Dark valence electrons and vision

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Abstract

By its large orbital radius dark valence electron (dark in TGD sense, $h_{eff} = n \times h$) sees atomic nucleus and other electrons, which are ordinary, effectively as an object of charge $Z_{eff} = 1$. The spectrum of bound state energies and transition energies is scaled down by the factor $(h/h_{eff})^2$. This irrespective of what the atom is. The only condition is that there is single unpaired valence electron guaranteed if Z for the atom is odd. For even Z odd number of valence electrons must be associated with valence bonds: this would be the case for OH radical for instance.

The dynamics of dark valence electrons is universal with universal transition energy spectrum. One obtains a fractal hierarchy of dynamics labelled by the value of $(h/h_{eff})^2$, where $h_{eff} = n \times h_0$, h_0 the minimal value of Planck constant, not necessary equal to h so that one has $h = n_0 \times h_0$. The quantum critical dynamics characterizing living matter in TGD Universe is indeed universal.

The dark photon communications in living matter could utilize these universal energy spectra besides cyclotron energy spectrum and Larmor spectrum assignable to dark particles at flux tubes and the spectrum of generalized Josephson frequencies assignable to cell membrane.

In particular, vision and even other sensory modalities could rely on the transitions induced by the absorption of dark valence electron. In TGD also other sensory percepts are communicated from sensory receptors to the sensory areas of cortex and also here same universal transitions of dark valence electrons might be involved. This hypothesis when combined with the earlier ideas about color qualia leads to a highly predictive and testable model for the perception of colors. In particular the condition $h = n_0 \times h_0$, $n_0 > 1$, is necessary for the model to work. $n_0 = 4$ and $n_0 = 6$ look the most realistic options. For $n_0 = 4$ the number of values of $n = 8, 9, 10$ and correspond to the number 3 of color sensitive receptors whereas $n_0 = 6$ the number of values $n = 12, 13, 14, 15$ suggests the existence of a fourth color receptor sensitive to red light.

The statistical aspects of color summation can be understood from TGD inspired theory of consciousness in terms of the hypothesis that self experiences the mental images of sub-self as kind of statistical averages. The identification of quark colors as fundamental color qualia, the entanglement of quarks and antiquarks to form states in one-one correspondence with charged gluons, and the twistor space of CP_2 play key roles in the model of color summation.

1 Introduction

By its large orbital radius dark valence electron (dark in TGD sense, $h_{eff} = n \times h$) sees atomic nucleus and other electrons, which are ordinary, effectively as an object of charge $Z_{eff} = 1$. Dark valence electron has reduced mass which in excellent approximation equals to that of electron so that the spectrum of bound state energies and transition energies is scaled down by the factor $(h/h_{eff})^2$. This irrespective of what the atom is. The only condition is that there is single unpaired valence electron guaranteed if Z for the atom is odd. For even Z an odd number of valence electrons must be associated with valence bonds: this would be the case for OH radical for instance.

The dynamics of dark valence electrons is universal with universal transition energy spectrum. One obtains a fractal hierarchy of dynamics labelled by the value of $(h/h_{eff})^2$, where $h_{eff} = n \times h_0$, h_0 the minimal value of Planck constant, not necessary equal to h so that one has $h = n_0 \times h_0$. The quantum critical dynamics characterizing living matter in TGD Universe is indeed universal.

The dark photon communications in living matter could utilize these universal energy spectra besides cyclotron energy spectrum and Larmor spectrum assignable to dark particles at flux tubes and the spectrum of generalized Josephson frequencies assignable to cell membrane [K3, K2]. In particular, vision and even other sensory modalities could rely on the transitions induced by the absorption of dark valence electron. In TGD also other sensory percepts are communicated from sensory receptors to the sensory areas of cortex [L2] and also here same universal transition energies of dark valence electrons might be involved.

This hypothesis when combined with the earlier ideas about color qualia leads to a highly predictive and testable model for the perception of colors. In particular the condition $h = n_0 \times h_0$, $n_0 > 1$, is necessary for the model to work. $n_0 = 4$ and $n_0 = 6$ look the most realistic options. For $n_0 = 4$ the number of values of $n = 8, 9, 10$ and correspond to the number 3 of color sensitive receptors whereas $n_0 = 6$ the number of values $n = 12, 13, 14, 15$ suggests the existence of a fourth color receptor sensitive to red light.

The statistical aspects of color summation can be understood from TGD inspired theory of consciousness in terms of the hypothesis that self experiences the mental images of sub-self as kind of statistical averages. The identification of quark colors as fundamental color qualia, the entanglement of quarks and antiquarks to form states in one-one correspondence with charged gluons, and the twistor space of CP_2 play key roles in the model of color summation.

Remark: There is experimental evidence for the notion of dark valence electron coming from the decades old anomaly related to rare Earth metals [L4] (see `http://tinyurl.com/ybejzq87`) for which TGD provides an explanation [L4] (see `http://tinyurl.com/y8pqcc8s`). This finding led to a proposal that valence bonds could also involve non-standard values of Planck constant [L3] (see `http://tinyurl.com/ycg94xpl`).

1.1 What could happen in seeing?

For years ago I developed a model for color qualia [K3]. In QCD strong interactions are jokingly called color interactions because the algebra of color charges for quarks is analogous to that assignable to color summation. The sum of color charges of quarks vanishes and the situation is analogous to the summation of the basic colors with proper intensities to white color. If one considers charged gluons, one can extend the algebraic picture so that one has 3 pairs of complementary colors with black and white included as a complementary pair.

In case of quarks one has also the interpretation that quarks and antiquarks have complementary colors so that black and white are included as a pair of complementary colors. In this case the standard color summation would mean that white color assignable to rods and black color assignable to dark current would remain in visual field. This interpretations seems to be the most reasonable one.

As I realized that TGD "almost-predicts" a hierarchy of p-adic fractal copies of hadron physics and that the length scale range 10 nm -2.5 μm contains as many as 4 Gaussian Mersenne primes defining excellent candidates for copies of hadron physics, it became obvious that much more than analogy could be in question. Also the finding of topologist Barbara Shipman [A2, A3, A1] that honeybee dance seems to relate to the flag manifold $F = SU(3)/U(1) \times U(1)$ defining the twistor space of CP_2 and playing a key role in twistor lift of TGD [K9, K1, K8, K10] suggests that dark hadron physics might be highly relevant for living matter and visual consciousness [L8]. The realization of the hierarchy of Planck constants $h_{eff} = n \times h_0$ defining second length scale hierarchy gave further good reasons to take the analogy very seriously.

I have also studied several models for the visual qualia and perception.

1. TGD approach differs from neuroscience in that our sensory qualia are assigned to sensory receptors [K3] [L2] (see `http://tinyurl.com/yczv2o5b`). Note that we would represent only single level in self hierarchy. Entanglement would allow brain and also our magnetic body to share these qualia. In neuroscience approach they are believed to be somehow generated in brain, and the basic unsolved problem is to understand how this is possible: the neural network looks locally exactly the same at various sensory areas.

   Phantom limb phenomenon is the basic objection against this proposal but can be circumvented [K7]. The pain in non-existing limb would be memory of pain and sensory memories can be induced by electrical stimulation of temporal lobes. In zero energy ontology (ZEO) the pain would be in geometric past where the pain was felt in still existing limb.

   What is essential would be quantum entanglement between magnetic body, brain, and sensory organs and classical communications using dark photons propagating with light velocity. This allows very rapid virtual sensory input as feedback from brain (and MB) to brain and allows to build standardized sensory mental images by forth-and-back communications between brain and sensory organ [L2]. This is nothing but pattern recognition leading to standardized sensory mental images nearest to the sensory input. In the case of REM dreams one would have only the virtual sensory input.

2. Sensory capacitor model for sensory receptor [K3] assumes that sensory qualia correspond to flows of particles with fixed quantum numbers specifying the quale in question. In the case of color qualia quantum numbers would be color quantum numbers of quark or gluon. One would have the analog of di-electric breakdown occurring at critical voltage, whose analog

would be generated by sensory input. Note that this model is based on kinetics but that the identification of quale as color quantum numbers resulting in state function reduction is an essential element of the model.

3. Second - more quantal - model for sensory receptor emerged during writing this article. One would have a pair (A,B) of systems such that A contains quarks and B antiquarks (possible in principle since TGD predicts hierarchy of QCDs), which are entangled to form states analogous to gluon like states. The density matrix is 3×3 matrix and measurement of color quantum numbers produces an ensemble of quark states. The 3 quark states would correspond to basic colors (blue, red, white) having (yellow, green, black) as complementary colors represented by antiquarks.

   The ensemble would give rise to the experience of colors obtained by color summation: density matrix would correspond to intensities of various colors in color summation. White/dark would correspond to brightness/darkness of the color. If the ensemble would be associated with sub-self of self (perceiver) TGD inspired theory of consciousness [K5] [L7] predicts that the experience corresponds to a kind of ensemble average.

4. I have constructed a ZEO based model for the generation of color qualia. In ZEO [L7] ordinary states are replaced by zero energy states identified as pairs of ordinary states at opposite boundaries of causal diamond (CD, intersection of future and past directed light-cones of M^4 with points replaced with CP_2) serving as the embedding space correlate for self as a conscious entity and analogous to events. "Zero energy" means that the total conserved quantum numbers of the members of the pair are opposite, which is only a way state the conservation laws used also in QFT context. At either boundary one has ordinary states with a fixed sign of energy.

   CD sizes form a hierarchy and for sensory qualia the sizes are rather small: time scale would be around .1 seconds. During the sequence of state function reductions determining the life cycle of self the active boundary of CD drifts farther away from the passive one (flow of geometric time) and the states at it change reduction by reduction. These reductions would be analogous to so called weak measurements in standard quantum measurement theory. The states at the passive boundary of CD are unaffected in the sequence of state function reductions as also passive boundary itself. As a special case these states could correspond to quarks in eigenstates of color quantum numbers (Y, I_3) giving rise to a sensation of pure basic color with black and white counted also as pair of conjugate colors.

   The ensemble of quarks with well-defined color quantum numbers would correspond to sub-selves of sub-self and would give rise to color summation at the level of conscious experience.

At this moment it is better to keep mind open for various options. The kinetic picture could be consistent with this picture if the particles with fixed quantum numbers correspond to the passive boundaries of sub-CDs associated with sub-CD.

I was somewhat surprised as I realized that I have not considered what might happen in the series of events leading to color sensation at the first step atter photon is absorbed by sensory receptor. In the following I shall look what comes out if one takes the idea about the universality of color vision realized in terms of transitions of dark valence electrons.

1.2 Could the transitions of dark valence electron produce the universality associated with quantum criticality?

The basic hypothesis is that the value of Planck constant is quantized: $h_{eff} = n \times h_0$. Here h_0 is the minimum value of h_{eff}, which need not be equal to ordinary Planck constant h but one has $h = n_0 \times h_0$. $n_0 > 1$ is quite possible, and the experiments of Randell Mills in fact suggest $h = 6 \times h_0$ [L1](see `http://tinyurl.com/goruuzm`). What Mills claims [D2] is that hydrogen has states with binding energy scale larger that for the ordinary hydrogen atom. Therefore the scaling factor binding energy scale would be. The scaling factor for the binding energy scales would be

$$(\frac{h}{h_{eff}})^2 = (\frac{n_0}{n})^2 \quad , \quad n = 2n_0, 2n_0 + 1, ...$$

At fundamental level the real Planck constant would be h_0, and h_{eff} would be effective Planck constant and due the n-sheet covering character of the space-time surface equal the dimension of extension rationals defining the adele at the given level of hierarchy of adeles giving rise to a number theoretic characterization of evolutionary hierarchy [L5, L6].

The orbital radius of dark electron scales as $(n/n_0)^2$. This might have dramatic consequences concerning the understanding of the quantum criticality of biology strongly suggested by the quantum criticality of TGD Universe meaning that any system is quantum critical in some scale. Quantum criticality implies universal dynamics and this would be obviously true for dark valence electrons. Quantum criticality involves also fractality and the hierarchy of size scales of dark electron orbits would imply this.

1. Lonely dark electron of any atom seems the effective charge $Z_{eff} = 1$ because almost complete screening takes place because of other electrons with much smaller orbital radii. The atom behaves effectively like hydrogen as far as the lonely valence electron is considered.

2. The spectra of effective dark hydrogen could correspond to energies central for biology. Note that the frequencies (wavelengths) would be scaled down (up) by n_0/n (n/n_0). These energies would correspond to transitions $n_P = m_1 \rightarrow m_2$, $m_i = 1, 2, ...$ of hydrogen atom changing the principal quantum number denoted by n_P instead of n now). The transition energies would be given by

$$E(n, m_1, m_2) = (\frac{n_0}{n})^2[\frac{1}{m_1^2} - \frac{1}{m_2^2}] \times E_I(H) \ \ , \quad E_I(H) = 13.6 \ \ eV \ \ .$$

   These spectra produce a fractal being related to each other by a scaling of a square of rational number.

3. What ranges of n one can consider for given n_0?

   (a) A reasonable working hypothesis is that the values of n are such that the energies are above thermal energy about .027 eV at physiological temperature 37 K. The maximal value of n would correspond to $n_{max} \in \{89, 112, 134\}$ for $n_0 \in \{4, 5, 6\}$ and lowest value of n taken to be $2n_0$ and corresponding to the energy 3.4 eV somewhat above the visible energies (2.39 eV corresponds to the boundary between UV and visible).

   (b) A stronger working hypothesis is that the values of n are such that the transition energy associated with the ionizing transition $n_P = 1 \rightarrow \infty$ is such that the transition energies belong to the energy range of bio-photons containing at least visible and UV photons. UV region corresponds to the values $n < 2n_0$.

   (c) Even stronger condition is that these energies containing the energy range of visible photons spanning in good approximation one octave. For given value of n_0 this would give $n = 2n_0, 2n_0 + 1, ..., 2n_0 + \Delta$, where Δ is determined by octave condition and therefore satisfies $\Delta \geq 2(\sqrt{2} - 1) \times n_0$.

Some remarks are in order.

1. An energy conserving h_{eff} changing transition increasing n_0 to n must occur before the transition of dark valence electron. These transitions would be fundamental in TGD and could also involve emission or absorption of energy. I have proposed that the temporary reduction of the value of h_{eff} liberating energy and followed by return to the original value is a basic mechanism of catalyst action [?]see `http://tinyurl.com/goruuzm`). The reduction of h_{eff} would reduce the length of flux tubes connecting the reacting molecule and catalyst and liberate this energy kicking the reacting molecules over the potential wall making reaction fast. In particular, the transitions changing the value of n for lonely dark valence electron could play an important role in bio-catalysis. If so, the dynamics behind bio-catalysis could be extremely simple at the dark level.

2. The model for visual perception would fail for the conservation option $n_0 = 1$ so that the finding of Mills [?]onforms with the proposed view about vision. The model is most realistic for $n_0 = 4$ and $n_0 = 6$. for $n_0 = 6$ the model however suggets a yet un-identified photoreceptor sensitive to red light.

3. How the model of color qualia in terms of measurement of color quantum numbers of quark and antiquark could relate to the proposed model? The most natural proposal is that the excited dark electron returns to a lower excited state by emitting dark photon decaying to dark quark-antiquark pair. Quarks could correspond to the p-adically scaled up variants of hadron physics assignable to the Gaussian Mersennes with p-adic length scales in the length scale range relevant for cell nucleus are excellent candidates.

2 Could dark photon absorption give rise to visual perception?

What really happens as photon is absorbed by photoreceptor? Could the absorption give rise to transitions of dark valence electrons and have therefore scaled variant of hydrogen spectrum? In studying this hypothesis I will utilize information about visual perception in Wikipedia (see `http://tinyurl.com/y88k583f` and `http://tinyurl.com/d6tdw54`) and various web sources (see for instance `http://tinyurl.com/yarthc6u`).

2.1 Is vision at basic level seeing of dark photons?

Before continuing some general remarks are in order.

1. Color perception is defined as the ability of organism to distinguish between different wavelengths (or frequencies). In standard quantum theory one could replace wavelength with energy but if the hierarchy of Planck constants is accepted one must be cautious. If incoming photons have $h_{eff} = h = n_0 \times h_0$ the dark photons produced in the process have longer wavelength but same energy.
2. The colors produced by single frequency are so called pure colors. The mixing of light with different wavelengths and varying intensities produces colors, which need not be pure. For instance, brown cannot be produced by single wavelength. Summation of colors means that the mixing of light with two colors produces large number of colors produced by single wavelength.
3. TGD suggests that all sensory qualia involve transitions of dark valence electrons induced by dark photons in various wavelength ranges. In the case of olfaction there is indeed strong support that it is seeing in infrared [I1], [J2, J1] [K3]. The transitions of dark valence electrons with values of n corresponding to energies outside the visible range might be involved.
4. One cannot exclude the possibility that the absorption of ordinary photons is followed by emission of dark photon generated as dark valence electrons drops to the ground state. This option will not be however considered in the following.

One could argue that visual perception relies on universal mechanisms in the sense that very many molecular structures could allow it. The observations made above inspire the idea that the absorption of photon in photoreceptor involves the transformation of incoming ordinary photons to dark photons with $n = 2n_0, ..., 2n_0 + \Delta$ for n_0, which could be in the range $\{4, 5, 6\}$ as will be found, and induces a transition of dark valence electron to a state with higher energy.

1. This transformation could involve absorption and subsequent emission as dark photon with energy in the spectrum of effective dark hydrogen atom with discrete spectrum in the interval

   $$(\frac{n_0}{n})^2 E_I(H) \times [3/4, 1] \quad , \quad n \in \{2 \times n_0, ..., 2 \times n_0 + \Delta\}$$

   consisting of lines $(n_0/n)^2 E_I(H) \times [3/4, 8/9, 24/25, ..n^2 - 1/n^2, ...]$. There would be 4 clearly distinguishable basic energies corresponding to $(3/4) \times (n_0/n)^2 E_I(H)$ perhaps identifiable as basic colors. One as $\Delta = 2$ and 3 bands for $n_0 = 4$ and $\Delta = 3$ and 4 bands for $n_0 \in \{5, 6\}$.

   The conditions that the number 3 of cones equals to the number of values of n and that the range of visible wavelengths spans an octave selects $n_0 = 4$ uniquely. $n_0 = 6$ satisfies the octave condition but suggests strongly the existence of 4:th yet un-identified color-sensitive receptor.

Remark: The transitions $n_P = m_1 > 1 \rightarrow m_2$ from higher states would correspond to energies below the visible range and are not considered. They might however plays some role.

2. The model assumes that the incoming light - assuming that it has $h_{eff} = h$ - transforms to dark light in the receptors having $h_{eff} = (n/n_0) \times h$, $n = 2n_0, 2n_0 + 1, ..., 2n_0 + \Delta$, where Δ must be such that the range of visible wavelengths is covered. Wavelength would therefore increase by factor n/n_0 from that for incoming photon wavelength in the range $[2, 2 + \Delta/2]$ whereas energy would be same. Dark valence electron would be kicked to an excited state by the absorption of dark photon. This would lead to the color perception. How this happens is a separate problem.

The beauty of the mechanism would be that the atom involved could be almost anything: what is only required that there is lonely valence electron that can become dark. This hypothesis will be studied in the sequel. I try also to relate it to earlier ideas about vision and color qualia.

2.2 Comparison with empirical facts

In the following the predictions of the model are compared with empirical facts about photoreceptors and the conclusion is that $n = 4$ and $n_0 = 6$ options are the most realistic ones. $n = 6$ option however suggests the existence of a not yet identified receptor sensitive to red.

2.2.1 Basic facts about photoreceptors

Consider now a comparison with basic empirical facts about photoreceptors.

1. There are 4 kinds of receptors. 3 photoreceptors giving rise to color sensation are called blue, green, and red cones. Rods are receptors, which do not produce color sensation unless one counts white and black as colors. The sensation of black does not mean absence of visual consciousness so that black could be regarded as color. Black could be interpreted as the color produced by so called dark current (see `http://tinyurl.com/6tu3q26`) present in retina also in the absence of light stimulus. Furthermore, rods are sensitive to same wavelengths as green cones and also other receptors to some extent in accordance with the fact that color is not a property of light but characterizes the qualia induced by the absorption of light.

2. The Wikipedia article gives the wavelengths λ_{max} at which maximum absorbance occurs. Figure 14a)(`http://tinyurl.com/yc6dcqn7`) of the article of Helga Kolb gives slightly different values for λ_{max}. According to the Wikipedia article the maximum absorbance occurs for

   - red cones at $\lambda_{max} = 564$ nm, which is in yellow rather than red. Red cones respond to red, orange and yellow but very weakly to red light, which raises the question whether there could exist yet unidentified receptors sensitive to the red wavelengths;
   - green cones at $\lambda_{max} = 534$ nm; green cones respond mostly to green light;
   - blue cones at $\lambda_{max} = 420$ nm in violet. Blue cones respond to cyane, blue and violet and even in UV but the lense prevents the UV radiation from arriving to the receptors;
   - rods $\lambda_{max} = 498$ nm in cyane at the boundary of cyane and blue.

3. The absorption curves decrease rather rapidly above λ_{max} but approach to much larger value for small wavelengths, which suggests that given receptor is sensitive for values $n \leq n_{max}$ rather than single value of n. The absorbance curves are given only in finite interval, and I do not know whether this is due to the lack of empirical data or whether the absorbance reduces to zero outside the range spanned by the curve. For the model assigning single value of n to the receptor this would happen.

2.2.2 Predictions for $h = n_0 \times h_0$, $n_0 \in \{4, 5, 6\}$

In the following tables the energy and wavelength ranges for options $n_0 \in \{4, 5, 6\}$ are listed together with the list of λ_{max} values to see whether the option is realistic. Energy range for the photons corresponds to the range between the photon energy $3E_I(n, n_0)/4$ associated with $n_P = 1 \rightarrow 2$ transition equal and $E_I(n, n_0)$ corresponds to the ionization energy. The allowed photons energies form a discrete band like structure.

1. *$n_0 = 4$ case*

The predictions for $n_0 = 6$ are given in table 1.

n	E/eV	λ/nm	λ_{max}/nm
8	[2.55,3.40]	[365,486]	420
9	[2.02,2.68]	[462,615]	534 (498)
10	[1.63,2.18]	[570,759]	564

Table 1: Table gives energy and wavelength ranges for photons for option $n_0 = 4$ for various values of n. The last column gives the values of λ_{max} for cones and rods (in brackets) helping to see whether the option is realistic.

The wave length ranges look rather realistic except that $\lambda_{max}/nm = 534$ for red receptors does not belong to the range of wavelengths for $n = 10$ being slightly below it. Note however that the assumption $n \leq n_{max}$ is strongly suggested (if not forced) by the properties of absorbance curves: since there is considerable overlap between $n = 9$ and $n = 10$ bands, λ_{max} could be shifted towards $n = 9$. Visible spectrum extends to 750 nm in red and the prediction is that it should extend to 759 nm.

2. *$n_0 = 5$ case*

The predictions for $n_0 = 5$ are given in table 2.

n	E/eV	λ/nm	λ_{max}/nm
10	[2.55,3.4]	[365,486]	420
11	[2.11,2.81]	[442,588]	534 (498)
12	[1.77,2.36]	[526,700]	564
13	[1.51,2.01]	[617,822]	∼662?

Table 2: Table gives energy and wavelength ranges for photons for option $n_0 = 5$ for various values of n. The last column gives the values of λ_{max} for cones and rods (in brackets) helping to see whether the option is realistic.

One can assign to each λ_{max} a unique value of n such that the corresponding wavelength range contains λ_{max}. The visible spectrum extends to 750 nm in red whereas for $n = 12$ the end of the spectrum would be at 700 nm. The inclusion of also $n = 13$: this would give additional wavelength range $[617, 822]$ nm which would contain red wavelength range [620,750] nm. The estimate for the corresponding λ_{max} is obtaining by assuming that is scales like n^2. In this picture, red cones would be called yellow cones, and $n = 13$ would correspond to a new receptor sensitive to red and IR wavelengths. The upper bound 822 nm for visible wave lengths makes possible IR vision unless the receptors absorbing the incoming photons and transforming them to dark photons are insensitive to IR photons.

3. *$n_0 = 6$ case*

The predictions for $n_0 = 6$ are given in table 3.

n	E/eV	λ/nm	λ_{max}/nm
12	[2.55-3.4]	[365-486]	420
13	[2.17-2.89]	[429-571]	534 (498)
14	[1.87-2.49]	[498-663]	564
15	[1.63-2.18]	[570-761]	$\sim$ 649?

Table 3: Table gives energy and wavelength ranges for photons for option $n_0 = 6$ for various values of n. The last column gives the values of λ_{max} for cones and rods (in brackets) helping to see whether the option is realistic.

Wave length ranges look rather realistic. If one is accept that $n = 15$ corresponds to a new yet unidentified receptor, one can assign to each n a unique receptor and λ_{max} belongs to the wavelength range in question.

It would not be surprising if λ_{max} would scale as n^2 (for absorbance curves see `http://tinyurl.com/y7t5w2m2`). One should have $r(n) = \lambda_{max}(n+1)/\lambda_{max}(n) = (n/(n+1))^2$. Let $r_1(n)$ denote the corresponding ratio for cones (green/blue and red/green). The ratios $(r(n)/r_1(n)$, $n = 12, 13$ would .9 and 1.1: ideally they should be equal to 1. For $n = 14$ one would $r(n) = (15/14)^2 = 1.15$. This gives an estimate for λ_{max} of possibly existent $n = 15$ receptors as $\lambda_{max} \sim 1.15\lambda_{max}(15) = 649$ nm (red begins at 620 nm).

Remark: That $n = 13$ should correspond to both green and white cones is somewhat disturbing. $n = 14$ receptor for red - or rather yellow - however covers the wavelength range 498-663 nm whereas the upper boundary of $n = 12$ is 486 n. Only the range $[486, 498]$ nm remains uncovered. Could $n = 13$ correspond to color white? Perhaps this could be tested by using incoming radiation in the wavelength range $[486, 498]$ nm.

The cautious conclusion is that $n_0 = 4$ and $n_0 = 6$ are the most realistic options. For $n_0 = 4$ there would be only three cones but for $n_0 = 6$ the existence of new receptor is suggestive.

Some further remarks concerning are in order.

1. The absorbance graphs suggest that the receptors do not correspond to single value of n but to several values $n \leq n_{max}$.

2. Each receptor is sensitive in a region containing two values of n. Consider $n_0 = 6$ as example. $n = 15$ touches $n = 13$ if the transitions inducing large changes of the principal quantum number n_P are allowed (almost ionization). For given receptor the values $n < n_{max}$ are strongly represented: the value of absorbance decreases to a non-vanishing value in the region $\lambda < \lambda_{max}$ and can even slightly increase. For $n > n_{max}$ absorbance approaches zero rapidly. Blue cones would correspond to $n_{max} = 12$ and green cones to $n_{max} = 13$. Red cones would correspond to both $n_{max} = 14$ ja $n_{max} = 15$. Rods would correspond to $n = 13$.

3. Due to the overlap of the energy ranges, the same energy can correspond to two values of n and thus different dark wavelengths. This forces to ask how the color quale is determined: does the transition energy or the corresponding dark wavelength determine the color? If it is energy then very nearly the same transition energies for say $n = 14$ and 15 in case of $n_0 = 6$ would correspond to nearly the same color although the dark wavelengths would differ by factor 14/15. If it is wavelength then same energy for incoming photon could correspond to 2 different colors for overlapping dark energy bands.

   Remark: This raises a question about the determination of the sensitivity to photoreceptors to the incoming visible light: is it wavelength or energy? If would be wavelength according to Wikipedia definition and this one might expect since the experiments about color vision were carried out before emergence of quantum theory. It however seems that the incoming visible light must correspond to $h_{eff} = h = n_0 \times h_0$: otherwise the model leads to difficulties.

4. Evolution as a growth of h_{eff} would predict that small values of n have emerged before the low values. In particular, IR vision would correspond to a higher level in the evolution and larger values of n. Small values of n would correspond to a lower level and would have

been reached. Indeed, no examples about IR vision are known whereas UV vision requiring $n < 2n_0$ is common: bees provide one particular example.

5. Tetra-chromacy (see `http://tinyurl.com/mntowuw`) occurs for birds, fish, amphibians, reptiles, insects and some mammals and sometimes even for humans, means that there is additional color receptor in UV with $\lambda_{max} = 370$ nm slightly above minimum wavelength 365 m for blue cones. For $n_0 = 6$, the most natural interpretation would in terms of $n = 11$ which corresponds to wavelength range [307,408] nm.

2.2.3 Further phenomena that one should understand

Color vision involves several phenomena that one should understand.

1. In the summation of colors light beams with several wavelength and varying intensities are superposed. The perceived color need not correspond to a sensation created by single wavelength. One can however produce colors produced by single wavelength by using summation of two colors (actually not all of them). The perceived color depends on the ratio of the intensities: only its brightness depends on the intensity scale.

   This suggests that at quantum level the perceived color is determined as a kind of statistical average. In TGD inspired theory of consciousness this could mean that color qualia correspond to sub-sub-selves. The resulting mental images is sub-self determined as a kind of statistical average over sub-sub-selves defining mental images of sub-self.

2. In the subtraction of light one mixes different colored substances. In the mixture only the common wavelengths are reflected and the color becomes darker for this reason (one could see this as a mixture of colors with black regarded as a color).

3. There is also the phenomenon of complementary colors. Consider as an example $n_0 = 6$ option.

   (a) Red and green form pair of complementary colors. Complementary colors sum up to white in color summation, when the intensities are suitably chosen. For $n_0 = 6$ red is contained by $n = 14$ and $n = 15$ bands and green by $n = 13$ and $n = 14$. Could the complementary colors of colors in $n = 13$ band be in $n = 14, 15$ bands? Note that $n = 15$ band contains orange and yellow (partially).

   (b) Blue and yellow are also complementary colors. Yellow is contained partially in $n = 14$ ja $n = 15$. Blue is contained $n = 12$ ja partially $n = 13$.

   (c) As already argued that black and white could be seen as complementary colors and this interpretation would allow to see also rods as color receptors and dark currents as a generator of black background color. This view would also fit nicely with the TGD based model of color qualia to be discussed in the sequel.

2.3 What color summation could correspond in TGD framework?

In color summation the light stimuli at different wavelengths sum up. By combining two wavelengths one obtains other colors produced by single wavelengths. Not all of them can be produced and there are also composite colors not produced by single wavelength.

The rough rule is that for two colors one can find a third color such that the sum of all three is white. This means that one can construct colors as composites of two basic colors. These wavelengths are not unique but correspond to some wavelengths in some wavelength ranges. The third color corresponds to a suitablefor the intensities of the summands. The empirically deduced summation rules are described by "horse shoe" diagram (see `http://tinyurl.com/yc5yg4dg`).

1. One selects two wavelengths λ_1, λ_2, which correspond to two basic colors, say green and red. One mixes these wavelengths with fractions p ja $1-p$. Mixing fractions correspond to coordinate axes x for red ja y for green. One assigns to each pair $(p, 1-p)$ a rectangle, whose vertices are at $(0,0)$ (pure blue), $(0,p)$ (pure green), $(1-p)$ (pure red), and at $(p, 1-p)$, which corresponds to the sum color and is located at the edge of a triangle connecting points

(1,0) and (0,1). This points of this edge are labelled by wavelengths. The mixing ratios for the desired composite color can be read from the diagrams.

2. One however encounters a problem. One does not obtain all possible colors created by single wavelength in this manner. If one wants all colors one must allow also negative fractions p or $1-p$ so that the portion of one color would be larger than one and that of another color negative. The edge of the triangle indeed continues as "horse shoe" curve (see `http://tinyurl.com/yc5yg4dg`) to the negative values of x coordinate and y-coordinate going through origin (pure blue). The various nuances of blue correspond to the regions $x<0$ and $y<0$. In these regions one must use other pair of basic colors to construct the colors.

   At the negative values of x one would have blue, which is even more blue that origin $(0,0)$ and this is not possible since the portion of red would be negative. Hence one must use another pair of colors to produce the colors along for $x<0$ portion of the curve.

3. The ratio of the intensities of the mixed colors determines the resulting color. In quantum theory context this would suggests that mixed colors correspond to entangled quantum states such that the eigenvalues of the density matrix correspond to the portions p and $1-p$. A more realistic interpretation would be that quantum measurements of color for these entangled pairs produces pure states with red and green appearing with probabilities p ad $1-p$ in the resulting ensemble.

TGD suggests two basic models for the generation of color qualia quantum model and geometric model, which might correspond to quantum model via quantum classical correspondence.

1. One could assume that a particle with color hyper charge and color isospin given by (Y,I_3) determines basic colors and their number is given by those states of color multiplet for which one has $(Y,I_3)\neq(0,0)$. For the complementary color of (Y,I_3) the color quantum numbers would be $(-Y,-I_3)$.

   Color summation would correspond to the summation of the quantum numbers of quarks to zero. Quark triplet and its conjugate would give 3 colors and their complementary colors. One would not obtain black and white as colors. It is not however clear how to understand color summation in this picture. As a matter of fact, the color summation means that only the rods contribute to the color sensation and give rise to a sensation of white color. It would be better to say that the sum of color and its conjugate gives no sensation at all.

2. Another option is that the 6 charged members of gluon octet corresponds to the 3 basic colors and their complementary colors. Also now black and white are most naturally counted as a pair of complementary colors.

One can also consider a model in which there is a geometrical entity possessing naturally color quantum numbers. Both quark and gluon option can be formulated in this framework.

1. For quark option the two complex $CP_2=SU(3)/SU(2)\times U(1)$ coordinates transforming linearly under $U(2)$ satisfy the criterion. The rays of the Hilbert space for 3 quarks could be parameterized by CP_2. Note however that the superposition of states cannot be described if one uses CP_2 since phase information relevant to the superposition is lost in projective equivalence.

   This would suggest a geometric model of color summation in which three basic colors correspond to 3 different coordinate patches of CP_2. Given coordinate patch would correspond to a particular choices of 2 basic colors in the summation. Color rotations acting linearly would generate different choices of complex coordinates in given patch and would correspond to different choices the 2 basic colors. The intensities of summed colors would correspond to the moduli squared for the complex CP_2 coordinates. As a matter fact, the complex coordinates have anomalous hypercharge $-2/3$ due the division of the first two coordinates with the third coordinate having $(Y,I_3)=(2/3,0)$.

2. For the gluon option the two neutral gluons are eliminated by using instead of C^8 twistor space $F=SU(3)/U(1)\times U(1)$ of CP_2 playing key role in twistor lift of TGD [K9, K1, K8, K10].

F is 6-D and has 3 complex coordinates and is a bundle with CP_1 as fiber and CP_2 as base. CP_1 corresponds to charged members of isospin triplet representing the two colors black and white. CP_2 corresponds to the two gluon pairs with opposite isospins, which correspond two quarks out of 3 appearing in the color summation with the choice of basic colors interpreted as the choices of a particular coordinate patch for CP_2.

For CP_1 one has two coordinate patches and now the selection of patch would correspond to the selection of black or white as basic color the intensity of this color in the superposition of 3 colors would determine the darkness/brightness of the color. The generalization of color summation would mean that also the effect of the rod receptors is taken into account as counterpart for CP_1.

Could the geometric pictures based on F and CP_2 be interpreted in terms of Hilbert space picture? The twistor space picture indeed suggests quantum classical correspondence at the level of twistor lift of $M^4 \times CP_2$. Since the basic for quarks corresponds to a choice of free basic frequencies, one can however argue that the twistor space actually parametrizes different choices of basic colors.

2.3.1 Generalization of color summation to include black and white as colors

The simplest interpretation for color summation would be in terms of quark triplet representing points of complex Hilbert space C^3.

1. Quarks correspond to three basic colors and antiquarks to their conjugates. Other colors could be described in terms of entanglement of two quark states with reference states. Density matrix would describe the states.

2. The reference states could be states with opposite color quantum numbers that is antiquarks. What comes in mind first is that the entangled state has vanishing color quantum numbers but would be color singlet. This modification of color confinement in TGD framework to require only the vanishing of net values of Y and I_3 has been discussed already earlier in [K10].

3. Standard color summation would correspond to a superposition of two chosen quark states entangled with 2 reference states. The probabilities determined by the density matrix would correspond to normalized intensities for light stimuli at corresponding wavelengths. The perceived colors would be obtained by the empirical "horse shoe" rule (see `http://tinyurl.com/yc5yg4dg`). The statistical aspect could be understood if state function reduction occurs for the ensemble of paired states. The observed color would be determined as the average color quale as already explained.

   In the geometric picture color summation could be interpreted at the level of CP_2 and basic colors would be determined by the moduli of 2 complex CP_2 coordinates. Apart from brightness, the perceived color would depend on the ratio $|\xi^1/\xi^2|$ of these coordinates so that one would obtain the standard view about color summation but black and white could not be understood as colors.

   Ordinary color summation is however problematic from the point of view of Hilbert space interpretation since it means projection to 2-D subspace. Projectivity for Hilbert space does not mean that third state has vanishing coefficient but only that it can be transformed to unity. As a matter of fact, in given coordinate patch of CP_2 the coefficient must be non-vanishing! In Hilbert space interpretation that sum of 3 probabilities equals to one. The 3 probabilities of the density matrix would correspond to the normalized intensities assignable to the three chosen frequencies with one corresponding to white as color (rods).

Ordinary color summation tells nothing about colors dark and white and darkness/brightness of the color. This suggests a modification in which one considers normalized states of quarks in C^3. If the states are entangled pairs of 3 quarks with antiquarks with opposite quantum numbers, the density matrix would reduce to diagonal 3×3 matrix and one would have 3 probabilities summing to unity. Physically the probability for $(Y, I_3) = (2/3, 0)$ state would correspond to the contribution of white and black to the superposition affecting the darkness of the color. Rods would be responsible for white contribution. Black would correspond to the dark current creating kind of background color sensation.

For this option the connection of Hilber space description with flag manifold F and CP_2 would be accidental and different quarks states would not correspond to points of CP_2 or F.

2.3.2 The choices of basic colors triplets as points of flag manifold

There exists an infinite number of choices of the 3 basic colors if the frequencies are continuous: the identification as transition frequencies of dark electrons however discretizes the situation. Could the different allowed choices of these triplets are be related by a discrete subgroup of color rotations relating various state basis for quarks to each other?

1. Color rotations would produce different basis assignable to different choices of three basic frequencies defining the basic colors. Color groups is 8-D $SU(3)$ on 8-D and quark states correspond to C_3. $U(1)\times U(1)$ leaves invariant entangled quark-antiquark states which have vanishing color quantum numbers but are not color singlets. There the space of entangled quark-antiquark states which do not include color singlet is $SU(3)$ orbit for a single state of this kind and equals to flag manifold $F = SU(3)/U(1)\times U(1)$ with complex dimension 3 or equivalently the space for the choices of color quantization axes. I have discussed the space-time representation of points of F in the model of honeybee dance [L8].

2. As explained, F has fiber space structure with CP_1 as a fiber parameterized by a complex coordinate with color isospin $I_3 = 1$. Base is CP_2 has two complex coordinates. This would suggest that the complex coordinate z of CP_1 fiber of F would correspond $n = 13$ and rods and its conjugate to its conjugate and dark current. CP_2 base of F would correspond to all all 4 values of n with coordinates and their conjugates representing colors and conjugate colors identifiable as two pairs (n_1, n_2).

   CP_2 is non-trivial as a manifold and 3 coordinate patches are needed. One can choose from the complex C^3 coordinates (z_1, z_2, z_3) two coordinates and there are 3 choices corresponding to 3 coordinate patches. These would correspond to the 3 choices for basic color pairs used to obtained other colors in color summation. For instance, one could have $z_1 \leftrightarrow$ red, $z_2 \leftrightarrow$ green, $z_3 \leftrightarrow$ blue as basic colors. By projectivity

3. Since the flag manifold F labels the possible choices of color basis, one expects that the choice of the basic color triplets as triplets of frequencies is not completely free. Certainly one must keep the variation of the basic frequencies within some limits. Could only a discrete set of basic frequencies be allowed? Could the allowed frequencies correspond to the transition energies for dark valence electron? Could this discrete set of frequencies correspond to a discrete set of points of F for various values of $n \in \{12, 13, 14, 15\}$. Could this correspond to a number theoretic discretization of F by replacing $SU(3)$ with its discrete finite sub-group $U(1)\times U(1)$ with its discrete counterpart in discrete sub-group of $SU(3)$?

   $\lambda(z_1, z_2, z_3)$ and (z_1, z_2, z_3) correspond to the same point, and one can use the coordinates $(\xi_1 = z_1/z_3, \xi_2 = z_2/z_3, 1)$ in one particular coordinate patch, which could correspond to red and green as basic colors whose mixing would give the remaining colors but not all of them since single coordinate patch is not enough. The ratio $r_{12} = |z_1/z_2|$ would determine the color in the standard picture about color summation. Including white and black, the ratios $r_1 = |z_1/z|$ and $r_2 = |z_2/z|$ would determine the color and its brightness. The phases of the F coordinates would not affect the experienced color quale.

A couple of remarks are in order.

1. It would seem that the space of color qualia is locally like projective space RP_3, which is real variant of twistor space CP_3 appearing in the twistorialization of 4-momenta to be distinguished from the geometric twistor space $M^4 \times CP_2$ appearing at the level of M^4 geometry and possessing generalized Kähler structure ($M^4 \times CP_2$ is unique because the twistor spaces for the factors allow Kähler structure).

2. The obvious question concerns the qualia assignable to M^4 and interpretation of the corresponding twistor space. The point of twistor space could correspond to the choice of energy and spin quantization axes (energy quantization axis would define the rest frame). A possible identification for qualia could be as energy and spin in the rest frame. They would be analogous to brightness and color. Color triplet would correspond to spin 1 triplet.

2.3.3 How the two views about color vision might relate?

I have discussed above two views about color vision.

1. The transitions of dark valence electrons induced by the absorption of dark photon preceded by the absorption of ordinary visible photon by photoreceptor would represent the first step in the process leading to a color sensation.

2. The second step would give rise to a formation of entangled state of quarks and antiquarks with non-standard value of Planck constant and the measurement of color quantum numbers of quark as a state function reduction for the ensemble of entangled quark pairs would give rise to qualia, which in general would represent mixed colors.

A more detailed view about the second step could look like follows.

1. Quark-antiquark pair could be formed by the return of the dark valence electron to an excited or ground state by an emission of virtual dark photon decaying to a possibly dark quark-antiquark pair, which should be non-relativistic. This is of course only the simplest option that one can imagine.

2. Quark and antiquark would naturally correspond to a copy of hadron physics labelled by Gaussian Mersenne $M_{G,n}$, $n \in \{151, 157, 163, 167\}$: the appearance of 4 Gaussian Mersennes in the biologically most interesting p-adic length scale range $[10, 250]$ nm covering the length scale relevant to cell nucleus is a number theoretical miracle.

   The p-adic mass scales for quarks need not correspond to those for hadron physics itself. For instance, for ordinary M_{107} hadron physics only c quark corresponds to M_{107} whereas s quark most naturally corresponds to $M_{G,k}$, $k = 113$ assignable to nucleus [K4, K6] and u and d current quarks with masses about 5 and 20 MeV correspond to even longer p-adic length scales. Thus light quarks would correspond to longer mass scales than hadron: the interpretation is in terms of the assignment of quarks to the magnetic body of hadron. t and b quarks would correspond p-adic length scales considerably shorter than hadronic length scales.

   Whatever the detailed picture is, Gaussian Mersennes are excellent candidates for mass scales of u and d quarks involved. The mass scale of quark for $k = 167$ corresponding to a p-adic length scale about 2.5 μm would be same as that of electron scaled from $k = 127$ to $k = 167$ and by p-adic length scale hypothesis equal to $2^{(167-127)/2} \times .5$ MeV $\simeq .5$ eV in IR and identifiable as the nominal value of the metabolic energy quantum. The mass scales for $k = 151, 157, 163$ would be related by the scaling $2^{(k-167)/2}$ to this scale and would be given by 128 eV, 16 eV, and 2 eV (this corresponds to red light) for $k = 151, 157, 163$. For $k = 151$ and $k = 157$ the mass scales are too high for photons in the range of visible energies.

3. $k = 163$ is the most realistic option but also 167 can be considered although now quarks must be produced from virtual photons decaying to a non-relativistic mass shell quark pair. Note that also decays of dark valence quark to excited state are possible and could give rise to on mass shall non-relativistic quark pairs with energies around .2 eV for $k = 167$.

4. Charge separation must take place for quark and antiquark. One option is that negatively (positively) charged quarks and antiquarks move to the outside (interior) of the cell membrane in the membrane potential of photoreceptor neuron.

REFERENCES

Mathematics

[A1] Shipman B. Investigating bee behavior from the standpoint of fundamental physical principles. *Am Bee J*, 136(5):339–340, 1996.

[A2] Shipman B. The geometry of momentum mappings on generalized flag manifolds, connections with a dynamical system, quantum mechanics and the dance of honeybee, 1998. Available at: https://math.cornell.edu/~oliver/Shipman.gif.

[A3] Shipman B. The full Kostant -Toda lattice: Geometry of its singularities and its connection to honeybees and new developments in physics. 2007.

Condensed Matter Physics

[D1] Chatterjee S et al. Lifshitz transition from valence fluctuations in YbAl3. *Nature Communications*, 8(852), 2017. Available at: https://www.nature.com/articles/s41467-017-00946-1.

[D2] Mills R et al. Spectroscopic and NMR identification of novel hybrid ions in fractional quantum energy states formed by an exothermic reaction of atomic hydrogen with certain catalysts, 2003. Available at: https://www.blacklightpower.com/techpapers.html.

Biology

[I1] Callahan PS. Moth and Candle: the Candle Flame as a Sexual Mimic of the Coded Infrared Wavelengths from a Moth Sex Scent. *Appl Opt*, 16(12), 1977.

Neuroscience and Consciousness

[J1] A Secret Sense in The Human Nose? Available at: https://www.hhmi.org/senses/.

[J2] Turin L. *The Secret of Scent: Adventures in Perfume and the Sci of Smell.* Ecco Available at: https://en.wikipedia.org/wiki/Luca_Turin, New York, 2006.

Books related to TGD

[K1] Pitkänen M. About twistor lift of TGD? In *Quantum TGD: Part III. https://tgdtheory.fi/tgdhtml/Btgdquantum3.html*. Available at: https://tgdtheory.fi/pdfpool/hgrtwistor.pdf, 2023.

[K2] Pitkänen M. Dark Matter Hierarchy and Hierarchy of EEGs. In *TGD and EEG: Part I. https://tgdtheory.fi/tgdhtml/Btgdeeg1.html*. Available at: https://tgdtheory.fi/pdfpool/eegdark.pdf, 2023.

[K3] Pitkänen M. General Theory of Qualia. In *TGD Inspired Theory of Consciousness: Part I. https://tgdtheory.fi/tgdhtml/Btgdconsc1.html*. Available at: https://tgdtheory.fi/pdfpool/qualia.pdf, 2023.

[K4] Pitkänen M. Massless states and particle massivation. In *p-Adic Physics. https://tgdtheory.fi/tgdhtml/Bpadphys.html*. Available at: https://tgdtheory.fi/pdfpool/mless.pdf, 2023.

[K5] Pitkänen M. Matter, Mind, Quantum. In *TGD Inspired Theory of Consciousness: Part I. https://tgdtheory.fi/tgdhtml/Btgdconsc1.html*. Available at: https://tgdtheory.fi/pdfpool/conscic.pdf, 2023.

[K6] Pitkänen M. p-Adic Particle Massivation: Hadron Masses. In *p-Adic Physics. https://tgdtheory.fi/tgdhtml/Bpadphys.html*. Available at: https://tgdtheory.fi/pdfpool/mass3.pdf, 2023.

[K7] Pitkänen M. Quantum Model of Memory. In *TGD Inspired Theory of Consciousness: Part I. https://tgdtheory.fi/tgdhtml/Btgdconsc1.html*. Available at: https://tgdtheory.fi/pdfpool/memoryc.pdf, 2023.

[K8] Pitkänen M. Some questions related to the twistor lift of TGD. In *Quantum TGD: Part III. https://tgdtheory.fi/tgdhtml/Btgdquantum3.html*. Available at: https://tgdtheory.fi/pdfpool/twistquestions.pdf, 2023.

[K9] Pitkänen M. The classical part of the twistor story. In *Quantum TGD: Part III. https://tgdtheory.fi/tgdhtml/Btgdquantum3.html*. Available at: https://tgdtheory.fi/pdfpool/twistorstory.pdf, 2023.

[K10] Pitkänen M. The Recent View about Twistorialization in TGD Framework. In *Quantum TGD: Part III. https://tgdtheory.fi/tgdhtml/Btgdquantum3.html*. Available at: https://tgdtheory.fi/pdfpool/smatrix.pdf, 2023.

Articles about TGD

[L1] Pitkänen M. Hydrinos again. Available at: https://tgdtheory.fi/public_html/articles/Millsagain.pdf., 2016.

[L2] Pitkänen M. DMT, pineal gland, and the new view about sensory perception. Available at: https://tgdtheory.fi/public_html/articles/dmtpineal.pdf., 2017.

[L3] Pitkänen M. Does valence bond theory relate to the hierarchy of Planck constants? Available at: https://tgdtheory.fi/public_html/articles/valenceheff.pdf., 2017.

[L4] Pitkänen M. Mysteriously disappearing valence electrons of rare Earth metals and hierarchy of Planck constants. Available at: https://tgdtheory.fi/public_html/articles/rareearth.pdf., 2017.

[L5] Pitkänen M. Philosophy of Adelic Physics. In *Trends and Mathematical Methods in Interdisciplinary Mathematical Sciences*, pages 241–319. Springer.Available at: https://link.springer.com/chapter/10.1007/978-3-319-55612-3_11, 2017.

[L6] Pitkänen M. Philosophy of Adelic Physics. Available at: https://tgdtheory.fi/public_html/articles/adelephysics.pdf., 2017.

[L7] Pitkänen M. Re-examination of the basic notions of TGD inspired theory of consciousness. Available at: https://tgdtheory.fi/public_html/articles/conscrit.pdf., 2017.

[L8] Pitkänen M. Dance of the honeybee and New Physics. Available at: https://tgdtheory.fi/public_html/articles/Shipmanagain.pdf., 2018.