}$). This procedure is repeated for each object. We tested if there is any correlation between $\Delta R_{\text{MC}}$ versus continuum/line prop-

![Fig. 1. Examples of $[\text{N II}]+H\alpha$ wavelength band in AGNs Type 2. (a) The spectrum with blended $H\alpha$ and $[\text{N II}]$ lines, (b) the $H\alpha$ and $[\text{N II}]$ lines are unblended, but fitted with double Gaussian model for each line, (c) both lines are fitted with single Gaussian, but they slightly overlap at $\sim 6558$ Å and (d) the spectrum where $H\alpha$ and $[\text{N II}]$ lines are fitted well with single Gaussian and they do not overlap. The spectra as in cases (a) and (b) are rejected from the sample.](image)

![Fig. 2. Histogram of distribution of the $[\text{N II}]$$\lambda \lambda 6548, 6583$ Å lines ratio obtained from the best fit.](image)
5.2. The comparison with theoretical results

Following the relationship \( I \sim n_j \cdot A \cdot h\nu \), where \( I \) is line intensity, \( n_j \) the population of the level \( j \), \( A \) spontaneous transition probability and \( h\nu \) energy of the transition, the theoretically expected line intensity ratio of [N II] lines \( \left( I_{6583}/I_{6548} \right) \) could be calculated using obtained transition probability ratio and SNR. We found that \( \Delta R_{MC} \) do not correlate with any continuum and line properties, contrary to \( \Delta R_{FIT} \) which grows with larger line widths. On the other hand, \( \Delta R_{MC} \) is strongly correlated with SNR as shown in Figure 3b (\( r = -0.64 \), and \( p \)-value = 0).

Since \( \Delta R_{FIT} \) mainly represents uncertainty of [N II] ratio caused by line overlapping and \( \Delta R_{MC} \) uncertainty of due to noise, we adopted sum of these two error estimates to be the absolute error for each measured line ratio \( \Delta R = \Delta R_{FIT} + \Delta R_{MC} \). The weights of measurements are calculated as reciprocal square of the corresponding \( \Delta R \), and the final value of the [N II] flux ratio is obtained as the weighted mean of the sample measurements. The uncertainty of the result is estimated as error in the weighted mean as given in Bevington & Robinson (2003). Finally, the obtained result for total sample is \( R_{[NII]} = 3.049 \pm 0.021 \).

6. Conclusions

In order to check the theoretical value of the intensity ratio of the [N II] lines, we measured the corresponding flux ratio in a sample of 250 Type 2 AGNs with a high-S/N spectra taken from the SDSS data base. We compared our result with various theoretical results from existing...
References

Abolfathi, B., Aguado, D. S., Aguilar, G. et al. (2018). The fourteenth data release of the Sloan Digital Sky Survey: first spectroscopic data from the extended Baryon Oscillation Spectroscopic Survey and from the second phase of the Apache Point Observatory Galactic Evolution Experiment. ApJS, 235, 42, 1-19.

Acker, A., Koppen, J., Stenholt, B., Jasniecwig, G. (1989). Spectrophotometry of southern planetary nebulae. I. Plasma diagnostics. A&AS, 80, 201-213.

Bae, H.-J., Woo, J.-H. (2016). The prevalence of gas outflows in Type 2 AGNs. II. 3D biconical outflow models. ApJ, 828, 97, 1-14.

Bae, H.-J., Woo, J.-H., Karouzos, M., Gallo, E., Flobic, H., Shen, Y., Yoon, S.-Y. (2017). The limited impact of outflows: integral-field spectroscopy of FeII AGNs. ApJ, 837, 91, 1-25.

Baldwin, J.A., Phillips M.M., Terlevich R. (1981). Classification parameters for the emission-line spectra of extragalactic objects. PASP, 93, 5-19.

Barcons, X., Carrera, F.J., Ceballos, B.T. (2003). H1320+551: a type 1.8/1.9 Seyfert galaxy with an unabsorbed X-ray spectrum. MNRAS, 339, 757-764.

Bevington, P.R., Robinson, D.K. (2003). Data reduction and error analysis for the physical sciences, 3rd ed. McGraw-Hill, Boston.

Bowen, I.S. (1927). The origin of the chief nebular lines. PASP, 39, 295-297.

Bowen, I.S. (1928). The origin of the nebular lines and the structure of the planetary nebulae. ApJ, 67, 1-15.

Bowen, I.S. (1936). Forbidden lines. Rev. Mod. Physics, 8, 55-81.

Boyce, J.C., Menzel, D.H., Payne, C.H. (1933). Forbidden lines in astrophysical sources. Proc. Nat. Acad. Sci., 19, 581-591.

Condon, E.U. (1934). The absolute intensity of the nebular lines. ApJ, 79, 217-234.

Condon, E.U., Shortley, G.H. (1959). The theory of atomic spectra. University Press, Cambridge, UK.

Cooke, A.J., Baldwin, J.A., Ferland, G.J., Netzer, H., Wilson, A.S. (2000). The narrow-line region in the Seyfert 2 galaxy NGC 3393. ApJSS, 129, 517-545.

Davies, R.L., Forster Schreiber, N.M., Lutz, D. et al. (2020). From nuclear to circumgalactic: zooming in on AGN-driven outflows at z~2.2 with SINQONI.

Dietrich, M., Crenshaw, D.M., Kraemer, S.B. (2005). Probing the ionizing continuum of narrow-line Seyfert 1 galaxies. I. Observational results. ApJ, 623, 700-720.

Dimitrijević, M.S., Popović, L.Ć., Kovačević J., Dačić M., Ilić D. (2007). The flux ratio of the [O III] λλ5007, 4959 lines in AGN: comparison with theoretical calculations. MNRAS, 374, 1181-1184.

Eam, D., Woo, J.-H., Bae, H.-J. (2017). A systematic search for hidden Type 1 AGNs: gas kinematics and scaling relations. ApJ, 842, 5, 1-11.

Faisst, A.L., Masters, D., Wang, Y., Merson, A., Capak, P., Malhotra, S., Rhoads, J.E. (2018). Empirical modeling of the redshift evolution of the [N II]/H7 ratio for galaxy redshift surveys. ApJ, 855, 132, 1-15.

Fischer, T.C., Rigby, J.R., Mahler, G. et al. (2019). Spatially resolved outflows in a Seyfert galaxy at z=2.39. ApJ, 875, 102, 1-15.

Freitas, L.C., Riffel, R.A., Storchi-Bergmann, T., Elvis, M., Robinson, A., Crenshaw, D.M., Nagar, N.M., Leno, D., Schmitt, H.R., Kraemer, S.B. (2018). Outflows in the narrow-line region of bright Seyfert galaxies - I. GMOS-IFU data. MNRAS, 476, 2760-2778.

Galavis M.E., Mendoza C., Zeippen C.J. (1997). Atomic data from the IRON Project XXII. Radiative rates for forbidden transitions within the ground configuration of ions in the carbon and oxygen isoelectronic sequences. Astron. Astrophys. Suppl. Ser., 123, 159-171.

Greene, J.E., Ho, L.C. (2004). Active galactic nuclei with candidate intermediate-mass black holes. ApJ, 610, 722-736.

Groves, B.A., Heckman, T.M., Kauffmann, G. (2006). Emission-line diagnostics of low-metallicity active galactic nuclei. MNRAS, 371, 1559-1569.

Howarth, I.D. (1983). LMC and galactic extinction. MNRAS, 203, 301-304.

Kauffmann, G., Heckman, T.M., Tremonti, C., Brinchmann, J., Charlot, S., White, S.D.M., Ridgway S. E., Brinkmann J., Fukugita M., Hall, P.B., Ivezic, Z., Richards, G.T., Schneider, D.P. (2003). The host galaxies of active galactic nuclei. MNRAS, 346, 1055-1077.

Kawasaki, K., Nagao, T., Toba, Y., Terao, K., Matsuoka, K. (2017). Active galactic nuclei with a low-metallicity narrow-line region. ApJ, 842, 44, 1-13.

Kewley, L.J., Dopita, M.A., Sutherland, R.S., Heisler, C.A., Trevena, J. (2001). Theoretical modeling of starburst galaxies. ApJ, 556, 121-140.

Kovačević-Dojčinović, J., Dojčinović, I., Lakic'ević, M., Popović, L.Ć. (2022).
Tracing the outflow kinematics in Type 2 Active Galactic Nuclei. A&A, in press, DOI: 10.1051/0004-6361/202141043.

Kramida, A., Ralchenko, Yu., Reader, J., and NIST ASD Team (2020). NIST Atomic Spectra Database (ver. 5.8). National Institute of Standards and Technology, Gaithersburg, MD. Available at http://physics.nist.gov/asd (2021, June 21).

Lupton, R.H. (1993). Statistics in theory and practice. Princeton Univ. Press, Princeton, NJ.

Manzano-King, C.M., Canalizo, G., Sales, L.V. (2019). AGN-driven outflows in dwarf galaxies. ApJ, 884, 54, 1-13.

Marasco, A., Cresci, G., Nardini, E., Mannucci, F., Marconi, A. (2020). Galaxy-scale ionised winds driven by ultra-fast outflows in two nearby quasars. A&A, 644, 15, 1-18.

Martens, D., Fang, X., Troxel, M.A., DeRose, J., Hirata, C.M., Wechsler, R.H., Wang, Y. (2019). Effects of [NII] and Hα line blending on the WFIRST Galaxy redshift survey. MNRAS, 485, 211-228.

Mendoza, C. (1983). Recent advances in atomic calculations and experiments of interest in the study of planetary nebulae. IAUS, 103, 143-172.

Mullaney, J.R., Alexander, D.M., Fine, S., Goulding, A.D., Harrison, C.M., Hickox, R.C. (2013). Narrow-line region gas kinematics of 24 264 optically selected AGN: the radio connection. MNRAS, 433, 622-638.

Nazarova, L.S., O'Brien, P.T., Ward, M.J. (1996). The extended narrow line region in Mkn 79. I. Observations. A&A, 307, 365-375.

Osterbrock, D., Ferland, G. (2006). Astrophysics of Gaseous Nebulae and Active Galactic Nuclei. University Science Book, Sausalito, CA.

Pasternack, S. (1940). Transition probabilities of forbidden lines. ApJ, 92, 129-155.

Popović, L.Č., Mediavilla, E., Bon, E., Ilić, D. (2004). Contribution of the disk emission to the broad emission lines in AGNs: Two-component model. A&A, 423, 909-918.

Reines, A.E., Greene, J.E., Geha, M. (2013). Dwarf galaxies with optical signatures of active massive black holes. ApJ, 775, 116, 1-24.

Revalski, M., Crenshaw, D.M., Kraemer, S.B., Fischer, T.C., Schmitt, H.R., Machuca, C. (2018). Quantifying feedback from narrow line region outflows in nearby active galaxies. I. Spatially resolved mass outflow rates for the Seyfert 2 galaxy Markarian 573. ApJ, 856, 46, 1-23.

Schlafly, E.F., Finkbeiner, D.P. (2011). Measuring reddening with Sloan Digital Sky Survey stellar spectra and recalibrating SFD. ApJ, 737, 103, 1-13.

Smirnova, A.A., Gavrilović, N., Moiseev, A.V., Popović, L.Č., Afanasiev, V.L., Jovanović, P., Dačić, M. (2007). The gas kinematics in the Mrk 533 nucleus and circumnuclear region: a gaseous outflow. MNRAS, 377, 480-490.

Stevenson, A.F. (1932). The intensities of certain nebular lines and the mean lives of atoms emitting them. Proc. R. Soc. A., 137, 298-325.

Storey, P.J, Zeippen, C.J. (2000). Theoretical values for the [O III] 5007/4959 line-intensity ratio and homologous cases. MNRAS, 312, 813-816.

Tachiev, G., Fischer, C.F. (2001). Breit-Pauli energy levels and transition rates for the carbonlike sequence. Can. J. Phys., 79, 955-976.

Veilleux, S., Osterbrock, D.E. (1987). Spectral classification of emission-line galaxies. ApJS, 63, 295-310.

Woo, J.-H., Bae, H.-J., Son, D., Karouzos, M. (2016). The prevalence of gas outflows in Type 2 AGNs. ApJ, 817, 108, 1-15.

Woo, J.-H., Kim, J.-G., Park, D., Bae, H.-J., Kim, J.-H., Lee, S.-E., Kim, S.C., Kwon, H.-J. (2014). Misclassified Type 1 AGNs in the local universe. JKAS, 47, 167-178.

Zakamska, N.L., Strauss, M.A., Krolik, J.H. et al. (2003). Candidate Type II quasars from the Sloan Digital Sky Survey. I. Selection and optical properties of a sample at 0.3 < z < 0.83. ApJ, 126, 2125-2144.

Zakamska N.L., Hamann F., Paris I. et al. (2016). Discovery of extreme [O III] λ5007Å outflows in high-redshift red quasars. MNRAS, 459, 3144-3160.