245(2): Electromagnetic Experiments to Determine the Photon Mass

From note 157(9) it follows that there exists a vacuum current:

$$J_\mu^a = -\frac{1}{\mu_0}\left(\frac{mc}{\hbar}\right)^2 A_\mu^a \quad -(1)$$

which depends on the existence of photon mass m, and the vacuum four potential A_μ^a. For each sense of polarization:

$$J_\mu = -\frac{1}{\mu_0}\left(\frac{mc}{\hbar}\right)^2 A_\mu \quad -(2)$$

This gives rise to the vacuum charge density:

$$\rho = -\frac{A^{(0)}}{\mu_0 c}\left(\frac{mc}{\hbar}\right)^2 \quad -(3)$$

For positive values of:

$$\kappa^2 = \left(\frac{mc}{\hbar}\right)^2 \quad -(4)$$

then:

$$\boxed{\left(\frac{mc}{\hbar}\right)^2 = \mu_0 c \left|\frac{\rho}{A^{(0)}}\right|^2 = \mu_0 c^2 \left|\frac{\rho}{\phi}\right|^2} \quad -(5)$$

So the Coulomb law is not changed by photon mass.

It is:

$$\underline{\nabla} \cdot \underline{E} = \frac{1}{\epsilon_0}\left(\rho + \rho(\text{vacuum})\right)$$

$$= \frac{1}{\epsilon_0}\rho(\text{total}) \quad -(6)$$

and the inverse square law between charges is not changed by photon mass.

S. I. Units

$$\mu_0 = J s^2 C^{-2} m^{-1}, \quad \epsilon_0 = J^{-1} C^2 m^{-1}$$

$$E = J C^{-1} m^{-1}, \quad B = J s C^{-1} m^{-2}, \quad A = J s C^{-1} m^{-1},$$

$$\rho = C m^{-3}.$$

Similarly:

$$\underline{J} = -\frac{1}{\mu_0}\left(\frac{mc}{\hbar}\right)^2 \underline{A} \quad -(7)$$

and the vacuum current is:

$$\underline{J}(\text{vacuum}) = -\frac{1}{\mu_0}\left(\frac{mc}{\hbar}\right)^2 \underline{A}(\text{vacuum}) \quad -(8)$$

So the Ampère Maxwell law is:

$$\underline{\nabla} \times \underline{H} - \frac{\partial \underline{D}}{\partial t} = \underline{J} + \underline{J}(\text{vacuum})$$

$$=: \underline{J}(\text{total}) \quad -(9)$$

Therefore experiments designed to detect the

3) photon mass using electromagnetic methods will not be successful, because the laws are not changed by photon mass.

In the dispersion of light by photon mass, we have:

$$p^{\mu} p_{\mu} = m^2 c^2 \quad -(10)$$

where m is the photon mass. So:

$$\frac{E^2}{c^2} - p^2 = m^2 c^2 \quad -(11)$$

Now use:

$$E = \hbar \omega, \quad \underline{p} = \hbar \underline{\kappa} \quad -(12)$$

to obtain:

$$\omega^2 - c^2 \kappa^2 = \left(\frac{mc}{\hbar}\right)^2 c^2 \quad -(13)$$

where

$$\left(\frac{mc}{\hbar}\right)^2 = \mu_0 c^2 \left|\frac{\rho}{\phi}\right|^2 \quad -(14)$$

The photon mass is determined by the ratio ρ / ϕ of the charge density to scalar potential of the vacuum. The phase velocity is:

$$v_1 = \frac{\omega}{\kappa} = c\left(1 - \frac{m^2 c^2}{\omega^2}\right)^{-1/2} \quad -(15)$$

and the group velocity is:

$$v_2 = \frac{\partial \omega}{\partial \kappa} = c\left(1 - \frac{m^2 c^2}{\omega^2}\right)^{1/2} \quad -(16)$$

4) If (ρ/ϕ) vacuum is very small, the phase and group velocity of light in deep space are about the same. The tests of photon mass are as follows.

1) A. S. Goldhaber and M. M. Nieto, Rev. Mod. Phys., 43, 277 (1971), Speed of light, $< 5.6 \times 10^{-42}$ gm.

2) E. R. Williams, J. E. Faller and H. A. Hill, Phys. Rev. Lett., 26, 721 (1971), Coulomb Law, $< 1.6 \times 10^{-47}$ gm.

3) M. A. Chernikov, C. J. Gerber, H. R. Ott and H. J. Gerber, 68, 3383 (1992), Ampère Law, $< 8.4 \times 10^{-46}$ gm.

4) L. de Broglie, La Mechanique Ondulatoire du Photon vol 1, pp. 39 – 40 (1940, Hermann, Paris) $< 0.8 \times 10^{-39}$ gm, dispersion of starlight.

5) G. Feinberg, Science, 166, 879 (1969), dispersion of starlight $< 10^{-44}$ gm.

6) B. E. Schaefer, Phys. Rev. Lett., 82, 4964 (1999), dispersion of γ ray bursts, $< 4.2 \times 10^{-44}$ gm.

7) L. Davies, A. S. Goldhaber and M. M. Nieto, Phys. Rev. Lett., 35, 1402 (1975), Analysis of Jupiter's magnetic field, $< 10^{-49}$ gm.

8) E. Fischbach, H. Kloor, R. A. Langel, A. T. Y. Lui and M. Peredo, Phys. Rev. Lett., 73, 514 (1994), Analysis of Earth's Magnetic field, $< 1.0 \times 10^{-48}$ gm.

9) D. D. Ryutov, Plasma Phys., 39A, 73 (1997), solar wind magnetic field and plasma, $< 10^{-49}$ gm.

10) M. A. Gintsburg, Astron. Zh., 40, 703 (1963), analysis of geomagnetic field, 3×10^{-48} g.

11) V. L. Patel, Phys. Lett., 14, 105 (1965) Alfen Waves in Earth's magnetosphere $< 4 \times 10^{-47}$ gm.

12) J. V. Hollweg, Phys. Rev. Lett., 32, 961 (1974), interplanetary media $< 1.3 \times 10^{-48}$ gm.

13) A. Barnes and J. D. Scargle, Phys. Rev. Lett., 35, 1117 (1975), $< 3 \times 10^{-50}$ gm. Hydromagnetic waves.

14) P. de Bernardis, S. Masi, F. Melchiorri and A. Moleti, Astrophys. J., 284, L21 (1984), Cosmic Background 3×10^{-51} gm.

15) E. Williams and D. Park, Phys. Rev. Lett., 26, 1651 (1971) Galactic Magnetic Field, $< 3 \times 10^{-56}$ gm.

16) G. V. Chibisov, Usp. Fiz. Nauk., 119, 551 (1976), Stability of Galaxies, $< 10^{-60}$ gm.

Almost all of these experiments depended on their interpretation of the Yukawa potential, but the method of this note shows that they can all be reinterpreted with eq. (14). The Yukawa potential is disregarded as unphysical.

In contrast the heavy photon of de Broglie is estimated from kinematics and does not use Einstein equations, and classical electrodynamics.

The only experiments that need further investigation are those based on the torsion balance and stability of galaxies.