Searching of Ultra High Energy Cosmic Rays from Virgo A

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Introduction

Active galactic nuclei (AGN) are considered as one of the most appropriate sources of cosmic rays with energy exceeding ~10^{18} eV. Virgo A (M87 or NGC 4486) is the second closest to the Milky Way active galaxy located at a distance of 16.4 Mpc. According to existing estimations it can be a prominent source of ultra high energy cosmic rays (UHECR). However some zone of avoidance has been registered in the sky region near Virgo A, possibly due to the magnetic fields (MF) influence. In present work we check 72 UHECR events detected recently by Telescope Array as well as more early sets of data (AUGER etc.) for possibility of their origination in this AGN. We carried out the simulation of UHECR motion from Virgo A taking into account their deflections in galactic (GMF) as well as extragalactic (EGMF) magnetic fields according to several latest models [1 – 4].

Method

The influence of regular GMF component on the UHECR trajectory was calculated by numerical solving of motion equations $\frac{d\boldsymbol{r}}{dt}=\boldsymbol{v}$, $\frac{d\boldsymbol{v}}{dt}=\frac{qc}{E}[\boldsymbol{v}\times\boldsymbol{B}]$, where the CR energy $E\gg m_0c^2$ and hence $|\boldsymbol{v}|\approx c$. The influence of EGMF is described by CR diffusion due to its random structure. It results in scattering of arrival directions at the boundary of our Galaxy. Impact of random GMF component is similar to EGMF and it was taken into account as a minor part of total scattering. The average GMF magnitude in all used models is of the order of several μG. For EGMF we used the estimation of magnitude ~1 nG with coherent length ~1 Mpc according to the criterion $\langle B\rangle\sqrt{l_c}\le 10^{-9}$ G·Mpc$^{-1/2}$.

Since among the registered UHECR the events which could be assigned to Virgo A are still absent, we investigated the motion of particles with different rigidity E/Z in the range $(5\ \text{to}\ 100)\times10^{18}$ eV .

Results

All obtained results are presented on the following pictures in galactic coordinates. Owing to large angular distance of Virgo A from galactic plane we have illustrated only northern galactic hemisphere.

- AGN positions are denoted by stars.
- Black circles correspond to the expected events calculated for different E/Z accounting only regular GMF component (the events with higher Z are further from the AGN).
- Lots of colored dots denote the regions of expected arrival directions expanded due to EGMF as well as random GMF influence. Statistically these regions correspond to 68% of total CR amount.
- Registered UHECR events are denoted by colored circles:
  Telescope Array (E > 57 EeV), **AUGER** (E > 55 EeV) and **HiRes** (E > 50 EeV).
  Numbers correspond to the events energy in EeV (10^{18} eV).

Conclusions

1. UHECR deflection caused by EGMF is generally comparable with GMF one, moreover for the first two models the influence of EGMF even dominates.

2. Effect of EGMF demonstrates obvious asymmetry in final distribution of expected UHECR arrival directions, including multi-images, as well as overlapping for different Z.

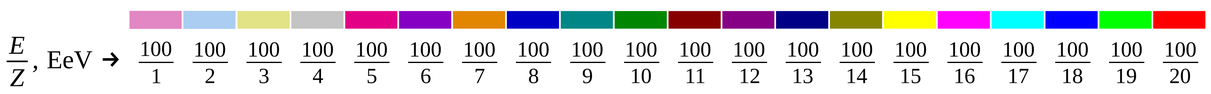
3. The use of different GMF models establishes correspondence of the various groups of events with Virgo A. They are following:

- GMF model [1] – 20 CR particles with E from 53 to 154 EeV and Z from 4 to 26.
- GMF model [2] – 7 CR particles with E from 51 to 162 EeV and Z from 7 to 21.
- GMF model [3] – 5 CR particles with E from 58 to 71 EeV and Z from 3 to 12.
- GMF model [4] – 7 CR particles with E from 60 to 84 EeV and Z from 6 to 14.

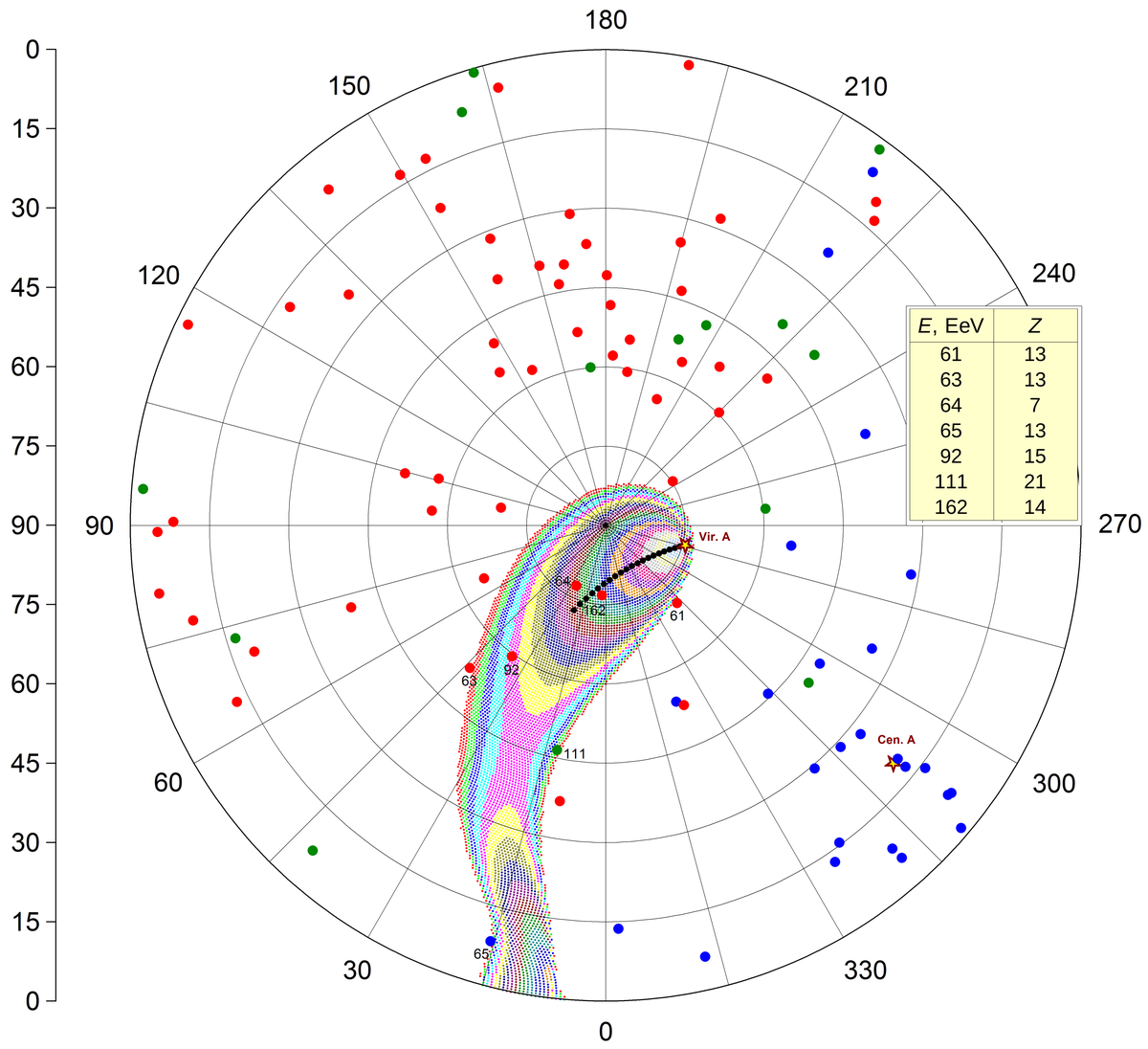
Full list of these events for each GMF model see in the tables.

**Note*: Each estimation of Z value corresponds to bottom limit of this parameter for given event, except only maximum value 26.

References – see captions under pictures.



Color denotation of expected arrival regions caused by EGMF for UHECR with different rigidities.



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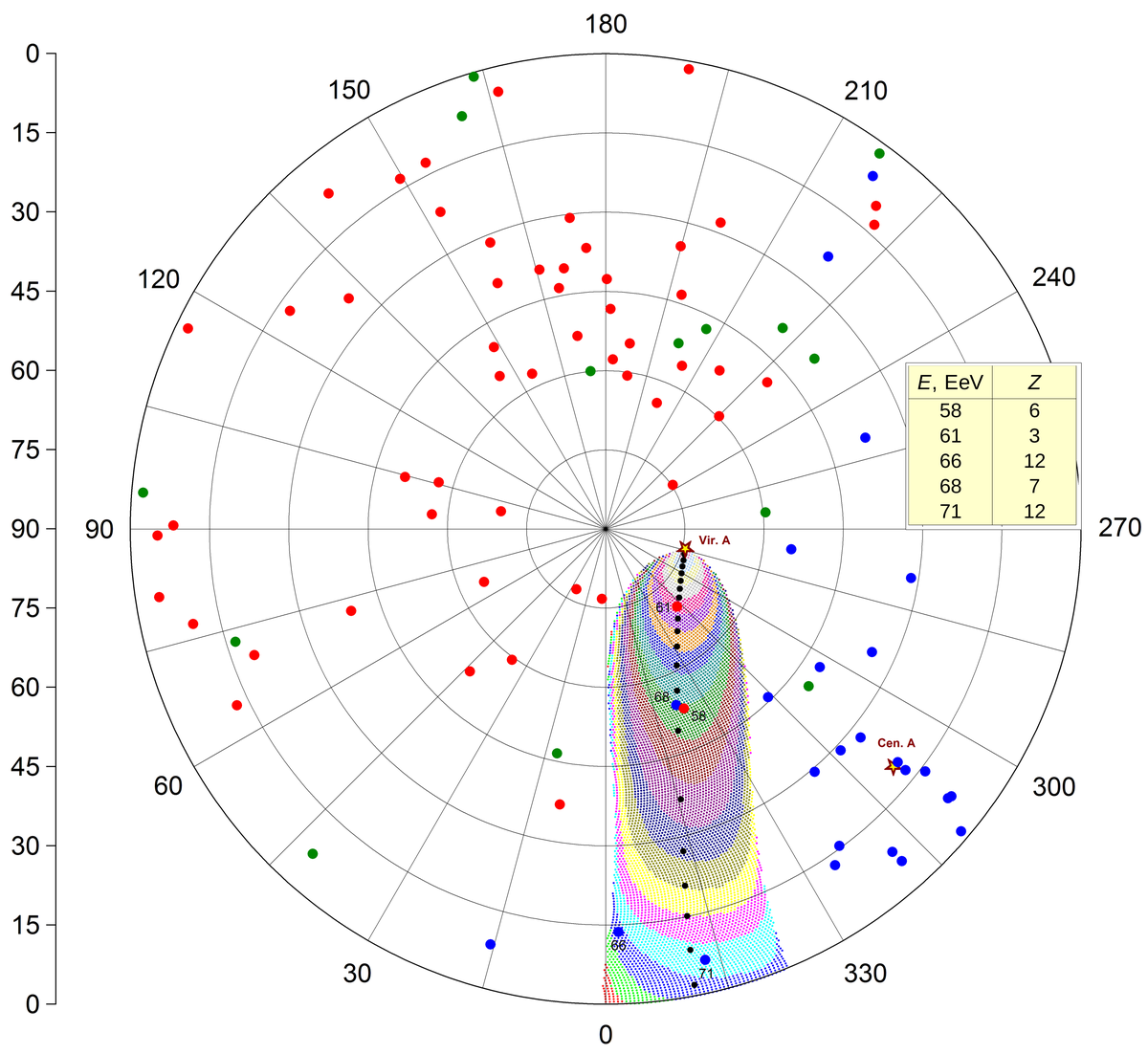

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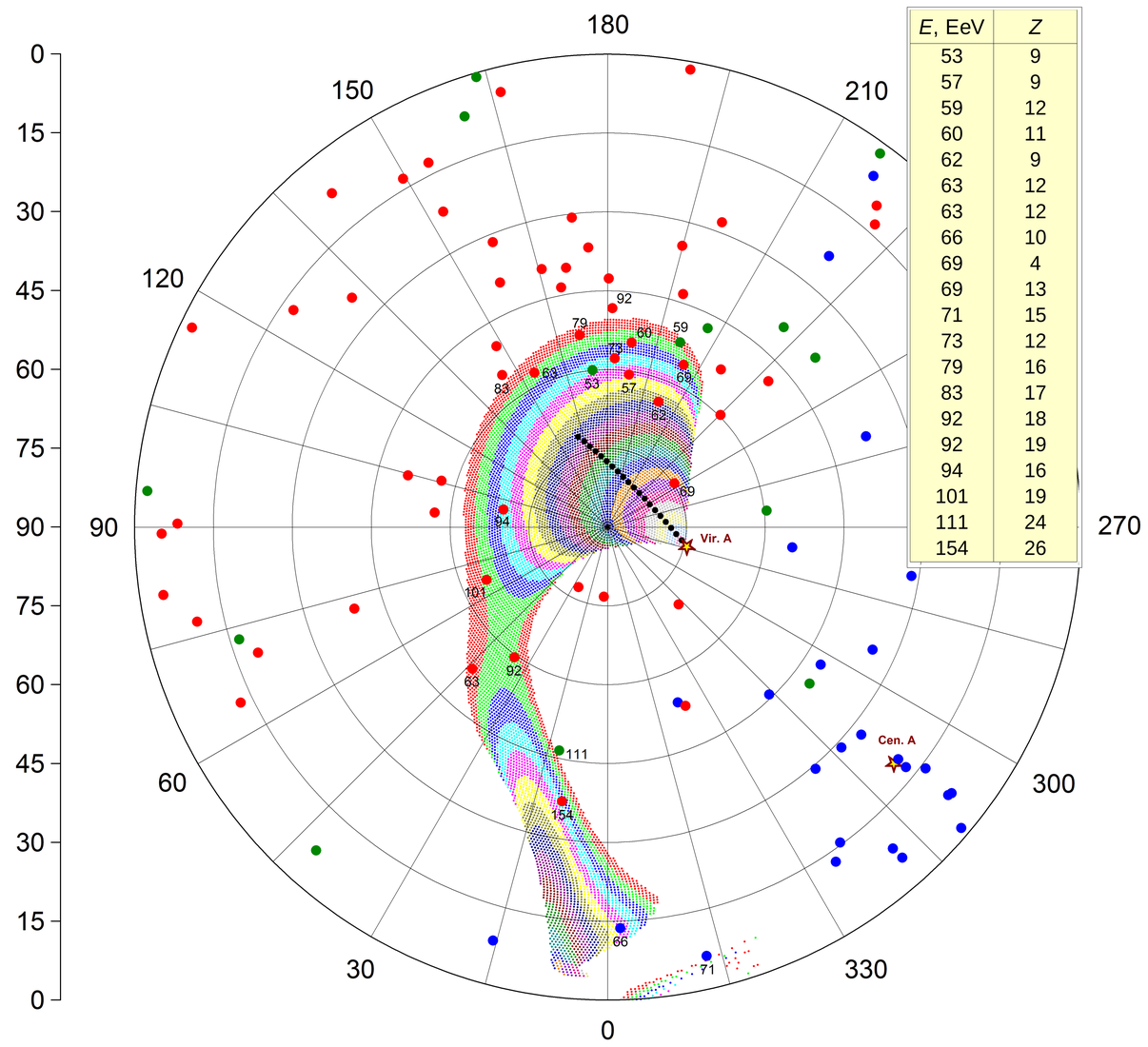

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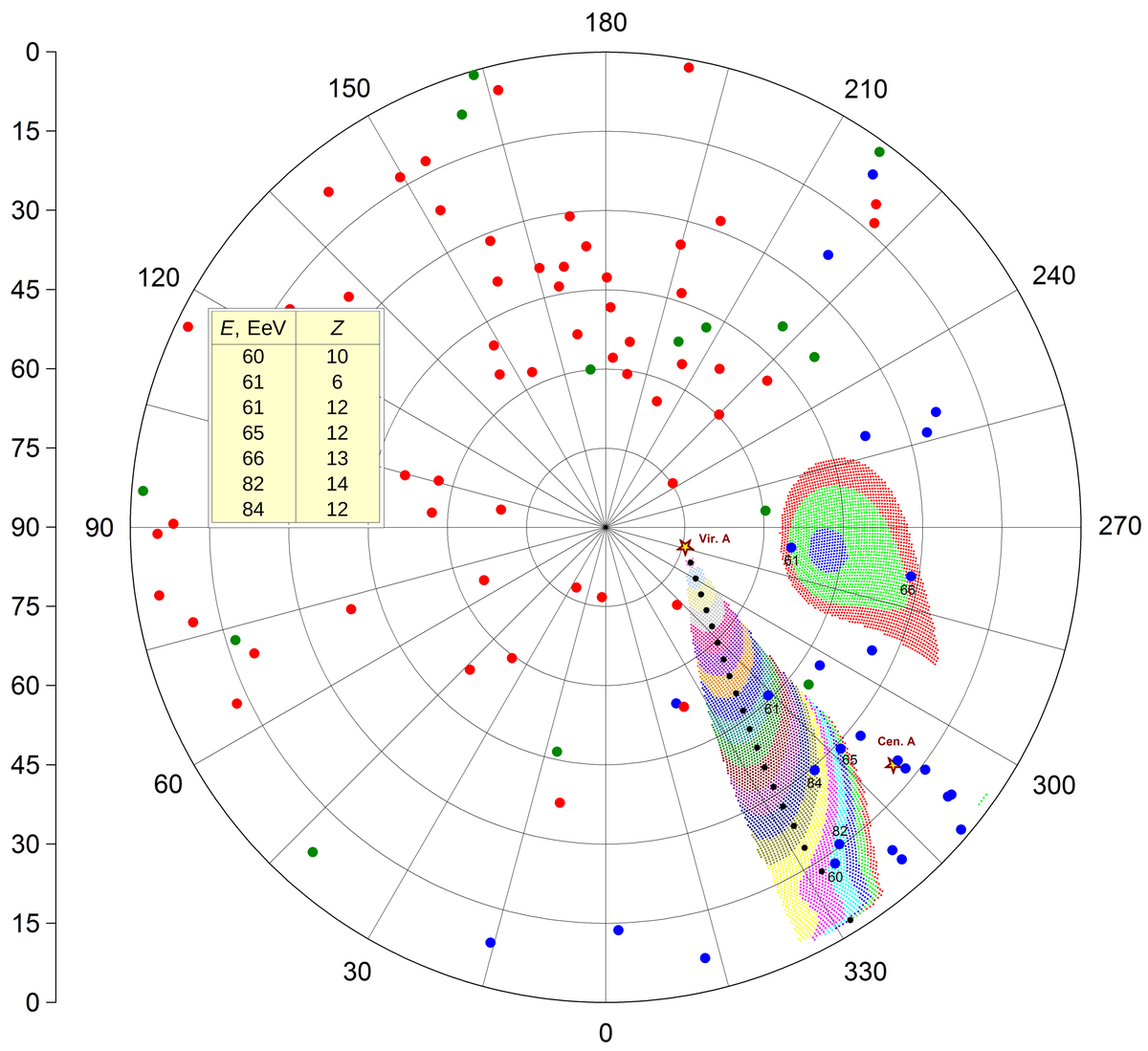

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