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Very High-energy Gamma-Ray Episodic Activity of Radio Galaxy NGC 1275 in 2022–2023 Measured with MACE

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Abstract

The radio galaxy NGC 1275, located at the central region of Perseus cluster, is a well-known very high-energy (VHE) gamma-ray emitter. The Major Atmospheric Cherenkov Experiment Telescope has detected two distinct episodes of VHE ($E > 80$ GeV) gamma-ray emission from NGC 1275 during 2022 December and 2023 January. The second outburst, observed on 2023 January 10, was the more intense of the two, with flux reaching 58% of the Crab Nebula flux above 80 GeV. The differential energy spectrum measured between 80 GeV and 1.5 TeV can be described by a power law with a spectral index of $\Gamma = -2.90 \pm 0.16_{\rm stat}$ for both flaring events. The broadband spectral energy distribution derived from these flares, along with quasisimultaneous low-energy counterparts, suggests that the observed gamma-ray emission can be explained using a homogeneous single-zone synchrotron self-Compton model. The physical parameters derived from this model for both flaring states are similar. The intermediate state observed between two flaring episodes is explained by a lower Doppler factor or magnetic field, which subsequently returned to its previous value during the high-activity state observed on 2023 January 10.

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1. Introduction

NGC 1275 is a type 1.5 Seyfert galaxy (L. C. Ho et al. 1997) in the Perseus cluster ($z = 0.0176$, M. A. Strauss et al. 1992; E. E. Falco et al. 1999). It resides near the center of the large Perseus cluster of galaxies. This galaxy hosts an active galactic nucleus (AGN), and it is classified as a Fanaroff–Riley type I radio galaxy based on its radio morphology. This object exhibits an extended jet visible in the very long baseline interferometry images (H. Nagai et al. 2010). Unlike blazars, the jet of NGC 1275 is viewed at a larger angle, resulting in relatively modest enhancement of the jet core emission due to beaming effects. Observing significant gamma-ray luminosities and fast variability in a nonblazar AGN, such as NGC 1275, where a larger viewing angle can cause radiation deboosting, is intriguing and opens up discussions on alternative models (VERITAS Collaboration et al. 2009; J. Aleksić et al. 2014). Gamma-ray observations and studies of the variability of nonblazar AGNs are crucial for understanding the location and physical processes responsible for extragalactic nonthermal emissions.

In the very high-energy (VHE) gamma-ray domain, the MAGIC telescope first detected NGC 1275 between 2009 and 2011 in stereoscopic mode (J. Aleksić et al. 2010). Six years later, MAGIC observed NGC 1275 from 2016 September to 2017 February and detected a remarkable gamma-ray flare on New Year's Eve 2016/2017 (MAGIC Collaboration et al. 2018). The peak value of the flux was approximately 50 times higher than during the first campaign from 2009 to 2011. While the measurements with Fermi-Large Area Telescope (LAT) yielded flux variability on timescales of (1.51 ± 0.02) days (A. M. Brown & J. Adams 2011), MAGIC measurements showed marginal flux changes on a monthly scale. The VHE-band flaring activity from NGC 1275 observed during the MACE observation period was also reported by Large-Sized Telescope (LST)-1 and MAGIC (O. Blanch et al. 2022; J. Cortina & CTA LST Collaboration 2022).

In this Letter, we present the results from observations of NGC 1275 in the VHE band performed with the MACE telescope between 2022 December and 2023 January, which led to the detection of the source above 80 GeV on two occasions. This Letter is structured as follows. The details of observations and data analysis procedure are given in Section 2. The results obtained with the MACE, Fermi-LAT, and Swift-X-ray Telescope (XRT)/Ultraviolet and Optical Telescope (UVOT) are discussed in Section 3. Finally, the discussion and conclusions are presented in Sections 4 and 5, respectively.

2. Observation Details and Analysis

2.1. MACE

The observations of NGC 1275 were carried out using the MACE telescope. MACE is a large-size (21 m) ground-based VHE gamma-ray telescope (C. Borwankar et al. 2024) installed at an altitude of 4270 m above sea level at Hanle, in the Ladakh region, a union territory of India. NGC 1275 data used in this paper cover a period of two months, from 2022 December to