Essay

On the Mechanism of the Energy Transfer in Photosynthesis

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Abstract

The basic mystery of photosynthesis is extreme energy efficiency. Up to 95% of the photon's energy is transmitted in a medium that would seem to be as inhospitable as possible for energy transmission with almost no dissipation. The use of very low temperatures, the shooting of monochromatic photons into a lattice, and superconductivity are out of the question. The incoming photons also have a wavelength distribution, which does not facilitate the energy transfer either. The recent experimental study of the LH2 antenna system has led to a view about how the photon energy is transferred to the reaction center where photosynthesis takes place. It is believed that the disorganization of the proteins is proposed to explain this. The proposed interpretation of the findings is as follows. A photon enters and excites the electron of the LH2 protein. When the electron is de-excited, one or more photons are generated which in turn excite the electrons of the next LH2 proteins. Finally, the generated photons excite the electrons of the reaction center and these electrons are used in the photosynthetic process to produce sugar molecules. I find it difficult to imagine how the irregular positions of proteins could make possible the low dissipation, as proposed. The TGD based proposal for the mechanism involves two key ideas. The required long range quantum coherence is made possible by the proposal that dark matter corresponds to the phases of ordinary matter characterized by effective Planck constant. The crystal structure making possible low dissipation would be icosa-tetrahedral hyperbolic honeycomb associated with a magnetic body of the system, which is central also in the dark realization of the genetic code in the TGD framework. Low dissipation for electrons would be possible since dark electron-hole pairs would be transferred along the magnetic body. The gravitational magnetic body of Earth could also play a central role.

1 Introduction

I learned about very interesting results related to photosynthesis. A popular article on the BigThink page (https://rb.gy/phb4c) tells about an article published in the journal PNAS [2] (rb.gy/9zppa).

The basic mystery of photosynthesis is extreme energy efficiency. Up to 95% of the photon's energy is transmitted in a medium that would seem to be as inhospitable as possible for energy transmission with almost no dissipation. The use of very low temperatures, the shooting of monochromatic photons into a lattice, and superconductivity are out of the question. The incoming photons also have a wavelength distribution, which does not facilitate the energy transfer either.

Consider first a summary of the basic findings and conclusions.

1. Chlorophyll is the basic structure involved with photosynthesis. Its basic function is to gather solar energy and transfer it to the reaction center where the energy is stored to various biomolecules. There are 2 wavelength bands, corresponding to 430 nm in blue and 662 nm in red, where the absorption is especially strong. The so-called LH2 proteins act as antennas absorbing photons. In the reaction center LH1 proteins perform photosynthesis by building biomolecules to which the solar energy is stored.

2. It has been observed that the lower limit of the size of the so-called light-absorbing LH2 antenna proteins is 2.5 nm. It is also the minimum distance between LH2 proteins. The proposal is that the LH2 antenna network could somehow make the transfer of energy almost without dissipation.

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It is believed that the disorganization of the proteins might explain this. However, in the popular article there was no intuitive argument as to why this is so. The claim is made on the basis of computational models and empirical facts gained by studying the transfer process. I find it difficult to imagine how the irregular positions of proteins could promote the process.

3. The proposed interpretation of the findings is as follows. A photon enters and excites the electron of the LH2 protein. When the electron is de-excited, one or more photons are generated which in turn excite the electrons of the next LH2 proteins. Finally, the generated photons excite the electrons of the reaction center and these electrons are used in the photosynthetic process to produce sugar molecules.

1.1 TGD view of the energy transfer

The findings seem to resonate with two key views of the TGD inspired quantum biology.

1. Photosynthesis involves at least a temporary storage of solar energy to quantum gravitational energy batteries [10, 9].

2. There is dark variant of the genetic code and realization of dark DNA double strand base on the icosahedral tessellation [11] of the hyperbolic 3-space H^3, which is realized both as a mass shell in $M^4 \subset M^8$ and light-cone proper time=constant 3-surface in $M^4 \subset M^4 \times CP_2$.

   Icosa-tetrahedral and possible other hyperbolic tessellations would be associated, not with the biological body, but with the magnetic body (MB) of the biosystem carrying dark matter identified as phases of the ordinary matter with effective Planck constant $h_{eff} = nh_0$. The location of dark matter at the field body would explain why dark matter has not been found in various searches.

What are the TGD answers to the basic questions waiting for an answer?

1. Why would the dissipation be so low? Quantum coherence in a scale of at least the order of tens of nanometers could guarantee this. Dark matter as phases with a large value of h_{eff} indeed implies a long quantum coherence scale. Also a regular crystal structure is a natural prerequisite for a low dissipation. The dissipation is minimized if the energy, or possibly the electrons, are transferred through the hyperbolic tessellation of the MB carrying dark matter.

2. The minimum distance between LH2 proteins is about 2.5-4 nanometers, which corresponds to the DNA codon size scale. In the TGD based model for genetic code, the dark realization of the genetic code and the DNA double helix are connected to an icosa-tetrahedral honeycomb in hyperbolic 3-space H^3 assigned with the MB [11]. Could the crystalline structure be realized by using the same icosa-tetrahedral tessellation as associated with the dark DNA and dark genome controlling the ordinary genome.

   If the transfer of energy to the reaction center occur at the MB as a transfer of dark electrons, the dissipation could be very small since there would be no direct interaction of the dark electrons with the ordinary matter if the interaction vertices can involve only particles with the same value of h_{eff}, as seems natural.

2 The TGD based model

Consider now the TGD proposal in more detail.

2.1 Quantitative data

Consider next the quantitative data.

1. The distance between LH2 proteins is in the range 2.5-3.1 nm. This scale corresponds to the DNA codon size scale and to the cell size of the fundamental region of the icosa-tetrahedral tessellation, which has Platonic solids as cells [11]. There are 12 icosahedrons, 20 tetrahedrons and 30 octahedrons forming a region of size 10 nm, which corresponds to the p-adic length scale $L(151)$ (associated with a p-adic prime $p \simeq 2^k$, $k = 151$) appearing as a characteristic length scale in bomatter. This region corresponds to 10 DNA codons for which the total twist along the DNA strand is 6π that is 3 full turns.

2. The size of the structure involved with the photosynthesis would be naturally cell size scale? The wavelength of the red light gives a length scale of order .5 μm and serves a natural lower bound. Note that cell nucleus size is about 1 μm.

3. The time τ required for the energy transfer between adjacent antenna proteins varies from 5.7 to 14 ps. In time τ, the distance traveled by the light is $L = 1.71 - 4.2$ mm. Interestingly, for Earth the gravitational Compton wavelength $\Lambda_{gr}(E) = GM_E/\beta_0(E)$ is for $\beta_0(E) = v_0/c = 1$ equal to $\Lambda_{gr}(E) = 4.5$ mm. Gravitational Compton frequency is $f_{gr}(E) = 67$ GHz and corresponds to a time of about $T_{gr}(E) = 15$ ps, the upper limit for the estimated time.

   f_{gr} corresponds to a photon energy of $E_{gr} = .27$ meV. The electronic metabolic energy quantum in the case of the Earth would be related by a factor m_e/m_p the protonic metabolic energy quantum identifiable as standard metabolic energy currency. The model for the findings of Andrew Adamatsky [4] suggests that sponges have a language based on membrane potential oscillations with membrane potential variations of order mV. The TGD based model suggests the existence of metabolic energy quantum of this order of magnitude [10]! meV is also the energy associated with the miniature membrane potentials. Could τ be identifiable as the gravitational Compton time T_{gr} at which the dark matter at the MB would oscillate?

2.2 How could the electrons be transferred to the reaction center as dark electrons?

Could the process at the level of LH2 antenna proteins correspond to the propagation of the dark electron and the hole associated with it? The dark electron would hop between the sites of the tessellation perhaps by quantum tunneling, which in TGD Universe corresponds to a pair of "big" (ordinary) state function reductions (BSFRs) changing the arrow of time temporarily. The dark electron current would be analogous to super current and the system "hole + dark electron" would be analogous to a Cooper pair.

1. The duration τ of a single step should correspond to the oscillation period $\tau \sim T_{gr}$. If so, the oscillation would play the role of EEG resonance oscillation coordinating the transfer by induces the pairs of BSFRs.

2. The first guess is that electrons are converted to dark electrons with a large value of the gravitational Planck's constant $\hbar_{eff} = \hbar_{gr} = GMm/\beta_0(M)$ [1] located at the gravitational MB of the Earth or Sun. They would be transferred to the U-shaped monopole flux tubes and the reduction of the binding energy of the electron would be equal to the energy of the incoming photon absorbed by it.

   The reduction of the binding energy cannot be however purely gravitational. For electrons, the maximal gravitational binding energy in the case of the Earth is about $E_{gr}(Earth, e) = .25$ meV whereas the incoming photon has energy $E \simeq x \times .5$ eV, where x is in the range 4 to 6 in the wavelength range considered. For the Sun the maximal binding energy E_{gr} is reduced by the ratio

$[M(Earth)/M(Sun)] \times [R(Sun)/R(Earth) = .071$. In the case of protons with $E_{gr}(Earth, p) = .5$ eV this gives to $E_{gr}(Sun, p) = .14$ eV, which happens to be roughly twice the energy assignable to membrane potential. For electrons this gives $E_{gr}(Sun, e) = 1.8$ μeV.

For the energy transfer in photosynthesis, the energy of the solar photon cannot therefore correspond to the change of gravitational binding energy in the case of electrons. Rather, the energy must be identified as the change of electromagnetic binding energy as an atom is effectively ionized when an electron becomes a dark electron at the MB. This MB need not be gravitational and could also correspond to a relatively small $h_{eff} > h$.

3. What comes to mind are dark unpaired valence electron states of atoms in which the h_{eff} of an unpaired electron increases so that binding energy is scaled down by $1/h_{eff}^2$. The binding energy spectrum of the dark electron states is obtained by scaling the ordinary binding energy spectrum and these states are analogous Rydgerg states in that the radius of Bohr orbits is scaled up by h_{eff}^2. If the valence electron becomes gravitationally dark ($h_{eff} = h_{gr}$), the atom effectively suffers ionization to a state with vanishing energy and positive charge. Dark ions could correspond to this kind of states.

4. How could the energy transfer to the reaction center take place? The simplest mechanism could be the following. One can charge the solar energy batteries by transforming ordinary electrons to dark electrons at the MB of the Sun. At the reaction center the dark electrons drop back and transform to ordinary electrons and are available for the photosynthesis proper, storing the energy to biomolecules.

   The experimental findings could be consistent with the assumption that the pairs formed by a dark electron and hole move to the reaction center, and the movement of the dark electron is analogous to a conduction in a lattice by hopping. The lattice could correspond to the tetra-icosahedral tessellation assignable also with DNA and genetic code. The time for one transition would correspond to $T_{gr}(Earth) \sim 15ns$. This supports the view that the MB of the Earth is present.

5. Why would the dropping down to Earth take place in the reaction center? The holes have an effective positive charge because the dark electrons have a large distance to the surface of Earth. If the reaction center has a negative charge, it attracts the positively charged holes. The holes move towards the reaction center and the dark electrons and gravitational monopole flux tubes and dark electrons follow. The electrons transform to normal ones and holes disappear. The predicted negative charge of the reaction center serves as a test for the proposal.

6. How this negatively charged region in the reaction center could be generated? Pollack effect [5, 3, 7, 6], discussed from the TGD point of view in [8], is caused by (say) IR radiation in the presence of gel phase, and indeed generates negatively charged exclusion zones. The exclusion zones could be due the transfer of protons of water molecules to dark protons at the flux tubes of the MB,which is however not gravitational. Both cells and DNA represent examples of negatively charged objects. Pollack effect is indeed a key element of the TGD inspired view of living matter. There it is natural to assume that the exclusion zone is present also in the reaction center.

If the energies of dark electrons and holes are separately conserved, they can annihilate to the ordinary electron in the reaction center. Can this be true?

1. Why would the energy of the dark electron be conserved in the hopping along the tessellation? Single step would correspond to a motion under the magnetic Lorentz force, which conserves energy since force is orthogonal to the velocity.

2. What about the dark electron-hole interaction? This interaction is present if the flux tube follows the motion of the hole-dark electron pair. This pair would form a bound state analogous to the Cooper

pair and its energy would be conserved if its scattering would reduce to the magnetic scattering of the dark electron. The situation would be very much like in the case of superconductivity.

3. If the hole corresponds to a transition of an unpaired valence electron to a large h_{eff} analog of a Rydberg state with a very large size, the binding energy and energy of the state is very near to zero. The ionization energy scale for valence electrons is measured in electron volts just like for the photons from the Sun.

   The energy scale for icosa-tetrahedral honeycomb scaling like $\hbar_{eff}^2/(2m_eL^2)$, L the size of the fundamental region, gives an estimate for the unit of energy quantization, which does not depend on $\hbar_{eff}$. The energy scale is 10^2 eV for $L = L(151) = 10$ nm. This scale is expected to be very large as compared to the energy gap so that transitions are not possible. The situation would be like in superconductivity and superfluidity.

4. What about energy conservation in the motion of the localized valence hole? Valence electron hole can be replaced with the valence electron of a neighboring atom and this makes possible its movement towards the negatively charged reaction center. The energy of the valence hole in the center of mass system of the atom is not changed but the ionized atom or the molecule containing it would experience the Coulomb force assumed to be associated with the reaction center and its center of mass energy can change.

   How is it possible that the attractive Coulomb field between the hole and the reaction center does not affect the energy of the valence hole? The question is well-motivated The Coulomb energy between the hole and the reaction center is expected to be much larger than the energy gap. For instance, for distance of 1 μm the Coulomb energy between unit charges is of order 10^{-2} eV.

   What prevents the valence hole from accelerating and getting more energetic? The U-shaped gravitational magnetic flux tube has a string tension and the lengthening of the flux tube could compensate for the Coulomb force. The Coulomb energy would be transformed to elastic energy of the flux tube. In the reaction center the flux tube would contract and the dark electron could fuse with the hole having the same energy.

2.3 Is this picture consistent with the quantum gravitational storage of metabolic energy?

Is this picture consistent with the earlier proposal for the metabolic energy storage, which is based on the notion of gravitationally dark protons [10] and also predicts electronic metabolic energy currency of about .25 meV for which there is some evidence [4]?

1. The motivation for the proposal is that the gravitational potential energy of a proton at the surface of Earth is .5 eV: this happens to be the nominal value of metabolic energy quantum. Of course, since the electromagnetic binding energies in molecular scale are measured using eV as units, this might be a pure accident. The weaker optimistic interpretation is that this co-incidence makes possible interaction between quantum gravitational and quantum electromagnetic degrees of freedom.

   When the distance from the surface of Earth in the direction of the Sun, the gravitational forces of Sun and Earth are identical. This condition gives an upper bound for the distance $r(Earth)$ of the particle from the Earth in the direction of Sun as $r(Earth)/AU - r(Earth) = \sqrt{M(Earth)/M(Sun)}$ giving $r(Earth) \simeq 100R(Earth)$ to be compared to the distance of Moon about $r(Moon) \simeq 60R(Earth)$. The value of the gravitational potential difference as is 99% of the maximal one.

   The proposal [10] is that the transformation of protons of water molecules to gravitationally dark protons could serve as a mechanism for the storage of metabolic energy.

   If the metabolic energy quantum is determined *solely* by the gravitation of Earth, this mechanism does not work at large distances from the surface of Earth. The fact that Moon travellers have survived does not favor a purely gravitational mechanism but the fact that molecular binding energies are of the same order, might save the mechanism. A more imaginative option is that the gravitational MB of the Moon traveller is still associated with Earth and makes it possible to store metabolic energy to the gravitational MB of Earth.

2. Dark protons triplets could serve as a storage of metabolic energy in the case of ATP (high energy phosphate bond) and maybe even in the case of biomolecules. This is supported by the appearance of 3 protons as a kind of basic unit in ATP→ ADP metabolic machinery.

3. In the Pollack effect, IR radiation effectively ionizes water molecules and produces effective stoichiometry $H_{1.5}O$ inside a negatively charged exclusion zone. The decrease of the electronic binding energy per water molecule in the Pollack effect could be naturally given by the energy of the IR photon and would be rather small. If the Coulomb binding energy of the dark proton triplets with the exclusion zone is equal the metabolic energy quantum $E = .5$ eV, the reduction of the gravitational binding energy in the transfer of dark proton triplet to the gravitational MB would be given by E and would lead to a zero energy state. Could one the build-up the energy carrying bio-molecules by transferring dark proton triplet to the gravitational magnetic bodies of the biomolecules by using the energy liberated by dark electrons as they drop down and transform to ordinary electrons in the reaction center?

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