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Constraining astrophysical sources of intermediate-mass UHECR

Constraining the astrophysical source populations of Ultra High Energy Cosmic Rays (UHECRs), CRs with energy higher than 10^{18}eV (1 Exa eV or EeV), is difficult because UHECRs deflect by the Galactic Magnetic Field (GMF).
Recent interpretations of cosmic-ray-produced air showers with hadronic interaction models suggest a gradual increase in the mean mass of UHECRs with energy. The decades-old view of UHECRs being a mix of hydrogen and iron (with relative composition varying with energy) also expands to consider intermediate nuclear compositions. Notably, while hydrogen and iron UHECRs have expected mean free paths of $\sim$ 100Mpc, intermediate composition UHECRs have mean free paths of only 10s of Mpc. %, further reducing the original source distances of UHECRs.

Sotomayor et al.2023 used Monte-Carlo simulations of H, O, and Fe composition UHECR tracks in 8 proposed GMF models to estimate deflections suffered by the UHECRs detected by the Pierre Auger Observatory and the Telescope Array. These deflections can identify sub-samples of 'least-deflected' UHECRs relatively independent of the assumed GMF model. The distribution of the GMF-deflection-corrected arrival directions of this 'least deflected' sample was correlated with astrophysical catalogs. There was a strong association between the (GMF-deflection-corrected) arrival directions of 'least deflected' UHECRs with nearby (D $\leq$ 20 Mpc) galaxies when considering an oxygen UHECR composition.
This work continues the analysis of Sotomayor et al. 2023, using O, a high-abundance intermediate mass species, H, and Fe samples. The correlation is replaced by a likelihood test approach. Instead of a distance cutoff, a weight proportional to a property is attenuated following Allard et al. 2008 results. It is proposed to account for the effect of the magnification of the flux outside the Galaxy due to GMF.
Until now, the anisotropy of the out-of-Galaxy UHECR distribution of oxygen composition, under the GMF BSS model is consistent with the distribution of SM and SFR of the nearby universe.

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