Testing Evolutional Sequence between Hidden Broad Line Region (HBLR) and Non-HBLR Seyfert 2 Galaxies with the 4000 Ångstrom Break

December 14, 2011

1 Scientific Background

1.1 Previous Studies

Seyfert galaxies are classified as radio-quiet active galactic nuclei (AGNs) and further divided into Seyfert 1 and Seyfert 2, according to their different optical line widths. Based on the unification model (Antonucci, 1993), Seyfert 2 galaxies are considered to be the same objects as Seyfert 1 galaxies, but viewed from a different direction; only narrow emission lines are presented in Seyfert 2 spectra. Photons from broad line regions could be scattered by electrons and thus might be detectable by polarimetry in Seyfert 2 galaxies. However, previous studies showed that only about 40% - 45% of Seyfert 2 galaxies show polarized hidden broad line regions (HBLR) (Tran, 2003). The reason of the non-detection of the polarized broad lines in some Seyfert 2 (non-HBLR Seyfert 2) is still under debate. Several possibilities have been proposed: (1) From the ratios of f_{25}/f_{60}, Heisler et al. (1997) suggested that the detectability of the HBLR in Seyfert 2 galaxies is related to the inclination of the torus. (2) Some evolutionary processes might be at work between the HBLR and the non-HBLR Seyfert 2 galaxies (Tran, 2003; Yu & Hwang, 2011). (3) Zhang & Wang (2006) found that the non-HBLR Seyfert 2 galaxies and narrow line Seyfert 1 galaxies have similar distribution of black hole masses, accretion rates and the ratios of f_{25}/f_{60}. They thus concluded that the non-HBLR Seyfert 2 galaxies are the counterparts of the NLS1s at edge-on orientation. (4) From X-ray data, Shu et al. (2007) indicated that the nuclear activity and obscuration might play an important role in the visibility of polarized broad lines. (5) Elitzur & Ho (2009) showed that the broad line regions might disappear at low luminosities in advection-dominated accretion models. (6) Tran et al. (2011) suggested that some Seyfert 2 galaxies could intrinsically lack broad line regions. (7) Some Seyfert 2 galaxies might be deficient in scattering material.

1.2 Metallicity and D_{4000}

Recently, Yu & Hwang (2011) discovered that the [N II]/Hα ratios of the non-HBLR Seyfert 2 galaxies are higher than those of the HBLR Seyfert 2 galaxies (Figure 1). The [N II]/Hα ratios can only be reproduced by increasing nitrogen abundance (Figure 2). Their results showed that the non-HBLR Seyfert 2 galaxies must have higher N/O relative abundance than the HBLR ones. Based on evolutionary models of starburst activities, Matteucci & Padovani (1993) showed that the N/O relative abundance reaches a maximum value at about 3×10^8 years. The nitrogen could be dredged up from red supergiants in the post-main-sequence stage and result in the nitrogen overabundance. Furthermore, due to the secondary nature of nitrogen, the nitrogen abundance is very sensitive on the metallicity. Therefore, the high nitrogen abundance of the non-HBLR Seyfert 2 galaxies implies that there could be an evolutionary connection between the non-HBLR and the HBLR Seyfert 2 galaxies.

Absorption lines could be a better probe of AGN environments. To further investigate the age of the stellar population around the nuclei of the HBLR and non-HBLR Seyfert 2 galaxies, we propose to compare the 4000 angstrom break (D_{4000}) strength of these galaxies using the NOAO telescope with long-slit spectrograph. The D_{4000} is created by absorption lines located around 4000 angstrom and defined as

$$D_{4000} = \frac{\int_{4000}^{4100} f_\lambda d\lambda}{\int_{3850}^{3950} f_\lambda d\lambda} \text{ (Bruzual, 1983).}$$

The D_{4000} arises because of an accumulation of absorption lines of ionized metals. As the opacity increases with decreasing stellar temperatures, the D_{4000} becomes larger with older ages. Therefore, D_{4000} can be an indicator that provides a reliable estimate of the age of stellar population (Kauffmann et al., 2003). The distributions of the D_{4000} strength of the HBLR and the non-HBLR Seyfert 2 galaxies are expected to be different if the different nitrogen abundance of the non-HBLR and the HBLR Seyfert 2 galaxies are caused by different stages of stellar evolution. By comparing the D_{4000} strength of these Seyfert 2 galaxies, we can test the evolutionary scenario between the HBLR and the non-HBLR Seyfert 2 galaxies.

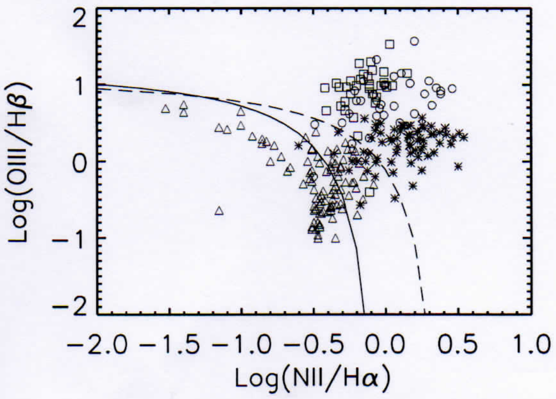

Figure 1: Diagnostic diagrams of [N II] and [O III] line ratios. The HBLR Seyfert 2 galaxies are shown as squares, the non-HBLR Seyfert 2 as open circles. The [N II]/Hα ratios of the non-HBLR Seyfert 2 galaxies are higher than those of the HBLR Seyfert 2 galaxies.

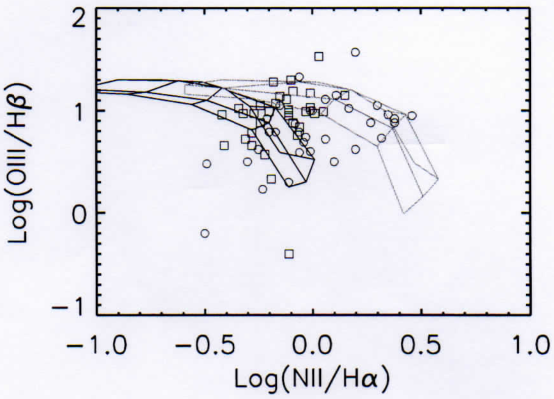

Figure 2: Results of photoionization models. The results with the standard solar abundance of nitrogen are shown in black curves (left grid), and those with five times solar abundance of nitrogen are shown in grey (right grid). The ionization parameter Γ varies from $10^{-1.5}$ to $10^{-3.5}$ (upper-left to lower-right for each model), and the density n_H varies from 10^2 to 10^5 cm^{-3} (left to right for each model).

References

Antonucci, R. R. J. 1993, ARA&A, 31, 473

Bruzual, A. G., 1983, ApJ, 273, 105

Elitzur, E., & Ho, L. C. 2009, ApJL, 701, L91

Heisler, C. A., Lumsden, S. L., & Bailey, J. A. 1997, Nature, 385, 700

Kauffmann, G., et al. 2003, MNRAS, 346, 1055

Matteucci, F., & Padovani, P., 1993, ApJ, 419, 485

Shu, X. W., Wang, J. X., Jiang, P., Fan, L. L., & Wang, T. G. 2007, ApJ, 657, 167

Tran, H. D. 2003, ApJ, 583, 632

Tran, H. D., Lyke, J. E., & Mader, J. A. 2011, ApJ, 726, L21

Yu, P. C., & Hwang, C. Y. 2011, AJ, 142, 14

Zhang, E., Wang, J. 2006, ApJ, 653, 137