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Optical monitoring observations of two γ-ray narrow-line Seyfert 1 galaxies

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HIGHLIGHTS

- Optical observations for 2 γ-ray NLS1s were carried out in B and R bands.
- Difference image subtraction was used for the extended host galaxy of 1H 0323+342.
- Variability on day timescale were observed for 1H 0323+342.
- INOV was confirmed for SDSS J094857.3+002225.
- Microvariability indicated the existence of a relativistic jet in these NLS1s.

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ABSTRACT

1H 0323+342 is a rather radio-loud narrow-line Seyfert 1 galaxy (NLS1) with γ-ray emission. Optical observations were carried out in B and R bands which covered 6 nights in 2011 to obtain light curves of 1H 0323+342. The difference image subtraction method was used to deal with the data of 1H 0323+342 because of the existence of extended host galaxy. Optical variability on day timescale was reported here. We also monitored the first γ-ray NLS1 SDSS J094857.3+002225 and confirmed the existence of intranight optical variability (INOV). These indicated the existence of a relativistic jet in these NLS1s.

1. Introduction

Narrow-line Seyfert 1 galaxies (NLS1s) are a peculiar and interesting class of active galactic nuclei (AGNs) with unusually narrow permitted lines (Osterbrock and Pogge, 1985). There are some classification criteria for NLS1s as (Osterbrock and Pogge, 1985; Goodrich, 1989; Pogge, 2000): (1) the narrow permitted lines only slightly broader than the forbidden lines; (2) [O III]/Hβ < 3, but exceptions are allowed if there is also strong [Fe VII] and [Fe X] present, unlike what is seen in Seyfert 2s; (3) the full widths at half-maximum (FWHM) of the Hβ line < 2000 km s^{-1}. Furthermore, strong Fe II emission lines or higher ionization iron lines can often be observed in NLS1s (Osterbrock and Pogge, 1985; Goodrich, 1989). They usually show steeper spectra and rapid variability in the X-ray regime (Boller et al., 1996; Boller, 1997; Leighly, 1999; Malizia et al., 2008; Panessa et al., 2011). Usually, they are considered as objects with small black hole masses and very high Eddington ratios (Boller et al., 1996; Boroson, 2002; Grupe and Mathur, 2004).

NLS1s show remarkable radio-loud/radio-quiet dichotomy. It is not surprising that NLS1s are usually found radio-quiet, for they are considered as AGNs with small black hole masses and high accretion rates (Laor, 2000; Ho, 2002; Greene et al., 2006). However, a small part (about 7%) of them are radio-loud (R > 10) (Zhou and Wang, 2002; Komossa et al., 2006; Whalen et al., 2006; Zhou et al., 2006), where the radio loudness R is usually defined as the flux ratio of radio to optical at λ4400 (Kellermann et al., 1989). The very radio-loud (R > 100) NLS1s are even less (~2.5%) (Komossa et al., 2006). Radio-loud NLS1s make up of an attractive and special group of AGNs.

The origin of radio-loud NLS1s (RL-NLS1s) has not been clearly understood. Several scenarios, considered the beaming effect (Remillard et al., 1991; Wang et al., 2001; Padovani et al., 2002; Zhou et al., 2003; 2005), accretion mode (e.g., Collin and Kawaguchi, 2004; Heinzeller and Duschl, 2007; Sikora et al., 2007), black hole mass and black hole

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spin (e.g., Blandford and Znajek, 1977; Blandford and Payne, 1982; Mathur and Grupe, 2005), for example, have been suggested to explain the sparseness of RL-NLS1s (see Komossa et al., 2006; Yuan et al., 2008). Some RL-NLS1s show interesting broadband properties which are unusually similar to those of blazars (Zhou et al., 2003; 2005; 2007; Gallo et al., 2006; Yuan et al., 2008). Some of them show flat spectra and blazar-like spectral energy distributions (SEDs) (Gallo et al., 2006; Zhou et al., 2006; Yuan et al., 2008). They also have high brightness temperatures which indicate the presence of relativistic jets (Zhou et al., 2003; Yuan et al., 2008; Abdo et al., 2009a).

The Large Area Telescope (LAT) onboard *Fermi Gamma-ray Space Telescope* (hereafter *Fermi*) discovered high-energy γ-ray emission from a RL-NLS1 SDSS J094857.3+002225 (Abdo et al., 2009a; Abdo et al., 2009b; Foschini et al., 2010). Soon, three new γ-ray-emitting RL-NLS1s were detected with *Fermi*/LAT (Abdo et al., 2009c). Foschini et al. (2011) reported more *Fermi*/LAT detections of γ-ray NLS1s, leading the number of detected γ-ray NLS1s to 7. Later, Eggen et al. (2014) reported two more γ-ray-emitting RL-NLS1s. Some of them have shown significant γ-ray flux variations (Calderone et al., 2011; Paliya et al., 2015). The γ-ray variability on timescale of several days supports the presence of a relativistic jet (Calderone et al., 2011). The variability and average photon indices are similar to those of flat spectrum radio quasars (FSRQs) (Paliya et al., 2015). Blazars and radio galaxies were known as two types of γ-ray AGNs. γ-ray-emitting RL-NLS1s above could be considered as a new class of γ-ray AGNs (Abdo et al., 2009c; Foschini et al., 2010).

Optical observations could provide important information about the AGN, for instance, the physical scales and structures of the engines (Webb and Malkan, 2000). The presence of relativistic jets suggests us to search for the intraday optical variability in those γ-ray RL-NLS1s for the relativistic beaming effect (Wagner and Witzel, 1995; Stalin et al., 2004). If these γ-ray NLS1s indeed host relativistic jets beaming towards our lines of sight, intraday variability should be detected. Liu et al. (2010) first discovered violent intranight optical variability (INOV) on the timescale of several hours and suggested the existence of a relativistic jet in SDSS J094857.3+002225. Later, more extreme optical variabilities on timescales ranging from minutes to years were observed in the same object (Maune et al., 2011; 2013; Paliya et al., 2013). Rapid optical variations were also detected in RL-NLS1s J1305+5116 (Maune et al., 2011) and PKS 1502+036 (Paliya et al., 2013). INOV was also detected in RL-NLS1 1H 0323+342, which indicated the presence of relativistic jets in the object (Paliya et al., 2013). However, it should be emphasized that aperture photometry was used to get the light curves in this work, while extended host galaxy has been detected in 1H 0323+342.

1H 0323+342 and SDSS J094857.3+002225 are two γ-ray RL-NLS1s which could be right candidates for searching for intraday variability. For the nearby one 1H 0323+342, although it is brighter, the contamination of the host galaxy should be considered (Zhou et al., 2007; Antón et al., 2008; León Tavares et al., 2014). In this work, we will introduce our effort on observations of these two γ-ray RL-NLS1s at optical band, including the attempt of plotting a light curve of 1H 0323+342 blended with extended host galaxy, and the farther monitoring of SDSS J094857.3+002225.

These two sources are introduced in Section 2. The observations and date reduction are presented in Section 3. The results are presented in Section 4. We presented our discussion in Section 5 and summarized conclusions in Section 6.

2. 1H 0323+342 and SDSS J094857.3+002225

1H 0323+342. The γ-ray detected object is identified as a NLS1 due to its small Balmer line width (about 1600 km s^{-1}), small [O III]/Hβ of about 0.12, strong optical Fe II complexes and evident X-ray excess (Zhou et al., 2007; Foschini et al., 2009). Radio observations indicate that it is a strong radio source with an 8 GHz radio power

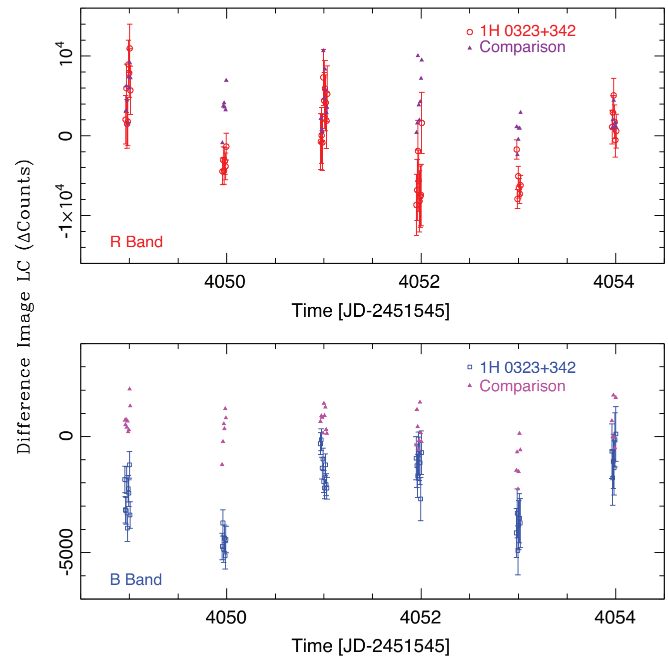

Fig. 1. Difference image residual flux light curves of 1H 0323+342 on the nights of 2011 February 1–6. The top and bottom panels give curves of R and B bands, respectively. The red open circles and blue open squares represent the residual flux of 1H 0323+342 in R and B band, respectively. The purple and magenta filled triangles represent the residual flux of comparison stars in R and B band, respectively. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article).

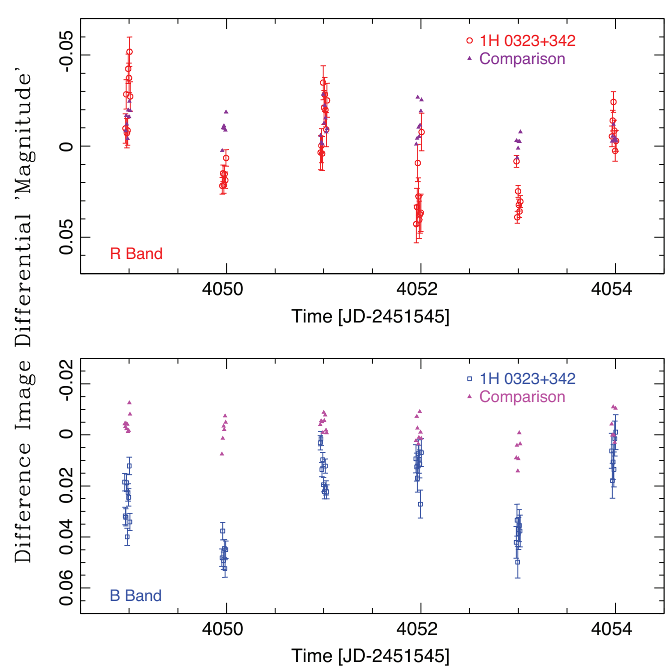

Fig. 2. Differential "magnitude" curves of 1H 0323+342 on the nights of 2011 February 1–6, which were obtained using the difference image subtraction method. The top and bottom panels give differential "magnitude" of R and B bands, respectively. The red open circles and blue open squares represent the differential "magnitude" of 1H 0323+342 in R and B band, respectively. The purple and magenta filled triangles represent the difference image differential "magnitude" of comparison stars in R and B band, respectively. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article).