Comments on Mikhailov's New Measurement

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1 Mikhailov new measurement

Mikhailov reports a new measurement [1] confirming his previous one [2] displaying *the electrostatic induction of an extra mass* $-c^{-2}eV$ *in an electron accelerated inside a hollow sphere charged at Coulomb potential* $V = Q/R$. Helmholtz[3] the first derived in 1872 such a statement from Weber's [4] electrodynamics, in which the constant c is defined as the ratio of the emu and esu units systems. Refusing this conclusion, he used it as an argument against Weber's electrodynamics.

Like Assis [5], but for slightly different reasons, *I believe that this phenomenon exists* [6], and will explain why. Anyhow, there is a consensus concerning the analogous effect in the field of gravity, namely "Mach's conjecture".

Mach [7] claimed that the inertial mass m_i of a mass point is *induced* in it by the cosmological potential U_o, namely $U_o = GM/R$ in the "sphere of fixed stars" model; Sciama [8] turned this conjecture into an algebraic formula. Following recent papers by Woodward-Mahood [9] and myself [10], let the matter be recalled in terms of the two premises of the Galileo-Newton equivalence $m_i = m_g$ of inertial and gravitational masses, and of the Weber-Einstein equivalence $W = c^2m$ of energy and mass.

Inside the uniform cosmological potential U_o a mass point of gravitational mass m_g has a potential energy U_om_g whence, via mass-energy equivalence, an induced mass $c^{-2}U_om_g$. This, according to Mach, is its inertial mass m_i. According then to inertia-gravity equivalence we get [9,10] $U_o = c^2$; and of course $GM/c^2R \approx 1$ is a formula valid in most cosmological models.

But this ends not the story. If a gravitational potential confers an inertial mass to a mass point, then a test particle (say the planet Mercury) orbiting a strong gravity source (say the Sun) of potential U_s must, like Sommerfeld's electron orbiting the proton, pick up an extra mass $c^{-2} U_s m_g$; Tisserand [11], using a transposition of Weber's electrodynamics, proposed this in 1872. So, on the whole, Mercury's effective inertial mass must read

$$m_i = (1 + c^{-2}U_s)\, m_g \; ; \tag{1}$$

for some un-elucidated reason this formula yields only $^1/_3$ of the observed perihelion advance [9].

What if the test particle's mass is not negligibly small, so that the source recoils ? De Broglie [12] and Lucas [13] show, via barycenter conservation, that *the overall mutual potential mass is distributed inversely to the bare masses*. Essentially, their argument consists of this.

The formulas $\Sigma\, m\mathbf{r} = \mathbf{0}$ and $\Sigma\, m\mathbf{v} = \mathbf{0}$ valid in the barycenter's rest frame say that the particles' displacements and velocities are inversely proportional to their masses. The kinetic energies $\frac{1}{2}\, m\mathbf{v}.\mathbf{v}$ are naturally thought of as localized in the particles, and so are also, according to mass-energy equivalence, the associated contributions of the potential energy.

In the case of just two interacting particles, the one very heavy, the other very light, the light particle picks up almost all the potential mass. This is Mach's statement, yielding a derivation of mass-energy equivalence from purely mechanical arguments. It likens the resistance to accelerating a body to "action-reaction with the distant stars" -a *momentous conclusion* !

2 Let us go back to electrodynamics.

In Sommerfeld's hydrogen atom model the electron's kinetic energy equals minus its potential energy expressed in the Coulomb gauge. So, via Einstein's mass-energy equivalence, *the system's potential mass resides entirely in the orbiting electron,* in accord with de Broglie's and Lucas' statement. Similar to the perihelion advance, the peri-proton advance thus evidences the *electrostatically induced extra mass*. It is then likely that, similar to Mach's induced inertia, the Helmholtz one exists for an electron accelerated inside a hollow charged sphere enclosing a Coulomb potential $V = Q/R$. And indeed an electron, accelerated by any means (say, the force of gravity) from zero to a small velocity $\mathbf{v}$ confers to the sphere a momentum $-eR^{-1}Q\mathbf{v}$; the *induced extra mass* $c^{-2}eV$ expresses the reaction it must feel.

As this has to do with barycenter conservation let us look at the matter from the other side. Inside a charged hollow sphere accelerated at $\mathbf{g}$ the 4-potential "rotates hyperbolically à la Minkowski"; so, according to the formula $\mathbf{E} = c^{-1}\partial_t\mathbf{A}$, *the sphere contains a uniform electric field* $\mathbf{E} = c^{-2}V\mathbf{g}$, via inertia-gravity equivalence the same holds if the sphere is fixed in a gravity field **g**, say "if it rests on the laboratory floor". So *inside this sphere a test electron feels the force* -e**E** = $-c^{-2}eV$**g**; *its induced extra mass is thus "weighed" as equal to the overall potential mass*.

As such electric style thinking is unfitting in magnetic cases let us tackle directly a typical magnetic example.

A test electron flying at velocity **v** in presence of a heavy toroidal magnet moves inside a curlless vector potential **A**, the gradient of a multivalued function. Denoting by **dM** = Φ **dl** a *linear magnet's* elementary moment, we express the system's mutual energy as

$$W = -e\Phi \int r^{-3}\, [\mathbf{v}\times\mathbf{r}].\mathbf{dl} = -e\Phi \int r^{-3}\, [\mathbf{r}\times\mathbf{dl}].\mathbf{v} \qquad (2)$$

evidencing the electron's magnetic field **H** and the magnet's vector potential **A** via

$$W = \Phi \int \mathbf{H}.\mathbf{dl} = -e\mathbf{A}.\mathbf{v}\ ; \qquad (3)$$

W is thus thought of as residing either in the magnet or the electron. As for the opposite moments, they are expressed via

$$\mathbf{P} = -e\Phi \int r^{-3}\, [\mathbf{v}\times\mathbf{r}].\mathbf{dl} = e\Phi \int \Omega^{-3}\, [\mathbf{dl}\times\mathbf{r}].\mathbf{v} \qquad (4)$$

evidencing the electron's electric field **E** , and again **A**, via

$$\mathbf{P} = -c^{-2}e\Phi \int \mathbf{E}\times\mathbf{dl} = -c^{-2}e(\mathbf{A}.\mathbf{v})\mathbf{v}\ . \qquad (5)$$

The magnet's moment -**P** is Poynting style; the electron's magnetically induced one +**P** transposes Helmholtz' electrically induced moment. If the magnet's recoil is negligible the totality of the mutual inertia is transferred to the test electron. This extends the validity of the de Broglie-Lucas investigation.

Finally, for issuing a covariant electromagnetic statement, two remarks are in order: 1° Action-reaction is a key ingredient, 2° A curl-less 4-potential induces an extra 4-momentum. The guess is that the effective rest mass of a test electron containing an induced contribution should be expressed as

$$m = \mu - c^{-2}e\, A_k U^k \quad \textit{with} \quad U_K U^k = -c^2 \qquad (6)$$

Is this compatible with acceleration of the electron by an electromagnetic field B^{ij} ?

It is. the Lorentz equation of motion of an electron, or equivalently its spacetime trajectory, is derivable via the extreme action formula

$$0 = \delta \int (\mu U_i - eA_i)dx^i = \delta \int mU_i dx^i \qquad (7)$$

where the second expression has been obtained by multiplying $-eA_i$ by $U_k U^k = -c^2$ and exchanging indexes between the *then collinear* 4-vectors U^i and dx^i.

So, whenever the 4-potential contains a curlless contribution, this acts as an extra 4-force modifying the rest mass by inducing a contribution $-c^{-2}e A_k U^k$. In this consists a yet overlooked action-reaction effect between a test electron and the sources of a curlless 4-potential.

For example there must exist, underlying the phase velocity Aharonov-Bohm effect, *an overlooked group velocity effect.* The extreme action recipe (7) displays these if integrated respectively along $\mu U^i - eA^i$ or along μU^i lines.

Indeed, this group velocity effect is already displayed as Meissner effect, where a superconductor guides the electrons. The Meissner effect selects [14] the gauge via the formula $m\mathbf{v} = e\mathbf{A}$; the electron's total kinetic energy equals [15] minus the interaction energy.

3 Concluding.

Mikhailov's experiment, confirming a Helmholtz 1872 calculation and vindicating statements by Assis and myself, is of significance. Its full import shows up even more clearly in the magnetic form transposing the original electric form.

Electrodynamically, or synthetically speaking, the phenomenon consists of an extra rest mass induced in (say) a test electron by action-reaction with the sources of a fieldless 4-potential. This potential shows up as a measurable magnitude, its gauge being the source adhering one.

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