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Kinematic properties of the Broad Absorption Line Regions in the spectra of quasars

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Abstract. We use the GR model in order to fit broad spectral lines (absorption and emission) of several BAL QSOs. According to this motdel, we assume that the Broad Line Regions (BLR), which originate in a disk wind, are composed of a number of successive independent absorbing density layers, which may have different random, rotational and radial velocities. The GR model is easily used in order to fit the observed absorption lines, providing us with basic parameters of BLRs, such as random, rotational and radial velocities, as well as column density and total absorbed or emitted energy. This model supposes that the density regions of matter that construct the BLRs are independent and successive. Here we present a new form of this model, supposing that the density regions of matter are independent but not successive. We apply the two forms of the GR model on the UV spectral lines of several BAL QSOs observed with the HST and we compare the results of the two methods. Finally, we present some first concluding remarks about this comparison.

Key words. Quasars: spectral lines

1. Introduction

Assuming that the Broad Line Regions - BLR (originated in a disk wind) are composed of a number of successive independent absorbing density layers, which may have different random, rotational and radial velocities, we used the GR model (Danezis et al. 2007) in order to fit broad spectral lines. The model can be easily used in fitting the observed absorption lines, providing us with basic parameters of BLRs (random, rotational and radial velocities and column density). This model supposes that the density regions of matter that construct the BLRs are independent and successive. In this paper we present a new form of this model, supposing that the density regions of matter are independent but not successive. We apply the two forms of the GR model on

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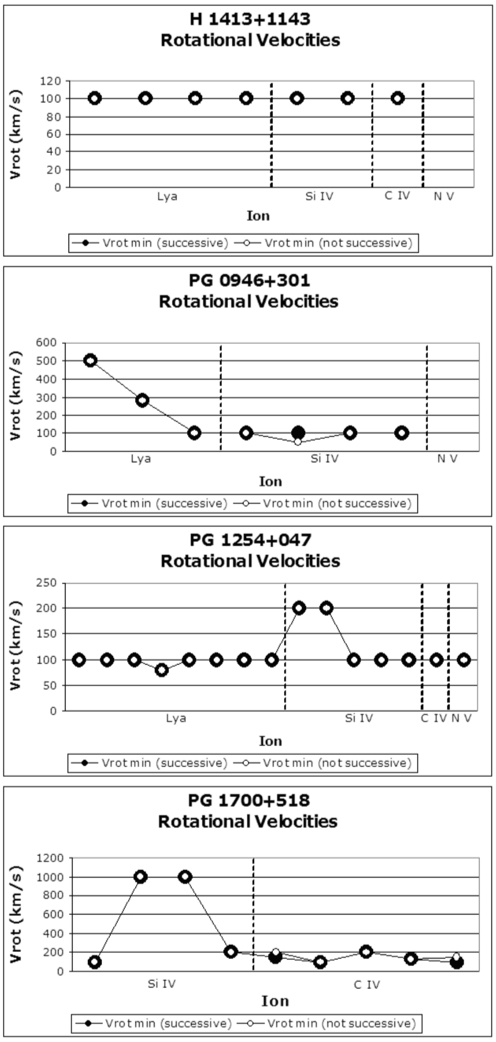

Fig. 1. Rotational Velocities taken from the analysis of the Lya, Si IV, C IV and N V spectral lines in the case of successive (black circles) or not successive (white circles) density regions. One can see that there is almost no difference between the two cases.

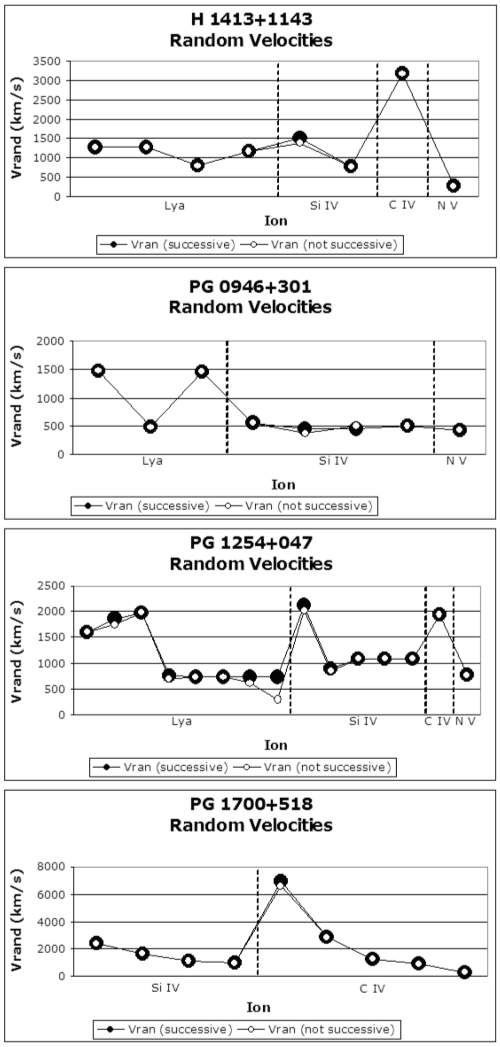

Fig. 2. Random Velocities taken from the analysis of the Lya, Si IV, C IV and N V spectral lines in the case of successive (black circles) or not successive (white circles) density regions. One can see that there is almost no difference between the two cases.

the UV C IV ($\lambda\lambda$ 1548.187, 1550.772 Å), Si IV ($\lambda\lambda$ 1393.755, 1402.77 Å), N V ($\lambda\lambda$ 1238.821, 1242.804 Å) as well as the Lya (λ 1215.68 Å) spectral lines of H 1413+1143, PG 0946+301, PG 1254+047 and PG 1700+518 BAL QSOs observed with the HST. We calculate the kinematical parameters (rotational, radial and random velocities) as well as the total absorbed energy per ion and compare the results of the two methods. We also compare our results with the respective study concerning some hot emission stars (Antoniou et al. 2010). Finally, we present some first concluding remarks about these comparisons.

2. The model

In order to study the BALs and the BELs we use the GR model (Danezis et al. 2007), which can be used successfully, for both hot emission stars and AGNs (Danezis et al. 2005). By solving the radiation transfer equations through a complex structure, as the one described, we conclude to a function for the line profile, able to give the best fit for the main spectral line and its Satellite Components at the same time.

$$I_\lambda = [I_{\lambda 0} \prod_i e^{-L_i \xi_i} + \sum_j S_{\lambda ej}(1 - e^{-L_{ej}\xi_{ej}})] \prod_g e^{-L_g \xi_g} \quad (1)$$

where: $I_{\lambda 0}$: is the initial radiation intensity,
L_i, L_{ej}, L_g : are the distribution functions of the absorption coefficients k_i, k_{ej}, k_g,
ξ: is the optical depth in the centre of the spectral line,
S_{ej}: is the source function that is constant during one observation.

2.1. The case of many absorption or emission components

In the GR line function, in the case of a number of independent and successive absorbing or emitting density layers of matter, the final profile that is produced by a group of absorption lines is given by the product of the line functions of each component. On the other hand, the final profile that is produced by a group of emission lines is given by the addition of the line functions of each component. The addition of a group of functions is completely different from the multiplication of functions. The spectral line profile that results from the addition of a group of functions is exactly the same with the profile that results from a composition of the same functions. On the contrary, the product of a group of functions is completely different from the composition of the same functions. As a result, we can use the composition of functions for the emission lines, but not for a group of absorption components. This means that in such a case we can not refer to the law of reversion of the spectral lines.

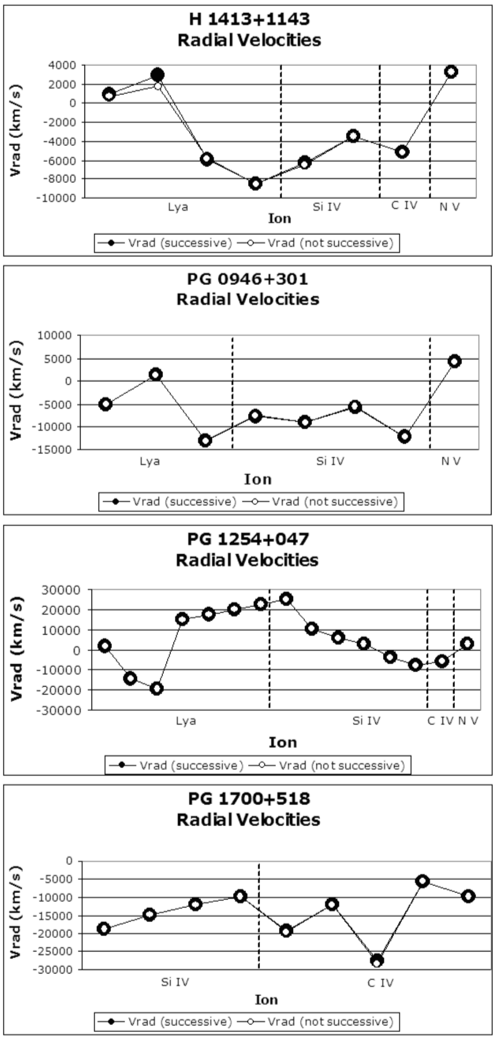

Fig. 3. Radial Velocities taken from the analysis of the Lya, Si IV, C IV and N V spectral lines in the case of successive (black circles) or not successive (white circles) density regions. One can see that there is almost no difference between the two cases.

2.2. The case of independent but not successive regions of matter

An idea of our scientific group is to examine the form of GR line function if the density regions of matter that produce the satellite absorption or emission components are

Independent but Not Successive. In this case the GR line function has the following form:

$$I_\lambda = I_{\lambda 0} \sum_i e^{-L_i \xi_i} + \sum_j S_{\lambda ej}(1 - e^{-L_{ej}\xi_{ej}}) \qquad (2)$$

We expect considerable changes in the absorbed energy. When the density regions are not successive, the initial energy flux is the same for all of them. On the other hand, when the density regions are successive, the initial energy flux for the second region is smaller than for the first, as the first density region has already absorbed an amount of the initial energy. In the same way, the initial energy flux for the third region is smaller than for the second and so on. The new idea of this study is to measure the values of the parameters that we calculate in the case that the independent density regions of matter producing the absorption or emission satellite components are not successive. Then, we compare the values extracted from both cases (successive and not successive density regions).

3. Spectral analysis

In Table 1 we present the quasars and the spectral lines that we have studied in each one of them.

3.1. Kinematical parameters

In figures 1, 2 and 3 we give a comparison of the kinematical parameters (rotational, random and radial velocities) of the regions which create the Lya, Si IV, C IV and N V spectral lines, calculated in the cases when the independent density regions of matter producing the absorption or emission satellite components are successive (black circles) or not (white circles). As one can see, the values of the kinematical parameters remain the same in both cases of successive or not successive density regions.

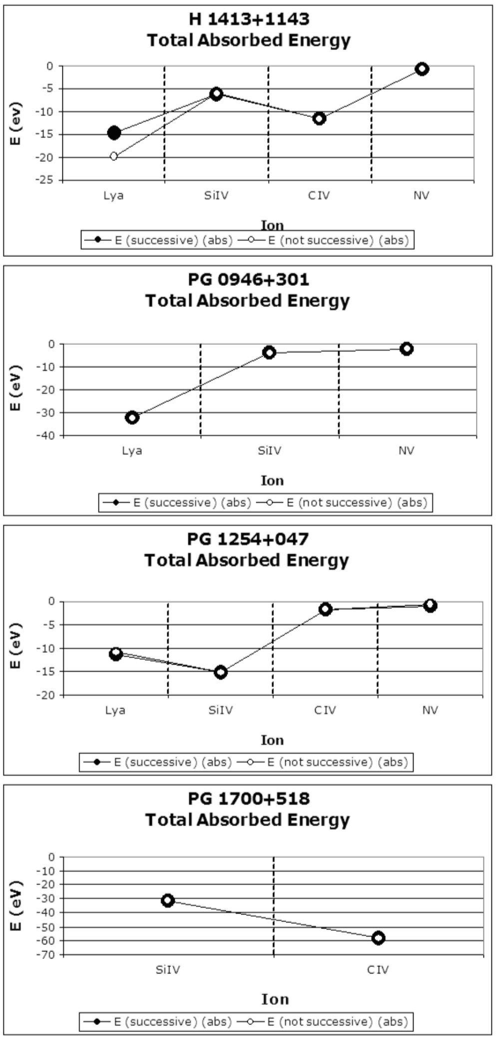

Fig. 4. Total absorbed energy, taken from the analysis of the Lya, Si IV, C IV and N V spectral lines in the case of successive (black circles) or not successive (white circles) density regions. One can see that there is almost no difference between the two cases. These results are opposed to what we theoretically expected, i.e. differentiation in the absorbed energy.

3.2. Total absorbed energy

In figure 4, we present the values of the total absorbed energy of the regions which create the Lya, Si IV, C IV and N V spectral lines, calculated in the cases when the independent density regions of matter producing the absorption or emission satellite components are successive (black circles) or not (white circles). As one can see there is no considerable change in

Table 1. The list of selected BAL QSOs with basic observational data

Name	z	Obs.Date	Ins./grat	Lines
H 1413+1143	2.551	Jun 23, 1993, Dec 23,1994	FOS/G400H,G570H	Lya, Si IV, C IV
PG 0946+301	1.216	Feb 16,1992	FOS/G400,G570	Lya, Si IV, C IV
PG 1254+047	1.024	Feb 17, 1993	FOS/G160L,G270H	Lya, Si IV, C IV, N V
PG 1700+518	0.212	Sep 12, 2000	STIS/G430L,G750L	Si IV, C IV

the values of the total absorbed energy depending on the two methods of calculation.

4. Concluding remarks

As we have already explained, we expected that the values of the total absorbed energy should present considerable differences supposing successive and not successive density regions. However, this is not the case in the spectral lines of the studied quasars. As one of our purposes is to compare the origin of DACs and SACs in hot emission stars and quasars, we made a similar study on hot emission stars (see Antoniou et al. 2010). In the case of Be stars presenting DACs and SACs, we found the same results as in the case of quasars, i.e. no considerable change in the values of the total absorbed energy depending on the two methods of calculation. On the contrary, in the case of Oe stars, when we considered that the density regions of matter that produce the observed DACs and SACs are not successive, we calculated larger values for the total absorbed energy, as we expected theoretically. As we have checked the validity of GR model and as we know that these differences are not due to mistakes of the mathematical model, in the near future we intend to study a great number of quasars of the same type, in order to make a statistical study on this phenomenon and its origin. A first aspect is that it depends on the extent of the area in which the density regions of matter evolve, as well as on the optical depth of the lines that are created in these regions (see also Antoniou et al. 2010).

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