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Ultra-high-energy Cosmic Ray Outburst from GRB 221009A

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Gamma-ray bursts (GRBs) are proposed as origins of ultra-high-energy cosmic rays (UHECRs) since 1995. The non-detection of high-energy neutrinos from the observed GRBs by the IceCube observatory constrain the contriubtion of GRBs to cosmic rays. Lately, GRB 221009A was detected as the B.O.A.T. ("brightest of all time") GRB with photons of energy up to $\sim$ 18 TeV. We compare timescales of the acceleration, energy loss and escape of cosmic rays in GRB 221009A, suggest that GRB 221009A is able to accelerate protons to $> 10^{20}$ eV. It is difficult for ultra-high-energy protons to escape from the host galaxy, while neutrons with energy larger than 10 EeV, produced in the process of $p + \gamma \to n + \pi^+$, are able to escape from the source as well as the host galaxy without suffering from the serious magnetic field deflection. The escaped neutrons decay into protons in the inter-galactic space, and lose energy via interactions with the extragalactic background light photons and cosmic microwave background photons. After entering the Milky Way, protons will be deflected by the Galactic magnetic field, and arrive at Earth with a time delay. We make predictions on the possible future observations on ultra-high-energy cosmic rays from GRB 221009A by cosmic ray detectors, such as the Pierre Auger Observatory, TA$\times$4 and GRAND.

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