Essay

Mapping the Universe Using Cosmic Neutrinos

Matti Pitkänen [1]

Abstract

This article was inspired by the findings of the IceCube neutrino laboratory. The most recent findings show that the high energy neutrino background in the galactic plane could be caused by the galactic nucleus and is by a factor 1/100 too small to be produced by the interactions of high energy cosmic rays with very strong magnetic fields. The neutrino flux is so weak in the case of Earth that the Milky Way is described as a neutrino desert. Earlier discovery by IceCube of ultrahigh energy (UHE) cosmic neutrinos coming from galaxies TXS and NGC suggest that they originate from active galactic nuclei (AGNs). Unlike in the case of NGC, AGN is a quasar in the case of TXS so that its jet points toward the Earth. There are notable differences between these neutrino sources. In this article, a TGD based model for the sources of UHE neutrinos and for the neutrino propagation mechanisms is proposed. The model relies on a new view of space and on a general model of astrophysical objects inspired by the notion of cosmic strings as 4-D surfaces in $M^4 \times CP_2$ having 2-D string world sheet as M^4 projection.

1 Introduction

The Quanta Magazine article "A New Map of the Universe, Painted With Cosmic Neutrinos" (`rb.gy/0yd7g`) tells about the findings suggesting that ultrahigh energy (UHE) neutrinos do not originate from a continuous diffuse source but from discrete sources, presumably active galactic nuclei (AGNs).

1.1 The findings IceCube related to Milky Way neutrinos

Consider first the most recent observations of the IceCube laboratory.

1. A mapping of the Milky Way is carried by the IceCube laboratory using high energy neutrinos. Diffuse haze of cosmic neutrinos is found to be emanating along the plane the Milky Way [1]. Neutrinos could emanate from the inner region of Milky Way (`rb.gy/kp6ll`) [2], or even from the galactic blackhole.

2. If the neutrinos were generated in the collisions of very high cosmic rays, accelerated in ultra strong magnetic fields in the galactic plane, perhaps magnetic fields prevailing near the galactic blackhole, their flux would be by a factor of 100 higher than the observed flux. This suggests that active galactic nuclei (AGN) are the sources of UHE neutrinos.

3. The neutrino flux from milky Way is by a fact or order 1/100 lower than from other galactic sources so that that Milky Way might be called neutrino desert [3].

1.2 The findings IceCube related to discrete sources of cosmic neutrinos

IceCube studies have already earlier connected UHE cosmic neutrinos with individual sources.

1. IceCube found [5] that the galaxy called TXS 0506+056 (`rb.gy/ypekf`), briefly TXS, was emitting UHE neutrinos and flares of X-rays and gamma rays simultaneously. The distance of TXS is 5.7 billion light years. TXS is a blazar (`rb.gy/468q7`), which means that there is a jet directed towards the Earth. The neutrinos and other high energy particles arrive along this jet.

[1] Correspondence: Matti Pitkänen `http://tgdtheory.fi/`. Address: Rinnekatu 2-4 8A, 03620, Karkkila, Finland. Email: matpitka6@gmail.com.

2. IceCube has also found a second patch emitting UHE neutrinos [4]. It has an active galaxy NGC 1068 (Messier 77) (`rb.gy/hgi3w`) in the center. It is located at a distance 47 million light years, which is by a factor of 1/100 smaller than the distance of the TSX. Gamma ray burst is absent is absent in this case. One proposal is that the high energy neutrinos and gammas arrive along the galactic plane but there is an absorption of gamma rays by the matter at the galactic plane near the active galactic nucleus.

   A possible explanation is that high energy neutrinos arise in the decays of cosmic rays, which have accelerated in very strong magnetic fields. These magnetic fields could be associated with the stars that become supernovas or when two neutron stars collide. they would be accompanied by gamma ray bursts and high energy neutrinos. The problem is that the flux of high energy neutrinos should be much higher. AGNs therefore remains the only viable candidate.

2 Could TGD allow to understand the findings of IceCube?

Could TGD (Topological GeometroDynamics) based view of astrophysics explain these findings? TGD predicts a lot of new physics. Geometrization and number theoretization of quantum physics provide complementary approaches to TGD.

2.1 What is the origin of UHE neutrinos?

Consider first an explanation for the origin of UHE neutrinos and for their huge energies.

1. Number theoretical vision predicts a hierarchy of p-adic physics, where p is the prime characterizes p-adic number field. Number theoretically p would correspond to a ramified prime for an extension of rationals assignable to a given space-time region. One of the basic conjectures is p-adic length (mass) scale hypothesis stating the existence of a a hierarchy $L_p = L(k) \propto 2^{k/2}$, $p \simeq 2^k$, k some integer, of p-adic length scales. This hypothesis is central in p-adic mass calculations, which replace the Higgs mechanism with p-adic thermodynamics [7].

2. Family replication phenomenon is one of the mysteries of recent day particle physics. In the TGD Universe family replication phenomenon has topological origin [6] [8].

   Elementary particles have as basic building bricks partonic 2-surfaces assignable to the wormhole contacts with Euclidean signature of the induced metric and connecting two space-time sheets with a Minkowskian signature of induced metric. Partonic 2-surfaces carry fermions as point-like particles at the ends of strings connecting partonic 2-surfaces to each other.

   The partonic 2-surfaces are characterized by genus g identifiable as the number of handles attached to 2-sphere. The lowest 3 genera (with handle number $g = 0, 1, 2$) always allow global Z_2 conformal symmetry unlike the higher genera. The proposal is that this means that for these genera the g handles form a bound state (trivially for $g \leq 2$) whereas for $g \geq 2$ one has many-handle states with a mass continuum so that one does not obtain elementary particles. The 3 fermion genera are assumed to give rise to a combinatorial symmetry $U(3)_g$ and the 3 fermion generations correspond to the fundamental representation 3_g.

3. In TGD there are no bosons as fundamental particles. Bosons would correspond to fermion antifermion bound states of fundamental fermions. This suggests that gauge bosons and Higgs correspond to the tensor product of 3_g and its conjugate representation so that bosons would correspond to the $8_g + 1_g$, where 8+1=9 is the dimension of the dynamically generated symmetry group $U(3)_g$.

   Ordinary bosons would correspond to $SU(3)_g$ singlet 1_g. Besides this new exotic boson octet 8_g is predicted. The original proposal was that the 2 bosons of 8_g with vanishing $SU(3)_g$ quantum numbers in 8_g are light so that there would be 3 boson generations. This assumption is not necessary [9].

4. The ultrahigh energy (UHE) neutrinos (energy range [13 TeV, 7.9 PeV]) would correspond to very large p-adic mass scales characterizing the masscales for the analogs of weak bosons decaying to charged lepton and neutrino/antineutrino.

5. The lepton-neutrino pairs could be created in the decays of exotic counterparts of W bosons in 8_g. From the energies of UHE neutrinos one can conclude that these exotic bosons could correspond to the p-adic length scale $L(k = 61)$, where $p = 2^{61} - 1$ is Mersenne prime. Higgs, would be associated with the p-adic length scale $L(89)$, $p = 2^{89} - 1$. W and Z could correspond to p-adic primes with $k = 91$.

2.2 How to achieve the required ultra-high temperatures

These huge mass scales require an enormous temperature in [13 TeV, 7.9 PeV] range, possibly reached inside active galactic nuclei (AGNs). In standard physics it is difficult to imagine how high these temperatures could be achieved.

1. In the TGD Universe space-times are 4-D surfaces in $M^4 \times CP_2$. TGD predicts, besides Einsteinian space-time surfaces with 4-D M^4 projection, also space-time surfaces with 2-D M^4 projection. I have called them cosmic strings but they are not the cosmic strings of gauge theories. Cosmic strings have a huge string tension and energy identifiable as dark energy.

2. In TGD based view of galaxy formation, galaxies are formed as tangles along long cosmic strings with 2-D M^4 projection They are unstable against the thickening of M^4 projection, which can be induced by the collision of cosmic strings inducing their intersection leading to the thickening. The thickenning generates monopole flux tubes with a 4-D M^4 projection and since the string tension decreases, the dark energy decays in an explosive manner to ordinary matter and dark matter. This process would be the TGD counterpart of inflation. This would explain the needed huge temperature. Kind of a local mini big bang would be in question.

3. The TGD counterparts of the galactic blackholes can be associated with the decaying cosmic strings. The recent observations suggesting that dark energy is assignable to AGNs supports this view. The temperature in these regions can be huge and make possible p-adically scaled up versions of hadron physics and also the presence of 8_g bosons. Their decay to lepton-neutrino pairs would generate UHE neutrinos but they could be also generated in the collisions of UHE cosmic rays with matter.

4. Note that in the TGD Universe gravitational quantum coherence is possible in arbitrarily long length scales. This network could be analogous to a nervous system and make possible very intense highly targeted beams of cosmic rays. Diffraction in the tessellation of cosmic time=constant hyperboloid, having stars as analogs of unit cells of a lattice, could explain the recently observed gravitational hum difficult to understand in standard astrophysics [11].

2.2.1 What distinguishes between various cosmic neutrino sources?

Two different production mechanisms are suggested as an explanation for the differences between UHE emissions from TXS and NGC 106. One should also explain why the Milky Way seems to be a neutrino desert.

1. The galaxies are accompanied by cosmic strings or flux tubes obtained as their thickenings, roughly orthogonal to the galactic plane. Galactic jets can be assigned to these flux tubes. The cosmic strings would form a fractal network connecting galactic blackhole-like objects and the stars inside them to each other. The channelling of high energy particles to jets would be caused by the space-time topology (the cross section of the flux tube would be a closed 2-surface).

The huge magnetic fields associated with these flux tubes would accelerate cosmic rays to ultrahigh energies. Both gamma ray bursts and the UHE neutrinos and accompanying gamma rays from TXS could be assigned with these jets. UHE neutrinos could be created either in the galactic nucleus or produced in the collisions of UHE cosmic rays with matter.

2. Also the flux tube tangles in the galactic plane could give rise to analogous jets. TGD Universe is fractal and in TGD inspired quantum biology U-shaped flux tube tentacles play a key role in biocatalysis, in which the reconnection of them creates a flux tube pair between two objects. These tentacles could also appear in astrophysical scales and mediate gravitational interaction as gravitons, which propagate along them. In fact, the thin structures found to emanate from the center of the Milky Way could be associated with monopole flux tube pairs in the galactic plane. The view about the formation of astrophysical structures based on magnetic bubbles generated by monopole flux tubes is discussed in [**?**, 10].

   For the thick flux tubes in the galactic plane, the string tension would be much lower than for the environment of the cosmic string parallel to the jets. The acceleration of cosmic rays in their much weaker magnetic fields would not allow them to reach ultra high energies as in the case of jets normal to the galactic plane and the collisions of cosmic rays with matter could not create UHE neutrinos. Also gamma ray bursts would be absent.

3. The UHE neutrinos created in the AGN propagating along these flux tubes should generate the observed signal. This would suggest that neutrino flux is the sum of the primary flux from AGN and the flux generated by the interactions of cosmic rays inside the flux tube. The latter generates most of the signal for the galactic jets with ultra-strong magnetic fields. In the case of NGC, the UHE neutrino flux would be in the galactic plane. It is by a factor of order 1/100 weaker than predicted by the model in which the neutrinos are created in the collisions of cosmic rays accelerated in ultra strong magnetic fields with matter.

4. What about the Milky Way neutrino desert? Since the flux tube normal to the plane of the Milky Way does not reach Earth, the high energy neutrino flux would be so low that one could speak of neutrino desert. Whether the UHE neutrino flux from AGN is consistent with the finding that the Milky Way is a neutrino desert, is not clear. One explanation is that the Milky Way blackhole-like object is not active. This could mean that the ultra-hot regions where the generation of UHE neutrinos is possible are not present.

Received September 23, 2023; Accepted December 13, 2023

References

[1] IceCube Collaboration. Observation of high-energy neutrinos from the Galactic plane Emission along the plane of Milky Way. *Science*, 380(6652), 2023. Available at: https://www.science.org/doi/10.1126/science.adc9818.

[2] Antonio Fusco. Galactic neutrinos in the Milky Way. *Science*, 380(6652), 2023. Available at: https://www.science.org/doi/10.1126/science.adi6277.

[3] Halzen F Fang K, Gallagher JS. Milky Way as a Neutrino Desert: Implications of the IceCube Galactic Diffuse Neutrino Emission, 2023. Available at: https://arxiv.org/abs/2306.17275.

[4] IceCube Collaboration: Abbasi et al. Evidence for neutrino emission from the nearby active galaxy NGC 1068. *Science*, 378(6619):538–543, 2022. Available at: https://arxiv.org/abs/2211.09972.

[5] IceCube Collaboration: Padovani et al. Dissecting the region around IceCube-170922A: the blazar TXS 0506+056 as the first cosmic neutrino source. *Monthly Notices of the Royal Astronomical Society*, 480((1)):192–203.

[6] Pitkänen M. Construction of elementary particle vacuum functionals. In *p-Adic Physics*. Available at: `https:/tgdtheory.fi/pdfpool/elvafu.pdf`, 2006.

[7] Pitkänen M. Massless states and particle massivation. In *p-Adic Physics*. Available at: `https:/tgdtheory.fi/pdfpool/mless.pdf`, 2006.

[8] Pitkänen M. Topological description of family replication and evidence for higher gauge boson generations. Available at: `https:/tgdtheory.fi/public_html/articles/dabc.pdf`., 2018.

[9] Pitkänen M. About the TGD based views of family replication phenomenon and color confinement. `https://tgdtheory.fi/public_html/articles/emuanomaly.pdf`., 2023.

[10] Pitkänen M. Magnetic Bubbles in TGD Universe: Part II. `https://tgdtheory.fi/public_html/articles/magnbubble2.pdf`., 2023.

[11] Pitkänen M. The TGD view of the recently discovered gravitational hum as gravitational diffraction. `https://tgdtheory.fi/public_html/articles/gravhum.pdf`., 2023.