Summary about an article of Clint Seward

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November 29, 2014

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Abstract

In the following I represents comments about the article "Ball Lightning Events Explained as Self-Stable Spinning High-Density Plasma Toroids or Atmospheric Spheromaks" of Clint Seward. The discussion represented in the book about possible applications is highly speculative and must be taken with a grain of salt. The general problem is that the energies involved are magnetic energies and very small as compared to the energies involved with the applications. If new physics is involved with the formation of spheromaks, situation might change.

1 Introduction

In the following try to understand the findings of Clint Steward about what he calls ESTSs from theoretical point of view. ESTSs are structures which could explain the stability of ball lightnings and Steward makes rather speculative suggestions about ESTS based technologies.

1.1 Observations

The following gives a short summary about what has been observed.

1. A rotating plasma toroid is in question. The terms used are spheromak, spiral toroidal spheromak, and ESTS. The structure consists of a self-organized plasma which is in magnetic confinement in the magnetic field it has crated. No external magnetic field is needed as in Tokamak and the system is stable.

   Some numbers are in order: the duration τ of the configuration is at least 600 ms. The structure is estimated to carry density of about 10^{19} ions per cubic centimeter. Avogadro's number is about 10^{23}. The density wold be about 10 ions per cube with 10 nm side (cell membrane thickness) and obviously very high. Also here cold plasmas are encountered (various biologically important ions)

2. It has been observed that ESTSs accelerate in an external magnetic field. If the field is constant, this is not possible if ESTS is neutral: whether this is the case is not clear from the report.

   If the magnetic field has a gradient, the situation changes. Toroid generates a magnetic field, which is dipole field characterized by dipole strength μ in good approximation. The interaction energy with external field is $E = -\mu \cdot B$. If the external field B is constant, only torque results. If it has also gradient, also acceleration results. Among other things this makes possible the levitation of superconductors. Now one has magnetic bottles. Since the flux lines converge as one approaches the poles, magnetic field has gradient along the field and gives rise to a force as gradient of the interaction energy.

   In TGD description one would talk about flux tubes getting thinner as one approaches poles.

3. Magnetic reconnection is observed. Two ESTSs fuse to form a bigger one. If the colliding ESTSs can be given high enough energy, one might hope that the charged particles could overcome Coulomb barrier so that nuclear fusion could take place. The energies needed are however enormous since macroscopic object is now in question unlike in nuclear collisions due to high temperature. A more plausible mechanism would be based on heating of ESTSs assuming that they are stable against heating as magnetic structures.

4. ESTSs rotate and look spherical. Actually they are toroidal due to the toroidal shape of the magnetic field. Ball lightnings could correspond to ESTSs.

It is of course not at all clear how the ESTSs can be stable, and the challenge for theoretician is to explain the stability.

1.2 Proposed technologies

The proposals for technologies are rather imaginative.

1. Air defence is mentioned first in the list. ESTSs would accelerate in magnetic bottle and hit the targe producing great damage! The criticism is that it is at all obvious how to build the flux tube connecting the weapon to the target. It also get thinner in order to achieve the accelerations.

   A more peaceful application might be already utilized in biology. Flux tubes connecting molecules could force charged particles to move along the tube by deforming the flux tube so that it would become thinner at the second end. The idea about magnetic body having motor actions supports this kind of idea. To me this kind of application looks more realistic than the proposed applications.

2. The production of X-rays is proposed as a second possible application. The energies involved are in keV range. One accelerates ESTS with high ion density and allows its to hit the target. This should product X-rays as brehmstrahlung in collisions of charged particles with target. Television uses this mechanism. The energy needed is rather high: if the charged particle is proton, the energy of 1 keV would correspond to an velocity of order $10^{-3}c \simeq 3 \times 10^5$ m/s: once around the globe in 100 seconds! So high a velocity for the ESTS dod not look feasible but I am not a professional.

3. Nuclear fusion is also proposed as an application. Usually nuclear fusion is achieved by producing a high enough temperature. Laser beam might allow the needed heating. The temperature needed in thermal fusion in Sun corresponds to about 10^7 Kelvin and corresponds to an energy about keV (eV corresponds to 10^4 Kelvin). This energy is actually much less than the height of Coulomb wall defining the minimal energy that charged particle must have in order to entire to the nucleus. From my Alonso Finn I find the estimate $E_c = .15 \times Z_1Z_2$ MeV for the Coulomb wall when the target particle is at rest. This corresponds to a temperature of about 10^9 Kelvin which is two orders of magnitude higher than 10^7 Kelvins which corresponds to energy of order 1 keV. The explanation is that in thermal equilibrium some fraction of ions have energy above Coulomb wall and this is needed to initiate the fusion reaction. Still the difference huge since Boltzmann factor $exp(-H/T)$ becomes extremely small as T is scale down by 10^{-2} factor. Presumably the experimentalists and theorists have indeed demonstrated that nuclear fusion is possible in solar interior despite this.

   In the recent situation the situation this advantage is lost and every ion inside ESTS and thus ESTS should have a velocity which corresponds to charged particles with energy above Coulomb wall. This energy corresponds to a velocity which is about $c/100 \simeq 3 \times 10^6$ m/s. Once around the glob in one second! All charged particles in ESTS should have this energy so that the total kinetic energy should be about $10^{18} \times Z_1Z_2\ MeV/cm^3 \simeq (Z_1Z_2/6) \times 10^6$ J/cm^3. This is a gigantic energy: a mass of 1 kg moving with velocity of 10 m/s has energy of 50 Joules. If the size scale of the accelerating volume is $L = 1$ meter it corresponds to a force given by $F \sim \Delta E/L$ For 1 cm^3 sized ESTS this would require force about $(Z_1Z_2/6) \times 10^6$ N. Gravitational force at the surface of Earth is 10 N for an object weighing one kg. High dipole moment of ESTS perhaps resulting from charge separation and relativistic kinematics for electrons combined with strong external magnetic field with strong gradient should give rise to this force. Seward argues that his estimates support for this.

   This looks unfeasible to me. The acceleration would require quite high an energy and one can expect dissipative losses. Also the proposed mechanism of acceleration using magnetic fields turns out to be unfeasible. The energies gained are totally negligible in magnetic fields of order Tesla. The needed energies even for relativistic electrons would be by 5 orders of magnitude higher than the lab energies in LHC!

4. Situation is however not hopeless. If ESTSs are stable in heating one might consider them as a solution to the plasma confinement problem in hot fusion. If ESTSs carry monopole flux (possible in TGD Universe), this kind of stability is expected.

To my opinion the effect itself is extremely interesting and might involve even new physics but the proposed applications as such look to me unrealistic.

2 Theoretical background

2.1 Various magnetic fields involved

Before continuing it is good to list the magnetic fields involved.

1. The magnetic field associated with the current of di-electric breakdown. This gives lower bound for the strength of the internal magnetic field B_{int} of ESTS.

2. Magnetic field B_{int} inside ESTS. This is certainly important if the electron current at the surface of ESTS creates the phenomenon.

3. The magnetic field of ESTS outside it. This field is in good approximation a dipole field. The model for dipole strength requires a model for the electronic and ionic currents inside ESTS.

4. Also external magnetic field can be involved.

2.2 Stability of magnetic fields involved with ESTS

One can try to understand ESTSs using simple arguments. Consider first stability arguments since they give rather non-trivial conditions on the structure of ESTS.

1. ESTS is in mechanical equilibrium. In other words the net em force, which is sum of magnetic Lorentz force and electric Coulomb force cancels. The formula expressing this is $\rho E + j \times B = 0$. Now work is done: $j \cdot E = 0$. In the static situation electric field vanishes and also the Lorentz force : $j \times B = 0$. Magnetic field and the current creating it are parallel to each other - at least in the interior of the toroids.

2. When the current generating the magnetic field is inside torus (this might not be the case now if electrons at the surface of torus generate the magnetic field), the outcome consists of a helical magnetic field and helical current parallel to each other: charged particles move along field lines of B. Note that for this case the current can have a component which rotates around the cross section of torus but that also component along the torus is necessary. If B were not helical, the current could not create it.

   These field configurations are known as Beltrami fields and they have highly interesting properties: the topology of Beltrami fields can be very complex: field lines are knotted and linked. Kiehn [B1] has studied these field configurations. The 4-D variants of these fields involving also electric fields are in key role in TGD. Linked magnetic flux tubes carrying currents parallel to them would be the TGD counter part for Beltrami fields and are in key role in TGD inspired biology.

3. It is assumed that in the lowest order approximation electron current is a surface current rotating transversally the torus. Electron current would generate a magnetic field inside torus with field lines rotating longitudinally around the torus. In the lowest order, electron current is not expected to generate a component of magnetic field outside the torus whereas ion current does so: one expects that this magnetic field rotates around torus transversally.

4. Ionic current is assumed to rotate longitudinally inside the torus. If this current is not helical it generates a magnetic field, whose lines rotate transversally around the torus. This would make magnetic field helical inside the torus. Equilibrium conditions (ion current parallel to magnetic field) are not satisfied unless ion current becomes also helical. Hence it seems that the ion current and the magnetic field inside the torus must be helical. Also electron current is expected to generate a longitudinal component so that both currents would be helical and generate helical magnetic field parallel to the current.

5. Ions could be assumed to rotate along cyclotron orbits inside the torus with cyclotron frequency. A natural guess is that the longitudinal rotation frequency is rational multiple of this frequency with rational number $q = m/n$ which is ratio of small integers so that the helical orbits closed after finitely many full turns. Also the assumption that ions and electrons rotate with same longitudinal velocity is feasible since it would minimize dissipative effects. Same velocity for ions and electrons would however minimize the magnetic dipole moment of the torus and acceleration mechanism based on the magnetic field gradient would not be effective.

6. Outside the torus ionic and electric currents (with longitudinal component) generate a magnetic field which in good approximation is dipole field (ideal dipole field is generated by a torus along infinitesimal torus). The axis of the dipole is orthogonal to the plane of torus. This dipole moment makes possible acceleration in an external field possessing a gradient (magnetic bottle). Situation is analogous to that for a hydrodynamical flow in a tube which gets thinner: flow velocity increases as the tube gets thinner. Now the reason for this is that magnetic flux analogous to the total conserved liquid flow is conserved.

2.3 Mechanical equilibrium for electrons at the surface of ESTS

One can also consider mechanical equilibrium at the surface of torus.

1. The centrifugal acceleration at the surface of torus must be compensated by the Coulombic attraction by ions. This condition allows to deduce the value of the electronic rotation velocity once the total force (that is electric field generated by ions is known.

2. A simplified model for purely local physics is obtained by approximating the torus with a cylinder carrying constant ionic charge density (for volume and area of torus this model gives right values). The mechanical equilibrium condition

$$\frac{mv^2}{d} = eE$$

allows to solve velocity as $v = \sqrt{eE/2m}$.

3. The radial electric field constant along surface of torus can be deduced from Gauss law

$$\int E \cdot dS = \frac{Q}{\epsilon_0}$$

giving

$$E = \frac{N_e e}{4\pi^2 dR} \ .$$

4. Substituting to the mechanical equilibrium condition, one obtains for the velocity the expression

$$\frac{v_L}{c} = \frac{\sqrt{N_e L_e/2R}}{\pi} = \sqrt{n_e d^2 L_e} \simeq 49 \times (d/cm) \ .$$

The result means that the velocity is superluminal if the condition $d < .2$ mm is satisfied. This is in conflict with the sizes scale of few centimeters for the ESTS tori.

5. What the result means that assuming only electric attraction of ions and the large value of ion density, one ends up with nonsense prediction. If the ion density is reduced by a factor $x^2 = 10^{-4}$ the velocity is reduced by x by square root dependence and velocity is about $v = c/2$. This is not the only theoretical argument challenging the claim about high charge density

6. The reason for the failure might be that the situation is actually relativistic for electrons. In relativistic treatment one should replace electron's kinetic energy in centrigural force $T/r = mv^2/r$ with relativistic kinetic energy $T = m(1/1 - \beta^2 - 1)$, $\beta = v/c$, so that the condition $\beta = X$ transforms to $\beta = \sqrt{X}X + 1 < 1$. In this case the claimed value of charge density makes sense. The assumption that electron's rotation frequency is of the same order of magnitude as cyclotron frequency, must be given up.

It seems that the only way to proceed is to assume that electrons are relativistic in longitudinal degrees of freedom.

Notice that if electrons are inside flux tube carrying monopole flux, it is not clear whether the proposed condition is needed since there is no boundary now.

2.4 How ESTSs are created?

Consider next the mechanism creating ESTSs.

1. ESTS would be created when electron current associated with a dielectric breakdown generates a magnetic field whose flux lines rotate around it. This magnetic field weakens like 1/distance from the axis defined by the direction of the current. Electrons experience Lorentz force in the radial direction tending to drive them out. Some fraction of electrons leaks out. This leakage can be seen directly from the photos representing the formation of ESTS.

2. Why should it begin to rotate around this axis? This is easiest to understand if field line form flux tubes at which electrons reside and start to rotate around the flux lines in cyclotron orbits and simultaneously rotate longitudinally. One obtains helical orbits.

3. Why electrons would rotate around the current of di-electric breakdown along magnetic flux line? What makes the situation stable? Why electrons do not drop down along spiral orbits because of brehmstrahlung or does this proces actually occur. One could understand this if the flux lines form a flux tube and electrons are located at its boundaries. If is of course not absolutely clear whether the electrons really reside at the boundary of the torus.

4. In TGD framework one cannot exclude the possibility that ESTS torus is actually a flux tube carrying monopole flux so that there is not actual boundary involved. This would explain the stability and allow to circumvent the conflict between the estimated value of n_e coming from Maxwell's electrodynamics and the reported value of n_e, which is several orders of magnitude larger.

2.5 What ESTSs are quantum mechanically?

It is not clear whether quantum coherence in long length scales is needed to understand ESTS.

1. The absence of dissipation for magnetic field (Beltrami field property) could be interpreted as a correlate for a macroscopic quantum coherence. In standard quantum theory macroscopic quantum coherence in 10 cm scale does not look plausible so that $h_{eff} = n \times h$ suggests itself in TGD framework. Also the localization to the surface of toroid might be made possible: electrons would be at quantized cyclotron orbits at surfaces of toroids inside toroids with radii proportional to $\sqrt{n}$, where n labels the oscillator orbit. Something like this is indeed suggested.

2. Perhaps electrons claimed to be located at the boundary of the ESTS torus are in cyclotron states in the magnetic field that they create. Of so, then cyclotron period would be an essential time scale and depend on the magnetic field strength only $\omega_c = eB/m$. Cyclotron energy is given by $E_c = h_{eff}eB/m$ and is below thermal energy unless h_{eff} is large. Nottale's hypothesis suggests $h_{eff} = GMm/v_0$, where M could be the mass of Earth and V_0 would be of the order of the rotation velocity of Earth. This would predict energy range of dark cyclotron photons to be independent of the mass of the charged particle and to be in the visible and UV range or living matter.

3. ESTS as a flux tube carrying monopole flux is a further option. In fact, the most stringent form of $h_{eff} = n \times h$ hypothesis is that these phases identified as dark matter reside at this kind of flux tubes.

3 More quantitative estimates

In the following more quantitative estimates are made using the available data.

3.1 What data is needed?

A lot of quantitative data would be needed to model the situation realistically.

1. What is the value of the current associated with the di-electric breakdown? This would allow to estimate the strength of the magnetic field inside the ESTS torus.

2. How does one know that ion current indeed flows inside the torus and electron current at its surface? How the density of ions is estimated? Is it possible to measure it directly or does one assume neutrality and measures electronic surface current at the surface (corresponds directly to the strength B of the magnetic field inside the torus)? Has this been measured?

3. What is the estimate for the field strength inside the torus. Knowing the dimensions of torus and the intensity of electron current (density plus velocity) one could estimate the field strength from Maxwell's equations.

4. Visible light is generated. How much is understood about this process. Do the collisions of ions with each other and/or atomic transitions generate it. Is brehmstrahlung generated. Does the emission of light relate to the decay of the system.

   [TGD allows to play with the exotic option that dark cyclotron photons with energies in visible and UV range are generated and are partially transformed to "biophotons".]

3.2 Trying to estimate theoretically the orders of magnitude

Beltrami field property could be responsible for the stability of the structure. The conservation of magnetic flux could prevent the pinching and splitting of the torus.

The system lives for about .6 seconds. What determines this time scale?

1. This time scale is rather long. Could it relate to cyclotron period $T = 2\pi m/eB$? The answer is negative. Using for m electron mass one obtains an estimate for the intensity of the magnetic field. For Earth's magnetic field strength $B = .5$ Gauss (1 Gauss=10^{-4} Tesla) the time T would be of order $10^{-6}/1.5$ seconds. Magnetic field should be about million times weaker -about 10^{-11} Tesla and this is not feasible.

2. A more plausible guess is that dissipation rates determines the life time. To estimate the time scale would require a model for how the current loses its energy by radiation and how the electrons and ions leak out of it.

3.3 Estimates for the electron density and magnetic field strength in the interior of torus

One can try to estimate the magnetic field strength in the interior of the torus. Although it turns out that the following argument does not allow to estimate it, one obtains an estimate for the density of electrons. The estimate seems to be inconsistent with the claimed value $n_e \sim 10^{19}/cm^3$. This estimate can be taken rather seriously since it involves basic electro-dynamics only.

3.3.1 Estimate for the density of electrons from Maxwell's equations is not consistent with the reported value of electron density

The attempt to estimate magnetic field strength inside ESTS leads to an estimate for the density of electrons.

1. Assume that dominant contribution to the electronic current at the surface of torus is transversal. The resulting magnetic field is confined inside the torus and its value is apart from a constant factor equal to the surface current.

   $$B = k \times K \ ,$$

   where $k = \mu_0$ is a constant and K is surface current.

2. One can try to estimate the surface current by using various data bits. The average 3-D density of electronic charge for torus is about $\rho = en_3 \simeq 10^{19}/cm^3$. The total electronic charge inside ESTS is $Q = N_e e = en_3 V$, where V is the volume of the torus. One can also calculate the surface charge density σ as $\sigma = Q/S = en_3 V/S$, where S is the surface area of torus.

3. In the non-relativistic situation the transversal electronic surface current K equals to $K = \sigma v$. $v = \omega d$ is the velocity of electron, where d is the minor radius of the torus as flux tube to be distinguished from the major radius R of torus. In relativistic situation one must replace σ with $\gamma\sigma$ $\gamma = 1/\sqrt{1-\beta^2}$, $.\beta = v/c$

4. Assume that electrons move in transversal directions along cyclotron orbits. With this assumption one has $\omega_c = eB/m$ for the angular cyclotron frequency. In relativistic situation one must replace rest mass m with dynamical mass to give $\omega_c = eB/\gamma m$ so that cyclotron frequency is reduced by factor $\sqrt{1-\beta^2}$.

5. The unexpected outcome is that magnetic field appears at both sides of the equation! The equation tells nothing about the magnetic field strength but provides a consistency condition between the parameters characterizing the geometry of the torus, electron mass, and the density n_e of electrons to deduce the value of n_e. This option can be of course tested by looking what the predicted value of n_e. Equivalently the number of electrons inside torus is predicted. The only available parameters are fine structure constant, the ratio of the suitably defined scale of the torus to the proton Compton radius h/mc.

6. Consider first non-relativistic case. The condition $B = kK$ leads to an expression for the total number N_e of electrons

$$N_e = \frac{2\pi}{\alpha}\frac{S}{dL_e} \ , \quad L_e = \frac{h}{mc} \ , \quad \alpha = \frac{e^2}{4\pi\hbar c} \ .$$

   The torus is characterized by major radius R and minor radius r. The volume and surface area are given by $V = 2\pi^2 Rd^2$ and $S = 4\pi^2 Rd$ as one might naively guess by directly generalizing the formulas for cylinder.

   Feeding in the expression for S one obtains

$$N_e = \frac{8\pi^3}{\alpha}\frac{R}{L_e} \ , \quad L_e = \frac{h}{mc} \ , \quad \alpha = \frac{e^2}{4\pi\hbar c} \simeq \frac{1}{137} \ .$$

   Electron Compton length is $L_e \simeq 2.4 \times 10^{-12}$ meters. Altogether this gives the expression

$$N_e = \frac{R}{cm} \times 1.4 \times 10^{14}$$

7. One can test the estimate for N_e resulting from cyclotron orbit hypothesis. A direct estimate for N_e comes from the claimed density $n_e \sim 10^{19}/cm^3$ multiplied by the volume $V = 4\pi^2 Rr^2$. One has

$$N_e = 2\pi^2 Rr^2 n_e \simeq 2 \times 10^{20} \times (R/cm) \times (r/cm)^2$$

   predicting electron density

$$n_e =\simeq (\frac{cm}{d})^2 \times 7.1 \times 10^{12}/cm^3 \ .$$

   The consistency for the experimental and theoretical estimates for n_e gives

$$\frac{d}{cm)} \simeq .9 \times 10^{-4} \sim 10\mu m \ .$$

   One should have $d/cm = 10$ μm. So small minor radius for ESTS torus does not sound feasible. Note that already earlier the assumption $n_e = 10^{19}/m^3$ led to the prediction that electrons must rotate super-luminally along the longitudinal direction.

8. Some assumption is wrong. The situation might be non-relativistic for electrons, the cyclotron orbit hypothesis could be non-realistic, or the value $n \sim 10^{19}/cm^3$ is too optimistic. $n_e \sim 10^{13}/cm^3$ would be consistent with the above estimate for ESTSs with centimeter size scale and is 6 orders of magnitude smaller than the reported density.

Could the problems be cured if electrons are relativistic. Electrons might be relativistic in longitudinal direction: as a matter fact. the (non-relativistic) mechanical equilibrium condition predicts superluminal electron velocity if one assumes the reported $n_e = 10^{19}/cm^3$.

1. Cyclotron hypothesis might hold true also in relativistic regime in suitable modified form. It would seem that the expression for the cyclotron frequency must be modified. The naive guess is that the rest mass is replaced with relativistic mass: $\omega_c = \sqrt{1-\beta_L^2}eB/m$, $\beta_L = v_L/c$, where v_L is the longitudinal velocity of electron to be distinguished from the transversal velocity $v_T = \omega_c d = \sqrt{1-\beta_L^2}eB/m$

2. What happens to the current component $j = \rho v_T$. Charge density receives a factor $\sqrt{1-\beta_L^2}$, which cancels the factor from ω_c so that nothing happens to the transversal component of the current.

   Hence it seems that non-relativistic formula works also in relativistic case because transversal degrees of freedom are not affected by longitudinal Lorentz boosts. The problem does not therefore disappear!

The overall conclusion is that the reported density of electrons and the condition deduced from the boundary condition for the magnetic field is are not consistent with each other.

In TGD framework one can consider one possibility to solve the problem: there is not boundary at all! The flux tube carriers magnetic monopole flux and and its cross section be regarded as two surfaces glued together along their boundaries. Monopole character would also explain the stability of the structure. Flux tubes carrying monopole flux could actually provide a more general solution to the plasma confinement problem of nuclear fusion.

3.3.2 Attempts to estimate the magnetic field strength inside ESTS

The above argument did not allow to deduce any information about the value of the magnetic field strength. Experimentally this information could be deduced by measuring the transversal rotation velocity of electrons around the torus. One can also try to estimate orders of magnitude for the magnetic field inside torus using some other arguments.

1. The magnetic field inside torus modellable as a flux tube is partially caused by the dielectric breakdown current I and partially amplified by the electronic surface current. If one knows I, one can estimate the magnetic field strength inside torus as $B \sim kI/R$, R is the major radius of the torus. This should give at least the order of magnitude.

2. How could one estimate the magnetic field strength inside the flux tube? Could one try flux quantization? If this is assumed, the field strength for minimum flux is inversely proportional to the area of the flux tube. This field strength is really weak since one Tesla corresponds to a flux tube with radius of order 1 Tesla. For 1 cm radius the field strength would be around 10^{-12} Tesla. This would imply lifetime longer than .6 second (roughly 6 seconds) but the field strength seems quite too weak. The situation would correspond to the classical limit with large number of flux quanta?

3.4 Estimate for the dipole moment of ESTS

One can try to estimate orders of magnitude for the magnetic field outside torus too. The magnetic moment depends strongly on whether the electrons are non-relativistic or relativistic. For relativistic electrons the current density is proportional to $v/\sqrt{1-\beta^2}$, $\beta = v/c$ and the electronic contribution to the magnetic moment can become arbitrarily large in principle.

1. In analogy with electric dipole moment, the magnetic dipole moment is from dimensional analysis of the order of magnitude $\mu \simeq IR$, R the major radius of torus, I the current.

2. Electrons with largest distance from the center of torus are favored as contributors to the magnetic moment but the longitudinal rotation velocity of electrons vanishes in the first approximation.

   Therefore both electrons and ions could contribute to the magnetic moment. From charge neutrality the ion electron current is $en_I A v_I = -en_e v_I$, where $A = \pi r^2$ the area of transversal cross section of torus and v_I is the flow velocity of ions.

3. The mechanical equilibrium condition implies relativistic electron velocity $v \simeq c/2$ even for $n_e = 10^{15}/cm^3$ and super-luminality for the claimed $n_e = 10^{19}/cm^3$. If electrons have much higher velocities than ions they give the main contribution to the dipole moment.

4. Also ions could rotate around cyclotron orbits - at least in average sense when thermal motions is averaged out. One could argue that ions and electrons could have same longitudinal rotation velocity to minimize dissipation. Also one can ask whether the cyclotron frequency

of ions could determine the scale for the longitudinal rotation frequency of ions and therefore also of electrons. This kind of assumption would look worth of studying both physically and mathematically. This assumption allows to get rough estimate for the dipole moment of the torus. Note v could be estimated from the faraway magnetic field generated by ESTS.

3.5 Could one overcome the Coulomb barrier?: quantitative estimate

Could magnetic bottle produce so high an acceleration that the velocity of ions would correspond to kinetic energy above Coulomb wall. Seward argues that this calculations support this. There are however severe potential problems.

It was already found that the needed force in laboratory scale would be very large: the force experience by ion would be of order $F \sim E_c/L$ $E_c = .14 \times Z_1 \times Z_2$ MeV and L the length of the bottle.

The acceleration is proportional to dipole moment of ESTS and to the gradient of the magnetic field. Is it really have so large a dipole moment and large a gradient that one achieves the needed acceleration.

In the following I consider a quantitative argument. There are two options to consider. Non-relativistic and relativistic.

1. If electrons are non-relativistic the magnetic moment of ESTS is of order $\mu \sim Q \times R^2 \times \omega_L$, where ω_L is the longitudinal rotation velocity.

   $Q = Ne$ is the total charge of electrons at the surface of the torus equal to the ionic charge inside torus apart from sign. R is the major radius of ESTS, ω is the longitudinal angular frequency of ions (assuming that their contribution dominates, it could be also that electrons dominate, or that both contribute significantly). The density of electrons is reported to be of order $10^{19}/cm^3$. This estimate was not consistent with the hypothesis that electrons are at cyclotron orbits in the magnetic field they create inside orbits: the density should be in this case be smaller by roughly 4 orders of magnitude.

2. In relativistic case the electron current nv_L is scaled by a factor $\gamma_L = 1/\sqrt{1-\beta_L^2}$, $\beta_L = (v_L/c)$ so that the magnetic moment is proportional to $\gamma_L v_L$ rather v_L. If only mathematics is considered, there is no upper bound for the magnetic moment. Physics however poses stringent bounds.

Let us estimate the energy needed to overcome the Coulomb wall.

1. The energy gained in the acceleration by gradient of magnetic field is

$$\Delta E = \int_0 \mu \cdot \frac{dB}{dx} dx = \mu \cdot B_{max} \quad .$$

   μ is the magnetic moment of ESTS:

$$\mu = \frac{1}{2} \int j \times r dV \quad , \quad j = J_I + j_e \quad .$$

   This gives

$$\mu = \mu_I + \mu_e \quad .$$

2. The current density defines the current through a transversal cross section of ESTS torus as $I = \int jdS$. In the case of electrons the longitudinal component of the surface current K_e (to be distinguished from the transversal one considered in previous argument) gives $I_e = K \times 2\pi R$. In the case of ions one could assume that the flow is effectively rotation of a rigid body so that one would have $v = \omega_L(I)\rho$ such that the longitudinal rotation frequency $\omega_L(I)$ is constant. This would give $j_I = Ne\omega_L(I)\rho/V(torus)$. Q would be total charge oppose to the electronic total charge. This would give

$$I_I = Ne\omega_I(L)x \ ,$$
$$x = \frac{2\pi R^3}{3V(torus)} = \frac{1}{6\pi}\frac{R^2}{d^2} \ .$$

One obtains for the electronic current

$$I_e = \frac{Nev_L}{2\pi R} = \frac{Qe\gamma_L\omega_L(e)}{2\pi} \ ,$$
$$\gamma_L = \frac{1}{1-\beta_L^2} \ , \ \beta_L = \frac{v_L}{c} \ .$$

3. For the ionic contribution to the magnetic moment of ESTS one would obtain

$$\mu_I = \frac{1}{2}N_I e\omega_L(I) \times x_I \ ,$$
$$x_I = \frac{\int_{torus,R,d} r2dV}{V(torus,R)} \ ,$$
$$V(torus,R) = 2\pi^2 2Rr^2$$

R and d are the major and minor radii of torus. $N_e = N_I$ is total number of electrons.

4. In an analogous manner one has for the electronic contribution the formula

$$\mu_e = \frac{1}{2}N_e\gamma_L\omega_L(e) \times r_e^2 \ ,$$
$$r_e^2 = \frac{\int_{torus,R,dr} r^2 dS}{S(torus,R)} \ ,$$
$$S(torus,R) = 4\pi^2 Rd \ .$$

Contributions are proportional to geometric factors x_I and x_e having having dimensions of length squared: essentially averages of r^2 over torus and its surface respectively and cannot differ much and in the first approximation one has $r_I^2 = r_e^2 = R^2$.

5. The most important factor is the proportionality to the longitudinal rotation frequency ω_L, or to the factor $\gamma\omega_L$ in the case of electrons. What could one say about this factor?

   (a) Conservatively one could argue that the minimization of dissipative effects requires that ω_L and v_L are same for electrons and ions. Opposite sign for charges means that the contributions to the magnetic moment are of opposite sign and would tend to cancel each other. This is not a good news concerning the proposed acceleration mechanism. Relativistic electrons are the only hope of obtaining large enough magnetic moment and in this case electrons dominate.

   (b) One expects that also ions rotate in the magnetic field created in the first approximation solely by electrons. The transversal angular rotation frequency is cyclotron frequency $\omega_c(I) = eB/m_I$.

   (c) The natural guess is that the ratio of longitudinal and transversal frequencies for ions is a rational number $q = m/n$ not too far from unity such that m and n are small integers. This implies that the helical orbit closes after small number of turns. This implies $\omega_L(I) = r \times eB/m_I$. The average longitudinal rotation velocity would be $v_L = \omega_L R = q \times eBR/m_I$, $q = m/n$.

   (d) The hypothesis that longitudinal velocities for electrons and ions are same, does not give large electronic contribution to the dipole moment. As a consequence, the longitudinal rotation frequency for electron would be by a factor rm_e/m_p smaller than the transversal frequency $\omega_c(e)$. This would conform with the assumption that in the first approximation electrons do not rotate longitudinally.

   (e) Whether right or wrong, this assumption allows to estimate the order of magnitude for electronic and ionic contributions to the dipole strength of the dipole magnetic field

$$\mu = zp_I \ ,$$
$$p_I \sim -p_e \sim IR = en_ISv_LR = qen_I \times \pi d^2 \frac{eBR}{m_I}R^2 = \frac{q\alpha}{2} \times n_e \times d^2R^3B_{int}L_I = \frac{q\alpha}{4\pi^2}N_e \times B_{int}L_IR^2 \ ,$$
$$L_I = \frac{h}{m_Ic}$$

The contributions tend do cancel each other and it is not clear how precisely this happens.

(f) Using relativistic formula for electrons means only that one allows $\omega_L(e)$ to be arbitrary and the the velocity $v_L(e) = \omega_L d$ be near light velocity. The electronic contribution to the magnetic moment is scale up by a factor $\gamma = 1/\sqrt{1-\beta_L^2}$, $\beta_L = v_L(e)/c$.

Consider now the energy gain needed to achieve fusion. Consider first non-relativistic electrons.

1. The order of magnitude for the energy gain per particle (ϵ) is

$$\epsilon = \frac{E}{N_I} = \frac{\mu B_{max}}{N_e} = z \times \frac{q\alpha}{4\pi^2} \times L_IB_{int}B_{max}R^2 \ .$$

The coefficient z is here crucial and should not be too much below unity.

2. This energy should be above the energy needed to overcome Coulomb wall $E_c = .16Z_1Z_2$ MeV:

$$\epsilon \geq E_c = .16Z_IZ_2 \ \ MeV \ .$$

Z_2 denotes the charge of the targe nucleus and Z_I the charge of the nucleus in the ESTS.

3. One can look the situation assuming orders of magnitude for B_{max} and B_{int} to be order of 1 Tesla. These magnetic fields correspond to magnetic lengths $L_B = \sqrt{eB} \sim 10$ nm which corresponds to an energy of 10^2 eV roughly. L_I for proton corresponds to about 10^{-15} meters.

Substituting to the left hand side of the above equation one obtains order of magnitude upper bound 10^{-12} eV for ϵ so that the failure of hopes is about 16 orders of magnitude.

4. Relativistic formula brings a factor γ to the velocity and to the energy. $\gamma \sim 10^{16}$ would be needed. This however means that electrons energy would be $10^{16}m_e \sim 10^{13}$ GeV which is hundred thousand times higher than the lab frame energies of order 10^8 GeV achieved at LHC! It seems clear that this acceleration mechanism cannot work for reasonable magnetic field strengths and reasonable electron velocities.

4 Critical questions inspired by TGD

In the following some TGD inspired questions are considered.

4.1 What could make possible the claimed localization of electrons?

1. Is the probably helical electron current really a surface current? Beltrami field is the basic condition from mechanical equilibrium: can electronic surface current plus ionic current generate this.

2. Is it possible to localized electrons to the surface in standard physics. Can this localization consistent be consistent with thermodynamics? Analogous phenomena exist.

   (a) Conduction electrons in external electric field are driven to the surface of conductor. Could one imagine counterparts of conduction electrons now?

(b) In quantum Hall effect electrons form a surface phase: this is is a large scale quantum phenomenon. The problem is to understand the mechanism behind charge separation. A possible quantum level mechanism would involve strong localization to cyclotron orbit as in the case of harmonic oscillator. Cyclotron energy is however very small even in magnetic fields of order Tesla for the ordinary value of Planck constant. For electron the cyclotron frequency would be about 30 GHz and corresponding energy would be of order 3×10^{-4} eV and below thermal energy at room temperature. This objection can be circumvented in TGD framework if one assumes dark matter identified as a hierarchy of phases of the ordinary matter with quantized Planck constant $h_{eff} = n \times h$.

4.2 Some crazy TGD inspired questions

It was found that cyclotron orbits provide an attractive manner to localize electrons to a surface. The smallness of cyclotron energy is however a problem. Here the hierarchy of Planck constants might come in rescue.

1. If one allows hierarchy of Planck constants $h_{eff} = n \times h$ interpreted in terms of dark matter. The hypothesis $h_{eff} = h_{gr} = GMm/v_0$, where h_{gr} is the gravitational Planck constant introduced by Nottale, m the mass of charged particle, M Earth mass, and v_0 a velocity parameter - for instance rotation velocity of Earth - predicts that cyclotron energy spectrum is universal and in the range of bio-photon energies (visible and ultraviolet) optimal for the interaction with biomolecules. With this assumption electrons cyclotron energy would be in visible and UV range. A second prediction is that gravitational Compton lengths of particles are same irrespective of their mass.

2. If one accepts the presence of dark matter at magnetic flux tubes, one cannot avoid associations with the experiments of Pollack [I1] demonstrating the formation of exclusion zones in water. EZs carry large electronic charge and part of protons is driven outside the EZ. In TGD framework the protons would be at magnetic flux tubes. Could something like this happen also now? Not however that in Pollack's experiments water is the medium. Now it is air in which di-electric breakdown takes place.

The association with Pollack's findings [I1] raises some further crazy questions.

1. Could the charge separation be analogous to that taking place in Pollack's experiments? One can imagine alternatives.

2. Could ions be inside the torus and electrons at the flux tubes outside the torus? Or could torus contain only electrons and could ions be outside it at magnetic fluxes? Probably experimenters can immediately exclude these options on basis of existing data.

   If ions reside at magnetic flux tubes outside the torus, torus is not neutral but has very high charge. This would change totally the behavior in external electric and magnetic fields if one can assume that the "magnetic body" of the torus containing electrons or protons is much larger than the torus itself. ESTS would behave like charged particle and would be accelerated in both electric and magnetic fields by Lorentz and electric forces. Probably this would have been observed since the experimental situation involves strong electric fields. Also by study of the properties of the magnetic dipole field outside the torus can probably easily kill these options.

One of the basic differences between TGD and Maxwell's electrodynamics is that magnetic fluxes can be monopole fluxes although there are no magnetic monopoles.

1. This kind of magnetic fields need not current to generate them and could explain why cosmos is full of magnetic fields in all scales although there is no known mechanism making possible coherent currents in cosmic scales (flux tube would require the analog of coil carrying current around it). This kind of flux tubes have no boundary where the "coil" would be located but are like two copies of flux tubes glued together along the boundary (recall that space-time is regarded as 4-surface in 8-D $M^4 \times CP_2$).

2. Could the ESTS torus correspond to a flux tube carrying a monopole flux? Could the conservation of magnetic flux explain its stability? Could the magnetic field associated with a current current wire (the dielectric breakdown gives rise to an analog of current wire) involve such circular flux tubes carrying monopole flux?

5 Summary

ESTS - if real - is a fascinating phenomenon and might involve the mechanism behind ball lightings. Even new physics could be involved as it might be involved also with ball lightnings. It might not be possible to understand ESTS without quantum theory. This is not however trivially true if electrons really reside at the surface of the torus. Magnetic flux tubes carrying dark matter as large $\hbar$ phases is the TGD inspired model for the magnetic tori.

The acceleration mechanism based on magnetic field gradient might have applications in TGD inspired biology, where magnetic flux tubes are key players and could be used to drive charged particles to a desired target by varying the thickness of the magnetic flux tubes.

Concerning the speculative applications I remain skeptic in the framework of standard physics.

1. The reported density of electrons is not consistent with the estimate coming from Maxwell's equations: in TGD situation would be changed if ESTSs are actually monopole flux carrying flux tubes.

2. Already for the production of X rays the needed accelerations and energies obtained in this manner seem quite too large to be achievable by the magnetic gradient mechanism. For relativistic electrons the dipole moment can be arbitrarily large but the needed electron energies are quite too high.

3. For nuclear fusion the situation gets by about two orders of magnitudes worse. A possible further difficulty is that the magnetic dipole moment of the torus tends to be very small since ionic and electronic contributions tend to cancel for non-relativistic electrons. Even for relativistic electrons the energies gained by magnetic gradient acceleration seem hopelessly small.

4. Heating to a high temperature provides a much more effective mechanism of nuclear fusion and one could consider heating of the plasma confined inside ESTSs as a possible solution to the plasma confinement problem. The monopole character of the magnetic field inside flux tube could guarantee its stability even at high temperatures. One must also consider cold fusion if dark matter is involved.

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