**Title:** Heisenberg's Unified Field Theory of Elementary Particles and Lorentzian Relativity

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Dedicated to the memory of Kurt Symanzik

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## Abstract

To bypass Lehmann's theorem against Heisenberg's "Unified Field Theory of Elementary Particles," requiring a Hilbert space with an indefinite metric, which is in conflict with the quantum mechanical probability interpretation, it was proposed by the author that Lorentz invariance, on of the fundamental assumptions made by Heisenberg, is a dynamic symmetry, approximately only valid for energies small compared to the Planck energy of $\sim 10^{19}\ GeV$, with the fundamental symmetry of nature the Galilei group, in agreement with Mach's principle. There then Heisenberg's theory can be reformulated as an exactly non-relativistic quantum field theory with a positive definite metric in Hilbert space. With the Hamiltonian operator in such a theory commuting with the particle number operator, Heisenberg's ground state of the vacuum is permitted to be a zero temperature plasma made up of positive and negative Planck mass particles which are one Planck mass per Planck length volume, interacting with the Planck force over a Planck length. Making for this Planck mass plasma the Hartree-Foch approximation, one obtains the Landau-Ginzburg equation of a super-fluid, and from the Boltzmann equation the quantum potential of the Madelung transformed Schrödinger equation. Quantum mechanics is thereby explained as a completely deterministic theory, as required by Kant's law of causality.

This paper was inspired by a remarkable paper recently published by I. Licata [1], who compared the work by the author for a deterministic interpretation of quantum mechanics to the work of 't Hooft with the same goal.

## 1. Introduction

The author was an eyewitness when in a seminar talk by Heisenberg in 1954 [2], at the Max Planck Institute in Göttingen, where Heisenberg had for the first time presented his groundbreaking idea that all elementary quantities should be obtained from the solution of a nonlinear spinor field equation with a novel kind of quantization assuming the existence of a large cut-off energy (by him called a large limiting mass). From the first moment I was convinced of his idea, and that I had become a witness of a historic event in science.

Following his lecture, he told me that he first tried to make a model of his idea with a nonlinear scalar field equation, but after Symanzik had shown that this would not work, proposed a nonlinear spinor field theory, which he had in mind to explain the half-integer spin particles like the electron. But his assumption of a limiting mass, required for the regularization of his theory, necessitated the assumption of a (non-positive) indefinite metric in Hilbert space. However, because of the quantum mechanical probability definition, this would imply the existence of states with a negative probability ("ghosts"). Furthermore, the regularization of his theory by a large limiting mass is in violation of a theorem by Lehmann [3], who under very general conditions had shown that the singularities on the lightcone cannot be eliminated in a theory with interaction.

Following his lecture I had asked him why he did not assume for his large limiting mass the Planck mass of $\sim 10^{19} GeV$. His answer was that as an extremely weak force gravity can be neglected, an opinion repeated in a letter he had written me in 1957, (copy with my translation into English attached) about my proposal to test general relativity by placing atomic clocks onto artificial earth satellites [4] (realized in the GPS), where he writes that one day in the future gravity might be explained by the weak nuclear force.

Many years before Heisenberg, Einstein tried to find equations of physics with his general theory of relativity and gravitation, but like Heisenberg, he failed. But how was it possible that two great geniuses failed? There can be only one answer: they erred because they wanted to err. They did not wish to believe that the special—and by implication, the general—theory of relativity could be only an approximation. The reason why can be found in a paper by Kurt Symanzik [5], outlining the axiomatic structure of a theory in "field free space." By "field free," he means the vacuum of space, that is in Minkowski space-time. But because in Einstein's general theory of relativity gravitational fields can be transformed away by the principle of equivalence, Symanzik's paper also can be extended from the uncurved Minkoski space-time to a curved Riemannian space-time.

The question both Einstein and Heisenberg were faced with was "Could it be that the theory of relativity, both special and general, are only approximations?" This was a price too high for them to pay. In the general theory of relativity it would mean to extend the theory for 11 dimensions with $10^{500}$ or more possibilities, in opposition to Einstein's belief that "God is subtle, not malicious;" one might think that a God in 11 dimensions would be.

There can be little doubt that Einstein's general theory of relativity and gravitation, predicting the perhelion motion of Mercury, the deflection of light by the Sun, the time dilation by the GPS, and the existence of gravitational waves, must be an *extremely good* approximation, but there are at least three things which show that the theory cannot be entirely correct:

1. The singularities of its solutions, not permitted in a theory describing physical reality.
2. The black hole information paradox, in violation of the quantum mechanical unitarity.
3. The double slit experiment, where the gravitational field of a particle is split into two such parts.

In quantum mechanics, it is the indeterministic Copenhagen interpretation, which is in contradiction to Kant's fundamental law of causality.

Heisenberg had requested the existence of a highly degenerate vacuum state. Such a state is in line with Mach's principle

It was Hund [6], who had shown that all the known and explored consequences of Einstein's general theory of relativity and gravitation can be obtained from Mach's principle, assuming a preferred reference system at rest with the star-filled universe. And by replacing rods and clocks with Lorentz-contracted rods and clocks, one obtains what has been called "Lorentzian Relativity." It was with "Lorentzian Relativity" that the author succeeded to explain the mysterious gamma ray bursts, where in a very short time the rest mass of a large star is converted into radiation [7]. In "Lorentzian Relativity," matter becomes unstable when approaching the event horizon, implying a small—but significant—departure from Einstein's theory.

## 2. The Planck Aether Hypothesis

In his "Optics," Newton makes the conjecture that the ultimate building blocks of matter are hard frictionless spheres. With a few assumptions, similar but different from those made by Newton, I will derive quantum mechanics with a spectrum of elementary particles greatly resembling the known spectrum of elementary particles, and Lorentz invariance as a dynamic symmetry for energies which are small compared to the Planck energy. These assumptions are (with $G$ being Newton's constant, ħ being Planck's constant, and $c$ the velocity of light):

1. The ultimate building blocks of matter are Planck mass particles which obey the laws of classical Newtonian mechanics, but there can also be negative Planck mass particles.
2. A positive Planck mass particle exerts a short-range repulsive—and a negative Planck mass particle likewise exhibits an attractive—force on a positive Planck mass particle, with magnitude and range equal to the Planck force $F_p$ and 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.

From the two Planck relations

$$Gm_p^2 = \hbar c$$

$$m_p r_p c = \hbar$$

($h = 2\pi\hbar$) Planck's mass, length, and time are obtained:

$$m_p = \sqrt{\hbar c/G} = 10^{-5} g$$

$$r_p = \sqrt{\hbar G/c^3} \cong 10^{-33} cm$$

$$t_p = \sqrt{\hbar G/c^5} \cong 10^{-44} sec$$

Expressed in terms of these units the Planck force is

$$F_p = \frac{c^4}{G} \cong 10^{50} dyn$$

Unlike $m_p$, $r_p$, and $t_p$, $F_p$ does not depend on ħ. The potential of $F_p$ over the range $r_p$ is equal to $U = F_p r_p = m_p c^2$.

Because the compactified assembly of positive and negative Planck mass particles defines an absolute system at rest with these particles, one may speak of an aether composed of densely packed Planck mass particles which one may simply call the Planck aether.

## 3. Boltzmann Equation for the Planck Aether

Because two negative Planck mass particles repel each other, as do two positive Planck mass particles, the outcome of a collision between two negative Planck mass particles is the same as between two positive Planck mass particles, but the outcome of a collision between a positive and negative Planck mass particle is different. Under the assumed force law, a positive and negative Planck mass particle are attracted towards each other. With a negative mass thereby accelerated in a direction opposite to the acceleration of the positive mass, the law of linear momentum conservation is violated even though linear momentum is restored to its original value after the completion of the collision, in contrast to the energy which is conserved during the entire collision process, with the sum of kinetic and potential energies remaining unchanged. A force between a positive and negative mass of equal magnitude obeying Newton's actio = reactio axiom conserving linear momentum would lead to the self-accelerated positive-negative mass dipoles. The only other way a force, accelerating the positive and negative Planck mass particles can be realized is through the constraint that space is densely filled with an equal number of positive and negative Planck mass particles, with each Planck length volume in space occupied in the average by one Planck mass particle.

During the collision of a positive with a negative Planck mass particle, momentum of each Planck mass particle fluctuates by $\Delta \mathrm{p} = \mathrm{m}_p c$, with the total fluctuation in momentum $2m_p c$ compensated by the recoil to the positive and negative Planck mass fluid. This momentum fluctuation is accompanied by an energy fluctuation $\Delta E = \hbar/t_p$, hence

$$\begin{aligned} \Delta p &= \hbar/r_p \\ \Delta E &= \hbar/t_p \end{aligned} \tag{1}$$

Heisenberg's uncertainty relations for momentum and energy are thus explained by the mechanical fluctuations of the positive-negative Planck mass particle fluid, and it is for this reason of no surprise, that Schrödinger's equation for a Planck mass particle can be derived from the Boltzmann equation for such a field.

The Boltzmann equation is given by:

$$\frac{\partial f}{\partial t} + \boldsymbol{v} \cdot \frac{\partial f}{\partial \boldsymbol{r}} + \boldsymbol{a} \cdot \frac{\partial f}{d\boldsymbol{v}} = \int v_{rel}(f' f_1' - f f_1) d\sigma d\boldsymbol{v}_1 \tag{2}$$

where $f$ is the distribution function of the colliding particles, $f', f_1'$ before and $f, f_1$ after the collision, with $f_1'$ and $f_1$ the distribution functions of the particles, which change distribution from $f'$ to $f$ during the collision. The magnitude of the relative collision velocity is $v_{rel}$ and the collision cross section is $\sigma$. The particle number density is $\int f(\boldsymbol{v}, \boldsymbol{r}, t) d\boldsymbol{v}$ and the average velocity $\boldsymbol{V} = \int \boldsymbol{v} f(\boldsymbol{v}, \boldsymbol{r}) d\boldsymbol{v} \mid n(\boldsymbol{r}, t)$. The acceleration is $\boldsymbol{a} = \mp(\frac{1}{m_p})\nabla U$, where $U(t)$ is the potential of a force.

The Boltzmann equation for the distribution function $f_\pm$ of the positive and negative Planck mass particles is

$$\frac{\partial f_\pm}{\partial t} + v_\pm \cdot \frac{\partial f_\pm}{\partial \boldsymbol{r}} \mp \frac{1}{m_p}\frac{\partial U}{\partial \boldsymbol{r}} \cdot \frac{\partial f_\pm}{\partial \boldsymbol{v}_\pm} = 4\alpha c r_\rho^2 \int \left(f'_\pm f'_\mp - f_\pm f_\mp\right) d\boldsymbol{v}_\mp \tag{3}$$

where we have set $\sigma = \left(2r_p\right)^2 = 4r_p^2$ and $v_{rel} = \alpha c$ with $\alpha$ a numerical factor. In (3), $U$ describes the average potential of all Planck mass particles on one Planck mass particle. The constraint keeping constant the average number density of all Planck mass particles leads to a pressure which has to be included in the potential $U$. It can be viewed as a potential holding together by the positive and negative Planck mass particles, which otherwise would fly apart. The effective interaction between the positive and negative Planck mass particles is separated into the short range "Zitterbewegung" part entering the collision integral and the long range average potential part included in the potential $U$.

Because of

$$f'_\pm(\mathbf{r}) = f_\pm(\mathbf{r} \pm \frac{\boldsymbol{r_p}}{\mathbf{2}}) \tag{4}$$

where one has to average over all possible displacements and velocities of the "Zitterbewegung." With the distribution index function $f'$ before the collision set equal the displaced distribution function $f$, the direction of the "Zitterbewegung" velocity is in the opposite direction of the displacement vector $\frac{\mathbf{r}_p}{2}$. With (4) the integrand in the collision integral becomes

$$f'_\pm f'_\mp - f_\pm f_\mp = f_\pm\left(\boldsymbol{r} \pm \frac{\boldsymbol{r}_\rho}{2}\right) f_\mp\left(\boldsymbol{r} \mp \frac{\boldsymbol{r}_\rho}{2}\right) - f_\pm(\boldsymbol{r}) f_\mp(\boldsymbol{r}) \tag{5}$$

Expanding $f_\pm\left(\boldsymbol{r} \pm \frac{\mathbf{r}_\rho}{2}\right)$ and $f_\mp\left(\boldsymbol{r} \mp \frac{\mathbf{r}_\rho}{2}\right)$ into a Taylor series

$$f_\pm\left(\boldsymbol{r} \pm \frac{\boldsymbol{r}_\rho}{2}\right) = f_\pm \pm \frac{\boldsymbol{r}_\rho}{2} \cdot \frac{\partial f_\pm}{\partial \boldsymbol{r}} + \frac{\boldsymbol{r}_\rho^2}{8} \cdot \frac{\partial^2 f_\pm}{\partial \boldsymbol{r}^2} + \cdots$$

$$f_\mp\left(\boldsymbol{r} \mp \frac{\boldsymbol{r}_\rho}{2}\right) = f_\mp \mp \frac{\boldsymbol{r}_\rho}{2} \cdot \frac{\partial f_\mp}{\partial \boldsymbol{r}} + \frac{\boldsymbol{r}_\rho^2}{8} \cdot \frac{\partial^2 f_\mp}{\partial \boldsymbol{r}^2} + \cdots$$

one finds up to second order that

$$f'_\pm f'_\mp - f_\pm f_\mp \cong \pm \frac{\boldsymbol{r}_\rho}{2} \cdot \left(f_\mp \frac{\partial f_\pm}{\partial \boldsymbol{r}} - f_\pm \frac{\partial f_\mp}{\partial \boldsymbol{r}}\right) - \frac{\boldsymbol{r}_\rho^2}{4} \cdot \left(\frac{\partial f_\pm}{\partial \boldsymbol{r}} \cdot \frac{\partial f_\mp}{\partial \boldsymbol{r}}\right) + \frac{\boldsymbol{r}_\rho^2}{8} (f_\mp \frac{\partial^2 f_\pm}{\partial \boldsymbol{r}^2} + f_\pm \frac{\partial^2 f_\mp}{\partial \boldsymbol{r}^2}) \tag{6}$$

with higher order terms suppressed by the Planck length. Because $f_\mp(\boldsymbol{v}_\mp, \boldsymbol{r}, t) \cong f_\pm(\boldsymbol{v}_\pm, \boldsymbol{r}, t)$, one has

$$f'_\pm f'_\mp - f_\pm f_\mp \cong -\frac{\boldsymbol{r}_\rho^2}{4} \cdot \left(\frac{\partial f_\pm}{\partial \boldsymbol{r}}\right)^2 + \frac{\boldsymbol{r}_\rho^2}{4}\left(f_\pm \frac{\partial^2 f_\pm}{\partial \boldsymbol{r}^2}\right) = \left(\frac{\boldsymbol{r}_\rho}{2}\right)^2 f_\pm^2 \frac{\partial^2 \log(f_\pm)}{\partial \boldsymbol{r}^2} = \left(\frac{\boldsymbol{r}_\rho}{2}\right)^2 f_\pm f_\mp \frac{\partial^2 \log(f_\pm)}{\partial \boldsymbol{r}^2} \tag{7}$$

To obtain the net “Zitterbewegung” displacement over a sphere with a volume to surface ratio $\left(\frac{r_\rho}{2}\right)^3 / (\frac{r_\rho}{2})^2 = \frac{r_\rho}{2}$, (8) must be multiplied by the operator $\frac{\mathbf{r}_\rho}{2} \cdot \frac{\partial}{\partial \mathbf{r}}$, and to obtain the corresponding net value in velocity space it must in addition be multiplied by the operator $\boldsymbol{c} \cdot \frac{\partial}{\partial \boldsymbol{v}_\pm}$ with the vector $\boldsymbol{c}$ in the opposite direction to $\boldsymbol{r}_\rho$.

Integrating the r.h.s. of (3) over $dv_\mp$ and setting $\int f_\mp d\boldsymbol{v}_\mp$, the number density of one Planck mass species in the undisturbed configuration of the Planck mass particles filling space, one has

$$\frac{\partial f_\pm}{\partial t} + \boldsymbol{v}_\pm \cdot \frac{\partial f_\pm}{\partial \boldsymbol{r}} \mp \frac{1}{m_p} \cdot \frac{\partial U}{\partial \boldsymbol{r}} \cdot \frac{\partial f_\pm}{\partial \boldsymbol{v}_\pm} = -\frac{\alpha c^2 \boldsymbol{r}_\rho^2}{4} \cdot \frac{\partial^2}{\partial \boldsymbol{v}_\pm \partial \boldsymbol{r}} (f_\pm \frac{\partial^2 log f_\pm}{\partial \boldsymbol{r}^2}) \tag{8}$$

For an approximate solution of (8), one computes its zeroth and first moment. The zeroth moment is obtained by integrating (8) over $d\boldsymbol{v}_\pm$, with the result that

$$\frac{\partial n_\pm}{\partial t} + \frac{\partial (n_\pm \boldsymbol{V}_\pm)}{\partial \boldsymbol{r}} = 0 \tag{9}$$

which is the continuity equation for the macroscopic quantities $n_\pm$ and $\boldsymbol{V}_\pm$. The first moment is obtained by multiplying (8) with $v_\pm$ and integrating over $\partial \boldsymbol{v}_\pm$. Because the logarithmic dependence can be written with sufficient accuracy as $\frac{\partial^2 log(f_\pm)}{\partial \boldsymbol{r}^2} \approx \frac{\partial^2 log(n_\pm)}{\partial \boldsymbol{r}^2}$, one finds

$$\frac{\partial (n_\pm \boldsymbol{V}_\pm)}{\partial t} + \frac{\partial (n_\pm \boldsymbol{V}_\pm)}{\partial \boldsymbol{r}} \cdot \boldsymbol{V}_\pm = \mp \frac{n_\pm}{m_\rho} \cdot \frac{\partial U}{\partial \boldsymbol{r}} + \frac{\alpha c^2 \boldsymbol{r}_\rho^2}{4} \cdot \frac{\partial}{\partial \boldsymbol{r}} (n_\pm \frac{\partial^2 log n_\pm}{\partial \boldsymbol{r}^2}) \tag{10}$$

With the help of (9), this can be written as

$$\frac{\partial \boldsymbol{V}_\pm}{\partial t} + \boldsymbol{V}_\pm \frac{\partial \boldsymbol{V}_\pm}{\partial \boldsymbol{r}} = \mp \frac{1}{m_\rho} \cdot \frac{\partial U}{\partial \boldsymbol{r}} + \frac{\alpha \hbar^2}{4 m_p^2 n_\pm} \cdot \frac{\partial}{\partial \boldsymbol{r}} (n_\pm \frac{\partial^2 log n_\pm}{\partial \boldsymbol{r}^2}) \tag{11}$$

for which one can also write

$$\frac{\partial \boldsymbol{V}_\pm}{\partial t} + \boldsymbol{V}_\pm \frac{\partial \boldsymbol{V}_\pm}{\partial \boldsymbol{r}} = \mp \frac{1}{m_\rho} \cdot \frac{\partial U}{\partial \boldsymbol{r}} + \frac{\alpha \hbar^2}{2 m_p^2} \cdot \frac{\partial}{\partial \boldsymbol{r}} (\frac{1}{\sqrt{n_\pm}} \frac{\partial^2 \sqrt{n_\pm}}{\partial \boldsymbol{r}^2}). \tag{12}$$

The equivalence of (9) and (12) with the one-body Schrödinger equation for a positive or negative Planck mass can now be established by Madelung’s transformation

$$\left.\begin{aligned} n_\pm &= \psi'_\pm \psi_\pm \\ n_\pm \boldsymbol{V}_\pm &= \mp \frac{i\hbar}{2 m_\rho} [\psi_\pm^* \nabla \psi_\pm - \psi_\pm \psi_\pm^*] \end{aligned}\right\} \tag{13}$$

transforming the equation of a Planck mass $\pm m_\rho$

$$i\hbar \frac{\partial \psi_\pm}{\partial t} = \mp \frac{\hbar^2}{2 m_\rho} \nabla^2 \psi_\pm + U(\boldsymbol{r}) \psi_\pm \tag{14}$$

into

$$\left.\begin{aligned}\frac{\partial n_\pm}{\partial t}+\frac{\partial(n_\pm \boldsymbol{V}_\pm)}{\partial \boldsymbol{r}}=0\\ \frac{\partial \boldsymbol{V}_\pm}{\partial t}+\boldsymbol{V}_\pm\frac{\partial \mathbf{V}_\pm}{\partial \boldsymbol{r}}=\mp\frac{1}{m_\rho}\frac{\partial}{\partial \boldsymbol{r}}[U+Q_\pm]\end{aligned}\right\} \tag{15}$$

where

$$Q_\pm=\mp\frac{\hbar^2}{2m_\rho}\cdot\frac{1}{\sqrt{n_\pm}}\cdot\frac{\partial^2\sqrt{n_\pm}}{\partial \boldsymbol{r}^2} \tag{16}$$

is the so-called quantum potential. By comparison with (9) and (12), one finds full equivalence for $\alpha=1$, that is for $v_{rel}=c$.

The uncertainty in quantum mechanics is not seen here due to a fundamental noncausal structure, but rather the consequence of the principal inability to make measurements for distances and times smaller than $\boldsymbol{r}_\rho$ and $t_\rho$.

## 4. Quantum Mechanics of the Densely Packed Assembly of Positive and Negative Planck Mass Particles

Having established quantum mechanics for a single Planck mass particle with a dense assembly of positive and negative Planck mass particles, a quantum mechanical description of the many body problem for all the Planck mass particles can be given, It is achieved 1) by setting the potential $U$ in (15) equal to

$$U = 2\hbar c r_\rho^2[\psi_+^*\psi_+ - \psi_-^*\psi_-] \tag{17}$$

2) by replacing the field functions $\psi_\pm, \psi_\pm^*$ with the operators $\psi_\pm, \psi_\pm^\dagger$, obeying the canonical commutation relations

$$\left[\psi_\pm(\boldsymbol{r})\psi_\pm^\dagger(\boldsymbol{r})\right] = \delta(\boldsymbol{r}-\boldsymbol{r}'), [\psi_\pm(\boldsymbol{r})\psi_\pm(\boldsymbol{r}')] = [\psi_\pm^\dagger(\boldsymbol{r})\psi_\pm^\dagger(\boldsymbol{r}')] = 0 \tag{18}$$

whereby (15) becomes the operator field equation

$$i\hbar\frac{\partial\psi_\pm}{\partial t} = \mp\frac{\hbar^2}{2m_\rho}\nabla^2\psi_\pm \pm 2\hbar c r_\rho^2(\psi_\pm^\dagger\psi_\pm - \psi_\mp^\dagger\psi_\mp)\psi_\pm \tag{19}$$

We justify this as follows: 1) an undisturbed dense assembly of Planck mass particles, each particle occupying the volume $r_\rho^3$, has the expectation value $< \psi_\pm^*\psi_\pm > = \frac{1}{2}r_\rho^3$, whereby $2\hbar c r_\rho^2 < \psi_\pm^*\psi_\pm > = m_p c^2$, implying an average potential energy $\pm m_\rho c^2$ for the positive and negative Planck mass particles within the assembly of all Planck masses, consistent with the value of the potential $F_\rho r_\rho = m_\rho c^2$ of the Planck force acting over the distance $r_\rho$. The interaction term between the positive and negative Planck mass fluid results from the constraint demanding that the number density of Planck mass particles shall (in the average) be equal to $1/2r_\rho^3$. 2) The rules of quantum mechanics for one Planck mass imply the one-particle commutation rule $[p,q] = \frac{\hbar}{i}$, for which a many-particle system of Planck mass particles leads to the canonical commutation relation (18) applied to the operator field equation (19) describing the many Planck mass particle system.

Equation (19) has the form of a nonrelativistic nonlinear Heisenberg equation, similar to Heisenberg's nonlinear spinor field equation proposed by him as a model of elementary particles. The two values for the chirality of the zero rest mass spinors in his equation are relaced by the two signs for the Planck mass $m_\rho$ in the kinetic energy term of (19). The limiting mass conjectured by Heisenberg to separate the Hilbert space I, containing states of positive norm from those of Hilbert space II having those of negative norm, becomes the Planck mass. But in contrast to Heisenberg's relativistic spinor equation, (19) is nonrelativistic. The Hilbert space derived from it is, for this reason, always positive definite.

## 5. Hartree and the Hartree-Fock Approximation

To obtain solutions of the nonlinear quantized field equation (19), suitable nonperturbative approximation methods must be used. Perturbation theory would contradict the spirit of the theory, because before perturbation theory can be applied, a spectrum of elementary particles should be derived nonperturbatively. Fortunately, this is possible for a nonrelativistic theory. The most simple nonperturbative method which can be used to obtain approximate solutions of (19) is the self-consistent Hartree approximation.

In the Hartree approximation, one sets the expectation value of the product of three field operators equal to the product of their expectation values:

$$\begin{aligned} <\psi_\pm^\dagger \psi_\pm \psi_\pm> &\cong \phi_\pm^* \phi_\pm^2 \\ <\psi_\mp^\dagger \psi_\mp \psi_\pm> &\cong \phi_\mp^* \phi_\mp \phi_\pm \end{aligned} \tag{20}$$

where $<\psi_\pm> = \phi_\pm, <\psi_\pm^\dagger> = \phi_\pm^*$. Taking the expectation value of (19), one obtains in this approximation:

$$i\hbar \frac{\partial \phi_\pm}{\partial t} = \mp \frac{\hbar^2}{2m_\rho} \nabla \phi_\pm^2 \pm 2\hbar c r_\rho^2 [\phi_\pm^* \phi_\pm - \phi_\mp^* \phi_\mp] \phi_\pm \tag{21}$$

which is the classical field equation.

However, if the temperature of the Planck aether is close to absolute zero, each component is superfluid and should therefore be described by a completely symmetric wave function. Under these circumstances, the Hartree approximation has to be replaced by the more accurate Hartree-Fock approximation, taking into account the exchange interactions neglected in the Hartree approximation. In the Hartree-Fock approximation, one has to consider the symmetric wave function of two identical Planck masses

$$\psi(1,2) = \frac{1}{\sqrt{2}} [\phi_1(\boldsymbol{r})\phi_2(\boldsymbol{r}') + \phi_1(\boldsymbol{r}')\phi_2(\boldsymbol{r})]$$

There, the expectation value for a delta-function-type contact interaction between the identical Planck mass particles is

$$<\psi(1,2)|\delta(\boldsymbol{r} - \boldsymbol{r}')|\psi(1,2)> = 2\phi_1^2(\boldsymbol{r})\phi_2^2(\boldsymbol{r})$$

with the direct and exchange integrals making an equal contribution. One therefore has to put instead of (20)

$$\begin{aligned} <\psi_\pm^\dagger \psi_\pm \psi_\pm> &\cong 2\phi_\pm^* \phi_\pm^2 \\ <\psi_\mp^\dagger \psi_\mp \psi_\pm> &\cong \phi_\mp^* \phi_\mp \phi_\pm \end{aligned}$$

In this approximation, one obtains from (18):

$$i\hbar \frac{\partial \phi_\pm}{\partial t} = \mp \frac{\hbar^2}{2m_\rho} \nabla^2 \phi_\pm \pm 2\hbar c r_\rho^2 [2\phi_\pm^* \phi_\pm - \phi_\mp^* \phi_\mp] \phi_\pm \tag{22}$$

In the Hartree-Fock approximation the twice as large interaction between identical Planck masses results from the completely symmetric wave function of the superfluid state, which is the Ginzburg-Landau equation.

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Lieber Winterberg!

Haben Sie vielen Dank für Ihren Sonderdruck über die Möglichkeit einer Kontrolle der relativistischen Zeitdilatation durch die künstlichen Satelliten. Ich finde die von Ihnen erwähnte Möglichkeit sehr interessant, habe mich aber schon so viele Jahre nicht mehr mit allgemeiner Relativitätstheorie beschäftigt, daß ich zu den Einzelheiten Ihrer Rechnungen im Augenblick keine Meinung äußern möchte.

Sie werfen am Schluß Ihres Briefes noch die Frage auf, ob die allgemeine Relativitätstheorie auch für die Theorie der Elementarteilchen von Bedeutung sei. Zu diesem Punkt habe ich eine bestimmte Meinung. Ich glaube nämlich, daß man alle Gravitationseffekte völlig vernachlässigen kann, so lange man auch die sogenannte schwache Wechselwirkung (die für den radioaktiven Betazerfall maßgebend ist) außer Betracht läßt. Für die Berechnung des Massenspektrums der Elementarteilchen wird weder die sogenannte schwache Wechselwirkung noch die Gravitation von Bedeutung sein. Ich vermute aber, daß die Berücksichtigung der schwachen Wechselwirkung auch zu einem Verständnis der Gravitation führen wird, und daß an dieser Stelle dann der Gedankenkreis der Quantenfeldtheorie mit dem der allgemeinen Relativitätstheorie in Verbindung treten wird. Aber es werden wohl noch einige Jahre vergehen, bis man in der Quantenfeldtheorie bis zu dieser Verbindungsstelle vorgedrungen sein wird.

Mit vielen Grüßen, auch an Professor Bagge,

Ihr W. Heisenberg

**Translation of Letter by Heisenberg**

**November 28, 1957**

Dear Winterberg,

many thanks for your reprint about the possibility to test the relativistic time dilation by artificial satellites. I consider your mentioning this possibility very interesting, however, since I have for many years not done anything in general relativity, I do not wish to voice an opinion on the details of your calculations.

At the end of your letter you raise the question, if the general theory of relativity could be of importance in the theory of the elementary particles. About this point I have a definite opinion. I believe, that one can completely neglect all gravitational effects, as long as one also neglects the weak interaction (which is responsible for the radioactive beta-decay). For the determination of the mass spectrum of the elementary particles, neither the weak nor the gravitational interaction is going to be of importance. However, I suspect that the inclusion of the weak interaction is going to lead also to an understanding of gravitation, and that at this place the ideas underlaying quantum field theory are going to find a connection with those of the general theory of relativity. But quite a few years are going to pass before the quantum field theory has advanced that far.

With many greetings
also to Professor Bagge

Yours

Fig. Epilogue: Letter from W. Heisenberg and its Translation