MAGIC observation of BL Lacertae flaring period in 2020

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ABSTRACT

The MAGIC (Major Atmospheric Gamma-ray Imaging Cherenkov) telescopes observed BL Lacertae (BL Lac) during this flaring period together with multi-wavelength (MWL) instruments from August to October 2020. In the VHE (very-high-energy, E > 100 GeV) gamma-ray range, BL Lac was detected in several nights during an especially bright period in HE range. In the long-term light curves, X-ray and HE gamma-ray flux overall show correlation, but sometimes only HE gamma-ray was bright. These MWL correlations may relate to the emission mechanisms and the origin of the observed flaring activity. In this contribution we will show the preliminary results on the MWL campaign of BL Lac in September 2020, with a focus on the X-ray and gamma-ray activity, based on the data collected by MAGIC, Fermi-LAT, and Swift-XRT telescopes.

Introduction

Target: BL Lacertae (BL Lac)
- Redshift $z \sim 0.069$ [1]
- Low energy peaked BL Lac object [2]
- TeV flares detected also in the past [3], [4]
- Historical outbursts seen in optical and GeV bands in Aug 2020.

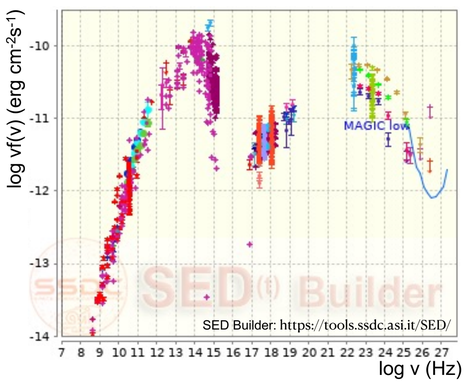

Fig.1: Spectral Energy Distribution (SED) of BL Lac from archival data. The MAGIC sensitivity plot as blue solid line.

Observation

MAGIC is a system of two 17-m diameter Imaging Atmospheric Cherenkov Telescopes (IACT) located in the Canary island of La Palma, Spain. They are operated in an energy range from ~ 50 GeV to tens of TeV. MAGIC telescopes observed BL Lac in 2020 based on ToO campaign and it detected a flare in the TeV range. We analyzed a dataset obtained from August to October 2020.

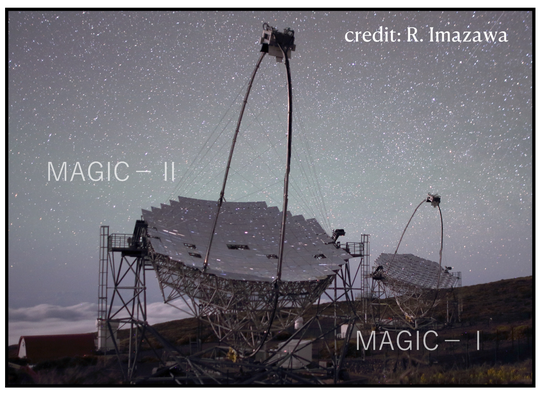

Fig.2: The picture of MAGIC telescopes.

Fermi-LAT is a GeV gamma-ray detector which has an energy range 100 MeV~500 GeV. It has a wide field of view of ~3 degrees, and thus it can observe daily flux variations and thus It can take daily flux variations. We used archival data from Light Curve Repository.

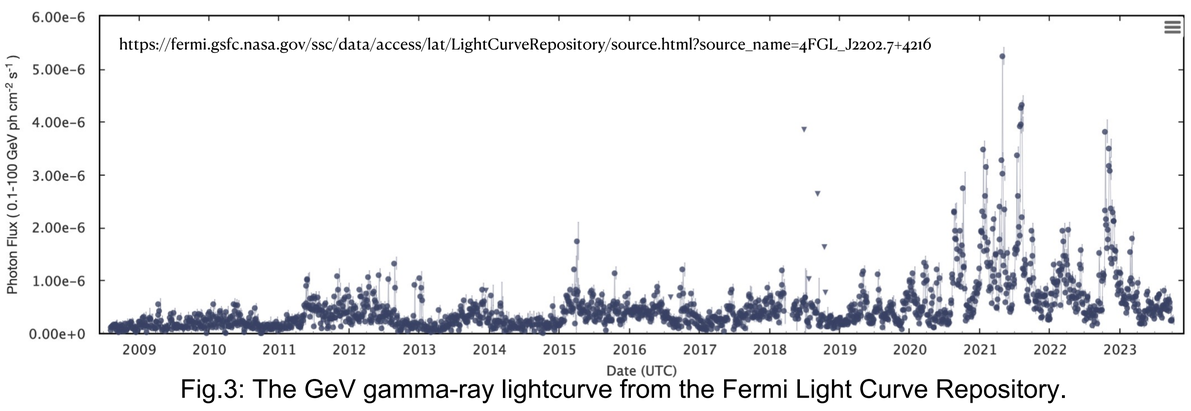

Fig.3: The GeV gamma-ray lightcurve from the Fermi Light Curve Repository.

Swift-XRT is an X-ray instrument, and it was also observing BL Lac during the MAGIC observation period. We analyzed it by `XRTPIPELINE` using `HEADAS 6.28` software with spectral analysis procedure as below.

model: Galactic absorption*power law; `wabs*pegpwrlw`
fixed parameters
nH: 0.344×10^{22} cm-2, min. energy: 0.2 keV, max. energy: 10.0 keV
free parameters
photon index, normalization

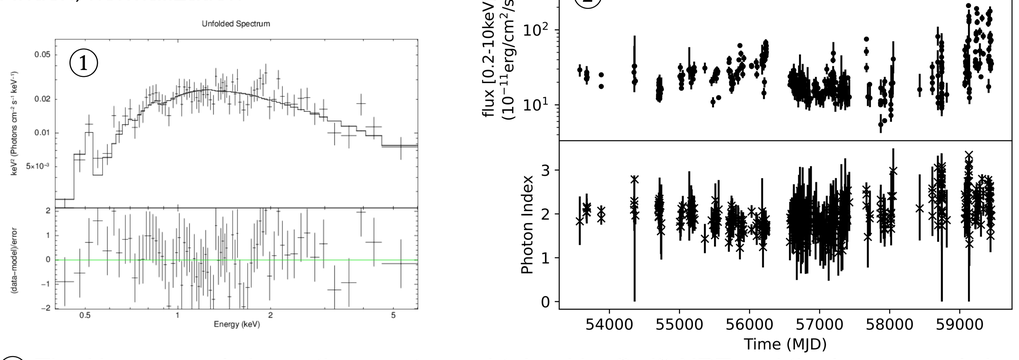

Fig.4: ① The Upper panel shows the spectrum obtained by Swift-XRT and the lower panel shows chi-squared value from the fitting. ② The obtained flux (upper) and photon index (lower) variations.

Results

We obtained the MWL light curve of BL Lac from August to October 2020. In the VHE gamma-ray band, it was detected significantly (> 5σ) in four nights and **a large TeV flare was seen** in September 2020. The HE gamma-ray flux also reached a high state on this day, but the X-ray showed no flare.

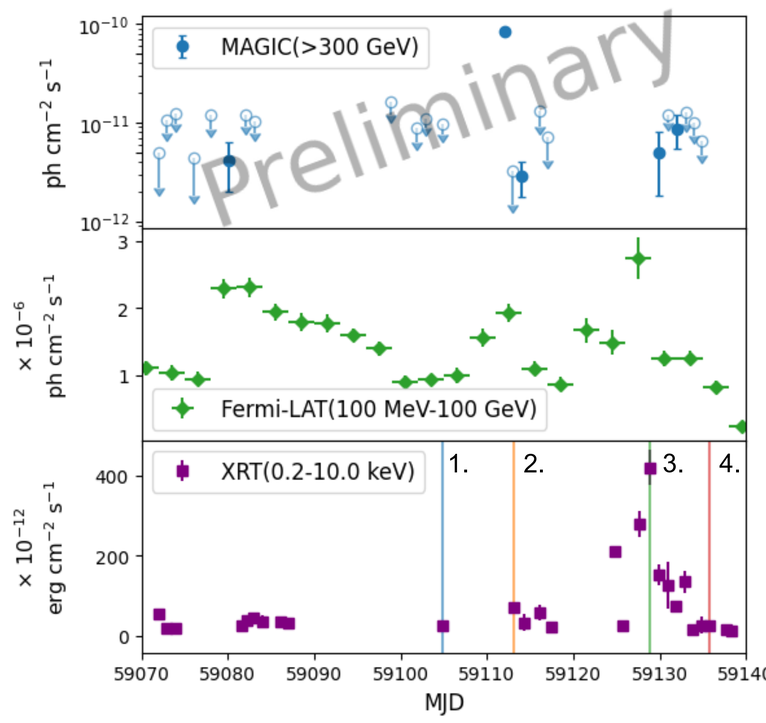

Fig.5: Multi-wavelength light curves of BL Lac in the time range from MJD 59070 (2020 August 9th) to 59140 (2020 October 18th). From top to bottom panels: MAGIC, Fermi-LAT, and Swift-XRT. The Fermi-LAT data are obtained from the public NASA repository (Fermi Light Curve Repository). The vertical solid line in the bottom panel mark the period reported in fig. 6.

The X-ray spectrum showed different shapes within one month. The X-ray and HE gamma-ray flux variation showed different slope, meaning that the X-ray and HE gamma-ray flux show positive correlation, but the **X-ray-to-HE-gamma-ray flux ratio changed**; sometimes only HE gamma-ray was bright.

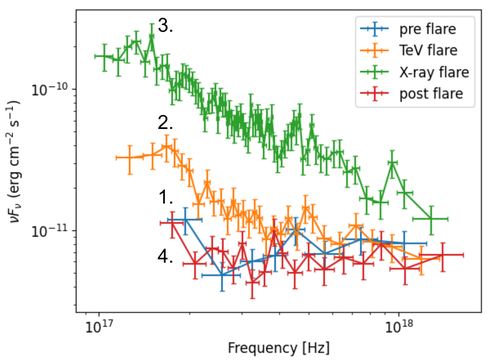

Fig.6: X-ray spectrum for each period defined in fig. 5.

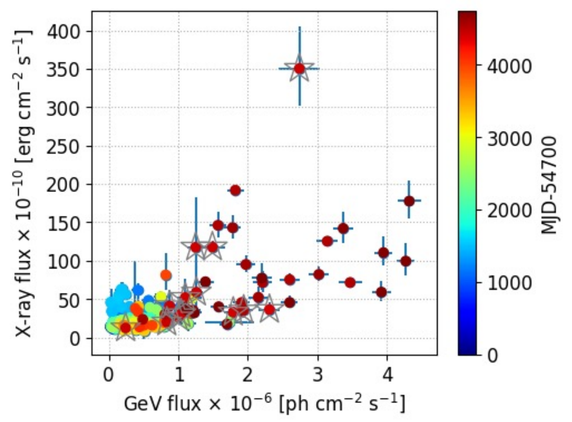

Fig.7: The variations of X-ray flux versus HE gamma-ray flux from 2008 to November 2022. The different markers show the mean value of each 3 day flux and the error bars show the standard errors. The star mark indicates the period included in the Figure 5.

Summary

MAGIC observed BL Lac as a part of a MWL campaign in 2020. As preliminary results, we show the MWL light curves from X-rays to VHE gamma-rays and the X-ray spectra. In addition, we performed correlation studies between the GeV and X-ray fluxes, implying a possible connection with these two emission regions. Our aim is to proceed to modelling the MWL SED and to further study the MWL variability.

References:
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