Time Lag Between the Optical Continuum and Line Variabilities of NGC 4151

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INTRODUCTION

Variability of the continuum and emission line of broad line AGN has been known for several decades.

The characteristic time scales are of the order of a week or less. Specifically, line and continuum monitoring has been extensively exploited in recent years to probe unresolved broad line region (BLR).

Investigations of the continuum and broad emission lines provides dynamical and kinematical characteristics of the BLR.

AIM

Despite the fact that AGN of NGC 4151 is well investigated, questions concerning the BLR kinematics and dimensions of the innermost region are still existing.

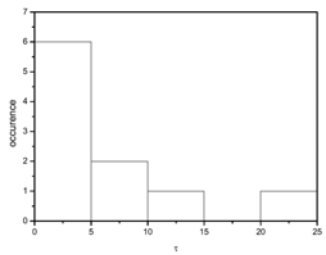
So, the new observations of the NGC 4151 nucleus are needed to explore metric and geometry of the BLR.

Within this aim an analysis of the spectral monitoring of the NGC 4151 are presented. The time span covered by observations are almost 10 years long.

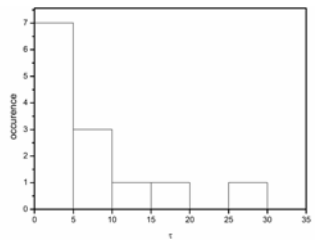
ZDCF METHOD

Using a long term spectroscopic observations of NGC 4151 (1996 to 2005) we used z-transformed discrete correlation function (ZDCF) to find the lag time between the broad lines (Hβ and Hα) and the optical continuum. The method:

- approximates the bin's distribution by bi-normal distribution
- bins the data points into equal population bins
- uses Fisher's z-transform to stabilize the distribution of the correlation coefficient
- more efficient than DCF in detecting correlations
- more sensitive to the undersampled light curves than both the DCF and ICCF.



Distribution of time lags for Hα and Hβ. The lags were calculated for 5 subsets of observations. The lag mean value is $6^d.83 \pm 8^d.64$



Distribution of time lags for Hα and Hβ. The lags were calculated for each year of observations. The lag mean value is $5^d.2 \pm 6^d.52$.

RESULTS

Table 1. The time lag and CCF coefficient for each year in the monitoring period.

year	Hβ lag (days)	CCF	Hα lag (days)	CCF
1996	$7.18^{+29.22}_{-7.18}$	$0.573^{+0.22}_{-0.27}$		
1997				
1998	$2.71^{+2.23}_{-1.73}$	$0.41^{+0.26}_{-0.30}$	$0.64^{+2.36}_{-0.64}$	$0.04^{+0.33}_{-0.34}$
1999	$1.68^{+1.26}_{-0.69}$	$0.98^{+0.01}_{-0.01}$	$8.00^{+36.00}_{-8.00}$	$0.83^{+0.09}_{-0.12}$
2000	$15.61^{+3.36}_{-2.28}$	$0.95^{+0.03}_{-0.04}$	$29.64^{+59.36}_{-28.64}$	$0.75^{+0.13}_{-0.16}$
2001	$0.43^{+1.40}_{-0.43}$	$0.72^{+0.14}_{-0.18}$		
2002	$8.72^{+9.55}_{-6.72}$	$0.41^{+0.30}_{-0.30}$		
2003	$0.28^{+0.78}_{-0.28}$	$0.29^{+0.28}_{-0.31}$		
2004	$0.27^{+0.73}_{-0.27}$	$0.77^{+0.11}_{-0.15}$		
2005	$13.38^{+10.88}_{-9.29}$	$0.94^{+0.03}_{-0.05}$	$31.36^{+59.64}_{-30.36}$	$-0.10^{+0.34}_{-0.33}$
2006	$0.32^{+0.67}_{-0.32}$	$0.92^{+0.04}_{-0.06}$		

Table 2. The time lag and CCF coefficient for entire monitoring period.

Hβ lag (days)	CCF	Hα lag (days)	CCF
$4.61^{+28.56}_{-4.61}$	$0.94^{+0.01}_{-0.01}$	$6.34^{+26.66}_{-6.34}$	$0.89^{+0.02}_{-0.02}$

Table 3. The time lag and CCF coefficients for five periods: 1 JD(2450094.466-2453846.403),2 JD(2451166-2451515), 3JD(2451552-2452237) 4 JD(2452299-2453503) and 5 JD(2453704-2453846).

period	Hβ lag (days)	CCF	Hα lag (days)	CCF
1	$0.88^{+3.24}_{-0.88}$	$0.75^{+0.07}_{-0.08}$	$0.79^{+3.21}_{-0.79}$	$0.75^{+0.10}_{-0.12}$
2	$1.65^{+1.34}_{-0.66}$	$0.98^{+0.01}_{-0.02}$	$2.46^{+8.55}_{-2.46}$	$0.71^{+0.15}_{-0.19}$
3	$9.09^{+4.86}_{-3.14}$	$0.81^{+0.09}_{-0.12}$	$0.56^{+1.44}_{-0.56}$	$0.70^{+0.12}_{-0.15}$
4	$0.53^{+2.39}_{-0.53}$	$0.87^{+0.03}_{-0.04}$	$20.73^{+8.27}_{-16.73}$	$0.92^{+0.04}_{-0.06}$
5	$5.16^{+4.16}_{-3.23}$	$0.72^{+0.14}_{-0.18}$	$10.18^{+32.82}_{-10.18}$	$0.77^{+0.12}_{-0.55}$

CONCLUSIONS

Presented results obtained for time lag between Hα and Hβ and continuum lines of NGC 4151 are preliminary.

Further examinations of Hα are highly desirable due to lack of observations. Despite of this fact calculated time lags using whole set of observations (see Table 2) are close to each other. Also it is in good agreement with result $6.6^{+1.1}_{-0.8}$ obtained by Bentz et al. (2006). Consequently, the BLR is compact.

The time lags obtained by using years and five periods (for both lines) show variations which implies that the metric of the BLR are changing.

Acknowledgements

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