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Review

Is Cen A surrounded by tens-EeV UHECR multiplet?

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ABSTRACT

Ultra High Energy Cosmic Rays (UHECR) at GZK cut off energy ($E \geq 5.5 \cdot 10^{19}$ eV) may keep sharp or diffused directionality wherever their composition is made by nucleon or light nuclei. Auger experiment UHECR (2007–2010) did show a mild clustering around Cen A. Two over three of the recently discovered AUGER multiplet (a dozen of events each) tails clustering at twenty EeV are pointing to primary sources very near the same UHECR crowded Cen A region. These twin tens-EeV UHECR tail is aligned with the same UHECR events. We foresaw such a possibility as fragment tails of lightest UHECR nuclei. We discuss the relevance of this correlation within a model where UHECR clustering along extragalactic Cen A are mostly lightest He like nuclei. UHECR fragment multiplet clustering aligned along higher Cen A events (above $5.5 \cdot 10^{19}$ eV energy) probe and reinforce our interpretation with an a priori probability to occur below $3 \cdot 10^{-5}$.

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1. Fragments in flight along UHECR

UHECR Astronomy and nuclear composition are more and more often in severe conflict. This contradiction was already apparent early on, during the discovery of a Super Galactic UHECR correlation [1]. In that key article the required UHECR directionality (assumed nucleon) have been, at the same time, in disagreement with the first observed nuclei composition. Indeed UHECR particle astronomy may rise, suffering however from some directionality spread by the smearing of magnetic field bending along the UHECR flight. This bending is negligible for protons and He, but severe for iron. The bending may be coherent (just one direction) if the magnetic field is constant or random, if the field directions are changing, as it happens inside the galactic plane along and across the galactic arms while pointing to Cen A. The nucleon, the light nuclei may keep more or less precise directionality, a smearing astronomy, while heaviest ones may exhibit only tiny anisotropy if sources are near. In addition to these signals, UHECR in flight are making fragment secondary nuclei as well as, because of photo-dissociation, parasite gamma and neutrino tails which are somehow correlated. These UHECR compositions lead to different secondary gamma and neutrino spectra; these different natures are making UHECR nucleon origination local and well directed (GZK cut off, tens of Mpc distances) or even much more local and smeared (a few Mpc) for our lightest UHECR nuclei considered in recent articles [2]. Heavy nuclei may also have, by photon-disruption, a gamma and neutrino secondary tail, probably so smeared as to sink into background noise; if UHECR are only iron, as some authors still believe, than UHECR astronomy, in particular the extragalactic one, will be so bent, polluted and smeared as to be hopeless; only large scale iron anisotropy might occur by nearest galactic sources. On the contrary, extragalactic lightest nuclei UHECR astronomy may be surrounded by a parasite (a little smeared) trace made by point source gamma, neutrinos (TeVs–PeVs) and also tens of EeV energy UHECR fragments. We have suggested this possibility for a few years [3]. The lightest UHECR nuclei model [2] is able to explain the surprising absence or paucity of events toward Virgo (the nearest extragalactic cluster of galaxy) and the angle range 10°–15°, the spread directionality (orthogonal to galactic arms) of events around and along Cen A. A large

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number of authors discussed mainly the spectra of UHECR cut off as a key discriminator for UHECR modeling. However the mass composition role may confuse the real shape of any (apparent) GZK cut off. We address more on the UHECR anisotropy nature, able we hope to correlate UHECR maps and composition, using all radio, IR, gamma MeV–GeV–TeV, maps available.

1.1. Deuterium, proton, gamma and neutrino tails

UHECR formed (mostly) by lightest nuclei may explain a partial clustering of events, as the one around CenA as well as a puzzling UHECR absence around Virgo. Light nuclei are fragile and fly a few Mpc before being halted by photo-disruption [2,4,5]. Their fragments $He + \gamma \to D + D$, $D + \gamma \to p + n + \gamma$, $He + \gamma \to He^3 + n$, $He + \gamma \to T + p$ may nevertheless trace the same UHECR maps by a secondary clustering at half or even a fourth of the UHECR primary energy [3]. Neutrinos and gamma are tracing (both for nucleon or light nuclei) their UHECR trajectory, respectively growing at EeVs (if nucleon) or PeV–TeV (if light nuclei) energy. Gamma secondary rays from cosmic sources are partially absorbed by microwave and infrared background making once again a very local limited UHECR-gamma astronomy. Among neutrinos ν, muons ν_μ, the most penetrating and easy to detect on Earth, are unfortunately deeply polluted by a rich atmospheric component (as smeared and as the isotropic parent CR nucleons and nuclei). This atmospheric isotropy and homogeneity is probed by last TeV muon neutrino maps in a very smooth ICECUBE neutrino map. Tau neutrinos on the contrary, the last neutral lepton discovered, are almost absent in atmospheric secondaries (about five orders of magnitude suppressed at TeVs). Rare $\nu_\mu \to \nu_\tau$ neutrino oscillation at ten GeV atmospheric windows, may nevertheless arise; at tens of TeV–PeV up to EeV, the ν_τ neutrino might be a clean signal of UHECR-neutrino associated astronomy [6]. Their tau birth in ice may shine as a double bang (disentangled above PeV) [7]. In addition UHE tau, born tangential to the Earth or a mountain, while escaping in air may lead, by decay in flight, to loud, amplified and well detectable tau-airshowers at horizons [8,6], both in atmospheric fluorescence tracks or by Cherenkov blazing, or by partial skimming ground detectors. Tau astronomy versus UHECR is going to reveal the most violent sky as the deepest probe. These tau airshowers or Earth skimming neutrinos [9] have been considered for more than a decade and are going to be observed in AUGER or TA in a few years [6,10,9,11]. Regarding the puzzle of UHECR let us also remind that more than a decade ago we were facing and an obsolete problem due to AGASA and Fly Eyes events; such events were calling for sources at distances above GZK cut off. The solution was based on very far (distances larger than GZK cut off) sources ejecting primary UHE neutrinos at ZeV energy scattering on relic (cosmic) ones making Z bosons in flight and, after decay, UHECR nucleons on Earth [12].

2. Multiplet: Cen A, Magellanic stream and galactic sources

In recent maps of UHECR we noted the first hint of Vela (see Fig. 3), the brightest and nearest gamma source, a first galactic source is rising as a UHECR triplet nearby [13]. Since the earliest maps we found that Cen A (the most active and nearby extragalactic AGN) is an apparently shining UHECR source whose clustering (almost a quarter of the event) along a narrow solid angle around (whose opening angular size is $\simeq 17°$) seems firm and it is favoring as we mentioned, the lightest nuclei [2,14,13,4]. Remaining UHECR events are possibly heavier nuclei more bent and smeared of galactic and–or partially nearby extragalactic origin, as a possible Magellanic stream (see Fig. 3) following the third multiplet disposal. As we mentioned in the abstract UHECR map, initially (2007) consistent with GZK volumes [1], to day (2010 map) seem to be not very correlated with the expected Super Galactic Plane [15]. Moreover the slant depth data of UHECR from the AUGER airshower shape do not favor the proton but points to a nuclei. To create even more confusion HIRES, on the contrary, seems to favor, with less statistical weight, UHECR mostly nucleons. We tried (at least partially) to solve the contradictions assuming UHECR mostly as light nuclei (He^4 and maybe Li, Be) spread by planar spiral galactic fields, randomly, bending them as observed, vertically to galactic axis.

2.1. The Lorentz bending and the UHECR and multiplet

Cosmic Ray directions are blurred by magnetic fields. Also UHECR suffer from a Lorentz force deviation, more if nuclei, little if nucleon. As mentioned this smearing may be a source of UHECR features. We see them mostly along Cen A. There are at least three main bendings of UHECR along the galactic plane. The extra-galactic events in intergalactic spaces do not suffer from much bending. However UHECR in late (local group, galactic) bending feel coherent galactic arm fields, as well as random fields due to the turbulence or random fields along the whole galactic plane, or inside each arm. Let us renumber them:

(1) The coherent Lorentz angle bending δ_{Coh} of a proton (or nuclei) UHECR (above GZK [16]) within a galactic magnetic field in a final nearby coherent length of $l_c = 1 \cdot kpc$ is $\delta_{Coh-p} \cdot \simeq 2.3° \cdot \frac{Z}{Z_H} \cdot \left(\frac{6 \cdot 10^{19}\ \mathrm{eV}}{E_{CR}}\right) \left(\frac{B}{3 \cdot \mu G}\right) \frac{l_c}{kpc}$.

(2) The random bending by random turbulent magnetic fields, whose coherent sizes (tens parsecs) are short and whose final deflection angle is smaller than others and they are here ignored.

(3) The random, but alternate, multiple UHECR bending along the galactic plane across an alternate arm magnetic field, whose directions are inverted from each other (see Fig. 2). Its effect will be a ruling for UHECR and multiplet Cen A bending.

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