

## Extreme HBL behavior of Markarian 501 during 2012

Ahnen M., Ansoldi S., Antonelli L., Arcaro C., Babić A., Banerjee B., Bangale P., Barresde Almeida U., Barrio J., Becerragonzález J., Bednarek W., Bernardini E., Berti A., Bhattacharyya W., Blanch O., Bonnoli G., Carosi R., Carosi A., Chatterjee A., Colak S., Colin P., Colombo E., Contreras J., Cortina J., Covino S., Cumani P., Da Vela P., Dazzi F., De Angelis A., De Lotto B., Delfino M., Delgado J., Di Ierro F., Doert M., Domínguez A., Dominis Prester D., Doro M., Eisenacher Lawion D., Engelkemeier M., Fallah Ramazani V., Fernández-Barral A., Fidalgo D., Fonseca M., Font L., Fruck C., Galindo D., García López R., Garczarczyk M., Gaug M., Giammaria P., Godinović N., Gora D., Guberman D., Hadasch D., Hahn A., Hassan T., Hayashida M., Herrera J., Hose J., Hrupec D., Ishio K., Konno Y., Kubo H., Kushida J., Kuve Dić D., Lelas D., Lindfors E., Lombardi S., Longo F., López M., Maggio C., Majumdar P., Makariev M., Maneva G., Manganaro M., Maraschi L., Mariotti M., Martínez M., Mazin D., Menzel U., Minev M., Miranda J., Mirzoyan R., Moralejo A., Moreno V., Moretti E., Nagayoshi T., Neustroev V., Niedzwiecki A., Nievas Rosillo M., Nigro C., Nilsson K., Ninci D., Nishijima K.

*Kazan Federal University, 420008, Kremlevskaya 18, Kazan, Russia*

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### Abstract

© ESO 2018. Aims. We aim to characterize the multiwavelength emission from Markarian 501 (Mrk 501), quantify the energy-dependent variability, study the potential multiband correlations, and describe the temporal evolution of the broadband emission within leptonic theoretical scenarios. Methods. We organized a multiwavelength campaign to take place between March and July of 2012. Excellent temporal coverage was obtained with more than 25 instruments, including the MAGIC, FACT and VERITAS Cherenkov telescopes, the instruments on board the Swift and Fermi spacecraft, and the telescopes operated by the GASP-WEBT collaboration. Results. Mrk 501 showed a very high energy (VHE) gamma-ray flux above 0.2 TeV of  $\sim 0.5$  times the Crab Nebula flux (CU) for most of the campaign. The highest activity occurred on 2012 June 9, when the VHE flux was  $\sim 3$  CU, and the peak of the high-energy spectral component was found to be at  $\sim 2$  TeV. Both the X-ray and VHE gamma-ray spectral slopes were measured to be extremely hard, with spectral indices  $< 2$  during most of the observing campaign, regardless of the X-ray and VHE flux. This study reports the hardest Mrk 501 VHE spectra measured to date. The fractional variability was found to increase with energy, with the highest variability occurring at VHE. Using the complete data set, we found correlation between the X-ray and VHE bands; however, if the June 9 flare is excluded, the correlation disappears (significance  $< 3\sigma$ ) despite the existence of substantial variability in the X-ray and VHE bands throughout the campaign. Conclusions. The unprecedentedly hard X-ray and VHE spectra measured imply that their low- and high-energy components peaked above 5 keV and 0.5 TeV, respectively, during a large fraction of the observing campaign, and hence that Mrk 501 behaved like an extreme high-frequency-peaked blazar (EHBL) throughout the 2012 observing season. This suggests that being an EHBL may not be a permanent characteristic of a blazar, but rather a state which may change over time. The data set acquired shows that the broadband spectral energy distribution (SED) of Mrk 501, and its transient evolution, is very complex, requiring, within the framework of synchrotron self-Compton (SSC) models, various emission regions for a satisfactory description.

Nevertheless the one-zone SSC scenario can successfully describe the segments of the SED where most energy is emitted, with a significant correlation between the electron energy density and the VHE gamma-ray activity, suggesting that most of the variability may be explained by the injection of high-energy electrons. The one-zone SSC scenario used reproduces the behavior seen between the measured X-ray and VHE gamma-ray fluxes, and predicts that the correlation becomes stronger with increasing energy of the X-rays.

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## Keywords

Acceleration of particles, Astroparticle physics, BL Lacertae objects: general, BL Lacertae objects: individual: Mrk501, Radiation mechanisms: non-thermal

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