The phenomenology of electrostatically induced inertia

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ABSTRACT. Einstein's mass-energy equivalence law fixes the energy constant in bound systems; it thus selects the Coulomb gauge in the electric case. This exemplifies a much larger phenomenology including linear or angular momentum balance which I have named "electromagnetic gauge as an integration condition". Recently Mikhailov has evidenced the electrically induced extra mass for an electron accelerated inside a charged sphere. Tests using angular momentum are here proposed, one via the Zeeman effect.

RESUME. L'équivalence masse-énergie d'Einstein fixe la constante de l'énergie d'un système liés; dans le cas électrique le potentiel de Coulomb est ainsi sélectionné. Ceci fait partie d'une plus vaste phénoménologie incluant les moments linéaire et angulaire ; je l'ai appelée 'la jauge électromagnétique comme condition d'intégration'. Mikhailov a récemment mis en évidence l'extra masse électriquement induite dans un électron accéléré à l'intérieur d'une sphère chargée. Des tests impliquant le moment angulaire sont ici proposés, dont l'un via l'effet Zeeman.

1 Introduction

Electric mass defect of the hydrogen atom is one example among a wide class of analogous phenomena yet largely unexplored. Two recent experiments by Mikhailov[1] display an effect of this family: *electrostatic extra mass* $-c^{-2}eV$ *induced* in an electron accelerated inside the fieldless Coulomb potential V = Q/R enclosed in a charged hollow sphere. Electromagnetic gauge as integration condition is the naming I[2,3] have proposed for the overall phenomenology thus defined: As gauge invariance is a differential law pertaining to the 6-field B^{ij} together with the forces (linear or angular) it controls, and as contributions of the 4-potential A^i are contained in the measurable moments (linear or angular) generated by the forces, the gauge is selected as an integration condition. This confers physicality to the 4-potential; in fact it is the source adhering gauge that is usually selected. The present investigation is restricted to various aspects of the *electrostatic extra mass* $-c^{-2}eV$ *induced* in an electron accelerated inside a Coulomb *potential*.

2 Remarks on Sommerfeld's hydrogen atom

Sommerfeld's electron of rest mass μ and charge -e orbits in the proton's central potential $V = r^{-1}e$; $\mathbf{v} = \mathbf{dr}/dt$ denoting its velocity in this frame its relativistic mass and momentum can be written as :

$$m = \mu - c^{-2}eV \quad , \quad \mathbf{p} = m\mathbf{v} \; ; \tag{1}$$

m-μ being thus likened to the atom's mass defect the potential V comes out as *measured in the Coulomb gauge*.

In view of the following let be mentioned *existence of an induced angular recoil* evidenced in the periproton advance. So, $-c^{-2}eV$ really is an *electrostatic contribution* to the electron's *effective mass* m.

3 Remarks on the "magnetodynamic effect"

Thus named by Jouguet[4] and operationally discussed in 1967 by Penfield-Haus[5], Shockley-James[6] and me[7], the effect is formalized as an *electrostatically induced momentum*

$$\mathbf{p} = c^{-2}\, I \int V\, \mathbf{dl} \equiv c^{-2}\, I \iint \mathbf{E}\times\mathbf{ds} \quad \text{(esu)} \tag{2}$$

conferred to an Amperian circuit of intensity I immersed in an electrostatic potential $V(\mathbf{r})$; this follows from the *effective mass and momentum* of the conduction electrons expressed as (1).

So *the circuit recoils if its intensity* I *is varied* -this being *an extremely low velocity* relativistic effect.

In the simple case where the potential $V(\mathbf{r})$ is generated by a point charge Q, circuit and charge both contain (indirectly) opposite linear momenta $\pm\,\mathbf{p}$ because one has

$$V(r) = Qr^{-1}, \qquad \mathbf{A}(\mathbf{r}) = i \int r^{-1}\, \mathbf{dl}\, . \tag{3}$$

Let be mentioned that *the circuit contains also an induced angular momentum* -as does Sommerfeld's orbiting electron.

Thanks to Ampère's expression of a circuit's magnetic moment $\mathcal{M}$, the induced linear **P** and angular **C** moments of a dipole immersed in a potential V come out as

$$\mathbf{P} = c^{-2}\,\mathbf{E} \times \mathcal{M}\ , \qquad \mathbf{C} = c^{-2}\, I \int \mathbf{r} \times \mathbf{dl} = 2\, c^{-2}\, V\, \mathcal{M}\,. \tag{4}$$

Consider the special case of a superconducting circular circuit with a point charge at its center ; if a magnetic field **B** coaxial with the circuit is present *the Meissner effect's formula is modified* so as to read

$$(\mu - c^{-2}\, eV)\, \mathbf{v} - e\, \mathbf{A} = \mathbf{0}\,, \tag{5}$$

this being a testable effect.

The "magnetodynamic effect" is closely related to various c^{-2} electromagnetic effects discussed by many authors; a 1967 and a 1969 papers of mine[8,9] discuss the matter.

4 The electron's induced mass inside a hollow charged sphere

If an electron at rest immersed in the Coulomb potential $V = R^{-1}Q$ enclosed in a hollow charged sphere is accelerated in a very short time up to a velocity **v** it imparts to the sphere a momentum $-\mathbf{p} = c^{-2}eV\,\mathbf{v}$; according to momentum balance it thus picks up the momentum $+\mathbf{p}$.

This effect has been recently tested in two independent experiments by Mikhailov[1] with electrons accelerated inside a sphere at a controllable potential up to ± 20 KV.

In fact there was a reduction factor; this is quite understandable: the electrons were conduction electrons in a circuit, so *the problem at stake was angular momentum balance*.

5 Variable magnet or current loop inside a charged hollow sphere

If a charged hollow sphere enclosing a uniform Coulomb potential V = Q/R rotates at an angular velocity Ω it also contains[10] a uniform magnetic field

$$\mathbf{B} = {}^{2}/_{3}\, c^{-2}\, \Omega\,. \tag{6}$$

This, compared with Larmor's equivalence recipe for diamagnetism

$$2\ m\ B = -e\ \Omega \tag{7}$$

shows that if what rotates is the plasma inside a conducting sphere each electron contains a *self induced extra mass* - $^1/_3\ c^{-2}$ eV.

Consider then a small circuit or dipole inside a hollow non rotating charged sphere. If its magnetic moment is changed from zero to $\mathcal{M}$ the sphere picks up[2,3] an angular momentum

$$\mathbf{C} = {}^2/_3\ c^{-2}\ V\ \mathbf{M}\ ; \tag{8}$$

the calculation is straightforward if the dipole is at the sphere's center; if it is not the result remains because there is no orbital momentum.

Comparing this with the dia-magnetic equivalence formula

$$\mathcal{M} = -\ {}^e/_{2m}\ \mathbf{C} \tag{9}$$

shows that 1/3 of the angular momentum gets "potential".

But what really matters is *existence of an angular recoil of the circuit or magnet,* testable via[2,3] the Einstein-de-Haas or the Barnett effect -or more interestingly via superconduction or the Zeeman effect.

6 Modified Zeeman effect inside a hollow charged sphere

Let two well known facts be recalled.

The "classical Zeeman effect" is a form of diamagnetism. If a uniform magnetic field **B** is applied normally to the hydrogen atom's orbiting electron the orbit is unchanged; what is changed is the frequency $\nu = \omega/2\pi$, in accord with Larmor's formula (7).

As the hydrogen atom's eigenfunctions are $\psi(x,t) = \varphi(\mathbf{r})\ e^{ih\nu}$, changing the central potential's gauge affects not the radial distribution $\varphi(\mathbf{r})$ but displaces by a constant all the energy levels; this leaves the optical spectrum unchanged. But if, as said before, the added constant has physicality the change in ν must be testable via the Zeeman effect.

Referring to the preceding Section we write as expression of the *modified Zeeman effect inside a charged hollow sphere* at *potential* V_o

$$2\ (m - c^{-2}\ e\ V_o)\ \Omega \approx -e\ B\ , \tag{10}$$

m denoting the orbiting electron's effective mass in terms of the central potential V(r). *We assume that* V_o *is positive and very much larger than* V(**r**).

Via the familiar substitution $\Omega \rightarrow 2\,\pi\,\nu$ we express the *classical Zeeman effect,* or *strong Paschen-Back effect,* in the form

$$4\pi\,(\mu - c^{-2}\,e\,V)\,\Delta\nu \approx \pm\,e\,B\,. \tag{11}$$

This formula we propose to test modulo the previously mentioned corrective factor :

$$4\pi\,(m - {}^{2}/_{3}\,c^{-2}\,e\,V)\,\Delta\nu = \pm\,e\,B\,. \tag{12}$$

Analogous gravitational effects

These are well known and more generally accepted than the electric ones.

Machian induced inertia has been studied by Sciama[11] and others[12,13,14]. The idea is that a mass point of *active gravitational mass* or "mass charge" m immersed in the cosmic potential U has a *potential gravitational energy* Um whence an *induced inertial mass* c^{-2}Um ; whence

$$U = c^2. \tag{13}$$

In the model where the particle is thought of as moving inside a "sphere of fixed stars" of mass M and radius R one has[11], G denoting Newton's constant,

$$U = c^{-2}\,R^{-1}\,G\,M \tag{14}$$

Schrödingerian induced inertia. Consider a planet orbiting a star, say Mercury inside the Sun's potential energy $U = r^{-1}\,GM_s$. Its *effective mass* is the sum of its *proper mass* m plus an *induced extra mass* c^{-2} U; the computation of the orbit parallels that of Sommerfeld's electron. Schrödinger[15], Lucas[16], Assis[17] have discussed the matter.

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