Structure and Kinematics of Quasar Broad Line Regions
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Spectral Variability of NGC 4151 During 1990

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Abstract. We investigate the profile and intensity variations of Hα and Hβ emission lines in NGC4151 using the data obtained during the LAG compaign. Cross-correlation analysis shows that the time delay between continuum changes and variability of Hβ and Hα is about 4$\pm$2 days. During the first half of 1990 interesting peaks were observed in the red wings of Hα and Hβ. The same peaks were seen in UV lines CIV and MgII during this interval. The results obtained are briefly discussed.

1. Introduction

NGC 4151 is one of the nearest and intrinsically weakest galaxies of Seyfert class. NGC 4151 has often been presented as a typical example of type 1 Seyfert nucleus (Sy 1), but after the disappearance of the broad optical lines during the spring 1984 (Lyuty, Oknyanskij, & Chuvaev 1984) this object should rather be regarded as a typical example of a Seyfert nucleus with variations of spectral type. The 1990 year was peculiar for NGC 4151 because the object returned to a state which was typical of before 1980. A very strong dip in the covering factor was deduced from X-ray observations (Yaqoob et al. 1993) for first half of 1990.

2. Data and Results

We have used the intensive optical spectral monitoring of NGC 4151 obtained during the LAG campaign from January until June 1990, to investigate the profile and intensity variations of Hα and Hβ emission lines. The continuum light curve values have been supplemented with photoelectrical photometry (11 dates) obtained at the Crimean Observatory of the SAI by V.M. Lyuty. The details of data reductions and description of our straight-forward method for seeing effect correction can be found in Oknyanskij & van Groningen (1997). The light curves after the reduction for seeing effect are shown in the Fig. 1. We

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can note two variability components in these lines changes: fast and slow one (trend). The amplitude of the slow component relative to the fast component is higher for $H\alpha$ than for $H\beta$.

We use a new version of the cross-correlation technique: the MCCF (Oknyanskij 1994), and it shows that the lag between continuum changes and variability of Hβ and Hα is about 4$\pm$2 days (see Fig. 2). The error in the delay was found by applying cross-correlation analysis to model time series, with the same temporal distribution, power spectrum, and signal-to-noise ratio as the actual data. Our lag for 1990 is much lower than the one found for other epochs. For example, we used the MCCF technique for Hβ (Oknyanskij et al. 1991; Peterson & Cota 1988) and blue continuum in the interval 1983-1988 and found a lag of about 12 days.

During the first half of 1990 interesting peaks were observed in red wings of Hα and Hβ (see Fig. 3) which were rarely observed at other epochs. The same peaks were seen in UV lines CIV and MgII (see Fig. 4 and Fig. 5) during first half of 1990. Intensities of the peaks changed in correlation with continuum and line variability. We noted some differences of these peaks in Hα and Hβ. It is interesting to note that the red peak in the Balmer lines was absent next season but a new blue peak in these lines, and possibly in CIV and MgII, arose (Oknyanskij 1994; Oknyanskij & van Groningen 1997). This coincidence seems to indicate that parts of the CIV and MgII lines and Balmer lines may emitted from clouds whose kinematics are similar. On previous occasions, during 1975-1978 (Chuvaev & Oknyanskij 1988) and 1985, these blue and red peaks appeared at nearly the same locations as in 1990-1991, however some variations in shifts and profile shapes were observed. The variations of these peaks are following with some delay the fast continuum variations, however some additional long-term component is present due to independent variations in both peaks. We note that the blue peak was generally located systematically nearer to central narrow component than the red one. We draw attention to the fact that 8 objects (NGC 4151, 3C 390.3, Mkn 6, NGC 5548, NGC 7603, Mkn 1218, Mkn 728, Mkn 1018) among the 12 (or more) AGNs with known cases of type transitions, also have similar structured line profiles sometimes. This is appreciably more often than for all AGNs, although the statistics are rather poor and selection effects may play a role also.

3. Discussion

The phenomena of transitions from one Seyfert type to another during several years or months has not been explained yet, however it is possible that many if not all variable nuclei in AGNs undergo these changes of spectral class quite frequently. The unified model of AGN offers no explanation for objects that change from one Seyfert type to the other on short time scales, and other explanations have to be invoked. One possibility is that the change of type is caused by some dust clouds which temporally block our line of sight to the nucleus. Many ideas have been proposed in the literature to explain the occurrences and behavior of double peaks in the broad emission lines: complex double-stream, or bipolar, distributions of outflowing clouds; variation of the ionizing continuum or changes in orientation of the radiating cones; the presence of large hot spots on

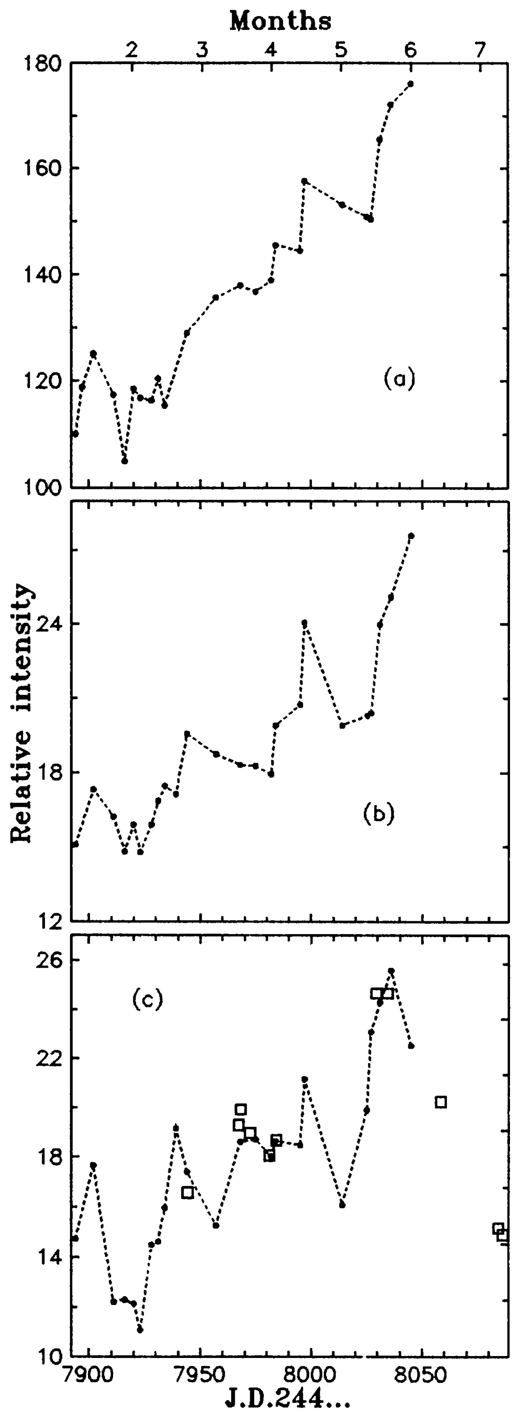

Figure 1. Light curves after reduction for seeing effect (a - $H\alpha$, b - $H\beta$, c - green continuum. Boxes - continuum values obtained from Lyuty's photoelectrical measurements in filter B).

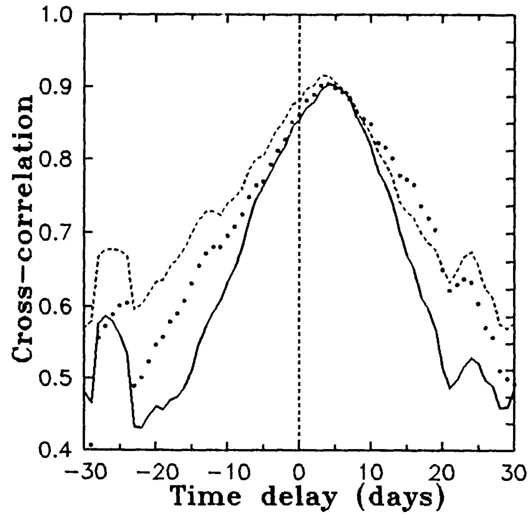

Figure 2. Cross-correlation functions MCCF for $H\alpha$ (dashed) and $H\beta$ (solid) (Perez et al. 1999) measurements with our correction for seeing effect) from green continuum (see Fig. 1c). Points - MCCF for $H\alpha$ (our measurements corrected for seeing) from the green continuum.

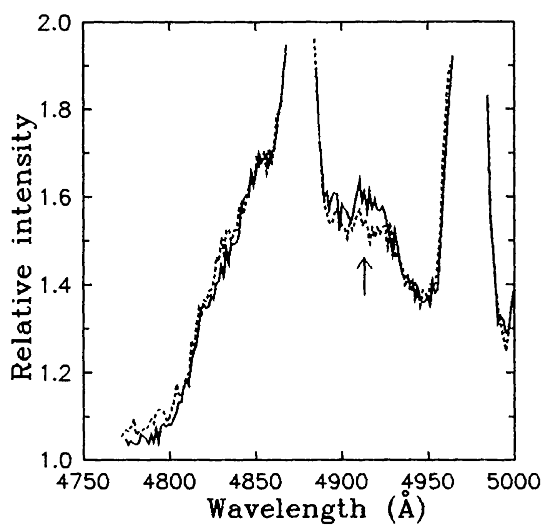

Figure 3. Profiles of $H\beta$ in two dates (solid line - 13.05.90, dashed - 16.02.90).

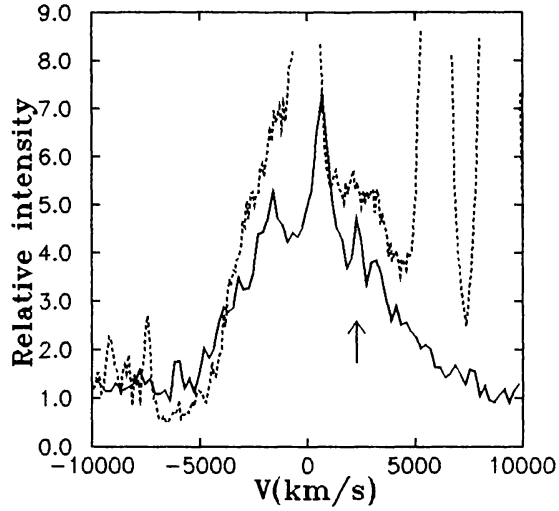

Figure 4. Peaks in CIV (solid) and $H\beta$ (dashed) in close dates (12.04.90 and 15.04.90).

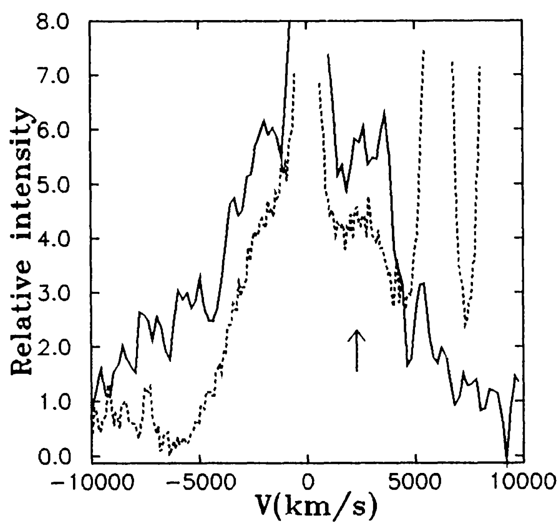

Figure 5. Peaks in MgII 2800 (solid) and $H\beta$ (dashed) in close dates (01.04.90 and 15.04.90).

a relativistic accretion disc (AD); spiral shock structure in the AD; supermassive binary black holes; elliptical ADs. If we will assume that all the aforementioned peculiarities of NGC 4151 (e.g., spectral type changes, appearance and disappearance of peaks in the profiles, variable time delays) are common occurrences in Seyfert galaxies then it is natural to search for some preliminary interpretation without involving some specific orientation or any exotic phenomenon. It is very easy to explain the different kinds of anisotropy in the most common AGN model: a supermassive black hole with an AD. However, this model provides a wide variety of different explanations for the peaks in the line profile. A key question is whether we can distinguish between possible classes of models for double-peaked emission: bipolar flow, jets, or emission from the AD. We found from modeling that partial obscuration of emission clouds beyond the AD can explain asymmetry in double peaks locations (for both possibilities: inflow or outflow streams). These explanations are valid only if the far side of the BLR is not completely obscured by a thick AD, since otherwise only one-side peaks would be observed in general. We did not find any systematic difference in time delay for the peaks and other parts of line profiles. However, for double jet or stream models, the expected time delay between blue and red peaks is of the order of weeks or even years (!?) – see discussion by Livio & Pringle (1996).

Finally, we can conclude that a simple double stream model might be rejected. Only one possibility can save this type of model: if some clouds (probably more dense ones) fall to the central source and other ones (probably less dense ones) are ejected. The systematical asymmetry in shifts of the double peaks would be due to the fact that falling clouds radiate emission lines closer to the central source where the systematic radial velocity is higher than farther out where ejected clouds might radiate. It is unclear why at various times we see one or both of these components which appear from time to time at about the same shifts. A change in obscuration of broad-line region (BLR) might be a possible explanation. If we observe the AD and BLR through some ensemble of thick dusty clouds, we can observe emission from the internal part of AGN (such as streams of clouds or an AD with hot spots) only temporarily. This could explain the correlation of the strong deep X-ray covering factor with changes in continuum level, the appearance of peaks in lines, and the change in the lag.

References

Chuvaev, K. K., & Oknyanskij V. L. 1988, Soviet Astron., 30, 1

Livio, M., & Pringle, J. E. 1996, MNRAS, 278, L35

Lyuty, V. M., Oknyanskij, V. L., & Chuvaev, K. K. 1984, Astron. Lett., 10, 335

Oknyanskij, V. L., Lyuty V. M., & Chuvaev K. K. 1991, Astron. Lett., 17, 100

Oknyanskij, V. L. 1994, Ap&SS, 222, 157

Oknyanskij, V. L. & van Groningen, E. 1997, Astron.& Astroph. Trans., 14, 105

Peterson, B.M., & Cota, S.A. 1988, ApJ, 330, 111

Yaqoob, T., et al. 1993, MNRAS, 262, 435