Maxwell's Aether, The Planck Aether Hypothesis and Sommerfeld's Finestructure Constant

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1. Maxwell's Aether

I have come across a little known article Maxwell had written about the physical constitution of the aether for the 1878 edition of the Encyclopedia Britannica. Written shortly before his untimely death the article provides us with a rare insight into Maxwell's thinking, substantially differing from his much better known and widely publicized "cogwheel model" of the aether. I let Maxwell speak in his own words:

> "The aether, if it is the medium of electromagnetic phenomena, is probably molecular in the sense of Sir W. Thomson's hypothesis of vortex – molecules in a perfect fluid. Sir W. Thomson has shown that the magnetic influence on light discovered by Faraday depends on the direction of motion of moving particles, and that it indicates a rotational motion in the medium when magnetized
> Now it is manifest that this rotation cannot be that of the medium as a whole about an axis, for the magnetic field may be of any breadth, and there is no evidence of any motion the velocity of which increases with the distance from a single fixed line in the field. If there is any motion of rotation, it must be a rotation of very small portions of the medium each about its own axis, so that the medium must be broken up into a number of molecular vortices.
>
> We have as yet no data from which to determine the size or the number of these molecular vortices. We know, however, that the magnetic force in the region in the neighborhood of a magnet is maintained as long as the steel retains its magnetization, and as we have no reason to believe that a steel magnet would lose all its magnetization by the mere lapse of time, we conclude that the molecular vortices do not require a continual expenditure of work in order to maintain their motion, and that therefore this motion does not necessarily involve dissipation of energy.
>
> No theory of the constitution of the aether has yet been invented which will account for such a system of molecular vortices being maintained for an indefinite time without their energy being gradually dissipated into that irregular agitation of the medium which, in ordinary media, is called heat.
>
> Whatever difficulties we may have in forming a consistent idea of the constitution of the aether, there can be no doubt that the interplanetary and interstellar spaces are not empty, but are occupied by a material substance or body, which is certainly the largest, and probably the most uniform body of which we have any knowledge.

> Whether this vast homogeneous expanse of isotropic matter is fitted not only to be a medium of physical interaction between distant bodies, and to fulfill other physical functions of which, perhaps, we have as yet no conception, but also to constitute the material organism of beings exercising functions of life and mind as high or higher than ours are at present, is a question far transcending the limits of physical speculation."

In listening to these words of one of the greatest scientists of all times one cannot help but to be struck with awe.

The two crucial elements of Maxwell's aether are 1) that the aether is a frictionless fluid and 2) that it is made up of a very large number of tiny vortices.

2. The Physical Constitution of the Universe

With greatly improved observational techniques a number of important facts about the physical content and large scale structure of our universe have emerged. They are:

1. About 70% of the material content of the universe is a negative pressure energy called quintessence,
2. About 26% nonbaryonic cold dark matter,
3. About 4% ordinary matter and radiation,
4. The universe is Euclidean flat,
5. It's cosmological constant very small,
6. It's expansion slightly accelerated.

These are the basic facts which have to be explained, and no model which at least can make them plausible can be considered credible.

String theory has candidates for the nonbaryonic cold dark matter but is unable to explain the 70% negative pressure energy. Candidates for the 26% cold dark matter are axions and neutralinos, but none of them have ever been observed in a laboratory or else. String theory can also not explain the observed small cosmological constant. It rather predicts a value at least 55 orders of magnitude too large. And string theory cannot give an explanation for the accelerated cosmological expansion.
The analogies between Yang Mills theories and vortex dynamics [3], and the analogies between general relativity and condensed matter physics [4-10] suggest that string theory should perhaps be replaced by some kind of vortex dynamics at the Planck scale. The successful replacement of the bosonic string theory in 26 dimensions (dual resonance model) with QCD in 4 dimensions to describe nuclear forces, and the mentioned analogies between Yang-Mills theories and vortex dynamics make one wonder if supersymmetric string theories in 10 dimensions should perhaps be replaced by some vortex dynamics at the Planck length.

A fluid dynamic model, of course, implies that the vacuum is a medium. As Planck had shown back in 1911 [11], quantum theory demands that the vacuum is not empty but rather filled with

the quantum mechanical zero point energy, by Nernst called an aether, which I call the Planck aether.

The present situation can be summarized as follows:

1. **The way it was:** Bosonic string theory for nuclear forces in 26 dimensions at ~ 10^{-13} cm.

2. **The way it is now:** Quantum chromodynamics for nuclear forces in 4 space-time dimensions at 10^{-13} cm.

3. **The way it is now conjectured:** Supersymmetric string theory in 10 dimensions at ~10^{-33} cm.

4. **The way it may be:** Nonrelativistic vortex dynamics in 3 space and 1 time dimensions at ~10^{-33} cm, with Lorentz invariance a low energy dynamic symmetry.

3. The Planck Aether Hypothesis

An analog of Maxwell's aether as a frictionless fluid with small vortices, is a quantum fluid made up of Bose particles. This analogy leads to the Planck aether hypothesis which makes the assumption that the vacuum of space is a kind of plasma, made up of positive and negative masses (not positive and negative electric charges),with small vortices embedded in it. More specifically, it makes the following assumptions [1,2]:

1. The ultimate building blocks of matter are Planck mass particles which obey the laws of classical Newtonian mechanics, but that there are also negative Planck mass particles.

2. A positive Planck mass particle exerts a short range repulsive and a negative Planck mass particle a likewise attractive force, with the magnitude of the force equal to the Planck force $F_{p,}$ and the range of the force equal the Planck length r_p.

3. Space is filled with an equal number of positive and negative Planck mass particles, whereby each Planck length volume is in the average occupied by one Planck mass particle.

This hypothesis can explain:

1. Nonrelativistic quantum mechanics as an approximation with departures from this approximation suppressed by the Planck length.

2. Lorentz invariance as a dynamic symmetry for energies small compared to the Planck energy.

3. A spectrum of quasiparticles resembling the particles of the standard model.

It further leads to a solution for the problem of quantum gravity, and it makes possible a finitistic (Non-Archimedean) formulation.

According to Planck all of physics should be reduced to equations containing as free parameters only *h*, *G*, and *c* [12], but in an approach fully consistent with Planck's program differentials in these equations would have to be replaced by finite difference operators, with the finite difference equal the Planck length. Without violating microcausality this appears possible only in an exactly nonrelativistic theory, where as in the pre-Einstein theory of relativity by Lorentz and Poincaré [13] Lorentz invariance is recovered as an asymptotic low energy limit. A reduction to *h*, *G*, and *c* allows for two signs for the Planck mass, and leaves open the direction of the Planck force. The freedom in the direction of the Planck force permits to construct in a unique may a stable vacuum in the presence of negative masses. The two possible signs suggest that the fundamental symmetry of nature is SU2, with nature working like a computer with a binary number system. With SU2 isomorph to SO3, the rotation group in three dimensions, then explains why space is three-dimensional.

4. Planck Mass Rotons As Cold Dark Matter and Quintessence.

With the Planck aether having an equal number of positive and negative Planck mass particles, the cosmological constant is zero and the universe Euclidean flat. In its groundstate the Planck aether is a two component positive-negative mass superfluid with a phonon-roton energy spectrum for each component. Assuming that the phonon-roton spectrum measured in superfluid helium is universal, this would mean that in the Planck aether this spectrum has the same shape, with the Planck energy replacing the Debye energy in superfluid helium (see Fig. 1).

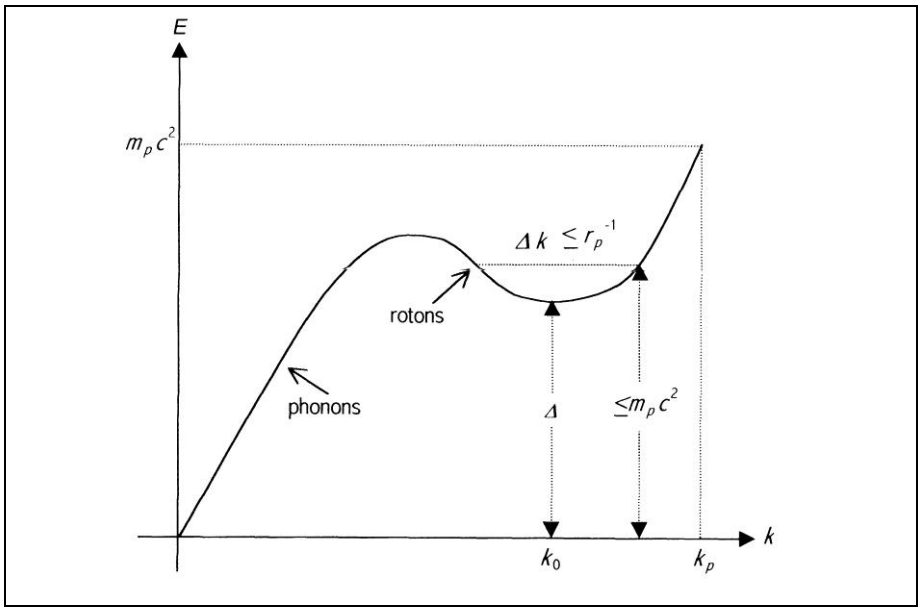

Figure 1. The phonon-roton energy spectrum of the hypothetical Planck aether.

Rotons can be viewed as small vortex rings with the ring radius of the same order of magnitude as the vortex core radius. A fluid with cavitons is in a state of negative pressure, and the same is true for a fluid with vortex rings [14], because the centrifugal force creates a vacuum in the core of the vortex, making a vortex ring to behave like a caviton.

In the Planck aether the negative pressure is provided by the zero point energy, which has the same frequency dependence as for the phonon-roton spectrum, with the magnitude of the negative pressure equal to the value of the zero point energy.

The kinetic roton energy is bound by the height of the potential in frequency space. From Fig. 1 it follows that the ratio of the energy gap (which is equal the roton rest mass energy), to the maximum kinetic roton energy is about 70 to 25, close to the observed ratio of the negative pressure energy to the cold dark matter energy. The roton hypothesis can therefore explain both the cold dark matter and the negative pressure energy, the latter mimicking a cosmological constant [15].

5. Vortex Model

In a superfluid made up of Planck mass particles, with each Planck length volume occupied by a Planck mass, there can be quantized vortices. With the quantization condition $m_{\mathrm{p}} r v_{\phi} = \hbar$, the vortices are potential vortices with the azimuthal velocity

$$\begin{aligned} v_{\phi} &= c r_{\mathrm{p}} / r, \quad r > r_{\mathrm{p}} \\ &= 0, \qquad r < r_{\mathrm{p}} \end{aligned}, \tag{1}$$

with the vortex core radius equal the Planck length.

A vortex ring of ring radius R and core radius r_{p} has a resonance frequency given by [16]

$$\omega_{\mathrm{v}} \cong c r_{\mathrm{p}} / R^2 \tag{2}$$

and if quantized the energy

$$\hbar \omega_{\mathrm{v}} \cong m_{\mathrm{p}} c^2 \left(r_{\mathrm{p}} / R \right)^2 . \tag{3}$$

If the vacuum is occupied with an equal number of positive and negative Planck mass particles, the quantized vortex solution is a double vortex where both mass components share the same core. Because the positive kinetic energy is there balanced by an equal negative kinetic energy, such a double vortex can be created out of the vacuum without expenditure of energy.

In nonquantized fluid dynamics the vortex core has a radius about equal a mean free path λ, where the velocity reaches the velocity of sound, the latter about equal the thermal velocity v_{t}. The Reynolds number in the vortex core therefore is

$$\mathrm{Re} = vr/\nu = v_t\lambda/\nu\,, \tag{4}$$

where ν is the kinematic viscosity. Since the kinematic viscosity of a gas is of the order $\nu \sim v_t\lambda$, one has Re~1.

Interpreting Schrödinger's equation as an equation with the imaginary viscosity $\nu_Q = i\hbar/2m_p \sim ir_pc$, and likewise defining for a frictionless quantum fluid a quantum Reynolds number

$$\mathrm{Re}^Q = ivr/\nu_Q, \tag{5}$$

one finds that in the core of a quantized vortex $\mathrm{Re}^Q \sim 1$. For a dimensional analysis it is therefore sufficient to replace nonquantized with quantized vortices. This permits us to translate the results obtained for a vortex lattice in nonquantized fluid dynamics to a lattice of quantized vortices. It is through the hydrodynamic stability of such a vortex lattice that large nondimensional numbers arise.

We first consider a lattice of line vortices, as they occur in the Karman vortex street [17]. The stability of this configuration was analyzed by Schlayer [18], who found that the radius r_0 of the vortex core must be related to the distance of separation ℓ between two line vortices by

$$r_0 \cong 3.4\mathrm{x}10^{-3}\,\ell\,. \tag{6}$$

Setting $r_0 = r_p$ and $\ell = 2R$, where R is the radius of the vortex lattice cell occupied by one line vortex, one has

$$\mathrm{R/r_p} \cong 147. \tag{7}$$

For a quantum vortex the quantum viscosity inside the core is $\nu_Q \cong ir_pc$, and outside the core it is $\nu_Q = 0$, Averaged over one vortex lattice cell it is $\overline{\nu_Q} = ir_pc\left(r_p/R\right)^2$. With $\mathrm{Re}^Q = icr_p/\nu_Q \cong 1$ inside the vortex core, the quantum Reynolds number averaged over the volume of one cell is

$$\overline{\mathrm{Re}^Q} \cong (R/r_p)^2 \cong 2.15\mathrm{x}10^4\,. \tag{8}$$

No comparable stability calculation has been made for a three-dimensional lattice of vortex rings, but we can make some guesses. The instability arises from the fluid velocity of one vortex ring acting upon an adjacent ring, and only for $R/\nu_p \sim 147$ is the vortex lattice stable. At the distance R/r_p, the velocity of a ring vortex is larger by the factor $\log(8R/r_p)$ compared to the velocity of a line vortex [17]. With $R/r_p = 147$ for a line vortex, a better value for R/r_p can then be obtained by solving for R/r_p the equation

$$R/r_p = 147 \log (8\, R/r_p). \qquad (9)$$

One finds

$$R/r_p \cong 1360 \qquad (10)$$

and $\overline{\mathrm{Re}^Q} \cong (R/r_p)^2 \cong 1.85\mathrm{x}10^6$.

It was shown by the author [19] that the three-dimensional vortex lattice has two wave modes, one mimicking Maxwell's electromagnetic and the other one Einstein's gravitational waves, thus unifying Maxwell's and Einstein's equations.

6. Quantum Gravity

For a dimensional analysis the most elementary form of quantum gravity is sufficient, except that we also allow for negative masses. According to Hönl and Papapetrou [20] negative masses can explain the Dirac equation as the quantum mechanical equation for a mass pole with a superimposed mass dipole (pole-dipole particle), and in the framework of the Einstein-Maxwell equations it has been shown by Bonner and Cooperstock [21] that the electron must contain some negative mass. Negative masses seem to be an impossibility in a relativistic theory, but they are quite possible in an exactly nonrelativistic theory where the Hamilton operator commutes with the particle number operator and where Lorentz invariance can be a low energy dynamic symmetry [1,2].

The postulated existence of negative masses permits the generation of positive masses by the positive gravitational interaction energy of a positive with a negative mass. If the magnitude, not the sign, of two interacting masses is equal, the interaction energy is (G Newton's constant)

$$E_{\text{in}} = \frac{G|m_{\pm}|^2}{r}. \tag{11}$$

In quantum gravity this equation has to be supplemented by

$$|m_{\pm}|rc \cong \hbar, \tag{12}$$

assuming that the particles reach relativistic velocities.. Setting $E_{\text{in}}=mc^2$, r can be eliminated from (13) and (14), and one finds for m (making use of $Gm_{\text{P}}^2 = \hbar c$):

$$m = G|m_{\pm}|^3/\hbar c = |m_{\pm}|^3/m_{\text{P}}^2. \tag{13}$$

Instead of (13) one can write

$$|m_{\pm}|/m = (m_{\text{P}}/m)^{2/3}. \tag{14}$$

Setting $m_{\text{P}}/m=m_{\text{P}}/M \cong 10^{19}$ where M is the proton mass, one finds that $m_{\pm} \cong \pm 5\text{x}10^{12}\,\text{GeV}$. Therefore the gravitational interaction energy of a large ($5\text{x}10^{12}$ GeV) positive mass with a likewise negative mass can produce a mass of the order of the proton mass. The mass of $5\text{x}10^{12}$ GeV is of course still much smaller than the Planck mass of $\sim 10^{19}$ GeV.

7. Sommerfeld's Finestructure Constant

The first serious attempt to derive the finestructure constant $\alpha \approx 1/137$ was made by Heisenberg with his nonlinear spinor theory as a model for a fundamental field theory [22]. At this time it was not known that the finestructure constant is in reality not a constant, but changes with

energy, whereby the inverse of this "constant" depends linearly on the logarithm of the energy. Because of unavoidable divergences the theory was abandoned. Heisenberg, however, showed us how to proceed, not by numerological speculations but by an understanding of the dynamics. What is true for the electromagnetic coupling constant is true for the strong coupling constant, except that with increasing energy the electromagnetic coupling constant gets stronger, while the strong coupling constant gets weaker. The getting stronger, resp. weaker results from the screening resp. antiscreening of the interaction force through virtual particles. At the energy where the strong and electroweak interaction become equal, presumably at the Planck energy, one has $\alpha \cong 1/25$. With this value of α the proton mass is expressed in terms of the Planck mass m_{p} by [23]:

$$M/m_{\mathrm{p}}=e^{-k/\alpha}, \tag{15}$$

where k=11/2π is a calculable factor computed from the antiscreening of the strong force. The problem is therefore reduced to obtain a value for M/m_{p}, from which one compute α by

$$\frac{1}{\alpha}=\frac{2\pi}{11}\log\left(\frac{m_{\mathrm{p}}}{M}\right). \tag{16}$$

By order of magnitude $m_p / M \cong 10^{19}$, which is a very large nondimensional number. In classical fluid dynamics one has critical Reynolds numbers as large as 4×10^5 [24], but the number is still far away from the nondimensional number ~ 10^{19}. However, fluid dynamics in conjunction with quantum gravity, the latter analytically continued to negative masses, can produce such large nondimensional numbers.

Writing (14) in the form

$$\frac{m}{m_{\mathrm{p}}}=\left(\frac{|m_{\pm}|}{m_{\mathrm{p}}}\right)^3 \tag{17}$$

we have in accordance with (3)

$$\hbar\omega_{\mathrm{v}} = |m_{\pm}|c^2 = m_{\mathrm{p}}c^2(r_{\mathrm{p}}/R)^6\,, \tag{18}$$

and thus from (17) and (18)

$$m/m_{\mathrm{p}} = (r_{\mathrm{p}}/R)^6\,. \tag{19}$$

We have here assumed that the vortex resonance energy acts like a quasiparticle, and since an equal number of positive and negative Planck masses are present in the vortex, the votex resonance energy is double valued with $\hbar\omega_{\mathrm{v}} = m_{\pm}c^2 = \pm m_{\mathrm{p}}c^2\left(r_{\mathrm{p}}/R\right)^2$. One therefore has $m_{\pm} = \pm m_{\mathrm{p}}\left(r_{\mathrm{p}}/R\right)^2$. Equating m in (19) with the proton mass *M*, and inserting (19) into (16) one finds that

$$\frac{1}{\alpha} = \frac{12\pi}{11}\log\left(\frac{R}{r_{\mathrm{p}}}\right) \tag{20}$$

With R/r_{p}=1360 one finds that

$$1/\alpha \cong 24.8\,, \tag{21}$$

in surprisingly good agreement with the empirical value $1/\alpha \cong 25$.

8. Conclusion

The good agreement of the finestructure constant obtained by a dimensional analysis of quantum gravity and quantum fluid dynamics supports the Planck aether hypothesis, which is the conjecture that the vacuum of space is a kind of plasma consisting of positive and negative Planck mass particles. In the computation of the finestructure constant two very different disciplines of physics have come together: Quantum gravity and hydrodynamic stability. To obtain an accurate value for α, and thereby test the proposed conjecture, requires a correct value for the ratio R/r_{p}. If not by elaborate computations, this nondimensional number quite possibly may be obtained experimentally with superfluid helium.

References

1. F. Winterberg, Z. Naturforsch. **52a**, 183 (1997).
2. F. Winterberg, The Planck Aether Hypothesis – An Attempt for a Finitistic Theory of Elementary Particles. VRI, Karlsbad, Germany 2000; 2nd edition published by the Carl Friedrich Gauss Academy of Science Press 2002.
3. F. Winterberg, Int. J. Theor. Phys. **34**, 265 (1995).
4. W. G. Unruh, Phys. Rev. Lett. **46**, 1351 (1981).
5. T. Jacobsen, Phys. Rev. **D48**, 728 (1993).
6. W.G. Unruh, Phys. Rev. **D51**, 2827 (1995).
7. M. Visser, Class. Quantum Grav. **15**, 1767 (1998).
8. S. Liberati, S. Sonegro, and M. Visser, Class. Quantum Grav. **17**, 2903 (2000).
9. G. E. Volovik, Low Temp. Phys. **24,** 127 (1998)
10. N. B. Kipnin and G. E. Volovik, Pisma Zh. Eksp. Teor. Fix. **67,**, 124 (1998).
11. M. Planck, Deutsch. Phys. Gesell, Verh. 13.13, Feb. 15, 1911.
12. M. Planck, Preuss. Akad, Wiss. 440 (1899).
13. F Winterberg, Int. J. Theor. Physics **32**, 261 (1993).
14. H. Maris and S. Balibar, Physics Today, February 2000.
15. F. Winterberg, Int. J. Theor. Phys. **34,**, 399 (1995).
16. J. J. Thomson, Phil. Trans. 1882.
17. A. Sommerfeld, Mechanik der Deformierbaren Medien, Dietrich'sche Verlagsbuchhandlung, Wiesbaden 1947.
18. K. Schlayer, Z. angew. Mathem. Mech. **8,** 352 (1928).
19. F. Winterberg, Z. Naturforsch. **45a**, 1102 (1990).
20. H. Hönl and A. Papapetrou, Z. f. Phys. **112,** 512 (1939).
21. W. B. Bonner and F. I. Cooperstock, Phys. Lett. **A139,** 442 (1989).
22. W. Heisenberg, Introduction to the Unified Field Theory of Elementary Particles, Interscience Publishers, London 1966, p. 118.
23. F. Wilczek, Nature (London) **397**, 303 (1999).
24. G. Birkhoff, Hydrodynamics, Dover Publications, 1959, p. 12.