Bull. Astr. Soc. India (2000) **28**, 409-411

Coordinated TeV gamma-ray and optical polarization study of BL Lac object Mkn 501

U.C. Joshi, K.S. Baliyan, S. Ganesh, M.R. Deshpande

Physical Research Laboratory, Ahmedabad 380 009, India

S. Bhattacharyya, R.K. Kaul, C.L. Kaul, C.L. Bhat

Bhabha Atomic Research Centre, Nuclear Research Laboratory, Trombay, Mumbai 400 085, India

Abstract. Coordinated TeV gamma-ray and optical polarization observations of the BL Lac object Mkn 501, carried out during 1997 with the TACTIC imaging Cerenkov telescope of the BARC and the 1.2 m Gurushikhar optical/IR telescope at Mt. Abu, have revealed a significant increase in the degree of polarization of the optical radiation in association with a Tev gamma-ray flare. The observations indicate a possible leptonic origin of the TeV gamma-ray signal as against a hadronic origin proposed in some models.

Key words : active galactic nuclei, Mkn 501, TeV γ–ray emission, polarized optical emission, coordinated observations

1. Introduction

Mkn 501 is a BL Lac type active galactic nucleus located at a redshift of z=0.0337 (Urich et al, 1975) which has been identified with the radio source B2 1652+39 in the second Bologna survey (Colla et al, 1972) and the X-ray source 4U 1651 + 39 (Schwartz et al, 1978). It was first discovered as a VHE gamma-ray source by the Whipple system (Quinn et al, 1996) and was subsequently detected by the HEGRA system above 1.5 TeV (Bradbury et al, 1997). The imaging element of the TACTIC array successfully captured Mkn 501 in a high activity state during its first observational run in March 1997 when it detected a number of flaring episodes during April - May, 1997 (Bhat et al, 1997). A large number of successful VHE detections of Mkn 501 were also reported at the 25th ICRC (Protheroe et al, 1997 and references therein) including the first-ever near simultaneous observation of a TeV gamma-ray flare from an extragalactic object by a global network of Cerenkov telescopes (Bhat, 1997). In the present communication, we describe the results of time-coordinated optical polarimetry and TeV gamma-ray observations of this source carried out from Mt. Abu in April - May, 1997.

2. Instrumental details

The TeV gamma-ray observations were carried out with the recently-commissioned Imaging Element (IE) of the TACTIC Cerenkov telescope array. The IE essentially comprises a $9.5m^2$ quasi-paraboloid light collector equipped with an 81-pixel (9 x 9) Cerenkov Light Imaging Camera (CLiC), providing a field of view of ~ 2.8^0 with a pixel resolution of 0.31^o. The detailed description of the TACTIC imaging element alongwith the observational methodology and data reduction and analysis technique is available elsewhere (Bhat et al, 1997). The imaging element was deployed for observations on Mkn 501 for 47.9 h during clear, moonless nights in April - May, 1997.

Polarization measurements have been carried out with an optical polarimeter coupled to the Gurushikhar 1.2 m optical/IR telescope. A detailed description of the optical polarimeter is available elsewhere (Deshpande et al, 1985). The present observations were carried out in white light to maximize the signal. Mkn 501 was observed on three nights during April - May, 1997.

3. Results and Discussion

Fig.1 shows the TeV gamma-ray light curve of Mkn 501 for the period April 9 - May 30, 1997, obtained from the TACTIC observations (Bhat et al, 1997). Also shown are the three measurements (filled circles) of the degree of optical polarization during this period, obtained from the Gurushikhar optical/IR telescope observations. The TeV gamma-ray rate is found to vary appreciably on a day-to-day basis with source-related emission peaks on April 13, 16, 17

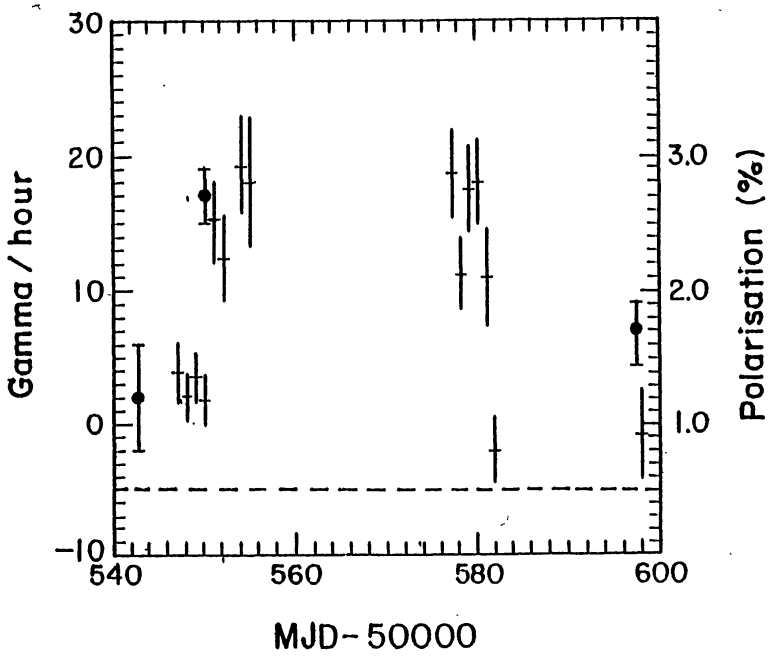

Figure 1. TeV light curve of Mkn 501 during April - May, 1997, derived from the TACTIC observations. The three measurements of the degree of polarized optical emission, derived from the Gurushikhar optical/IR telescope observations, are shown by the filled circles.

and May 16, 1997 and leads to a time-averaged flux of ~ (8.0 ± 0.5) χ 10^{-12} photons cm^{-2} s^{-1} above 2 TeV energy. Some morphological similarity is apparent between the TeV light curve and the optical polarization measurements, with the degree of polarization attaining a peak value of ~ 3% close to the beginning of the first TeV gamma-ray flare on April 16, 1997, as compared to a value of ~ 1.5% on either side of the flare. Although the paucity of the optical polarimetry data does not allow us to draw any firm conclusions, the broad similarity in the time variability of the TeV gamma-ray flux and the degree of optical polarization suggests that the emission in the two energy bands may have a common origin. As the only plausible origin for the enhanced optically polarized radiation is through synchrotron radiation from energetic electrons, the morphological similarity between the polarized optical emission and the TeV gamma-ray light curve is indicative of a leptonic origin for the high energy gamma-rays. It is likely that, while the polarized optical radiation is produced by energetic electrons through the sychrotron process, the TeV gamma-rays result from the inverse Compton upscattering of these photons by the parent electrons. Synchrotron photons of frequency ν_s are produced by electrons of Lorentz factor γ, gyrating in a magnetic field of intensity B, such that

$$\nu_s = \frac{4}{3}\,\gamma^2\left(\frac{eB}{2\pi mc}\right) \tag{1}$$

The electron cooling times is inversely proportional to the square of the magnetic field intensity.

$$t_s = \frac{6\pi mc^2}{\sigma_T c\,\gamma B^2} \tag{2}$$

where σ_T is the Thompson scattering cross-section. The correlated TeV gamma-ray and polarized optical emission can be accounted for in terms of an energetic electron population in a region of low B (slow cooling). The present observations, therefore, indicate a leptonic origin of the TeV gamma-rays in a region away from the central regions of the jet, as against a possible hadronic origin proposed in some models of AGN's, because of the difficulty in accounting for the polarized optical emission from hardonic progenitors.

References

Bhat C.L., et al, 1997, Proc. Towards a Major Atmospheric Cerenkov Detector-V, Kruger Park, South Africa, 196.

Bradbury S.M., et al, 1997, A & A, 320, L5.

Bhat C.L., 1997, 25th ICRC, Durban (Rapporteur Talk), 8, 211

Colla G., et al, 1972, A & AS, 7, 1.

Deshpande M.R., et al, 1985, BASI, 13, 157.

Protheroe R.J. et al, 1997, Proc. 25th ICRC, Highlight Session.

Quinn J., et al, 1996, ApJ, 456, L83.

Schwartz D.A., et al, 1978, ApJ, 224, L103.

Ulrich M.H., et al, 1975, ApJ, 198, 261.