# Instability of Black Hole Horizon With Respect to Electromagnetic Excitations.

Alexander Burinskii
Gravity Research Group, NSI, Russian Academy of Sciences,
B. Tulskaya 52 Moscow 115191 Russia, email: bur@ibrae.ac.ru

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**Abstract**

Analyzing exact solutions of the Einstein-Maxwell equations in the Kerr-Schild formalism we show that black hole horizon is instable with respect to electromagnetic excitations. Contrary to perturbative smooth harmonic solutions, the exact solutions for electromagnetic excitations on the Kerr background are accompanied by singular beams which have very strong back reaction to metric and break the horizon, forming the holes which allow radiation to escape interior of black-hole. As a result, even the weak vacuum fluctuations break the horizon topologically, covering it by a set of fluctuating microholes. We conclude with a series of nontrivial consequences, one of which is that there is no information loss inside of black-hole.

The statements on stability of the black-hole horizon are based on the theorems (Robinson and Carter) claiming the uniqueness of the Kerr solution. As usual, these theorems are valid under a series of conditions, among which are stationarity, axial symmetry and asymptotic flatness of the metric [1]. Meanwhile, many of these conditions turns out to be vulnerable in practice. In particular, in the problem of interaction of a black-hole (BH) with electromagnetic perturbations, the conditions of stationarity and axial symmetry are broken, as well as the condition of asymptotic flatness, since the perturbations are coming from asymptotic region and are scattered back to infinity.

Second vulnerable point is the use of perturbative approach. The BH solutions belong to type D which has two principal null congruences (PNC) $\mathcal{K}^{\pm}$. All the tensor fields of the exact solutions of type D are to be aligned to the PNC. Meanwhile, the Kerr and Kerr-Newman (KN) solutions are twosheeted, and $\mathcal{K}^{+}$ (PNC on the $(+)$ sheet) differs from $\mathcal{K}^{-}$ (PNC on the $(-)$ sheet), which is exhibited in the Kerr-Schild form of metric

$$g^{\pm}_{\mu\nu} = \eta_{\mu\nu} + 2H k^{\pm}_{\mu} k^{\pm}_{\nu}, \tag{1}$$

were $\eta_{\mu\nu}$ is metric of auxiliary Minkowski space-time $M^4$ and $k^{\mu(x)\pm}$, $(x = x^{\mu} \in M^4)$ are two different vector fields tangent to the corresponding $\mathcal{K}^{\pm}$. Direction of PNC is determined in the null coordinates $u = z - t, \quad v = z + t, \quad \zeta = x + iy, \quad \bar{\zeta} = x - iy$, by 1-form

$$k^{(\pm)}_{\mu} dx^{\mu} = P^{-1}(du + \bar{Y}^{\pm} d\zeta + Y^{\pm} d\bar{\zeta} - Y^{\pm}\bar{Y}^{(\pm)} dv), \tag{2}$$

and depends on the complex coordinate on celestial sphere

$$Y = e^{i\phi} \tan\frac{\theta}{2}. \tag{3}$$

Two solutions $Y^{\pm}(x)$ are determined by the Kerr Theorem [2, 3, 4, 5, 6].

Projection of the Kerr PNC on auxiliary background $M^4$ is depicted on Fig.1 .

The PNC covers the spacetime twice: in the form of ingoing PNC $k^{\mu -} \in \mathcal{K}^{-}$ which falls on the disk spanned by Kerr singular ring, and as outgoing one, $k^{\mu +} \in \mathcal{K}^{+}$, positioned on the second sheet of the same spacetime $M^4$. The metric $g^{\pm}_{\mu\nu} = \eta_{\mu\nu} + 2H k^{\pm}_{\mu} k^{\pm}_{\nu}$ and electromagnetic fields, being aligned with PNC, are to be different on the in- and out- sheets and should not be mixed. This twosheetedness is ignored in perturbative approaches, leading

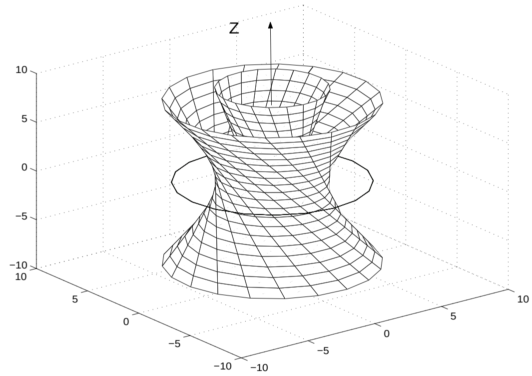


Figure 1: The Kerr singular ring and congruence.

to drastic discrepancies in the solutions and in the structure of horizon. *The typical exact electromagnetic solutions on the Kerr background take the form of singular beams propagating along the rays of PNC, contrary to smooth angular dependence of the wave solutions used in perturbative approach!*

Position of the horizon is determined by function $H$ which has for the exact KS solutions the form, [2],

$$H = \frac{mr - |\psi|^2/2}{r^2 + a^2 \cos^2 \theta} \ , \tag{4}$$

where $\psi(x)$ is related to vector potential of electromagnetic field

$$\alpha = \alpha_\mu dx^\mu = -\frac{1}{2} Re \ [(\frac{\psi}{r + ia\cos\theta}) e^3 + \chi d\bar{Y}], \quad \chi = 2 \int (1 + Y\bar{Y})^{-2} \psi dY \ , \tag{5}$$

which obeys the alignment condition

$$\alpha_\mu k^\mu = 0. \tag{6}$$

The equations (1)and (4) display compliance and elasticity of the horizon with respect to electromagnetic field.

The Kerr-Newman solution corresponds to $\psi = q = const.$. However, any nonconstant holomorphic function $\psi(Y)$ yields also an exact KS solution, [2]. On the other hand, any nonconstant holomorphic functions on sphere acquire at least one pole. A single pole at $Y = Y_i$

$$\psi_i(Y) = q_i/(Y - Y_i) \tag{7}$$

produces the beam in angular directions

$$Y_i = e^{i\phi_i} \tan \frac{\theta_i}{2}. \tag{8}$$

The function $\psi(Y)$ acts immediately on the function $H$ which determines the metric and the position of the horizon. The given in [7] analysis showed that electromagnetic beams have very strong back reaction to metric and deform topologically the horizon, forming the holes which allows matter to escape interior (see fig.2).

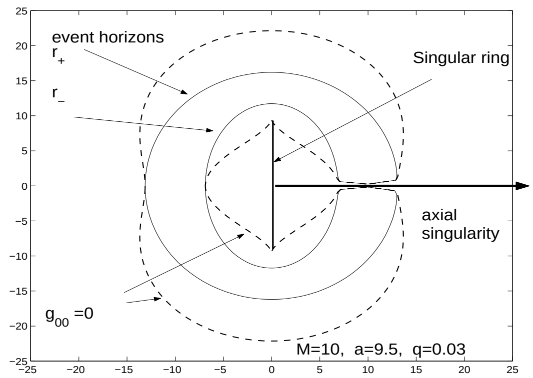


Figure 2: Hole in the horizon of a rotating black hole formed by a singular beam directed along axis of symmetry.

The exact KS solutions may have arbitrary number of beams in angular directions $Y_i = e^{i\phi_i} \tan \frac{\theta_i}{2}$. The corresponding function

$$\psi(Y) = \sum_i \frac{q_i}{Y - Y_i}, \tag{9}$$

leads to the horizon with many holes. In the far zone the beams tend to the known exact singular pp-wave solutions (A.Peres) [6]. The multi-center KS solutions considered in [3] showed that the beams are extended up to other matter sources, which may also be assumed at infinity.

The stationary KS beamlike solutions may be generalized to time-dependent wave pulses, [8], which tend to exact solutions in the low-frequency limit [9].

Since the horizon is extra sensitive to electromagnetic excitations, it should also be sensitive to the vacuum electromagnetic field which is exhibited classically as a Casimir effect, and it was proposed in [9, 10] that the vacuum beam pulses shall produce a fine-grained structure of fluctuating microholes in the horizon, allowing radiation to escape interior of black-hole, as it is depicted on Fig.3.

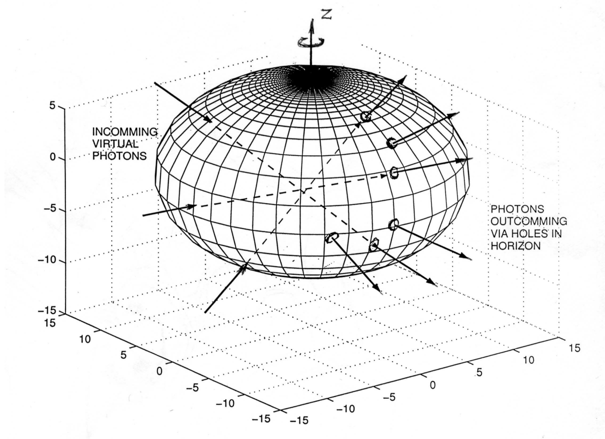


Figure 3: Excitation of a black hole by the zero-point field of virtual photons forming a set of micro-holes at its horizon.

The function $\psi(Y,\tau)$ corresponding to beam pulses has to depend on retarded time $\tau$ and satisfy to the obtained in [2] nonstationary Debney-Kerr-Schild (DKS) equations leading to the extra long-range radiative term $\gamma(Y,\tau)Z$. The expression for the null electromagnetic radiation take the form, [2], $F^{\mu\nu} = Re\mathcal{F}_{31} e^{3\mu} \wedge e^{1\nu}$, where

$$\mathcal{F}_{31} = \gamma Z - (AZ)_{,1} \ , \tag{10}$$

$Z = P/(r + ia\cos\theta), \quad P = 2^{-1/2}(1 + \bar{Y}\bar{\bar{Y}})$, and the null tetrad vectors have the form $e^{3\mu} = Pk^\mu, \ e^{1\mu} = \partial_{\bar{Y}} e^{3\mu}$.

The long-term attack on the DKS equations performed in [4, 5, 8, 9, 10] has led to the obtained in [11] time-dependent solutions which revealed a holographic structure of the fluctuating Kerr-Schild spacetimes and showed explicitly that electromagnetic radiation from a black-hole interacting with vacuum contains two components:

a) a set of the singular beam pulses (determined by function $\psi(Y,\tau)$,) propagating along the Kerr PNC and breaking the topology and stability of the horizon;

b)the regularized radiative component (determined by $\gamma_{reg}(Y,\tau)$) which is smooth and, similar to that of the the Vaidya 'shining star' solution [6], determines evaporation of the black-hole,

$$\dot{m} = -\frac{1}{2}P^2 < \gamma_{reg}\bar{\gamma}_{reg} > . \tag{11}$$

The mysterious twosheetedness of the Kerr-Schild geometry plays principal role in the holographic black-hole spacetime [11], allowing one to consider action of the electromagnetic in-going vacuum as a time-dependent process of scattering. The obtained solutions describe excitations of electromagnetic beams on the Kerr-Schild background, the fine-grained fluctuations of the black-hole horizon, and the consistent back reaction of the beams to metric. The holographic space-time is twosheeted and forms a fluctuating pre-geometry which reflects the dynamics of singular beam pulses. This pregeometry is classical, but has to be still regularized to get the usual smooth classical space-time. In this sense it takes an intermediate position between the classical and quantum gravity.

We arrive at the following nontrivial conclusions:

- contrary to the perturbative results, the exact time-dependent solutions of the Maxwell equations on the Kerr background contain commonly the light-like singular beam pulses which lead unavoidable to formation of the holes in horizon,

- topological instability of black hole horizon with respect to electromagnetic excitations rejects the recent speculations on the possible creation of black holes in the scattering processes at high energies.

- black hole horizon is topologically nonstable even with the respect to the very weak electromagnetic excitations, in particular, with respect to the action of vacuum fluctuations leading to the fine-grained topological fluctuations of the horizon structure,

- interior of a black hole is not isolated from the exterior region and matter may leave the interior in the form of the outgoing null radiation, and so, there is no information loss paradox.

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