On the Correlation of IR and Optical Variability in NGC4151

V. L. Oknyanskij, V. M. Lyuty, O. G. Taranova, V. I. Shenavrin

Sternberg State Astronomical Institute, Moscow State University, Universitetskiy Prospekt 13, Moscow, 119899, Russia

Abstract. We combine all published NIR and optical photometrical observations of NGC 4151 as well as our new unpublished yet data which can be used for determination of time delays between optical and NIR variations. Before we have found change of time delay value for variations in $K$ and $L$ filters for different states of the luminosity. Here we are considering new data for deep minimum after the very high state of the nucleus. We conclude that dust recovering time after the high state is for any case more then several years.

1. Introduction

The review of past results on the optical-NIR time delay investigations for this object as well as for other AGNs can be found in Oknyanskij (2002), Oknyanskij and Horne (2001). Here we take into account and discuss new result for NGC 4151 Minezaki et al. (2004).

In past papers (Oknyanskij, 1993, Oknyanskij et al., 1999) has been found time delay values between optical UBV and NIR (JHKL) variations for two different luminosity cycles of NGC 4151 activities (see Fig.1): Case A (1969-1980) and Case B (1990-1998). We have found that time delay is longer for Case B following to significantly more high level of luminosity in this cycle comparative to the past case A.

We are going to report about the new time delay determinations using optical UBV and NIR data for NGC 4151 in the minimum after high state B (then we call interval 1999-2004 as Case C).

The past NIR time delays for NGC 4151 at Cases A and B as well as new ones for Case C (this work and Minezaki at al. 2004) are collected in Table 1.

1.1. Data

Details and needed references about used here optical and NIR data can be found at Oknyanskij et al. (1999). Here we are using for analysis published in part UBV and NIR data for Case C till 2004. The details and all references can be found in our past paper Oknyanskij (1999) and in Lyuty (2004), which has to be published soon.
Table 1. Collects optical–infrared time delays measured in NGC 4151

| object                  | delay bands | reference                  |
|-------------------------|-------------|----------------------------|
| NGC 4151 (Event A)      | (d)         |                            |
|                         | 30 $-$ 60   | Penston 1974               |
|                         | 18 $\pm$ 6  | Oknyanskij 1994            |
|                         | 26 $\pm$ 6  | Oknyanskij & Horne 2000    |
| NGC4151 (Event B)       | $\sim$ 6    | Oknyanskij et al. 1999     |
|                         | $8 \pm 4$   | $H(UBV)$                   |
|                         | $35 \pm 8$  | $K(UBV)$                   |
|                         | $97 \pm 10$ | $L(UBV)$                   |
| NGC4151 (Event C)       | $94 \pm 10$ | $H(UBV)$                   |
|                         | $48 \pm 2$  | $K(V)$                     |
|                         | $104 \pm 10$| $K(UBV)$                   |
|                         | $105 \pm 10$| $L(UBV)$                   |

Figure 1. Overall $K$ light curve ($F_K = 2.512^{9-K}$) reduced to 12" aperture in comparison with optical $U$ flux variation ($F_U = 2.512^{11-U}$) through 27" aperture (solid line).
2. Cross-Correlation analysis

For cross-correlation analysis we are using the same MCCF method as in our past papers (see details and references in Oknyanskij 1993, Oknyanskij at al. 1999, Oknyanskij & Horne, 2001, Oknyanskij 2002). The ratio of slow-to-fast variations amplitudes are much bigger for the Case C than it was before. Due to the reason we need to remove the slow components in the optical and NIR light curves before using them for cross-correlation. This operation does not change the results but makes the peak in cross-correlation significantly more sharper.

As it is seen from the Fig.2 time delay for $K$ variations from optical ones is about 100 days.

Our data are in very good coincidences with light curves in Minezaki et al (2004). We were able to combine the data with our results and then use the combined data for cross-correlation analysis. We have got time delay between $V$ and $K$ variations about 50 days for the same time interval as in the Minezaki et al. Meanwhile the result has not got any confirmation in our analysis with all optical data but the same time interval data for $K$ data as in Minezaki et al. Minezaki et al. Really Minezaki et al have used for analysis just two short and smooth curves with only one minimum in them. If IR and optical data have some difference at additional slow trend then obtained value for time delay might be very significantly depending from this fact.
3. Discussion

The dust (graphite grains) can not be survived on distances from nucleus closer than some critical value. So radiation of central source cleans dust from the inner region leaving a hole in its distribution. Radii of these holes can be estimated using NIR variations time delays. These time delays probably can give us redshift-independent luminosities of AGNs Oknyanskij (2000, 2002). This interpretation has obvious problem if take into account strong variability of AGNs. If the grains are depleted when the UV luminosity peaks, and cannot reform, then a dust-free hole surrounding the central source will be created with radius corresponding to the sublimation distance at the UV peak (Barvanis, 1992). So to explain short NIR time delay values in Case A (in despite of known from historical light curve previous very high states) we have to involve some explanation for recovering or reformation for the dust particles. One of the way has been considered by Barvanis (1992) - the dust partical can survive in clouds into the sublimation radius for the peak cases. The high state at case B was untypically long and dust particles probably were sublimated very significantly. So it is interesting to find from observatios how fast the dust can be recovered or reform.

4. Conclusion

Time delay between optical and NIR variations is a variable value and it is changed with state of the nucleus activity. We have found that time delay for $K$ variations in the last low state is about 100 days, ie about the same as it is for $L$ in Cases B and C.

In a case NGC 4151 we have an opportunity to investigate changes of the dust hole radius in different activity states of the nucleus and estimate that the time needed for recovering or reformation for the dust particles is longer than several years. Alternative explanations can be: anisotropy of radiation field, shielding of the central source on a light of sight, and also special orientation of the dust region.

References

Barvainis, R. 1992, ApJ, 400, 502
Lyuty, V.M. 2004, (in preparation)
Minezaki, T., Yoshii, Y., Kobayashi, Y., Enya, K. et al., 2004, APJ, 600, L35
Oknyanskij, V.L., 1993, Astronomy Letters, 19, 416
Oknyanskij, V.L., Lyuty, V.M., Taranova, O.G., & Shenavrin V.I. 1999, Astronomy Letters, 25, 483
Oknyanskij, V.L. 1999, Odessa Astronomical Publications, 12, 99
Oknyanskij, V.L. & Horne, K. 2001, ASP Conf. Ser., 224, 149
Oknyanskij, V.L. 2002, ASP Conf. Ser., 282, 330
Penston, M.V., Balonek, T.J., Selmes, R.A., et al. 1974, MNRAS, 169, 357