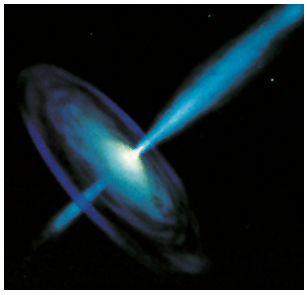
Connecting AGN with Ultra-High Energy Cosmic Rays



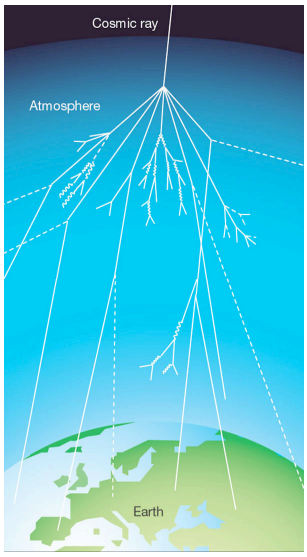


Illustration credits: (*i*) NASA
(*ii*) Amelino-Camelia G., 2008, Nature, 418, 34

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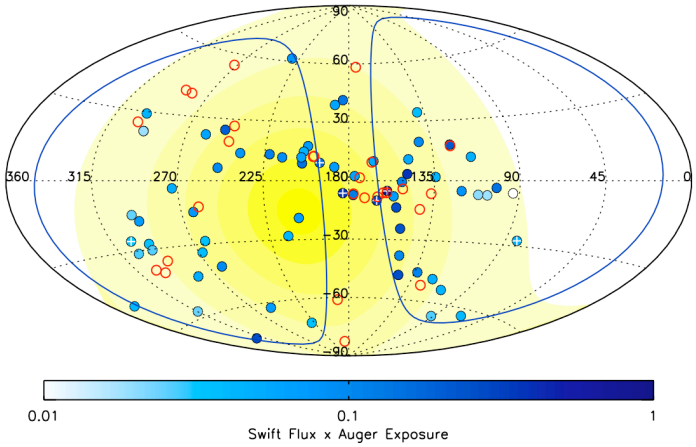
We measure the correlation between sky coordinates of the Swift BAT catalogue [1] of active galactic nuclei with the arrival directions of the highest energy (>5.7x10^{19}eV) cosmic rays detected by the Auger Observatory [2]. The statistically complete, hard X-ray catalog helps to distinguish between AGN and other source candidates that follow the distribution of local large-scale structure. When weighted by their hard X-ray flux, AGN within 100 Mpc are correlated with UHECR arrival directions at a significance level of 98%. This correlation sharply decreases for sources beyond ~100 Mpc, suggestive of a GZK suppression.

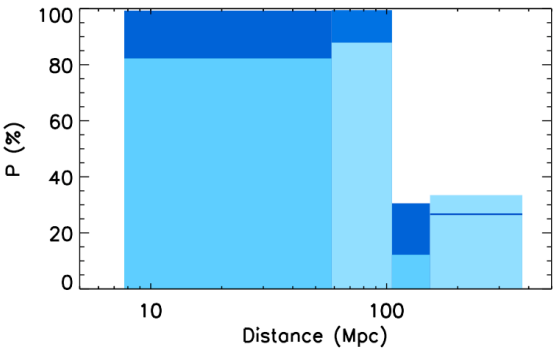


Left: Map of UHECR arrival directions (open red circles) against AGN positions (filled blue circles, color scaled by hard X-ray flux and relative Auger exposure), in supergalactic coordinates. Nearest AGN (d < 20 Mpc) marked by white crosses; 4/6 of these have UHECR arrival directions within 6°.

Visually, there is not a 1-to-1 correlation between the arrival directions of cosmic ray showers with astrophysical sources. But using a 2-dimensional K-S test [3], we are able to statistically compare the correlation with Monte Carlo realizations of an isotropic distribution of UHECRs. The correlation increases when AGN positions are weighted by their hard X-ray flux, a measure of the accretion rate and intrinsic power. Another source population that follows the spatial distribution of local large-scale structure could be responsible for the first correlation, but it is unlikely to also follow the luminosity distribution of AGN across the sky, indicating that AGN are the likely sources.

The ability to trace sources of UHECRs is of crucial importance to particle astronomy and will improve constraints on Galactic and extragalactic magnetic fields, set upper limits on Lorenz invariance through GZK considerations, and probe the AGN engine as an acceleration mechanism.

Right: Correlation as a function of distance, with dark regions showing the increase due to flux-weighting. The sharp decline near 100 Mpc indicates a reduction in the UHECR flux beyond that distance due to the GZK effect.



We are not yet able to identify distinguishing characteristics in the set of AGN correlated with UHECR directions, though Cen A is a noteworthy source with 2 UHECRs nearby. Future work will analyze the relevance of jets and synchrotron emission, black hole spin, obscuration, and other AGN properties. Increased statistics from Auger and planned observatories will further test and clarify the AGN-UHECR connection.

References

See George M.R., et al., MNRAS, 2008 (astro-ph/0805.2053)
[1] Tueller J., et al., 2008, ApJ, in press
[2] Abraham J., et al., 2008, Astroparticle Physics, 29, 188
[3] Fasano G., Franceschini A., 1987, MNRAS 225, 155;
Press, W.H., et al., 2007, *Numerical Recipes*