E-Cat SK and long-range particle interactions

Preprint · January 2019

DOI: 10.13140/RG.2.2.28382.48966/3

1 author:

Andrea Rossi
Leonardo Corporation

E-Cat SK and long-range particle interactions

Andrea Rossi

Abstract

Some theoretical frameworks that explore the possible formation of dense exotic electron clusters in E-Cat SK are presented. Some considerations on the probable role of Casimir, Aharonov-Bohm, and vacuum polarization effects in the formation of such structures are proposed. 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 [14]. 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.

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*" [21], 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"* [14]: *"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 P. De Sia nuclear force model [20] based on the Biot-Savart law, 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 at multiples of Compton wavelength is proposed. In section 3 the L. Nelson hypothesis that virtual particles generate screening forces in the vacuum tube space-charge is briefly presented as another possible mechanism for long range particle interaction. In section 4 it is hypothesized that the Aharonov-Bohm effect may be exploited in the E-Cat to create peculiar conditions under which self-organized dense electron clusters and pico-metric proton-electron aggregates are formed. In this last section one spectroscopic signature of these structures is discussed. Section 5 contains a brief description of the experimental setup, while in section 6 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*" [17] propose, as a possible cause of the high-density charge clustering seen by K. Shoulders and other researchers, the "vacuum pressure" hypothesized in 1948 by H. B. G. Casimir and experimentally verified by S. K. Lamoreaux [18] 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:

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

were $r_e = \frac{c}{\omega_e} = \frac{\lambda_e}{2\pi}$ 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

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

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*" [19]. To compute the Casimir force between electrons, Maruani suggests to apply 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 consider a "Zitterbewegung" [4, 7, 1, 11] 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 $F_e(d)$:

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

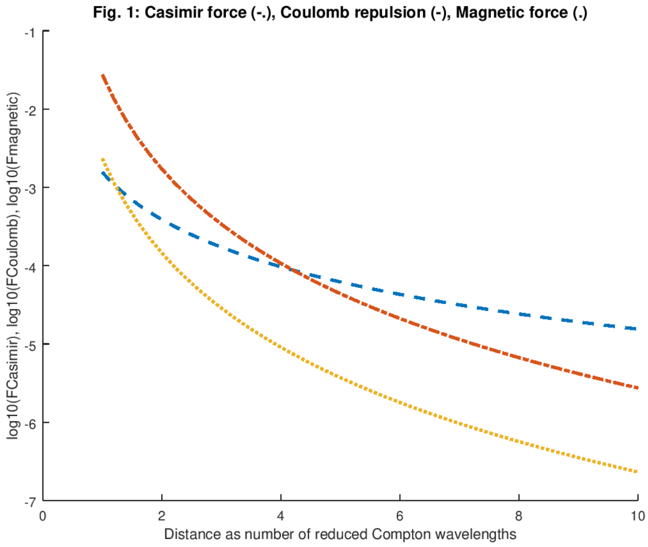

Figure 1: Trends of Casimir, Coulomb and magnetic forces as a function of distance.

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

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 [19]).

According to another Zitterbewegung electron model [11, 13] 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.

2 Charge clusters, Lorentz force and Zitterbewegung phase coherence

According to [11, 10], the electron is associated to 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 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 [11, 12] 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 parallelly at light-speed c at a distance vector $\vec{d}$ orthogonal to the charge velocity vector.

A similar approach has been suggested by P. Di Sia in [20, 22], where the Biot-Savart law is proposed as the possible origin of strong nuclear force. The condition that the charges must be in the same light-cone [15] 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 6 can be applied may be created only in very peculiar environments. A possible solution has been suggested in [13] 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 [13] *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 [6, 8, 1]. 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 [9]. In [13] 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*".

These very peculiar electron configurations 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 [13]. A critical, cathode-temperature-dependent, threshold of electron density is an important precondition for the creation of such structures. In this electron-rich environment, the creation-annihilation of virtual particles may play a particular role, as shown in the following section.

3 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 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, lowers 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 hypothesis, based on self-organizing Zitterbewegung electron phases in vacuum and Lorentz force are however possible (see Section 2).

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.

4 Neutral pico-metric aggregates

The existence of electron-proton and electron-deuteron structures at this scale has been already experimentally verified and studied [3, 16, 2]. In [5] 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 Holmid, Maruani and Hestenes[1], is one half the zbw radius value r_e in [11], 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 [13] is given by the possibility to experimentally verify the existence of some specific spectral signatures. According to [13] 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 [11]

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

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 has been used in the charge instead of protium. This consideration is supported by the observation that deuteron has a much smaller magnetogyric ratio then proton ($g_D = 41.066 \cdot 10^6\, rad \cdot s^{-1} \cdot T^{-1}$). Consequently, considering the strong chemical similarity of deuterium and hydrogen, this large macroscopic difference in spectral emission under the same conditions reveals its nuclear origin.

5 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 to allow 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 from the control panel start the two cables connected with the plasma electrodes. A frequency meter, a laser, and a tesla-meter have been connected with the plasma for auxiliary measurements and a Van der Graaf 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.

6 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 cylindrically shaped plasma core is $l \approx 1\, cm$, while its diameter is $d \approx 0.3\, cm$). Now, calling E_1 the energy consumed by the control panel in one hour

$$E_1 = 380\, Wh$$

and E_2 the energy consumed by the E-Cat SK in one hour

$$E_2 = 8 \cdot 10^{-4}\, Wh,$$

together with the other following experimental values,

$$V_{in} = 0.25\, V$$

$$R = 78\, \Omega$$

$$I = 0.0032\, A$$

$$W_{in} = V_{in} I$$

we can compute the average coefficient of performance (COP), first considering the energy consumed by the control panel

$$COP_1 = \frac{E_{out}}{E_1 + E_2} \approx \frac{E_{out}}{E_1} \approx 58$$

and, after considering only the energy consumed by the E-Cat (i.e. in SSM: Self Sustaining Mode),

$$COP_2 = \frac{E_{out}}{E_2} > 10^7 \ (SSM)$$

Definitely a huge value! After 60 days of continued operation an E-Cat SK has produced (as we can find from a simple extrapolation) 31680 kWh of heat, approximately the equivalent of $2762\, kg$ of heating oil (avoiding, at same time, the emission of more than $8000\, kg$ of CO_2).

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 deals with the Lorentz forces in coherent systems, where electron Zitterbewegung phases are synchronized and electron charges are in the same light cone. The third one is based on the possible electrostatic screening effect of virtual particles pairs created by the fluctuations of quantum vacuum.

As a consequence of these relatively long-range forces, 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.

Acknowledgments

I acknowledge, for interesting discussions and collaborations on the subject, Carl Oscar Gullström and Giorgio Vassallo.

Bibliography

[1] D. Hestenes. Hunting for Snarks in Quantum Mechanics. In P. M. Goggans and C.-Y. Chan, editors, *American Institute of Physics Conference Series*, volume 1193 of *American Institute of Physics Conference Series*, pages 115–131, December 2009.

[2] Frederick J. Mayer and John R. Reitz. Electromagnetic Composites at the Compton Scale. *International Journal of Theoretical Physics*, 51(1):322–330, 2012.

[3] Shahriar Badiei and Patrik U. Andersson and Leif Holmlid. High-energy Coulomb explosions in ultra-dense deuterium: Time-of-flight-mass spectrometry with variable energy and flight length. *International Journal of Mass Spectrometry*, 282(1–2):70–76, 2009.

[4] David Hestenes. Zitterbewegung Modeling. *Foundations of Physics*, 23(3):365–387, 1993.

[5] Leif Holmlid and Sveinn Olafsson. Spontaneous Ejection of High-energy Particles from Ultra-dense Deuterium D(0). *International Journal of Hydrogen Energy*, 40(33):10559 – 10567, 2015.

[6] David Hestenes. The zitterbewegung interpretation of quantum mechanics. *Foundations of Physics*, 20(10):1213–1232, 1990.

[7] David Hestenes. Zitterbewegung in quantum mechanics. *Foundations of Physics*, 40(1):1–54, 2010.

[8] David Hestenes. Mysteries and insights of Dirac theory. In *Annales de la Fondation Louis de Broglie*, volume 28, page 3. Fondation Louis de Broglie, 2003.

[9] Aharonov, Y. and Bohm, D. Significance of Electromagnetic Potentials in the Quantum Theory. *Physical Review*, 115:485–491, aug 1959.

[10] Oliver Consa. Helical Model of the Electron. *The General Science Journal*, pages 1–14, June 2014.

[11] Celani, F. and Di Tommaso, A.O. and Vassallo, G. The Electron and Occam's razor. *Journal of Condensed matter nuclear science*, 25:76–99, Nov 2017.

[12] Celani, F. and Di Tommaso, A.O. and Vassallo, G. Maxwell's Equations and Occam's razor. *Journal of Condensed Matter Nuclear Science*, 25:100–128, Nov 2017.

[13] Di Tommaso, A.O. and Vassallo, G. Electron Structure, Ultra-dense Hydrogen and Low Energy Nuclear Reactions. *to appear in Journal of Condensed Matter Nuclear Science*, (accepted) 2019.

[14] Carl-Oscar Gullström and Andrea Rossi. Nucleon polarizability and long range strong force from $\sigma_{I=2}$ meson exchange potential. arXiv 1703.05249, 2017.

[15] Carver Mead. The nature of light: what are photons? *Proc.SPIE*, 8832:8832 – 8832 – 7, 2013.

[16] S. Zeiner-Gundersen and S. Olafsson. Hydrogen reactor for Rydberg Matter and Ultra Dense Hydrogen, a replication of Leif Holmlid. International Conference on Condensed Matter Nuclear Science, ICCF-21, Fort Collins, USA, 2018.

[17] H. E. Puthoff and M. A. Piestrup. Charge confinement by Casimir forces. arXiv:physics/0408114, 2004.

[18] S. K. Lamoreaux. Demonstration of the Casimir force in the 0.6 to 6 micrometers range. *Phys. Rev. Lett.*, 78:5–8, 1997. [Erratum: Phys. Rev. Lett.81,5475(1998)].

[19] Jean Maruani. *The Dirac Electron and Elementary Interactions: The Gyromagnetic Factor, Fine-Structure Constant, and Gravitational Invariant: Deviations from Whole Numbers*, pages 361–380. 01 2018. isbn = 978-3-319-74581-7.

[20] Paolo Di Sia. A solution to the 80 years old problem of the nuclear force. pages 34–37, 10 2018. doi = 10.5281/zenodo.1472981.

[21] Eugene Paul Wigner, Alvin M Weinberg, and Arthur Wightman. *The Collected Works of Eugene Paul Wigner: the Scientific Papers*. Springer, Berlin, 1993.

[22] Norman D. Cook and Andrea Rossi. On the nuclear mechanisms underlying the heat production by the e-cat, 2015.