UHE Cosmic Ray Charge ID Using Template Backtracking Simulations

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[part of AK Thesis Work]

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Outline

• Develop and test a method to assign individual cosmic ray charge assuming a source and GMF model

• Generate rigidity \((R = E / Z)\) simulations from a specific source to determine arrival direction distributions

• Compare event reconstruction with individual rigidity arrival distributions

• Best match (overlap) corresponds to a charge value \(Z\)
  • Explicitly dependent on hypotheses that source is correct and GMF is an accurate representation

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• Quick look at effect of a turbulent Kolmogorov random field on arrival directions
Simulation Parameters – GMF and Source

Assume Cen-A is a powerful sole source
(l, b) = (-50.5°, 19.4°)

- regular (coherent), striated random, turbulent random
- only consider regular here for Cen-A study
- regular+turbulent for last slide (no striated)
Rigidity Maps – Actual Directions

Simulations part of GF NASA grant

Backtrack HEALPix res 11 (51M points)
Rigidity Maps - Centroids

Obs. dir. in JF12-reg: srcs within 3° of CenA Center

- Latitude (°) range: -5 to 25
- Longitude (°) range: -100 to -40

- Data points labeled with different colors indicating different rigidity values (R in EV: 2.00, 2.24, 2.51, ..., 100)

- Cen A Center marked with a star
Charge Assignment Procedure

- The red star is an event with measured energy and direction with uncertainties

- Consider a 2D normalized Gaussian with mean \((l_g, b_g)\) and standard deviations \((\sigma_g, \sigma_g)\), for the event and each rigidity simulation
  - event \(\sigma\) corresponds to the measurement uncertainties (1°, 14% energy)
  - Simulation \(\sigma\) corresponds to the distribution's \(\sigma\)

- Calculate overlap value between event and individual simulations
  - Maximum value indicates most consistent rigidity \(\rightarrow Z\)
Charge Assignment – Sanity Checks and Uncertainties

• Select random event from simulations and assign “truth” charges

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<th>$Z_{\text{predict}}$</th>
<th>Counts (%)</th>
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Error on Z Reconstruction vs. E: Helium, $p > 10\%$

Error on Z Reconstruction vs. E: Nitrogen, $p > 10\%$
Charge Assignment – Results from Data

- Herald until mid September 2013, latest reconstructions, $E > 2$ EeV
- This would be the charge if Cen-A origin and GMF model were true
Effect of Turbulent Field on Arrival Directions

• A. Keivani has developed a CRT module for implementing turbulent Kolmogorov spectra random fields