E-Cat SK and long-range particle interactions

Andrea Rossi

Premise

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Abstract

Some theoretical frameworks that explore the possible formation of dense exotic electron clusters in the E-Cat SK are presented. Some considerations on the probable role of Casimir, Aharonov-Bohm, and collective effects in the formation of such structures are proposed. A relativistic interaction Lagrangian, based on a pure electromagnetic electron model, that suggests the possible existence of very low entropy charge aggregates and that highlights the primary role of the electromagnetic potentials in these clusters, is presented. The formation of these cluster may be associated to a localized Vacuum polarization generated by a rapid radial charge displacement. The formation of these dense electron clusters are introduced as a probable precursor for the formation of proton-electron aggregates at pico-metric scale, stressing the importance of evaluating the plausibility of special electron-nucleon interactions, as already suggested in [21]. An observed isotopic dependence of a particular spectral line in the visible range of E-Cat plasma spectrum seems to confirm the presence of a specific proton-electron interaction at electron Compton wavelength scale.

keywords: Aharonov-Bohm effect, Anomalous Heat Effect, Bose-Einstein Condensate, Casimir effect, charge clusters, collective effects, Darwin Lagrangian, electron model, Electrum Validum, geometric phase coherence, long range interactions, low entropy aggregates, pico-metric structures, Electron Energy Distribution Function (EEDF), relativistic interaction Lagrangian, vector potential, Zitterbewegung electron model

Introduction

The E-Cat technology poses a serious and interesting challenge to the conceptual foundations of modern physics. Particularly promising, for understanding this technology, is the exploration of long-range particle interactions. In paragraph "*Nuclear Reactions in Distant Collisions*" [49], E. P. Wigner highlights their importance in nuclear transfer reactions: "*The fact that nuclear reactions of the type* $Au^{197} + N^{14} \rightarrow Au^{198} + N^{13}$ *take place at energies at which colliding nuclei do not come in contact is an interesting though little-advertised discovery*". More recently a possible double role of electrons in long range interactions has been suggested in *"Nucleon polarizability and long range strong force from* $\sigma I = 2$ *meson exchange potential"* [21]: *"In other words these two views deals with the electrons' role. One is as a carrier of the nucleon and the other is as a trigger for a long-range potential of the nucleon".*

In this paper we propose that, at a relatively long distance, intermediate between the atomic and nuclear scale, in the same order of magnitude of electron Compton wavelength, the effects of magnetic force, the Casimir force and quantum vacuum/virtual particles should not be dismissed. In particular, in section 1 we show that Coulomb repulsion between electrons at a distance of four reduced Compton wavelengths can be balanced by the Casimir force in specific geometric configurations. The possible role of Casimir forces in the E-Cat technology has been firstly proposed by Professor Sven Kullander during our discussions in 2013. In section 2, extending to leptons the N.D. Cook, V. Dallacasa and P. Di Sia nuclear force model [13, 14], based on the magnetic attraction between nucleons, and applying the condition that the four-distance between charges in Minkowski space-time is a light-like vector, a possible balance of magnetic and Coulomb force is proposed. A relativistic interaction Lagrangian that suggests the possibility of these coherent low entropy aggregates is presented. In section 3, it is hypothesized that a relatively narrow Electron Energy Distribution Function (EEDF) is a pre-condition that may favor the formation of these coherent aggregates. A mechanism that may allow Zero Point Energy within the E-Cat technology will be presented in section 4. In section 5 dense electron clusters are introduced as a probable precursor for the formation of proton-electron aggregates at pico-metric scale. In this last section one spectroscopic signature of these structures is discussed. Section 6 contains a brief description of the experimental setup, while in section 7 the E-Cat SK performance is computed.

1 Charge clusters and the Casimir force

Puthoff and Piestrup in their paper "*Charge confinement by Casimir force*" [41] propose, as a possible cause of the high-density charge clustering seen by K. Shoulders [44] and other researchers, the "vacuum pressure" hypothesized in 1948 by H. B. G. Casimir and experimentally verified by S. K. Lamoreaux [32] in 1996. To compensate electron Coulomb repulsion with vacuum pressure in a spherical shell distribution of N electrons, Puthoff found a critical value for the sphere radius R_N:

$$R_N \approx \frac{\hbar\sqrt{N}}{2m_e c} = \frac{c\sqrt{N}}{2\omega_e} = \frac{r_e\sqrt{N}}{2}, \tag{1}$$

where $r_e = \frac{c}{\omega_e} = \frac{\lambda_e}{2\pi}$ is the reduced electron Compton wavelength. This value is derived by applying the Compton angular frequency $\omega_e = {m_e c^2}/{\hbar}$ as the cutoff frequency for electron-vacuum interactions and assuming a vacuum spectral energy density $\rho(\omega)$:

$$\rho(\omega) = \frac{\hbar\omega^3}{2\pi^2 c^3} d\omega.$$

For a charge cluster of $N = 10^{11}$ electrons, the computed cluster size D is approximately $D = 2R_N \approx 0.12\,\mu$m, a value not too far from the typical charge cluster size seen by Shoulders. The electron distance d_E in the spherical shell that minimizes electrostatic potential can be roughly approximated as

$$d_E \approx \sqrt{\frac{4\pi R_N^2}{N}} = \sqrt{\pi} r_e \approx 1.78 r_e \approx 0.68 \cdot 10^{-12}\ \mathrm{m}. \tag{2}$$

It's interesting to note that this distance is not a function of N but a constant value of the same order of the reduced electron Compton wavelength $r_e = {\lambda_e}/{2\pi} \approx 0.38 \cdot 10^{-12}$ m. At this scale the electron should not be modeled as a point-like particle, not even as a first approximation. Consequently, a more detailed and realistic electron model is preferable to evaluate the Casimir effect in free electron clusters.

An interesting approach along this direction is proposed by J. Maruani in his paper "*The Dirac Electron and Elementary Interactions*" [33]. To compute the Casimir force between electrons, Maruani suggests applying the Casimir force F_C formula per unit area A for "*the ideal case of perfect plates in perfect vacuum at 0 Kelvin*":

$$\frac{F_C(d)}{A} = \frac{\pi^2 \hbar c}{240 d^4}. \tag{3}$$

where d is the distance between plates and c is the light speed in vacuum. Maruani considers a Zitterbewegung [26, 25, 23, 8] electron model where the reduced Compton wavelength is the electron *"diameter"*. In this case the "plate" area in (3) becomes $A = \pi \left({}^{\lambda_e}\!/_{4\pi}\right)^2$ and the attractive Casimir Force $F_C(d)$ between electrons can be computed and compared with the Coulomb repulsion force $F_e(d)$:

$$F_C(d) = \frac{\pi \hbar c \lambda_e^2}{3840 d^4}, \tag{4}$$

$$F_e(d) = \frac{1}{4\pi\varepsilon_0} \frac{e^2}{d^2}. \tag{5}$$

According to this approach, the Casimir force balances Coulomb repulsion approximately at a distance $d_b \approx 2{}^{\lambda_e}\!/_{2\pi} \approx 0.77 \cdot 10^{-12} m$, a value close to that of two reduced Compton wavelengths (see Fig. 1 in [33]).

According to another Zitterbewegung electron model [8, 15, 31], the electron can be modeled by a current loop, with radius r_e, generated by a charge distribution that rotates at the speed of light. This current loop is proposed as the origin of the electron's mass, inertia, angular momentum, spin and magnetic momentum. In this case the area enclosed by the zbw current is $A = \pi \left({}^{\lambda_e}\!/_{2\pi}\right)^2 = \pi r_e^2$, a value four times larger than that used by Maruani, and consequently the Casimir force may reach a value four times greater than the one indicated in (4). With this larger area, Coulomb repulsion is balanced at a distance $d_b \approx 4{}^{\lambda_e}\!/_{2\pi} \approx 1.54 \cdot 10^{-12} m$, as shown in Fig. 1, where in a logarithmic scale the hypothesized Casimir force between two electrons is plotted together with Coulomb and a magnetic force computed considering the electrons as two parallel aligned current loops. We can find the idea of an internal rapid motion (Zitterbewegung) at light-speed in electrons in the P.A.M. Dirac Nobel lecture [16].

2 Charge clusters and magnetic interactions

2.1 Space-charge, vacuum polarization and virtual particles

An important effect in vacuum tubes is the so-called "space-charge". This name is related to the spontaneous formation of an electron cloud around a cathode heated in vacuum. Although well known and exploited since the early years of vacuum tube technology, this effect lacks a well-defined theory. This statement is supported by the observation that the formation of a stable space-charge should be prevented by the Coulomb repulsion between free electrons. L. Nelson in US patent 6465965 proposes, as a rationale for this long-range electrostatic screening, a possible vacuum polarization, generated by the creation-annihilation of virtual charges pairs as a consequence of the quantum vacuum fluctuations predicted by the Heisenberg uncertainty principle. The lifetime of such particle-antiparticle couples is

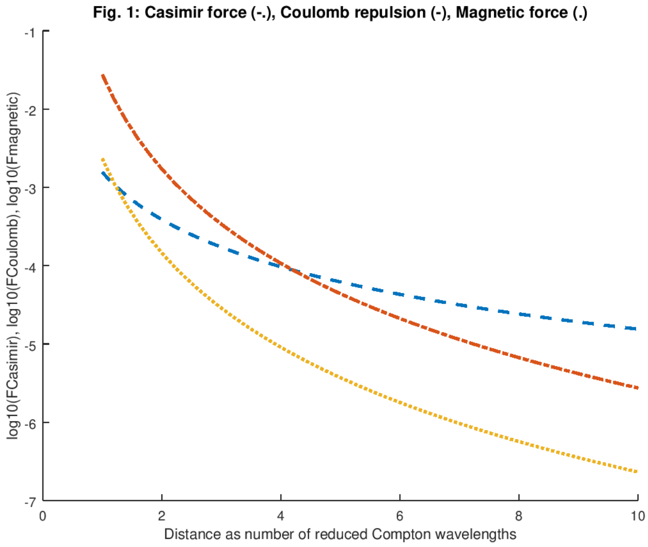

Figure 1: Trends of Casimir, Coulomb and magnetic forces as a function of distance.

inversely proportional to their mass-energy, but, during their short existence, these may act as the charges in the solid dielectric of a capacitor that, screening the electric field, lower the voltage required to accumulate a charge in capacitor plates. The creation of these virtual particles is favored by the high density of allowable energy states in vacuum and is hindered by the relatively low number of permitted states in an ordinary metallic conductor. According to Nelson, this difference may be exploited to generate a macroscopic voltage and an energy gain. Alternative hypotheses, based on self-organizing Zitterbewegung electron phases in vacuum and Lorentz force, are however possible as will be shown in the next sub-sections.

In any case, the long-range interaction between the electrons in the space charge is a phenomenon that deserves to be seriously studied and investigated [47].

2.2 Lorentz force and Zitterbewegung phase coherence

According to [8, 10, 31], the electron is associated with a magnetic flux $\Phi_M = {}^{h}\!/_{e}$ equal to the ratio of the Planck constant h and the elementary charge e. Consequently, the possible role of a magnetic attraction in charge confinement cannot be dismissed *a priori*. As shown in Fig. 1, the magnetic force between two electrons, if naively modeled as two parallel aligned current loops, cannot compensate for the Coulomb repulsion. However, at this point, it is important to remember that the Zitterbewegung current is generated by an elementary charge e that rotates at light-speed c along a circumference equal to the electron Compton wavelength [8, 31] and, consequently, that a rotation phase coherence between charges in the same light cone may greatly enhance the magnetic attraction.

In this case, the force can be computed as the Lorentz force F_L acting on an elementary charge moving at the speed of light. Its value can balance the Coulomb repulsion:

$$F_L\left(d\right) = ecB\left(d\right) = \frac{\mu_o}{4\pi} \cdot \frac{e^2c^2}{d^2} = \frac{1}{4\pi\epsilon_0} \cdot \frac{e^2}{d^2}, \tag{6}$$

where

$$B\left(d\right) = \frac{\mu_o ec}{4\pi d^2} \tag{7}$$

is the magnetic flux density generated by another elementary charge that moves in parallel at light-speed c at a distance vector $\vec{d}$ orthogonal to the charge velocity vector.

A similar approach has been suggested by Norman Cook, Paolo Di Sia and Valerio Dallacasa [13, 14, 11], as the possible magnetic origin of the strong nuclear force. The condition that the charges must be in the same light-cone [34] can be satisfied if the electron distance d is an integer multiple of Compton wavelength while the rotating charges have the same Zitterbewegung phase:

$$d = n\lambda_e \tag{8}$$

The very restrictive conditions under which eq. 6 can be applied may be created only in very peculiar environments. A possible solution has been suggested in [15] where the spin value $\pm\hbar/2$ is interpreted as the component of the electron's angular momentum $\hbar$ parallel to an external magnetic field while the electron, like a tiny gyroscope, is subjected to Larmor precession. This particular, semi-classical, interpretation of spin does not exclude the possibility that the electron's angular momentum may be aligned, in particular conditions, to the external magnetic field, so that electrons behave as elementary particles with whole spin $\hbar$. In this case electron clusters may form Bose-Einstein condensates where electron Zitterbewegung phases are synchronized and electron distances respect equation (8). In this highly ordered, low entropy, hypothetical structure the Coulomb repulsion is balanced by the magnetic force F_L in agreement with (6). In section 2.3 we will propose a Lagrangian for N interacting charged particles that suggests the possible existence of these coherent states.

In [15] *a fundamental connection* between Aharonov-Bohm equations and an electron model is proposed, starting from a geometric interpretation of the electron wave-function complex phase [24, 23, 25]. This approach suggests the possibility of efficiently creating electron condensates exploiting the Aharonov-Bohm effect, a phenomenon that shows the dependence of the electron wave-function phase from electromagnetic potentials [1]. In [15] it is hypothesized that a voltage pulse with a very short, critical rise time may favor the creation of coherent and dense electron clusters: "*The conjecture is based on the possibility that, as a consequence of Aharonov-Bohm effect, a rapid, collective and simultaneous variation of the Zitterbewegung phase catalyzes the creation of coherent systems*".

2.3 Darwin Lagrangian

In his work "*Magnetic energy, superconductivity, and dark matter*" [17] Prof. Essén emphasizes the importance of long-range magnetic interactions in systems where a large number of charged particles are involved. He proposes, as a possible useful tool in modeling such interactions, a Darwin Lagrangian L_D, that relates the electromagnetic potentials with the kinetic energy:

$$L_D = \sum_{a=1}^{N} \left[\frac{m_a}{2} v_a^2 - \frac{e_a}{2} \phi_a(\boldsymbol{r}_a) + \frac{e_a}{2c} \boldsymbol{v}_a \cdot \boldsymbol{A}_a(\boldsymbol{r}_a) \right] \tag{9}$$

$$\boldsymbol{A}_a(\boldsymbol{r}_a) = \sum_{b \neq a}^{N} \frac{e_b \left[\boldsymbol{v}_b + (\boldsymbol{v}_b \cdot \boldsymbol{r}_{uab}) \boldsymbol{r}_{uab} \right]}{2c r_{ab}}$$

$$\phi_a(\boldsymbol{r}_a) = \sum_{b \neq a}^{N} \frac{e_b}{r_{ab}}$$

$$r_{ab} = |\boldsymbol{r}_a - \boldsymbol{r}_b|$$

$$\boldsymbol{r}_{uab} = \frac{\boldsymbol{r}_a - \boldsymbol{r}_b}{|\boldsymbol{r}_a - \boldsymbol{r}_b|}$$

In these equations the letters a and b are used as indexes of the massive charged particles, $\boldsymbol{r}_a$ are their spatial coordinates, e_a their charge value, $\boldsymbol{v}_a$ their velocity, m_a their mass, $\boldsymbol{A}_a(\boldsymbol{r}_a)$ and $\phi(\boldsymbol{r}_a)$ are respectively the vector and electric potential at $\boldsymbol{r}_a$ and N is the total number of the interacting particles. Gaussian unit system has been used.

The Darwin Lagrangian can be conceptually simplified recognizing that the mechanical momentum $\boldsymbol{p}_a$ of a massive charged elementary particle has a pure electromagnetic origin:

$$\boldsymbol{p}_a = m_a \boldsymbol{v}_a = \frac{e_a}{c} \boldsymbol{A}_{azp}$$

In this last equation $\boldsymbol{A}_{azp}$ is the component of the vector potential $\boldsymbol{A}_{az}$, generated by the Zitterbewegung current, parallel to the particle's velocity vector $\boldsymbol{v}_a$. This means that we can write a kinetic energy term that is only a function of the magnetic vector potential:

$$\frac{m_a}{2} v_a^2 = \frac{p_a^2}{2m_a}$$

$$\frac{p_a^2}{2m_a} = \frac{e_a^2 A_{azp}^2}{2c^2 m_a}$$

$$m_a = \frac{e_a A_{az}}{c^2}$$

$$\frac{p_a^2}{2m_a} = \frac{e_a A_{azp}^2}{2A_{az}}$$

For non-relativistic speed we can write:

$$\frac{A_{azp}}{A_{az}} \simeq \frac{v_a}{c} \tag{10}$$

Being that v_a and A_{azp} are parallel vectors it's possible to substitute the product of their modules with the dot product:

$$\frac{m_a}{2} v_a^2 = \frac{e_a v_a A_{azp}}{2c} = \frac{e_a}{2c} \boldsymbol{v}_a \cdot \boldsymbol{A}_{azp} \tag{11}$$

consequently we can encapsulate the kinetic energy terms inside the vector potential ones:

$$\boldsymbol{A}_{at}(\boldsymbol{r}_a) = \boldsymbol{A}_{azp} + \boldsymbol{A}_a(\boldsymbol{r}_a) \tag{12}$$

$$L_D = \sum_{a=1}^{N} \left[-\frac{e_a}{2} \phi_a(\boldsymbol{r}_a) + \frac{e_a}{2c} \boldsymbol{v}_a \cdot \boldsymbol{A}_{at}(\boldsymbol{r}_a) \right] \tag{13}$$

Equation 13 is a rewriting of eq. 9 that clearly shows a more fundamental role of the electromagnetic potentials, considering that all the kinetic energy terms can be expressed as a function of the magnetic vector potential.

2.4 Zitterbewegung Lagrangian

The component $\boldsymbol{A}_{azp}$ in eq. 12, for non-relativistic speeds, is a tiny fraction of the Zitterbewegung generated vector potential $\boldsymbol{A}_{az}$ as shown in eq. 10. This observation suggests the possibility to write a new Lagrangian that does not exclude the role of $\boldsymbol{A}_{az}$.

Accepting an appropriate, pure electromagnetic, Zitterbewegung model for the electrons [15, 31], the first step along this path starts with substituting the concept of "massive charged particles" with the more fundamental idea of mass-less elementary charges e moving at the speed of light with a mechanical momentum proportional to the dot product of their velocity and the vector potential value [31]. This choice implies a possible active role of the vector potential, associated with the rest-mass energy, in the magnetic interactions. The interactions occur only between charges that are in the same light-cone. This means that their distance in Minkowski space-time must be a light-like (nilpotent) vector (eq. 23). Using natural units, where $\hbar = c = 1$, this relativistic interaction Lagrangian has a very simple form:

$$L_z = \sum_{a=1}^{N} \left[e_a \boldsymbol{c}_a \cdot \boldsymbol{A}_a \left(\boldsymbol{r}_a \right) - e_a \phi_a \left(\boldsymbol{r}_a \right) \right] \tag{14}$$

To confirm the validity of 14 we must demonstrate that it satisfies the classical Lagrangian definition:

$$L = T - U \tag{15}$$

$$T = \sum_{a=1}^{N} e_a \boldsymbol{c}_a \cdot \boldsymbol{A}_a \left(\boldsymbol{r}_a \right)$$

$$U = \sum_{a=1}^{N} e_a \phi_a \left(\boldsymbol{r}_a \right)$$

Now, according to the Ehrenberg-Siday-Aharonov-Bohm equations, the Zitterbewegung geometric phase is ruled by the vector potential (eq. 16) and by the electric potential (eq. 17):

$$d\varphi_{aM} = e_a \boldsymbol{A}_a \left(\boldsymbol{r}_a \right) \cdot d\boldsymbol{l}$$

$$d\boldsymbol{l} = \boldsymbol{c}_a dt$$

$$d\varphi_{aM} = e_a \boldsymbol{A}_a \left(\boldsymbol{r}_a \right) \cdot \boldsymbol{c}_a dt \tag{16}$$

$$d\varphi_{aE} = e_a \phi_a \left(\boldsymbol{r}_a \right) dt \tag{17}$$

Dividing eq. 16 for dt we obtain the value of the Zitterbewegung frequency of the charge e_a, a value equal to the relativistic mass-energy of the particle a:

$$\omega_{zbw} = \frac{d\varphi_{aM}}{dt} = m_a$$

$$T = \sum_{a=1}^{N} m_a$$

These observations confirm that eq. 14 respects the classical Lagrangian definition, considering that the “kinetic energy” of the electron’s mass-less charge is exactly equal to its relativistic mass.

The vector potential $\boldsymbol{A}_a(\boldsymbol{r}_a)$ is the sum of the self-interaction term $\frac{e_a \boldsymbol{c}_a}{\alpha r_{ea}}$ with an interaction term:

$$\boldsymbol{A}_a(r_a) = \frac{e_a \boldsymbol{c}_a}{\alpha r_{ea}} + \sum_{b \neq a} \frac{e_b \left[\boldsymbol{c}_b + (\boldsymbol{c}_b \cdot \boldsymbol{r}_{uab}) \boldsymbol{r}_{uab}\right]}{r_{ab}} \tag{18}$$

$$\phi_a(\boldsymbol{r}_a) = \frac{e_a}{\alpha r_{ea}} + \sum_{b \neq a} \frac{e_b}{r_{ab}} \tag{19}$$

$$L_z = \sum_{a=1}^{N} \left\{ \frac{1}{r_{ea}} + \sum_{b \neq a} \frac{\alpha \boldsymbol{c}_a \cdot \boldsymbol{c}_b + \alpha (\boldsymbol{c}_b \cdot \boldsymbol{r}_{uab})(\boldsymbol{c}_a \cdot \boldsymbol{r}_{uab})}{r_{ab}} - \left[\frac{1}{r_{ea}} + \sum_{b \neq a} \frac{\alpha}{r_{ab}} \right] \right\} \tag{20}$$

$$L_z = \sum_{a=1}^{N} \sum_{b \neq a} \frac{\alpha \left[\boldsymbol{c}_a \cdot \boldsymbol{c}_b + (\boldsymbol{c}_b \cdot \boldsymbol{r}_{uab})(\boldsymbol{c}_a \cdot \boldsymbol{r}_{uab}) - 1\right]}{r_{ab}} \tag{21}$$

$$\boldsymbol{r}_{ab} = \boldsymbol{r}_a - \boldsymbol{r}_b$$

$$r_{ab} = |\boldsymbol{r}_a - \boldsymbol{r}_b|$$

$$\boldsymbol{r}_{uab} = \frac{\boldsymbol{r}_{ab}}{r_{ab}}$$

$$\boldsymbol{c}_a \cdot \boldsymbol{c}_b = \cos(\vartheta_{ab1})$$

$$\boldsymbol{c}_a \cdot \boldsymbol{r}_{uab} = \cos(\vartheta_{ab2})$$

$$\boldsymbol{c}_b \cdot \boldsymbol{r}_{uab} = \cos(\vartheta_{ab3})$$

$$\vartheta_{ab1} = \vartheta_{ab2} - \vartheta_{ab3}$$

$$L_z = \sum_{a=1}^{N} \sum_{b \neq a} \frac{\alpha \left[\cos(\vartheta_{ab2} - \vartheta_{ab3}) + \cos(\vartheta_{ab2}) \cos(\vartheta_{ab3}) - 1\right]}{r_{ab}}$$

$$L_{zab} = \frac{\alpha \left[\cos(\vartheta_{ab2} - \vartheta_{ab3}) + \cos(\vartheta_{ab2}) \cos(\vartheta_{ab3}) - 1\right]}{r_{ab}}$$

In these latter equations r_a is the generic spatial position of the mass-less charge e_a, $\boldsymbol{c}_a$ its unit velocity vector ($\boldsymbol{c}_a^2 = 1$), $\alpha = e_a^2$ the fine structure constant ($\alpha^{-1} \approx 137.036$), r_{ea} the Zitterbewegung radius, r_{ab} is the Euclidean distance between the mass-less charges and t_{ab} their time distance. $\boldsymbol{r}_{uab}$ is a unit vector that has the same direction of $\boldsymbol{r}_{ab}$. The inverse of the Zitterbewegung radius in natural units is equal to the value of the relativistic mass of the charged particle ($m_{ea} = r_{ea}^{-1}$). The product αr_{ea} is the charge radius.

The phase space trajectory of the N charges is determined by the stationary Action condition $\delta\left(\mathscr{S}\right) = 0$

$$\mathscr{S} = \int_{\triangle T} L_z dt.$$

According to eq. 21 the Action has the following simple form

$$\mathscr{S} = \sum_{a=1}^{N}\sum_{b\neq a}\int_{\triangle T}\frac{\alpha\left[\cos\left(\vartheta_{ab2}-\vartheta_{ab3}\right)+\cos\left(\vartheta_{ab2}\right)\cos\left(\vartheta_{ab3}\right)-1\right]}{r_{ab}}dt \tag{22}$$

$$\mathscr{S} = \sum_{a=1}^{N}\sum_{b\neq a}\int_{\triangle T} L_{zab} dt$$

$$\delta\left(L_{zab}\right) = 0 \Longrightarrow \delta(\mathscr{S}) = 0$$

$$\delta\left(L_{zab}\left(r_{ab},\vartheta_{ab2},\vartheta_{ab3}\right)\right) = \frac{\partial L_z}{\partial r_{ab}}\delta r_{ab} + \frac{\partial L_z}{\partial \vartheta_{ab2}}\delta\vartheta_{ab2} + \frac{\partial L_z}{\partial \vartheta_{ab3}}\delta\vartheta_{ab3} = 0$$

$$\frac{\partial L_z}{\partial r_{ab}} = -\frac{\alpha\left[\cos\left(\vartheta_{ab2}-\vartheta_{ab3}\right)+\cos\left(\vartheta_{ab2}\right)\cos\left(\vartheta_{ab3}\right)-1\right]}{r_{ab}^2}$$

$$\frac{\partial L_z}{\partial \vartheta_{ab2}} = \frac{\alpha\left[-\sin\left(\vartheta_{ab2}-\vartheta_{ab3}\right)-\sin\left(\vartheta_{ab2}\right)\cos\left(\vartheta_{ab3}\right)\right]}{r_{ab}}$$

$$\frac{\partial L_z}{\partial \vartheta_{ab3}} = \frac{\alpha\left[\sin\left(\vartheta_{ab2}-\vartheta_{ab3}\right)-\cos\left(\vartheta_{ab2}\right)\sin\left(\vartheta_{ab3}\right)\right]}{r_{ab}}$$

$$r_{ab}^2 - c^2 t_{ab}^2 = 0 \tag{23}$$

From these equations we can see that the *coherence condition* (eq. 24) satisfies the principle of stationary Action

$$\left(\vartheta_{ab1} = 2\pi n\right) \cap \left(\vartheta_{ab2} = \frac{\pi}{2} + \pi m\right) \Longrightarrow \delta\left(\mathscr{S}\right) = 0 \quad \left(n, m \in \mathbb{Z}\right). \tag{24}$$

When these coherence conditions are satisfied the Coulomb repulsion is balanced by the Lorentz force as already shown in par. 2.2. This may explain the high density of the electron clusters studied by Kenneth Shoulders [44][46][45].

2.5 Entropy of the coherent clusters

Although the formation of charge cluster coherent states is compatible with the condition of stationary Action (eq. 22), its probability is heavily hindered by the extremely low entropy of such states. The order of magnitude of the entropy ratio between non-coherent and coherent configurations is approximately equal to the number N of interacting particles, considering that the coherent state can be described by a single "wave-function", as in BEC condensate.

The Darwin Lagrangian may be used for non coherent states of N interacting electrons observed at time scales larger than the Zitterbewegung period ($t_z \simeq 8.1 \cdot 10^{-21} s$). In this case the average value of the component of the vector potential orthogonal to electron velocity vanishes and does not play a role in magnetic interactions, but is hidden in the kinetic energy term, being the value of its module multiplied by the elementary charge equal to the electron rest mass in natural units.

3 Coherent clusters and EEDF

The Zitterbewegung angular frequency ω_{zbw} is exactly equal the electron relativistic mass-energy m in natural units:

$$\omega_{zbw} = m$$

The relativistic mass-energy m is the sum of the rest mass m_0 and the kinetic energy E_k

$$m = m_0 + E_k$$

The collective phase-lock in the charge clusters requires "monochromatic electrons" [3] or a very narrow distribution of Zitterbewegung frequency and consequently an environment with a narrow Electron Energy Distribution Function (EEDF) may favor the creation of these coherent structures. The EEDF in a gas mixture plasma discharge is a function of the pressure and gas composition [6] [19], consequently an appropriate choice of these parameters [37], narrowing the EEDF, may favor the formation of these aggregates.

4 Energy from the Vacuum

In his book "An Introduction To A Realistic Quantum Physics" [38, 39], Giuliano Preparata defines the Vacuum as "*the template of physical reality*" that "*does not precede creation but is, actually, a fundamental piece of it*".

Following this point of view some authors [2] claim that the keys to understand the emergence of matter-energy from Vacuum are the magnetic vector potential and the Aharonov-Bohm effect, completely reversing the widely accepted idea that considers the vector potential only as an useful math tool. In their work "*Aharonov-Bohm effect as the basis of electromagnetic energy inherent in the vacuum*" [2] the authors, starting from this concept, deduce that "*devices can be manufactured in principle to take an unlimited amount of electromagnetic energy from the vacuum as defined by the Aharonov-Bohm effect, without violating Noether's Theorem*".

Within this conceptual framework Puthoff has explored [9][40] the idea that, in principle, it's possible to extract energy and heat from electromagnetic zero-point radiation via the use of Vacuum pressure. A device that may reach this goal has been proposed in the US patent US7379286 [22], where the authors consider the possibility of a local energy extraction that is "*replenished globally from and by the electromagnetic quantum vacuum*".

The idea that Vacuum is structured and that can be exploited to localize energy extracted from the environment needs a clear definition of this structure and its relation with energy and matter. The first step starts with recognizing the electromagnetic potentials as the "Vacuum structure" and consequently as the fundamental entities of the physical reality. The second one requires an encoding of their relations with both the energy density and the energy flux in the space-time continuum. Calling $\Box$ the four-gradient and γ_t the unit vector along the time axis of the Minkowski space-time, we can define a scalar field $\mathcal{S}$ that is the four-divergence of the electromagnetic four-potential $\mathscr{A}$:

$$\mathscr{A} = \boldsymbol{A} + \gamma_t \phi$$

$$\Box \cdot \mathscr{A} = \mathcal{S}$$

Now, the derivatives of the four-potential can be viewed as an operator that "rotates" in the four dimensions of space-time the unit vector γ_t, giving raise to a four-vector that has the time component equal to the Vacuum energy density U and the three space components equal to the energy density flux vector $\boldsymbol{P}$ [31]:

$$\frac{1}{8\pi}\left(\Box\mathscr{A}\gamma_t\widetilde{\Box\mathscr{A}}\right) = U\gamma_t + \boldsymbol{P}$$

$$\boldsymbol{P} = -\frac{1}{4\pi}\left(\boldsymbol{E}\times\boldsymbol{B} - \mathcal{S}\boldsymbol{E}\right) \tag{25}$$

As we can see the vector $\boldsymbol{P}$ is the sum of two vectors: the first one is the Poynting vector while the second one is a vector equal to the product of the scalar field $\mathcal{S}$ and the electric field $\boldsymbol{E}$. In mainstream literature, as a consequence of the widespread application of the Lorenz gauge ($\Box \cdot \mathscr{A} = 0$), the scalar field S and the vector $\mathcal{S}\boldsymbol{E}$ are generally ignored, but nevertheless their significance has been highlighted by many authors [42, 48, 7, 36, 28, 29, 35, 50, 51, 43].

Combining the Gauss law (eq. 26) with the component $\mathcal{S}\boldsymbol{E}/4\pi$ of the generalized Poynting vector $\boldsymbol{P}$, there emerges a non-null divergence of an energy flux density that clearly implies the presence of a power source or a power sink where both charge density ρ and scalar field $\mathcal{S}$ are not vanishing. In this case the time derivative of the energy density U is equal to the product of the charge density ρ and the scalar field $\mathcal{S}$

$$4\pi\rho = \nabla \cdot \boldsymbol{E} \tag{26}$$

$$\rho\mathcal{S} = \frac{1}{4\pi}\nabla \cdot \boldsymbol{E}S$$

$$\frac{dU}{dt} = \rho\mathcal{S} \tag{27}$$

This time derivative of the energy density can be interpreted as a power flux that is a consequence of a non-null derivative of the electric potential ϕ:

$$\frac{dU}{dt} = \rho\frac{d\phi}{dt}$$

Integrating over a volume that contains a single electron the eq. 27 becomes:

$$eS = e\frac{d\phi}{dt} \tag{28}$$

Now, combining eq. 28 with the differential form of the electric Aharonov-Bohm equation (eq. 29), we can see that the presence of a scalar field implies a variation $\delta\omega_{zbw}$ of the electron's Zitterbewegung frequency ω_{zbw} and the appearance of a force $\boldsymbol{f}_S$:

$$e\phi = \frac{d\varphi}{dt} \tag{29}$$

$$\delta\omega_{zbw} = \frac{d\varphi}{dt}$$

$$e\mathcal{S} = \frac{de\phi}{dt}$$

$$e\mathcal{S} = \frac{d^2\varphi}{dt^2}$$

$$e\mathcal{S} = \frac{d\omega_{zbw}}{dt} \tag{30}$$

$$\phi = \int \mathcal{S} dt \tag{31}$$

$$\boldsymbol{f}_S = -e\nabla\phi$$

Experimental data suggest that an intense impulsive current with a radial/cylindrical symmetry and a critical rise time creates a Scalar field that generates radial forces that, confining the charges, create the conditions for the formation of the coherent aggregates discussed in the previous sections. This radial charge displacement can be generated by an appropriate electrode geometry [4, 20, 12] or by the pinch effect generated by short and intense current impulses [46]. Eq. 30 describes an energy-mass change, the sign of which depends on the sign of the product $e\mathcal{S}$. This process is a consequence of a Vacuum polarization caused by the presence of the Scalar field $\mathcal{S}$. This implies the possibility of a long range interaction that consists in a mass-energy transfer from positive charged particles to negative ones or vice-versa. This mass-transfer obviously does not violate the principle of energy conservation and apparently does not lead to the instability of the nuclei of the positive ions present in the plasma, even if some authors claim the possibility that Scalar fields may alter the nucleus dynamic [27]. The tiny energy lost by the nuclei can be replenished by their interaction with the active Vacuum.

The hypothesis that a mass-transfer mechanism may be the cause of the anomalous heat seen in the E-Cat QX has been presented in a previous paper [21], inside however a different theoretical framework.

To evaluate the power generated in a device as the E-Cat-QX, assuming that the thermal energy is generated by the electron transition from a coherent to an incoherent state and assuming an electron distance in the coherent state that is equal to the electron Compton wavelength ($\lambda_e \approx 2.43 \cdot 10^{-12} m$), we get a power output in the order of several tens of watts:

$$I = 0.25A$$

$$\frac{dn_e}{dt} = \frac{I}{e} = 1.56 \cdot 10^{18} {n_e}/{s}$$

$$E_e = \frac{1}{4\pi\varepsilon_0} \frac{e^2}{\lambda_e}$$

$$w_{out} = E_e \frac{dn_e}{dt} \simeq 150w$$

5 Neutral pico-metric aggregates

Coherent charge clusters may form, in presence of protons, compact neutral aggregates at a pico-metric ($10^{-12}\,m$) scale, intermediate between the atomic ($10^{-10}\,m$) and nuclear size ($10^{-15}\,m$), formed by a coherent chain of bosonic electrons with protons located in the center of their Zitterbewegung orbits [15]. A critical, cathode-temperature-dependent, threshold of electron density is an important precondition for the creation of such structures.

The existence of electron-proton and electron-deuteron structures at this scale has been already experimentally verified and studied [5, 52, 18]. In [30] Holmlid recognizes the electron Zitterbewegung as the underlying rationale for such aggregates: "*This electron spin motion may be interpreted as a motion of the charge with orbit radius $r_q = \hbar/2m_e c \approx 0.192$ pm and with the velocity of light c ('zitterbewegung')*". It's important to note that this radius value, as proposed by Holmlid, Maruani and Hestenes [23], is one half the zbw radius value r_e in [8, 31], and that the choice of such value ($r_q = r_e/2$) implies that no distinction is made between electron "intrinsic" angular momentum and spin, excluding consequently the possibility of existence of "bosonic electrons" with spin$=\hbar$.

An interesting aspect of the electron-proton interactions proposed in [15] is given by the possibility to experimentally verify the existence of some specific spectral signatures. According to [15] the electron's charge can orbit around a proton at a distance of about $r_e = 0.38\,pm$. The intense magnetic flux density B_{zbw} generated by the rotating charge at the center of the Zitterbewegung current loop is [8]

$$B_{zbw} = 32.21 \cdot 10^6\,T.$$

Now, the proton magnetogyric ratio g_H is

$$g_H = 267.52 \cdot 10^6\,rad \cdot s^{-1} \cdot T^{-1}$$

and consequently the Nuclear Magnetic Resonance frequency is

$$\nu_{NMR} = \frac{g_H B_{zbw}}{2\pi} = 1.3714 \cdot 10^{15}\,Hz$$

and the relative precession frequency ν_p is

$$\nu_p = \nu_{NMR}/2 = 6.8571 \cdot 10^{14}\,Hz.$$

This frequency corresponds to a wavelength in the visible spectrum

$$\lambda_p = \frac{c}{\nu_p} = 4.372 \cdot 10^{-7}\,m$$

The presence of this line in the E-Cat plasma spectrum is a possible indication of the existence of this type of pico-metric aggregate. A stronger and reliable clue in this direction comes from observing that the amplitude of this spectral line is a clear function of the hydrogen isotope present in the plasma: the line is strongly reduced when deuterium is used in the charge instead of protium. This consideration is supported by the observation that a deuteron has a much smaller magnetogyric ratio than proton ($g_D = 41.066 \cdot 10^6 \, rad \cdot s^{-1} \cdot T^{-1}$). Consequently, considering the strong chemical similarity of deuterium and protium, this large macroscopic difference in spectral emission under the same conditions reveals its nuclear origin.

6 Experimental Setup

The plausibility of these hypotheses is supported by a series of experiments made with the E-cat SK. The E-cat SK has been put in a position that allows the lens of a spectrometer to exactly view the plasma in a dark room: an ohmmeter measures the resistance across the circuit that gives energy to the E-Cat; the control panel is connected to a $220\,V$ outlet, while the two cables connected with the plasma electrodes start from the control panel. A frequency meter, a laser, and a tesla-meter have been connected with the plasma for auxiliary measurements and a Van de Graaff electron accelerator ($200\,kV$) has been used for the examination of the plasma electric charge. Other instruments used in the experimental setup are: a voltage generator/modulator; two oscilloscopes, one for the power source and one for monitoring the energy consumed by the E-Cat; Omega thermocouples to measure the delta T of the cooling air; IR thermometer; a frequency generator; a Geiger counter and bubbles columns to measure emissions of ionizing radiations and neutrons.

7 Evaluation of E-Cat SK performance

The performance of the E-Cat SK is summarized in the following calculations. The plasma temperature can be calculated applying the Wien equation. Calling b the Wien displacement law constant and λ_{max} the observed peak wavelength of the radiation we have

$$T_k = \frac{b}{\lambda_{max}}$$

$$T_k = \frac{2.898 \cdot 10^{-3}}{0.3575 \cdot 10^{-6}} = 8106\,K.$$

Power emission and the average energy produced in one hour can be computed applying the Stefan-Boltzmann law

$$W_{out} = \sigma \varepsilon T_k^4 A \approx 22\,kW$$

$$E_{out} = 22\,kWh$$

where $\sigma = 5.67 \cdot 10^{-8}\,Wm^{-2}K^{-4}$, $\varepsilon = 0.9$ (assuming a non-perfect black body) and $A \approx 10^{-4}\,m^2$(the length of the cylindrical shaped plasma core is $l \approx 1\,cm$, while its diameter is $d \approx 0.3\,cm$).

This value must be compared with the calorimetric measurements, considering that the spectrum of the radiations has not a full Maxwellian curve. The E-Cat has been installed in a laboratory of an industry in the State of Tennessee, in the USA, to keep warm a room that has a surface of 3000 sq.ft (about 300 sq.m.) and a height of 15 ft (about 5 m). The temperature outside when we made the measurements was about 32 °F (0°C) and the temperature in the room was about 61°F (16°C). To keep this temperature it was used before a heater of about 20-22 kW.

In detail:

Fan flow rate: 5500 $^{m^3}/_h \simeq 6700$ $^{kg}/_h$

delta T = 16 °C

Cp air = 0.17

W = 6700 x 0.17 x 16 = 18224 $^{Kcal}/_h$ = 20.5 $^{kWh}/_h$

We also made a test with an air flow of 330$^{m^3}/_h$ and obtained a deltaT of 312°C.

Every 60 days of continued operation the E-Cat SK produces- as we can find with a simple extrapolation- 30000 kWh of heat, approximately the equivalent of 2600 kg of heating oil, therefore avoiding, at the same time, the emission of more than 8000 kg of CO_2. Now, calling E_{inp} the energy consumed by the control panel in one hour

$$E_{inp} = 380\, Wh$$

we can compute the average coefficient of performance (COP), as the ratio of output and input energies

$$COP = \frac{E_{out}}{E_{inp}} \approx 54$$

Conclusions

In this paper, three different, not mutually exclusive Ansätze, for long-range particle interactions in E-Cat SK have been proposed. The first one is based on the possible role of the Casimir force in dense electron aggregates: two different approaches, one of which is based on Zitterbewegung electron models, both indicate that Coulomb repulsion between electrons may be balanced at a pico-metric scale. The second one, in analogy with the Norman Cook idea of magnetic origin of strong force [13, 11], deals with the Lorentz forces in coherent systems, where electron Zitterbewegung phases are synchronized and electron charges are in the same light cone. A relativistic interaction Lagrangian for a set of elementary charged particles that suggests the possible existence of these coherent states has been proposed. An hypothesis that peculiar discharge geometries and dynamics create a Vacuum polarization that favors the formation of these low entropy structure, has been presented. The third one is based on the possible electrostatic screening effect of virtual particle pairs created by the fluctuations of quantum vacuum.

As a consequence of these relatively long-range interactions, the possible formation of dense aggregates at pico-metric scale has been proposed. An E-Cat plasma spectral signature, isotopic dependent, in the visible range of a proton-electron pico-metric structure has been reported.

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