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Markarian 421: TeV Gamma-ray Flares and VLBI Structure

P. G. Edwards, G. A. Moellenbrock
ISAS, 3-1-1 Yoshinodai, Sagamihara, Kanagawa 229, Japan

S. C. Unwin
Jet Propulsion Laboratory, MS 301-370, Pasadena, CA 91109-8099, USA

A. E. Wehrle
IPAC/JPL/Caltech, Pasadena, USA

T. C. Weekes
Harvard-Smithsonian CfA, Amado, AZ 85645-0097, USA

Abstract. Photons spanning over 17 decades in energy have been detected from Markarian 421. The discovery of >100 MeV photons by the EGRET instrument on board the Compton Gamma Ray Observatory led to the discovery of >300 GeV photons by the Whipple group using the air Čerenkov method. In May 1996 the source underwent an unprecedented outburst at these energies, inspiring observations with the VLBA to determine whether such high energy flares are associated with changes in the milliarcsecond structure of this BL Lac object.

1. Introduction

As the closest BL Lac object ($z = 0.0308$), Mrk 421 lends itself to detailed study of its sub-parsec scale structure with VLBI imaging, with a linear scale of $0.44\,h$ pc/milliarcsec. In the radio it has a flat-spectrum core ($S_{22} \approx 0.5$ Jy), a milliarcsecond-scale jet, and very faint extended emission out to about 50 kpc (Xu et al. 1995). Among the first images produced by the completed VLBA were images at 15 and 43 GHz, which showed the nucleus to be unresolved, with a size $< 0.06\,h$ pc (Unwin et al. in preparation). A series of four EVN observations between 1980.4 and 1983.4 led to the suggestion that the source displayed superluminal motion, with two components having motions of $\sim 1.4h^{-1}\,c$ and $\sim 1.9h^{-1}\,c$ (Zhang & Bååth 1990).

Markarian 421 was the first extragalactic source detected in $>$ 300 GeV gamma rays (Punch et al. 1991)—and remains one of only a handful of known extragalactic sources at these high energies. During a May 1994 flare, the >250 GeV flux increased by almost an order of magnitude over a two day period. Contemporaneous ASCA data revealed that Mrk 421 was in a very high X-ray state, but simultaneous EGRET data showed only a slight increase (Macomb et al. 1995). A natural interpretation for this in terms of the synchrotron self-Compton (SSC) model is made by Macomb et al., in which the flares are produced by an increase in the upper energy cut-off to the relativistic electron distribution. Such an increase would cause a synchrotron flare to occur at X-ray energies, and inverse Compton scattering from these electrons produces the very high energy gamma rays.

An extraordinary outburst of >300 GeV gamma-ray activity was detected in May 1996. In two hours of observations on 7 May 1996 the gamma ray event rate increased by a factor of 30. On 15 May a flare to, and fall from, a rate five times the quiescent level was observed in less that an hour, constraining the emission region size to $1 < R < 10$ light hours (Gaidos et al. 1996).

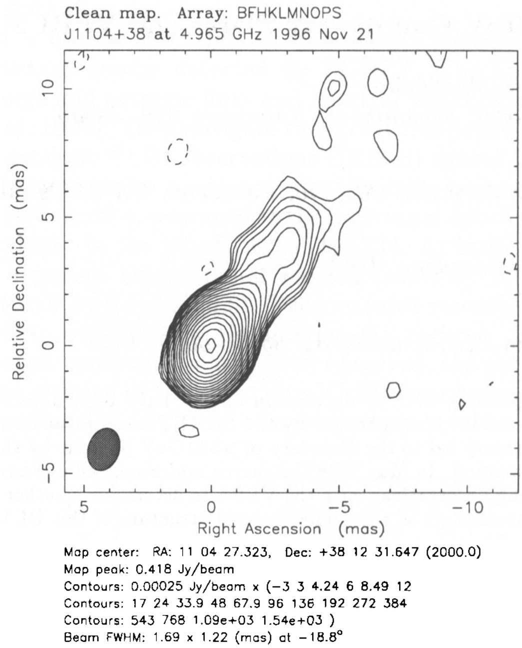

Figure 1. Image from ~7 hours data of the inner regions of Mrk 421.

We have used the VLBA to make follow-up observations at 5 and 22 GHz in November 1996 to investigate whether the May 1996 gamma ray activity is associated with changes in the VLBI structure. Scans of 22 minutes duration at the two frequencies were interleaved to obtain full (u, v)-plane coverage. Our 5 GHz image of the core region, made with the long baseline data weighted more highly than natural weighting, is shown in Figure 1. Model-fitting of the image reveals a compact core (410 mJy) with a secondary point-like feature (38 mJy) at a distance of ~1.2 mas at a PA of −39°, with other extended features further out. Data from a second epoch in May 1997 will provide an indication of the motion of this apparently new component.

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