APPLICATIONS OF RELATIVISTIC QUANTUM m THEORY: THE RADIATIVE CORRECTIONS

by

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ABSTRACT

Relativistic quantum m theory is used to calculate and compute the radiative corrections, exemplified by the anomalous g factor of the electron and the Lamb shift in atomic hydrogen. In this way it is shown that the well known radiative corrections are the result of m space, the most general spherically symmetric space. The radiative corrections can be expressed in terms of the m parameter of this space, and show that energy is available in the m space.

Keywords: ECE unified field theory, m theory, radiative corrections.

UFT 429

1. INTRODUCTION

In recent papers of this series {1 - 41} the m theory has been developed in classical and quantum mechanics. This means that classical and quantum mechanics have been developed in the most general spherically symmetric space, characterized by the m function. In the preceding paper UFT428, relativistic quantum m theory was used to show that the radiative corrections can be described by the nature of m space. In Section 2 the anomalous g factor of the electron and the Lamb shift are considered within the context of relativistic quantum m theory. It is shown that the electron g factor is the result of a given m function, and the spin orbit interaction in relativistic quantum m theory is changed in detail by the m function.

This paper is a brief synopsis of detailed calculations in the Notes accompanying UFT429 on www.aias.us. Notes 429(1) and 429(2) develop methods of calculation of the g factor of the electron, and develop the theory of the vacuum particle first given in UFT338, giving the m theory of the mass of the universe. Note 429(3) develops the relativistic quantum m theory of spin orbit interaction, showing that m space changes the spin orbit energy levels of the Dirac equation, producing the possibility of a Lamb shift. Self consistently, the latter has already been derived using the spin connection of ECE2 theory.

Section 3 is a computational and graphical analysis using the hydrogenic wavefunctions in the first approximation. Expectation values are computed with the m function.

2. CALCULATION OF THE RADIATIVE CORRECTIONS

As shown in complete detail in Note 429(1) the g factor of the electron in Dirac theory is exactly two, and is calculated from the Zeeman hamiltonian:

$$H_2\phi = \frac{ie\hbar}{2m}\,\underline{\sigma}\cdot\underline{\nabla}\,\underline{\sigma}\cdot\underline{A}\,\phi + \dots \quad -(1)$$

Here ϕ is the wavefunction, - e is the charge on the electron, m is the mass of the electron, $\hbar$ is the reduced Planck constant and $\underline{A}$ the vector potential. Dirac defined the magnetic field by:

$$\underline{B} = \underline{\nabla} \times \underline{A}. \quad -(2)$$

In this theory the Bohr magneton is defined by:

$$\gamma_B = \frac{e\hbar}{2m} \quad -(3)$$

and the spin angular momentum by:

$$\underline{S} = \frac{\hbar}{2}\underline{\sigma} \quad -(4)$$

with the property:

$$S\phi = m_s\hbar\phi. \quad -(5)$$

It follows that:

$$H_2\phi = 2\gamma_B\hbar m_s\phi \quad -(6)$$

and the electron g factor is the factor two appearing in this well known equation.

In relativistic quantum m theory the hamiltonian (1) is changed to:

$$H_2\phi = \frac{ie\hbar}{2m}\,\underline{\sigma}\cdot\underline{\nabla}\,\frac{1}{n(r)^{1/2}}\,\underline{\sigma}\cdot\underline{A}\,\phi + \dots \quad -(7)$$

where m (r) is the m function of the m space. In general m is a function of r. Using the Leibnitz Theorem:

$$H_2\phi = \frac{ie\hbar}{2m}\left(\frac{1}{m(r)^{1/2}}\underline{\sigma}\cdot\underline{\nabla}\,\underline{\sigma}\cdot\underline{A} + \underline{\sigma}\cdot\underline{\nabla}\left(\frac{1}{m(r)^{1/2}}\right)\underline{\sigma}\cdot\underline{A}\right)\phi + \ldots \quad -(8)$$

and using the Pauli algebra:

$$\underline{\sigma}\cdot\underline{B}\,\underline{\sigma}\cdot\underline{A} = \underline{B}\cdot\underline{A} + i\,\underline{\sigma}\cdot\underline{B}\times\underline{A} \quad -(9)$$

the real and physical part of the hamiltonian is:

$$H_2\phi = \frac{e\hbar}{2m\,m(r)^{1/2}}\underline{\sigma}\cdot\underline{\nabla}\times\underline{A}\phi - \frac{e\hbar}{2m}\underline{\sigma}\cdot\underline{\nabla}\left(\frac{1}{m(r)^{1/2}}\right)\times\underline{A}\phi$$

$$= -\left(\frac{2}{m(r)^{1/2}}\right)\left(\frac{e\hbar}{2m}\right)m_s B_Z\phi - 2\left(\frac{e}{2m}\right)\underline{S}\cdot\underline{\nabla}\left(\frac{1}{m(r)^{1/2}}\right)\times\underline{A}\phi \quad -(10)$$

Therefore the anomalous g factor of the electron is:

$$g = \frac{2}{m(r)^{1/2}}. \quad -(11)$$

Experimentally:

$$g = 2.002319314 \quad -(12)$$

so:

$$m(r) = 0.99942068. \quad -(13)$$

The relativistic quantum m theory gives the g factor of the electron to any accuracy. It is seen that m (r) is very close to unity, so the space is close to being the Minkowski spacetime in which Dirac's theory of the electron was developed.

The theory of the anomalous g factor can also be developed following the methods of UFT338, in which the vacuum particle of ECE2 theory was inferred. As shown in Note 429(2) the classical hamiltonian of m theory in frame (r_1 , ϕ) is:

$$H = m(r_1)\gamma mc^2 + U \quad -(14)$$

where the total relativistic energy is:

$$E = m(r_1)\gamma mc^2 \quad -(15)$$

and where γ is the generalized Lorentz factor of m theory. Here U is the potential energy. In immediately preceding papers it is shown that:

$$E^2 = m(r_1)(c^2 p_1^2 + m^2 c^4). \quad -(16)$$

It follows as in Note 429(2) that:

$$H = \frac{c^2 p^2}{E + m(r)^{1/2} mc^2} + m(r)^{1/2}(mc^2 + U_0) \quad -(17)$$

where

$$U_0 = -\frac{e^2}{4\pi\epsilon_0 r} \quad -(18)$$

is the potential energy due to the interaction of the electron and proton in an H atom.

Now develop the de Broglie / Einstein energy equation of UFT338 to m space

$$E = m(r)\gamma mc^2 = \hbar\omega \quad -(19)$$

It follows that:

$$H = \frac{p^2}{m\left(\frac{\hbar\omega}{mc^2} + m(r)^{1/2}\right)} + m(r)^{1/2}(mc^2 + U_0) \quad -(20)$$

For:

$$m(r) = 1 \quad -(21)$$

Eq. (20) reduces to the theory of UFT338:

$$H = \frac{p^2}{m\left(\frac{\hbar\omega}{mc^2} + 1\right)} + mc^2 + U_0 \quad -(22)$$

Q. E. D.

In the SU(2) basis Eq. (20) is

$$H = \frac{1}{m}\, \underline{\sigma} \cdot \underline{p}\, \frac{1}{\left(\frac{\hbar\omega}{mc^2} + m(r)^{1/2}\right)}\, \underline{\sigma} \cdot \underline{p} + m(r)^{1/2}\left(mc^2 + U_0\right) \quad -(23)$$

and in the presence of a magnetic field:

$$H = \frac{1}{m}\, \underline{\sigma} \cdot \left(\underline{p} - e\underline{A}\right) \frac{1}{\frac{\hbar\omega}{mc^2} + m(r)^{1/2}}\, \underline{\sigma} \cdot \left(\underline{p} - e\underline{A}\right) + m(r)^{1/2}\left(mc^2 + U_0\right) \quad -(24)$$

On quantization it is found that:

$$H\phi = -2\frac{e}{m}\left(\frac{1}{\frac{\hbar\omega}{mc^2} + m(r)^{1/2}}\right) \underline{S} \cdot \underline{B}\, \phi + \cdots \quad -(25)$$

as in Note 429(2). The g factor of the electron is defined as:

$$H\phi = -g\frac{e}{2m}\, \underline{S} \cdot \underline{B}\, \phi. \quad -(26)$$

So from Eqs. (25) and (26):

$$\frac{g}{2} = \frac{2}{\left(\frac{\hbar\omega}{mc^2} + m(r)^{1/2}\right)} \quad -(27)$$

and

$$g = \frac{4}{\frac{\hbar\omega}{mc^2} + m(r)^{1/2}} \quad -(28)$$

In the limit:

$$m(r) = 1 \quad -(29)$$

it follows that:

$$g = \frac{4}{\frac{\hbar\omega}{mc^2} + 1} \quad -(30)$$

and for the rest electron:

$$\hbar\omega_0 = mc^2 \quad -(31)$$

so the Dirac g factor follows:

$$g = 2 \quad -(32)$$

Q. E. D.

The Dirac g factor is a limit of m theory.

For the rest electron with finite m(r):

$$g = \frac{4}{1 + m(r)^{1/2}} \quad -(33)$$

and using the observed g factor (12) it is found that:

$$m(r) = 0.99884 \quad -(34)$$

which is close to the m (r) given in Eq. (13).

The Lamb shift in atomic H can be calculated from the spin orbit hamiltonian. In Dirac theory (Note 330(1)) this is given by:

$$H\phi = \frac{1}{4m^2c^2}\,\underline{\sigma}\cdot\underline{p}\,U\,\underline{\sigma}\cdot\underline{p}\,\phi \quad -(35)$$

and as shown in all detail in Note 429(3) the hamiltonian (35) gives:

$$H\phi = \frac{e^2}{8\pi c^2 \epsilon_0 m^2 r^3}\,\underline{S}\cdot\underline{L}\,\phi \quad -(36)$$

$$= \frac{e^2}{16\pi^2 c^2 \epsilon_0 m^2 r^3}\left(J(J+1) - L(L+1) - S(S+1)\right)\phi$$

where ϵ_0 is the vacuum permittivity. The total angular momentum quantum number J is defined by the Clebsch Gordan series: $L - S, \ldots, L + S.$

$$-(37)$$

The expectation value of H is evaluated with:

$$\left\langle \frac{1}{r^3} \right\rangle = \int \phi^* \frac{1}{r^3} \phi \, d\tau = \left(\frac{Z}{a_0}\right)^3 \frac{1}{n^3 L\left(L+\frac{1}{2}\right)(L+1)}$$

where a_0 is the Bohr radius, and in atomic H:

$$Z = 1 \quad -(38)$$

Here n is the principal quantum number. So the energy levels of atomic H are given by:

$$\langle H_{SO} \rangle = \frac{e^2 \hbar^2}{16\pi c^2 \epsilon_0 m^2 a_0^3}\left(\frac{J(J+1) - L(L+1) - S(S+1)}{n^3 L\left(L+\frac{1}{2}\right)(L+1)}\right) \quad -(39)$$

where:

$$J = L - S, \ldots, L + S \quad (40)$$

in which L is the orbital angular momentum quantum number and S the spin angular momentum quantum number.

In this Dirac theory it is well known that there is no Lamb shift, there is no difference between the energy of $^2P_{1/2}$ and $^2S_{1/2}$, contradicting experiment.

In m theory denote:

$$U_1 = \frac{U}{m(r)^{1/2}} \quad (41)$$

so the real part of the relevant hamiltonian is:

$$\mathrm{Re}\, H_{so}\, \phi = \frac{e\hbar}{4m^2c^2}\, \underline{\sigma} \cdot \underline{\nabla} U_1 \times \underline{p}\, \phi \quad (42)$$

Using the Leibnitz theorem:

$$\underline{\nabla} U_1 = \underline{\nabla}\left(\frac{U}{m(r)^{1/2}}\right) = \frac{1}{m(r)^{1/2}}\, \underline{\nabla} U + U\, \underline{\nabla}\left(\frac{1}{m(r)^{1/2}}\right) \quad (43)$$

and it follows that:

$$\mathrm{Re}\, H_{so}\, \phi = \frac{e^2\hbar}{16\pi\epsilon_0 m^2c^2 r^3 m(r)^{1/2}}\, \underline{\sigma} \cdot \underline{L}\, \phi + \frac{e\hbar}{4m^2c^2}\, U \underline{\sigma} \cdot \underline{\nabla}\left(\frac{1}{m(r)^{1/2}}\right) \times \underline{p}\, \phi \quad (44)$$

Therefore the energy levels of the H atom are:

$$\langle H_{so} \rangle = \frac{e^2 \left(J(J+1) - L(L+1) - S(S+1)\right)}{16\pi c^2 \epsilon_0 m^2} \left\langle \frac{1}{r^3 m(r)^{1/2}} \right\rangle + \ldots \quad (45)$$

where

$$\left\langle \frac{1}{r^3 m(r)^{1/2}} \right\rangle = \int \psi^* \frac{1}{r^3 m(r)^{1/2}} \psi \, d\tau \quad -(46)$$

The appearance of $m(r)^{1/2}$ in the expectation value, Eq. (46), may already be sufficient to give the Lamb shift and to lift the degeneracy of $^2P_{1/2}$ and $^2S_{1/2}$. If not, additional terms may be used in Eq. (44).

Applications of relativistic quantum m theory: The radiative corrections

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3 Computational and graphical analysis

The anomalous electronic g factor and the Lamb shift are treated in this section. There are two ways to determine an effective m function from the g factor. According to Eq. (11) of section 2, from the Dirac Hamiltonian follows:

$$g = \frac{2}{\mathrm{m}(r)^{\frac{1}{2}}}. \tag{47}$$

With the experimental value of

$$g = 2.002319304 \tag{48}$$

we obtain the constant m function

$$\mathrm{m}(r) = \left(\frac{2}{g}\right)^2 = 0.997684724. \tag{49}$$

Alternatively, the de Broglie/Einstein energy equation (19) leads to the expression of Eq. (33):

$$g = \frac{4}{1 + \mathrm{m}(r)^{\frac{1}{2}}} \tag{50}$$

or

$$\mathrm{m}(r) = \left(\frac{4}{g} - 1\right)^2 = 0.995372132. \tag{51}$$

Both values are very similar, differing by only 0.2%.

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Th Lamb shift of atomic Hydrogen is computed according to the method described in UFT 428,3. The total electronic energy is evaluated with the known wave functions of Hydrogen. m theory requires a numerical solution for the radial integrals because the factor $\mathrm{m}(r)^{1/2}$ appears in the integrals. In relativistic Dirac theory the levels p, d, etc. are split by spin-orbit interaction. However there remains a degeneracy of the levels $2S_{1/2}$ and $2P_{1/2}$ for example as can be seen from the energy diagram in Fig. 1. This degeneracy is abolished by "radiative corrections". It is not clear from the literature whether the $2P_{1/2}$ level comes to lie above or below the $2S_{1/2}$ level. Absolute energy level determination is required while spectroscopic data produce only differences between the levels involved in the transitions. Here we assume that $2S_{1/2}$ is lifted while the $2P_{1/2}$ level is not, as suggested by Fig. 1. Then the method presented in UFT 428,3 is applicable. We computed the energy level of $2S_{1/2}$ by using the model m function

$$\mathrm{m}(r) = 2 - \exp\left(\log(2)\exp(-\frac{r}{R})\right) \tag{52}$$

with an adjustable parameter R. The m function deviates significantly from unity only for values $r < R$. The resulting lifting of the $2S_{1/2}$ level in dependence of R is graphed in Fig. 2. R is given in Bohr radii (atomic units). It can be seen that for $R \approx 0.0009$ the experimental Lamb shift value of $4.372 \cdot 10^{-6}$eV is met. The radius of the proton is $r_p \approx 0.85 \cdot 10^{-11}$m which is $1.6 \cdot 10^{-5}$ in atomic units. Therefore we have

$$\frac{R}{r_p} \approx 56. \tag{53}$$

This means that the m functions begins to deviate from unity at about the fiftyfold core radius of the Hydrogen atom. This is the region where Minkowski space is distorted by the m function. At the proton radius m is nearly zero. This should have a massive impact on the nuclear structure.

According to Eq. (77) of UFT 428,3 the energy of the second shell of Hydrogen can be described by a constant function $\mathrm{m}(r) = x$:

$$E_{n=2} = \frac{1}{8\sqrt{x}} - \frac{\sqrt{x}}{4}. \tag{54}$$

The Lamb shift splitting ΔE_L can be expressed by

$$\begin{aligned} \Delta E_L &= E_{n=2}(x) - E_{n=2}(x=1) \\ &= \frac{1}{8\sqrt{x}} - \frac{\sqrt{x}}{4} - (\frac{1}{8} - \frac{1}{4}). \end{aligned} \tag{55}$$

This gives a quadratic equation for x with the physical solution

$$x = 0.99999914310. \tag{56}$$

Assuming a constant $\mathrm{m}(r)$ obviously requires a value deviating form 1 only in the seventh decimal place.

The Lamb shift cannot be computed directly from the spin-orbit Hamiltonian (45) for the following reason. For the level $2P_{1/2}$ the quantum numbers are

$L = 0$, $S = 1/2$, leading to $J = L + S = 1/2$. Inserting this into the quantum number factor of Eq. (45) gives

$$J(J+1) - L(L+1) - S(S+1) = 0. \tag{57}$$

Therefore there is no shift by $\langle H_{\text{so}} \rangle$, there is only a contribution for the $2P_{3/2}$ term. What we can do with the non-relativistic radial wave functions is to evaluate the $2P_{3/2}$ term to see how this level is impacted by m theory. The above sum of quantum numbers gives 1 for L=1, S=1/2 so that Eq. (45) in atomic units reads

$$\langle H_{\text{so}} \rangle = \frac{1}{4c^2} \left\langle \frac{1}{r^3 \mathrm{m}(r)^{\frac{1}{2}}} \right\rangle \tag{58}$$

with $c = 1/\alpha$ where α is the fine structure constant. Evaluating the above equation numerically gives the spin-orbit splitting of the P level as graphed in Fig. 3. As can be seen from Fig. 1, the splitting is much wider than the Lamb shift. The experimental value is $4.5 \cdot 10^{-5}$eV which is by a factor of 3 larger than the computed values. The reason may be that we used non-relativistic wave functions in the calculation.

The impact of the m function on the splitting is quite small, it is in the seventh decimal place, compared to the splitting itself. This result is consistent with the results of UFT 428, where we found that the S levels are impacted much more by the m function than P and D levels. The reason is that only S-like wave functions are at maximum at $r = 0$ while wave functions of higher angular momenta vanish at this position. Since m(r) deviates from unity only near to the centre, it is consistent that other than S-like wave functions are less influenced by $\mathrm{m}(r)$.

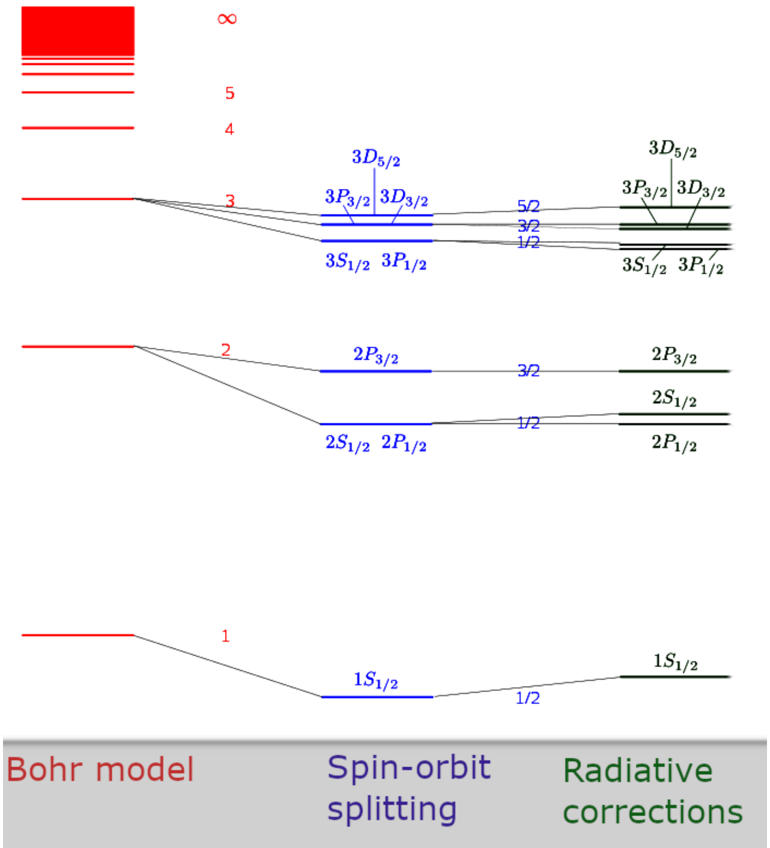

Figure 1: Energy levels of H with finestructure and radiative corrections[1].

[1]original source: https://upload.wikimedia.org/wikipedia/commons/9/94/Wasserstoff_Aufspaltung.svg, Ellarie [CC BY-SA 3.0 (https://creativecommons.org/licenses/by-sa/3.0)

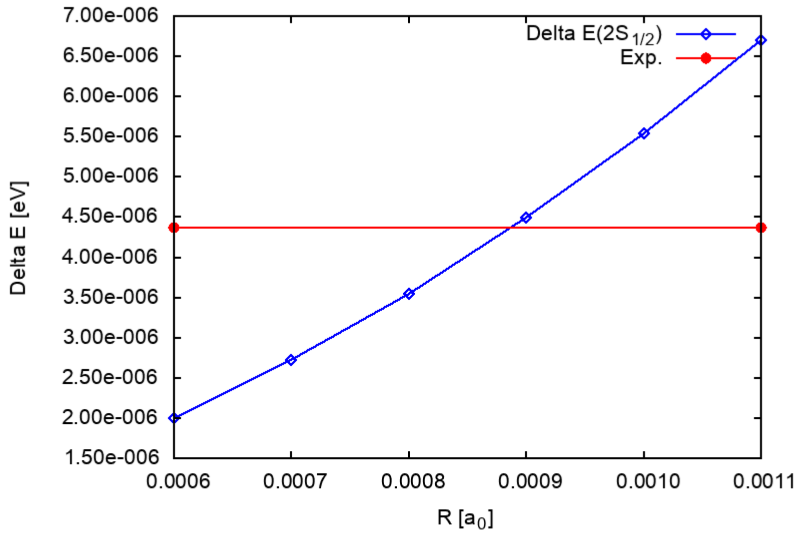

Figure 2: Lamb shift of hydrogenic $2S_{1/2}$ in dependence of m function parameter R.

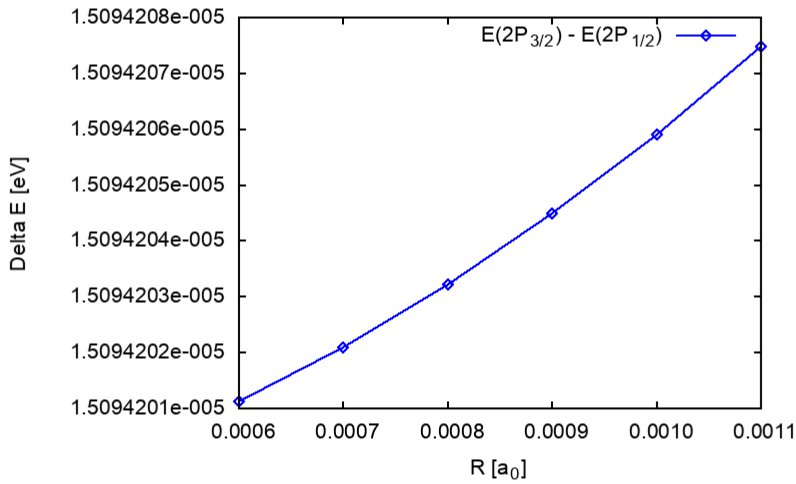

Figure 3: Spin-orbit splitting of hydrogenic $2P$ level in dependence of m function parameter R.

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