

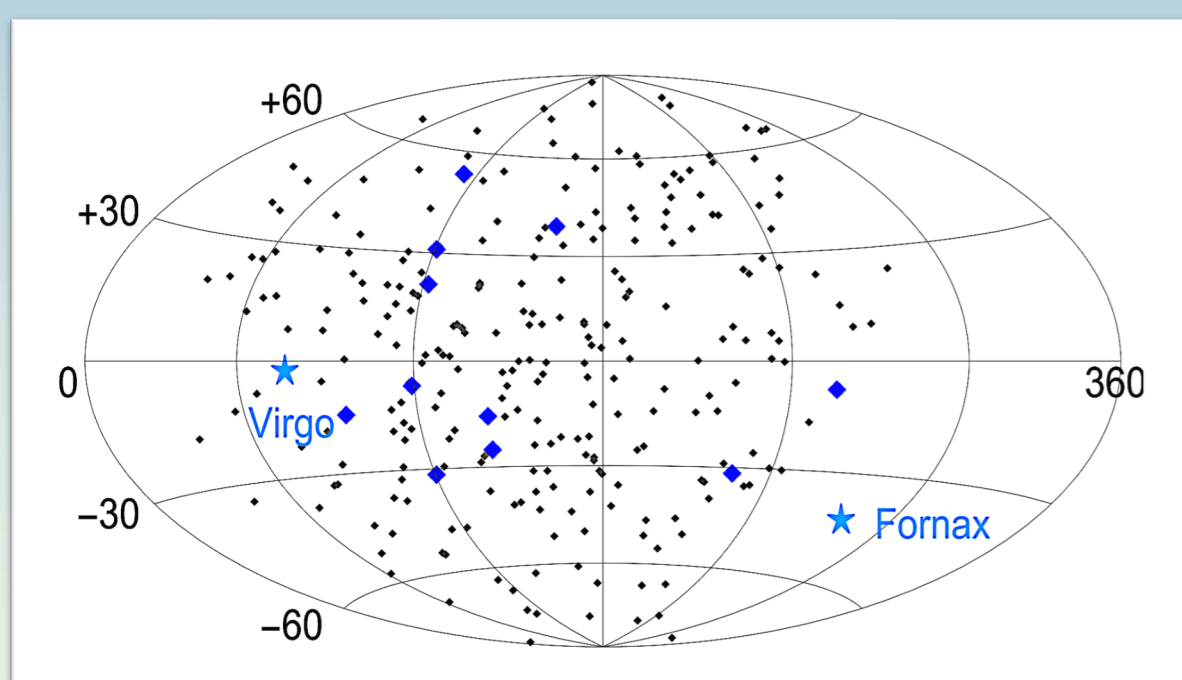
Towards new tests of cosmic-ray correlations with BL Lac type objects

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Highlights

- In 2004 correlations of arrival directions of UHECR and BLL were detected in HiRes stereo data set [1,2]. For original analysis was used catalog [3] not complete by any criteria.
- We made two different sets of objects with the use of Radio fundamental catalogue and Fermi LAT data, which are isotropic.
- With BLL selected these sets can be used in repeating that result and adopted for future tests with the new Telescope Array data.

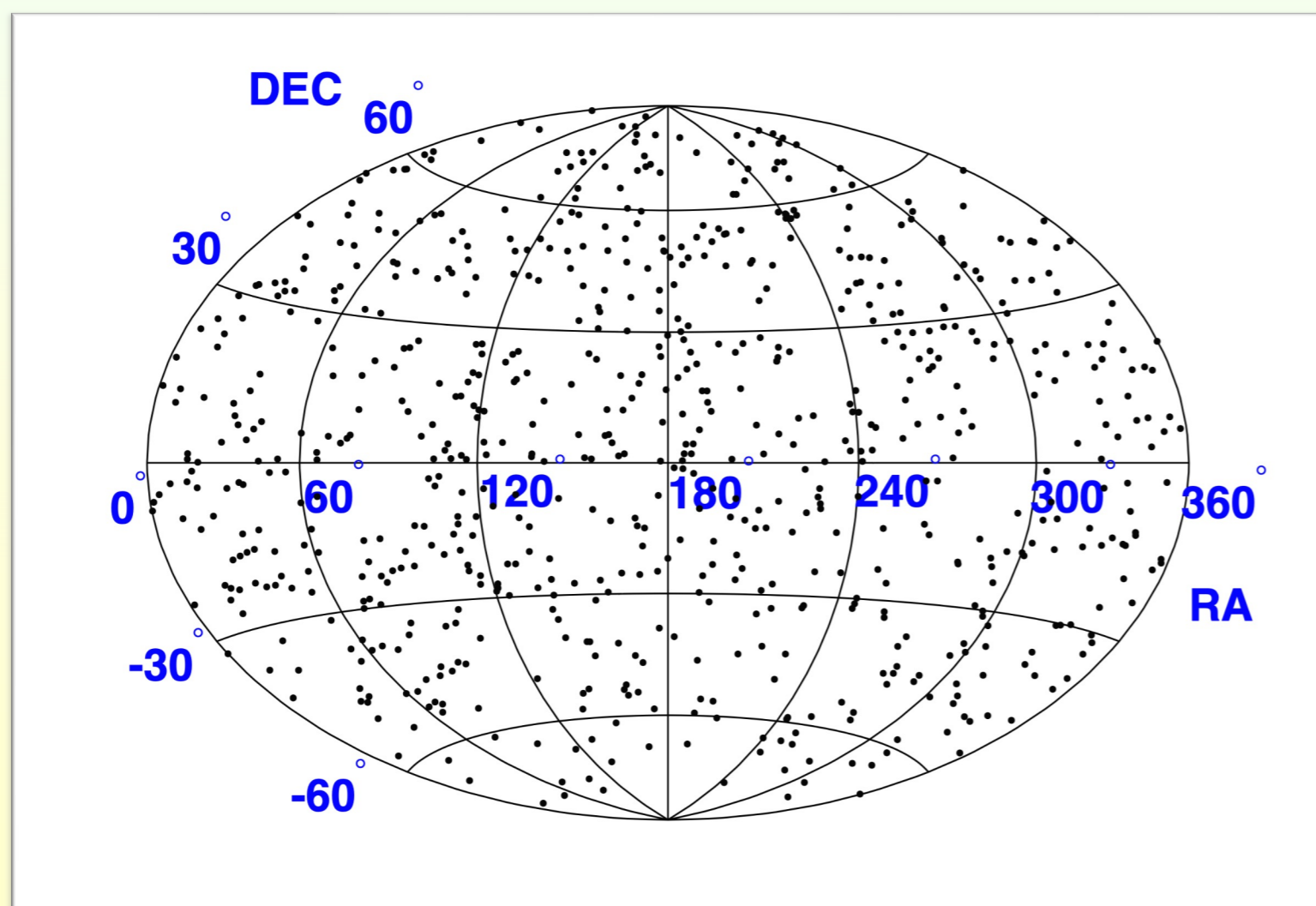
Motivation



As it can be seen from the picture, correlating objects found in 2004 analysis [1] are distributed not isotropically. This can be a pointer to new effects related to axion-like particles propagation through the Universe. Blue diamonds – BL Lac correlating with UHECR; Black dots – directions of other showers. Picture taken from [6]

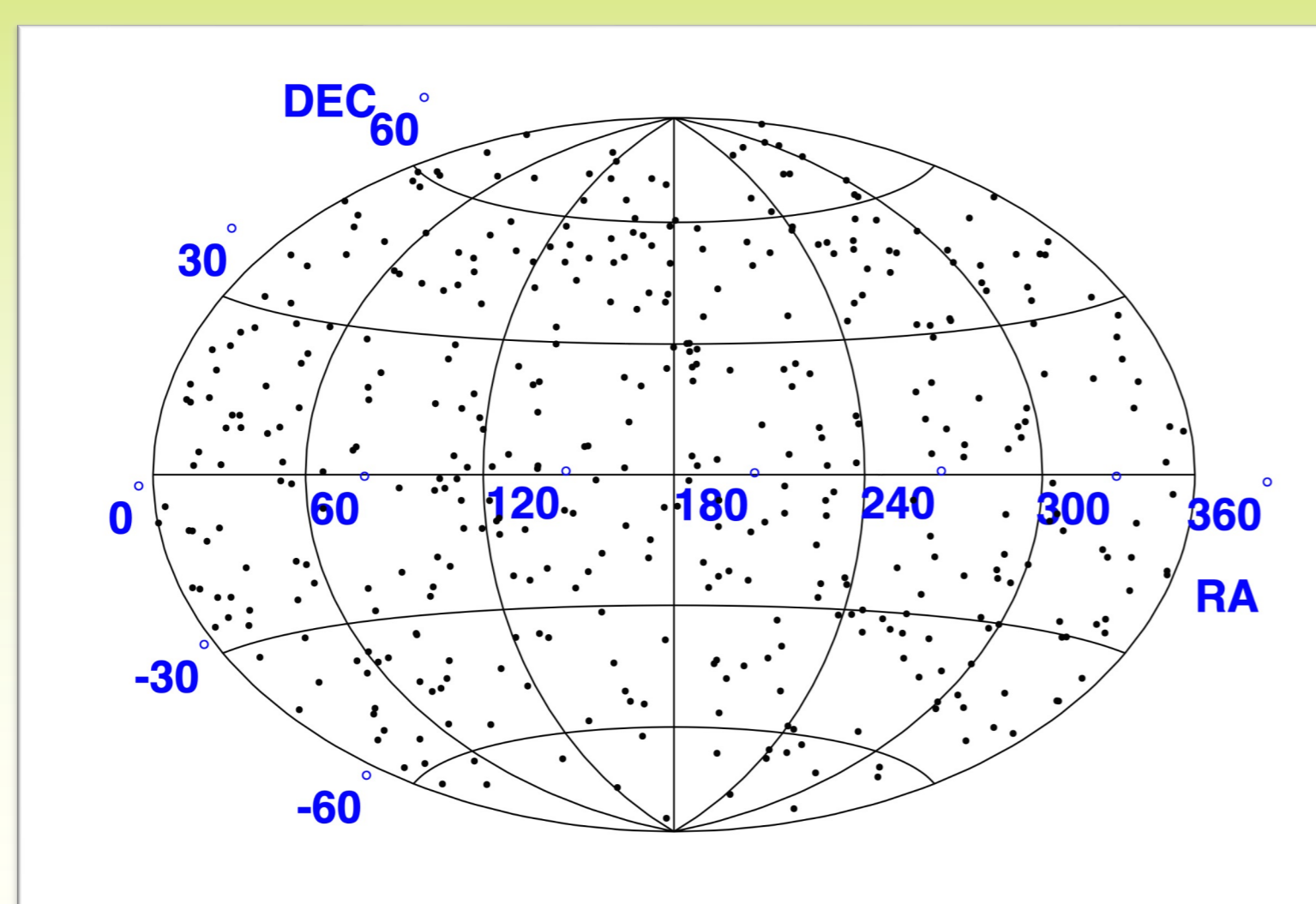
RFC-set

- A complete and isotropic set of 738 objects with flux on 8GGz $\geq 0.15 Jy$ and corrected magnitude < 18 . This set was collected from the compact radio loud sources which were detected with very long baseline interferometry.



Fermi set

- A complete and isotropic set of 424 objects with flux of photons in 1-100 GeV $\geq 7 \cdot 10^{-10} \frac{\text{photons}}{\text{cm}^2 \cdot \text{s}}$ and corrected magnitude < 18 . This set was collected from 4FGL catalog of FERMI LAT data.

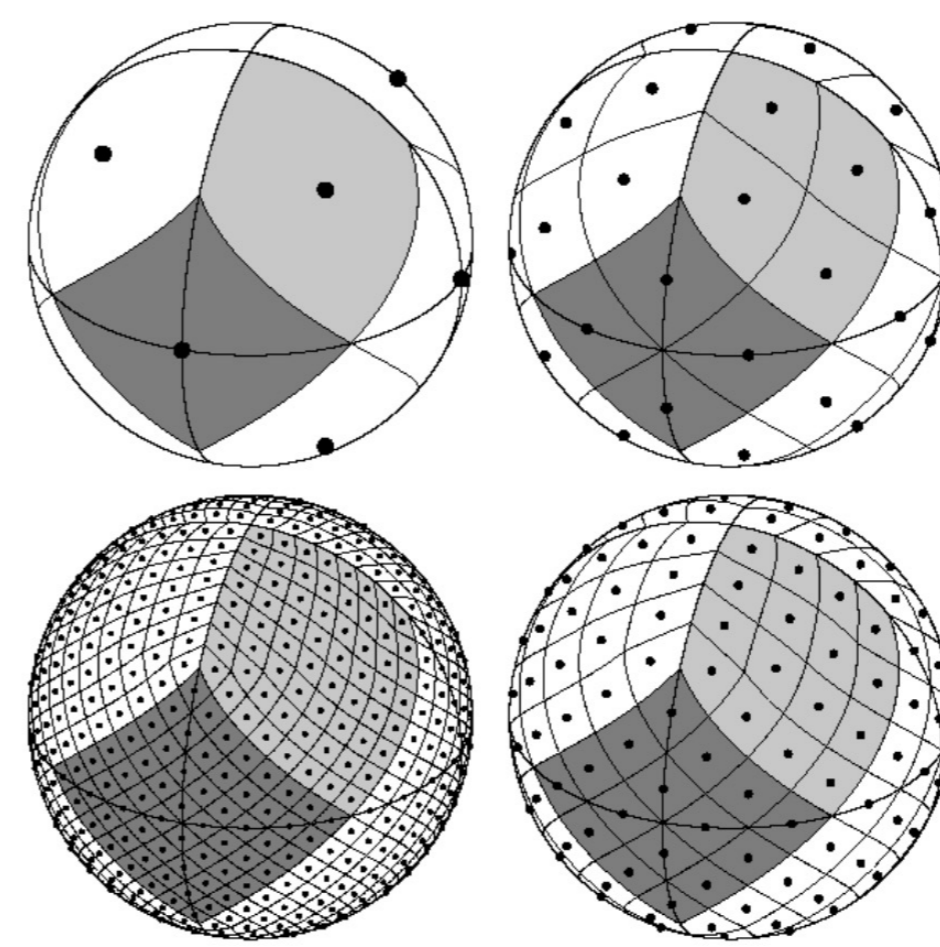


Methods of work

We checked isotropy of sets with the use of two different methods. The first one included HEALPix [4] and the second one involved galactic latitude distribution.

• Main method

For a given set of sources, direction on the sphere and the angle δ we count the amount of objects separated from the chosen direction by the angular distance less or equal δ . We continue this procedure for 3 sets of central HEALPIX pixels with different resolution and different angles δ . This allows us to have 3 uniform on the sphere sets of data which we later compare to the isotropic ones with Kolmogorov-Smirnov test.



HEALPIX (the Hierarchical Equal Area, iso-Latitude Pixelization) on sphere for different resolution parameters. Clockwise: $N_{side} = 1, 2, 4, 8$.

Picture taken from [4].

• Additional method

We compare latitude distribution of our set of objects to the isotropic one with Kolmogorov-Smirnov test. Distribution of HEALPIX pixel centers with $N_{side} = 256$ used as an isotropic one in this comparison. This method is needed because extragalactical sources are poorly identified in galactical plane. For the same reason we take into account magnitude correction via Amores&Lepine A2 model [5].

Perspectives

- As it was shown in [7], objects responsible for possible correlations can be selected from our sets with the use of spectral indexes.
- These sets can be used in repeating analysis from [1]. If confirmed this result would mean new physics or very unconventional astrophysics because it implies neutral particles travelling for cosmological distances.
- Our sets also can be adopted for future tests of correlations with the new data obtained from Telescope Array experiments. And we are planning to formulate new hypothesis (based on HiRes analysis) to be tested with TA data.

References:

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5. Amores & Lepin, 2005, AJ, 130, 679; 2007, AJ, 133, 1519;
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