Int J Theor Phys (2012) 51:322–330
DOI 10.1007/s10773-011-0959-8

Electromagnetic Composites at the Compton Scale

Frederick J. Mayer · John R. Reitz

Received: 30 June 2011 / Accepted: 8 September 2011 / Published online: 23 September 2011

Abstract A new class of electromagnetic composite particles is proposed. The composites are very small (the Compton scale), potentially long-lived, would have unique interactions with atomic and nuclear systems, and, if they exist, could explain a number of otherwise anomalous and conflicting observations in diverse research areas.

Keywords Electromagnetic composites · Compton scale · Bound states · Formation energy

1 Introduction

In recent years there have been a number of experimental observations that are difficult to explain within our now-standard models of atomic and nuclear physics and cosmology. The case of so-called "dark matter" is an example. It appears that only a small fraction of the mass of the universe is constructed from ordinary protons, neutrons, and electrons. So, many cosmologists have turned to some relic elementary particle as the candidate to complete the mass deficit. Strange observations such as the excess heat from the earth and "cold fusion" are still other examples. We have wondered if there might be configurations of nucleons and electrons that would not be directly observable in the same way as are the ordinary nucleon atomic systems. This consideration was the genesis of the work presented here.

The possibility of new electromagnetic bound states in which the magnetic and electric forces are treated equally and are of comparable size was suggested in our recent paper [1]. For example, the electrostatic force between two electrons e^2/r^2 is comparable with the dipole-dipole magnetic force μ_e^2/r^4 at a distance $r \approx \lambda_c$, where λ_c is the electron Compton wavelength. In fact, a number of bound states involving two electron-like particles were

F.J. Mayer (✉)
Mayer Applied Research, Inc., 1417 Dicken Drive, Ann Arbor, Michigan 48103, USA
e-mail: fmayer@sysmatrix.net

J.R. Reitz
2260 Chaucer Ct., Ann Arbor, Michigan 48103, USA
e-mail: jrreitz@ameritech.net

found as solutions to the Dirac equation. However, none of these states involved nucleons because the nuclear magnetic moments are too small to produce binding. Yet, it seemed plausible that composites that included nucleons might be possible at the Compton scale. These composites might resemble normal atoms perhaps with different characteristics, but would be, of course, much smaller than atoms.

In this paper, we propose simple composite systems that include nucleons but are still bound together by comparable electric and magnetic forces. These entities make up a three-body system which is too complicated to treat rigorously in a quantum mechanical manner, so we present a simple Schrödinger model (one which is consistent with its Dirac equation origin) to get quantitative estimates of the system's size and binding energy. Clearly, without a quantum electrodynamical formulation for these composites, their existence is unproven; however, since these entities appear plausible, we will look at the consequences as if they do exist.

We first describe several model calculations for these three-body systems and determine whether bound states appear possible. Second, we examine the situations in which these composites might be expected to be formed. Finally, we connect the characteristics of the proposed composite particles to a number of anomalous observations over the past years. In a later papers, we will consider such anomalous observations in detail.

2 The Electromagnetic Configuration

The simplest classical model of one of these three-body systems consists of a positively charged nucleus (Ze) and two "point" electrons on opposite sides of the nucleon. The electrons have their customary magnetic moment $\mu_e = e\lambda_c/2$. The nucleon provides the attractive electrostatic force pulling the electrons together; the electrons repel each other electrostatically and magnetically through the dipole-dipole interaction. The electronic motion must be highly correlated—i.e., the electrons move in such a way that they stay apart as far as possible, consistent with maximizing their interaction with the nucleon. Is this a possible configuration at the Compton scale, i.e., is the electron magnetic moment developed to the point that $\mu_\mathbf{e} \cdot \mathbf{B}$ represents an appropriate energy term? There is no such term in the Dirac equation, only a vector potential that interacts with the electronic motion. However, Schiff [2] shows that the Dirac equation for an electron in an electromagnetic field is equivalent to a Schrödinger equation with the usual $\mu_\mathbf{e} \cdot \mathbf{B}$ term [Schiff's Eq. (43.27)] if $2mc^2 \gg E' - e\phi$ where $E' = E_{total} - mc^2$. This turns out to be the case for the model considered herein.

Of course, one aspect of the electronic motion predicted by the Dirac equation does not appear in the Schrödinger equation, namely, the *zitterbewegung* [3, 4]. This motion occurs on a very short time scale, is confined to small distances (of the order of λ_c), does not affect the classical trajectory, and is believed to be responsible for creating the electron-spin magnetic moment. However, the *zitterbewegung* must traverse distances of at least one Compton in order to develop the observed magnetic moment. The classical models described below have equilibrium radii smaller than this, so the magnetic moments cannot be treated as point entities in any final picture.

There are two cases with no orbital angular momentum. In the first case, the electrons are located equatorially, on opposite sides, at distance r from a nucleon Ze—see Fig. 1(a).

We neglect the nuclear magnetic moment. Consider the case where the total angular momentum is zero, i.e., when one electron's particle momentum is canceled by the magnetic

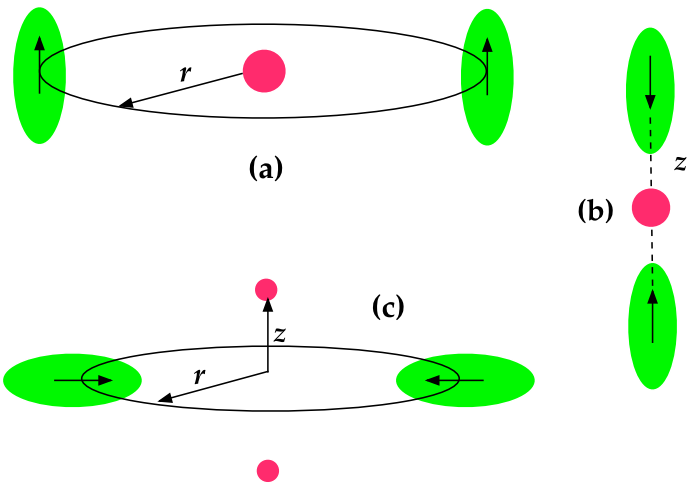

Fig. 1 (Color online) Compton composite "classical" depictions showing protons (*red*) and electrons (*green*)

field momentum of the other electron.

$$n\hbar = r(mv + (e/c)A_\phi) = mvr - (e/c)\mu_e/4r = 0 \tag{1}$$

where μ_e is the electron's magnetic moment. The centripetal force equation for one of the electrons is then

$$mv^2/r = Z_{eff}e^2/r^2 - (e/c)\mu_e v/8r^3 - 3\mu_e^2/16r^4 \tag{2}$$

where $Z_{eff} = Z - 1/4$. Equation (1) gives

$$\beta = v/c = \alpha/8r^2 \tag{3}$$

where α is the fine structure constant, and (*Note*), from here and henceforth, distances are measured in units of λ_c, and energies in units of $E_c = e^2/\lambda_c = 3.7$ keV. These equations will show that $\beta \ll 1$. The total electromagnetic energy of this system is

$$W_{\rm em} = -2\,Z_{eff}/r + 1/(32\,r^3). \tag{4}$$

Solving (1) and (2) gives $r = \sqrt{3/Z_{eff}}/8$. This system has a total electron spin of 1. With $Z = 1$, $r = 1/4$, and the binding energy $E_{\rm B} = 4$.

In the second case—see Fig. 1(b), the electrons are located on the z-axis at $+z$ and $-z$, with the nucleon at the origin. The total electromagnetic energy of the system as a function of z (the electron-nucleon distance) is

$$W_{\rm em}(z) = -2Z_{eff}/z + 1/16z^3. \tag{5}$$

This has a minimum at $z = \sqrt{6/Z_{eff}}/8$; for $Z = 1$, $z = 0.354$. We note that this represents a potential which is about 10 keV deep at an electron-nucleon distance of about one third of a Compton. In addition to $W_{\rm em}$ there is also kinetic energy, presumably due to vibration.

Summarizing, we have found two (classical) bound states for three-body electromagnetic composites: a compact equatorial state with spin 1 and a binding energy of about 15 keV (for $Z = 1$), and a more loosely-bound axial state with spin zero. But the classical models cannot provide a valid picture. The deBroglie wavelength is not short enough to localize an electron in a fraction of a Compton.

What is required is a non-perturbative QED treatment of the three-body system, but this is not presently available. We can, however, solve a simplified Schrödinger model. Here, again, we note that the deBroglie wavelength is not short enough to keep the electrons apart and at the same time localize them in the Compton range. Thus, the electron wave-functions must overlap, so that an $S = 0$ spin state is required.

The *zitterbewegung* loops can form around any axis; there is no net spin and hence no preferred axis. In writing a Schrödinger Hamiltonian for one of the electrons we choose a Hartree model [5] in which the electron under consideration is a "point"-electron e_1 interacting with a nucleus and the electron distribution of e_2 (electron-2). The Hartree field model is a central-field model, so we can use spherical coordinates. We make two assumptions to differentiate this new type of wave-function from the atomic case: the magnetic interaction between the electrons plays an essential role, and the electrons are completely correlated so that r_1 equals $-r_2$ at any instant. Since the two electrons in this model have the same wave-function we can just as easily solve a Schrödinger equation for the 2-*electron system*; this takes the form:

$$\left[\frac{\partial^2}{\partial r^2} + \alpha[E - V(r)]\right]\psi(r) = 0 \tag{6}$$

where α is the fine structure constant, E is the eigenvalue (the particle binding energy is $-E$), and the potential $V(r)$ is given by:

$$V(r) = \frac{1}{4(1+4r^2)^{\frac{3}{2}}} + \frac{1}{\sqrt{1+4r^2}} - \frac{2Z}{\sqrt{r^2 + {r_n}^2}} \tag{7}$$

where r_n is the nuclear radius in Compton units.

The first term in (7) is the magnetic interaction between the electrons. To calculate this we need the axial magnetic field of a loop, and this can be obtained from expressions derived by Smythe [6]. The spin dipole is produced by swirling *zitterbewegung* currents with dimensions of order of λ_c, this swirl of currents around the image point of r_1 forms the electron distribution of electron e_2.

The result of our quantum mechanical calculation is as follows: the two one-electron wavefunctions overlap and have strong maxima at the origin (the nucleus). Taking $Z = 1$, the wavefunction ψ (squared) is shown in Fig. 2 where the average value of r is about six Comptons and the particle binding energy, $E_B \approx 1$, or about 3.7 keV.

3 Characteristics of Hydrogen Tresinos

For convenience, we have given these three-body electromagnetic composites the name *tresinos*. In this section we discuss the properties of the hydrogen tresinos (the $Z = 1$ case). Where and under what conditions might they be formed and will they survive for some length of time? Clearly, the physical conditions favoring tresino formation require a nucleon and a source of electrons such that two opposing-spin electrons have a reasonable probability of "falling into" the potential well of the nucleon (perhaps requiring another nearby particle to conserve energy and momentum). Sufficiently high density plasmas, either gaseous or metallic, might be expected to present these conditions. On the other hand, ionic materials, in which a pair of donor electrons are in close proximity to each other (such as might be found in a chemical bond) might similarly be advantageous to tresino formation. It would appear, however, that tresinos are not particularly easy to make. Their formation involves

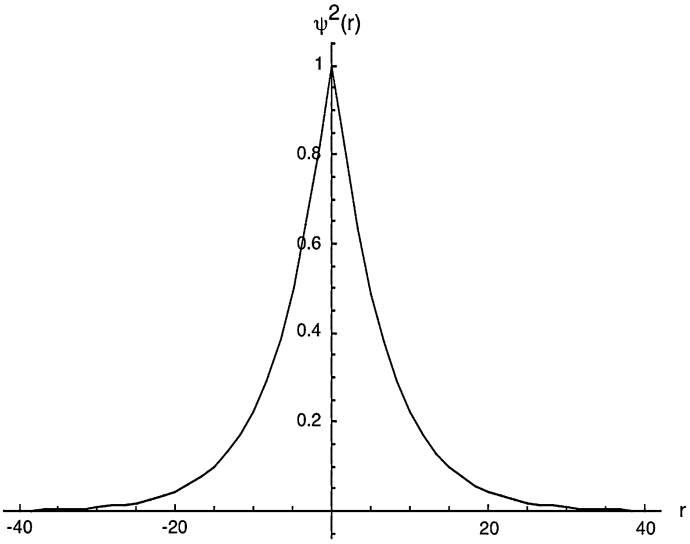

Fig. 2 Plot of $\psi^2(r)$ based on a simplified Schrödinger model

the interaction of three particles: protons (or deuterons or tritons) and two electrons, in a restricted geometry. A situation involving high densities of both protons and electrons would seem to be required for them to be produced.

Aside from being charged and thus responsive to an electric field, the tresino would appear to have little or no interaction with atomic systems. It would, therefore, stay around until being eventually destroyed or neutralized, very likely through attachment to a positive nucleon. The most likely nucleon is another hydrogen nucleus (p, d, or t) and, at least classically, it appears that this would be energetically favorable. The attachment would form either a tresino-proton pair (somewhat like a molecule) or what we will call a "quatrino".

A classical model of the quatrino is shown in Fig. 1(c). It is a four-body composite with two hydrogen nuclei located on the axis at $\pm z$ and two electrons on a circle of radius r in the midplane. The orbital velocity of the electrons is very small, and as before, and there is zero angular momentum (see Sect. 2). Using the same type of classical analysis used in Sect. 2, we find that $r = \sqrt{3}z = 0.211$, and the (classical) binding energy of the quatrino is about 25 keV. However, we admit that we do not have a quantum mechanical model of this complex composite.

Why haven't tresinos been seen? As already mentioned, they would not be readily created, they would not be reactive with electrons or atomic systems, and, although the h-tresinos are charged, they probably would not remain un-neutralized for very long. However, a tresino-proton pair (or a quatrino) being neutral, would be expected to move easily through macroscopic systems. The tresinos do not appear to have excited states therefore they would not have photon interactions other than possibly rotational or vibrational excitations.

Compton composite formation would release the binding energy for the h-tresino—3.7 keV from our Schrödinger solution. We speculate that this heat of formation may have been observed, but misinterpreted, in observations discussed in Sects. 5 and 7. In the 1990s there were many cases where this heat of formation may have been observed and measured, starting with the "cold fusion" experiments of Fleischmann and Pons [7]. Although usually these experiments involved deuterium-loaded Pd and/or ionic solutions containing deuterium ions, some cases [8, 9] used ordinary hydrogen in place of deuterium. The experimenters generally attributed the observation of the excess heat to nuclear reactions. But this interpretation has not been accepted by nuclear physicists. Still, the source of this excess heat, which is more than an order of magnitude larger than that from known chemical

reactions, has not been definitively identified. We propose that much of this heat (perhaps all of it in experiments using ordinary "light" water) comes from tresino formation energy. We present more discussion of these controversial observations in Sect. 7.

4 Compton Composites and Dark Matter

So far, we have been describing the characteristics and interactions of the h-tresinos which carry a net charge of minus one. Let us now consider the He-tresino. As with its atomic counterpart, the He-tresino is very strongly bound ($E_B = 14.3$ keV) and a neutral composite. This particle would be very small, neutral, and have a mass of about 3.7 GeV. It would be expected to have very few interactions of any kind with ordinary matter and would not be ionized except in the cores of very hot stars. As such, it might be a candidate for the so-called dark matter in the cosmological context.

The quatrino, if it exists, is also a neutral composite with a mass of 1.8 GeV. Here, we are considering the h-quatrino made of protons. This Compton composite should be stable and long-lived, and could also be a dark matter candidate. And yet another possibility for the dark matter: a combination of h-tresinos and protons in approximate charge balance, possibly bound together as proton-tresino molecules.

The He-tresino, the h-quatrino, and the tresino-proton pair, would be classified as weakly interacting massive particles (WIMPs). Interestingly, Peacock [10], notes that, "the universe may be closed by massive neutrino-like particles with masses around 3 GeV." But he also states "that none of the known neutrinos can be as massive as 3 GeV." The proton-tresino molecule (or the He-tresino) could have been formed in the early universe before the cooling and recombination of ordinary matter and might have continued to drift along with the universal expansion, being affected only by gravitational forces. These ideas are discussed more fully in a later paper.

5 Compton Composites and Heat from the Earth

For some time, it has been realized that there is a substantial discrepancy regarding the earth's internal heat source. That there is such a source is not in dispute, but the conventional explanation for the earth's internal heat (alpha decay of uranium and thorium) has an associated problem. Namely, where is all of the helium? At the elevated temperatures of the earth's interior, helium should readily escape. Therefore, measurements of the helium emanating from the earth would be expected to be in balance with the radioactive decay heat from these nuclides. Yet, this appears not to be the case. According to some measurements [11], there is approximately twenty times more heat than can be accounted for by the helium measured.

Perhaps tresino formation as mentioned above is possible in the high-temperature and pressure materials in the earth. There is also water in the earth's crust and mantle, and these conditions may favor the formation of Compton composites. If tresino formation energy is, in fact, the largest source of the earth's heat generation, it would explain why the major source of this heat comes from the crust and upper mantle, and it would also resolve a number of other unexplained anomalies concerning the earth's heat and helium emanations (Mayer and Reitz [12]).

6 Compton Composite-Induced Nuclear Reactions

As discussed in Sect. 3, the h-tresino in a hydrogen environment (p, d, t) will probably end up in the vicinity of hydrogen ions. Even if there is not permanent attachment to the ion, the electron shielding in the tresino will allow frequent nuclear encounters at a distance of a Compton or less. This opens up the possibility of nuclear reactions.

A tresino diffusing through a metal like Pd which has absorbed hydrogen (or deuterium) will be attracted to a hydrogen nucleon. At sub-coulomb barrier energies, neutron "stripping" (or transfer) reactions [13, 14] are the most common nuclear reactions. Tresino-induced neutron stripping may occur with a d-tresino operating in an environment containing other deuterons (more about these reactions can be found in [12]. The electrostatic force between the d-tresino and a deuteron favors bringing them into close proximity and with dynamic electron shielding the two nuclei may be brought to within a fraction of a Compton. Since the neutron in the deuteron is rather loosely bound and the energy for the reaction is favorable, the neutron may be picked up by the d-tresino (or, in some cases, the pick-up may be in the reverse direction) in the reaction $d + d^* \rightarrow p + t + 2e + 4\,\mathrm{MeV}$ where we use d^* to indicate the d-tresino and we might expect that the tresino breaks up in the process (however, see [12]). This type of neutron transfer reaction appears to be considerably more probable than *compound nucleus* formation requiring much closer encounters.

7 Compton Composites and "Cold Fusion"

The area known as "cold fusion" [15] has received much attention, both good and bad, over the past two decades. We will not attempt to explain all the claims or even all the experimental observations from this complex and muddled research area, but we will show that a number of otherwise unexplained observations are consistent with tresino induced reactions. A good overview of all of the anomalous results from this area can be found in a review paper by Storms [16, 17]. In addition, we note that there have been a number of models that have sought to find compact electron-proton systems to explain enhanced screening in "cold fusion" experiments. In particular, the work of Rice et al. [18] examined this issue and conclude that "models in which the electron is tightly bound to the hydrogen or deuterium nucleus were found to have serious qualitative or quantitative defects." In contrast to their work, the present paper requires two electrons interacting with a proton and has to include the electrons' dipole-dipole interaction. Hence, our Hamiltonian is quite different—one that yields the compact (and energetic) bound states presented above.

7.1 Observations of Excess Heat

The original papers by Fleishmann and Pons [7] introduced the cold fusion idea and claimed nuclear fusion as the source of "excess" heat in their electrochemical (deuterium-loaded Pd) cells. Although the heat was present, the expected energetic nuclear reaction products were not. These experiments were repeated by others, including some using non-deuterated water, many reporting "excess heat."

Now, if d-tresinos are formed during deuteron loading of palladium, there are at least two possibilities to generate heat. First, there is the binding energy of the tresino which is released during its formation ($\approx 2 \times 10^8$ joules/gram). Second, there is the much larger energy per reaction if neutron transfer reactions take place. There may have been many instances in which the heat of tresino formation has been observed but misinterpreted as chemical reaction heat.

7.2 Observations of Tritium

For many years, there have been observations of tritium being produced in deuterium loaded metal experiments [19, 20]. These observations were not accompanied by other nuclear reaction products such as neutrons which might have been expected from ordinary $d-d$ fusion reactions because the neutron and triton branches, through compound nucleus formation, are about equally probable. Although the tritium was many orders of magnitude above background, extensive measurements were made to eliminate the possibility of tritium being somehow introduced into the experiment as an impurity. These experiments may be explained as the result of the tresino-induced neutron transfer reactions in deuterated material (see previous section).

Many (but not all) of the controversial claims and observations of this experimental area may have straightforward explanations through the heats of formation of tresinos and quatrinos or through nuclear reactions in which they play a role. This possibility will be the focus of a future paper.

8 Discussion

We have proposed the existence of a new class of subatomic, composite particles which might have eluded direct observation. Although we are unable to present a formal quantum electrodynamical solution for the Compton composite particles, we have shown that their existence is not in conflict with well-established quantum mechanical principles.

But perhaps more interesting is the indirect evidence. The existence of these particles can provide explanations for a number of physical observations which have so far eluded attempts at explanation. These include (1) the discrepancy between the heat emanating from the earth and its proposed source from radioactive material, (2) the unexplained excess heat generated in "cold fusion" experiments, and (3) the composition of the dark matter filling the universe. Perhaps most telling is the thermal emanations from the earth: not only is the heat evolved about twenty times larger than its "supposed source" from radioactive material, based upon the amount of helium emitted, but this helium also contains ^{3}He (not a component of radioactive decay from U and Th). Furthermore, there is evidence that at least some of the large scale magma deposits had their origin in surface-derived material, not from deep in the mantle. Thermal energy generation in the earth is discussed in a later paper [12].

Finally, we mention that if our tresino picture applied to dark matter is correct [21], it shows that the dark matter—the material filling most of the universe—is composed of well-known entities—electrons and hydrogen nuclei.

References

1. Reitz, J.R., Mayer, F.J.: J. Math. Phys. **41**, 4572 (2000)
2. Schiff, L.I.: Quantum Mechanics, Second Edition. McGraw-Hill, New York (1955)
3. Messiah, A.: Quantum Mechanics, vol.II, Wiley, New York, (1962)
4. Barut, A.O., Bracken, A.J.: Phys. Rev D **24**, 3333 (1981)
5. Slater, J.C.: Quantum Theory of Atomic Structure, pp 189–192, McGraw-Hill, New York (1960). Also Schiff, ibid, p. 283
6. Smythe, W.R.: Static and Dynamic Electricity, pp. 270–271. McGraw-Hill, New York (1950)
7. Fleishmann, M., Pons, S.: J. Electroanal. Chem. **261**, 301 (1989)
8. Notoya, R.: Fus. Technol. **24**, 202 (1993)
9. Mills, R., Kneizys, K.: Fus. Technol. **20**, 65 (1991)

10. Peacock, J.A.: Cosmological Physics, p. 384. Cambridge University Press, Cambridge (1999)
11. Oxburgh, E.R., O'Nions, R.K.: Science **237**, 1583 (1987)
12. Mayer, F.J., Reitz, J.R.: Thermal Energy Generation in the Earth (to be published)
13. Satchler, G.R.: Introduction to Nuclear Reactions, Oxford University Press, New York, p. 67 (1990)
14. Switkowski, Z.E., Wieland, R.M., Winther, A.: Phys. Rev. Lett. **33**, 840 (1974) for sub-barrier neutron transfer reactions
15. Beaudette, C.G.: Excess Heat: Why Cold Fusion Research Prevailed, Oak Grove Press, South Bristol (2000)
16. Storms, E.: A critical evaluation of the Pons-Fleishmann effect. Part I. Infinite Energy **6**(31), 10 (2000)
17. Storms, E.: A critical evaluation of the Pons-Fleishmann effect. Part II. Infinite Energy **6**(32), 52 (2000)
18. Rice, R.A., Kim, Y.E., Rabinowitz, M., Zubarev, A.L.: Comments on exotic chemistry models and deep Dirac states for cold fusion. In: Proc. International Conference Cold Fusion, vol. 4 pp. 4-1–4-7 (1993)
19. Claytor, T.N., Tuggle, D.G., Menlove, H.O., Seeger, P.A., Doty, W.R., Rohwer, R.K.: ibid [14], p. 467
20. Clarke, W.B., Oliver, B.M., McKubre, M.C., Tanzella, F.L., Tripodi, P.: Fus. Sci. Technol. **40**, 152 (2001) and references therein
21. Mayer, F.J., Reitz, J.R.: Compton composites late in the early universe (to be published)