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Ultrahigh energy neutrinos scattering off relic light neutrinos to explain UHECR above GZK cut off and thin blazars jets

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Abstract

UHE neutrinos may transfer highest cosmic-rays energies overcoming $2.75K^{\circ}$ BBR and radio-waves opacities (the GZK cut off) from most distant AGN sources at the age of the Universe. These UHE ν might scatter onto those (light and cosmological) relic neutrinos clustered around our galactic halo or nearby neutrino hot dark halo clustered around the AGN blazar and its jets. The branched chain reactions from a primordial nucleon (via photoproduction of pions and decay to UHE neutrinos) toward the consequent beam dump scattering on galactic relic neutrinos is at least three order of magnitude more efficient than any known neutrino interactions with Earth atmosphere or direct nucleon propagation. Therefore the rarest cosmic rays (as the 320 EeV event) might be originated at far $(\tilde{>}100Mpc)$ distances (as Seyfert galaxy MCG 8-11-11); its corresponding UHE radiation power is in agreement with the observed one in MeV gamma energies. The final chain products observed on Earth by the Fly's Eye and AGASA detectors might be mainly neutron and anti-neutrons and delayed, protons and anti-protons at symmetric off-axis angles. These hadronic products are most probably secondaries of W^+W^- or ZZ pair productions and might be consistent with the last AGASA discoveries of doublets and one triplet event.

1 Introduction:

Most energetic cosmic rays UHE $(E_{CR} > 10^{19} eV)$ are bounded to short $(\tilde{<}10Mpc)$ distances by the 2.73 K BBR opacity (Greisen K.1966; Zat'sepin G.T., Kuz'min V.A., 1966) (the GZK cut off) and by diffused radio noise (Clark T.A. et al.1970,Protheroe R.J.,Biermann P.L. 1996. The main electromagnetic "viscosities" stopping the UHE cosmic ray (nuclei, nucleons, photons, electrons) propagation above $\sim 10Mpc$ are:
(1) The Inverse Compton scattering of any charged lepton (mainly electrons) on the BBR $(e^{\pm}_{CR}\gamma_{BBR} \to e^{\pm}\gamma)$ (Longair 1994),(Fargion et all 1997),(Fargion D.,Salis A. 1998),
(2) the nucleons photopair production at higher energies $(p_{CR} + \gamma_{BBR} \to pe^+e^-)$,
(3) the UHE photon BBR or radio photon electron-pair productions $(\gamma_{CR}\gamma_{BBR} \to e^+e^-)$,
(4) nuclei fragmentation by photo-pion interactions.
(5) the dominant nucleon photo-production of pions $(p_{CR} + \gamma_{BBR} \to p + N\pi; n + \gamma_{BBR} \to n + N\pi)$.

The above GZK constrains apply to all known particles (protons, neutrons, photons, nuclei) excluding neutrinos. Nevertheless, the UHE cosmic rays, either charged or neutral, flight straight keeping memory of the primordial source direction, because of the extreme magnetic rigidity (Bird D.J. 1994). However all last well localized and most energetic cosmic rays (as the Fly's Eye 320 EeV event on October 1991) do not exhibit any cosmic nearby $(< 60Mpc)$ source candidate in the same arrival direction error box. Indeed even most recent data from AGASA (Takeda et all 1999)show the clustering of doublets and one triplet UHE cosmic rays. These events might be associated with Markarian sources (as Mrk 359,Mrk 40,Mrk 171) at distances (¿50Mpc) well above GZK cut-off. From here the UHE cosmic ray paradox arises: the few known solutions are difficult to be accepted.

2 Possible solution to GZK puzzle.

(a) An *exceptional* $(B\tilde{>}10^{-7}Gauss)$ *coherent* magnetic field on huge extra-galactic distance able to bend (by a large angle) the UHECR trajectory coming not from distant but from nearest off-axis sources like M 82 or Virgo A (Elbert J.W,Somers P.,1995). This solution was found not plausible (Medina-Tanco, G.A., 1997).

(b) Exotic topological defect annihilations (Elbert J.W,Somers P.,1995) in diffused galactic halo is an ad hoc, and a posteriori solution. Moreover it is in contradiction with recent evidences by AGASA detector of data inhomogeneities, i.e. of doublets or triplet UHECR events arriving from the same directions. (Takeda M. et al., 1998)
(c) A galactic halo population of UHECR sources (as the fast running pulsars associated with SGRs(Fargion D., Salis A., 1995)). These small size (neutron star - black-hole) jets source must be extremely efficient in cosmic ray acceleration at energies well above the expected maximum energy $E < BR \tilde{<} 10^{17} eV (\frac{B}{3.10^{-6}G})(\frac{R}{50pc})$ required by a supernova accelerating blast wave. Moreover their extended halo distribution must exhibit a dipole and/or a quadrupole UHECR anisotropy, signature not yet identified. Therefore it seems at least premature to call for a solution by local galactic or local group sources as microquasar jets.
(d) A direct nucleus or a nucleon at high energies will be severely suppressed by GZK (10^{-5}) cut off and, more dramatically, they will induce a strong signal (hundreds) of secondaries cosmic rays at energies just below the GZK bound; indeed such a copious signal is absent.

3 UHE neutrino-antineutrino interaction in galactic halo solving the GZK puzzle

Our present (Fargion D., Salis A., 1997; (Fargion D., Mele B., Salis A., 1997) solution is based on the key role of light $(m_\nu \tilde{>} eV)$ cosmic neutrinos clustered in extended galactic halo. These relic neutrinos act as a target calorimeter able to absorb the UHEν's from cosmic distances and to produce hadronic showers in our galaxy. The primary UHECRs are the usual AGNs or Blazars able to produce huge powers and energies. Their electronic production and decays, near the source, into muonic and electronic neutrinos, generate the main νs messenger toward cosmic distance up to our galactic halo. Their final interactions with clustered relic ν_r (and $\bar{\nu}_r$) of all flavours (but preferentially with the heaviest and best clustered one $(\nu_\tau, \bar{\nu}_\tau)$) may offer different channel reactions:
(A) $\nu\bar{\nu}_r$ scattering via a Z exchanged in the s channel leading to nucleons and photons.
(B) $\nu\bar{\nu}_r$ scattering via t-channel of virtual W exchange among different flavour. This is able to produce copious UHE photons (mainly by $\nu_\mu\bar{\nu}_\tau \to \mu^-\tau^+$ and τ pion decay),
(C) $\nu\bar{\nu}_r$ production of W^-W^+ or ZZ pairs. The latter channels are in our opinion the best ones to produce final nucleons $(p, \bar{p}, n, \bar{n})$ which fit observational data.

The UHE ν cross section interacting with relic $\nu_\tau, \bar{\nu}_\tau$.

The general framework to solve the GZK puzzle we proposed is a tale story beginning from a far AGN source whose UHE protons $(E_p \tilde{>} 10^{23} eV)$ are themselves a source of pions, secondaries muons and UHE neutrinos. The latter may actually escape the GZK cut off, traveling unbounded all the needed cosmic distances $(\sim 100 Mpc)$. Once near our galactic halo, the denser gravitationally-clustered light relic neutrinos, forming a hot dark halo, might be able to convert the UHE ν's energies by scattering and subsequent decays into observable nucleons (or anti-nucleons), the final observed UHECR remnants. The $\nu - \nu$ interaction cross-sections are the key filter which makes possible and efficient the whole process. In fig. 1 from (Fargion D., Mele B., Salis A., 1997) we show the three main processes cross-section as a function of the center of mass energy s. The s - channel $\nu_\mu\bar{\nu}_{\mu R} \to Z$ which exhibits a resonance at $E_\nu = 10^{21} eV (\frac{m\nu}{4eV})^{-1}$ and the t - channel $\nu_\mu\nu_{\tau_R} \to \mu^-\tau^+$ via virtual W. These reactions are the most probable ones but UHE photons seem to be excluded by geomagnetic high altitude cut off. The $\nu\bar{\nu}_\tau \to W^+W^-$ cross section is also shown. There is an additional Z pair production channel $\nu\bar{\nu}_\tau \to ZZ$ almost coincident in its general behaviour with the W^+W^- production. It is not shown on the figure, but its global contribution (to be discussed elsewhere) is to almost double the $\nu\bar{\nu}_\tau \to W^-W^+$ chain products making easier their detection. The reaction chain from the primordial proton, via electronic production and neutrino-neutrino interactions down to the final cosmic ray event considered, the corresponding probability the consequent multiplicity are discussed in (Fargion D., Mele B., Salis A., 1997).

Assuming that the clustered neutrino density contrast is comparable to the barionic one $\frac{n\nu_\tau}{n\nu_{BBR}} \sim \frac{\rho_G}{\rho_W} \sim 10^{5\div 7}$, one finds the total probability of the processes and the corresponding needed primordial proton energy E_p^{WW}. The probability (taking into account the global multiplicity) to occur is at least $P^{WW} \tilde{>} 10^{-3}(\frac{m\nu}{10eV})^{-1}$ corresponding, for the candidate source MCG 8-11-11, to a needed average power $E^{WW} \sim 1.2 \cdot 10^{48} ergs^{-1}$. This value is comparable with the MCG8-11-11 observed low-gamma MeV luminosity $(L_\gamma \sim 7 \cdot 10^{46} ergs^{-1})$. We predicted parasite signals photons at $10^{16}eV$ energies (Fargion D., Mele B., Salis A., 1997) as well as a peculiar imprint on larger sample data, due to the central overlapping of neutron-antineutron prompt arrival toward the source line of sight. Additional twin (deviated) signals due to proton and antiprotons random walk will arrive late nearly at opposite (few degrees off-axis) sides. These characteristic signatures might be already recorded by AGASA in the last few doublet and triplet UHECR and associated events. The UHE neutrinos above the GZK cut-off are observable from almost all the Universe while the corresponding UHE nucleons (or gamma) above the GZK energies are born in a smaller constrained "GZK" volume of a ten of Mpc. Therefore the expected flux ratio for UHE ν's over nucleons or photons at GZK energies is roughly (in Euclidean approximation) independently on the source spectra:

$$\frac{\phi_\nu}{\phi_{GZK}} \sim [\frac{z_\nu}{z_{GZK}}]^{3/2} \simeq 3 \cdot 10^4 \eta (\frac{z_\nu}{2})^{3/2} (\frac{z_{GzK}}{2 \cdot 10^{-3}})^{-3/2}$$

where z_ν is a characteristic UHE ν' source redshift $\simeq 2$ and $z_{GZK} \sim 2 \cdot 10^{-3}$. Assuming an efficiency ratio η for the conversion from UHE proton to UHE ν's of a few percent, the ratio $\phi_\nu/\phi_{GZK} \tilde{>} 10^3$ is naturally consistent with the inverse probability $(P^{WW} \tilde{>} 10^{-3})^{-1}$ found above.

Therefore a 10^{+3} fold larger flux of UHE ν's (than the corresponding nucleon cosmic ray flux) above GZK (mainly of tau nature (Fargion D., B.Mele, Salis A., 1997) should be observed easily in a Km^3 neutrino detector in a very near future. This prediction is somehow in disagreement with recent controversial upper bounds on neutrino fluxes (Waxmann & Bachall 1999).

Finally the same presence of relic clustered neutrinos around the AGN source should reveal the thin neutrino jet at wide distances (∼Mpc) from central engine of the jet. Indeed the UHE ν jet may dissipate (with low but non negligible efficiency) its energy with the relic νs at far distances ($\geq 10Kpc$) leading to UHE electron pairs which may be the source (by synchrotron radiation) of X and gamma radiation all along the thin jet. These UHE electrons, if they had directly arisen from the source, cannot escape far away (few pc) from the AGN because of the Inverse Compton Scattering "viscosity". Their presence in the thin AGN jet far away (tens Kpc) from the source might be associated only with UHE ν-ν_r scattering as proposed in the present paper.

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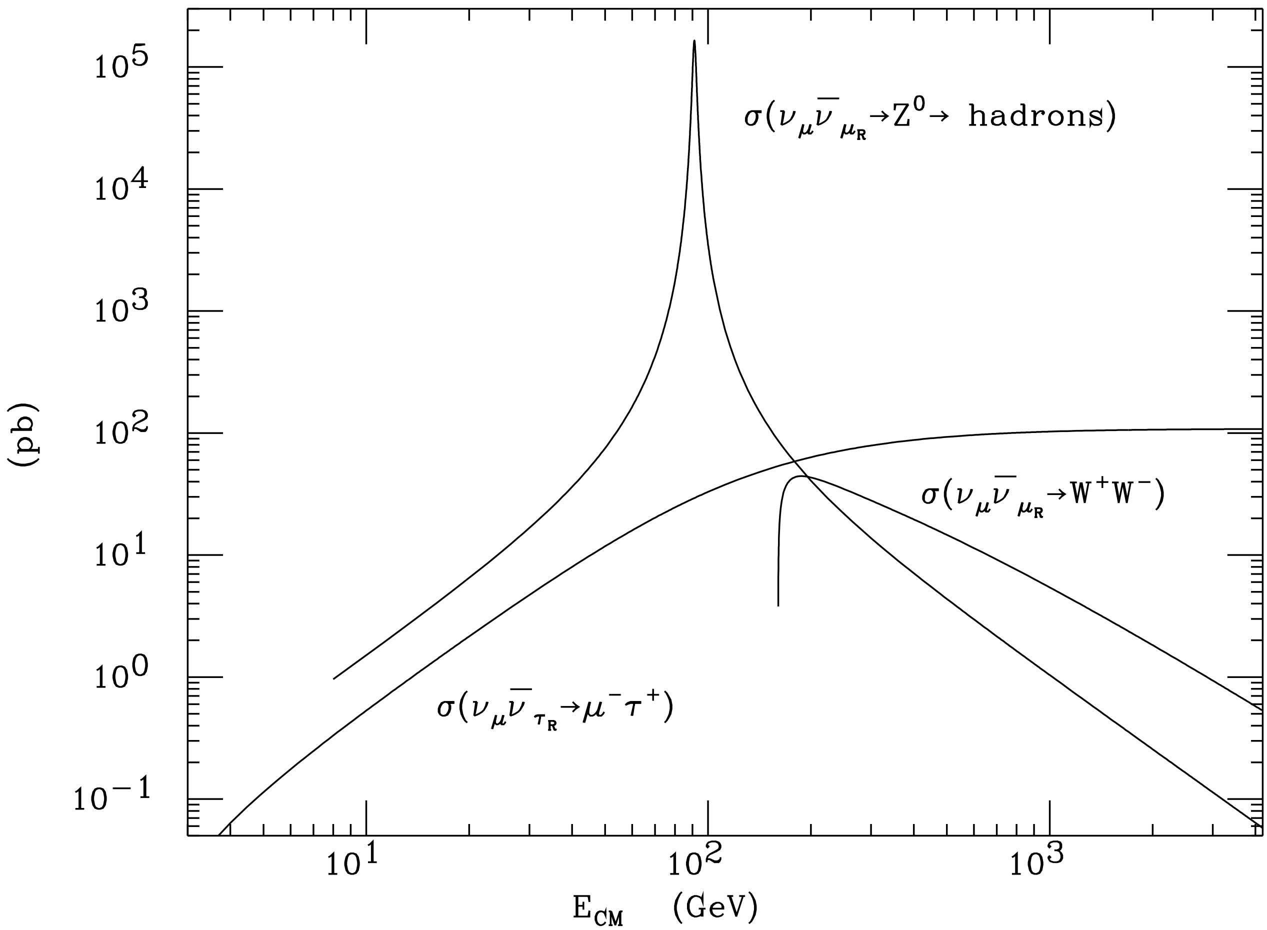

Figure 1: