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# MAGIC observation of BL Lacertae flaring period in 2020

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BL Lacertae (BL Lac) is one of the low-frequency peaked BL Lac object (LBL). Since August 2020, BL Lac has shown a historically high activity in HE (high-energy, 0.1 GeV < E < 100 GeV) gamma-ray and optical bands. The MAGIC (Major Atmospheric Gamma-ray Imaging Cherenkov) telescopes performed joint observations during this flaring period with instruments operating in gamma-ray, X-ray, optical, and radio bands 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 flare simultaneous with a HE flare. 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 multi-wavelength (MWL) correlations may relate to the emission mechanisms and the origin of the observed flaring activity. In this contribution we will present some of 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 *Swift*-XRT, MAGIC and *Fermi*-LAT telescopes.

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## 1. Introduction

Blazars are active galactic nuclei (AGN) whose relativistic jets is aligned with the observer's line of sight [12]. They are characterised by intense flux variations at different wavelengths, and their emission is described by non-thermal radiation from relativistic particles accelerated in the jet. So far 84 blazars[1] have been found to emit VHE gamma-rays. When collecting simultaneous or quasi simultaneous MWL data, blazars show a broadband spectral energy distribution (SED) characterised by two peaks. In particular, the low-energy component is used to further classify blazars into subgroups. The high-energy peak can be constrained in particular when also VHE gamma-ray data are obtained: in this case, the HE gamma-ray data and the VHE gamma-ray data play an important role in the modeling of the SED and in the understanding of the broadband emission mechanism.

By studying the MWL SED and the time scales of the flux variations, we can investigate the particle acceleration mechanisms in the blazar jets. BL Lacs are divided into LBL (low-energy-peaked), IBL (intermediate-energy-peaked) and HBL (high-energy-peaked), with syncrothron peaks located at $\sim 10^{13-14}\,Hz$, $\sim 10^{15-16}\,Hz$, $\sim 10^{17-18}\,Hz$, respectively. BL Lacertae (BL Lac) is one of LSP-BL Lacs [2]. BL Lac has been a target of MWL campaigns in the past, and several flaring activities in all energy bands have been observed. In connection with the HE gamma-ray flaring activity, [10] reported a rotation of the optical polarization angle of more than 180 degrees. They suggested that it was caused by the shock acceleration and the ordered magnetic field in the jet. However, BL Lac also showed intraday VHE gamma-ray flares in 2015 [9] and 2016 [1], and in those cases a magnetic reconnection was suggested as origin of the fast variability.

On August 2020, BL Lac reached an historically bright state in optical and HE gamma-ray bands [6, 8]. VHE gamma-ray observations were performed and some flares were detected [4, 5, 7]. We have analyzed VHE gamma-ray data taken by the MAGIC telescopes from August to October 2020. and collected data from many instruments from radio up to VHE gamma-rays. Here we focus on X-ray, HE gamma-rays and VHE gamma-rays and leave the complete dataset to be described in our paper in preparation.

## 2. Observations

### 2.1 VHE gamma-rays

We performed VHE gamma-ray observation using MAGIC, which is a system of two imaging atmospheric Cherenkov telescopes located in the Canary island of La Palma, Spain. MAGIC have a low energy threshold of about 50 GeV at low zenith observations [3]. In total, 22hours of good quality data were obtained. The zenith angle is cut from 5 to 50 degrees. MAGIC data have been analyzed with standard analysis using MAGIC Analysis and Reconstruction Software (`MARS`) [14].

### 2.2 HE gamma-rays

The HE light curve was taken from the *Fermi* Light Curve Repository. We obtained the flux integrated over 3-day bins in the energy range 0.1-100 GeV. The photon index was left as a free

[1] http://tevcat.uchicago.edu/,[13]

parameter in each time bin. We find that the photon index ranged from 1.8±0.08 to 2.27±0.19 in the period showed in Figure 1.

### 2.3 X-rays

The X-ray (0.2–10.0 keV) fluxes were measured by *Swift*–XRT. We performed spectral fitting by power-law models with Galactic absorption: `wabs×pegpwrlw` and assumed a hydrogen column density of $0.344 \times 10^{22}$ cm$^{-2}$ [11]. The reprocessing was conducted by `XRTPIPELINE` using `HEADAS 6.28` and the latest calibration database (CALDB). Because of the possibility of piled-up in the center region, we analyzed in the annulus region from 7 to 40 arcsec from the center of the source. The analysis was conducted by considering the background in the 90–150 arcsec region from BL Lac. We made ancillary response files and performed the grouping of the spectrum, using `xrtmkarf` and `grppha` command.

## 3. Results

Figure 1 shows the MWL light curve of BL Lac in the MAGIC observation period, from August to October 2020 (MJD 59070–59140). In the VHE band, it was detected significantly ($> 5\sigma$) in four nights. In September 2020, a VHE flare was observed with an integral flux above 300 GeV corresponding to $\sim$ 70% of the Crab Nebula flux (=(8.39±0.31)×10$^{-11}$ ph cm$^{-2}$ s$^{-1}$). The HE gamma-ray flux also reached a high state on this day, but the X-ray showed no flare. This behaviour is similar to that of [9]. We plot a scatter plot of the X-ray and HE gamma-ray flux in figure 2. Here we can see 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.

## 4. Summary

The MAGIC telescopes observed a VHE gamma-ray flare from BL Lac in September 2020. The MWL observations showed that the HE gamma-ray flux was increased corresponding to the VHE flare, but the X-ray flux did not show a flux increase simultaneously to the gamma-ray flare. The change of the X-ray vs. HE gamma-ray ratio may be explained by different emission scenarios. More detailed analysis, such as SED fitting and shorter timescale analysis, is needed to discuss in detail the broadband emission machanism, and it will be reported in a future paper.

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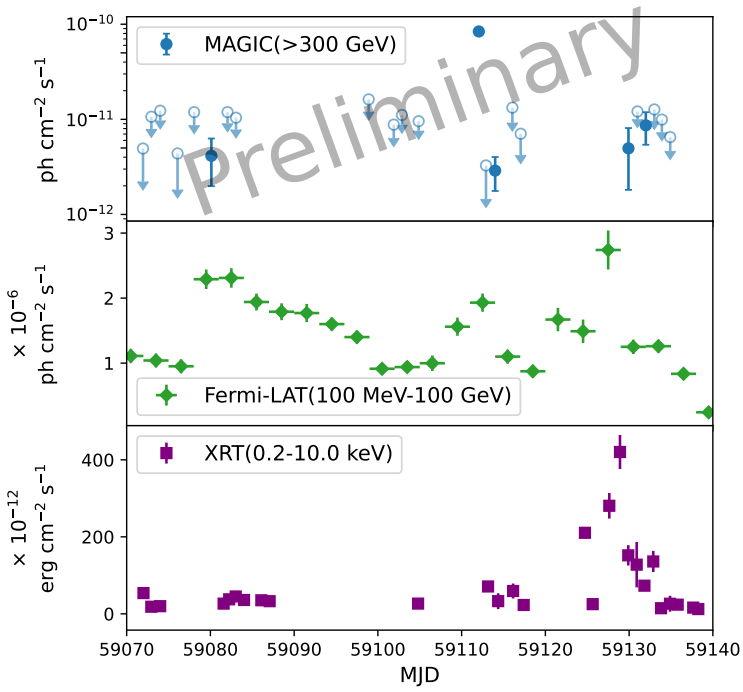


**Figure 1:** Multi-wavelength light curves of BL Lac in the time range from MJD 59070 (2020 August 9th) to 59140 (2020 October 18th). From top to bottom panels: MAGIC, *Fermi*-LAT, and Swift-XRT. The *Fermi*-LAT data are obtained from the public NASA repository (Fermi Light Curve Repository[2]).

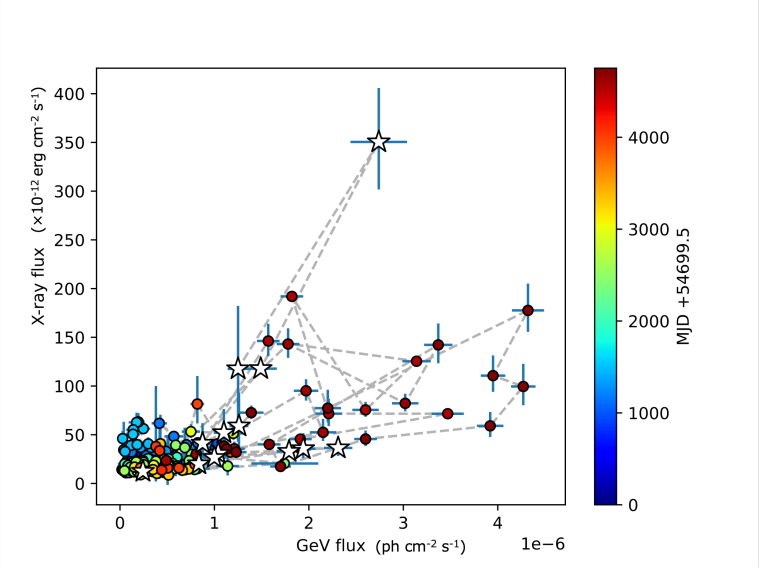


**Figure 2:** X-ray flux versus HE gamma-ray flux variations from the start of *Swift* observations until November 2022. The different markers show the mean value of each 3-day data and the error bars show the standard errors for each bin. The star mark indicates the period included in the Figure 1.

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