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Study of 23 day periodicity of Blazar Mkn501 in 1997

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Abstract

We confirm a 23 day periodicity during a large flare in 1997 for X-ray data of X-ray satellite RXTE all sky monitor (ASM), 2 TeV gamma ray data from Utah Seven Telescope and HEGRA, with a Fourier analysis. We found the three results to be the same with a newly estimated error. We confirm the presence of a frequency dependent power ($1/f$ noise) in a frequency–power diagram. Further, we calculated a chance probability of the occurrence of the 23 day periodicity by considering the $1/f$ noise and obtained a chance probability 4.88×10^{-3} for the HEGRA data: this is more significant than the previous result by an order. We also obtained an indentical periodicity with another kind of timing analysis–epoch folding method for the ASM data and HEGRA data. We strongly suggest an existence of the periodicity. We divided the HEGRA data into two data sets, analyzed them with a Fourier method, and found an unstableness of the periodicity with a 3.4 sigma significance. We also analyzed an energy spectra of the X-ray data of a RXTE proportional counter array and we found that a combination of three physical parameters—a magnetic field, a Lorentz factor, and a beaming factor—is related to the periodicity.

Keywords: Blazar; Periodicity; X-ray; TeV gamma ray; Thermal instability

1. Introduction

Gamma ray emission from active galactic nuclei (AGN) has been measured by detectors in an orbit and by detectors on the ground. The EGRET [1] detector on the gamma ray satellite *CGRO* was sensitive to GeV gamma rays and detected 90 Blazars (e.g., [2]). Air Cherenkov detectors on the ground are sensitive to TeV energies. They detected the ten Blazars—Mkn421 ($z = 0.030$), Mkn501 ($z = 0.034$), PKS2155−304 ($z = 0.116$), 1ES1959+650 ($z = 0.048$), 1ES2344+514 ($z = 0.044$), H1426+428 ($z = 0.129$), PKS2005−489 ($z = 0.071$), H2356−309 ($z = 0.165$), 1ES1218+304 ($z = 0.182$) and 1ES1101−232 ($z = 0.186$). The energy spectra of Blazars has two components. One component extends from the radio to the X-ray band, while the other is in the gamma ray range. Low energy photons are interpreted to be a result of synchrotron emission by accelerated high energy electrons, and high energy photons are interpreted to be resulted of inverse Compton scattering of the synchrotron emission by high energy electrons. There are two types of Blazars, the BL Lac type and the QSO type. The BL Lac is of two types: high frequency BL Lac (HBL) and low frequency BL Lac (LBL), where the names correspond to the peak frequency of the synchrotron emission. The peak frequency of the synchrotron emission and that of the inverse Compton emission occur in the radio band and X-ray band for LBL and in the X-ray band and TeV band for HBL.

The TeV gamma ray flux of HBLs Mkn421 and Mkn501 are usually lower than that of the Crab nebula. In 1997, the flux of Mkn501 increased up to 10 Crab over 3 months. Two Cherenkov detectors—Utah Seven Telescope (Utah TA) and HEGRA—and X-ray satellite RXTE all sky monitor (ASM) observed Mkn501 simultaneously during this flare. Hayashida et al. [3] studied the Utah TA data during

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this flare with a Fourier analysis and suggested two periodicities—13 day and 23 day. Kranich [4] studied both the HEGRA and ASM data during this flare with a Fourier analysis and obtained a 22.5 day periodicity with a chance probability of 0.028 for the HEGRA data and a 22.5 day periodicity with a chance probability of 0.047 for the ASM data. These results weakly suggest the 23 day periodicity. There is some problem in these results. The frequency–power diagram shows frequency dependent power ($1/f$ noise). This $1/f$ noise in the frequency–power diagram is well known in AGN and a Blackhole candidate binary in X-ray band. The origin of the noise is unknown. Hayashida et al. [3] do not consider an effect of the $1/f$ noise on both a significance and an error of the periodicity. Kranich [4] does not consider an effect of the $1/f$ noise on an error of the periodicity, but he considers an effect of the $1/f$ noise on a significance of the periodicity. However, he uses an unreliable model of the $1/f$ noise for deducing a chance probability. He fitted a raw power spectra to obtain a model of the $1/f$ noise without discussing model reliability. With Poisson statistics, the power in a raw power spectra has a 100% error because it follows a χ^2 distribution of 2 degrees of freedom. In the case of Poisson statistics and the $1/f$ noise, this error is less than 100%: however, power still has a large error.

In this study, we study these three data sets with a Fourier analysis and also use another kind of a timing analysis in order to increase the reliability of the periodicity. We binned a raw power spectra in order to obtain a power spectra that is statistically reasonable, obtain the best model of the $1/f$ noise, and estimate a chance probability by considering the reliability of the $1/f$ noise model. We obtain a lower chance probability than Kranich [4] by an order. We obtain an error of the periodicity by considering an effect of the $1/f$ noise and found that the three results are same with a newly estimated error. We study the stability of the periodicity and analyze an energy spectra of the X-ray satellite RXTE proportional counter array (PCA) during this flare, in order to set a limit on an origin of the periodicity.

2. Data

2.1. Timing analysis

We obtained the HEGRA data [4] in 1997 as a form of (a MJD, flux, an error of flux). There are four kinds of data—CT1 (no moon), CT1(moon), CT2, and CTsys corresponding to different data acquisition conditions or detectors. We use summed data for a timing analysis and show a lightcurve of the HEGRA data in MJD 50,545–50,661 in Fig. 1. We obtained the Utah TA data [3] in 1997 as the form of (a MJD, flux, an error of flux) for a timing analysis and show a lightcurve of the Utah TA data in Fig. 2. We obtained the ASM data of a 90 s dwell in the form of (a MJD, a rate, an error of a rate) for a timing analysis. The error of a rate for the ASM data includes a systematic error of 3% derived using a lightcurve of Crab. We show a lightcurve of the ASM data from 1996 to 2000 in Fig. 3. We use a span MJD 50,545–50,661 for both the HEGRA and ASM data, which is the same as in Kranich [4]. Further we use a span MJD 50,520–50,665 for the Utah TA data. We show a lightcurve of the ASM data in MJD 50,545–50,661 in Fig. 4. We also use a span MJD 50,300–50,900 for the ASM data because the ASM data is plentiful and we require more than 10 cycles for increasing a reliability of a periodicity.

2.2. Spectral analysis

We obtain the PCA raw data—standard 2 data that is suitable for an energy spectral analysis—and use a span MJD 50,300–50,900. We use only the data of the top layer in the PCA, which has a low background. Using a standard tool FTOOLS 4.2, we selected the data with normal conditions—an elevation greater than 10°, neglecting time of the

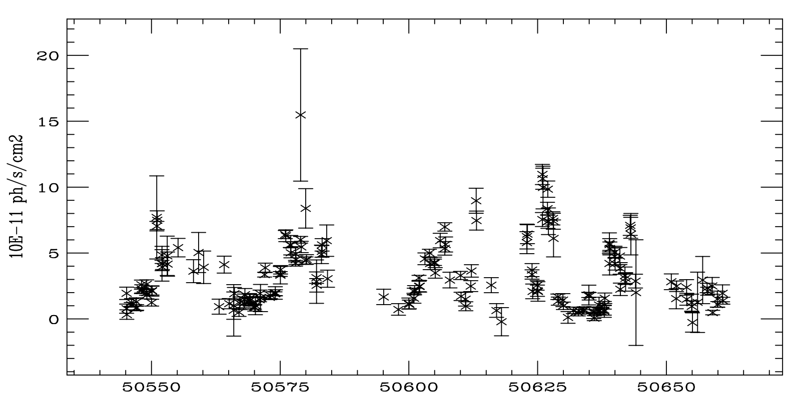

Fig. 1. A lightcurve of HEGRA data in MJD 50,545–50,661.