Weakness of gravity as illusion which hides true path to unification of gravity with particle physics (Supersymmetric bag model)

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Based on: **arXiv:1701.01025** and

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.**

"... a realistic model of elementary particles
still appears to be a distant dream ... "
John Schwarz, arXiv:1201.0981.

Quantum theory and Gravity cannot be combined in a unified theory. Gravity refuses pointlike, structureless quantum particles, requiring *extended field structure* for right side of Einstein equations, $G_{\mu\nu} = 8\pi T_{\mu\nu}$.

Perfect old theory of unification is Kaluza-Klein model $^5G_{MN} = 0 \;\Rightarrow\; ^4G_{\mu\nu} = 8\pi T_{\mu\nu}$, vector potential A^μ, scalar field Φ.
Problems: invisible extra dimension require compactification at Planck scale; KK excitations lead to unrealistic spectrum of mass, about $M_p \approx 10^{22} m_e$, unclear meaning of Φ.

Compactification of higher dimensions (KK model) is also basic of superstring theory. Weakness of gravity leads to Planck scale of interaction, which is the principal problem of the KK-theory and superstring theory.

Underestimation of the role of spin: weakness of Gravity in particle physics is an illusion.

Spin distorts metric along with mass, and indeed much stronger because of the giant spin/mass ratio for spinning particles! ($S/m > 10^{20}$ in units $G = c = \hbar = 1$)

Spin shifts-up scale of effective interaction from Planck scale to Compton lengths.

Nobody says that gravity is weak in COSMIC scale. Reason – great masses in cosmos. Similarly, in particle physics, enormous spin makes gravity strong at the Compton scale. Spin acts on the metric as the frame-dragging or Lense-Thirring effect.

We will be interested in the Kerr-Newman (KN) spinning solution, and consider KN solution with parameters of an electron.
It confirms crucial role of spin and shift of scale of interaction.

Schwarzschild's estimation of gravitational coupling constant $r_g \sim 2m$. Kerr geometry indicates strong influence of the SPIN at the Compton distance $r_c \sim \frac{\hbar}{2m_e}$, contrary to the usually accepted Planck length. Horizons of Kerr black hole (BH) disappear. Kerr singularity becomes naked and deforms space topologically at Compton distance.

Singularity is signal of New Physics! Quantum theory is inapplicable on such space. Conflict Quantum theory with Gravity begins at the Compton scale! New physics should modify the Einstein-Maxwell gravity already at the Compton distances!

We show that the Einstein-Maxwell gravity should not be really modified!

The problem of *consistency Q-theory with Kerr's gravity* is solved by the model of Super-bag, which is a nonperturbative SUPERSYMMETRIC model based on the Higgs model of symmetry breaking, consistent with principles of the Standard Model (SM) and connected with nonperturbative Super-QED model.

There is no need in extra variables of the KK and superstring theory. KK circle is realized in Kerr geometry without compactification!

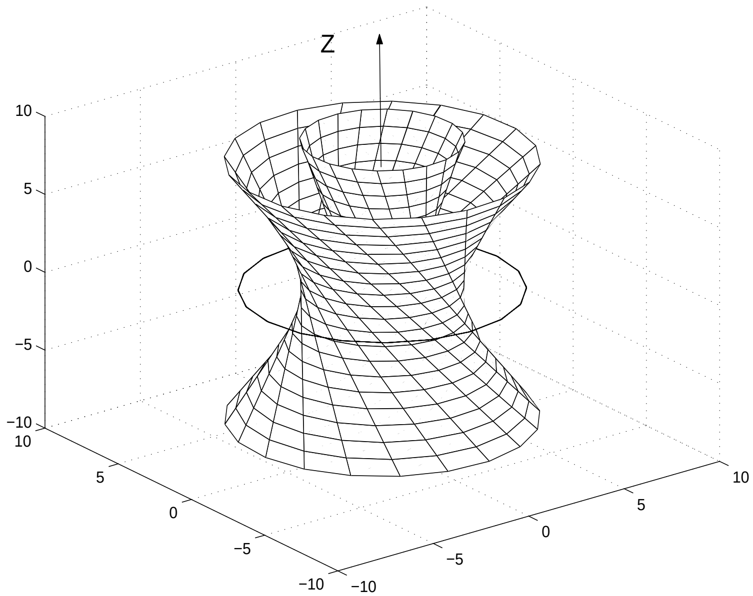
The Kerr-Schild form of metric

$$g_{\mu\nu} = \eta^{\mu\nu} + 2Hk^{\mu}k^{\nu}, \tag{1}$$

vector potential

$$A^{\mu} = ek^{\mu}/(r + ia\cos\theta), \tag{2}$$

and Kerr Theorem, determines Principal Null Congruence k^{μ} in terms of twistors.



KN GRAVITY with SPIN gives to electron an EXTENDED VORTEX of Compton size!
Kerr singular ring as a closed lightlike string (AB, JETP 1974, D.Ivanenko & AB. Sov.Phys.J. 1975, AB PRD 1995).
Objections: experiment shows that electron is point-like!
The light-like closed string looks like a point due to Lorentz contraction! B. Punsly, 1985.

FRAME-DRAGGING along directions of Kerr congruence k^μ. Formation of Wilson loop. Lense-Thyrring effect. Kerr solution gives Lense-Thyring at large distances (Kerr, 1963).

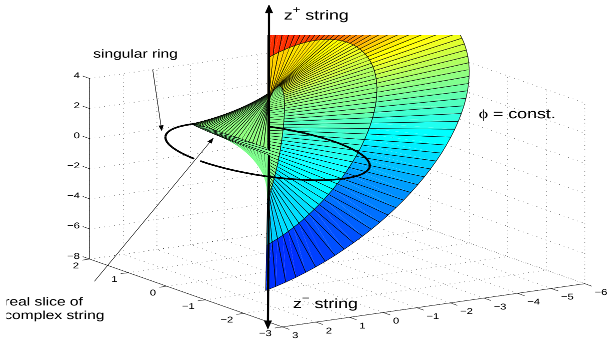


Рис. 1: The Kerr congruence and vector potential are dragged by Kerr singular ring, forming a closed Wilson loop.

Frame-dragging is local Lorentz deformation of light cones, which cannot be removed globally: creation of BH-horizons, ergosphere, topological deformation of space.

Lense-Thirring effect – gravitational analog of the Aharonow-Bohm topological effect created by Wilson lines.

Loop of the vector potential and traveling waves along the Kerr ring – attributes of string model! KK-excitations! Compactification without extra dimensions!

What is physical source of Kerr-Newman solution? (Bubble and soliton sols.) KN solution as model of electron. (H.Keres 1967, B.Carter 1968, W.Israel 1970, AB 1974, Ivanenko& AB 1975, A.Krasinski 1978, C.López 1985, I.Dymnikova 2006, AB 2010 etc.)

Gyromagnetic ratio of KN solution, $g = 2$, corresponds to electromagnetic and gravitational field of the Dirac electron (Carter, 1968). Super-Bag model, AB 2015-2017.

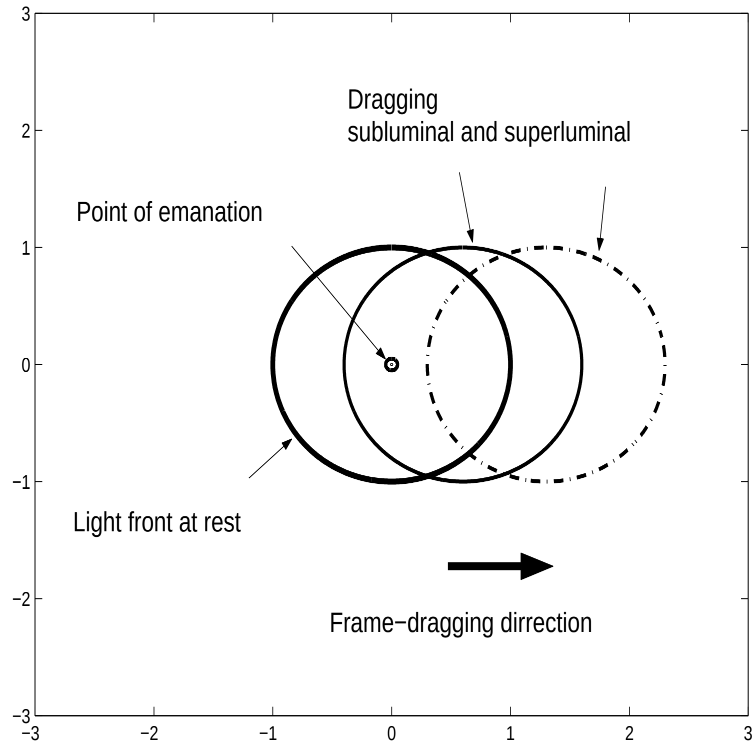


Рис. 2: **Frame-dragging as local deformation of light cones.**

Supersymmetric bag model as New Path to particle physics!

Quantum theory requires flat space in Compton zone.

REGULARIZATION: Excision of singular region!

SUPERSYMMETRY as alternative to excising. Supersymmetric domain wall (DW) separates flat QUANTUM zone from external KN GRAVITY forming tree zones:

(I) – flat quantum interior (bubble or bag),
(E) – external zone with exact KN solution,
(R) – zone of transition from (I) to (E).

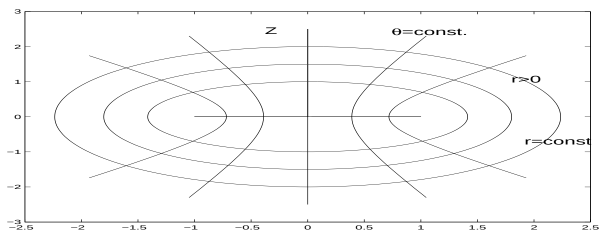
INSIDE: supersymmetric vacuum, OUTSIDE: Einstein-Maxwell gravity.

Supersymmetric Landau-Ginzburg model **expels gravitational field from Compton zone of spinning particle, similar to expulsion of electromagnetic field from superconductor.**

ROTATING BUBBLE MODEL (López 1984). Shape of bubble is uniquely determined by KN metric

$$g^{(KN)}_{\mu\nu} = \eta_{\mu\nu} + 2H_{(KN)} k_\mu k_\nu, \quad \textbf{where} \quad H_{(KN)} = \frac{mr - e^2/2}{r^2 + a^2 \cos^2\theta}.$$

ZERO GRAVITY SURFACE: $H_{(KN)}(r) = 0$, **is** $r = e^2/2m$, **where** r **is Kerr spheroidal coordinate. It represents a disk of Compton radius** $r_c \approx a = J/m$ **and of thickness** $r_e = e^2/2m$ **.**



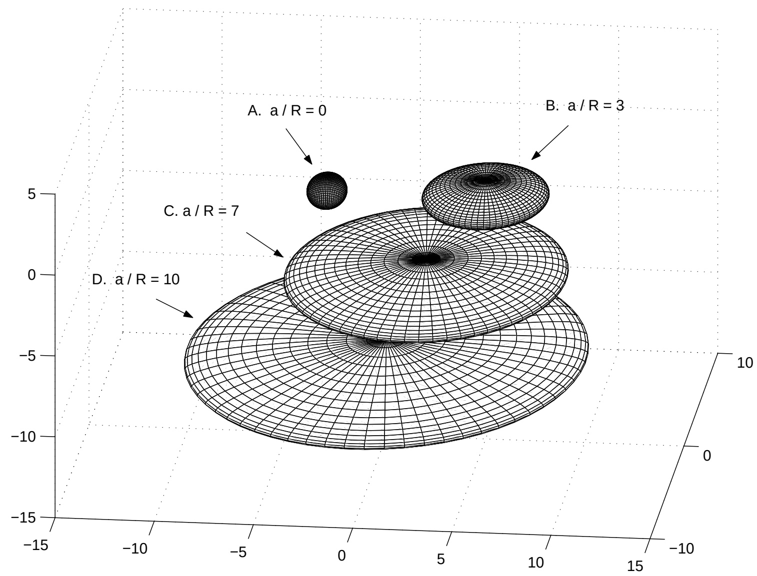


Рис. 3: Shape of disk for different $a = J/m$: (A) - $a/R = 0$, (B)- $a/R = 3$; (C) - $a/R = 7$; and (D) - $a/R = 10$.

Universality of Landau-Ginzburg (LG) field model: Higgs models, Nielsen-Olesen (NO) dual string, solitons, the MIT and SLAC bag models. However, the usual quartic potential cannot provide the required behavior. In particular, the NO model describes string as a vortex in superconductor, and the usual bag models form "cavity in superconducting media while the right behavior should be vice versa – the Higgs field should create superconducting vacuum inside the core.

Compatibility with gravity according to (I),(E),(R) gives only the supersymmetric LG model with tree chiral fields (AB JETP 2015, 2016; Phys.Lett.B 2016).

SUPERSYMMETRIC scheme of phase transition.

Triplet of the chiral fields $\Phi^{(i)} = \{H, Z, \Sigma\}$, where H is the Higgs field.

Lagrangian $\mathcal{L} = -\frac{1}{4}\sum_{i=1}^{3} F^{(i)}_{\mu\nu} F^{(i)\mu\nu} - \frac{1}{2}\sum_{i=1}^{3}(\mathcal{D}^{(i)}_{\mu}\Phi^{(i)})(\mathcal{D}^{(i)\mu}\Phi^{(i)})^{*} - V$, covariant derivatives $\mathcal{D}^{(i)}_{\mu} = \nabla_{\mu} + ieA^{(i)}_{\mu}$.

Superpotential (suggested by J. Morris, 1996)

$$W = \Phi^{(2)}(\Phi^{(3)}\bar{\Phi}^{(3)} - \eta^2) + (\Phi^{(2)} + \mu)\Phi^{(1)}\bar{\Phi}^{(1)}, \tag{3}$$

determines the potential

$$V(r) = \sum_i |\partial_i W|^2, \tag{4}$$

where $\mathcal{H} \equiv \Phi^{(1)}$ is taken as Higgs field.

Vacuum states $V_{(vac)} = 0$ are determined by the conditions $\partial_i W = 0$. The model yields two vacuum states:

(I) the supersymmetric false-vacuum state inside: $|H| = \eta; \ Z = -\mu; \ \Sigma = 0$,

(II) the vacuum state outside: $|H| = 0; \ Z = 0; \ \Sigma = \eta$.

Higgs field H forms inside the bag the supersymmetric and superconducting vacuum state.

Einstein-Maxwell eqs. are trivially satisfied inside and outside the bag.

The Landau-Ginzburg (LG) field model describes NO model of vortex line in superconductor and is fully equivalent to Higgs mechanism of symmetry breaking. Setting $\Phi^{(1)} \equiv H$ we have

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

Corresponding eqs. describe concentration of the Higgs field $H(x) = |H|e^{i\chi(x)}$ in the core of particle and its interaction with vector potential:

$$\mathcal{D}^{(1)}_\nu \mathcal{D}^{(1)\nu} H = \partial_{H^*} V, \tag{5}$$

$$\nabla_\nu \nabla^\nu A_\mu = I_\mu = \frac{1}{2}e|H|^2(\chi,_\mu + eA_\mu). \tag{6}$$

At the rim of disk, $r = e^2/2m, \cos\theta = 0$, KN potential is $A_\mu dx^\mu = A^{max}_\mu dx^\mu = -\frac{2m}{e}(dr - dt - ad\phi)$. Inside superconducting core $I_\mu = 0$, and from $\chi,_\mu + eA_\mu = 0$ and $eA_t = 2m$, $eA_\varphi = 2ma$, we obtain $\chi = -2mt - 2ma\varphi$, which leads to important consequences:

(i) closed flux of the vector potential $\oint eA_\varphi d\varphi = -4\pi ma$ forms a *quantum Wilson loop* leading to quantized angular momentum, $J = ma = n\hbar/2,\ n = 1, 2, 3, ...$

(ii) phase of the Higgs χ oscillates with frequency $\omega = 2m$ similar to solitonic models of oscillons and Q-balls (G.Rosen 1968, Coleman 1985).

Wilson line of the vector potential is parametrized by periodic phase of the Higgs field creating cylindricity of the model!
KK cylindricity at the Compton scale allows us to do compactification without extra dimensions!

SUPER-BAG as a NONPERTURBATIVE BPS-saturated SOLUTION. **AB, JETP, v.148, 937(2015), arXiv:1706.02979, AB, Phys.Lett. B754, 99(2016), arXiv:1602.04215.**

Supersymmetic DOMAIN WALL phase transition between (I) and (E). Hamiltonian:

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

Kerr's coordinate system $x + iy = (r + ia)e^{i\phi}\sin\theta, \quad z = r\cos\theta, \quad t = \rho - r.$ **Vector potential**

$$A_\mu dx^\mu = -Re\ [(\frac{e}{r + ia\cos\theta})](dr - dt - a\sin^2\theta d\phi). \tag{7}$$

Terms $A_\phi d\phi$ **and** $A_t dt$ **drop out of the Hamiltonian due the constraints**

$$\mathcal{D}_t^{(1)}\Phi^1 = 0, \quad \mathcal{D}_\phi^{(1)}\Phi^1 = 0, \tag{8}$$

consistent with (i) and (ii). The rest is reduced to integral over variable r.

$$H^{(ch)} = T_0^{\ 0(ch)} = \frac{1}{2}\sum_{i=1}^{3} [|\mathcal{D}_r^{(i)}\Phi^i|^2 + |\partial_i W|^2], \tag{9}$$

Then we use the TRICK suggested by Cvetiĉ & Rey for planar Dom Wall, which WORKS! and allows to transform Hamiltonian to Bogomolnyi form

$$H^{(ch)} = T_0^{\ 0(ch)} = \frac{1}{2}\sum_{i=1}^{3} [|\mathcal{D}_r^{(i)}\Phi^i - e^{i\chi_i}\partial_i\bar{W}|^2 + 2Re\ e^{-i\chi_i}\partial_i\bar{W}\mathcal{D}_r^{(i)}\Phi^i] \tag{10}$$

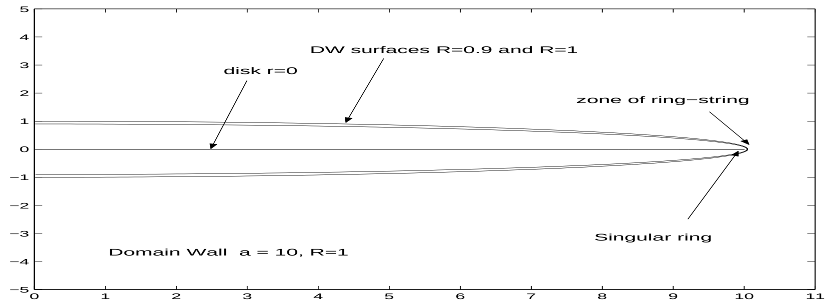


Рис. 4: **Axial section of the spheroidal domain wall phase transition**.

The angles χ_i are determined by phase of the oscillating Higgs field

$$\Phi(x) \equiv \Phi^1(x) = |\Phi^1(r)|e^{i\chi(t,\phi)}. \tag{11}$$

It yields $\chi_1 = 2\chi(t,\phi), \ \chi_2 = \chi_3 = 0$, and We obtain the Bogomolnyi equations

$$\mathcal{D}_r^{(i)}\Phi^i = \partial W/\partial\Phi^i, \quad \mathcal{D}_r^{(i)}\bar{\Phi}^i = \partial\bar{W}/\partial\bar{\Phi}^i. \tag{12}$$

Hamiltonian turns into full differential ($\mathcal{D}_r \to \partial_r$ due structure of W)

$$H^{(ch-r)} = Re\ (\partial W/\partial\Phi^i)\partial_r\Phi^i = \partial W/\partial r. \tag{13}$$

Using the Kerr coordinate system, and $\Delta W = W(R+\delta) - W(R-\delta) = -\mu\eta^2$, we obtain

$$\delta M_{bag} = 2\pi\Delta W \int_{-1}^{1} dX(R^2 + a^2X^2) = 4\pi(R^2 + \frac{1}{3}a^2)\Delta W. \tag{14}$$

BPS-saturated solution $\Rightarrow$ Stability.

STRINGY STRUCTURES

BAGs are soft and elastic. While rotating they take shape of a string. The meson bag turns in fluxtube (K. Johnson and C. B. Thorn, Stringlike solutions of the bag model, PRD 13, 1934 (1976); Chodos et al. PRD 9, 3471 (1974).)

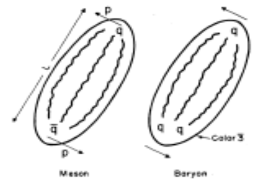


FIG. 1. Rotating meson and baryon bags.

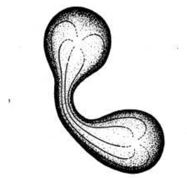


FIG. 1. A color-singlet bag attempting to fission into two bags which are not color singlets. The flux lines of the colored gluon field are shown explicitly.

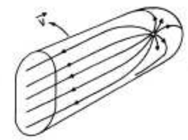


FIG. 2. Color electric flux lines. The magnetic color lines are given by $\vec{\nabla}\times\vec{E}$.

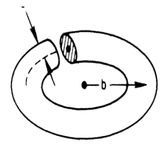
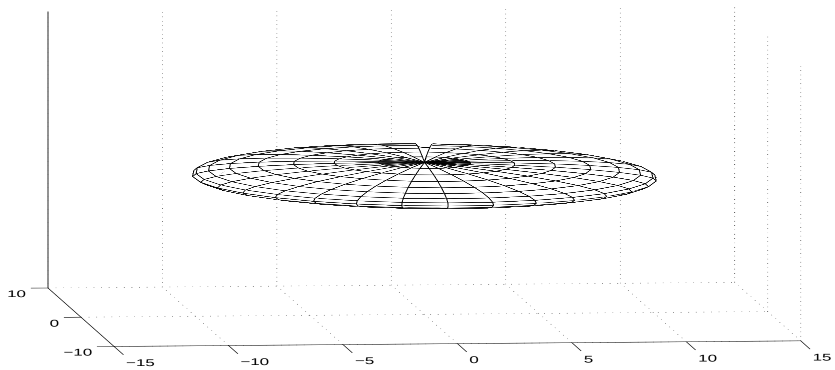


FIG. 6. Potential with torus shape.

Kerr-Newman bag creates circular string at the border of oblate bag.



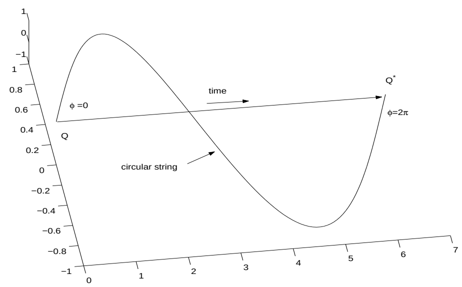
KERR's CIRCULAR STRING and its excitations

The Kerr singular ring as a closed string – "gravitational waveguide"for traveling EM waves (pp-waves), (A.B. 1974. A.B.& Ivanenko 1975.) Similar to fundamental string solutions to low energy string theory (A.Sen NPB, 1992; PRL 1995; Strings as solitons, Dabholkar at al. 1995, AB PRD 1995,2003).

Circular string of the Kerr geometry is LIGHTLIKE.

Phase of the oscillating Higgs field φ plays the role of periodic coordinate of compactification, and together with time t of the oscillating Higgs field $H = |H|e^{i2m(t+a\varphi)}$ they form parametrization of the worldsheet.

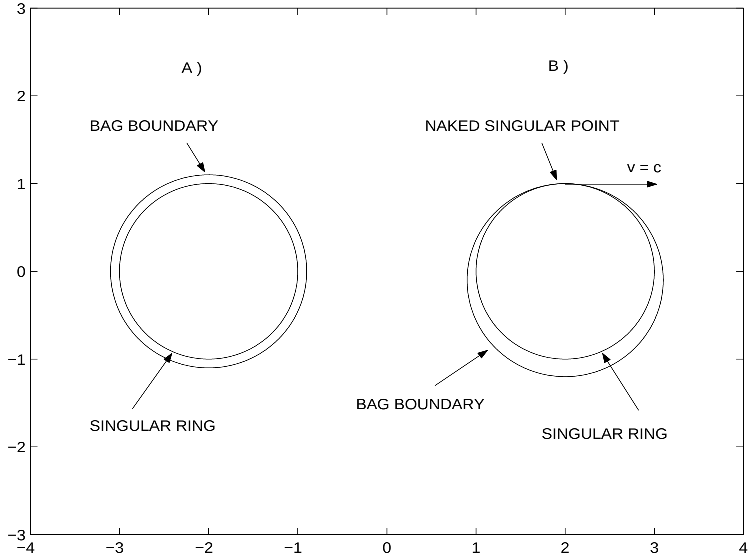
EXCITATIONS: Stationary Kerr-Newman solution $\psi = e$ creates a frozen electromagnetic wave along boundary of the bag defined by $H(r, \psi) = 0$. Electromagnetic excitations create traveling waves.



Boundary of bag is determined by "zero gravity surface"$H = 0$, where

$$H = \frac{mr - |\psi|^2/2}{r^2 + a^2\cos^2\theta} \ . \qquad (15)$$

Condition $H = 0$ determines boundary of disk $R = |\psi|^2/2m$, which acts as cut-off for EM field.



The lowest exact EM excitations of KN solution

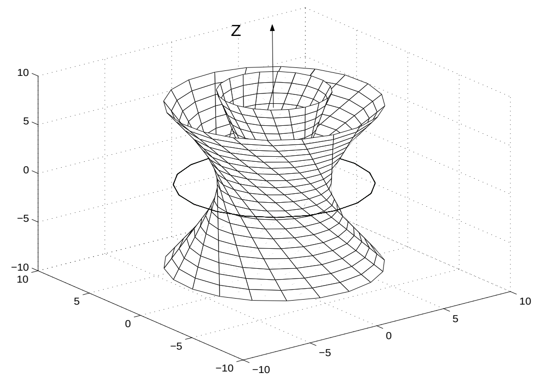
$$\psi_0 = e, \quad \psi_1 = e(1 + \frac{1}{Y} e^{i\omega\tau}) \tag{16}$$

takes in equatorial plane $\cos\theta = 0$ **the form** $\psi = e(1 + e^{-i(\phi - \omega t)})$, **and the cut-off parameter**

$$R = |\psi|^2/2m = \frac{e^2}{m}(1 + \cos(\phi - \omega t))$$

depends on $\phi - \omega t$.
Vanishing R **at** $\phi = \omega t$ **creates singular pole which circulates along the ring-string. Closed string turns into an open string with singular end points – analog of circulating quark.**
More high excitations $\psi_2 = e(1 + (Ye^{i\phi})^2)$ **give two nodes leading to two traveling singular points – analog two circulating quarks of the bosonic solutions of the SM.**

Consistency of the Dirac equation with twistorial structure of the Kerr geometry.



Algebraically special KN solution – all fields are collinear to Principal Null Directions k^μ of the Kerr congruence k^μ.

Metric of the Kerr-Newman solution: $g_{\mu\nu} = \eta_{\mu\nu} + 2Hk_\mu k_\nu$ **and vector potential** $A^\mu_{KN} = Re\frac{e}{r+ia\cos\theta}k^\mu$. **The null directions k^μ determine a collinear spinor field.**

THE KERR THEOREM: Kerr congruence has two solutions $k^\pm_\mu$ creating two metrics $g^\pm_{\mu\nu} = \eta_{\mu\nu} + 2Hk^\pm_\mu k^\pm_\nu$. TWOSHEETED Kerr space!

Geodesic and Shear-free congruences are obtained as analytic solutions of the equation $F(T^a) = 0$ **, where F is a holomorphic function of the projective twistor coordinates in CP**^{3}**,** $T^a = \{Y, \quad \zeta - Yv, \quad u + Y\bar\zeta\}$.

Projective coordinate $Y = \phi_1/\phi_0$, is equivalent to Weyl spinor ϕ_α.

TWISTOR ⇔ SPINOR relation is origin of the consistent Dirac field.

DIRAC EQUATION splits in the Weyl representation into two equations

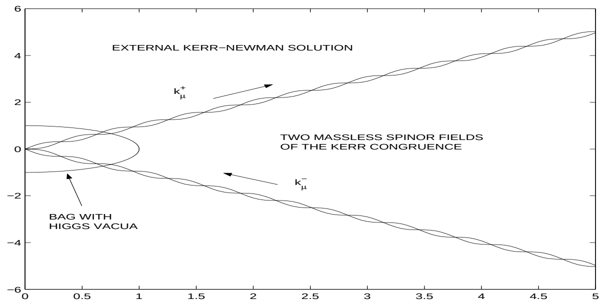
$$\sigma^{\mu}_{\alpha\dot\alpha} i\partial_\mu \bar\chi^{\dot\alpha} = m\phi_\alpha, \quad \bar\sigma^{\mu\dot\alpha\alpha} i\partial_\mu \phi_\alpha = m\bar\chi^{\dot\alpha}, \tag{17}$$

the “left-handed"and “right-handed"electron fields, Weyl spinors.

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

$$\phi_\alpha = \begin{pmatrix} e^{-i\phi/2}\cos\frac{\theta}{2} \\ e^{i\phi/2}\sin\frac{\theta}{2} \end{pmatrix}, \quad \bar\chi^{\dot\alpha} = \begin{pmatrix} -e^{-i\phi/2}\sin\frac{\theta}{2} \\ e^{i\phi/2}\cos\frac{\theta}{2} \end{pmatrix}, \tag{18}$$

which are aligned to different $k^{\mu\pm}(x)$ and different metrics $g^{\pm}_{\mu\nu} = \eta_{\mu\nu} + 2H_{(KN)} k^{\pm}_\mu k^{\pm}_\nu$.
The “left"and “right"spinors should be placed on different sheets of metric.



Inside the bag the Weyl spinors are united into Dirac bispinor Ψ, and Dirac equation $(\gamma^\mu\partial_\mu + m)\Psi(x) = 0$, acquires mass $m(x) \equiv g\mathcal{H}(x)$ from the Higgs condensate $\mathcal{H}(x)$.

SUPER-BAG – nonperturbative analog to Wess-Zumino SuperQED model.
Super-QED forms a bridge to perturbative QED of the electron!

Supersymmetric perturbation theory is developed as a direct extension of the ordinary perturbation theory.

Φ^i **become chiral fields in the component form** $\Phi_i(y) = A_i(y^\mu) + \sqrt{2}\theta\psi_i(y^\mu) + \theta\theta F_i(y^\mu)$.
Kinetic term super-QED has two chiral fields Φ_+ **and** Φ_-,

$$\mathcal{L}_{kinQED} = \frac{1}{4}Re\int d^4x\, d^2\theta\, W^a W_a + \int d^4x\, d^4\theta\, (\Phi_+^+ e^{eV}\Phi_+ + \Phi_-^+ e^{-eV}\Phi_-), \tag{19}$$

and potential term is formed as the sum of the 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".)

GENERALIZATION: **Nonperturbative Super-QED field model is constructed as unification of the kinetic part of super-QED with potential of the bosonic super-Bag. In notations** $\Phi_+ = \Phi,\ \Phi_- = \bar\Phi$, **and** $\Phi_1 = \Sigma,\ \Phi_2 = \bar\Sigma$, **and** $\Phi_0 = Z$, **superpotential takes the form** $W(\Phi_i) = \Phi_0(\Phi_1\Phi_2 - \eta^2) + (\Phi_0 + \mu)\Phi_+\Phi_-$.

Nonperturbative Super-QED bag model of dressed electron is matched with QED and principles of the SM. It shows that the Compton zone of the consistent with gravity dressed electron must have the form a superconducting disk, built from supersymmetric vacuum state of the Higgs field. It contains the light-like string on perimeter of the bag and circulating pole. The known zitterbewegung of the Dirac electron acquires natural explanation as consequence of the traveling wave solutions.

CONCLUSION:

- **Great contribution of spin shows that Einstein's gravity is not weak and has crucial influence at the Compton scae.**
- **The particle physics compatible with gravity should be based on Compton scale.**
- **Sharp conflict between quantum theory and gravity is resolved by SUPERSYMMETRY without modifications of the Einstein-Maxwell equations.**
- **The nonperturbative Super-bag solution is obtained compatible with external Kerr-Newman gravity and basic principles of the Standard Model.**
- **SUPERSYMMETRY provides consistency of the super-bag model with Wess-Zumino Super-QED model, showing the path to perturbative QED model of dressed electron.**

THANK YOU FOR YOUR ATTENTION!