The bare and gravitationally dressed electron based on the Kerr-Newman black hole solution

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Development of works by B. Carter (1968), W. Israel (1969), C. López (1984) and
A.B., Microgeons with spins, JETP, **39** *193 (1974)*
A.B., Gravitating Lepton Bag Model, JETP, v.148 (8), 228 (2015),
A.B., Source of the Kerr-Newman ...., Phys. Lett. B754, 99 (2016),
A.B., Gravitating Electron Based on Over-rotating Kerr-Newman Solution
Universe 2022, 8, 553.

(1) The point, structureless electron of quantum theory *incompatible* with gravity.
(2) The extended gravitating electron *is incompatible* with quantum theory.
(3) Gravity is believed to be the most a weak interaction that should not be taken into account in particle models.

The over-rotating Kerr-Newman (KN) was first considered as a gravitational model of the electron by Brandton CARTER (1968), and then studied by Debney-Kerr-Schild (1969), W.Israel (1970), C.López (1984), AB and D.Ivanenko (1974-1975).

KN electron resolves contradictions (1),(2),(3), setting relation gravity with Quantum Theory .

KN nonperturbative electron model is consistent with gravity and QED (AB 2021-2022).

Contrary to assumption (3), the Kerr-Newman gravitational field is not weak and, interacting with gravity through gravitational FRAME-DRAGGING with the formation of Wilson loops of the vector potential, it plays a strong and even decisive role in fixing the mass of the spinning particles [AB, PHPL 2020; *Grav.Cosmol.* 2020].

Our work in this direction began 50 years ago [AB, JETP 1974, AB and D.Ivanenko Izv. Vuz. 1975]

Crazy idea that elementary particles are black holes, has been proposed by Nobel laureates: G. t'Hooft, F. Wilczek, A. Salam, and supported by some string theorists [A.Sen, Leonard Susskind, A. Dabholkar et. al. 1996 (Strings as solitons, and black holes as strings)], but the structure of the KN string discussed here is really very far from the strings of superstring theory and closer to the classical massless relativistic string.

Super-rotating Black Hole solution with twisting congruence of the light rays:
[R.Kerr (1963), Debney-Kerr-Schild (1969)].

Kerr Congruence $\mathbf{k}_\mu(\mathbf{x}) \to \mathbf{k}^\pm_\mu(\mathbf{x})$ – two direction of frame-dragging

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

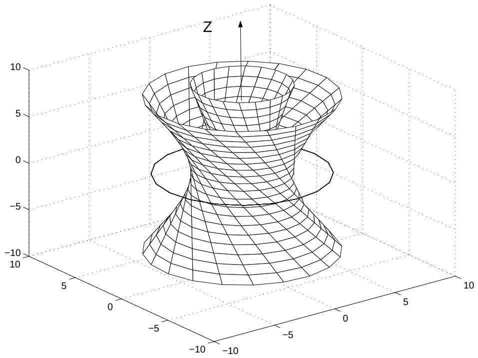

Figure 1: Vortex structure of Kerr congruence k^μ and singular ring of half Compton radius.

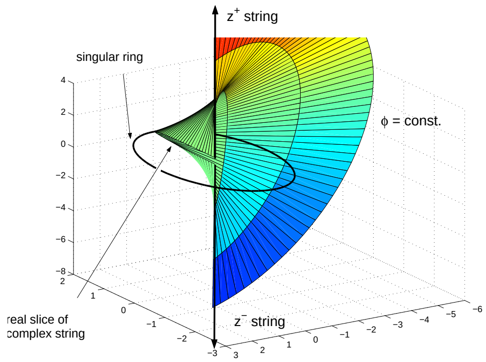

Figure 2: Frame-dragging of vector potential in Kerr-Schild geometry.

Electron is over-rotating Kerr-Newman (KN) solution, $a^2 + e^2 >> m^2$, and the Kerr singular ring is naked and forms a CLOSED RING STRING of half Compton radius

$$a = J/mc = \hbar/mc \sim 10^{-11} cm. \tag{1}$$

Two sheeted topology like the Einstein-Rosen briddge.

Energy-momentum tensor diverges, displaying excess energy on Compton scale $a \sim 10^{-11}$ cm.

Two-sheeted topology of KN solution was seen initially as its flaw, and

W. Israel (1970) proposed to truncate negative sheet by replacing it with the distribution of matter on the cutting surface, consistent with Einstein's equations.

C. López (1984) regularized Israel's solution by cutting Kerr's singular ring at a specially selected distance $r = r_e$.

New version of the electron model since 2022 [AB, Universe 2022]. Doubling of the black hole structure with a BLACK sheet of INCOMING radiation and a WHITE sheet of OUTGOING radiation, which together form the electron-positron vacuum state of the electron model.

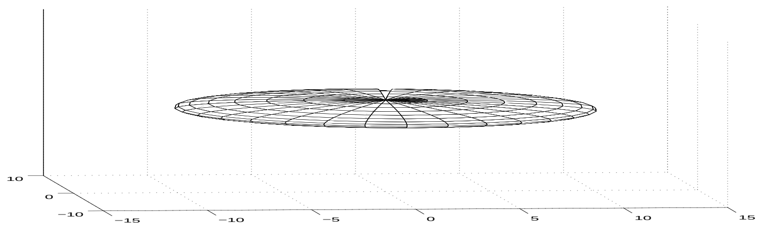

Figure 3: Regularized KN electron: a superconducting core getting mass from the Higgs fields.

Similar to QED, we consider separately the bare and dressed electron.

BARE electron is considered as a classical solution of the Einstein-Maxwell equations, forming a massless relativistic ring string of half Compton radius.
DRESSED electron forms a thin SUPERCNDUCTING DISK, which is flat and HEAVY, since the energy of singular ring is transformed by the Higgs fields in the rest mass of the Kerr disk.

KN gravity becomes a strong and even major decisive interaction.
The resulting excess energy is regularized, similar to perturbative QED.
Two-sheeted structure of the KN solution is determined by the gravitational frame-dragging caused by two-sheeted Kerr's congruence $k^{\pm}(x)$,

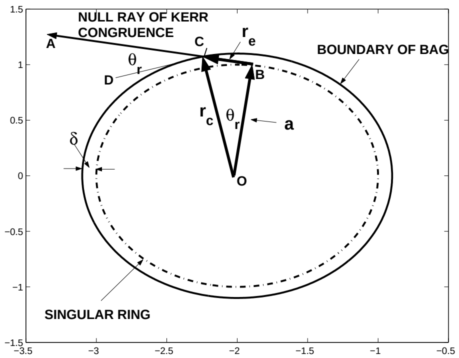

Figure 4: **Front side of Kerr's disk related to outgoing Kerr congruence.**

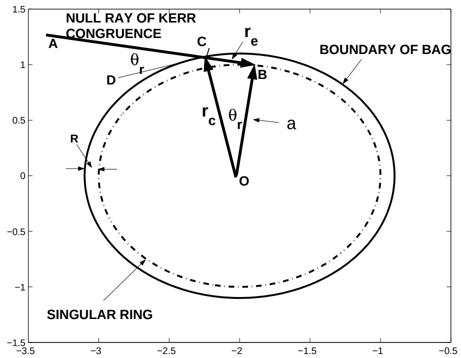

Figure 5: **Back side of Kerr's disk related to in-coming Kerr congruence.**

By replacing "negative" sheet of KN solution with a "mirror" space, we obtain a two-sheeted space with "front" and "back" sides associated with two different frame-dragging and two Kerr's congruences:
$k^+_\mu(x)$ – outgoing congruence associated with retarded potentials A^+_μ, and incoming congru- ence
$k^-_\mu(x)$ - related to advanced potentials A^-_μ.
In this case, two different metrics appear: $g^{\pm}_{\mu\nu} = \eta_{\mu\nu} + H_{KH} k^{\pm}_\mu k^{\pm}_\nu$,
two boundaries $B^{\pm}(r^{\pm})$, and two Wilson loops $C^{\pm}$ with two vector potentials $A^{\pm}_\mu$, smeared on the loops $C^{\pm}$.

CLASSICAL BARE ELECTRON is formed by a massless relativistic string placed on boundary of the relativistically rotating Kerr disk.

ONE TURN of the sting, $\phi_K \in [0, 2\pi]$ at $t = const.$, corresponds to electron state vector $|bra>$ in Heisenberg picture, as the most elementary (indivisible) ring string state.

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

$$H = \pm p^\mu = \pm i\hbar\partial/\partial_\mu, \tag{2}$$

and the Schrodinger equation takes the form $i\hbar\partial\Psi_S/\partial t = \mp\mathbf{p}c\Psi_S$.
The momentum operator $\mathbf{p} = \mathbf{p}^{(tr)} + \mathbf{p}^{(s)}$ is decomposed into a translational part $\mathbf{p}^{(tr)}$, related to the moving the particle as a whole, and the angular momentum $\mathbf{p}^{(s)} = \partial/\partial\phi_K$, related to rotation of the ring string in direction ϕ_K.
Mass of the ring string arises from its relativistic rotation.

The Heisenberg and Schrödinger state vectors are connected by a unitary transformation

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

in which unitary factor $U = e^{-iHt}$ corresponds to kinetic energy of rotation of the ring string.

Contrary to superstring theory,
the classical electron ring string allows longitudinal modes of excitations: [A. Patrascioiu, *Nucl.Phys.***B81** 525 (1974); Bardeen, Bars, Hanson and Peccei. *Phys. Rev.* **D 13** 2364 (1976).].

Gravitationally DRESSED electron is formed by Wilson loops: $p^\mu \to p^\mu - \frac{e}{c} A^m$, accompanied by frame-dragging [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 $r = r^+$

$$A_\mu^{+max} dx^\mu = \frac{2m}{e}(dt + a d\phi_K). \tag{3}$$

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 $C^+ : \phi_K \in [0, 2\pi]$

$$W(C^+) = P \exp(e \oint_{C^+} A_\mu^{+max} dx^\mu), \tag{4}$$

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

$$\delta\phi^+ = e \oint_{C^+} A_{\phi_K}^+ d\phi_K = 4\pi m a. \tag{5}$$

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 $\delta\phi^- = -4\pi ma.$

MUTUAL COMPENSATION. The gravitational contribution from the Wilson loop $W(C^-)$ is almost equal to contribution from $W(C^+)$. **A small asymmetry:** $W(C^+) \neq W(C^-)$, related with electrostatic component $A_0 = -e\frac{r}{r^2+a^2\cos^2\theta}$ associated with electromagnetic mass of electron $m = \frac{e}{2}\int_{r_e}^{\infty} A_0(r)dr$ [V.F. Weisskopf (1949)].
This term is included ONLY in the retarded potential of the *outgoing* Kerr congruence, and gives electromagnetic mass-energy of the electron m (mass term of the Dirac equations) which is very small with respect to large gravitational energy m_G hidden in Wilson loops!

Emergence of the Monopole-Antimonopole pair.

According to Stokes' theorem, the closed Wilson loop C^+ should generate a magnetic flux $\Phi = \oint_{C^+} A_{\phi_K}^{+max} d\phi_K = 4\pi ma = 4\pi\hbar/2 = h/e$ equal to half of the quantum of the magnetic field $\Phi_0 = h/2e$.
This means that the Dirac monopole must be born.
But a monopole cannot be alone, and the second Wilson loop C^- should create an anti-monopole.

Two Wilson loops placed on two boundaries of the Kerr disk C^+ and C^- create *a magnetically coupled pair* consisting of a monopole and a magnetically bound anti-monopole, that is, a Cooper pair that gives rise to a superconducting state in the vacuum core of the Kerr disk.

Radiative KN solutions.

The known radiative generalizations of the Schwarzschild solution, the Vaidya shining star solution (1951) and the Kinnersley photon rocket solution (1969) cannot be generalized to analogous radiative KN solution.

This obstacle is overcome by the dual KN solution, containing both the OUTGOING radiative side and the side RECEVING the incoming radiation, which is associated with the *coupled electron-positron vacuum state* of the KN solution.

In the fundamental work DKS (1969), derivation of KN solution was done in the assumption $\gamma^{\pm} = 0$, which meant there was no the incoming and emitted flow of the EM radiation $T^{\pm}_{\mu\nu} = \gamma^{\pm} k^{\pm}_{\mu} k^{\pm}_{\nu}$, and the resulting wave excitations in the ELECTRON and POSITRON string excitations appeared to be uncorrelated and INDEPENDENT of each other.

The Kerr theorem, which determines the complex functions $Y(x^\mu), x^\mu = (t, x, y, z)$, plays central role in DKS formalism, allowing us to fix the chiral outgoing (or antichiral incoming) Kerr congruences $k^{\pm}$ in the null Cartesian coordinates u, v, ζ, ζ of Minkowski space,

$$k^{\pm} = \frac{1}{P}(du + \bar{Y} d\zeta + Y d\bar{\zeta} - Y\bar{Y} dv), \;\; P = \frac{1}{\sqrt{2}}(1 + Y\bar{Y}), \tag{6}$$

representing congruences $k^{\pm}$ through ratios $\mathbf{Y}^{+} = \phi_{\mathbf{1}}/\phi_{\mathbf{0}}$, $\mathbf{Y}^{-} = \bar{\chi}^{\dot{\mathbf{1}}}/\bar{\chi}^{\dot{\mathbf{0}}}$ of two component spinor fields ϕ_α and $\bar{\chi}^{\dot{\alpha}}$.

Kerr theorem defines $Y(x)$ as holomorphic solution of the algebraic equation $F = 0$, where $F(Y, \lambda_1, \lambda_2)$ is an arbitrary holomorphic function of three projective twistor coordinates $\{Y, \quad \lambda_1 = \zeta - Yv, \quad \lambda_2 = u + Y\zeta\}$.
For KN solution, function F is quadratic in Y, and the equation $F = 0$ has two roots $Y^\pm$, which are connected by antipodal correspondence[1]

$$Y^+ = -1/\bar{Y}^-. \tag{7}$$

Although congruences $k^\pm$ are determined by complex conjugate functions Y and $\bar{Y}$, the DKS theory is chiral, because Y and $\bar{Y}$, are treated as independent variables in the process of integration.

In works [AB PRD**68** (2003); Grav.Cosm.(2004); PRD **70**(2004)],**the DKS equations were reintegrated for the case of radiating KN solutions, showing a new important feature – emergence of the extra incoming and outgoing axial stringy structure, controlled by two projective angular coordinates $Y^\pm$, related by antipodal correspondence (7), which sets the spinor correlation between the left and right modes of excitation of electron and positron branches.**

The relation is based on the Lind-Newman complex retarded-time construction [Lind-Newman, J. Math. Phys. **15** 1103 (1974)] **used in twistor-string model**[AB PRD **70** (2004)].
The second root of the Kerr theorem $Y^- = -1/\bar{Y}^+$ turns the chiral solution into antichiral, replacing the incoming EM field with outgoing EM radiation .
In a specially adapted case, supported by the Lind-Newman retarded-time construction, the antipodal conjugation coincides with complex conjugation, and the incoming and outgoing radiations are collimated, creating an additional axial singular string, see Fig.6.

[1] Functions Y^+ and Y^- must possess the same Killing symmetry.

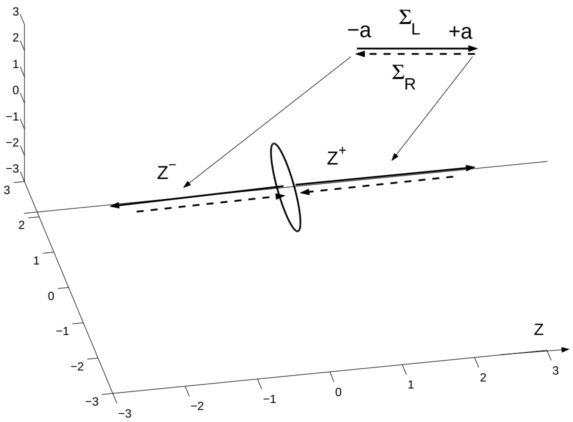

Figure 6: **Correspondence between complex retarded time and real Kerr geometry.**

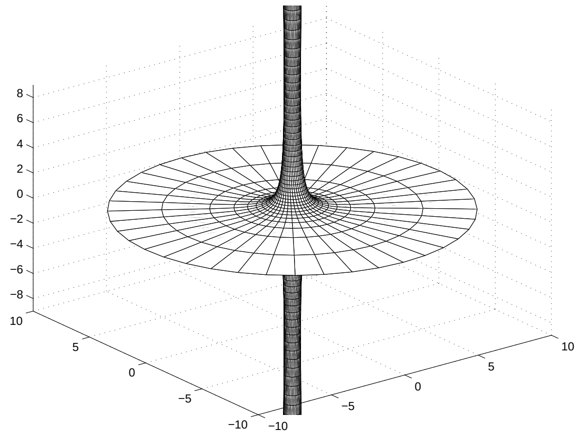

Figure 7: **Emergence the axial singular line relating the left and right excitations of the KN electron.**

In DKS authors proposed also an alternative way to describe the EM field through the vector potential one-form α presenting i as a sum of the chiral and anti-chiral parts[2]: the chiral α_L for radiating electron and the anti-chirar α_R for the incoming positron field, which can be expressed through antipodal correspondence (7), taking into account the change of charge $-e \to e$, radial direction $r^+ \to r^-$ and orientation $a \to -a$. As it was shown in [AB PRD 2004 and GrCos2004], **the potential $\alpha = \alpha_L + \alpha_R$ gives the consistent radiating KN solution with the additional axial stringy system which combines the electron-positron half-string excitations in a single wave function.**

THANK YOU FOR ATTENTION !

[2]See eqs. (5.78),(5.79) in DKS.