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ORIGINAL ARTICLE

Optical variability of Mrk 421

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Abstract We observed Mrk 421 in V and R band using the 1.0 m telescope at Weihai Observatory of Shandong University since 2009 April to 2012 May. The available historical data in B and V band were also assembled for constructing light curves. The brightness of Mrk 421 ranges from 11.40 to 16.14 in the B band light curve, and from 11.38 to 14.56 in the V band. Analyses with the Jurkevich method and the structure function method showed a possible period of about 1.36 years for its long periodic variability. This period could be explained by a close binary black hole system (BBHS) model with a primary black hole mass of $1.70 \times 10^8 M_\odot$ and a secondary $\sim(0.49–2.9) \times 10^7 M_\odot$. We showed the color variability of Mrk 421, a bluer when brighter behavior during its lower state. Analyses of spectral index variations show that only a host galaxy contribution is not sufficient to explain the spectral index variations in Mrk 421, and some intrinsic mechanism is needed.

Keywords BL Lac object · Mrk 421 · Periodic variability · Color index · Spectral index

1 Introduction

Blazars, the most extreme class of Active Galactic Nuclei (AGNs), are thought to be with strong relativistically beamed component close to the line of sight. Strong variabilities of blazars are found from Radio to Gamma-Ray wavelengths (Ulrich et al. 1997). Different spectral variability and timescale analyses are the most powerful methods to understand the radiation mechanism and constrain the parameters of the physical model (e.g., Sillanpää et al. 1988; Lainela et al. 1999; Ramírez et al. 2004; Hu et al. 2006).

Variability timescales of blazars could be roughly divided into three classes: intra-day variability (IDV) or intra-night variability or micro-variability with timescales from tens of minutes to less than a day, short timescale variability (STV) with timescales from several days to a few months, and long timescale variability (LTV) with timescales from months to many years (Gupta et al. 2004). IDV and STV have been investigated extensively (e.g. Wagner et al. 1996; Lainela et al. 1999; Villata et al. 2002; Fan et al. 2004; Gupta et al. 2008, 2012), while LTV have been investigated less for lacking of long term data (e.g. Sillanpää et al. 1988; Liu et al. 1997; Zhang et al. 2007; Li et al. 2009). Mrk 421 (B2 1101+384) is one of the closest blazars with a redshift of 0.031. It has been monitored for more than a century, dating back to 1899 (Miller 1975; Liu et al. 1997). Mrk 421 was the first BL Lac object detected at gamma-ray energy (Punch et al. 1992). This source is characterized with large variations in B band (Miller 1975; Liu et al. 1997). Liu et al. (1997) analyzed the B band historical data of Mrk 421 using Jurkevich method and possible periods of 23.1 ± 1.1 and 15.3 ± 0.7 years were found. To check these periods with additional 21 years data, and considering that they analyzed the data only in one band, we use the data observed and collected in B and V band to analyze its long-term variability periods using the Jurkevich method and the first order Structure Function (SF).

Studying properties of the spectral energy distribution (SED) is an effective tool for understanding the physical radiation mechanism. The synchrotron self-Compton model predicts a flatter spectrum when the source turns brighter. Trèvese and Vagnetti (2002) analyzed spectral index variations of 42 PG quasars and they concluded that the spec-

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