ON THE DISAPPEARANCE OF THE BROAD-LINE REGION IN LOW-LUMINOSITY ACTIVE GALACTIC NUCLEI: THE ROLE OF THE OUTFLOWS FROM ADVECTION DOMINATED ACCRETION FLOWS

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ABSTRACT

The broad-line region (BLR) disappears in many low-luminosity active galactic nuclei (AGNs), the reason of which is still controversial. The BLRs in AGNs are believed to be associated with the outflows from the accretion disks. Most of the low-luminosity AGNs contain advection-dominated accretion flows (ADAFs) which are very hot and have a positive Bernoulli parameter. ADAFs are therefore associated with strong outflows. We estimate the cooling of the outflows from the ADAFs and find that the gases in such hot outflows cannot always be cooled efficiently by bremsstrahlung radiation. The ADAF may co-exist with the standard disk, i.e., the inner ADAF connects to the outer thin accretion disk at radius $R_{\text{d,u}}$ in the sources accreting at slightly lower than the critical rate $\dot{m}_{\text{crit}}$ ($\dot{m} = \dot{M}/\dot{M}_{\text{Edd}}$). For the ADAFs with $L_{\text{bol}}/L_{\text{Edd}} \gtrsim 0.001$, a secondary small inner cold disk is suggested to co-exist with the ADAF due to the condensation process. We estimate the Compton cooling of the outflow, of which the soft seed photons either come from the outer cold disk or the secondary inner cold disk. It is found that the gas in the outflow far from the ADAF may be efficiently cooled to form BLR clouds due to the soft seed photons emitted from the cold disks, provided the transition radius of the ADAF to the outer cold disk is small ($r_{d,u} = R_{d,u}/(2GM/c^2) \lesssim 20$) or/and the secondary small cold disk has a luminosity $L_{\text{sd}} \gtrsim 0.003 L_{\text{Edd}}$. The BLR clouds can still be formed in the outflows from the outer cold thin disks, if the transition radius $r_{d,u}$ is not very large. For the sources with $L_{\text{bol}}/L_{\text{Edd}} \lesssim 0.001$, the inner small cold disk is evaporated completely in the ADAF and the outer thin accretion disk may be suppressed by the ADAF, which leads to the disappearance of the BLR. The physical implications of this scenario on the double-peaked broad-line emitters are also discussed.

Key words: accretion, accretion disks – galaxies: active – quasars: emission lines

1. INTRODUCTION

Active galactic nuclei (AGNs) are classified as either type 1 and 2 according to their line emission. Type 1 AGNs show broad emission lines and narrow forbidden lines, while only narrow lines are observed in type 2 AGNs. According to the unification scheme of AGNs, all AGNs are intrinsically the same, but are viewed at different orientations (e.g., Antonucci 1993). The broad-line regions (BLRs) in type 2 AGNs are obscured by the dusty tori, as they are supposed to be viewed at large angles with respect to the axes of the tori. However, there is evidence that the BLR disappears in many low-luminosity active galactic nuclei (LLAGNs; e.g., Tran 2001, 2003; Gu & Huang 2002), and most of the type 1 AGNs have relatively high Eddington ratios (e.g., Trump et al. 2009). These low-luminosity sources are called “true” type 2 AGNs, which do not have hidden BLRs (see Ho 2008 for a review and references therein). Many workers have explored why the BLR disappears in LLAGNs (e.g., Nicastro et al. 2003; Laor 2003; Elitzur & Shlosman 2006; Elitzur & Ho 2009). Laor (2003) suggested that an upper limit on the observed width of broad emission lines leads to a lower limit on the radius of the BLR based on the empirical correlation between BLR size and optical continuum luminosity (Kaspi et al. 2000). In this scenario, the BLR radius shrinks below a critical value for LLAGNs, which leads to the disappearance of BLRs in these sources. Although the origin of BLRs is still unclear, an attractive suggestion is that the BLR structure is associated with the outflow from the accretion disk (Emmering et al. 1992). Nicastro (2000) assumed that the winds from the accretion disk are triggered by the thermal instability of the radiation-pressure-dominated region of the disk (Shakura & Sunyaev 1976). The transition radius between the radiation-pressure-dominated and gas-pressure-dominated regions in the disk increases with the dimensionless mass accretion rate $\dot{m}$ (Shakura & Sunyaev 1973). In this scenario, the transition radius becomes smaller than the marginal stable orbit of the black hole for low accretion rates (low luminosities), and the winds are switched off and no BLRs can be formed in LLAGNs (Nicastro et al. 2003). A correlation between the width of the BLR and the luminosity is expected in this model, which is consistent with the observations of AGN samples (Warner et al. 2004; Xu & Cao 2007). An alternative disk-wind scenario was suggested for the BLR and dust torus, in which both the BLR and torus disappear when the bolometric luminosity is low (Elitzur & Shlosman 2006; Elitzur & Ho 2009). The outflow from the accretion disk being switched off is a key ingredient in these scenarios when accretion rates are low, though the detailed physics of the outflow dynamics has not been included in these works.

Low-mass accretion rate $\dot{m}$ may lead to the accretion flows being advection dominated (Narayan & Yi 1994, 1995b). Advection-dominated accretion flows (ADAFs) are suggested to be present in LLAGNs (see Narayan 2002 for a review and references therein), which can successfully explain most observational features of LLAGNs (e.g., Lasota et al. 1996; Gammie et al. 1999; Quataert et al. 1999; Xu & Cao 2009). It was suggested that the ADAF co-exists with the standard disk, i.e., the inner ADAF connects to the outer thin accretion disk, in some sources accreting at rates slightly lower than the critical rate $\dot{m}_{\text{crit}}$ (e.g., Esin et al. 1997; Quataert et al. 1999). For even lower accretion rates, a secondary small cold accretion disk is suggested to co-exist with the ADAF in the inner region due to the condensation process (Różańska & Czerny 2000). This
The temperature of the gases in the ADAFs is nearly virialized (Narayan & Yi 1995a), and we assume the gases to be virialized in the outflow:

$$T_{\text{gas}}(R) \sim T_{\text{vir}}(R) = \frac{GMm_p}{kR}. \quad (6)$$

The internal energy per unit volume of the gases in the outflow is

$$U = \frac{3}{2} \rho_{\text{gas}} = \frac{3p_{\text{gas}}}{2\mu_m m_p} + \frac{3\eta k T_e}{2\mu_e m_p}, \quad (7)$$

where the effective molecular weights of the ions and electrons are $\mu_i = 1.23$ and $\mu_e = 1.14$, respectively. As the ion temperature is significantly higher than the electron temperature in the inner region of the ADAF and most of the internal energy is stored in the ions, the electron temperature $T_e \leq T_i$ is required in the outflow. The electron temperature $T_e$ is mainly determined by the radiative cooling and the Coulomb interaction between the electrons and ions. In this work, we assume $T_e = \xi_e T_{\text{gas}}$ ($\xi_e \leq 1$) in our estimates on the cooling of the outflow. Thus, the bremsstrahlung cooling timescale of the gases in the outflow can be estimated as

$$\tau_{\text{cool}}(r) \sim \frac{U}{F_{\text{brem}}}, \quad (8)$$

where the bremsstrahlung cooling rate in unit volume of the gases is (Rybicki & Lightman 1986)

$$F_{\text{brem}} = 2.36 \times 10^{-27} n_i^2 T_e^{1/2} \text{ erg s}^{-1} \text{ cm}^{-3}. \quad (9)$$

Substituting Equations (6), (7), and (9) into Equation (8), the bremsstrahlung cooling timescale of the gases in the outflow is available,

$$\tau_{\text{cool}}(r) \sim \frac{U}{F_{\text{brem}}} = 1.00 \times 10^{-3} f_w \eta_{\text{w}}^{-1} \xi_e^{-1/2} m_{\text{w}}^{-1} \text{ mm}^{-1} \text{ r. s.} \quad (10)$$

The cooling length scale of the outflow is therefore estimated by

$$l_{\text{cool}}(r) = \tau_{\text{cool}} v = 2.12 \times 10^7 f_w \eta_{\text{w}}^{-1} \xi_e^{-1/2} m_{\text{w}}^{-1} r_{\text{vir}}^{-1/2} \text{ cm}. \quad (11)$$

The mass accretion rate $\dot{m}$ being lower than a critical value $\dot{m}_{\text{crit}}$ is required for an ADAF. The critical rate $\dot{m}_{\text{crit}} \simeq 0.01$ is suggested either by the observations or the theoretical models (see Narayan 2002 for a review and references therein). The lower limit on $l_{\text{cool}}(r)$ is derived as

$$l_{\text{cool}}^\text{min}(r) = \tau_{\text{cool}} v = 2.12 \times 10^7 f_w \eta_{\text{w}}^{-1} m_{\text{w}} r_{\text{vir}}^{1/2} \text{ cm}, \quad (12)$$

if $\dot{m} = \dot{m}_{\text{crit}} = 0.01$ and $\xi_e = 1$ are substituted into Equation (11), i.e., the electrons and ions have the same temperature in the outflow. The electron temperature should be significantly lower than the ion temperature at the base of the outflow, because it comes from a two temperature ADAF (Narayan & Yi 1995b). As the cooling rate increases with electron temperature $T_e$, the estimate performed with $T_e = T_i$ gives the minimal cooling timescale (see Equation (11)). Comparing the cooling length scale with radius $R$, we have

$$\frac{l_{\text{cool}}^\text{min}(R)}{R} = 7.18 \times 10^3 f_w \eta_{\text{w}}^{-1} r_{\text{vir}}^{-1/2}. \quad (13)$$
The outflow is bremsstrahlung cooled efficiently, as functions of Figure 1. For comparison, we also plot the BLR size estimated from the bolometric luminosity with the empirical correlation given by Bentz et al. (see Equation (14)). For comparison, we also plot the BLR size estimated from the bolometric luminosity with the empirical correlation given by Bentz et al. (see Equation (14)). For comparison, we also plot the BLR size estimated from the bolometric luminosity with the empirical correlation given by Bentz et al. (see Equation (14)). For comparison, we also plot the BLR size estimated from the bolometric luminosity with the empirical correlation given by Bentz et al. (see Equation (14)). For comparison, we also plot the BLR size estimated from the bolometric luminosity with the empirical correlation given by Bentz et al. (see Equation (14)).

The radiative cooling of the gases in the outflow is inefficient if \( r_{\text{cool}}(R) > R \), which leads to

\[
R < 5.15 \times 10^7 f_w^2 \eta_w^{-2}. \tag{14}
\]

The reverberation-mapping method (Netzer & Peterson 1997; Peterson 1993) was applied to measure the size of the BLR from the time delay between the line and continuum variations. The correlations between the optical luminosity and BLR size were derived by different authors (e.g., Kaspi et al. 2000; Bentz et al. 2006). Subtracting the contribution from the host galaxy starlight to the AGN emission, Bentz et al. (2006) found that

\[
\log R_{\text{BLR}} = -21.69 + 0.518 \log L_{\text{bol}}, \tag{15}
\]

where \( L_{\text{bol}} \approx 9.3L_*(5100\AA) \) is used (Kaspi et al. 2000). This is consistent with \( R_{\text{BLR}} \propto L_{\text{bol}}^{0.3} \) expected from the photoionization model if all BLRs have similar physical properties. The distances from the black hole in the outflow, within which the outflows are radiatively cooled inefficiently (see Equation (14)), are compared with the BLR sizes of broad-line AGNs in Figure 1. It is found that radiative cooling is always unimportant except in the region far from the BLRs, which implies that the hot outflow from an ADAF is unable to be cooled to form BLR clouds.

When the accretion rate is slightly lower than the critical value \( m_{\text{crit}} \), an ADAF is present near the black hole, and it may connect to the outer standard disk at a transition radius \( R_{\text{std}} \). In this case, the soft photons emitted from the outer cold disk will be Compton upscattered by the hot electrons in the outflow, and the plasma in the outflow is therefore cooled. The flux due to viscous dissipation in the outer region of the disk is

\[
F_{\text{vis}}(R_d) \sim \frac{3GM\dot{M}}{8\pi R_d^3}. \tag{16}
\]

The irradiation of the inner ADAF on the outer cold disk is almost negligible compared with the viscous dissipation in the outer cold disk, because the solid angle of the outer disk subtended to the inner region of the ADAF is too small (Cao & Wang 2006). We neglect this effect in estimating the cooling caused by the Compton scattering in the outflow. The cooling rate in unit volume of the gases at radius \( R \) in the outflow is

\[
F_{\text{Comp}} \sim \int_{R_d}^{R_{\text{out}}} \frac{4kT_e}{m_e c^2} \frac{F_{\text{vis}} R}{\pi (R^2 + R_d^2)^{3/2}} n_e \sigma_T 2\pi R_d dR_d, \tag{17}
\]

where \( n_e \) is the number density of the electrons in the outflow at \( R \), and \( \sigma_T \) is the Thompson cross-section of electron. Using Equations (5) and (6), we rewrite Equation (17) as

\[
F_{\text{Comp}} \sim 4.17 \times 10^9 e n_e (r) m^{-1} m \times \int_{R_d}^{R_{\text{out}}} \frac{dr_d}{r_d^3 (r^2 + r_d^2)^{3/2}} \text{erg s}^{-1} \text{cm}^{-3}, \tag{18}
\]

where \( r_d = R_d/(2GM/c^2) \). The Compton cooling timescale for the outflow is available,

\[
\tau_{\text{Comp}}(r) \sim \frac{U}{F_{\text{Comp}}} = 5.20 \times 10^{-10} \xi_e^{-1} r^{-1} \text{mm}^{-1}
\times \left[ \int_{R_d}^{R_{\text{out}}} \frac{dr_d}{r_d^3 (r^2 + r_d^2)^{3/2}} \right]^{-1} \text{s}, \tag{19}
\]

and the dynamical timescale of the outflow can be estimated by

\[
\tau_{\text{dyn}} \sim \frac{R}{v} = \frac{R^{3/2}}{(GM)^{1/2}} = 1.39 \times 10^{-5} m r^{3/2} \text{s}. \tag{20}
\]

The importance of the Compton cooling of the gases in the outflow can be evaluated by

\[
\frac{\tau_{\text{Comp}}}{\tau_{\text{dyn}}} = 3.74 \times 10^{-5} \xi_e^{-1} m^{-1} r^{-5/2} \left[ \int_{R_d}^{R_{\text{out}}} \frac{dr_d}{r_d^3 (r^2 + r_d^2)^{3/2}} \right]^{-1}. \tag{21}
\]

In the inner region of the ADAF, the electron temperature can be more than one order of magnitude lower than the ion temperature (Narayan & Yi 1995b). Thus, the parameter \( \xi_e \lesssim 0.1 \) in the base of the outflow from the ADAF, while \( \xi_e \rightarrow 1 \) in the outflow from the black hole. The results derived with different disk parameters are plotted in Figure 2. We find that the timescale ratio, \( \tau_{\text{Comp}} / \tau_{\text{dyn}} \), decreases with increasing radius \( r \) in the outflow when \( r \) is small (see Figure 2) because the solid angle of the outer cold disk region subtended to the outflow increases with \( r \) at small radii. At large radii, the solid angle decreases with increasing \( r \), and therefore the timescale ratio, \( \tau_{\text{Comp}} / \tau_{\text{dyn}} \), increases with \( r \). The Compton cooling becomes less important for a disk accreting at a lower rate, because less soft seed photons are emitted from the outer disk.

For ADAFs in the sources with \( L_{\text{bol}}/L_{\text{Edd}} \gtrsim 0.001 \), a secondary small cold accretion disk extending to the marginal stable orbit of the black hole can co-exist with an ADAF due to the condensation process. The outflow can be cooled due to the Compton scattering of the soft seed photons emitted from such an inner cold disk. The radiative power of the inner cold disk consists of the viscously dissipated power in the disk and the power of the irradiation from the ADAF. In order to avoid exploring the complicated processes of the interaction between the ADAF and the cold disk, we assume the flux from the unit surface area of the inner cold disk to have the same radial
dependence as the standard cold disk (Shakura & Sunyaev 1973),

\[ F_{\text{vis}}(R_d) = \frac{C_{sd} \dot{m} L_{sd}}{R_d^3} \left[ 1 - \left( \frac{\dot{m}_{\text{in}}}{\dot{m}} \right)^{1/2} \right], \tag{22} \]

where \( L_{sd} \) is the luminosity of the small cold disk, and \( \dot{m}_{\text{in}} \) is the radius of the inner edge of the disk. This small disk can extend to the marginal stable orbit of the black hole, and we adopt \( \dot{m}_{\text{in}} = \dot{m}_{\text{ms}} = 6GM/c^2 \) for a non-rotating black hole in all our calculations. The luminosity of the small disk is

\[ L_{sd} = 2 \int_{R_{d,\text{min}}}^{R_{d,\text{max}}} F_{\text{vis}}(R_d) 2\pi R_d dR_d, \tag{23} \]

which leads to

\[ C_{sd} = 2.35 \times 10^4 \left\{ \frac{1}{R_{d,\text{min}}} \left[ 1 - \frac{2}{3} \left( \frac{3}{R_{d,\text{min}}} \right)^{1/2} \right] - \frac{1}{R_{d,\text{max}}} \left[ 1 - \frac{2}{3} \left( \frac{3}{R_{d,\text{max}}} \right)^{1/2} \right] \right\}^{-1}. \tag{24} \]

Similar to the above estimates for the Compton cooling caused by the emission from the outer cold disk, the ratio of the Compton cooling timescale due to the presence of the inner small cold disk to the dynamical timescale of the outflow is estimated as

\[ \frac{\tau_{\text{comp}}}{\tau_{\text{dyn}}} = 6.59e^{-1} \lambda_{sd}^{-1} \lambda_{sd}^{-1} r^{-5/2} \left[ \int_{r_{d,\text{min}}}^{3} \frac{1 - (3/r_d)^{1/2}}{r_d^2 (r^2 + r_d^2)^{3/2}} \left. dR_d \right]^{-1}, \tag{25} \]

where the Eddington ratio of the small disk \( \lambda_{sd} = L_{sd}/L_{\text{Edd}} \). The inner cold small disk is usually truncated at several tens of Schwarzschild radii (Liu et al. 2007), and \( r_{d,\text{max}} = 20 \) is therefore adopted in the estimates. The final results are insensitive to the exact values of \( r_{d,\text{max}} \) adopted, because most of the emission is from the region of the disk very close to the black hole. We plot the results in Figure 3, which show that the Compton cooling of the outflow near the ADAF due to the presence of the inner small accretion disk is always unimportant, while the outflow can be cooled efficiently at large distances from the black hole.

For the LLAGNs, the radius of the BLR should be lower than that for broad-line AGNs, if the correlation between \( R_{\text{BLR}} \) and \( L_{\text{bol}} \) (Equation (15)) still holds for low-luminosity sources (but also see Wang & Zhang 2003). Our estimate shows that the radiative cooling of the outflow in the source accreting at a rate significantly lower than \( m_{\text{crit}} \) is inefficient, which means that the outflow expanding adiabatically is a good approximation. Considering a small volume \( V \) in the outflow with gas temperature \( T_{\text{gas}} \) and particle number density \( n \), we have

\[ dU = \frac{3}{2} dp_{\text{gas}} V = -p_{\text{gas}} dV \tag{26} \]

for an adiabatic expanding outflow, where \( p_{\text{gas}} = n k T_{\text{gas}} \). The conservation of particles requires

\[ \frac{dV}{V} = \frac{dn}{n}. \tag{27} \]

Substituting Equation (27) into (26), we arrive at

\[ d \ln T_{\text{gas}} = \frac{2}{3} d \ln n, \tag{28} \]

i.e., \( T_{\text{gas}} \propto n^{2/3} \). As the number density \( n \propto r^{-3/2} \) in the outflow (see Equation (4)), we find that the gas temperature \( T_{\text{gas}} \propto r^{-1} \) in an adiabatically expanding outflow.

3. DISCUSSION

The broad-line AGNs are relatively luminous, which contain cold accretion disks. The accretion flows transit to hot ADAFs when the sources are accreting at very low rates. Strong outflows...
may probably be present in LLAGNs, as the ADAFs have a positive Bernoulli parameter (Narayan & Yi 1995a). This implies that the disappearance of BLRs in LLAGNs cannot be simply attributed to the lack of outflows from the accretion disk.

We estimate the cooling of the hot outflows from the ADAF, and find that the radiative cooling of the outflows is always inefficient within the radius of the BLR with any values of the parameters adopted (see Figure 2). The internal energy $U \propto n_e$, and the cooling rate $F^\sim \propto n_e^2$, which indicates that the cooling timescale increases with decreasing electron number density $n_e$. In estimating the cooling, we assume that the radial velocity of the outflow is the same as the virialized velocity, which is the minimum velocity that the outflow can have to escape to infinity. If the gases in the outflow move at the speed higher than the virialized velocity, the number density $n_e$ of the electrons decreases with increasing outflow velocity provided all other parameters are fixed, and therefore the cooling timescale becomes larger for higher outflow velocity. The results plotted in Figure 1 are calculated with $\eta_w = 1$, i.e., $M_w = M$, and $m = m_{\text{crit}} = 0.01$, which, of course, leads to a lower limit on the cooling length scale (see Equations (12) and (14)). For most of the LLAGNs, the two parameters, $\eta_w \ll 1$ and $m \ll m_{\text{crit}}$, are satisfied, which strengthens the conclusion derived in our estimates.

The detailed physics for the transition of accretion modes is still unclear. It was suggested that the ADAF co-exists with the standard disk, i.e., the inner ADAF connects to the outer thin accretion disk, in some sources accreting at rates slightly lower than the critical rate $m_{\text{crit}}$ (e.g., Quataert et al. 1999; Cao 2003; Xu & Cao 2009). The transition radius increases with decreasing accretion rate $m$, which is expected by the thermal instability or disk evaporation induced transition scenarios (e.g., Abramowicz et al. 1995; Liu et al. 1999; Różyńska & Czerny 2000; Spruit & Deufel 2002). In the presence of an outer cold disk, the soft photons from the cold disk will be Compton upscattered by the hot electrons in the outflow. For the ADAF accreting at a rate lower than $m_{\text{crit}}$ but with $L_{\text{bol}}/L_{\text{Edd}} \gtrsim 10^{-3}$, a secondary inner cold small disk will surround the black hole together with an ADAF. The mass accretion rate of the small cold disk is regulated by the condensation process, which is always significantly lower than the total accretion rate (see Liu et al. 2007 for details). Similar to the accretion disk–corona system, the small cold disk is also irradiated by the ADAF, which implies that the luminosity of the small disk should be less than half of the bolometric luminosity. We adopt $\xi_c = 0.1$ in our calculations of the Compton cooling in the outflow near the ADAF, while $\xi_c = 1$ is adopted in the calculations for the outflow far from the ADAF. We find that the Compton cooling of the outflow near the ADAF is always inefficient due to the soft seed photons from the outer cold disk (see Figure 2). The situation is similar for the small inner cold disk, even if the luminosity of the inner cold disk is as high as $L_{\text{bol}} = 0.01L_{\text{Edd}}$ (see Figure 3). The transition radius of the ADAF to the outer cold disk is small ($r_{\text{tr}} \lesssim 20$) or/and the secondary small cold disk has a luminosity $L_{\text{bol}} \gtrsim 0.003L_{\text{Edd}}$. We note that our estimates of the importance of Compton cooling are independent of the density of the outflow, i.e., the mass-loss rate in the outflow, which is due to both the Compton cooling rate and the internal energy of the gas being proportional to the density of the gas in the outflow. The cold outflows can still be driven from the outer cold thin disk if the sources are accreting at rates slightly lower than $m_{\text{crit}}$, i.e., the transition radius is not very large. In this case, the outflow from the ADAF can still be cooled at large distances from the black hole due to the Compton scattering of the soft seed photons from the outer cold disk or/and the secondary small inner cold disk. The small inner cold disk is evaporated completely in the ADAF, which may connect to the outer thin disk at a very large radius (or the outer cold disk is suppressed by the ADAF), when $L_{\text{bol}}/L_{\text{Edd}} \lesssim 10^{-3}$, and therefore the BLR disappears due to the lack of cold outflow from the disk or the cooling of the outflow from the ADAF being inefficient. This is consistent with the observations that almost all “true” type 2 AGNs have mass accretion rates $L_{\text{bol}}/L_{\text{Edd}} \lesssim 10^{-3}$ (e.g., Nicastro et al. 2003).

For the cases where radiative cooling can be neglected, the temperature of the gas will drop in an adiabatically expanding outflow. Our estimate shows that the gas temperature $T_{\text{gas}} \propto r^{-1}$ in the outflow. The typical temperature of the ions in an ADAF near the black hole is $\sim 10^8$–$10^9$ K (e.g., Narayan & Mcclintock 2008), the gases can be cooled to the typical temperature of BLRs ($\sim 10^5$ K) only in the outflow with a distance of $>10^6$–$10^7$ Schwarzschild radii from the black hole. It corresponds to $\sim 10^6$–$10^7$ lt-days for a black hole with $M = 10^7$ $M_\odot$, which is obviously beyond the BLR in luminous AGNs (see Figure 1). Therefore, we propose that the outflows from the ADAFs in LLAGNs are too hot to be cooled to form clouds in the BLRs, which leads to the disappearance of the BLR in LLAGNs.

A small fraction of AGNs were found to have emission lines with double-peaked profiles (e.g., Eracleous & Halpern 1994; Strateva et al. 2003), which usually have low Eddington ratios (see Eracleous 2006 for a review and references therein; and also see Wu & Liu 2004; Bian et al. 2007). The favorite model for the double-peaked emitters suggests that the double-peaked broad emission lines are emitted from a ring in the accretion disk, which may also be photoionized by the radiation from the inner region or/and the outflow (e.g., Chen et al. 1989; Nemmen et al. 2006; Cao & Wang 2006). The observed broad-line emission may originate from two separate regions: the clouds in the normal BLRs or/and the outer ring in the thin accretion disk. The broad-line emission from the BLR clouds dominates over that from the outer region of the accretion disk in normal broad-line AGNs. For the double-peaked emitters accreting at rates lower than the critical accretion rate $m_{\text{crit}}$, the ADAF is present in the inner region and connects to the outer thin accretion disk. The gases in the outflow from the ADAF are too hot to be cooled to form the clouds in the BLR when the transition radius of the ADAF to the outer disk $r_{\text{tr}} \lesssim 20$ and the secondary small cold disk is less luminous than $L_{\text{bol}} \lesssim 0.003L_{\text{Edd}}$, which leads to the disappearance of BLR clouds in these sources. Thus, the line emission from the outer region of the accretion disk is not contaminated by the emission from the BLR clouds, which emerges as double-peaked emission lines. This also provides a clue to the theoretical models for the accretion mode transition.

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