Spinning particle as a Kerr-Newman black hole: supersymmetry in the problem of unification quantum theory with gravity

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Based on: ***A.B., Illusion of the Weakness of Gravity...*** **arXiv:1701.01025,**
A.B., ***Gravitating Lepton Bag Model*** , **JETP, v.148 (8), 228 (2015),**
A.B., ***Stability of the Lepton Bag Model ...***, **JETP, v.148(11), 937 (2015), arXiv:1706.02979,**
A.B., Source of the Kerr-Newman solution ... **Phys.Lett. B754, 99 (2016), arXiv:1602.04215.**

The Kerr-Newman black hole as electron model.

In 1986 B. Carter mentioned [Phys.Rev. 174, 1559] that the Kerr-Newman (KN) black hole solution with parameters of an electron (mass m, charge e, and angular momentum $J = am = \frac{\hbar}{2}$) has the magnetic momentum $\mu = ea$, and thus its gyromagnetic ratio $J/\mu = m/e$ is the same as that of the Dirac electron.

Indeed, for parameters of electron, $e^2 + a^2 >> m^2$, horizons disappear, and the KN solution represents *not black hole*, but *a naked Kerr singular ring, which represents a topologically non-trivial two-sheeted space similar to wormhole or the Einstein-Rosen bridge.*.

However, following the recent work in this direction

However, following the recent work in this direction by N. Arkani-Hamed et.al. *Kerr Black Holes as Elementary Particles,* arXiv:1906.10100 we retain conventionally the term black hole in our title.

Unification of Quantum theory and Gravity – main problem of the modern physics.

Black holes are consistent with gravity by nature! Kerr-Newman black hole displays several properties of quantum particle – electron.

CONCEPT of the WEAK GRAVITY. Superstring theory and Loop Quantum gravity are based on Planck scale 10^{-33}cm which first originated as "invisible" fundamental length in Kaluza-Klein theory.

Gravity is negligible and estimated by Schwarzschild "gravitational radius"

$$\mathbf{R_g = 2Gm}. \tag{1}$$

Spinning KN black hole differs radically from the Schwarzschild solution. Main feature is the Kerr singular ring. For parameters of electron: mass m, charge e, spin $J = \hbar/2$, radius of singular ring is reduced *Compton radius*

$$\mathbf{a} = \frac{\hbar}{\mathbf{2mc}} \tag{2}$$

Under condition $a^2 + e^2 >> m^2$ the black hole horizons disappear, and *the naked Kerr singular ring creates diverging gravitational field on the Compton scale* [Carter (1968), Israel (1970), López (1984).]

The negative sheet of KN solution was initially considered as a drawback.

W. Israel (1970) proposed to *truncate negative sheet*, replacing it by a consistent matter distribution, and to consider the truncated KN solution as electron model.

Debney, Kerr and Schild (1969) showed that the KN electron has correct asymptotic properties.

However, the *naked Kerr singular ring required a regularization*.

López (1984) suggested a *regularization of the KN solution by cut-off the diverging gravitational and electromagnetic field* at some small radial distance $r < r_e$ from the Kerr singular ring.
López's regularization created *a flat core of the electron model*, forming a free from gravity and electromagnetic field vacuum bubble.

***Regularization with cut-off singularity* created *strong boundary effect: interaction with gravity via Wilson loops* [A.B. (PHPL 2000), (Grav.Cosmol. 2020)], which was not considered before in SM of particle physics.**

The KN electron model is based on the classical solutions of the Einstein-Maxwell equations, and *it is the most natural way to study the effect of gravity on particle physics.*

The transition from the Planck scale to the Compton scale is too sharp and unexpected which causes a natural distrust to KN electron model.

***Weak point is that KN model is pure classical* (action of the Wilson loops is also classical effect) and the main problem is specification of *the quantum aspects of the KN black hole electron* model.**

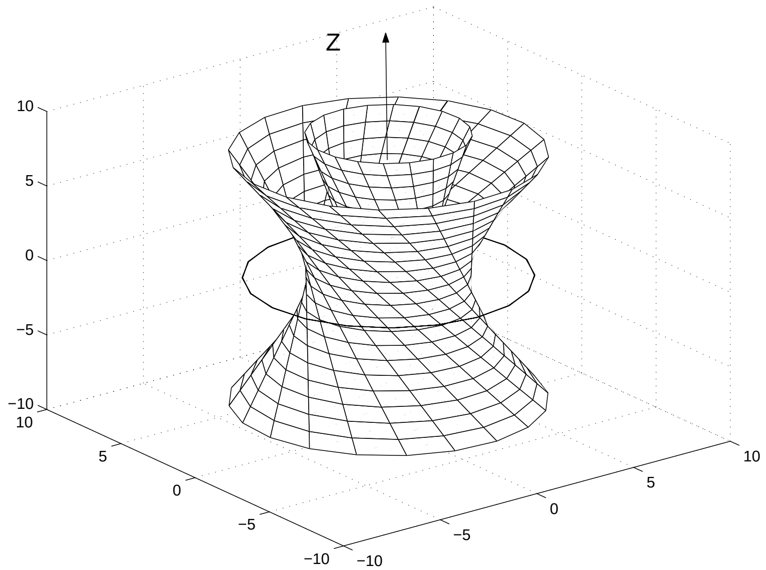
We obtain that the Israel and López models of the KN electron *are not full*, and may be considered as a *bare electron* forming the quantum *dressed electron-positron system consistent with QED.*

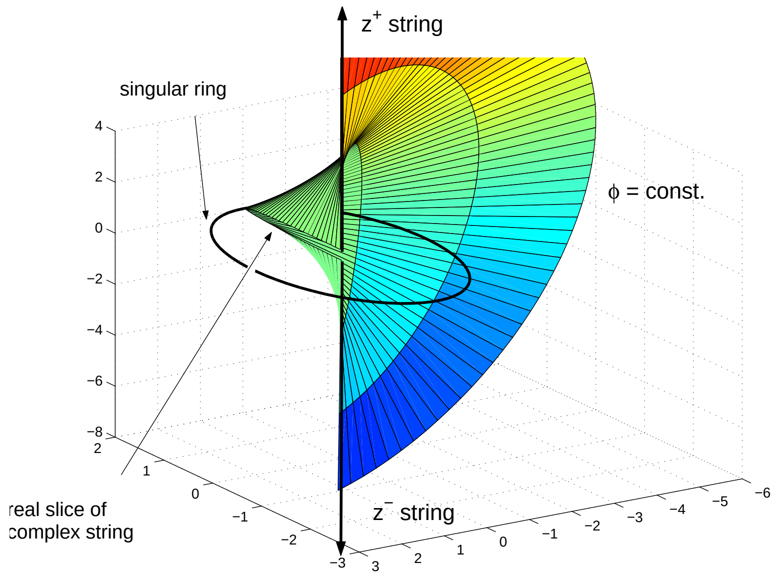
A specific classical stringy system – noncritical 4D Nambu-Goto string model [Adrian PATRASCIOIU, QUANTUM DYNAMICS OF A MASSLESS RELATIVISTIC STRING, Nuclear Physics B81 (1974) 525].

Kerr singular ring is branch line of the two-sheeted KN space.

Structure of the KN solution is defined by the field of Principal Null Congruence $\mathbf{k}^\mu(\mathbf{x})$ – direction of gravitational frame-dragging.

$$\mathbf{g}^{\mu\nu} = \eta^{\mu\nu} + \mathbf{2H}(\mathbf{r}, \theta)\mathbf{k}^\mu \mathbf{k}^\nu, \quad \mathbf{A}^\mu = \frac{-\mathbf{er}}{\mathbf{r^2} + \mathbf{a^2}\cos^2\theta}\mathbf{k}^\mu, \quad \mathbf{H} = \frac{\mathbf{mr} - \mathbf{e}^2/2}{\mathbf{r^2} + \mathbf{a^2}\cos^2\theta}$$





The over-rotating KN solution has no horizons and looks like wormhole or the Einstein-Rosen bridge. *The Kerr disk*, bounded by Kerr singular ring, plays the role of a neck connecting the positive and negative half-spaces $\mathbb{M}^\pm$ with *two different metrics $g^\pm_{\mu\nu}$, related with two congruencies $k^\pm_\mu$*.

Shape and size of the Kerr-Newman electron is *fixed by gravity.*

Israel (1970) truncated negative sheet of KN space, identifying positive sheet with electron.

López (1985) complemented the external KN solution with a FLAT CORE obtained by regularization

$$\mathbf{g}^{(\mathbf{KN})}_{\mu\nu} = \eta_{\mu\nu} + \mathbf{2H}_{(\mathbf{KN})}\mathbf{k}_\mu \mathbf{k}_\nu, \quad \text{where} \quad \mathbf{H}_{(\mathbf{KN})} = \frac{\mathbf{mr} - \mathbf{e}^2/\mathbf{2}}{\mathbf{r}^2 + \mathbf{a}^2 \cos^2\theta},$$

where r is oblate spheroidal coordinate.

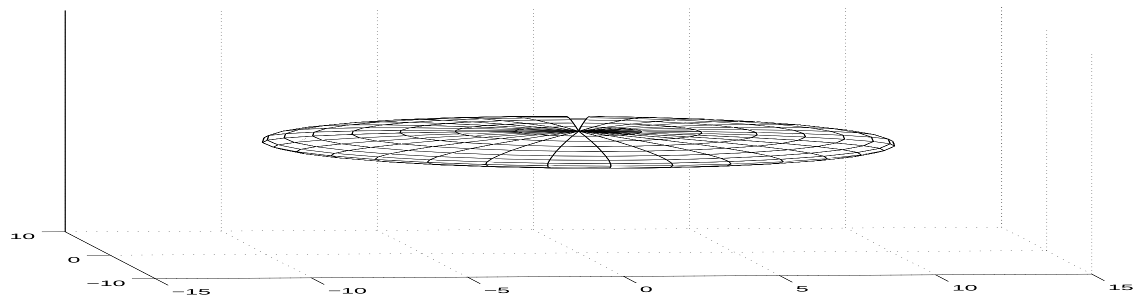


Figure 1: **Ellipsoidal CORE of the Kerr-Newman electron.**

Gravity controls radius and shape of the electron CORE: setting $H_{(KN)} = 0$ we obtain boundary of bag at $r = R_e = e^2/2m$, and flat interior at $g^{(KN)}_{\mu\nu} = \eta_{\mu\nu}$. CORE takes form of a thin ellipsoidal disk fixed by fine structure constant α. Since $a = J/m = \hbar/2m$, and $R_e = e^2/2m, \Rightarrow R_e/a = e^2/\hbar = \alpha$, a Wilson loop of potential A^{max}_μ is formed on the sharp border of the Kerr disk.

Emergence of the DIRAC eq. from twistor structure of the Kerr geometry.

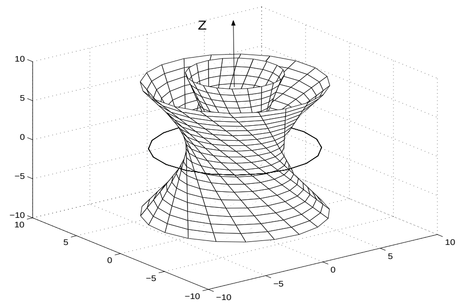


Figure 2: The lightlike Kerr congruence k^μ.

KERR THEOREM: Geodesic and Shear-free congruences $\mathbf{k^\pm(x)}$ ***are obtained as analytic solutions of the equation*** $\mathbf{F(T^a) = 0}$, ***where*** F ***is a holomorphic function of the projective twistor coordinates***

$\mathbf{T^a = \{Y, \quad \zeta - Yv, \quad u + Y\bar\zeta\}}$.

$\mathbf{Y^+ = \phi_1/\phi_0}$, **is equivalent to Weyl spinor** ϕ_α **and** $\mathbf{Y^-}$, **to** $\bar\chi^{\dot\alpha}$.

TWISTOR $\Leftrightarrow$ **SPINOR relation is origin of the Dirac field.**

Dirac equation splits in the Weyl representation into two equations

$$\sigma^\mu_{\alpha\dot\alpha}\mathbf{i}\partial_\mu\bar\chi^{\dot\alpha} = \mathbf{m}\phi_\alpha, \quad \bar\sigma^{\mu\dot\alpha\alpha}\mathbf{i}\partial_\mu\phi_\alpha = \mathbf{m}\bar\chi^{\dot\alpha}, \tag{3}$$

the "left-handed" and "right-handed" electron fields.

Two antipodally conjugate solutions of the Kerr theorem $Y^+ = -1/\bar Y^-$ **determine two Weyl spinor fields** ϕ^α **and** $\bar\chi_{\dot\alpha}$, **corresponding to antipodal congruences** $\mathbf{Y^+ = \phi_1/\phi_0}$, $\mathbf{Y^- = \bar\chi^{\dot 1}/\bar\chi^{\dot 0}}$

For Y^+ we have

$$\phi_\alpha = \begin{pmatrix} e^{-i\phi/2}\cos\frac{\theta}{2} \\ e^{i\phi/2}\sin\frac{\theta}{2} \end{pmatrix}, \qquad (4)$$

and for $\mathbf{Y^- = -1/\bar{Y}^+}$,

$$\bar{\chi}^{\dot{\alpha}} = \begin{pmatrix} -e^{-i\phi/2}\sin\frac{\theta}{2} \\ e^{i\phi/2}\cos\frac{\theta}{2} \end{pmatrix}. \qquad (5)$$

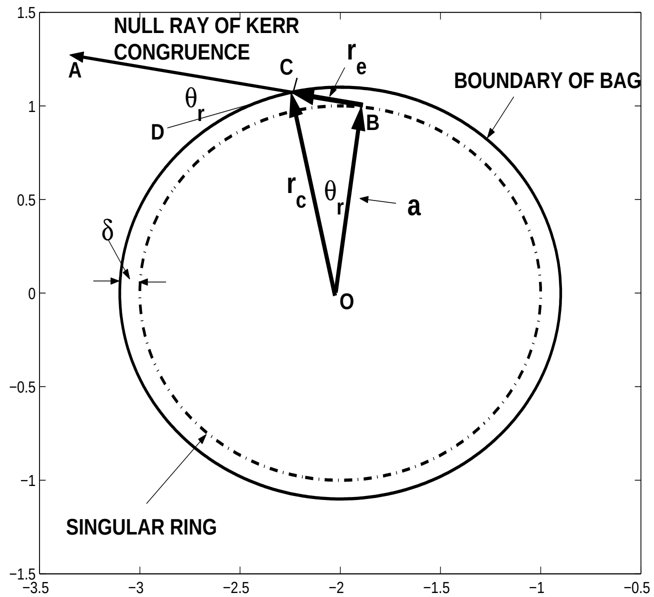


Figure 3: **Kinematic relation in the equatorial plane** $\cos\theta = 0$. **A light-like beam of the Kerr congruence crosses edge of the bag at angle** $\theta_{\mathbf{c}} = \arctan \mathbf{r_e}/\mathbf{a} \sim \alpha$ **.**

Kerr's stringy structure. Orientifold string.

The Kerr singular ring as a circular string – "gravitational waveguide" for traveling EM waves (pp-waves), (A.B. 1974. A.B.& Ivanenko 1975.)
Kerr singular ring is lightlike, and coordinate system is dragged by ring.
String is formed by sharp border of the bag, and it can be identified with the Kerr singular ring up to the cut-off parameter $\delta \sim \alpha^2$
The Kerr string is light-like and can be considered as tangential to the Kerr singular ring

$$\mathbf{k}^+_\mu \mathbf{dx}^\mu = (\mathbf{dt} - \mathbf{a d}\phi_\mathbf{K}) \tag{6}$$

Really, the string direction $d\phi$ deviates slightly from the lightlike direction of the Kerr congruence k^+_μ, and the real velocity of the bag border becomes smaller than the speed of the light.
This effect can be described as a small component A^-_μ in direction

$$\mathbf{k}^-_\mu \mathbf{dx}^\mu = (\mathbf{dt} + \mathbf{a d}\phi_\mathbf{K}), \tag{7}$$

which is opposite (antipodal) to k^+_μ. The potentials A^+_μ and A^-_μ form two closed Wilson loops as two half-string at the bag border, forming the lift and right modes of string excitation

$$\mathbf{A}^{\mathbf{max}}_\mu \mathbf{dx}^\mu = \mathbf{A}^+_\mu \mathbf{dx}^\mu + \mathbf{A}^-_\mu \mathbf{dx}^\mu \approx -\frac{\mathbf{2m}}{\mathbf{e}}(\mathbf{dt} - \mathbf{a d}\phi_\mathbf{K}) + \mathbf{A}^-_\mu(\mathbf{dt} + \mathbf{a d}\phi_\mathbf{K}). \tag{8}$$

Orientifold D-string. [A.B. ***Phys.Rev.*D** (2003)] **A non-critical Nambu-Goto ring string**

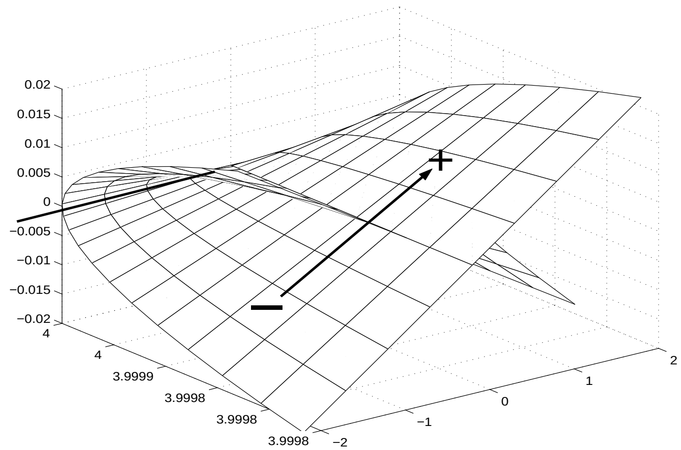


Figure 4: **Möbius structure of the Kerr coordinate ϕ_K generated by Kerr congruence k^μ.**

with orientifold world-sheet is consistent with KN solution, and forms the "left" and "right" surface currents J^-_μ and J^+_μ created by the "left" and "right" Wilson loops of the vector potentials A^-_μ and A^+_μ concentrated on the *sharp border of the bi-sided supercon-ducting Kerr disk*, created by supersymmetric *Landau-Ginzburg* [ZhETP, 20, 1064 (1950)] field model of phase transition

$$\Box \mathbf{A}_\mu = \mathbf{J}^-_\mu + \mathbf{J}^+_\mu = \mathbf{e}[|\mathbf{\Psi}^+|^2(\chi^+,_\mu + \mathbf{e}\mathbf{A}^+_\mu) + |\mathbf{\Psi}^-|^2(\chi^-,_\mu - \mathbf{e}\mathbf{A}^-_\mu)] \quad (=0).$$

The world-sheet coordinates $\chi^- = t - \sigma$ and $\chi^+ = t + \sigma$, (here $\sigma = a\phi \in [0, 2\pi]$) which are phases of Higgs fields $H_+ = \Psi^+$ and $H_- = \Psi^-$, form the left and right modes of the KN ring string model.)

Landau-Ginzburg phase transition. Formation of the disk-like BAG.

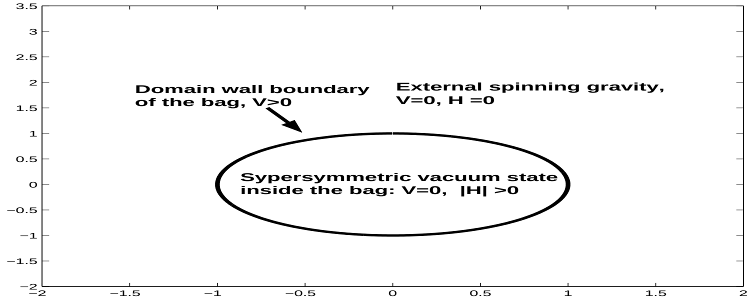


Figure 5: **Domain Wall separates external gravity from vacuum state inside the bag.**

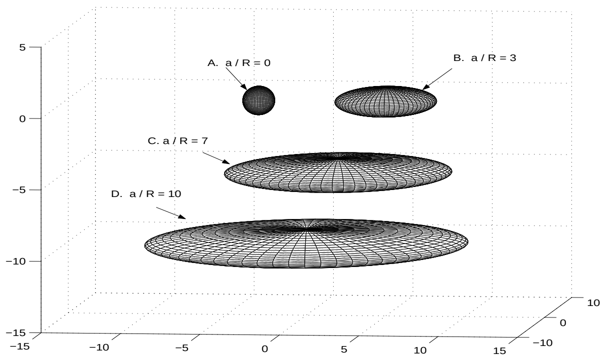


Figure 6: **Deformation of the bag caused by Kerr's spin parameter $a = J/m$.**

Supersymmetric Landau-Ginzburg (LG) field model of phase transition, superconducting core of KN electron model.

Broad class of *nonperturbative models* is based on the NO Lagrangian

$$\mathcal{L}_{NO} = -\frac{1}{4}F_{\mu\nu}F^{\mu\nu} - \frac{1}{2}(\mathcal{D}_\mu H)(\mathcal{D}^\mu H)^* - V(|H|)$$

where $H = |H|e^{i\chi}$ **is the complex Higgs field,** $\mathcal{D}_\mu = \nabla_\mu + ieA_\mu$**, and** $F_{\mu\nu} = A_{\mu,\nu} - A_{\nu,\mu}$. **Usually, it is considered with quartic potential**

$$V = g(H\bar{H} - \sigma^2)^2$$

in many models:

(i) Nielsen-Olesen model of the vortex line in superconductor,

(ii) domain walls, supersymmetric Landau-Ginzburg field model,

(iii) kink solutions,

(iv) solitons and bag models.

Supersymmetric LG model [Wess and Bagger book (1983)] has two charges $e\pm$**. Application to two boundaries of a superconducing core** $C^\pm$ **gives eqs. for two superficial currents on the**

$$\Box A^\pm_\mu = J^\pm_\mu = e|H|^2(\chi^\pm{}_{,\mu} + eA^\pm_\mu) \ (\ \textbf{inside} \ = 0).$$

Inside the core, equations $J^\pm_\mu = 0$**, are easily integrated and give two Higgs phases** $\chi^\pm(t,\sigma) = e^{i2m(t\mp a\phi_K)}$ **which are controlled by two Wilson loops** $A^\pm_\mu$.

Gravitational frame-dragging and quantum Wilson loops. [A.B, J. Phys. A: Math. Theor. (2010), Grav.Cosmol. (2020)].

Regularized Kerr disk $\cos\theta = 0$ **has two sharp borders** $C^\pm : r = r_e^\pm = \pm e^2/2m$ **in equatorial plane** $\cos\theta = 0$**, where the potential** A_μ **takes its maximum value. At** $r = r^+$

$$A_\mu^{+max} dx^\mu = \frac{2m}{e}(dt + ad\phi_K). \tag{9}$$

Potential $eA^+ = 2m(dt + ad\phi_K)$ **is tangent to Kerr disk, and forms by** $t = const., r = r_e^+ = const.$ **the closed Wilson loop along the border** $C^+ : \phi_K \in [0, 2\pi]$

$$W(C^+) = P\exp(e\oint_{C^+} A_\mu^{+max} dx^\mu), \tag{10}$$

Integration of the potential eA^+ **along the loop** C^+ **gives the phase increment**

$$\delta\phi^+ = e\oint_{C^+} A_{\phi_K}^+ d\phi_K = 4\pi ma. \tag{11}$$

Definiteness of the phase $\delta\phi^+ = 2\pi n$**, gives condition** $2ma = n, \ \ n = 1, 2, 3...$**, which, in accordance with basic Kerr relation** $J = ma$ **is proportional to** $2\pi\hbar$ **and gives the electron quantum angular momentum** $J = \frac{\hbar}{2}$.
Angular momentum quantization occurs as a consequence of gravitational frame-dragging and solutions with $n = 1, 2, 3...$ **indicate a possible existence of other leptons with** $J = \frac{n\hbar}{2}$.

The "mirror" potential $eA^- = -2m(dt - ad\phi_K)$ **creates on the "mirror" border** $C^- : \phi_K \in [2\pi, 0], \ r_e^- = -e^2/2m$ **the Wilson loop** $W(C^-)$ **and integration gives** $\delta\phi^- = -4\pi ma$.

Contribution of WL at boundary C^- *almost completely reduces* WL contribution of C^+. However, there is *an important asymmetry*: C^+ is associated with a retarded potential, and *outgoing "basic"* Kerr congruence,
while C^- is associated with *ingoing* congruence, and potential $A_\mu^{-max} dx^\mu$, and does not contain an *electrostatic component* $A_0 = -e \frac{r}{r^2 + a^2 \cos^2\theta}$ *associated with e.m. mass of the electron* $m_e = \frac{e}{2} \int_{r_e}^\infty A_0(r) dr$ [V.F. Weisskopf (1949)].

Emergence of the Monopole-Antimonopole pair: **according to Stokes' theorem, the Wilson loop C^+ should generate a magnetic flux**

$$\Phi = \oint_{C^+} A_{\phi_K}^{+max} d\phi_K = 4\pi ma = 4\pi\hbar/2 = h/e, \tag{12}$$

equal to half of the quantum of the magnetic field $\Phi_0 = \hbar/2e$, i.e., the Dirac monopole is to be born.
But *a monopole cannot be born alone*, and the second Wilson loop C^- should generate an anti-monopole. Thus, two Wilson loops generate on two boundaries of the Kerr disk C^+ and C^- a magnetically coupled pair consisting of the Dirac monopole and the magnetically coupled anti-monopole, that is, a Cooper pair that gives rise to a superconducting state in the vacuum core of the Kerr disk. Thus, *the electron vacuum core contains the hidden magnetic energy of electron-positron vacuum pairs, which affects the gravitational field of the KN electron.*
Renormalization. **Wilson loops C^+ and C^- give an additional contribution to mass-energy of particle, indicating that regularization requires also the known from the QED renormalization. Mass m_0 should be formed as the sum $m_0 = m_e + \delta m$, where mass m_e, must be reduced by a hidden part δm during the renormalization process.**

Kerr-Newman gravity and QED.

In accordance with the QED, the energy-moment tensor of the regularized KN solution in the Heisenberg representation compatible with the KN metric have in the Kerr-Schild coordinates the form [Akhiezer and Berestetskii, Quantum Electrodynamics (1965)]

$$T_{\mu\nu} = \frac{1}{2}(A_{\nu,\sigma}A^{\sigma}_{\mu} + A_{\mu,\sigma}A^{\sigma}_{\nu} - g_{\mu\nu}A_{\sigma,\lambda}A_{\sigma,\lambda}) + \frac{1}{4}(\bar{\psi}\gamma^{\nu}\partial_{\mu}\psi - \partial_{\mu}\bar{\psi}\gamma^{\nu}\psi) + \frac{1}{4}(\psi^{c}\gamma^{\nu}\partial_{\mu}\psi^{c} - \partial_{\mu}\bar{\psi}^{c}\gamma^{\nu}\psi_{c}). \quad (13)$$

This expression unites quantum theory with gravity through the system of Einstein-Maxwell equations, which in the Kerr-Schild formalism are presented in the tetrad form

$$R_{ab} - \frac{1}{2}g_{ab}R = -8\pi T_{ab}, \quad (14)$$

where

$$T_{ab} = \frac{1}{4\pi}(F_{b}F^{c} - \frac{1}{4}g_{ab}F_{cd}F^{cd}). \quad (15)$$

The Wilson loop contributions from counters C^{+} and C^{-} are mutually canceled, for exclusion of the electrostatic (time-) component

$$A_{t} = \frac{-er}{(r^{2} + a^{2}\cos^{2}\theta)}dt, \quad (16)$$

which is located only on the border $r^{+} = r_{e}$, and *corresponds to electrostatic mass-energy of the electron* $U = \frac{e}{2}\int_{r_e}^{\infty} A_{0}(r)dr = m_{e}$.

Fermionic components in the expression (13) correspond to orbital part of the current density fluctuations $\bar{\psi}\overleftrightarrow{\partial_\mu}\psi = \frac{2m}{ie} j_\mu^{(orb)}$ **[Walter Thirring, *Princles.Quant.Electrod.* (1958)]. V.e.v. of this sum is zero, since the Dirac electron ring current cancels the oppositely oriented ring current of the positron, *forming the vacuum binding energy of the electron-positron pairs.* Similar interpretation of these components is related with Cooper pairs in the Ginzburg-Landau theory of superconductivity.**

Comparison with the expression for electron current in QED

$$j_\mu(x) = \frac{ie}{2}(\bar{\psi}\gamma_\mu\psi - \bar{\psi}^c\gamma_\nu\psi^c) \qquad (17)$$

shows, that the term $\bar{\psi}\gamma^\nu\partial_\mu\psi - \partial_\mu\bar{\psi}\gamma^\nu\psi$ **in (13) is proportional to the density of the electron current** $\frac{ie}{2m}\bar{\psi}\gamma^\mu\psi$, **and the term** $\bar{\psi}^c\gamma^\nu\partial_\mu\psi^c - \partial_\mu\bar{\psi}^c\gamma^\nu\psi_c$ **is proportional to density of the positron current** $-\frac{ie}{2m}\bar{\psi}^c\gamma^\nu\psi^c$.

KN electron as a RELATIVISTIC RING STRING.

Relativistic Nambu-Goto string as a minimal 2d surface in 4d space

$$x^\mu(\sigma,\tau) = X^\mu_L(t+\sigma) + X^\mu_R(t-\sigma), \tag{18}$$

where $X^\mu_L(t+\phi_K)$ and $X^\mu_R(t-\phi_K)$ are the left and right lightlike modes of excitations, and ϕ_K is the Kerr angular coordinate. A relativistic string has zero rest mass $m=0$.

In the Kerr-Schild coordinates, the Kerr singular ring is light-like,

$$a\frac{\partial \phi_K}{\partial t} = c, \tag{19}$$

and the KN electron is described as the "left" excitation of a spinor relativistic STRING parameterized by the state vector $|ket>$ in Heisenberg picture.

Relativistic rotation of the string results in a point electron as it is seen by a resting observer due to Lorentz contraction.

Following the standard derivation of the Dirac equation, we linearize the Hamiltonian $H=\sqrt{\mathbf{p}c^2+m^2c^4}$, and find that it turns out to be *automatically linearized* when $m=0$,

$$H = \pm p^\mu = \pm i\hbar\partial/\partial_\mu, \tag{20}$$

and the Schrdinger equation takes the form

$$i\hbar\partial\Psi_S/\partial t = \mp\mathbf{p}c\Psi_S, \tag{21}$$

where the momentum operator $\mathbf{p}=\mathbf{p}^{(tr)}+\mathbf{p}^{(s)}$ is decomposed into a translational part $\mathbf{p}^{(tr)}$, associated with the slow movement of the particle as a whole, and $\mathbf{p}^{(s)}=\partial/\partial\phi_K$, the moment related with angular rotation of the ring string ϕ_K.

By $\mathbf{p}^{(tr)}=0$, we obtain $H=(\partial/\partial t, \partial/\partial\phi_K)$,

i.e. *the mass arises due to rotation of the ring string.*

The Dirac equation takes the form

$$i\hbar\partial\psi(\phi_K,t)/\partial t=\gamma_i\partial\psi(\phi_K,t)/\partial\phi_K, \tag{22}$$

where matrices $\gamma^\mu=(1,\gamma^i)$ **are given in Cartesian coordinates** $x^\mu=(t,x,y,z)$ **of auxiliary Minkowski space.**
In Weyl basis, the Dirac matrices take form

$$\gamma^\mu=\begin{pmatrix} 0 & \sigma^\mu \\ \bar\sigma^\mu & 0 \end{pmatrix}\ , \tag{23}$$

and Dirac spinor contains two Weyl spinors $\psi^D(\phi_K,t)=\begin{pmatrix} \chi_\alpha \\ \bar\psi^{\dot\alpha} \end{pmatrix}$. **The Dirac equation (22) splits, and two spinor fields** χ_α **and** $\bar\psi^{\dot\alpha}$ **determine two state vectors** $|left>$ **and** $<right|$**, which correspond to two opposite helicities** $\mathbf{n}=\mathbf{p}/p$**.**
The Heisenberg and Schrdinger state vectors are connected by unitary transformation

$$|\Psi_S(x,t)>=e^{-iHt}|\Psi_H(\phi,t_0)>, \tag{24}$$

in which factor $U=e^{-iHt}$ **corresponds to the kinetic energy of rotation of the ring string. We see that the negative sign (21) must be associated with the negative frequency of the wave function, and generates a conjugate relation for the covector representation of the positron**

$$<\Psi_H(\phi,t_0)|e^{+iHt}=<\Psi_S(x,t)|. \tag{25}$$

CONCLUSION:

- **The over-rotating KN black hole solution forms the consistent with gravity non-perturbative electron model.**
- **The KN electron models given by Israel and López are not full and must be completed by two interacting with gravity Wilson lines, forming the consistent with QED model of dressed electron, complementad by the the electron-positron vacuum pairs interacting with gravity on the Compton scale.**
- **The supersymmetric Landau-Ginzburg model of QED describes the non-perturbative structure of the KN electron model forms a superconducting vacuum disk of the reduced Compton radius, in which two vacuum states of the chiral fields $\Psi^{\pm}(\sigma, t)$ correspond to Higgs field of SM, and simultaneously play the role of the Schrödinger wave function of the QM, and movers of the light-like string modes in the relativistic noncritical 4d ring string theory.**

THANK YOU VERY MUCH FOR ATTENTION!

Indeed, this problem is more then fifty years old:

- **B.Carter 1968,** *Global structure of the Kerr family of gravitational fields,* Phys.Rev. 174, 1559.
- **W.Israel 1970,** *Source of the Kerr metric,* Phys. Rev. D 2, 641.
- **A.B. 1974,** *Microgeons with spins Sov. Phys. JETP* **39** 193.
- **D.D.Ivanenko and A.B. 1975,** *Gravitational strings in the models of elementary particles,* Izv. Vuz. Fiz., **5**, 135.
- **C.A. López (1984) An extended model of the electron in general relativity** *Phys. Rev.* D **30** 313 .
- **A.B. 2016,** *Source of the Kerr-Newman solution as a supersymmetric domain wall bubble: 50 years of the problem.* Phys.Lett. B754, 99 (2016).
- **A.B. 2015,** *Gravitating Lepton Bag Model* , JETP, **148** (8), 228 (2015).
- **A.B. 2020,** *Spinning Particle as Kerr-Newman Black Hole.* Phys. of Part. and Nucl. Lett. **17**(5) 724 (2020).

Wess-Zumino SuperQED model. Two Higgs superfields

$$\mathbf{\Phi_1 = \Phi_+(y) = H_+(y^\mu) + \sqrt{2}\theta\psi_+(y^\mu) + \theta\theta F_+(y^\mu).}$$

$$\mathbf{\Phi_2 = \Phi_-(y) = H_-(y^\mu) + \sqrt{2}\theta\psi_-(y^\mu) + \theta\theta F_-(y^\mu).}$$

completed by two Weyl spinors $\psi_+(\mathbf{y}^\mu),\ \psi_-(\mathbf{y}^\mu)$ of the Dirac equation. Other chiral fields $\Phi_i, i = 3, 4, 5$ we leave undetermined

$$\mathbf{\Phi_i(y) = A_i(y^\mu) + \sqrt{2}\theta\psi_i(y^\mu) + \theta\theta F_i(y^\mu).}$$

Kinetic term super-QED has two chiral fields Φ_+ and Φ_-,

$$\mathcal{L}_{kinQED} = \frac{1}{4} Re \int d^4x\, d^2\theta\, W^a W_a + \int d^4x\, d^4\theta\, (\Phi_+^+ e^{eV} \Phi_+ + \Phi_-^+ e^{-eV} \Phi_-), \tag{26}$$

and potential term is the sum of chiral and anti-chiral parts $W + W^+$. The Feynman rules are stated in terms of superfield vertices and propagators with miraculous cancellations between component diagrams. (Wess and Bagger "Supersymmetry and Supergravity".)

Supersymmetric Bag model acquires spinor structure. SuperQED forms a bridge to perturbative Quantum theory and shows that Compton zone of the dressed electron can be formed from a supersymmetric vacuum state of the Higgs field.

Why SUPERSYMMETRY IS NECESSARY.

The typical quartic potential $V = g(H\bar{H} - \sigma^2)^2$ gives incorrect result – the usual bag models are formed as a cavity in superconductor.

Correct model requires several Higgs-like fields (Witten, 1985) $\Phi^i, i = 1...5$.

Supersymmetry provides concentration of the Higgs field INSIDE the bag.

(A.B. *JETP* 2015, *Phys.Lett.B* 2016).

Supersymmetric Domain Wall forms boundary between gravity and quantum zone, and SUPERCONDUCTIVITY is placed inside the bag.

N=1 Landau-Ginzburg (LG) field model.

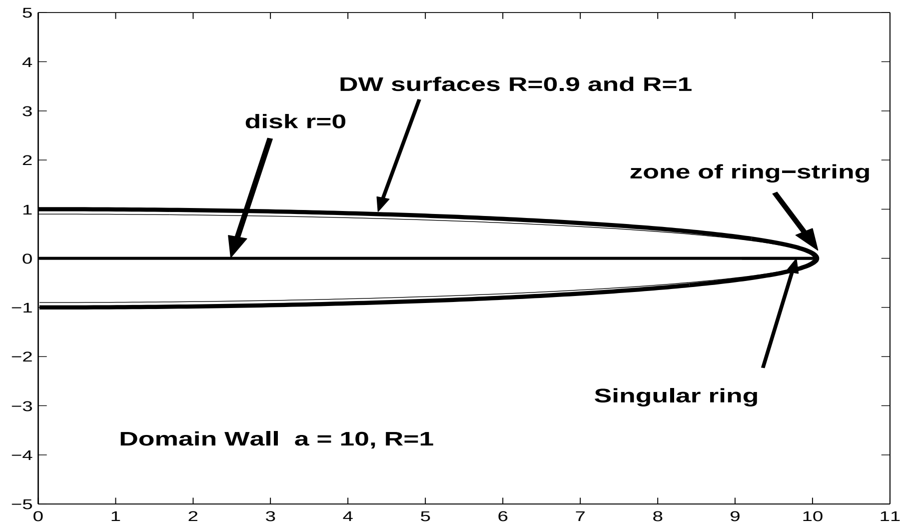


Figure 7: **Profile of the bag boundary.**

SUPERSYMMETRIC phase transition is built of the N=1 LG Lagrangian

$$\mathcal{L} = -\frac{1}{4}\sum_{i=1}^{3} F^{(i)}_{\mu\nu}F^{(i)\mu\nu} - \frac{1}{2}\sum_{i=1}^{3}(\mathcal{D}^{(i)}_{\mu}\Phi^{(i)})(\mathcal{D}^{(i)\mu}\Phi^{(i)})^{*} - V,$$

where $\mathcal{D}^{(i)}_{\mu} = \nabla_{\mu} + ieA^{(i)}_{\mu}$ **are covariant derivatives and five chiral fields**

$$\Phi^{(i)} = \{H_{+}, H_{-}, Z, \Sigma_{+}, \Sigma_{-}\}$$

include two Higgs fields H_{+} **and** H_{-}.

Holomorphic superpotential (suggested by J. Morris, 1996)

$$W = Z(\Sigma^{+}\Sigma^{-} - \eta^{2}) + (Z + \mu)H^{+}H^{-}, \tag{27}$$

determines the potential

$$V(r) = \sum_{i} |\partial_{i}W|^{2}. \tag{28}$$

Vacuum states $V_{(vac)} = 0$, **are determined by the conditions** $\bar{F}_{i} = \partial_{i}W = 0$.

SUPERSYMMETRIC Domain Wall generates two supersymmetric vacuum states:

(I) supersymmetric vacuum inside the bag:

$$H^{-}H^{+} = \eta^{2},\ Z = -\mu,\ \Sigma^{+} = \Sigma^{-} = 0,$$

(II) external supersymmetric vacuum state: $H^{-}H^{+} = 0;\ Z = 0;\ \Sigma^{+}\Sigma^{-} = \eta^{2}$.

Phases of the Higgs fields H^{+} **and** H^{-} **inside the bag become correlating .**

Complex shift. Paul Appell, 1887 ! (***Quelques remarques sur la théorie des potentiels multiforms.*** **Math. Ann., 30:155-156, 1887.)**
By complex shift $z \to z + ia$ **of the linear equation** $\Delta\frac{1}{r} = 0$ **the singular solution** $\phi = \frac{1}{r}$ **goes to solution** $\tilde{\phi} = \frac{1}{r+ia\cos\theta}$, **which singular at the ring** $\sqrt{x^2+y^2+(z+ia)^2} = r + ia\cos\theta = 0$.
Singular point $r = 0$ **of the solution** $\phi = \frac{1}{r}$ **blows up** $(\tilde{r})^2 = x^2+y^2+z^2-a^2+2iaz = 0$ **and turns into a circular branch line:** $x^2 + y^2 = a^2$ **in the plane** $z = 0$.

Complex shift lies in the basis of the geometrical structure of the rotating black holes!

Similarly, the singular spinor solution $\Phi(r) = \frac{\chi}{r}$ **of the linear Weyl equation**

$$\sigma_\mu \partial^\mu \frac{\chi}{r} = 0, \tag{29}$$

turns into solution $\tilde{\Phi} = \frac{\chi}{r+ia\cos\theta}$ **which is singular at the Kerr ring** $\tilde{r} = r + ia\cos\theta = 0$.
Just similar, the singular solution of the Dirac equation (with or without mass) is transformed by complex shift, turning in the solution which is singular at the Kerr singular ring – Dirac field becomes distributed along circular string of the Kerr stringy system.