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Variability of Fe II in Two NLS1s, PG 1700+815 and NGC 4051

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Abstract. We analyze the spectral variability for two narrow line Seyfert 1 galaxies, PG 1700+518 and NGC 4051 using the spectral decomposition method. We focus on their optical Fe II variability to investigate the origin of Fe II in AGNs. For PG 1700+518, we find that the Fe II size is about 200 light-days, which is consistent with the Hβ size derived from the empirical R–L relation. For NGC 4051, the [O III] 5007 Å flux is strongly correlated with continuum flux, suggesting that we should recalibrate the spectral flux on a scale defined by [O III] flux. The corrected light curves of Fe II, Hβ, He II, f_λ(5100 Å) are given here. A detailed analysis will be given in the near future.

Key words. Fe II—emission lines—light curves—time lag—PG 1700+518—NGC4051.

1. Introduction

Narrow line Seyfert 1 galaxies (NLS1s) belong to a peculiar subclass of AGNs, usually with strong optical Fe II emission (e.g., Bian & Zhao 2004). It is believed that NLS1s might be in the early stage of AGNs evolution with smaller supermassive black holes (SMBHs).

The variability is a common phenomenon in AGNs. With the AGNs watch and the Palomer–Green (PG) QSOs spectrophotometrical monitoring projects, the reverberation mapping method is used to investigate the inner structure in AGNs, as well as their central SMBHs (Kaspi *et al.* 2000, 2005; Peterson *et al.* 2004).

In order to investigate the Fe II origin in NLS1s, we select two NLS1s, PG 1700+518 and NGC 4051 from the public spectral archive of the AGNs watch and the PG QSOs monitoring projects (Peterson *et al.* 2004).

2. Data and analysis

For PG 1700+518 ($z = 0.292$), there are 39 spectra covering 7.5 years from 1991 to 1998, which were done by two telescopes (2.3 m and 1 m). The time resolution is about 1–4 months. The observational wavelength coverage is from $\sim$4000 to $\sim$8000 Å with a spectral resolution of $\sim$10 Å. Spectra were calibrated to an absolute flux scale using simultaneous observations of nearby standard stars. The 39 spectra of PG 1700+518 are available on the website[1] (Kaspi *et al.* 2000).

For NGC 4051 ($z = 0.0023$), a Seyfert galaxy, there are 125 spectra covering from January 1996 to July 1998, which were done by a 1.8 m telescope (dataset A) and a 1.5 m telescope (dataset B). The mean time resolution is 7.4 days. The nominal spectral resolution was 9 Å for all set A spectra; 5 Å for all set B.[2] With about 130 days spectral monitoring NGC 4051, Denney *et al.* (2009) presented a new spectral monitoring for NGC 4051, which covers about 130 days with a mean time resolution about 0.7 day. They found that the Hβ time delay is 1.75 light-days.

The spectral decomposition are briefly introduced as follows (Bian *et al.* 2010):

- The observed spectra are corrected for the galactic extinction, then transformed into the rest frame ($A_V = 0.116$ for PG1700+815 and $A_V = 0.043$ for NGC 4051).
- The optical Fe II template from the NLS1 I ZW 1 is used to subtract the Fe II emission from the spectra. The best modelling of the Fe II and the power-law continuum is found when χ^2 is minimized in the fitting windows. For PG1700+518, the fitting windows are 4430–4770, 5080–5550 Å (see an example fit in Fig. 2 in Bian *et al.* 2010). For NGC 4051, the fitting windows are 4170–4260, 4430–4550, 5080–5550, 6890–7010 Å which is different from that of PG 1700+518. This is due to strong and broad He II emission in NGC4051, and broad spectral coverage.[3]
- In the Fe II and power-law continuum removed spectra, several lines are fitted by multi-Gaussian functions. For PG 1700+518, four Gaussian functions are used to fit the Hβ, [O III] emission lines (see Fig. 2 in Bian *et al.* 2010). For NGC 4051, 10 Gaussian functions are used to fit Hβ, [O III] and He II.

3. Some results

3.1 *PG 1700+518*

(1) We gave the light curves of Fe II, as well as f_λ (5100 Å), Hβ, for PG 1700+518. The normalized variability of Fe II is 2.58, which is smaller than that for f_λ (5100 Å) (6.73), Hβ (3.65). (2) The Fe II time lag in PG1700+518 is about 209 light-days, and Hβ time lag cannot be determined. (3) After considering Fe II contribution, PG 1700+518 shares the same characteristic on spectral slope variability to other 15 PG QSOs in our previous work (Pu *et al.* 2006), i.e., harder spectrum during brighter phase. For details, please refer to Bian *et al.* (2010).

3.2 *NGC 4051*

A strong correlation is found between [O III] flux and f_λ(5100 Å) flux (the Pearson's correlation coefficient is 0.8). It is believed that the [O III] flux from extended low-density narrow line region is constant. Therefore, we should use the [O III] flux to

[1] http://wise-obs.tau.ac.il/∼shai/PG/
[2] http://www.astronomy.ohio-state.edu/∼agnwatch/
[3] There are some stellar light contributions in spectra of NGC 4051. The stellar light pseudo-continuum is degenerate with the nuclei power-law continuum.

calibrate other line flux (Peterson *et al*. 2000). The original and corrected light curves are shown in Fig. 1. In the corrected light curves, the normalized variability of Fe II is 1.68, which is smaller than that for f_λ (5100 Å) (5.96), larger than that for Hβ

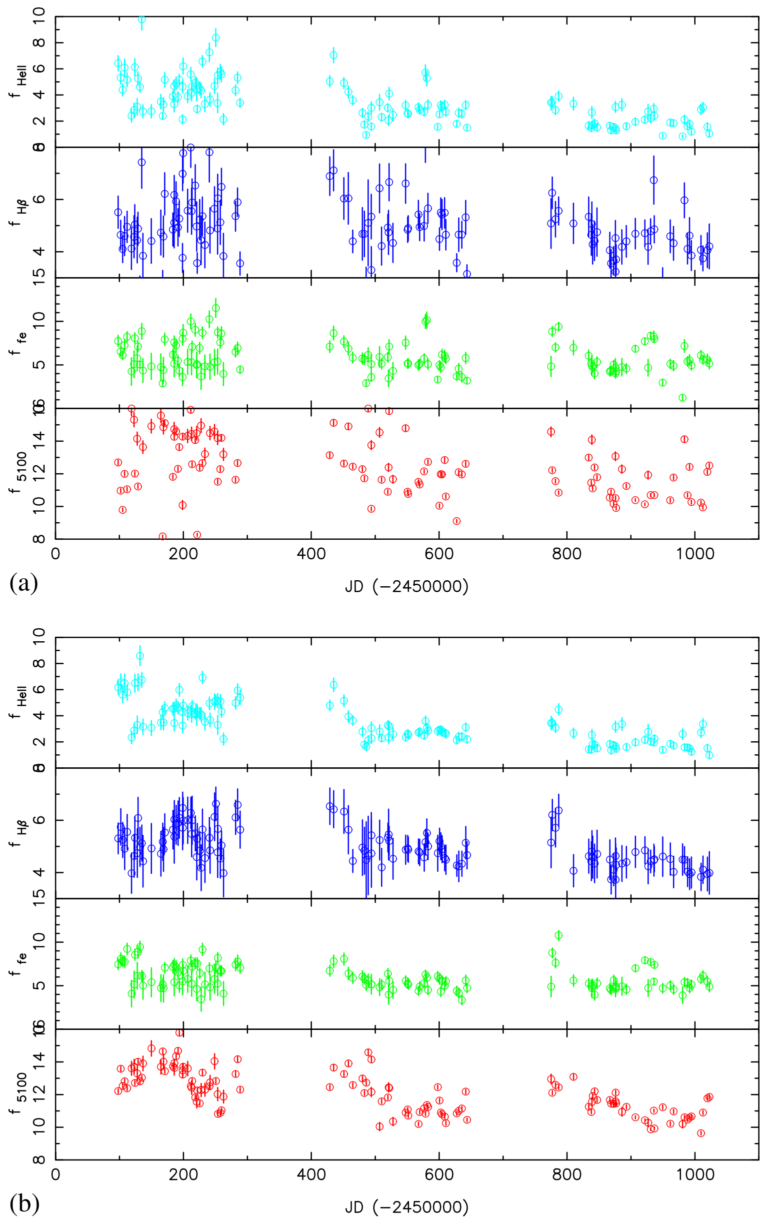

Figure 1. Uncorrected light curves (**a**) and corrected light curves (**b**) of He II, Hβ, Fe II, f_λ(5100 Å) (from top to bottom) for NGC 4051. Emission-line fluxes are displayed in units of 10^{-13} erg s^{-1} cm^{-2}, the continuum flux determined from the power-law at 5100 Å is given in units of 10^{-15} erg s^{-1} cm^{-2} Å^{-1}.

(0.95) and smaller than He II (3.42). In the future, the time lag analysis will be done for He II, Fe II, Hβ with respect to $f_\lambda(5100\ \text{Å})$.

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