PLANCK SCALE PHYSICS AND NEWTON'S ULTIMATE OBJECT CONJECTURE*

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According to Newton, the ultimate building blocks of matter are hard frictionless spheres. This conjecture is here analyzed under different assumptions, which are: 1. The ultimate objects of matter are frictionless positive and negative Planck mass particles obeying nonrelativistic Newtonian mechanics. 2. The Planck mass particles interact with the Planck force c^4G (c velocity of light, G Newton's constant) locally within a Planck length $r_{\rm p}$, with the positive Planck mass particles exerting a repulsive and the negative Planck mass particles an attractive force, whereby particles of equal sign are accelerated away from each other and those of opposite sign — as a particle-hole interaction — accelerated towards each other. 3. Space if filled with an equal number of positive and negative Planck mass particles, whereby each Planck length volume $r_{\rm p}^3$ occupies one Planck mass particle. Making these three assumptions we derive: 1. Nonrelativistic quantum mechanics as an approximation with depertures from this approximation suppressed by the Planck length. 2. Lorentz invariance as a dynamic symmetry for energies small compared to the Planck energy. 3. The operator field equation for the previously proposed Planck aether model of a unified theory of elementary particles. In contrast to theories in which the ultimate objects are strings at the Planck scale, the alternative theory proposed here does not need a higher dimensional space, but rather can be formulated in 3+1 dimensions.

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1. Introduction

At the turn of the last century Kelvin proclaimed his famous clouds of physics: The failure of the Michelson–Morley experiment to detect an aether wind and the violation of the classical mechanical equipartition theorem in

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statistical thermodynamics. The removal of these clouds led to the two great breakthroughs of 20th century physics, the theory of relativity and quantum mechanics. At the turn of this century there again are clouds which so far have withstood all attempts for their removal. These clouds are:

1. The riddle of quantum gravity.
2. The (observationally established) vanishing (resp. very small) cosmological constant.
3. The superluminal (experimentally over ~ 10 meters verified) quantum correlations.

The indication that the strong, the electromagnetic and the weak interaction become equal at an energy of $\sim 10^{15} - 10^{16}$ GeV which (on a logarithmic scale) is not far away from the Planck energy of $\sim 10^{19}$ GeV, supports Einstein's conjecture that it is gravity holding together all forms of matter in their innermost part, but also shows that physics has its root at extremely high energies far outside the reach of 20th particle accelerator technology. It has been pointed out by Weinberg [1] that the existence of such large mass scale lessens our admiration for the standard model, in particular the extremely good agreement between theory and experiment in Q.E.D., because it explains why higher order terms in the Lagrange density can be omitted, which in the presence of such a large mass scale could simply be suppressed by the Planck mass. Accordingly, the standard model and by implication Q.E.D. are then only low energy approximations of the correct theory hidden at the Planck scale. With no chance to conduct experiments at these high energies we are forced to guess the correct fundamental law. One type of guess is the multitude of string theories. These theories have to be formulated in more than the 4 space-time dimensions of physics, and they seem to fail the one test against which at the present time they can be tested: The prediction of the grand unified energy. String theories predict that this energy is close to the Planck energy, not the $10^3 - 10^4$ times smaller energy believed to be true. All string theories proposed postulate at ultimate truths: The theory of relativity and quantum mechanics. Departing from these postulates I have tried to show that both special relativity and quantum mechanics can be derived from a few conceptually very simple assumptions at the Planck scale. I believe that only such a radical approach can bring us closer to a solution of the three problems listed above.

2. Newton's ultimate objects

The first serious attempts towards a unified field theory (initiated by Einstein) tried to geometrize all of physics. They were abandoned when it was realized that Einstein's very successful geometrization of gravity not be extended to other fields, notably the electromagnetic field. The second kind of attempts seem to have their roots in Heisenberg's isospin symmetry. They seek the fundamental law through a special symmetry, and are directed towards ever larger groups, culminating in string theories with several hundred elements, each representing an elementary particle (of zero rest mass), most of them not observed in nature. A third kind of attempt can be traced back already to Newton who held the view that the ultimate objects of matter are hard frictionless spheres. It seeks the fundamental law neither in geometry or symmetry but in final indivisible "atomistic" objects.

Very much as the large number of crystal symmetry groups can be dynamically explained by the much simpler spherical symmetry of the Coulomb field, it is justified to ask if the observed, often broken, symmetries of physics can likewise be explained dynamically from a simple underlying law. Newton's hard frictionless spheres are as a group most likely too small, but the SU2 group, having two elements instead may be sufficient. The SU2 group is closely related to the binary number system used by a computer, and it is not unreasonable to guess that nature at its most fundamental level should work like a computer. Also because SU2 is isomorph to the rotation group it may explain why space is three-dimensional [2].

3. Newton's ultimate objects and Planck scale physics

In guiding our guess about the conjectured fundamental law at the Planck scale we are seeking, we take three clues. The first clue is the large ratio of $\sim 10^3 - 10^4$ separating the Planck scale from the grand unified scale. It is reminiscent of hydrodynamics where large dimensionless numbers, in particular large Reynolds numbers, are common. The second clue is provided by the vanishing cosmological constant. It is reminiscent of electric charge neutrality in condensed matter physics, suggesting a kind of mass neutrality for the vacuum involving negative masses. The third clue finally comes from the superluminal quantum correlations, suggesting the existence of a kind of an aether permitting superluminal velocities. Since no information can be transmitted by the quantum correlations superluminal phase velocities is all what is needed.

Guided by these clues Newton's idea is analyzed under somewhat different assumptions:

1. The ultimate objects are Planck mass particles, obeying nonrelativistic Newtonian mechanics, but where in addition to Planck mass particles of positive sign, those of negative sign are admitted as well.
2. All of space is densely filled with an equal number of positive and negative Planck mass particles, each occupying a Planck length volume.

3. The Planck mass particles interact locally within a Planck length with the positive Planck mass particles exerting a repulsive, and the negative Planck mass particles an attractive force, the absolute value of which is equal to c^4/G (c velocity of light, G Newton's constant).

Making these assumptions I have been able to derive [3, 4]:

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. The existence of a spectrum of quasiparticles and their interactions greatly resembling the spectrum of known elementary particles.

With an equal number of positive and negative Planck mass particles, the cosmological constant is equal to zero, and the conjectured underlying SU2 symmetry finds its expression in the two different signs the Planck mass particles can have. The hypothesis that space is densely filled with an equal number of positive and negative Planck masses I have called the Planck aether hypothesis.

With the mass length and time given by

$$\begin{aligned} m_p &= \sqrt{\hbar c/G} \simeq 10^{-5}\text{g} \\ r_p &= \sqrt{\hbar G/c^3} \simeq 10^{-33}\text{cm} \\ t_p &= \sqrt{\hbar G/c^5} \simeq 10^{-44}\text{sec} \end{aligned} \tag{1}$$

one obtains the Planck force $F_p = c^4/G \approx 10^{50}$dyn. Unlike m_p, r_p, and t_p, F_p does not depend on $\hbar$.

4. Boltzmann equation for the Planck aether

Because the Planck force F_p does not depend on $\hbar$ suggests that quantum mechanics may be explained by Newtonian mechanics analytically continued to negative masses. This conjecture can be proved in several steps as follows:

1. A collision between two negative Planck masses has the same outcome as one between those of positive sign. The collision of a positive with a negative mass of equal magnitude does not change the velocity of the colliding particles, neither in magnitude nor direction, but it permits a parallel displacement of the particle trajectories, of what Schrödinger [5] has called "Zitterbewegung" (quivering motion). With all of physics

at the Planck scale reduced to the tree fundamental Planck units, the Zitterbewegung displacement must be ($a_p = F/m_p$):

$$\delta = (1/2)a_p t_p^2 = (1/2)r_p \,. \tag{2}$$

2. Because of the Zitterbewegung displacement one has for the distribution function $f'_\pm$ before a collision takes place

$$f'_\pm(\boldsymbol{r}) = f_\pm(\boldsymbol{r} \pm \boldsymbol{r}_p/2) \,. \tag{3}$$

3. The Planck mass particles mass have a potential of range r_p:

$$U_\pm = \pm F_p r_p = \pm m_p c^2 \,. \tag{4}$$

4. The behavior of the locally interacting positive and negative Planck masses can then be described by Boltzmann's equation:

$$\frac{\partial f_\pm}{\partial t} + \boldsymbol{v}_\pm \frac{\partial f_\pm}{\partial \mathbf{r}} \mp \frac{1}{m_p}\frac{\partial U}{\partial \boldsymbol{r}} \cdot \frac{\partial f_\pm}{\partial \boldsymbol{v}_\pm} = 4cr_p^2 \int (f'_\pm f'_\mp - f_\pm f_\mp) \mathrm{d}\boldsymbol{v}_\mp \,, \tag{5}$$

where U is the average potential by all Planck mass particle on one Planck mass particle.

5. With the help of (5) the Boltzmann equation can be solved by evaluating its moments. The zeroth order moment gives the continuity equation

$$\frac{\partial n_\pm}{\partial t} + \frac{\partial (n_\pm \boldsymbol{V}_\pm)}{\partial \boldsymbol{r}} = 0 \,. \tag{6}$$

The next, first order moment gives an Euler equation with quantum potential

$$\frac{\partial \mathbf{V}_\pm}{\partial t} + \boldsymbol{V}_\pm \cdot \frac{\partial \mathbf{V}_\pm}{\partial \mathbf{r}} = \mp \frac{1}{m_p}\frac{\partial U}{\partial \mathbf{r}} + \frac{\hbar^2}{2m_p^2}\frac{\partial}{\partial \boldsymbol{r}}\left(\frac{1}{\sqrt{n_\pm}} \cdot \frac{\partial^2 \sqrt{n_\pm}}{\partial \boldsymbol{r}^2}\right) . \tag{7}$$

6. The equivalence of (6) and (7) with the one-body Schrödinger equation for a positive or negative Planck mass can then be established by Madelung's transformation

$$\begin{aligned} n_\pm &= \psi_\pm^* \psi_\pm \\ n_\pm \mathbf{V}_\pm &= \mp \frac{i\hbar}{2m_p}[\psi_\pm^* \nabla \psi_\pm - \psi_\pm \nabla \psi_\pm^*] \end{aligned} \tag{8}$$

transforming Schrödinger's equation for a Planck mass $\pm m_p$

$$i\hbar\frac{\partial\psi_\pm}{\partial t} = \mp\frac{\hbar^2}{2m_p}\nabla^2\psi_\pm + U(\boldsymbol{r})\psi_\pm \tag{9}$$

into (6) and (7).

With the establishment of the one body Schrödinger equation the particle momentum must be assigned the operator $(\hbar/i)\partial/\partial q$, and it thus follows that the many body problem of all Planck masses can in the same approximation be described by the operator field equation

$$i\hbar\frac{\partial\psi_\pm}{\partial t} = \mp\frac{\hbar^2}{2m_p}\nabla^2\psi_\pm \pm 2\hbar c r_p^2(\psi_\pm^\dagger\psi_\pm - \psi_\mp^\dagger\psi_\mp)\psi_\pm\,. \tag{10}$$

The average potential on one Planck mass particle is then

$$U = U_+ + U_- = 2\hbar c r_p^2\langle|\psi_+^\dagger\psi_+ - \psi_-^\dagger\psi_-|\rangle\,, \tag{11}$$

where in an undisturbed assembly of Planck masses one has $\langle\psi_+^\dagger\psi_+\rangle = \langle\psi_-^\dagger\psi_-\rangle = 1/2r_p^3$ making there $U_\pm = \pm m_p c^2$ as required by (3). Together with the canonical commutation relations for the Heisenberg operators, $\psi_\pm$, $\psi_\pm^\dagger$, (10) becomes a useful approximation for the description of the Planck aether.

5. Consequences

In its groundstate the Planck aether may be viewed as composed of two superfluids, one of positive the other one of negative mass. A suitable approximation of (10) is the Hartree–Fock approximation leading to the nonlinear Schrödinger equation

$$i\hbar\frac{\partial\psi_\pm}{\partial t} = \mp\frac{\hbar^2}{2m_p}\nabla^2\psi_\pm \pm 2\hbar c r_p^2(2\psi_\pm^*\psi_\pm - \psi_\mp^*\psi_\mp)\psi_\pm\,. \tag{12}$$

By the Madelung transformation it becomes an Euler equation with a quantum potential $Q_\pm$ as in (7), and a continuity equation:

$$\frac{\partial \boldsymbol{V}_\pm}{\partial t} + (\boldsymbol{V}_\pm\cdot\nabla)\boldsymbol{V}_\pm = -2c^2 r_p^3\nabla(2n_\pm - n_\mp) \mp \frac{1}{m_p}\nabla Q_\pm$$
$$\frac{\partial n_\pm}{\partial t} + \nabla\cdot(n_\pm\mathbf{V}_\pm) = 0\,. \tag{13}$$

The consequences of (13) can be summarized as follows:

1. For small amplitude disturbances (13) leads to longitudinal waves propagating with the velocity of light.
2. In addition, (13) leads to two types of potential vortex solutions with the vortex core radius equal a Planck length: One in witch the positive and negative mass component of the Planck aether are co-rotating and the other one where they are counter-rotating.
3. The zero point fluctuations of the Planck masses bound in the vortex filaments have the energy density $\varepsilon \sim \hbar c/r_p^4$ which is the same as the energy density $g^2 \sim (Gm_p/r_p^2)^2$ of a Newtonian gravitational field $g = Gm_p/r_p^2$ at the distance r_p away from a Planck mass m_p. Because the zero point fluctuations of the Planck masses bound in the vortex filaments are the source of a phonon field coupling different vortices, the phenomenon of charge is explained to result from quantum mechanical zero point fluctuations, which in turn are caused by negative masses.
4. A "vortex sponge" in the Planck aether permits the propagation of two types of transverse waves, one simulating Maxwell's electromagnetic the other one Einstein's gravitational waves.
5. The snapping and reconnecting of the vortex filaments in a vortex sponge leads to a lattice of vortex rings, and the hydrodynamics of the Karman vortex street makes plausible a distance of separation between the rings is of the order $\sim 10^3 r_p$, explaining the grand unified scale, in comparison to the Planck scale is 10^3 times smaller.
6. The vortex rings have a resonance energy at about $\pm 10^{12}$ GeV, and if the positive resonance energy of a vortex interacts gravitationally with its negative resonance energy through the phonon field established by the zero point oscillations of the Planck masses bound in the vortex filaments, the resulting positive-negative mass exciton configuration has a small net positive mass. This is due to the nonlinearity of the gravitational field, explaining why there are no negative mass quasi particles. Because there are two vortex configurations, one in which the positive and negative masses are co-rotating, and one where they are counter-rotating, there are two types of excitons, both of which can be shown to satisfy the Dirac equation. Their mass is given by

$$\begin{aligned} m/m_p &= (1/\sqrt{2})(r_p/R)^6 \\ m/m_p &= (1/\sqrt{2})(r_p/R)^8 \, , \end{aligned} \tag{14}$$

   where R is the ring radius of the vortices. Choosing $R/r_p \approx 5000$, corresponding to a grand unified scale at $10^{15} - 10^{16}$ GeV, one obtains the correct value for the electron mass. The other case realized for counter-rotating vortices, where the gravitational interaction is much smaller leads to a much smaller mass, of the order 2×10^{-2} eV, which could be the neutrino mass.

7. With small amplitude disturbances in the Planck aether propagated with the velocity of light, and with the excitonic quasiparticles held together by the long range forces transmitted through these waves, Lorentz invariance becomes a dynamic symmetry for the following reasons: As already shown by Lorentz an absolute aether theory leads to a true contraction of the forces in the forward direction, and if all clocks behave like light clocks, it leads to a likewise time dilation. Therefore, if a body is set in to absolute motion, a new equilibrium of the forces within the body is established provided the zero point energy is Lorentz invariant as well. With the zero point energy of a harmonic oscillator equal to $(1/2)\hbar\omega$, and $4\pi\omega^2 d\omega$ states between ω and $\omega + d\omega$ in frequency space, the spectrum of the zero point energy is proportional to ω^3, the only Lorentz invariant spectrum. Furthermore, as it was shown by Einstein and Hopf, the friction force exerted on a charged particle moving with the velocity v against a background field with the spectrum $f(\omega)$ is

$$F = -\text{const} \cdot [f(\omega) - \frac{\omega}{3}\frac{df(\omega)}{d\omega}]v\,, \tag{15}$$

which vanishes for $f(\omega) \propto \omega^3$. This explains why a Lorentz invariant spectrum, as the one where the friction is smallest is likely to establish itself. With $f(\omega) = 0$ for $\omega > \omega_p = c/r_p$, quantum mechanics becomes invalid for masses $m > m_p$ to be replaced by Newtonian mechanics.
8. The problem of quantum gravity is reduced to the nonrelativistic, albeit complicated, many body problem of the Planck mass particles filling space, with the geometric interpretation of general relativity breaking down for energies near the Planck energy.
9. Higher order particle families can be explained by internal excitations of the positive-negative excitons, predicting a maximum of four families. Because of the presence of negative masses, the energies of the excited states are much smaller than in preon models, which cannot explain the masses of the muon and tau by internal excitations.
10. Quarks may be explained by states similar to those observed in the fractional quantum Hall effect, where the electron wave function splits up into fractionally charged vortices. Accordingly, quarks would have to be understood to derive from leptons split up into vortices. This conjecture seems to be supported by the close relationship multicomponent fluid dynamics has with non-Abelian gauge theories, where the curvature tensor formed from the gauge potentials is displaced by one hierarchical step if compared with the curvature tensor in general relativity, formed by the Christoffel symbols which are derivatives of the potentials. The same displacement in the hierarchy occurs in Helmholtz line vortex dynamics compared with Newtonian point mechanics [6].

11. The Aharonov–Bohm effect is caused by (a positive-negative mass) potential vortex in the Planck aether, where the mass components are counter-rotating. In the Sagnac effect, the positive and negative mass components of the Planck aether are co-rotating, leading to a phase shift for light waves.

6. Conclusion

The hypothesis for the existence of a fundamental field at rest in a preferred system is supported by the cosmological evidence showing us a system of galaxies which (apart from a uniform expansion), are in relative rest. This makes it plausible that all forms of matter are bound states of a fundamental field relative to which matter is at rest. The special theory of relativity which denies the existence of an aether would still be in harmony with a system of galaxies having a large velocity distribution, like the molecules in a gas, but this is not what is observed. The absolute theory proposed, where the fundamental field composed of Planck mass particles plays the role of a kind of aether but very different from aether models of the 19th century, seems to be able in principle to remove the 20th century clouds of physics.

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