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Multiband variability studies and novel broadband SED modeling of Mrk 501 in 2009

Ahnen M., Ansoldi S., Antonelli L., Antoranz P., Babic A., Banerjee B., Bangale P., Barres De Almeida U., Barrio J., Becerra González J., Bednarek W., Bernardini E., Berti A., Biasuzzi B., Biland A., Blanch O., Bonnefoy S., Bonnoli G., Borracci F., Bretz T., Buson S., Carosi A., Chatterjee A., Clavero R., Colin P., Colombo E., Contreras J., Cortina J., Covino S., Da Vela P., Dazzi F., De Angelis A., De Lotto B., De Oña Wilhelmi E., Di Pierro F., Doert M., Domínguez A., Dominis Prester D., Dorner D., Doro M., Einecke S., Eisenacher Glawion D., Elsaesser D., Engelkemeier M., Fallah Ramazani V., Fernández-Barral A., Fidalgo D., Fonseca M., Font L., Frantzen K., Fruck C., Galindo D., García López R., Garczarczyk M., Garrido Terrats D., Gaug M., Giammaria P., Godinović N., González Muñoz A., Gora D., Guberman D., Hadasch D., Hahn A., Hanabata Y., Hayashida M., Herrera J., Hose J., Hrupec D., Hughes G., Idec W., Kodani K., Konno Y., Kubo H., Kushida J., La Barbera A., Lelas D., Lindfors E., Lombardi S., Longo F., López M., López-Coto R., Majumdar P., Makariev M., Mallot K., Maneva G., Manganaro M., Mannheim K., Maraschi L., Marcote B., Mariotti M., Martínez M., Mazin D.
Kazan Federal University, 420008, Kremlevskaya 18, Kazan, Russia

Abstract

© 2017 ESO. Context. We present an extensive study of the BL Lac object Mrk 501 based on a data set collected during the multi-instrument campaign spanning from 2009 March 15 to 2009 August 1, which includes, among other instruments, MAGIC, VERITAS, Whipple 10 m, and Fermi-LAT to cover the γ-ray range from 0.1 GeV to 20 TeV; RXTE and Swift to cover wavelengths from UV tohard X-rays; and GASP-WEBT, which provides coverage of radio and optical wavelengths. Optical polarization measurements were provided for a fraction of the campaign by the Steward and St. Petersburg observatories. We evaluate the variability of the source and interband correlations, the γ-ray flaring activity occurring in May 2009, and interpret the results within two synchrotron self-Compton (SSC) scenarios. Aims. The multiband variability observed during the full campaign is addressed in terms of the fractional variability, and the possible correlations are studied by calculating the discrete correlation function for each pair of energy bands where the significance was evaluated with dedicated Monte Carlo simulations. The space of SSC model parameters is probed following a dedicated grid-scan strategy, allowing for a wide range of models to be tested and offering a study of the degeneracy of model-to-data agreement in the individual model parameters, hence providing a less biased interpretation than the "single-curve SSC model adjustment" typically reported in the literature. Methods. We find an increase in the fractional variability with energy, while no significant interband correlations of flux changes are found on the basis of the acquired data set. The SSC model grid-scan shows that the flaring activity around May 22 cannot be modeled adequately with a one-zone SSC scenario (using an electron energy distribution with two breaks), while it can be suitably described within a two (independent) zone SSC scenario. Here, one zone is responsible for the quiescent emission from the averaged 4.5-month observing period, while the other one, which is spatially separated from the first, dominates the flaring emission occurring at X-rays and very-high-energy (> 100 GeV, VHE) γ rays. The flaring activity from May 1, which coincides with a rotation of the electric

vector polarization angle (EVPA), cannot be satisfactorily reproduced by either a one-zone or a two-independent-zone SSC model, yet this is partially affected by the lack of strictly simultaneous observations and the presence of large flux changes on sub-hour timescales (detected at VHE γ rays). Results. The higher variability in the VHE emission and lack of correlation with the X-ray emission indicate that, at least during the 4.5-month observing campaign in 2009, the highest energy (and most variable) electrons that are responsible for the VHE γ rays do not make a dominant contribution to the ~1 keV emission. Alternatively, there could be a very variable component contributing to the VHE γ-ray emission in addition to that coming from the SSC scenario. The studies with our dedicated SSC grid-scan show that there is some degeneracy in both the one-zone and the two-zone SSC scenarios probed, with several combinations of model parameters yielding a similar model-to-data agreement, and some parameters better constrained than others. The observed γ-ray flaring activity, with the EVPA rotation coincident with the first γ-ray flare, resembles those reported previously for low frequency peaked blazars, hence suggesting that there are many similarities in the flaring mechanisms of blazars with different jet properties.

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Keywords

BL Lacertae objects: individual: Markarian 501, Methods: data analysis

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