A parametrized catalog of radio galaxies as ultra-high energy cosmic ray sources

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Catalog of RGs as UHECR sources

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This is the second slide

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Radio Galaxies Great Again

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How to normalize cosmic ray power - radio vs. gamma rays

 $\hat{E}_{cr}, L_{cr}, X_Z$

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How to normalize cosmic ray power - radio vs. gamma rays



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How to normalize cosmic ray power – radio vs. gamma rays

leptonic L_{γ} ????? ↓ ????? $GeV \Leftrightarrow EeV??$ $\hat{E}_{cr}, L_{cr}, X_{Z}$????????? $L_{
m poy} \lesssim L_{
m jet} \propto (P_1 \, d^2)^{eta_L}$ $\tau_{p\gamma}/\tau_{pp}??$ $\beta RB \propto \sqrt{v_j (P_1 d^2)^{\beta_L}}$

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How to normalize cosmic ray power - radio vs. neutrinos



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Relativistic boosting and the blazar zoo



Relativistic boosting and the blazar zoo





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Relativistic boosting and the blazar zoo





$$b = 1 + 2\pi f \delta^2 \simeq 64$$

for $f = 0.1, \delta = 10$

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Catalog of RGs as UHECR sources

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Astronomical catalogs are bitches!

van Velzen et al., 2012



Context. To understand the feedback of black holes on their environment or the acceleration of ultrahigh energy cosmic rays in the present cosmic epoch, a comprehensive inventory of radio galaxies in the local universe is needed. This requires an all-sky catalog of radio-emitting galaxies, that hitherto has not been available.

Aims: We present such an all-sky sample. Our catalog allows one to build volume-limited subsamples containing all low-power radio galaxies, similar to the prototypical low-power radio galaxies Cen A or M 87, within some hundred Mpc.

Methods: We match radio emission from the NVSS and SUMSS surveys to galaxies of the 2MASS redshift survey (2MRS) using an image-level algorithm that properly treats the extended structure of radio sources.

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42 radio galaxies (boosting considered)

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UHECR transport - CRPropa simulations



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Results on the dipole

16 EeV



Results on the dipole

32 EeV





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Summary and outlook

- We present a demo sample of 42 radio galaxies as candidates for the strongest UHECR sources, based on radio scaling of non-thermal power, including possible effects of relativistc boosting.
- We define a "strong source sample" of 15 sources, which is (likely) complete in the sense that no radio galaxy is missing on that level of expected UHECR contribution. Five sources in this sample have so far never been considered in UHECR studies.
- Initial tests show that, for suitable parameters and extragalactic magnetic fields that are strong only in structures, the source sample can reproduce all known signatures of UHECR anisotropy.
- We plan to provide a complete parametrized catalogue of radio-scaled UHECR sources (plus corresponding continuous source functions for sources not contained) in electronic form (python class) to be included in CRPropa simulations.