Outflow Kinematics Manifested by the H\textalpha\ Line: Gas Outflows in Type 2 AGNs. IV.

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Received 2017 May 2; revised 2017 July 5; accepted 2017 July 17; published 2017 August 18

Abstract

Energetic ionized gas outflows driven by active galactic nuclei (AGNs) have been studied as a key phenomenon related to AGN feedback. To probe the kinematics of the gas in the narrow-line region, [O \textsc{iii}] \(\lambda\)5007 has been utilized in a number of studies showing nonviral kinematic properties due to AGN outflows. In this paper, we statistically investigate whether the H\textalpha\ emission line is influenced by AGN-driven outflows by measuring the kinematic properties based on the H\textalpha\ line profile and comparing them with those of [O \textsc{iii}]. Using the spatially integrated spectra of \(\sim\)37,000 Type 2 AGNs at \(z\) < 0.3 selected from the Sloan Digital Sky Survey DR7, we find a nonlinear correlation between H\textalpha\ velocity dispersion and stellar velocity dispersion that reveals the presence of the nongravitational component, especially for AGNs with a wing component in H\textalpha. The large H\textalpha\ velocity dispersion and velocity shift of luminous AGNs are clear evidence of AGN outflow impacts on hydrogen gas, while relatively smaller kinematic properties compared to those of [O \textsc{iii}] imply that the observed outflow effect on the H\textalpha\ line is weaker than the case of [O \textsc{iii}].

Key words: galaxies: active – galaxies: kinematics and dynamics – quasars: emission lines

1. Introduction

The scaling relations between black hole mass and galaxy properties suggest the coevolution of black holes and galaxies (Kormendy & Ho 2013), for which active galactic nucleus (AGN) feedback may play a crucial role (e.g., Somerville et al. 2008; Dubois et al. 2013; DeGraf et al. 2015; see King & Pounds 2015 for a review). Gas outflows related to the radiative mode of AGN feedback have been regarded as one of the feedback mechanisms (Fabian et al. 2006; Ciotti & Ostriker 2007), since energetic gas outflows may influence star formation over galactic scales by blowing out the surrounding interstellar medium (Dubois et al. 2013; see review by Fanbian 2012). The high-ionization [O \textsc{iii}] \(\lambda\)5007 emission line has been frequently used to trace the ionized gas outflows in the narrow-line region (NLR) for investigating outflow properties using individual AGNs and a large sample (Boroson 2005; Greene & Ho 2005; Crenshaw et al. 2010; Bae & Woo 2014; Harrison et al. 2014; Liu et al. 2014; Karouzos et al. 2016; Woo et al. 2016). For example, based on a sample of \(\sim\)400 quasars selected from the Sloan Digital Sky Survey (SDSS), Boroson (2005) suggested that both black hole mass and Eddington ratio play a role in determining the [O \textsc{iii}] kinematics. Crenshaw et al. (2010) reported that the distributions of the host galaxy inclination are systematically different between AGNs with blueshifted and redshifted [O \textsc{iii}], supporting that outflows are biconical and a dusty stellar disk preferentially obscures a part of the cone behind the disk.

To understand AGN-driven outflows as a potential feedback mechanism in the context of galaxy evolution, it is important to investigate how common and energetic these outflows are and how they are connected to star formation. To build up a robust outflow demography, Woo et al. (2016, hereafter Paper I) uniformly examined the [O \textsc{iii}] kinematics of \(\sim\)39,000 Type 2 AGNs at \(z\) < 0.3 (see also Bae & Woo 2014). They adopted a single- or double Gaussian function to fit the [O \textsc{iii}] line profile and measured the luminosity-weighted velocity shift and velocity dispersion of [O \textsc{iii}]. A majority of luminous AGNs shows a broad wing component in [O \textsc{iii}], which represents nongravitational kinematics, i.e., outflows. Also, they found that [O \textsc{iii}] velocity dispersion is larger than stellar velocity dispersion by an average factor of 1.3–1.4, suggesting that relatively strong outflows, which are comparable to the gravitational kinematic component, are prevalent in Type 2 AGNs. The distribution in the measured velocity-velocity dispersion diagram of [O \textsc{iii}] is dramatically different from that of star-forming galaxies (Woo et al. 2017), while it is well reproduced by the Monte Carlo simulations using the combined model of biconical outflows and a dusty stellar disk (e.g., Bae & Woo 2016, hereafter Paper II).

While the H\textalpha\ emission line is one of the strongest lines in the rest-frame optical range, H\textalpha\ is less utilized compared to [O \textsc{iii}] in AGN outflow studies for a few reasons. First, there is a downside of using H\textalpha\ to trace AGN-driven outflows, since H\textalpha\ is also emitted by star-forming regions. Thus, the total H\textalpha\ line profile observed within an aperture (e.g., 3\' in the case of the SDSS spectroscopy) represents a mixed nature of gas that is photoionized by AGNs as well as star formation. Second, in the case of Type 1 AGNs, there is an additional very broad component \(\sim\)1000 km s\(^{-1}\) originating from the broad-line region (BLR); hence, it is difficult to probe the outflows in the NLR unless a high spatial resolution is available to spatially separate the NLR from the BLR or a sophisticated spectral decomposition is performed to isolate the narrow component from the very broad component (e.g., Woo et al. 2014; Eun et al. 2017).

Although the significance of the outflow kinematics manifested by H\textalpha\ may be smaller than that by [O \textsc{iii}], H\textalpha\ can provide valuable constraints to study the nongravitational component (i.e., outflows), as well as the virial component (i.e., rotation in the gas kinematics). Bae & Woo (2014) compared the kinematics of H\textalpha\ and [O \textsc{iii}] in Type 2 AGNs, reporting that the fraction of AGNs with outflow signatures based on the H\textalpha\ velocity shift with respect to systemic velocity is smaller than that based on the [O \textsc{iii}] velocity shift, and that the
distributions of the Hα velocity shift are similar between AGNs and star-forming galaxies. Nevertheless, since Bae & Woo (2014) used the peak of the Hα line profile, rather than the flux-weighted center (the first moment) of the line, their measured velocity shift does not fully represent the outflow velocity, since the peak of the line is often strongly influenced by the gravitational (rotational) component, rather than the nongravitational outflow component (e.g., Karouzos et al. 2016).

In this paper, the fourth of a series of papers on AGN outflows, we investigate the gas kinematics traced by the Hα line by measuring the first and second moments of the Hα line profile for calculating velocity and velocity dispersion. We use the sample of Type 2 AGNs from Paper I, which selected them from the SDSS Data Release 7 (DR7) and reported the demography of AGN outflows and the kinematics of [O III] in detail. We describe how we measure the Hα kinematics in Section 2. In Section 3, we present the properties of the Hα kinematics and compare them with those of [O III]. We discuss the results and their implications in Section 4. Conclusions and a summary are given in Section 5. In this paper, we adopted ΛCDM cosmology with cosmological parameters: $H_0 = 70$ km s$^{-1}$ Mpc$^{-1}$, $\Omega_m = 0.30$, and $\Omega_\Lambda = 0.70$.

2. Sample and Methodology

2.1. Sample Selection

In order to probe the kinematics of the Hα emission line in this paper, we use the same sample of $\sim 39,000$ Type 2 AGNs at $z < 0.3$ that was used for the detailed study of the ionized gas outflows based on [O III] (Paper I). The details of the sample selection are presented in Paper I and Woo et al. (2017; see also Bae & Woo 2014). Here, we briefly summarize the selection criteria. For statistical studies of gas outflows in Type 2 AGNs, we selected galaxies with well-defined emission lines, i.e., signal-to-noise ratio (S/N) >3 for four major emission lines (H$\alpha$, [O III] $\lambda$5007, H$\beta$, and [N II] $\lambda$6584), amplitude-to-noise ratio >5 for H$\alpha$ and [O III], and S/N > 10 for the continuum, using the SDSS DR7 (Abazajian et al. 2009).

Each galaxy is classified as a Seyfert galaxy, low-ionization nuclear emission-line region (LINER), composite object, or star-forming galaxy based on the emission-line flux ratios (Kauffmann et al. 2003; Kewley et al. 2006). We use a loose criterion of [O III]/H$\beta$ >3 to distinguish Seyfert galaxies from less energetic AGNs, i.e., LINERs. Since the separation between Seyfert galaxies and LINERs is only based on the [O III]/H$\beta$ ratio, it is possible that more luminous and higher Eddington ratio AGNs than typical LINERs are included in the LINER group. Actually, 3.9% of LINERs have high [O III] luminosity (i.e., $>10^{42}$ erg s$^{-1}$), while 14.4% of LINERs have a high Eddington ratio (i.e., $>0.01$). These results are similar to those of the study by Kewley et al. (2006), who reported that 92% of their LINERs, which were classified by [O III]/H$\beta$ < 3, belonged to the more strictly defined LINER group based on both [S II]/H$\alpha$ and [O I]/H$\alpha$ ratios. Note that these LINERs with relatively high luminosity and Eddington ratio do not significantly change the main results (see Section 3). Thus, we use a loose definition of LINERs in this paper in order to separate less energetic AGNs from Seyfert galaxies.

To properly measure the kinematics of the Hα emission line, we exclude a total of 1681 objects from the sample. First, we eliminate Type 1 AGNs with a very broad component in the Hα line profile in order to focus on Type 2 AGNs. Some of these objects were confirmed as Type 1 AGNs and studied in detail by Woo et al. (2015) and Eun et al. (2017). In addition to these objects, we conservatively exclude additional Type 1 AGN candidates by carefully investigating the profile of Hα and checking whether its measured velocity dispersion is abnormally high (i.e., $>700$ km s$^{-1}$). It is possible that narrow-line Seyfert 1 galaxies might be included in Seyfert galaxies or LINERs, while we tried to identify and exclude Type 1 AGNs from the sample (see Eun et al. 2017). Nevertheless, since the number of AGNs with very high Hα velocity dispersion is extremely small, the effect of the potential contamination of Type 1 AGNs is insignificant. Second, we exclude 1197 objects due to the lack of suitable stellar velocity dispersion measurements or a too-small velocity dispersion of the Hα line (i.e., the velocity dispersion of Hα is smaller than 30 km s$^{-1}$). As a result, we finalize a total sample of 37,301 Type 2 AGNs for the Hα study (see Table 1).

2.2. Methodology

Adopting the same method of measuring gas kinematics as we used for the [O III] line in Paper I, we measure the velocity shift and velocity dispersion of Hα to trace the kinematics of the Hα gas by fitting the Hα and [N II] doublet ($\lambda$6549, $\lambda$6583) with the MPFIT package (Markwardt 2009). We choose a double Gaussian model to fit each emission line. However, if the amplitude-to-noise ratio of the second Gaussian component is less than 3, we instead use a single Gaussian model, as similarly done for [O III] in Paper I. Note that since we conservatively determine whether a wing component is required for the fit, the fraction of AGNs with a double Gaussian profile in Hα should be considered a lower limit.

Based on the best-fit model, we calculate the first and second moment as

$$\lambda_0 = \frac{\int \lambda f_\lambda d\lambda}{\int f_\lambda d\lambda},$$

$$[\Delta \lambda]_0^2 = \frac{\int \lambda^2 f_\lambda d\lambda}{\int f_\lambda d\lambda} - \lambda_0^2,$$

to obtain the velocity and velocity dispersion of Hα. Then, we calculate the velocity shift of Hα with respect to the systemic velocity measured from stellar absorption lines during the continuum subtraction process (see Paper I). To determine the measurement uncertainty of each parameter (i.e., flux, velocity shift, and velocity dispersion of Hα), we perform Monte Carlo simulations by generating 100 mock spectra for each object using flux errors. Then, we adopt the standard deviation of the distribution of the measurements as a 1σ uncertainty.

| Redshift | Composite Objects | LINER | Seyfert |
|----------|-------------------|-------|---------|
| $z < 0.05$ | 3570 (1967) | 3429 (1029) | 2142 (905) |
| 0.05 ≤ $z < 0.1$ | 7520 (4666) | 4356 (1890) | 4456 (2636) |
| 0.1 ≤ $z < 0.2$ | 4396 (3006) | 2478 (1430) | 4264 (2610) |
| 0.2 ≤ $z < 0.3$ | 311 (203) | 170 (84) | 209 (116) |

Notes. The number of samples at each redshift range for each group: Seyfert galaxies, LINERs, and composite objects. The number of samples with double Gaussian profiles is given in parentheses.
For AGN energetics, we adopt bolometric luminosity, black hole mass, and Eddington luminosity, as discussed in Paper I. To obtain the bolometric luminosity, we use the dust extinction–uncorrected luminosity of the [O III] emission line, multiplying it by bolometric correction, 3500 (Heckman et al. 2004). Black hole mass is determined based on the relationship between black hole mass and stellar mass (Marconi & Hunt 2003). Note that AGN luminosity and black hole mass have large uncertainties because they are not direct measurements. Nevertheless, they are good enough to investigate the relative trend between outflow kinematics and AGN energetics.

3. Results

3.1. Hα Luminosity

In this section, we compare the luminosities of the [O III] and Hα emission lines. Figure 1 presents the mean Hα luminosity of each group as a function of redshift. We find that Hα luminosity increases as a function of redshift for all three groups, as similarly found in the case of [O III] (see Figure 2 in Paper I), which reflects the fact that more luminous AGNs were observed at higher redshift due to the selection limit. Interestingly, the mean Hα luminosity of composite objects is higher by an average factor of 1.7 than that of pure AGNs (Seyfert galaxies and LINERs) in the overall redshift range, while the [O III] luminosity of pure AGNs was higher by an average factor of 2.9 than that of composite objects, as shown in Paper I. This is due to the fact that the [O III] emission mainly comes from AGNs, while Hα can be emitted from star-forming regions as well as AGNs (García-Barreto et al. 1996). Thus, this trend suggests that Hα luminosity is not a good proxy for AGN luminosity unless the contribution from star-forming regions is properly corrected for.

In Figure 2, we directly compare Hα and [O III] luminosities. While Hα luminosity broadly correlates with [O III] luminosity, Hα luminosity is, on average, higher than that of [O III], particularly for composite objects. Note that these luminosities are not corrected for dust extinction and that [O III] suffers more extinction than Hα. The average of the Hα-to-Hβ flux ratio is 5.0, which is larger than ~3 expected from the Case B recombination, clearly showing the different amount of dust extinction between the two spectral ranges. If we assume that the Hα-to-Hβ flux ratio should follow the prediction based on the Case B recombination, Hβ luminosity is underestimated by an average of ~0.22 dex. The fraction of Seyfert galaxies with [O III] luminosity higher than Hα luminosity is ~50%, while for the majority of composite objects, Hα luminosity is higher than [O III] luminosity.

We find that the distribution of Hα luminosity is similar between Seyfert galaxies and composite objects, while the LINERs have an order of magnitude lower mean Hα luminosity. This trend is very different from that of [O III], which shows a similar distribution between LINERs and composite objects, while Seyfert galaxies have a much higher mean [O III] luminosity. The difference of the luminosity distributions between Hα and [O III] suggests that the contribution from the star-forming region to the observed Hα is systematically different among Seyfert galaxies, composite objects, and LINERs. Note that since we loosely define LINERs, there are sources with high [O III] luminosity (i.e., [O III] luminosity >10^41 erg s^-1) and high Eddington ratios (i.e., >0.01) in the LINER group. However, even if we reclassify these AGNs as Seyfert galaxies rather than LINERs, the overall shape and difference of the luminosity distributions of Seyfert galaxies and LINERs do not significantly change.

To further investigate the relation between Hα and [O III] luminosities, we present the Hα-to-[O III] luminosity ratio as a function of [O III] luminosity in Figure 3 (left panel). Since [O III] suffers more extinction than Hα, we use Hβ luminosity rather than Hα luminosity after multiplying by a factor of three. Thus, we present the extinction-independent Hα-to-[O III] ratio (Figure 3, right panel). Considering the fact that the Hβ line is much weaker than Hα, we avoid uncertain Hβ luminosity measurements by excluding objects with a large fractional error, i.e., >1σ in Hβ luminosity. Consequently, 90% of composite objects, 40% of LINERs, and 47% of Seyfert galaxies remain. If Hα luminosity linearly correlates with [O III] luminosity, Figure 3 ought to show a flat trend. Instead, the luminosity ratio decreases, suggesting that the contribution from star-forming regions to Hα is significant in low-luminosity AGNs, particularly in composite objects. Note that the Hβ-to-[O III] ratio in the NLR also varies depending on the gas and ionization properties. However, it is shown that there is
a systematic difference of the H$\alpha$-to-[O III] luminosity ratio depending on the contribution from star-forming regions.

3.2. H$\alpha$ Kinematics

In this section, we investigate the kinematics traced by the H$\alpha$ line and compare them with those of [O III] and stellar lines. First, we present the velocity and velocity dispersion of H$\alpha$ and [O III] in Figure 4. As discussed in Paper I, the velocity shift is relatively small for both [O III] and H$\alpha$ due to the fact that the direction of AGN outflows is highly inclined from the line of sight (i.e., Type 2 AGNs). Despite the orientation effect, there are AGNs with a relatively large velocity shift for which the amplitude of the [O III] velocity shift is usually larger than that of H$\alpha$.

When we compare the velocity dispersion of H$\alpha$ and [O III], the correlation between them is tighter for Seyfert galaxies than composite objects. When we perform forward regression, the correlation slope slightly decreases from 1.01 ± 0.01 for composite objects to 0.82 ± 0.01 for Seyfert galaxies, and the scatter also decreases from 0.11 to 0.08 dex. This is due to the fact that the velocity dispersion of [O III] is mainly broadened by AGN activity, while H$\alpha$ velocity dispersion is influenced by AGNs as well as star-forming regions, which effectively reduces the total line broadening due to the lack of high-velocity gas in star-forming regions. Note that composite
objects show a significantly different distribution of Hα velocity dispersion compared to pure AGNs. We interpret that this trend is due to the contamination from star-forming regions, which narrows the observed total Hα profile. Since the kinematic properties of Hα correlate with those of [O III] in Figure 4, we expect that Hα kinematics will provide outflow properties similar to those of the [O III] kinematics studied in Paper I.

Second, we investigate whether Hα kinematics are governed by the gravitational potential of the host galaxy or any additional component (i.e., nongravitational component) exists, similar to the case of [O III], by comparing Hα velocity dispersion \((\sigma_{\text{H}\alpha})\) with stellar velocity dispersion \((\sigma_*)\). In Paper I, it is reported that [O III] velocity dispersion has a nonlinear correlation with stellar velocity dispersion. While the kinematics of [O III] are partly governed by the gravitational potential of the host galaxy, the majority of AGNs show an additional nonvirial component due to AGN outflows. We expect similar results for Hα gas kinematics, considering the correlation between [O III] and Hα velocity dispersion in Figure 4.

Figure 5 compares Hα velocity dispersion with stellar velocity dispersion. We perform forward regression, including errors of both Hα and stellar velocity dispersions, obtaining a slope of 1.25 ± 0.01 with a 0.13 dex scatter. In comparison, [O III] showed a steeper slope, 1.43 ± 0.01, and a larger scatter, 0.19 dex (Paper I), demonstrating that the effect of the nonvirial motion is weaker in Hα than [O III]. Note that for this comparison, we exclude objects with unreliably high stellar velocity dispersion above 420 km s\(^{-1}\), as recommended in the SDSS catalog. Considering the instrumental resolution of SDSS, \(\sim70\) km s\(^{-1}\), we also exclude objects for which either stellar or Hα velocity dispersion is below 30 km s\(^{-1}\).

When we divide the sample into two classes—those with a wing component in the Hα line profile (double Gaussian Hα) and those without (single Gaussian Hα)—we obtain the best-fit slope of 1.18 ± 0.01 with a scatter of 0.09 dex for single Gaussian Hα, while the best-fit slope for double Gaussian Hα was 1.39 ± 0.01 with a scatter of 0.16 dex. The best-fit slope for single Gaussian Hα is similar to that of the single Gaussian [O III] profile, which is 1.18 ± 0.01 (Paper I), while the best-fit slope for double Gaussian Hα is smaller than that of double Gaussian [O III], which is 1.66 ± 0.01. When we perform forward regression for Seyfert galaxies, we obtain the best-fit slope of 1.27 ± 0.01 with a 0.14 dex scatter, while the best-fit slope between [O III] and stellar velocity dispersion is much higher (1.69 ± 0.01). The nonlinear correlation between Hα and stellar velocity dispersions, similar to the case of [O III] (Paper I), implies that a nongravitational effect that makes Hα velocity dispersion broader exists, while the nonvirial effect on the Hα line is weaker than that on [O III]. In contrast, the kinematics represented by single Gaussian Hα and [O III] are mainly governed by the gravitational potential of the host galaxy (Paper I; Karouzos et al. 2016).

To estimate the nongravitational component in Hα, we divide Hα velocity dispersion by two components,

\[
(\eta_{\text{H}\alpha})^2 = (\sigma_*)^2 + (\sigma_{\text{non-gr}})^2,
\]

where \(\sigma_{\text{non-gr}}\) is the nongravitational component and \(\sigma_*\) is the gravitational component. We utilize the stellar velocity dispersion as a proxy for the gravitational component \((\sigma_* = \sigma_*)\). For AGNs with \(\sigma_{\text{H}\alpha} > \sigma_*\), we find that Hα velocity dispersion is larger than \(\sigma_*\) by an average factor of 1.35.

In Figure 6, we normalize Hα velocity dispersion by stellar velocity dispersion (hereafter dispersion ratio) and compare it with H0 luminosity to investigate whether the relative amount of nongravitational effect on Hα kinematics is related to emission-line luminosity. The mean dispersion ratio for pure AGNs with double Gaussian Hα profiles increases from 0.01 to 0.1, while that for pure AGNs with single Gaussian Hα shows a nearly flat trend around zero. The trend of pure AGNs with double Gaussian Hα is similar to the case of [O III], though the mean dispersion ratio value is much smaller than that of [O III].
since Paper I reported that the nongravitational component of [O III] was comparable to stellar velocity dispersion. By contrast, the mean dispersion ratio of composite objects with both single and double Hα profiles does not increase as a function of Hα luminosity. This implies that the Hα velocity dispersion of composite objects is dominated by virial motion.

In Figure 7, we present the distribution of the Hα-to-stellar velocity dispersion ratio. The blue line indicates where Hα dispersion is equal to the stellar velocity dispersion, and the pink line indicates where σ_{Hα} = σ_*. The velocity shift measured by Monte Carlo simulation is 13.9 km s^{-1}. In the case of double Gaussian Hα, the number ratio tends to increase as a function of Hα luminosity. This implies that the Hα velocity dispersion ratio increases with Hα luminosity, although not all luminous AGNs have high velocity shift values. In contrast, the majority of low-luminosity AGNs have small velocity shifts close to 0 km s^{-1}.

Using only reliable velocity measurements (|V| > 3σ), we present the average velocity shift in each velocity dispersion bin (filled circles) in Figure 9, which shows that [O III]-luminous AGNs typically have large blueshifts in Hα, although not all luminous AGNs have high velocity shift values. These results indicate that luminous AGNs tend to have strong outflows that manifest a stronger nonvirial kinematic component than virial kinematic component, while in the case of low-luminosity AGNs, the outflow component is often diluted by the virial component, leading to zero or small velocity shift and small normalized velocity dispersion. We find that the VVD distribution of Hα is qualitatively similar to that of [O III] and that the observed VVD distributions of Hα and [O III] are consistent with the interpretation that AGN outflows are biconical with a presumably large opening angle, as constrained based on the Monte Carlo simulations of the VVD distribution in Paper II.

3.4. Outflow Fractions

In this section, we investigate the outflow fraction based on the measured Hα kinematics. First, we examine the fraction of AGNs with double Gaussian Hα as a function of Hα luminosity. Since the double Gaussian profile (i.e., wing component) indicates the presence of outflow, we use this fraction as a proxy for the outflow fraction. Figure 10 shows the increasing fraction with increasing Hα luminosity, from 20% to ~90% over four orders of magnitude in Hα luminosity. All groups (Seyfert galaxies, composite objects, and LINERs) show a similar trend, as similarly found in the case of [O III], while the overall fraction based on Hα is slightly lower than that of [O III] by 5%–10%. Note that the much lower outflow fraction at low luminosity should be taken as a lower limit, since the detection of a wing component in Hα is presumably much more difficult for lower-luminosity AGNs.

Second, we use the measured Hα velocity dispersion to count AGNs with outflows. Since the observed total profile of Hα includes gravitational and nongravitational (outflow) components (see Equation (2)), we assume that outflows are
detected if the measured velocity dispersion based on the total H\(_{\alpha}\) profile is larger than the stellar velocity dispersion (i.e., \(\sigma_{H_{\alpha}}/\sigma_* > 1.0\)). For AGNs with strong outflows, we use the criterion that the outflow component in H\(_{\alpha}\) is comparable to or larger than the gravitational component, which is represented by stellar velocity dispersion (i.e., \(\sigma_{H_{\alpha}}/\sigma_* > 1.4\)). Figure 11 shows that the fraction of AGNs with detectable outflows increases from 40\% to 80\% with increasing H\(_{\alpha}\) luminosity in Seyfert galaxies. A similar trend is found in LINERs with overall smaller fractions, while the outflow fraction in composite objects is \(\sim 40\%\) without a significant change in H\(_{\alpha}\) luminosity. When we count AGNs with strong outflows (i.e., \(\sigma_{H_{\alpha}}/\sigma_* > 1.4\)), we find a similar trend with H\(_{\alpha}\) luminosity, but the fraction is much lower, as expected. For Seyfert galaxies, the fraction is 25\% at low luminosity and increases up to \(\sim 40\%\) at high luminosity, indicating that strong outflows are rare. LINERs show a similar increasing trend with increasing H\(_{\alpha}\) luminosity, but the fraction is lower than that of Seyfert galaxies at a given luminosity. In the case of composite objects, we see that the outflow fraction is relatively flat over the luminosity range, implying that the H\(_{\alpha}\) line profile is significantly affected by the contribution from star-forming regions.

In summary, we find that AGNs with a detectable kinematic signature in H\(_{\alpha}\) are common among pure AGNs, particularly at high H\(_{\alpha}\) luminosity and Eddington ratio ranges, while the fraction of composite objects seems significantly different, presumably due to the contamination in the H\(_{\alpha}\) line from star-forming regions.

4. Discussion

4.1. AGN Outflow Effect on the H\(_{\alpha}\) Emission Line

By comparing H\(_{\alpha}\) velocity dispersion with stellar velocity dispersion, we find that H\(_{\alpha}\)-emitting gas is not only tracing the gravitational potential of the host galaxy but also influenced by the additional nonvirial component (i.e., gas outflow). Outflow kinematics are often manifested by the wing component in H\(_{\alpha}\) (and [O\textsc{iii}]), which is common among AGNs with high H\(_{\alpha}\) luminosity (80\%–90\%). Also, detectable outflows are more prevalent among Seyfert galaxies than LINERs or composite objects. These trends indicate that the outflow component of H\(_{\alpha}\) is related to AGN activity, implying that outflows are AGN-driven.

The amount of nongravitational effect exerted on H\(_{\alpha}\) can be represented by the normalized H\(_{\alpha}\) velocity dispersion by stellar
velocity dispersion \((\sigma_{\text{H}\alpha}}/\sigma_*)\). By comparing this ratio with the Eddington ratio, we find that outflow kinematics increase with Eddington ratio, albeit with large scatter, indicating the connection between outflow kinematics and AGN energetics. The fraction of AGNs with large dispersion ratios also demonstrates that strong outflow on \(\text{H}\alpha\) is common for \(\text{H}\alpha\) luminous AGNs or AGNs with high Eddington ratios.

As a tracer of gas outflows, \(\text{H}\alpha\) velocity shift shows a correlation with AGN luminosity. However, the majority of AGNs have relatively small velocity shifts, less than 20 km s\(^{-1}\), which is comparable to the measurement...
uncertainty. This is due to the intrinsic nature of Type 2 AGNs, since the outflow direction is close to the plane of the sky and the projected velocity measured from the line of sight is relatively small. However, by counting AGNs with reliable velocity shift measurements, we find that the number ratio between blueshifted $\text{H} \alpha$ and redshifted $\text{H} \alpha$ increases with $\text{H} \alpha$ luminosity, which supports the biconical outflow geometry combined with a dusty galaxy plane, as investigated in detail by the 3D outflow models of Bae & Woo (2016). The extinction due to the large-scale dusty galaxy plane has to play a significant role in order to preferentially hide a part of the bicone so that the flux-weighted $\text{H} \alpha$ line is either blueshifted or redshifted in the observed spectra (see the discussion in Bae & Woo 2016).

The lower outflow fraction in AGNs with low luminosity or Eddington ratio can be interpreted as the combination of two effects. First, as we see the broad correlation between outflow kinematics and AGN luminosity, the kinematic signature of outflows—i.e., the wing component in $\text{H} \alpha$ or the velocity dispersion of $\text{H} \alpha$—is much weaker in low-luminosity AGNs. Consequently, it is more difficult to detect, leading to an apparently lower outflow fraction. Second, for a given galaxy gravitational potential, a weak outflow signature (i.e., a wing) can be easily diluted by the virial motion, since the gravitational component will be dominating in shaping the $\text{H} \alpha$ line profile. This effect is more outstanding for composite objects, since the star-forming regions can also substantially contribute to the observed $\text{H} \alpha$.

4.2. Comparison of $\text{H} \alpha$ Kinematics with $\text{[OIII]}$

In our previous study, Bae & Woo (2014) compared the velocity shift of $\text{[OIII]}$ and $\text{H} \alpha$ using a subsample at $z < 0.1$ and demonstrated that $\text{H} \alpha$ has a smaller velocity shift compared to $\text{[OIII]}$ due to the contamination of star-forming regions. Although they used single Gaussian models to fit the $\text{H} \alpha$ line and the peak of the line to calculate velocity shift with respect to systemic velocity, the reported results clearly indicated the difference of kinematics between $\text{[OIII]}$ and $\text{H} \alpha$. By consistently adopting double Gaussian models for $\text{H} \alpha$ and $\text{[OIII]}$ and using the first moment of the line profile in calculating velocity shift, our results presented in this paper supersede those of Bae & Woo (2014), showing more consistent analysis compared with $\text{[OIII]}$.

By comparing the kinematic measurements of $\text{H} \alpha$ in this paper with those of $\text{[OIII]}$ presented in Paper I, we find that the outflow kinematics traced by $\text{H} \alpha$ are qualitatively similar to those of $\text{[OIII]}$. However, the overall strength of outflows, i.e., velocity shift and velocity dispersion, and the fraction of outflows are relatively lower if we use the $\text{H} \alpha$ line instead of $\text{[OIII]}$. The difference is noticeable in the case of composite objects, as expected, since the contribution from non-AGNs, i.e., the star-forming regions, is most significant compared to Seyfert galaxies and LINERs.

While the limitation of this work is the lack of spatial resolution, Karouzos et al. (2016) and Bae et al. (2017) used a subsample of AGNs with strong outflow signatures in $\text{[OIII]}$ to obtain integral field spectroscopy data. By applying the same kinematic analysis with double Gaussian models adopted in this paper to each pixel in the outflow region, they found that both narrow and broad components of $\text{[OIII]}$ are presenting nonviral outflow kinematics. In the case of $\text{H} \alpha$, however, the broad component mainly reflects AGN outflows, while the narrow component follows the stellar rotation due to the gravitational potential of the host galaxy. Also, they reported that the broad component of $\text{H} \alpha$ at the center of the host galaxy is influenced by AGNs, while the broad component of $\text{H} \alpha$ detected in the outer pixels is mainly representing star-forming regions. These spatially resolved results suggest that it is more reliable to use the broad component of $\text{H} \alpha$ measured from the central part of host galaxies for investigating the AGN outflow kinematics. In the case of $\text{[OIII]}$, both narrow and broad components can be used for measuring AGN outflows. Without spatial resolution to separate AGNs and star-forming regions, a careful interpretation has to be applied for the outflow analysis. Although there may be significant uncertainties of kinematic measurements for certain individual objects, our results based on a large sample provide statistical constraints on the outflow kinematics and fraction from the flux-weighted $\text{H} \alpha$ line.

5. Summary and Conclusion

We used the spatially integrated spectra of $\sim$37,000 Type 2 AGNs at $z < 0.3$ to investigate the effect of AGN outflows on the $\text{H} \alpha$ line. We compared the measured kinematics of $\text{H} \alpha$ with those of $\text{[OIII]}$ and stars. The main results are summarized in this section.

1. By comparing $\text{[OIII]}$ and $\text{H} \alpha$ luminosities, we find that $\text{H} \alpha$ luminosity is significantly influenced by the contribution from star-forming regions, suggesting that $\text{H} \alpha$ luminosity is not a good surrogate for AGN luminosity.
2. The $\text{H} \alpha$ velocity dispersion has a nonlinear correlation with stellar velocity dispersion, indicating the presence of a nongravitational component (i.e., AGN-driven outflow) in the $\text{H} \alpha$ line profile.
3. The velocity shift and velocity dispersion of $\text{H} \alpha$ increase with AGN luminosity and Eddington ratio, suggesting that more energetic AGNs show stronger outflows. Among luminous AGNs, $\text{H} \alpha$ tends to be more blueshifted than redshifted, which can be understood as a characteristic feature of biconical outflows in Type 2 AGNs.
4. The fraction of AGNs with a wing component increases with $\text{H} \alpha$ luminosity. The fraction of galaxies with a considerable nongravitational component increases with $\text{H} \alpha$ luminosity for pure AGNs, while the outflow fraction of composite objects shows a flat trend. The fraction also increases as a function of Eddington ratio, but the overall outflow fraction is smaller than that measured from $\text{[OIII]}$ in Paper I, indicating that the outflow signature is weaker in $\text{H} \alpha$.

Based on these results, we conclude that the $\text{H} \alpha$ emission line is also strongly influenced by AGN-driven outflow, even though the amount of the detected kinematic effect is relatively smaller than that of $\text{[OIII]}$. Thus, the $\text{H} \alpha$ line is a very useful tracer of AGN outflows if other high-ionization lines are not available. At the same time, a careful analysis needs to be done with $\text{H} \alpha$, since the contribution from the star-forming regions can be significant, particularly for composite objects.

This work was supported by the National Research Foundation of Korea (NRF) funded by the Korean government (No. 2016R1A2B3011457).
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