Contribution ID : **90** Type : **Oral talk**

Limiting the number density of ultra-high-energy cosmic ray sources

Friday, 30 October 2026 17:30 (15)

The origin of ultra-high-energy cosmic rays (UHECRs) remains an open problem. In particular, the properties of their sources are difficult to constrain due to the limited statistics of observed events and the propagation effects experienced by charged cosmic rays. One of the important characteristics of sources is their number density. In this work, we investigate the possibility of constraining the number density of UHECR sources using statistical properties of experimentally observed cosmic-ray events.

The analysis is based on public data from the Pierre Auger Observatory. We simulate UHECR events as they would be observed at Earth for different assumptions about the primary composition, source number density, and energy threshold. For each set of parameters, ensembles of simulated event sets are generated and compared with the experimental data. The simulations account for the main effects relevant to the propagation and detection of UHECRs.

Several statistical methods are used to quantify the compatibility between the simulated event sets and the experimental data. In particular, we consider the two-point angular autocorrelation function, which characterizes the clustering of events on different angular scales. The distributions of the corresponding statistics obtained from the simulated event sets are compared with the values measured in the experimental data.

The preliminary results show that, for most of the considered primary compositions and energy thresholds, the simulated event sets are inconsistent with the experimental data across the investigated range of source densities.

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Session Classification : Astroparticle physics

Track Classification : Astroparticle physics