

The Value of Sommerfeld's Finestructure Constant as a Consequence of the Planck-Aether Hypothesis

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A value of the finestructure constant at the unification energy is obtained by a dimensional analysis of quantum gravity and fluid dynamics. The derivation assumes that the vacuum is a superfluid made up of positive and negative Planck mass particles obeying an exactly nonrelativistic law of motion with Lorentz invariance a low energy approximation. The dimensional analysis presented gives a value for the finestructure constant in good agreement with the empirical value $1/\alpha \approx 25$.

1. Introduction

The first serious attempt to derive the finestructure constant was made by Heisenberg with his nonlinear spinor theory as a model for a fundamental field theory [1]. At the time of Heisenberg's attempt 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 $\alpha \approx 1/25$. With this value of α the proton mass M is expressed in terms of the Planck mass m_p by [2].

$$M/m_p = e^{-k/\alpha}, \quad (1)$$

where $k = 11/2\pi$ 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 obtains

$$\frac{1}{\alpha} = \frac{2\pi}{11} \log \left(\frac{m_p}{M} \right). \quad (2)$$

By order of magnitude $m_p/M \approx 10^{19}$, which is a very large nondimensional number. In classical fluid dynamics one has critical Reynoldsnumbers as large as 4×10^5 [3], but they are still far away from the nondimensional number $\sim 10^{19}$. However, as will be shown, fluid dynamics in conjunction with quantum gravity, the latter analytically continued to negative masses, can produce such large nondimensional numbers.

2. Motivation

The recent discovery of a negative pressure medium making up $\approx 70\%$ of the energy in the physical universe, with $\approx 26\%$ in nonbaryonic cold dark matter, is in agreement with a conjecture by the author [4] that the 70% negative pressure energy and 26% nonbaryonic dark matter is as in a superfluid, like superfluid helium, where, if expressed in the Debye energy, the rotons have a $\sim 70\%$ energy gap and $\sim 25\%$ kinetic energy. Since rotons can be viewed as small vortex rings, a superfluid with rotons acts like a fluid filled with cavitons, which is known to have a negative pressure.

Further support for the idea that the vacuum is a kind of fluid comes from the analogies between fluid dynamics and general relativity [5–11]. Following Planck's postulate that physics should be reduced to \hbar , G , and c [12], and to account for a vanishing cosmological constant, it is hypothesized that the vacuum is made up of positive and negative Planck mass particles, forming a kind of plasma, with the Planck mass particles locally interacting over a Planck length by the Planck force, and with all other particles explained as collective quasipar-

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ticle excitations of the Planck mass plasma [13, 14]. The compensation of electric charges in condensed matter is through charges of opposite sign. In the Planck mass plasma there is a likewise compensation through masses of opposite sign, making the cosmological constant equal to zero. The observed residual cosmological constant is then in reality the negative pressure energy, mimicking a cosmological constant.

3. Vortex Model

The failure of the bosonic string theory in 26 dimensions (dual resonance model) to describe nuclear forces and its replacement by QCD in the 3 + 1 dimensions of physics, suggests that the presently fashionable string theories in higher dimensions may suffer a similar fate. This prediction is supported by the analogies between Yang-Mills theories and vortex dynamics [15], making it plausible that string theories should be replaced by some kind of vortex dynamics at the Planck scale.

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 $m_p r v_\phi = \hbar$, the vortices are potential vortices with the azimuthal velocity

$$\begin{aligned} v_\phi &= c r_p / r, & r > r_p \\ &= 0, & r < r_p, \end{aligned} \quad (3)$$

where r_p is the Planck length.

A vortex ring of ring radius R and core radius r_p has a resonance frequency given by [16]

$$\omega_v \cong c r_p / R^2 \quad (4)$$

and if quantized the energy

$$\hbar \omega_v \cong m_p c^2 (r_p / R)^2. \quad (5)$$

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.

4. Vortex Lattice

In nonquantized fluid dynamics the vortex core has a radius about equaling a mean free path λ where the ve-

locity reaches the velocity of sound, the latter about equaling the thermal velocity v_t . The Reynolds number in the vortex core therefore is

$$\text{Re} = v r / \nu = v_t \lambda / \nu, \quad (6)$$

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

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

$$\text{Re}^Q = i v r / \nu_Q, \quad (7)$$

one finds with $\nu_Q = i r_p c$ that in the core of a quantized vortex $\text{Re}^Q \sim 1$. 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

$$r_0 \cong 3.4 \times 10^{-3} \ell. \quad (8)$$

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

$$R/r_p \cong 147. \quad (9)$$

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

$$\overline{\text{Re}^Q} \cong (R/r_p)^2 \cong 2.15 \times 10^4. \quad (10)$$

No comparable stability calculation has been made for a three-dimensional lattice of vortex rings, but we can make some guesses. The instability apparently arises from the fluid velocity of one vortex ring acting upon an adjacent ring. 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

$$R/r_p = 147 \log(8R/r_p). \quad (11)$$

One finds

$$R/r_p \cong 1360 \quad (12)$$

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

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.

5. Quantum Gravity

For a dimensional analysis the most elementary form of quantum gravity is sufficient, except that we also allow negative masses. As it was shown by Bondi [20], negative masses can be incorporated into general relativity. According to Hönl and Papapetrou [21] 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 [22] 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 non-relativistic theory where the Hamilton operator commutes with the particle number operator and where Lorentz invariance can be a low energy dynamic symmetry [13, 14].

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)

$$E_{\text{in}} = \frac{G |m_{\pm}|^2}{r} \quad (13)$$

In quantum gravity this equation has to be supplemented by

$$|m_{\pm}| rc \cong \hbar, \quad (14)$$

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 $Gm_p^2 = \hbar c$):

$$m = G |m_{\pm}|^3 / \hbar c = |m_{\pm}|^3 / m_p^2. \quad (15)$$

Instead of (15) one can write

$$|m_{\pm}|/m = (m_p/m)^{2/3}. \quad (16)$$

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

6. Quantum Gravity and Fluid Dynamics

Writing (16) in the form

$$\frac{m}{m_p} = \left(\frac{|m_{\pm}|}{m_p} \right)^3 \quad (17)$$

we have in accordance with (5)

$$\hbar \omega_v = |m_{\pm}| c^2 = m_p c^2 (r_p/R)^2, \quad (18)$$

and thus from (17) and (18)

$$m/m_p = (r_p/R)^6. \quad (19)$$

We have 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 vortex resonance energy is double valued with $\hbar \omega_v = \pm m_p c^2 (r_p/R)^2$. One therefore has $m_{\pm} = \pm m_p (r_p/R)^2$. Equating m in (19) with the proton mass M , and inserting (19) into (2) one obtains

$$\frac{1}{\alpha} = \frac{12\pi}{11} \log \left(\frac{R}{r_p} \right). \quad (20)$$

For $R/r_p = 1360$ one finds

$$1/\alpha \cong 24.8, \quad (21)$$

in surprisingly good agreement with the empirical value $1/\alpha \cong 25$. The value $1/\alpha = 25$ would be obtained if $R/r_p \cong 1430$.

7. 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 neg-

ative 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.

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