Physical properties of the Broad Line Region

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Introduction:

The dominant emission in Active Galactic Nuclei (AGN) spectra comes from the Broad Emission Lines (BELs) which originate in the Broad Line Region (BLR). The understanding of the physics and kinematics of the BLR is crucial because: (i) kinematics of the BLR is probably determined by the massive Black Hole (BH), with the competing effects of gravity and radiation pressure, (ii) the BLR reprocesses the UV energy emitted by the continuum source, consequently BELs can provide indirect information about the continuum source, (iii) there is indication that the physical and kinematical parameters of the BELs can be connected with the general characteristics of an AGN (e.g. mass of the BH). In order to connect the physical and kinematical parameters of the BLR, we consider the intensities and widths of Balmer lines of a sample of 90 AGN from Sloan Digital Sky Survey (SDSS). Also, we consider the variation of the intensities and widths of Balmer lines from the BLR of NGC 5548 observed from 1996 till 2004. We apply the Boltzmann-Plot (BP) method (Popović 2003, Popović et al. 2006) to the Balmer lines in order to estimate the physics of a typical BLR.

Boltzmann Plot Method:

We have applied the BP method, commonly used for laboratory plasma diagnostics (Griem 1997), to the Balmer line series which is emitted from a region with the same physical properties (Ilić et al. 2006, La Mura et al. 2006, Popović 2003, Popović et al. 2006).

$$\log_{10}(I_n) = B - A * E_u$$

where E_u is the energy of the upper level and A is the temperature parameter, which in the case when the line emitting medium is in the Partial Local Thermodynamical Equilibrium (PLTE) can be used for average temperature estimates $A = \log_{10} e/(k_B T_e)$.

The BLR of NGC 5548:

We have studied the variability of physical parameters in 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). We found that variability seen in lines is also present in the BP parameter A (Figure 1). If the PLTE approximation is valid, than the average electron temperature for the considered period is T=10000 K. We found a correlation (r = 0.85) between the variation of optical continuum and temperature. This is first time that this correlation is confirmed, and it indicates a presence of an accretion disk in the BLR of NGC 5548 as it was suggested by Shapovalova et al. (2004). More detailed discussion is given in Popović et al. (2006).

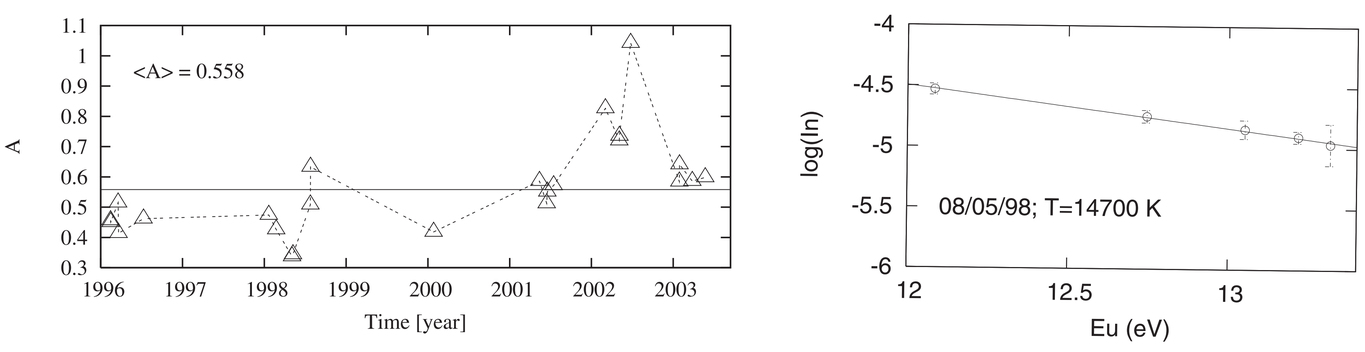

Figure 1: The variation of the BP parameter A from 1996 till 2004 (left) and one example of the BP plot (right) for the galaxy NGC 5548.

SDSS results

We apply the BP method to the Balmer lines and we discuss the physical parameters of the emitting plasma for an AGN sample collected at the 3rd data release from the Sloan Digital Sky Survey (SDSS) database and we study their correlations with other BLR and AGN parameters (La Mura et al. 2006). We perform line flux and profile analysis, together with continuum luminosity measurements in the optical domain, at 5100 Å, estimating some parameters of the sources, including the central BH mass, 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, an effect that appears to be well explained in terms of a Receding BLR model (Figure 2); the thermodynamical conditions in the BLR are correlated with central BH mass (Figure 3).

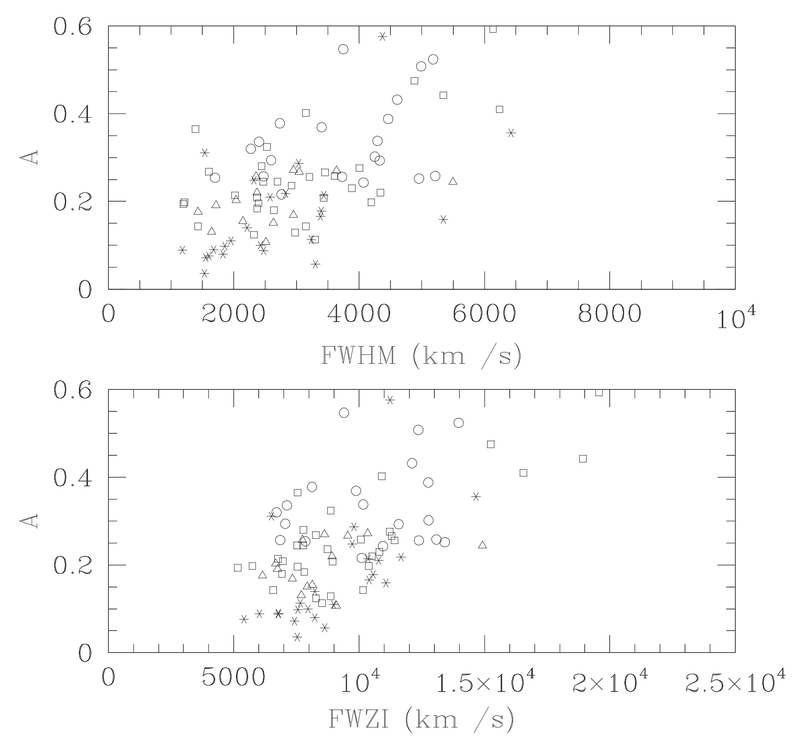

Figure 2: Temperature parameter A as a function of the FWHM (top) and FWZI (bottom) that we determined from the line profiles in the spectra of our SDSS sample. Open circles - the BP is working and T_e < 20000 K; Open squares - the BP is working, but one of the emission lines does not fit the expected straight sequence within its uncertainty range; Open triangles - the BP may either be unsatisfactory for two emission lines or it may result T_e > 20000 K, which is too high for PLTE; Asterisks - the BP cannot be applied.

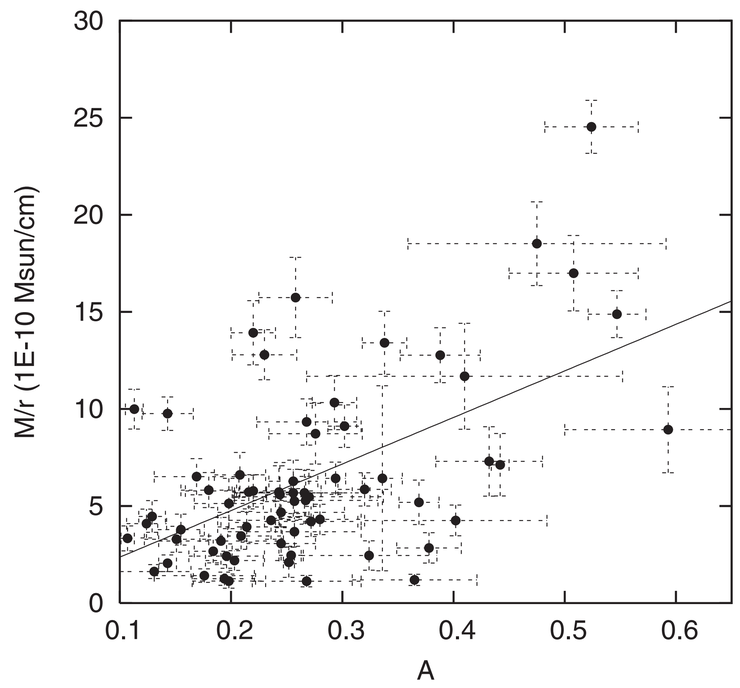

Figure 3: Gravitational potential of central Black Hole vs. BP parameter A for our SDSS sample.

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