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Modeling the spectrum and composition of ultrahigh-energy cosmic rays with two populations of extragalactic sources

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We fit the ultrahigh-energy cosmic-ray (UHECR, $E > 0.1$ EeV) spectrum and composition data from the Pierre Auger Observatory at energies $E > 5 \cdot 10^{18}$ eV, i.e., beyond the ankle using two populations of astrophysical sources. One population, accelerating dominantly protons (^{1}H), extends up to the highest observed energies with maximum energy close to the GZK cutoff and injection spectral index near the Fermi acceleration model; while another population accelerates light-to-heavy nuclei (^{4}He, ^{14}N, ^{28}Si, ^{56}Fe) with a relatively low rigidity cutoff and hard injection spectrum. A significant improvement in the combined fit is noted as we go from a one-population to two-population model. For the latter, we constrain the maximum allowed proton fraction at the highest-energy bin within 3.5σ statistical significance. In the single-population model, low-luminosity gamma-ray bursts turn out to match the best-fit evolution parameter. In the two-population model, the active galactic nuclei is consistent with the best-fit redshift evolution parameter of the pure proton-emitting sources, while the tidal disruption events could be responsible for emitting heavier nuclei. We also compute expected cosmogenic neutrino flux in such a hybrid source population scenario and discuss possibilities to detect these neutrinos by upcoming detectors to shed light on the sources of UHECRs.

Keywords

Ultrahigh-energy cosmic rays, Cosmogenic neutrinos, Hadronic interactions, UHECR composition, Shower depth distribution

Collaboration

other Collaboration

Subcategory

Theoretical Results

Primary author: DAS, Saikat (Raman Research Institute, India)

Co-authors: Prof. RAZZAQUE, Soebur (Department of Physics, University of Johannesburg); GUPTA, Nayantara (Raman Research Institute)

Presenter: DAS, Saikat (Raman Research Institute, India)

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