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Blazars as Ultra-High-Energy Cosmic-Ray Sources: Implications for TeV Gamma-Ray Observations

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The spectra of BL Lac objects and Fanaroff-Riley I radio galaxies are commonly explained by the one-zone leptonic synchrotron self-Compton (SSC) model. Spectral modeling of correlated multiwavelength data gives the comoving magnetic field strength, the bulk outflow Lorentz factor and the emission region size. Assuming the validity of the SSC model, the Hillas condition shows that only in rare cases can such sources accelerate protons to much above 10^19 eV, so > 10^20 eV ultra-high-energy cosmic rays (UHECRs) are likely to be heavy ions if powered by this type of radio-loud active galactic nuclei (AGN). Survival of nuclei is shown to be possible in TeV BL Lacs and misaligned counterparts with weak photohadronic emissions. Another signature of hadronic production is intergalactic UHECR-induced cascade emission, which is an alternative explanation of the TeV spectra of some extreme non-variable blazars such as 1ES 0229+200 or 1ES 1101-232. We study this kind of cascade signal, taking into account effects of the structured extragalactic magnetic fields in which the sources should be embedded. We demonstrate the importance of cosmic-ray deflections on the gamma-ray flux, and show that required absolute cosmic-ray luminosities are larger than the average UHECR luminosity inferred from UHECR observations and can even be comparable to the Eddington luminosity of supermassive black holes. Future TeV gamma-ray observations using the Cherenkov Telescope Array and the High Altitude Water Cherenkov detector array can test for UHECR acceleration by observing >25 TeV photons from relatively low-redshift sources such as 1ES 0229+200, and > TeV photons from more distant radio-loud AGN.

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