Probing UHECR and cosmic ray ensemble scenarios with a global CREDO network

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Please also follow the contribution ID 1448 “Invitation to the Cosmic Ray Extremely Distributed Observatory“ by P. Homola.

General Introduction: Among theoretical approaches in unveiling the physics of ultra-high-energy cosmic rays (UHECR) one can distinguish the models assuming interactions of exotic super-heavy matter (including extra dimensions, Lorentz invariance violation, cosmic strings, dark matter particles or particles beyond the standard model etc.) and acceleration scenarios describing processes, in which the particles are accelerated by a particular astrophysical object (shocks in relativistic plasma jets, unipolar induction mechanisms, second-order Fermi acceleration, energy transfer from black holes or compact stars etc.). Special interest is also paid to understanding of the cosmic ray ensembles (CRE) – the phenomena composed of at least two cosmic ray particles, including photons, with a common primary interaction vertex or the same parent particle with correlated arrival directions and arrival times. In this contribution, we review various theoretical UHECR models and CRE scenarios potentially observable by the global Cosmic Ray Extremely Distributed Observatory (CREDO).

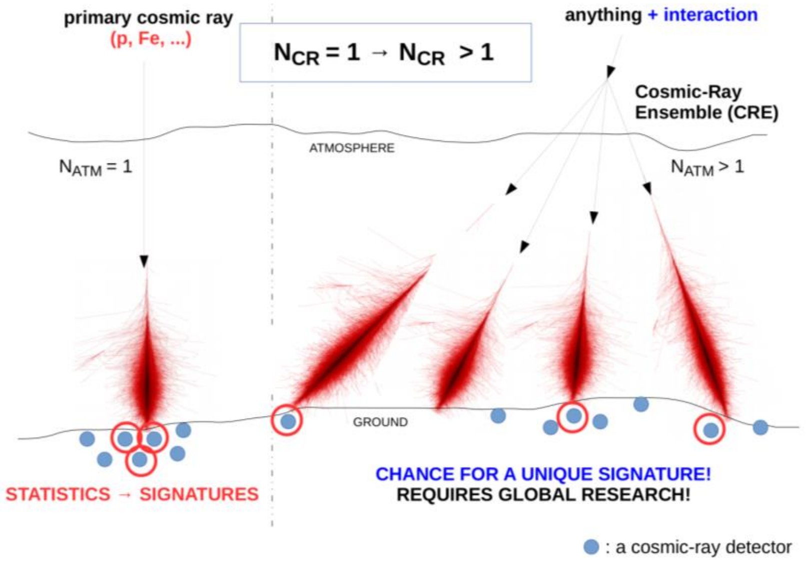

Fig. 1. Cosmic-Ray Ensembles: a novelty in cosmic-ray research.

Acceleration of UHECR & Cosmic-Ray Ensembles: In the age of multi-wavelength and multi-messenger astronomy, transient astronomical objects are of the great interest for UHECRs emission. There are several classes of astronomical objects which can be prime targets for UHECR observations e.g., gamma-ray bursts; supernovae; fast radio bursts; AGNs; radio galaxies and blazars. A candidate source of UHECR, if an astrophysical object, has to fulfil several conditions, such as power, radiation & interaction losses, geometry, accompanying radiation that can be in particular seen as the CRE. Several models have been proposed (see this review), which are the subjects of intensive studies within the CREDO collaboration. We are aimed to predict and find unique signatures of given scenarios using the global CR observations realized by the CREDO program and beyond. Possible astronomical source of UHECR must fulfil the Hillas criterion:

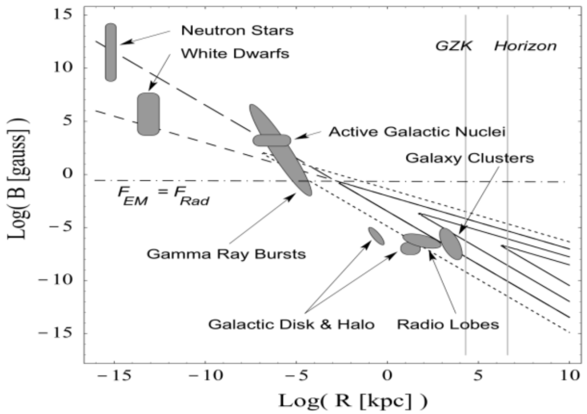

Fig. 2. The Hillas diagram, showing the magnetic field versus object size. See the review by CREDO col. in Symmetry **2020.**

Probe of exotic scenarios: we also investigate the alternative theories accounting the possibility of their probe with the global CREDO network of detectors. These scenarios include e.g. the hypotheses of existence of new exotic particles, such as super-heavy, dark matter and axion-like particles, which can serve as UHECR. More details can be found in this review.

UHECR as the Spacetime Structure Probe? The CRE hypothesis can be considered an explanation for several outlying cosmic-ray measurements. CREDO can offer a chance to confirm or question the aforementioned historical reports, potentially leading to the observation of New Physics effects, including probing the spacetime structure. The cumulative time delay of higher energy photons correlated with respect to the lower energy ones might or might not depend on photon energies. In CREDO, we hope to observe CRE composed of high-energy photons of different energies, possibly spanning the whole cosmic-ray energy spectrum, i.e., from GeV to ZeV; then we will have a new “spacetime probe” at hand that can further constrain the available spacetime models and theories.

Global network of CREDO detectors: investigation of large scale cosmic-ray correlations in the form of widely defined CRE require a global approach to cosmic-ray research. The role of CREDO can be understood as an umbrella research program that enables a collaborative effort dedicated to CRE with the use of existing infrastructure and expertise, and with openness for designing and building complementary detectors or arrays.

Fig.3.: the CREDO concept. More info is given in this review.