Structure and Kinematics of Quasar Broad Line Regions
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Polarimetry and Spectropolarimetry of a Sample of Broad Absorption Line Quasars

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Abstract. Optical polarimetric and spectropolarimetric observations of a sample of broad absorption line QSOs were recently carried out with the ESO 3.6 m telescope and EFOSC1 in La Silla, Chile. Some preliminary results are presented here with emphasis on interesting correlations between polarization and other quantities characterizing the optical spectra of the objects.

1. Introduction

The high ionization broad absorption line (HI BAL) QSOs are a class of quasars with deep, high-velocity absorption features, blueshifted with respect to the corresponding emission lines. These absorption lines are generally interpreted as the ejection of matter at very high velocities. In the framework of the unified theory of AGN, it is relevant to know whether the BAL and non-BAL QSOs are two distinctive populations of objects or whether the differences observed in their spectra are only view-dependent. In order to investigate this, we started a study of the optical polarization properties of a sample of radio-quiet quasars including several BAL QSOs.

In this paper we first present a brief introduction to the techniques used to perform our observations. Section 3 will be devoted to our final polarimetric results with emphasis on several interesting correlations, while in section 4, we show preliminary results of our spectropolarimetric study.

2. Observations

Our observations were carried out in La Silla (Chile) with the ESO 3.6 m telescope equipped with the EFOSC1 and a Wollaston prism. EFOSC1 works either in imaging mode or in spectroscopic mode. The Wollaston prism is a device that splits the incoming ray of light into two beams orthogonally polarized. When inserting the Wollaston in the grism wheel of EFOSC1, we can do imaging polarimetry. If we put the Wollaston in the filter wheel and add a grism and a slit, we can do spectropolarimetry (e.g., di Serego Alighieri, 1998).

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3. Broad band polarimetry

We have observed in the V-filter a sample of 42 optically selected quasars including 29 BAL QSOs. The sample was essentially chosen from Weymann et al. (1991, hereafter W91) because they gave a lot of indicators quantitatively describing the spectral characteristics. Among the BAL QSOs, there are several low ionization broad absorption line (LI BAL) QSOs, showing absorption in lower ionization species such as Mg II or Al III in addition to the high ionization lines.

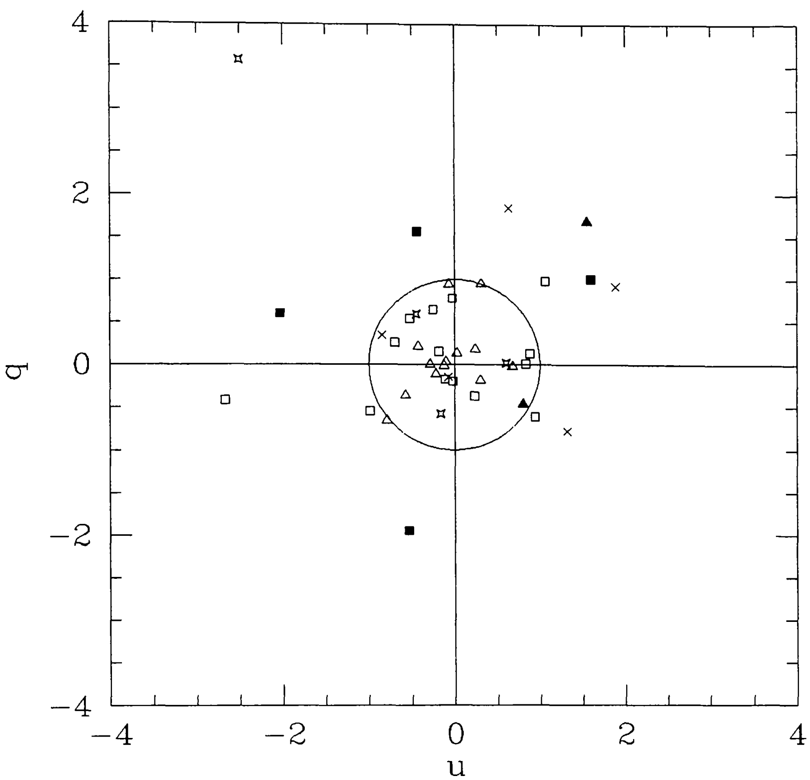

Figure 1. Results from our polarimetric sample shown in the u-q plane. The empty triangles are non-BAL QSOs; the empty squares are HI BALs; the empty stars are weak LI BALs; the crosses are possible LI BALs; the full squares are strong LI BALs; the full triangles are BALs that we could not categorize. The circle represent a degree of polarization of 1%.

Results are shown in the u-q plane (Fig.1) where u and q are the normalized Stokes parameters fully describing the linear polarization. The errors associated with these parameters are $\sigma_u \sim \sigma_q \sim 0.2\,\%$. Due to a possible different behaviour of the LI BAL QSOs, we carefully classified them into three categories: possible, weak or strong.

From this diagram it can be seen that there is apparently no polarization difference between HI BAL QSOs and non-BAL QSOs: they are all essentially polarized at a low level. All quasars with higher polarization are mainly LI BAL quasars. Note however that some LI BAL QSOs have low polarization.

Several correlations between the degree of polarization and other quantities characterizing the optical spectra of the BAL QSOs have been searched for. For most of them, we did not find any clear correlation. We investigated correlations with two indexes defined by W91 to characterize the broad absorption lines: the *balnicity index* which is a modified measure of the equivalent width of the absorption line (the higher the index, the stronger the absorption) and the *detachment index* which measures how detached is the absorption line from the corresponding emission line (the higher the index, the more detached the absorption line). Although there is no clear evidence for a relation with the balnicity index, we found a correlation between the polarization and the detachment index, at least for the LI BAL QSOs: the more detached the line, the less polarized the quasar. Note that if we introduce an 'ad-hoc' redshift dependence of the polarization to take into account the fact that we observe the polarization at different rest wavelengths, the correlation is slightly improved.

A more detailed account of this work will be given in Hutsemékers, Lamy & Remy (1998).

4. Spectropolarimetry

We have carried out spectropolarimetry for seven highly polarized LI BAL QSOs. They were observed with the B-300 grism (3600-6700 Å) and sometimes with the R-300 grism (5800-9600 Å) such that we could also study the Mg II line. Each step of the reduction was carefully checked in order to obtain a signal-to-noise ratio as high as possible. Fig 2. is an example (H1413+117, the "Cloverleaf") illustrating our data.

Some general trends can be inferred from our sample: the polarization in the BAL troughs is generally much higher than in the continuum, while the emission lines are polarized more or less at the same level as the continuum. The position angle of the polarization is roughly constant throughout the spectrum. This behaviour is in agreement with other results (Goodrich et al. 1995, Cohen et al 1995). These data are currently being modelled and will be published elsewhere with more details (Lamy & Hutsemékers, 1998).

5. Conclusion

Our polarimetric study shows that essentially all significantly polarized objects from our sample belong to the class of the LI BAL QSOs. Some LI BAL QSOs are nevertheless polarized at a low level. A correlation between the profile of the lines (measured by the detachment index) and the degree of polarization has been found for these objects.

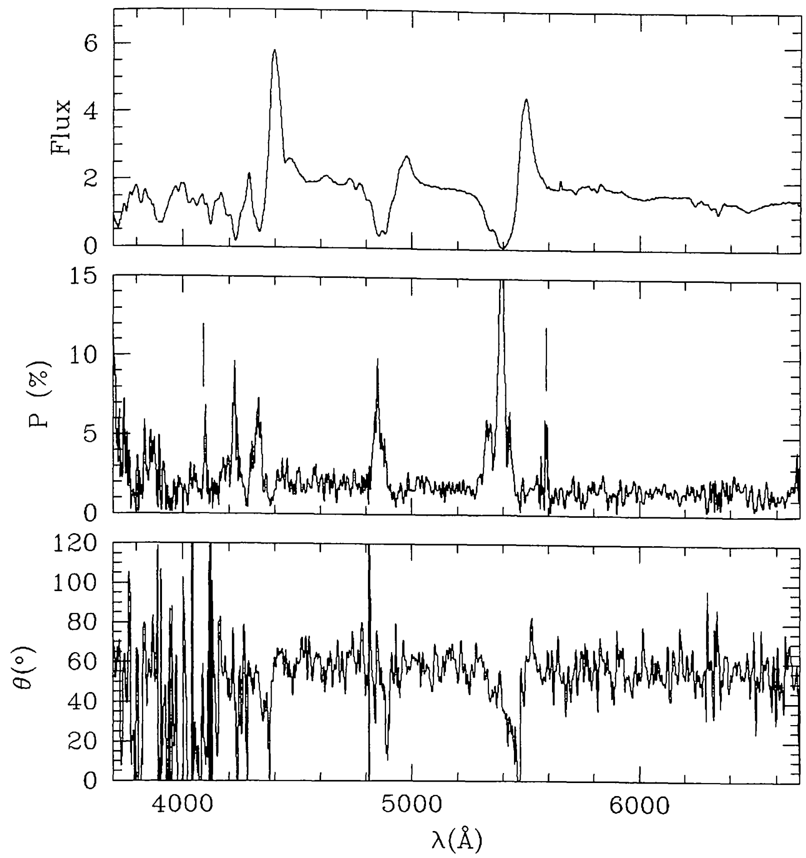

Figure 2. Spectropolarimetry of H1413+117. The top panel is the total flux F_λ in arbitrary units. The middle panel shows the degree of polarization and the bottom panel the polarization position angle in degrees. The vertical lines indicate the presence of uncorrected cosmic ray hits.

Our spectropolarimetric study shows that the broad absorption lines have in many cases a degree of polarization significantly higher than in the continuum. These results are compatible with a diluting light being more absorbed than the scattered light along the lines of sight crossing the broad absorption line clouds, resulting in a higher polarization in the BAL troughs. This interpretation has been suggested by several authors (e.g., Schmidt et al. 1997).

Acknowledgments

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Discussion

Bev Wills: In general, the most strongly absorbed light paths in BAL QSOs are those least polarized, resulting in smallest dilution of scattering polarization in the BAL troughs. Could greater equivalent width of BAL troughs in low-ionization compared with high-ionization BAL QSOs account for their higher broad-band polarization?

Hervé Lamy: If the greater equivalent widths in the LI BAL QSOs account for the higher broad-band polarization then one could expect a correlation between the polarization and the balnicity index (which is a modified equivalent width). But, within our sample, we do not find any clear correlation. Furthermore, stronger absorption in the lines is not necessarily related to the stronger attenuation of the direct continuum needed to explain the higher broad band (i.e., continuum) polarization via a dilution effect.