Highest Energy Cosmic Rays

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Primary cosmic rays arriving at the Earth have an energy spectrum smoothly decreasing with ~E^{-3}, and their arrival directions are known to be uniform at the level of 0.1%. These features no longer hold at the energy of ~10^{20} eV according to recent observations by the Pierre Auger Observatory and the Telescope Array (TA). A "dip" structure is found around $10^{18.7}$ eV signifying a change of power index in the energy spectrum, and a "cut-off" above which the flux is strongly suppressed is established at ~$10^{19.7}$ eV. The isotropy in the entire sky is largely broken above the cutoff as well; in the northern sky the TA recently announced evidence of a hotspot in the direction of Ursula-major, and the Auger remains to register an enhancement of cosmic ray flux toward the active galactic nuclei Cen A in the southern sky. The anisotropy is considered reflecting non-uniform cosmic ray source distribution in the nearby extra-galactic space, with the arrival of cosmic rays from distant sources being impeded by the interaction with the CMB (cosmic microwave background), also leaving peculiar features in the spectrum. We expect, in the near future, that source astronomical objects or regions of enhanced cosmic ray generation are identified within the GZK (Greisen-Zatsepin-Kuzmin) horizon (z<~0.01), and that our understanding of the physics of cosmic ray acceleration and propagation at the highest energy will further advance. Several experiments such as the TAx4 extension, Auger upgrade and K-EUSO have been proposed to meet this expectation.