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The very broad line region of AGN

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Abstract. An innermost shell of gas optically thin to the H I ionizing continuum may be a major source of high ionization line emission, and solve a photon deficit conundrum raised by the spectral properties of some active galactic nuclei (AGN).

Key words. galaxies: active – galaxies: quasars: general

1. Introduction

Quasars and Seyfert 1 nuclei are characterized by broad line emission, with FWHM ranging from 1000 to 10000 km s^{-1}. The broad line region (BLR) is unfortunately not resolved in even the nearest AGN. On the basis of time delays in response to ionizing continuum changes, it is estimated that line emission occurs very close to the central black hole, most likely within 0.1 – 1 pc. The profile and variability analysis of lines emitted by ions of widely different ionization potential has yielded many structural and kinematical clues. Yet, we are just starting to appreciate the complexity of the BLR. We will employ here the high ionization He IIλ4686 line as a diagnostic of the BLR innermost structure.

2. A telltale signature

He IIλ4686 is a line that is conveniently located less than 200 Å from Hβ. It is known since long that the He IIλ4686 profile can frequently be broader than that of Hβ. More than 20% of about 220 luminous Seyfert 1 and low redshift quasars show obviously strong and very broad He IIλ4686. This result comes from a database of spectroscopic observations obtained with high S/N and moderate dispersion (spectral resolution 4-6 Å FWHM), which is well suited to study the He IIλ4686 broad profile. Still, most cases with FWHM(He IIλ4686) $\sim$10000 km s^{-1} $\gg$ FWHM(H$\beta_{\rm BC}$) may not be identifiable because of noise, blended Fe II emission, and continuum misplacement. Hβ can be often decomposed in a very broad component (VBC) and a narrower core, while the He IIλ4686 line usually shows *only* a very broad, boxy profile. The region associated to the core apparently does not emit appreciable He IIλ4686, while the VBC (i.e., in correspondence of the broad line wings) can show I(He IIλ4686)/I(Hβ) $\gg$ 1, up to a value of several. For example, in PG 1138+222 the maximum value across the

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line profile ratio is ≈ 3 (Marziani & Sulentic 1993).

3. Demography

Our measurements of FWHM(He IIλ4686) and FWHM(H$\beta_{\rm BC}$) show that FWHM(He IIλ4686) $\gg$ FWHM(H$\beta_{\rm BC}$) is observed among objects whose FWHM(H$\beta_{\rm BC}$) < 4000 km s^{-1}. Above this value, FWHM of H$\beta_{\rm BC}$ and He IIλ4686 are more frequently of similar width even if He II is generally broader than Hβ. This trends reinforces the distinction between two different AGN populations, Population A (FWHM(H$\beta_{\rm BC}$) $\leq$ 4000 km s^{-1}) and B (FWHM(H$\beta_{\rm BC}$) $>$ 4000 km s^{-1}) drawn by Sulentic, Marziani & Dultzin-Hacyan (2000). For Population A sources, the FWHM difference between He IIλ4686 and H$\beta_{\rm BC}$ suggests that very broad He IIλ4686 is mainly emitted in a high ionization wind kinematically decoupled from the low-ionization emitting region. This hypothesis will be tested by comparing C IVλ1549, He IIλ4686, and He IIλ1640 line profiles. Population B sources are thought of having a single BLR of fairly high ionization (with prominent C IVλ1549, weak Fe II; Hβ and C IVλ1549 line profile parameters are correlated). The He II lines and the Balmer line wings may originate in an innermost region closest to the continuum source. Can this be considered a different emitting region that we might call the 'very broad line region (VBLR)'?

4. Extreme physical conditions

If I(He IIλ4686) is stronger than I(Hβ), extreme physical conditions are required. Electron density exceeding 10^{11} cm^{-3} is a necessary and sufficient condition for any value of the ionization parameter Γ larger than 10^{-2} (defined as ratio between number of H I ionizing photons and electron density). The high density conditions and the limit on Γ indicate that the emitting region is located very close to the source of ionizing photons and hence to the central black hole. The larger width of the very broad profiles is consistent with this result if gas motions are gravitationally bound and stable (i.e., is rotational or virial), suggesting a distance of a few hundred gravitational radii.

5. A solution to a photon deficit conundrum?

Only very broad components of He II and Hβ were visible in a May 2000 spectrum of the quasar PG 1416-129. A strong, narrower Hβ core had almost completely disappeared following a large luminosity decrease (Sulentic et al. 2000). The much smaller change in luminosity of the VBC suggests that the line emitting gas is marginally optically thick to the H I ionizing continuum. Energy considerations imply that the Hβ VBC luminosity can be accounted for if, in PG 1416-129, the covering factor is close to unity. Therefore, a reasonable picture of the VBLR may be that of an almost fully ionized, optically thin (to the H I ionizing continuum but not necessarily to the continuum at energy $\gtrsim$ 50 eV that ionizes Helium) shell of gas located at the innermost edge of the BLR. The large covering factor of the VBLR gas may solve a photon deficit pointed out by Korista (1997), and may explain the strength of some high ionization lines (like the Helium lines). It remains to be seen what is the typical contribution of optically thin/marginally thick gas to the Hβ line emission in most AGN.

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