Black Holes from Stars to Galaxies – Across the Range of Masses
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Physical properties of emitting plasma near massive black holes: the Broad Line Region

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Abstract. We apply the Boltzmann-Plot (BP) method to the Balmer lines to estimate the physical properties in the Broad Line Region of Active Galactic Nuclei. We study the Balmer lines of a sample of 90 AGN from Sloan Digital Sky Survey database, as well as the time variability of the BP parameter A of NGC 5548.

Keywords. Galaxies: active – (galaxies:) quasars: emission lines – galaxies: Seyfert

1. Introduction

The Broad Emission Lines (BELs), which originate in the Broad Line Region (BLR) of the Active Galactic Nuclei (AGN), could be used to probe the properties of the massive Black Hole (BH) that is assumed to be in the center of an AGN. The understanding of the physics and kinematics of the BLR is crucial because: (i) kinematics of the BLR is probably determined by the massive BH, with the competing effects of gravity and radiation pressure, therefore the parameters of the BLR should be connected with the general characteristics of an AGN (e.g. BH mass); (ii) the BLR reprocesses the UV energy emitted by the continuum source, consequently BELs can provide indirect information about the continuum source. In order to connect the physical and kinematical parameters of the BLR, we study the parameters of Balmer lines of the 90 AGN from Sloan Digital Sky Survey (SDSS), as well as the variation of the parameters of Balmer lines of NGC 5548 observed from 1996 till 2004. We apply the Boltzmann-Plot (BP) method, as described by Popović (2003, 2006), to the Balmer lines to estimate the physics of a typical BLR.

2. Application of the BP to the Balmer lines

The Boltzmann Plot Method. We start from the assumptions, that the BLR has a significant optically thin component and that the Balmer line series is emitted from a region with the same physical properties. In such a case, it has been demonstrated that the BP method, commonly used for laboratory plasma diagnostics – see Griem (1997), can be used for average temperature estimates of the line emitting medium; La Mura *et al.* (2006), Ilić *et al.* (2006), Popović (2003, 2006), Popović *et al.* (2006).

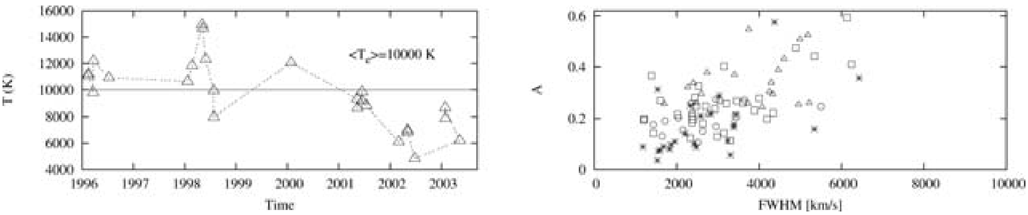

Figure 1. Left: the temperature variation from 1996 till 2004 of NGC 5548. Right: temperature parameter A as a function of the FWHM that we determined from the line profiles of the SDSS sample. Open circles are for the cases when BP is working and $T_e < 20000$ K; open squares are for the cases when the BP is working, but one point of the plot has too small error-bars that do not cover the BP line; open triangles are for the cases when the BP may work, but two points are not covering the BP line (with their estimated error-bars) or the BP works, but $T_e > 20000$ K; and asterisks are for the cases when BP does not work at all.

The BLR of NGC 5548. We study the variability of physical parameters in the BLR of NGC 5548 using the BP method. We apply the method on Balmer lines observed from 1996 till 2004 with the 6m and 1m telescopes of SAO (Russia, 1996–2004) and at INAOE's 2.1m telescope at the Guillermo Haro Observatory (GHO) at Cananea, Sonora, Mexico (1998–2004); Shapovalova *et al.* (2004). We found that variability seen in lines is also present in the electron temperature (Fig. 1, left panel). The average electron temperature for the considered period was T≈10000 K, and that varies from 6000 K (in 2002) till 15000 K (in 1998). The more detailed discussion is given in Popović *et al.* (2006).

The SDSS results. We apply the BP method to the Balmer series and we discuss the physical parameters of the emitting plasma for an AGN sample collected at the 3rd data release from the SDSS database, and we study their correlations with other BLR and AGN parameters (La Mura *et al.* (2006)). Moreover, we perform line flux and profile analysis, as well as continuum luminosity measurements at 5100 Å, estimating some parameters of the sources, including the mass of central BH, the velocity fields of the emitting gas and the size of the BLR. We use these results to discuss a model that can explain the observed effects. We found that: (i) PLTE is a suitable approximation to describe the physical conditions of the BLR emitting gas in a number of AGN (in our sample ∼ 30%) and this greatly simplifies the task of gathering even general information about the physics of these sources, since most of the standard methods used in astrophysics cannot deal with them; (ii) there is a general trend, for AGN showing broader line profiles, to be associated with averagely colder BLR (Fig. 1, right panel).

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