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Multi-Wavelength Variability Properties of Fermi Blazar S5 0716 + 714

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Abstract. The multi-wavelength variability properties of blazar S5 0716 + 714 are reported. We construct multi-wavelength light curves of radio, optical, X-ray and γ-ray including our optical observation at Yunnan Observatories. In all the bands, the light curves show intense variabilities. The variability amplitudes in γ-ray and optical bands are larger than those in the hard X-ray and radio bands. The characteristic variability timescales at 14.5 GHz, optical, X-ray, and γ-ray bands are comparable. The variations of the hard X-ray and 14.5 GHz emissions are correlated with zero lag, and so are the V band and γ-ray variations. The multi-wavelength variability behaviours can be naturally explained by the classic leptonic model. We model the average SED of S5 0716 + 714 by leptonic model. The SSC + ERC model using the external seed photons from hot dust or Broad Line Region (BLR) emission is probably favourable avoiding the extreme input parameters from the pure SSC model.

Key words. Galaxies: active—galaxies: jets—BL Lacertea objects: individual: S5 0716 + 714—radiation mechanisms: non-thermal.

1. Introduction

Blazars, including flat spectrum radio quasars and BL Lacertae objects are radio-loud active galactic nuclei (Urry & Padovani 1995), which are characterized by rapid and violent variability behaviour across different frequencies and high degree of polarization. The broad band non-thermal electromagnetic radiation can be well interpreted by the relativistic jet oriented close to the line-of-sight (Blandford & Rees 1978). But the radiation process of blazars is still an open question. Researching the relationship of variability behaviours between different bands by simultaneous multi-wavelength observations sheds light on the radiation process of the jet. On the other hand, simultaneous multi-frequency observations put constraints on different SED models helping us to understand the structure of the jet and the emission process of relativistic particles which are thought to be close to the centre of the black hole.

The S5 0716+714 (hereafter 0716) is a typical blazar which is a famous intra-day variability source in the radio and optical bands. Rapid X-ray flux variability and the doubling timescale ∼7000 s have been observed (Cappi *et al*. 1994). It is a strong γ-ray source since EGRET era and a flux increment by a factor of a least four has been detected within three days by AGILE (Lin *et al*. 1995; Chen *et al*. 2008). A VHE γ-ray excess has been detected by MAGIC, which makes 0716 one of the TeV detected LBLs (Anderhub *et al*. 2009). The redshift of 0716 is uncertain because of its figureless optical spectrum and $z \approx 0.3$ is used (Nilsson *et al*. 2008; Danforth *et al*. 2013).

2. Observations and data reduction

The whole data consists of the Fermi/LAT γ-ray data, RXTE/PCA and Swift/XRT X-ray data, the optical flux and polarization data and 14.5, 8 and 4.8 GHz radio data. The energy range of LAT data is from 0.1−300 GeV and time range is from 2008 August 4–2011 November 22. The standard LAT data analysis thread was followed. We used the unbinned likelihood algorithm implemented in the `gtlike` task to extract the flux and spectra of the source with the spectral model of `LogParabola`. The PCA data were analysed between 2009 February 7 and 2010 December 28 with the standard 2 data from all layers of PCU2. We applied the power-law model to fit the PCA spectra over the energy range of 2.6–50.0 KeV. Optical/NIR data mainly contains three parts: optical multi-band photometry observations by 2.4-m telescope and 1.02-m telescope of YNAO; the polarimetry and photometry observations of the V band from Steward Observatory (Smith *et al*. 2009); the published optical V and NIR J & K bands photometry and V band polarimetry data (Ikejiri *et al*. 2011). Besides these, optical photometry data were collected by several authors (Poon *et al*. 2009; Chandra *et al*. 2011). The radio data were observed from the 26-m paraboloid of University of Michigan Radio Astronomy Observatory (Aller *et al*. 1999). Multi-wavelength light curves are shown in Fig. 1. The ten days bin light curves of the γ-ray and X-ray are used.

3. Results and discussion

The multi-wavelength fluxes and optical polarimetry all perform intensity variabilities. The hard X-ray/14.5 GHz and V band/γ-ray variations exhibit strong correlation and zero-lag. It could be well explained that the X-ray/14.5 GHz emissions are from the synchrotron emission by low energy electrons, and the γ-ray/optical emissions

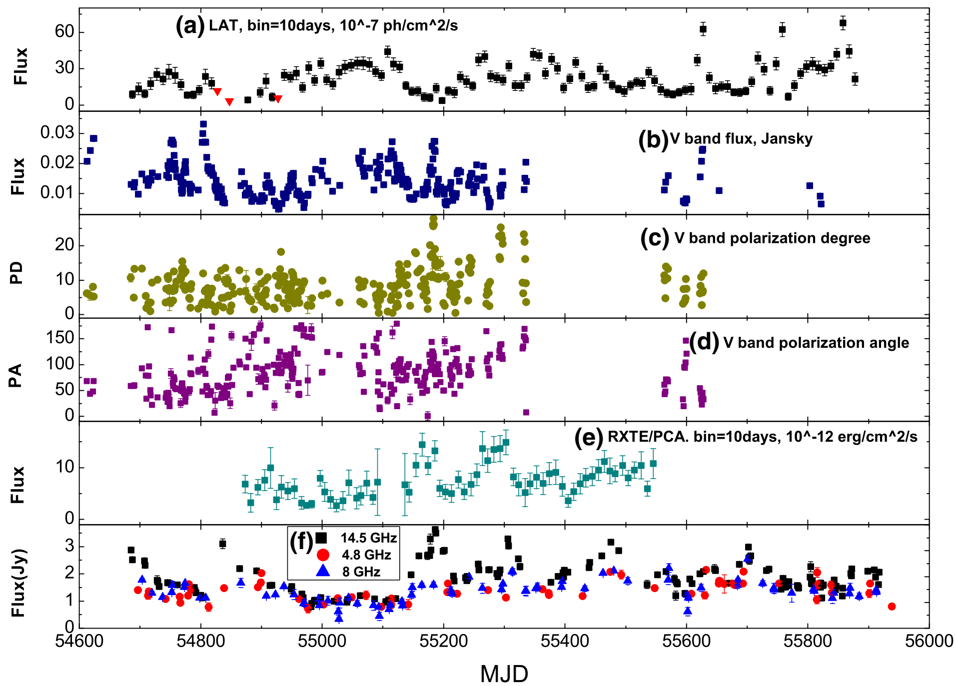

Figure 1. Multi-wavelength light curves are shown. The red triangles in the top panel correspond to the data points with TS < 25.

originate from the inverse Compton scattering by high energy electrons. The fractional variability amplitude increases from radio to optical/NIR, decreases to X-rays, and then increases to the γ-ray band. It could be explained that the variability amplitude may be proportional to the energy of the electrons. The characteristic variability timescales of 0716 at 14.5 GHz, V, X-ray, and γ-ray bands are comparable to each other, which indicates that these emission variations likely have the same origin. All the variability behaviours are in line with the classic leptonic model.

The classic homogeneous one zone synchrotron + IC model is used to fit SEDs of 0716. The average SED containing 40 months average γ-ray spectrum which extends to almost 100 GeV, is used to distinguish different radiation models. Pure SSC is likely ruled out because of the extreme input parameters. SSC + ERC of which the external photons are from the hot dust or the Lyα-line emissions could be more reasonable than the pure SSC model. The luminosity of the assumed external emissions are lower than the non-thermal luminosity from the jet. The $\gamma\gamma$ absorption caused by the external emissions are negligible. The external photons are necessary to explain the γ-ray emission for other LBLs (e.g., Abdo *et al.* 2011). Both SSC and EC processes may be indispensable for explaining γ-ray emission for LBLs.

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