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On the maximum energy of protons in the hotspots of AGN jets

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It has been suggested that relativistic shocks in extragalactic jets may accelerate the highest energy cosmic rays. The maximum energy to which particles can be accelerated via a diffusive mechanism depends on the magnetic turbulence near the shock but recent theoretical advances indicate that relativistic shocks are probably unable to accelerate particles to energies much larger than a PeV.
The cut-off of the synchrotron spectrum in the hotspots of powerful radiogalaxies is typically observed between infrared and optical frequencies, indicating that the maximum energy of non-thermal electrons accelerated at the jet termination shock is about 1 TeV for a canonical magnetic field of 100 micro Gauss. Based on theoretical considerations and observational data we show that the maximum energy of electrons cannot be constrained by synchrotron losses as usually assumed, unless the jet density is unreasonable large and most of the jet kinetic energy goes to non-thermal electrons. The maximum energy is ultimately determined by the ability to scatter particles downstream of the shock, and this limit applies to both electrons and protons. Therefore, the maximum energy of protons is also about 1 TeV. We show that non-resonant hybrid (Bell) instabilities generated by the streaming of cosmic rays can grow fast enough to amplify the jet magnetic field up to 100 micro Gauss and accelerate particles up to the maximum energies observed in the hotspots of radiogalaxies.

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