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Cosmic-Ray Mass Spectrometry and Starburst Galaxies

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Even when ultrahigh-energy (E > 10ˆ10 GeV) cosmic rays (UHECRs) are heavy nuclei (with nuclear charge Z) as indicated by existing data, the pointing of cosmic rays to the nearest extragalactic sources (distance D) at highest energies remains expected, because the bending of the cosmic ray goes as BZD/E (B is the extra-galactic magnetic field). In addition, the acceleration capability of the sources grows linearly in Z, while the energy loss per distance traveled decreases with increasing Z and nucleon number A. Each of these facts favors heavy nuclei as the primaries of UHECRs. A single dimensional analysis may miss the relative importance of the phenomena depending on these variables (D,B,E,Z,A, and direction). A multi-dimensional cross-correlation (MDCC) of the individual emission spectra with nearby putative sources is needed. I will use MDCC to study the hypothesis that primaries are heavy nuclei subject to GZK photo-disintegration, and that metal-rich starburst galaxies are the most plausible candidate sources by far: combining the 3.9-sigma probability of starburst-galaxy sources from Auger data with the significance of the hotspot derived from Telescope Array data, we arrive at a 5-sigma probability that starburst galaxies are the origin sites for UHECRs. Also, starburst galaxies possess a large density of supernovae and therefore of pulsars, and so can accelerate heavy nuclei to the hard spectrum that is needed to accommodate Auger observations. At face value, this result provides an important step in resolving the more than 100 year old mystery of the origin of highest-energy cosmic rays.

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