Updated Z-Burst Neutrinos at Horizons.

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Recent homogeneous and isotropic maps of UHECR, suggest an isotropic cosmic origin almost uncorrelated to nearby Local Universe prescribed by GZK (tens Mpc) cut-off. Z-Burst model, based on UHE neutrino resonant scattering on light relic ones in nearby Hot neutrino Dark Halo, may overcome the absence of such a local imprint and explain the recent correlation with BL-Lac at distances of a few hundred Mpc. Z-Burst multiple imprint, due to very possible lightest non-degenerated neutrino masses, may inject energy and modulate UHECR ZeV edge spectra. The Z-burst (and GZK) ultra high energy neutrinos (ZeV and EeV band) may also shine, by UHE neutrinos mass state mixing, and rise in corresponding UHE Tau neutrino flavor, whose charged current tau production and its decay in flight, maybe the source of UHE showering on Earth. The Radius and the atmosphere of our planet constrains the \( \tau \) maximal distance and energy to make a shower. These terrestrial tau energies are near GZK (\( 10^{19} \) eV). Higher distances and energies are available in bigger planets (up to \( (6 \cdot 10^{19} \) eV)); eventual solar atmosphere horizons may amplify the UHE tau flight allowing tau showering at ZeV energies (3.5 \( \cdot 10^{20} \) eV), offering a novel way to reveal the expected Z-Burst extreme neutrino fluxes.

1. UHECR Isotropy and Spectra.

The real Ultra High Energy (UHE) Cosmic Rays (CR), UHECR, paradox following K. Greisen, G.T. Zatsepin, V.A. Kuz'min, the famous GZK cut off, lays not just in the (contro-versial but nevertheless established) existence of UHECR spectra above GZK (\( \sim 4 \cdot 10^{19} \) eV) energies, but also in the extreme homogeneous and isotropic map of their arrival directions. The absence of any correlation or hint of nearby sources (G.C, Virgo, Super-Galactic Maps) is, in our opinion, a major growing puzzle. Let us briefly summarize the UHECR state of art:

1. The eventual appearance of a GZK cut-off as claimed by HIRES experiment [21] is in partial disagreement to the earliest AGASA data [23]. We note that a even more dramatic discrepancy takes place all along the UHECR spectra, by a factor two or more, from EeV energy band energy up to GZK edges, as shown in Fig[1][7]. This calibration problem maybe the source of the over-

all disagreement. The AUGER data seem to be consistent with HIRES more than AGASA, also at lower energies.

2. The absence of EeV correlation map, as claimed by AUGER, with Galactic Center might signal the premature end of a timid but exciting EeV neutron Astronomy, suggested by AGASA and SUGAR (see Fig[2]).

3. The absence of clear TeV correlation with UHECR, as noted in [14], disfavors a direct proton UHECR propagation at ten EeV energy [3], as well as the very possible neutral nature of the final UHECR associated to some BL-Lac source [21] (see Fig[3]). A gamma ray precursor or afterglow at UHECR arrival direction may disentangle the Z-Burst solution versus a primary proton candidate [14].

4. The Gorbunov, Tinyakov, Tkachev, and Troitsky [20] claim for an UHECR correlation with far BL-LAcs has been somehow excluded (as it was), but nevertheless it has been found out again, in a different set of records, by HIRES itself [21], therefore
Figure 1. Last Auger UHECR data versus HIRES and AGASA ones; it is remarkable how the disagreement between the spectra occurs already at few EeV energy band up to the most energetic edges. The arrows show the discrepancy all along the UHECR spectra among the AGASA versus HIRES-AUGER experiments [7].

BL-Lac are still on-stage candidate smoking gun for UHECR. Their imprint might be found in TeV gamma traces [14].

The BL-Lac sources that might be the primary objects (by their UHE jet emission toward us), are mostly located at distances quite above GZK volumes (hundreds of Mpc). Therefore either one find a reasonable way to transport these UHECR from cosmic edges to us (with negligible or null energy losses) or one must advocate for extreme random magnetic fields, $\sim 0.1 \mu$Gauss, in Universe to diffuse their maps. The latter seems quite unrealistic. In a total different frame-work tens EeV protons, long life and un-deflected in a nearly magnetic-free Universe has been proposed recently [3] (but see also critical remarks in [14]).

Among the exotic solutions for UHECR free arrival from cosmic edges, Lorentz invariance violation has been more and more advocated (but also dismissed) and even UHECR mirror neutrons have been postulated [2]. The Z-Burst model based on well established neutrino masses (even at $0.1 - 0.05$ eV) and on possible UHE neutrinos at ZeV energies [8, 20, 24], might solve quite naturally the puzzle without new assumption on.

New Physics.

1.1. UHECR and the BL Lac connection.

To make more compelling a UHECR - Z-Burst cosmic connection is the very possible correlation between most distant BL Lacs (found Gorbunov [20] group as the ones shown in Table 1, or in [21]) and UHECRs arrivals directions. These UHECR to reach us with the observed energy and to overcome the electron pairs energy losses, must be born at extreme energies, well above the ones needed for Z-Burst models [14]. Therefore the Z-Burst UHE neutrinos are more realistic than other extreme nucleon primary sources. It should be reminded that the very recent data by HIRES and Gorbunov group are finding correlation in a very narrow UHECR arrival angle, pointing for a neutral UHECR primary at ten EeV. Otherwise galactic field may slightly smear their directions. One must notice that among the Z-boson decay secondaries, UHE $\gamma$ rays (by neutral pion at ten EeV energy) are required. Their presence, nevertheless have been recently bounded by AUGER records [7]. However it maybe be that
Table 1
| EGRET Name   | z   | d (Mpc) | $E_{\text{obs}}$ ($10^{19}$eV) | $E_{\text{in}}$ ($10^{19}$eV) | Charge assignment |
|--------------|-----|---------|-----------------|-----------------|------------------|
| 0808+5114   | 0.138 | 455    | 3.4             | 9.2             | 0                |
| 1052+5718   | 0.144 | 475    | 7.76            | 14.7            | 0,-1             |
| 1424+3734   | 0.564 | 1861   | 4.97            | $6 \times 10^3$ | 0,+1             |
| 1850+5903   | 0.53  | 1750   | 5.8             | $10^4$          | +1               |

Figure 3. As above Last Auger UHECR data at ten EeV energy (633 events) from AUGER and overimpress the expected local mass (GZK volume) imprint, in negative colors. The absence of any correlation, (as for AGASA and HIRES records) confirm a surprising homogeneity and isotropy possibly of cosmic origin.

Figure 4. Z-Burst model is based on UHE ZeV neutrino, ejected by far cosmic BL-Lac, AGN sources, scattering onto relic light ones spread in huge Galactic Group Hot dark Halos. The halo radius maybe as large as GZK one and the Z decay might shower leading, among tens of pions, and gamma traces, to UHE neutral nucleons (neutron and anti-neutrons) or proton, anti-protons whose propagation and hitting the Earth arise as UHECR.

2. Z-Burst model for light neutrino mass.

The idea to use the relic neutrinos as a beam dump where to convert UHE cosmic $\nu$ and $\bar{\nu}$ hitting onto relic $\bar{\nu}$ and $\nu$ is multi-faces: it is already tuned, with present very possible light neutrino mass ($0.05 - 0.1$ eV) to UHE $\nu$ at $E_{\nu} = 4 - 2 \cdot 10^{22}$ eV and to the observed UHECR edges above $10^{20}$ eV, (namely $8 - 4 \cdot 10^{20}$ eV), fitting tens EeV photons secondaries. The light neutrino halo may extend to tens Mpc offering a wide nearly isotropic cloud to capture cosmic UHE ZeVs $\nu$ and $\bar{\nu}$. Fig.4 shows the scenario of such a large halo where UHE ZeV $\nu$ shower to observable nucleons: $p$, $\bar{p}$, $n$, $\bar{n}$. The last neutral ones are few Mpc long life.
while the charged ones are confined in a GZK volume (ten Mpc). The second role in light neutrino mass is the possibility to be so much light to split the mass degeneracy into twin or triple values. Consequently the Z-Burst may tune to different energies leading to different energy injection at UHECR spectra edges. Present and future large array, like Auger, may test this exciting UHE limits.

2.1. UHECR mirroring neutrino masses.

The different relic neutrino mass may be resonant in Z-boson production at different UHE incoming neutrino. The highest energy couple with the lightest neutrino mass. This has been noted and explained [9] and here summarized in Fig 7 and in Fig 8. The UHE incoming neutrino meets the lightest neutrino mass making a resonant Z-boson at different energies; the highest incoming $\nu$ energy scatters and resonates at lightest $\nu$ masses. The clustering of fermions are bounded by their $\nu$ masses (Pauli exclusion principle): the lightest relic $\nu$ reach a lower density contrast respect the heavier ones. Therefore the density and the interaction probability may also be enhanced in multi Z-Burst peak appearances at the UHECR edges (see Fig 7 and Fig 8).

3. UHE $\nu_\tau$ skimming the Sun.

The same UHE neutrinos at ZeV energy, predicted in Z-Burst model, might mix their primordial flavor, while travelling along stellar or galactic distances; for present atmospheric $\nu$ mixing a complete oscillation take place at a distance $L_{\nu_\mu \to \nu_\tau}$:

$$L_{\nu_\mu \to \nu_\tau} = 32 \text{ pc} \left( \frac{E_\nu}{10^{21}\text{eV}} \right) \left( \frac{\Delta m^2_{ij}}{2.5 \cdot 10^{-3}\text{eV}^2} \right)^{-1}$$
Figure 8. As above relic neutrino mass may be very light and totally non degenerated; each mass may interact at a different incoming neutrino energy: the lighter the $\nu$ mass the less is its clustering (Pauli principle) halo; the consequent neutrino scattering and its conversion probability in $Z$ boson is lower and lower, as shown in corresponding fluence figure tower height.

Figure 9. The interaction length of the tau and parental UHE neutrino in water, rock and solar atmosphere. For the best neutrino-tau conversion we considered here the sun limb where the solar density and pressure are a fraction of the terrestrial one (one third). The consequent approximated tau length is crossing the solar cord at $2 \cdot 10^4$ km size, in corresponding energies of ZeV values, shown by the two top arrows.

giving life to the most rare $\tau$ lepton components. These UHE $\nu_\tau$ (of Z-Burst nature), while interacting on terrestrial crust maybe source of skimming neutrinos (HorTaus [11], [12], preferentially at lower EeV energy band) whose ZeV tau decay in flight is too long, $\simeq 5 \cdot 10^4$ km, to be contained in Earth air atmosphere. It has been recently noted [19] that wider atmosphere layers are found in larger planets. The largest ones near Jupiter and Saturn may reach a corresponding $\tau$ energy at $4 - 6 \cdot 10^{19}$ eV. At ZeV energies the widest and nearest atmosphere horizons are found on our Sun. However such ZeV $\nu_\tau \rightarrow \tau$ solar grazing showers, while in general being discontinue, are making brief millisecond flashes. These showers may manifest themselves in wide areas (on far Earth detectors or satellites) by their overlapping and nearly persistent bremsstrahlung secondary pairs which are blazing into X-ray flare. This occurs while an observer is crossing into the beam showers cone radiated all along the sun limb edges; the solar skimming bremsstrahlung shower may mimic weakest solar flares or pulsed flashes within a narrow (few seconds) duration, due to the sharp density profile size of the sun ($\simeq 200 km$) where the phenomena occurs; these showers may be correlated to known sources arrival directions [19].

3.1. UHE $\nu_\tau$ and $\tau$ interaction lengths.
To estimate the UHE neutrino $\nu_\tau$ behavior while skimming the solar atmosphere, making its UHE $\tau$ whose later flight and decay may blaze at solar edges we show (see Fig.9) their interaction lengths in respect to the terrestrial cases. The tau showering at horizons has a long story [11], [12], [16], [17], [18], [4], [5]. The interaction length play a key role: the $\tau$ energy losses in solar atmosphere allows to reach distances as large as $2 \cdot 10^4$ km, because of the much large solar radius (than Earth one, by a factor 109) and its larger height growth (25 times the terrestrial ones); see also [19]. The consequent place where best tau skimming occur has an energy a ZeV edges, as shown in Fig.9

4. Conclusions
Z-Burst is still an open solution to UHECR puzzling isotropy, BL Lac Connections and possible future showering in solar edges. Z-Burst may
reflect itself, because of non-degenerated neutrino mass splitting, into a surprising anti-GZK bump modulation in Zev UHECR spectra edges. The field is growing and need to be carefully followed in view of the Auger near future response.

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