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ORIGINAL ARTICLE

Optical spectral decomposition of NGC 4051

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Abstract Considering the host galaxy contribution, a spectral decomposition method is used to reanalyzed the archive data of optical spectra for a narrow line Seyfert 1 galaxy, NGC 4051. The light curves of the continuum f_λ(5100 Å), and Hβ, He II, Fe II emission lines are given. We find strong flux correlations between line emissions of Hβ, He II, Fe II and the continuum f_λ(5100 Å). These low-ionization lines (Hβ, Fe II, He II) have "inverse" intrinsic Baldwin effects. Using the methods of the cross-correlation function and the Monte Carlo simulation, we find the time delays, with respect to the continuum, are $3.45^{+12.0}_{-0.5}$ days with the probability of 34 % for the intermediate component of Hβ, $6.45^{+13.0}_{-1.0}$ days with the probability of 65 % for the intermediate component of He II. From these intermediate components of Hβ and He II, the calculated central black hole masses are $0.86^{+4.35}_{-0.33} \times 10^6$ and $0.82^{+3.12}_{-0.45} \times 10^6\ M_\odot$. We also find that the time delays for Fe II are $9.7^{+3.0}_{-5.0}$ days with the probability of 36 %, $8.45^{+1.0}_{-2.0}$ days with the probability of 18 % for the total epochs and "subset 1" data, respectively. It seems that the Fe II emission region is outside of the Hβ emission region.

Keywords Active galactic nuclei · NGC 4051 · Emission line · Black hole

1 Introduction

Variability is a common phenomenon in Active Galactic Nuclei (AGN). With the AGN watch and the Palomer-Green (PG) QSOs spectrophotometrical monitoring projects, the reverberation mapping method is used to investigate inner structures in AGNs, as well as their central supermassive black holes (SMBHs) (Blandford and McKee 1982; Kaspi et al. 2000, 2005; Peterson et al. 2004). Narrow line Seyfert 1 galaxies (NLS1s) belong to a peculiar subclass of AGNs, usually with narrow Balmer emission lines but with broad wings, strong optical Fe II emission (Osterbrock and Pogge 1985; Bian and Zhao 2004; Bian et al. 2008). It is believed that NLS1s might be in the early stage of AGNs evolution with smaller SMBHs (Mathur 2000). Due to their strong Fe II emission, NLS1s can be used to investigate the debated origin of Fe II emission (Hu et al. 2008; Bian et al. 2010). It is found that the flux ratio of Fe II to Hβ, $R_{\rm Fe}$, where the optical Fe II flux is the flux of the Fe II emission between λ4434 and λ4684, strongly correlates with the so-called Eigenvector 1, which is suggested to be driven by the accretion rate (Boroson and Green 1992; Marziani et al. 2003).

NLS1s always have relatively high Eddington ratios of larger than about 0.1 Grupe (2004). However, for a NLS1 of NGC 4051, it was found that its Eddington ratio is about 0.03 (Denney et al. 2009). The key problem is the Hβ time delay measurement for NGC 4051, as well as its structure of emission lines. With three-years optical spectral monitoring of NGC 4051 (from Jan. 1996 to July 1998), Peterson et al. (2000) found, with respect to the light curve of f_λ(5100 Å), the Hβ light curve is delayed by about 6 days with an uncertainty of 2–3 days. He II delay is consistent with Hβ, but with a larger uncertainty. In their time delay analysis, the fluxes for different lines are measured by assuming a linear underlying continuum and integrating the flux above this continuum (Peterson et al. 2000). Shemmer et al. (2003) found the Hβ time lag for NGC 4051 is about 2.0 ± 2.3 days. Denney et al. (2009) presented a

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