Kerr-Newman Spinning Particle in the Problem of Compatibility of Quantum Theory With Gravity

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Abstract

As is known the Kerr-Newman (KN) solution corresponds to gravitational and electromagnetic fields of an electron. Contrary to the widespread opinion that the role of gravity is negligible, we show that the exclusively high spin/mass ratio of the electron ($\approx 10^{22}$) creates strong deformation of the KN metric. It requires regularization of KN background for consistent description of quantum processes in the Compton zone. We show that the regularized KN background takes the properties of a bag model, similar to known MIT and SLAC bag models, but with important advantage of consistency with gravity. The bag is formed by ellipsoidal domain-wall (DW) which interpolates between the flat and supersymmetric core of spinning particle and the external classical KN solution. The spinning particle emerges as a quantum Bag-String-Quark system, in which the confined Quark is identified with the pointlike Dirac electron.

Kerr-Newman (KN) solution takes central place in theoretical physics, permeating from Cosmology to Microcosm. However, conceptual influence KN solution are more important and apparently has not been assessed yet.

One of the inconsistency between Quantum theory and Gravity is the pointlike, structureless electron which conflicts with the required by Einstein equations *field model* of particle. As is known, the KN solution corresponds to gravitational and electromagnetic field of the electron, and structure of the source of KN solution could shed light on this principal problem of theoretical physics [1].

The idea that black holes (BH) are akin to elementary particles is very old [2]. The source of Schwarzschild solution is a singular point. The BH horizon forms a shell covering this source, and for BH with large charge, $|e| > M$, this shell disappears. The BH is defined as "BHshell + point", however, namely peculiarities of the shell determine it as BH. Similarly, the quantum electron is pointlike and structureless, but it has the shell of virtual photons forming the system "ELshell + point". Like the BH, features of electron are defined by shell.

Recall that Einstein, Schrodinger and de Broglie objected against structureless electron. Similarly, Dirac (1962) [3] considered model of "extensible electron" – prototype of the bag model.

The complex "BH + string" appears naturally in the rotating BH, where Kerr singular ring forms fundamental string solution to low energy string theory [4, 5, 6, 7].

Development of this analogy is hampered by weakness of the gravitational interaction. Estimations based on Schwarzschild solution indicated that elementary particles disturb metric only at the Planck scale, about $10^{-33}cm$, and thus, Einstein gravity should be negligible for sub-atomic particles. These estimates are basis for superstring theory – introduction of the extra compact dimensions and transfer to Planck scale where the string looks like point particle!

Contrarily, estimations based on the KN solution demonstrate that *the Einstein-Maxwell gravity is not weak*, and doesn't need extra dimensions and compactifications. Reason for this is the giant spin/mass ratio of the elementary particles.

Angular momentum of Kerr geometry J for parameters of electron exceeds mass m about 22 order (in the dimensionless units $G = c = \hbar = 1$). In this case, called the ultra-rotating Kerr geometry, the BH horizons disappear and there appears the naked Kerr singular ring, which is branch line of the Kerr space into two sheets, forming a stringlike topological defect of the space-time, see Fig.1.

Radius of the ring $a = \hbar/2m$ is the Compton wavelength of electron, and thus, the very weak gravitation field of the electron causes drastic distortion of the Minkowski background on the Compton distances and spoils completely the necessary conditions for application of Quantum Theory. *How can we say now that Einstein-Maxwell gravity*

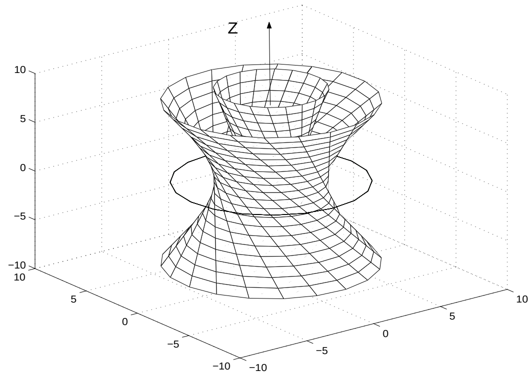

Figure 1: Vortex of the Kerr congruence. Twistor null lines are focused on the Kerr singular ring, forming a gravitational waveguide, or circular lightlike string.

weak?

Carter obtained [8, 9] that the KN solutions has double gyromagnetic ratio as that of the Dirac electron. As a result, the external gravitational and electromagnetic fields of the electron are correctly described by the KN solution.

The singular *metric should be regularized* to a flat space-time to ensure action of quantum theory. The regular source of KN solution was specified step by step by many authors during about four decades. During regularization, the region near Kerr singular ring is replaced by a flat vacuum state, and source of the KN solution turns into vacuum bubble.

The Kerr-Schild form of metric [8]

$$g_{\mu\nu} = \eta_{\mu\nu} + 2Hk_\mu k_\nu, \quad H = \frac{mr - e^2/2}{r^2 + a^2 \cos^2\theta} \tag{1}$$

in which $\eta_{\mu\nu}$ is metric of auxiliary Minkowski space M^4, (signature $(- + ++)$), H is a scalar function, r and θ are ellipsoidal coordinates and k_μ is a null vector field, $k_\mu k^\mu = 0$, forming a vortex polarization of Kerr space-time – the Principal Null Congruence (PNC) $\mathcal{K}$. The surface $r = 0$ represents a disklike "door" from negative sheet $r < 0$ to positive one $r > 0$. The smooth extension of the solution from retarded to advanced sheet (together with smooth extension of the Kerr PNC) occurs via disk $r = 0$ spanned by the Kerr singular ring $r = 0, \ \cos\theta = 0$ (see fig.1). The null vector fields $k^{\mu\pm}(x)$ turns out to be different on these sheets, and two different null congruences $\mathcal{K}^\pm$, create two different metrics $g^\pm_{\mu\nu} = \eta_{\mu\nu} + 2Hk^\pm_\mu k^\pm_\nu$ on the same Minkowski background.

This mysterious feature of the Kerr geometry created diverse models for source of the KN solution. Relevant "regularization" of this space was suggested by López [10], who excised singular region together with negative sheet and replaced it by a regular core with a flat internal metric $\eta_{\mu\nu}$, forming a *vacuum bubble* which must be matched with external KN solution. Boundary of the bubble $r = R$, is determined as the surface of "zero gravity potential"

$$H|_{r=R}(r) = 0, \tag{2}$$

which yields

$$R = r_e = \frac{e^2}{2m}. \tag{3}$$

Since r is the Kerr oblate ellipsoidal coordinate, see Fig.2, for $R > 0$ bubble covers the Kerr singular ring, forming a thin rotating disk of the Compton radius $r_c \sim a = \hbar/mc$, with degree of oblateness r_e/r_c corresponding to fine structure constant $r_e/r_c \sim e^2 = \alpha \sim 137^{-1}$.

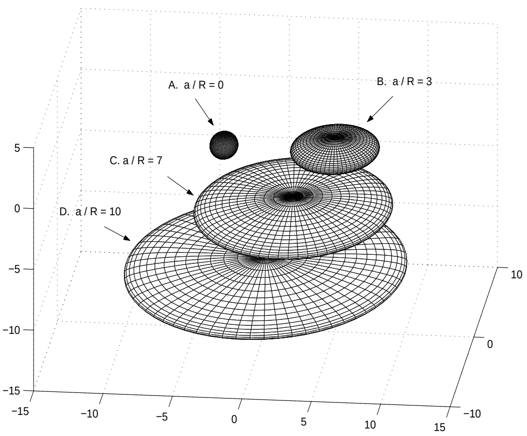

Figure 2: (A): Nonrotating spherical bag, $a/R = 0$, and the rotating bags with (B): $a/R = 3$;(C): $a/R = 7$, (D):$a/R = 10$.

Development of the López bubble model led unambiguously to the source of KN solution as a bag model [11, 12, 13] similar to the known MIT and SLAC bag models for hadrons, [15, 14]. The KN bag is formed by a supersymmetric domain wall [12, 13] interpolating between flat interior controlled by Quantum theory and classical external space-time controlled by KN Gravity. The conflict between Quantum Theory and Gravity is avoided by the conditions:

PI: the internal space-time – zone action of quantum theory is flat,

PII: the exterior is zone of classical Gravity – KN solution,

PIII: Smooth Domain Wall separates zones PI and PII along the surface of "zero gravity potential", (2), (3).

The requirements **PI–PIII** are satisfied by supersymmetric scheme of phase transition and the boundary **PIII** is precisely determined by Bogomolnyi bound [13]. Thus, **the shape, dynamics and stability of the bag are determined by supersymmetry.**

There are several principal features of the bag models. One of them is incorporation of fermionic sector, i.e. the Dirac equation which acquires the mass term from the Higgs field via Yukawa coupling [14]. Boundary of the bag is form by a domain-wall interpolating between external KN solution and flat internal pseudo-vacuum state. Phase transition between these states is controlled by the Higgs mechanism of symmetry breaking. The condition **PII** requires the Higgs condensate be enclosed *inside the bag,* that determines the use of *supersymmetric scheme of the phase transition with three chiral fields* $\Phi^{(i)}$, $i = 1, 2, 3$. One of the fields, say $\Phi^{(1)}$, is identified as the Higgs field Φ, and we set new notations

$$(\Phi, Z, \Sigma) \equiv (\Phi^1, \Phi^2, \Phi^3). \tag{4}$$

Supersymmetry determines two vacuum states, [16, 12]: **(I)** internal: $r < R - \delta$, $V(r) = 0$, $|\Phi| = \eta = const.$ and **(II)** external: $r > R + \delta$, $V(r) = 0$, $\Phi = 0$, separated by a positive spike of potential V in the flat transition zone $R - \delta < r < R - \delta$.

Due to condition **PI**, bag is placed in flat region, and domain wall phase transition may be considered with flat metric, $g_{\mu\nu} = \eta_{\mu\nu}$. Therefore the domain wall boundary of the bag and the bag as a whole are not dragged by rotation. Because of that, the supersymmetric interior is described by simple Hamiltonian

$$H^{(ch)} = T_0^{\ 0(ch)} = \frac{1}{2} \sum_{i=1}^{3} \ [\sum_{\mu=0}^{3} |\mathcal{D}_\mu^{(i)} \Phi^i|^2 + |\partial_i W|^2], \tag{5}$$

where the covariant derivatives $\mathcal{D}_\mu^{(i)} \equiv \partial_i - ieA_\mu^i$ are flat.

We note that although metric is flat, *influence of gravity is saved in the shape of the bag and also in dragging of the vector potential*, leading to two important results, [12, 13]:

(A) the Higgs field *oscillates* with the frequency $\omega = 2m$,

(B) the KN vector potential forms closed loop along boundary of the bag in equatorial plane, see Fig.3, leading to *quantization of angular momentum* $J = n/2, \quad n = 1, 2, 3, ...$

The typical bags are flexible and can form stringlike shape [14, 17]. In particular, meson takes the form of fluxtube which holds together the quark-antiquark pair. Similarly, a closed ring-string is created along the sharp boundary of the disk-like KN bubble, see

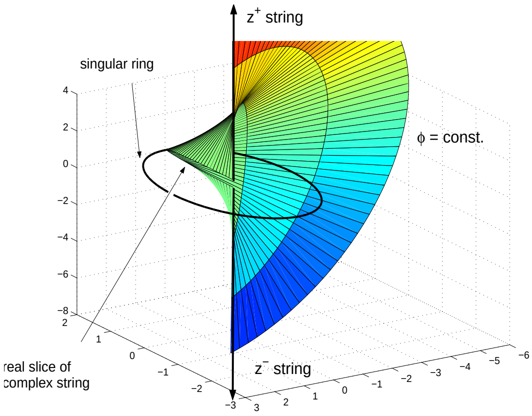

Figure 3: Kerr's coordinate $\phi = const$. Vector potential, dragged by singular ring, forms closed loop along edge border of bag.

Fig.6. This string gets electromagnetic excitations in the form of traveling pp-waves [4, 13], and as the consequence of requirements **PI-PIII**, there appears a circulating singular pole [13] imitating zitterbewegung of the Dirac naked electron [18]. This pole can also be associated with a single quark described by the Dirac equation consistent with KN gravity, [12], and finally, the KN bag takes the form of a coherent "bag-string-quark" system [13]. The amazing similarity between zitterbewegung of the naked electron along perimeter of the bag and the light-like motion of the quarks confined inside the hadrons shows that electrons and hadrons indeed have a similar structure.

Remarkable properties of *supersymmetry* allows us to understand the connection with QED. Perturbative approach for supersymmetric field theory is developed as a direct extension of ordinary perturbation theory [16], and Feynman rules are stated in terms of superfield vertices and propagators which have miraculous cancelations between components of the superfield diagram. In particular, all contributions to mass renormalization, cancel between the various component fields [16].

KN geometry predicts dramatic conceptual changes in the modern theoretical physics indicating that:

- Einstein's gravity is not weak and needs no extra dimensions and compactification,
- Supersymmetric bag-like electron model ensures consistency between gravity and quantum theory.

The modern theoretical physics, enriched with the Kerr geometry, supersymmetry, string theory and the Higgs mechanism of symmetry breaking in the past 50 years, once again leads us to geometric ideas of Einstein, Schrodinger, Dirac and de Broglie.

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