

Planck Mass Rotons as Cold Dark Matter and Quintessence*

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According to the Planck aether hypothesis, the vacuum of space is a superfluid made up of Planck mass particles, with the particles of the standard model explained as quasiparticle – excitations of this superfluid. Astrophysical data suggests that $\approx 70\%$ of the vacuum energy, called quintessence, is a negative pressure medium, with $\approx 26\%$ cold dark matter and the remaining $\approx 4\%$ baryonic matter and radiation. This division in parts is about the same as for rotons in superfluid helium, in terms of the Debye energy with $a \approx 70\%$ energy gap and $\approx 25\%$ kinetic energy. Having the structure of small vortices, the rotons act like a caviton fluid with a negative pressure. Replacing the Debye energy with the Planck energy, it is conjectured that cold dark matter and quintessence are Planck mass rotons with an energy below the Planck energy.

Key words: Analog Models of General Relativity.

1. Introduction

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,
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. Instead it incorrectly predicts a value for the cosmological constant at least 55 orders of magnitude too large. And it cannot give an explanation for the accelerated cosmological expansion.

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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 to describe nuclear forces (dual resonance model) with QCD in 4 dimensions, and the mentioned analogies between Yang-Mills theories and vortex dynamics, also speak in favor of replacing supersymmetric string theories in 10 dimensions by some vortex dynamics in the 3 + 1 space-time dimensions of physics.

A fluid dynamic model, of course, implies that the vacuum is a medium. As Planck had shown 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 $\approx 10^{-13}$ 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 $\approx 10^{-33}$ cm.
4. **The way it may be:** Vortex dynamics in 3 space and 1 time dimensions at $\approx 10^{-33}$ cm.

2. The Planck Aether Hypothesis

The Planck aether hypothesis (positive-negative Planck mass plasma) 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 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 and range of the force equal to the Planck force F_p and 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 makes the following predictions:

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 very much like 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 the differentials in these equations would have to be replaced by finite difference operators, with the finite difference given by the Planck length. Without violating microcausality this however, is only possible in an exactly nonrelativistic theory, where Lorentz invariance is recovered as an asymptotic limit for energies small compared to the Planck energy, as in the pre-Einstein theory of relativity by Lorentz and Poincaré [13]. A reduction to h , G , and c allows two signs for the Planck mass but it also leaves open the sign of the Planck force. This freedom permits to construct in a unique way a stable vacuum in the presence of negative masses. The two possible signs suggest that the fundamental symmetry of nature is SU_2 , with nature working like a computer with a binary number system.

With SU_2 isomorph to SO_3 , the rotation group in three dimensions, then would explain why space is three-dimensional.

3. Planck Mass Rotons

With 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 taking the place of the Debye energy in superfluid helium (see Fig. 1).

Rotons can be viewed as small vortex rings with the ring radius of the same order 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]. In vortices the centrifugal force creates a vacuum in the vortex core, making a vortex ring to behave like a caviton.

In the Planck aether the negative pressure is provided by the zero point energy (see appendix). It 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.

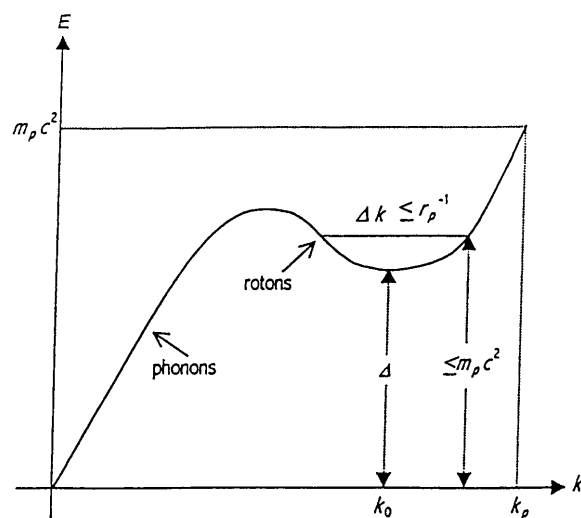


Fig. 1. The conjectured phonon-roton-like spectrum of the Planck mass plasma (Planck aether).

The kinetic roton energy is bound by the height of the potential well 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 negative pressure energy, the latter mimicking a cosmological constant [15].

Appendix

The equation of state for black body radiation and dust, the two most important cases for cosmology, can be written as

$$p = \varepsilon u \quad (\text{A.1})$$

where p is the pressure, u the energy density, $\varepsilon = 1/3$ for black body radiation, and $\varepsilon = 0$ for dust. From the first law of thermodynamics one has for an adiabatic change of state

$$dQ = d(uV) + p dV = 0 \quad (\text{A.2})$$

where V is the volume, hence

$$u dV + V du + p dV = 0 \quad (\text{A.3})$$

and with (A.1)

$$\frac{du}{u} = -(1 + \varepsilon) \frac{dV}{V}. \quad (\text{A.4})$$

hence

$$u = V^{-(1+\varepsilon)}. \quad (\text{A.5})$$

For black body radiation with $\varepsilon = 1/3$ one has

$$u = V^{-4/3} \quad (\text{A.6})$$

or because $u = aT^4$ (Stefan Boltzmann law)

$$TV^{1/3} = \text{const.} \quad (\text{A.7})$$

For dust with $\varepsilon = 0$ one has

$$uV = \text{const.} \quad (\text{A.8})$$

Because of Heisenberg's uncertainty principle, the energy density of the zero point vacuum energy does not change with a change in the volume V . Therefore, one has $du/dV = 0$, or $\varepsilon = -1$. The equation of state of the zero point vacuum energy therefore is

$$p = -u \quad (\text{A.9})$$

explaining why for a positive vacuum energy the pressure is negative, with the magnitude of the pressure equal the energy density.

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