Quasi black holes: general conception and physical applications

Oleg B. Zaslavskii
Kharkov V.N. Karazin National University,
Kharkov, Ukraine

Collaboration:
José P. S. Lemos
Centro Multidisciplinar de Astrofísica, CENTRA,
Lisbon, Portugal

Kirill Bronnikov, Moscow, Russia
Center for Gravitation and Fundamental Metrology, VNIIMS,
Institute of Gravitation and Cosmology

J. C. Fabris
R.' Silveira (Deceased)
Departamento de Fisica, Universidade Federal do Espirito Santo,
Vitoria, Brazil

Contents

- Physical realizations of QBH
- Spacetime properties, limiting transitions
- Mass formula: BH and QBH
- Entropy of QBH versus BH. Bekenstein-Hawking entropy without horizon
- QBH versus membrane paradigmeQBH with pressure
- MP (Majumdar-Papapetrou) and DMP (dilaton MP) systems

Usual situation: size approaches gravitational radius, system collapses

Special cases when gravitational radius is approached by sequence of static configurations

Majumdar –Papapetrou systems $p = 0,$

Compact objects: Bonnor stars $\rho = \rho_e$

Sphere of neutral hydrogen lost 10^{-18} of its electrons

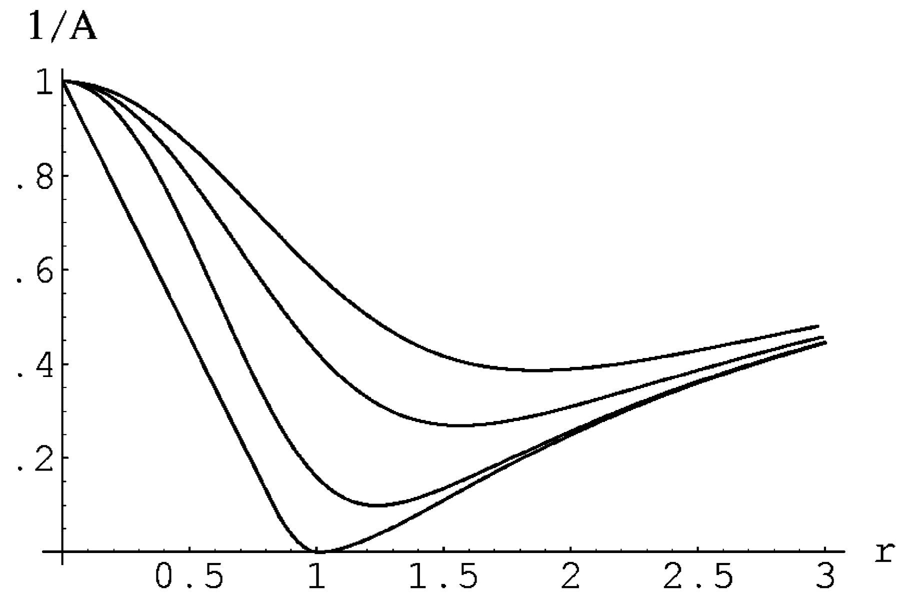
Self-gravitating magnetic monopole

Threshold of formation of event horizon. Quasihorizon

Massive charged extremal shells

Different physical systems share common features: geometry of spacetime

behavior of tidal forces



Lemos and E. Weinberg 2004

FIG. 1. A plot of $1/A$ as a function of r for $q=1$ and, reading from the top down, $c=0.5$, 0.3, 0.1, 0.001. The emergence of the quasihorizon is quite evident in the $c=0.001$ curve.

$$ds^2 = -B(r)dt^2 + A(r)dr^2 + r^2(d\theta^2 + \sin^2\theta d\phi^2)$$

Lue and E. Weinberg 2000

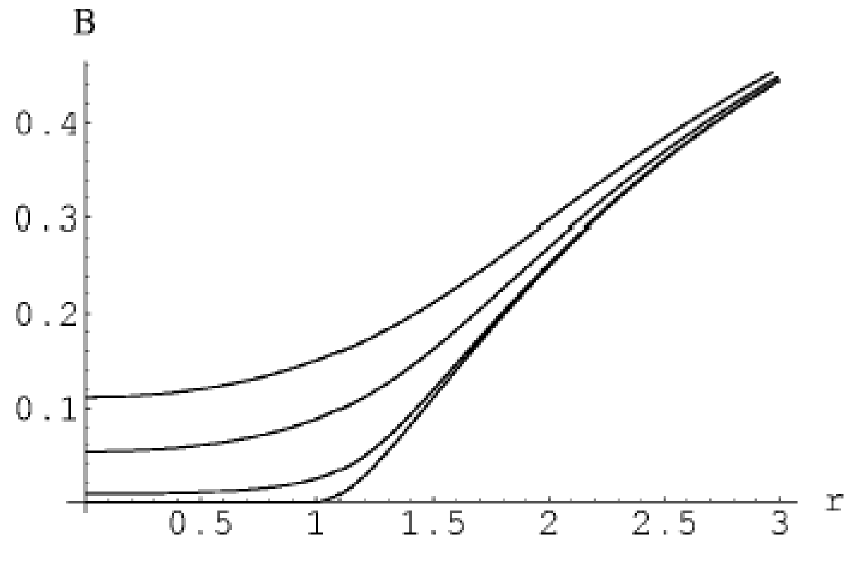
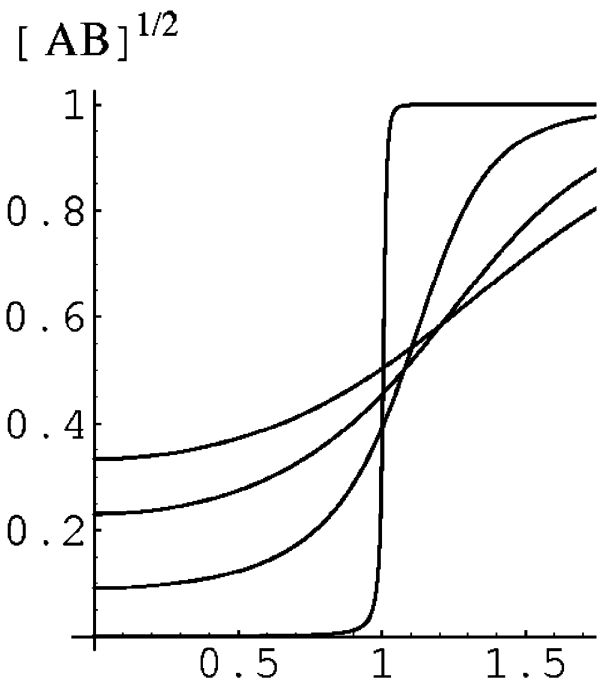


FIG. 2. A plot of $B(r)$ for $q=1$ and, reading from the top down, $c=0.5$, 0.3, 0.1, 0.001.



General approach (J. Lemos and O. Z.)

$$ds^2 = -B(r)dt^2 + A(r)dr^2 + r^2(d\theta^2 + \sin^2\theta d\phi^2) \qquad A = \frac{1}{V}$$

(i) V(r) attains minimum at $r^* \neq 0$ $\quad V(r^*) = \varepsilon \ll 1$

(ii) $\varepsilon \neq 0$ regular configuration

(iii) In limit $\varepsilon \to 0$ $V(r^*) \to 0$ $\quad B(r) \to 0$ for all $r \leq r^*$

Consequences:

(a) infinite redshift

$$V = \frac{(\nabla A)^2}{16\pi^2}$$

geometric meaning

(b) infinite tidal forces for free-falling observer

Limit $\varepsilon \to 0$ Singular (degenerate) or regular?

Properties of spacetimes -?

Extremal RN outside – Minkowski inside (shell)

Classical model of electron
A. V. Vilenkin, P. I. Fomin 1978

Outer metric

$$ds^2 = -\left(1-\frac{m}{r}\right)^2 dt^2 + \left(1-\frac{m}{r}\right)^{-2} dr^2 + r^2 d\Omega^2 \qquad r \geq r_0$$

Inner metric

$$ds^2 = -\left(1-\frac{m}{r_0}\right)^2 dt^2 + dr^2 + r^2 d\Omega^2 \qquad r \leq r_0$$

Inside. Two alternatives

1) Using time *t as* "good" coordinate. Then $g_{00} \rightarrow 0$

in the entire region $r \leq r_0$ Degenerate behavior

But Riemann tensor =0 there!

Surface $r = r_0$ becomes light-like in limit $r_0 \rightarrow m + 0$

2) Let us introduce inside the coordinate *T* :

$$t = \frac{T r_0}{r_0 - m} \qquad\qquad ds^2 = -dT^2 + dr^2 + r^2 d\Omega^2$$

Finite intervals of *T* – infinite intervals of *t* $\qquad -dT^2 = -\frac{(r_0 - m)^2}{r^2{}_0} dt^2$

Finite intervals of *t* – vanishing intervals of *T*

Let *T* be legitimate coordinate

$r_0 \to m$ Time-like surface. No matching between inside and outside

Complementarity

Zero mass particles

From inside to outside

Radial motion $\lambda = \tilde{\omega}^{-1} \int dl \sqrt{\tilde{B}}$

Outer region $\lambda - \lambda(r_0) \sim \dfrac{r - m}{r_0 - m}$ infinite in the limit $r_0 \to m$

for any $r > m$

Boundary as impenetrable barrier

Metrics

$$ds^2 = -B dt^2 + B^{-1}(dR^2 + R^2 d\Omega^2)$$

MP system, extremally charged dust

Bonnor star (1999)

$$U^I = 1 + \frac{m}{R_0} + \frac{m(R_0^n - R^n)}{nR_0^{n+1}}, \quad 0 \le R \le R_0,$$

$$U^E = 1 + \frac{m}{R}, \quad R \ge R_0 > 0,$$

RN metric

$$r = R + m$$

Schwarzschild coordinate outside

$$r_0 = m + R_0$$

$$R_0 \to 0$$

Substitution

$$R = R_0 x, \quad 0 \le x \le 1,$$

$$t = \frac{m\ T}{R_0}$$

$$ds^2 = -\left(1 + \frac{1}{n} - \frac{x^n}{n}\right)^{-1} dT^2 + m^2 \left(1 + \frac{1}{n} - \frac{x^n}{n}\right)^2 (dx^2 + x^2 d\Omega^2).$$

No horizons

Outer metric:

$$ds^2 = -\left(1 - \frac{m}{r}\right)^2 dt^2 + \left(1 - \frac{m}{r}\right)^{-2} dr^2 + r^2 d\Omega^2,$$

RN metric, horizon we cannot match smoothly the two geometries:

Bonnor star extended

$$\sqrt{B} = \frac{z}{z+q}, \qquad z \equiv \sqrt{R^2 + c^2},$$

If c=0 RN metric

3 regions

1) The inner core region $r \sim c$

$$t = \frac{q}{c}\tilde{t}, \qquad \cosh u \equiv y = \frac{z}{c},$$

$$ds^2 = q^2(-\cosh^2 u\, d\tilde{t}^2 + du^2 + \tanh^2 u\, d\Omega^2).$$

$u \to \infty$ Approaches Bertotti-Roninson

2) The vicinity of the quasihorizon $r = r^* = q$

$$T = z^* \frac{t}{q},$$

$$ds^2 = -\exp\left(\frac{2l}{q}\right) dT^2 + dl^2 + q^2 d\Omega^2.$$ Bertotti-Roninson

3) Outer region $r > r^*$ RN

Naked behavior

$$R_{0r}{}^{0r} = K \qquad R_{0\theta}{}^{0\theta} = \bar{K} \qquad R_{\phi\theta}{}^{\phi\theta} = F \qquad R_{r\theta}{}^{r\theta} = \bar{F}$$

finite in limit $\sqrt{B(r_0)} \to 0$ everywhere in inner region

Kretschmann scalar is finite geometry is regular

free-falling frame Enhancement of curvature components

G. T. Horowitz and S. F. Ross PRD 1997, 1998

$$\bar{Z} = Z\left(2\frac{E^2}{B} - 1\right) \qquad Z = \bar{F} - \bar{K} \qquad \sqrt{B} \to 0 \quad \boldsymbol{Z} \to \infty$$

$$Kr = R_{\alpha\beta\gamma\delta} R^{\alpha\beta\gamma\delta}$$

Non-scalar polynomial curvature singularities

S. W. Hawking and G. F. Ellis, G. F. R. Ellis and B. G. Schmidt

Redshift

$\omega(\infty) = \omega\sqrt{B(r)}$ $\qquad B \to 0$ in the whole inner region

infinite redshift in quasi-horizon limit $\leftrightarrow$ impossibility to penetrate from inside to outside

End state of family of configurations

no way in which one can get a more compact object

no way to somehow turn it into extremal BH

Vacuum with surface layer: gluing between extremal Reissner-Nordstrom and Bertotti-Robinson metrics

Gluing between BR and extremal RN (O.Z., PRD 2004)

Another version of "classical electron"

$$r \geq r_0 \quad B = \left(1 - \frac{m}{r}\right)^2 \qquad r \leq r_0 \quad \text{BR} \qquad q = r_0$$

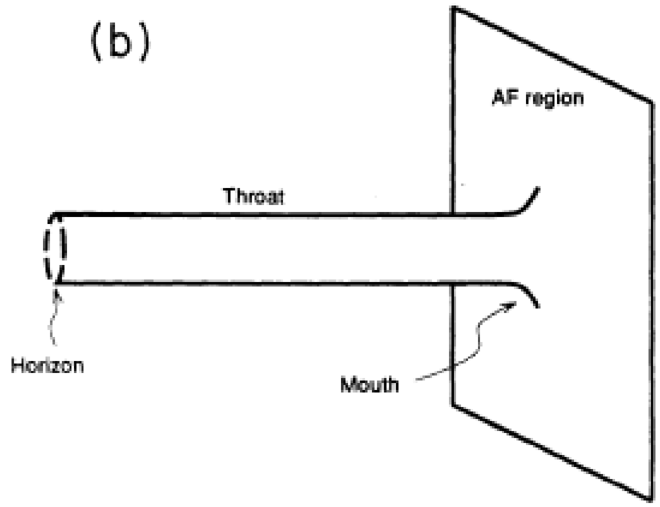
Surface stresses

Charge of shell

$$S_0^{\ 0} = \frac{\sqrt{B(r_0)}}{4\pi r_0^2} = \frac{\varepsilon}{4\pi r_0} \qquad \varepsilon = r_0 - m \qquad Q^{RN} - Q^{BR} = -\varepsilon$$

Contribution of shell vanishes in horizon limit, regular configuration

Extremal RN and BR



$$ds^2 = -dt^2 b^2 + dl^2 + r_0{}^2 d\omega^2 \qquad q = r_0$$

$$b = \sinh\frac{l}{r_0}, \exp\frac{l}{r_0}, \cosh\frac{l}{r_0}$$

For external observer like BH but no singularities inside

Reissner-Nordstrom core replaced by Bertotti-Robinson metric

Self-sustained configuration supported by electromagnetic forces without source
Mass without mass, charge without charge (Wheeler)

Reservation:
tidal stresses

$$\tilde{Z} = Z\left(\frac{2E^2}{B} - 1\right)$$

For BR Z=0

$$Y = S_1^{\ 1} - S_0^{\ 0} \qquad \tilde{Y} = \frac{1}{4\pi r^2_{\ 0}}\left(\varepsilon - \frac{2E^2 r^2_{\ 0}}{\varepsilon}\right) \sim \frac{1}{\varepsilon}$$

diverges: naked on surface

for $\varepsilon \neq 0$ boundary stresses finite and non-zero

$\varepsilon \to 0$ Stresses disappear in static frame, grow unbound in free-falling frame

Further property: regular QBHs with should be extremal

Boundary of body with Q<M cannot approach its own horizon: collapse

Particular models, numerics De Felice et al CQG 1999

Analytical proof generalizing Buchdal limits for charged perfect fluid

Yunqiang and Siming 1999

General statement

Static regular configuration cannot approach its own horizon arbitrarily closely if

horizon is non-extremal

Regular versus singular behavior and unattainability of quasi black hole limit

Kr finite but another manifestations of singular behavior

a) External observer: truly naked horizons and entire region in QBH limit
Boundary null

b) Internal observer: good inside but no matching to outside, boundary time-like

Complimentary relations between pictures viewed by different observers

Cannot arise from initially regular configuration, but approaches al closely as one likes (cf. 3d general law)

Usual horizon hides singularities, QH brings new singular features

Unusual counterpart of cosmic censorship

Inside may be regular and geodesically complete, no problem with limit

QBHs with pressure

$$ds^2 = -U(r)dt^2 + V(r)^{-1}dr^2 + r^2(d\theta^2 + \sin^2\theta d\phi^2).$$

$$T_\mu^\nu = \mathrm{diag}(-\rho, p_r, p_\perp, p_\perp),$$

It is supposed that in the outer region an extremal quasihorizon forms,

inside, the quasihorizon can be either nonextremal or extremal.

Role of electromagnetic field

$$U_{\text{in}}(r) = \varepsilon f(r),$$ Inside

Quasiblack holes with pressure, nonextremal from the inside

$$V_{\text{in}} = \varepsilon + k(r_0 - r) + \ldots,$$

$\varepsilon \ll 1$ $k > 0$

Quasiblack holes with pressure, extremal from the inside

$$V = \varepsilon + \kappa^2 (r_0 - r)^2 + \ldots,$$

If there is no electromagnetic field it requires a negative matter pressure (tension) on the boundary

situation with an electromagnetic field demands zero matter pressure on the boundary

electrified quasiblack hole can be obtained by the gradual compactification of a relativistic star with the usual zero pressure boundary condition

For the nonextremal case inside the density necessarily acquires a jump on the boundary,

For the extremal case inside we also state and prove the proposition that such a quasiblack hole cannot be made from phantom matter at the quasihorizon.

Impossible to built QBH from matter phanom everywhere inside

If phantom matter is present, it cannot border the quashihorizon and lies somewhere inside

Mass formula

Smarr (1973), Bardeen, Carter, Hawking (1973):

$$M_{tot} = \frac{\kappa A}{4\pi} + M_{out} \qquad M_{out} = \varphi_h Q + M^{matter}_{out}$$

Obtained from field equaitons by integration over the region outside the horizon only and taking into account the geometric properties of the horizon as null surface

Now, we consider the whole space, no horizon at all.
But the system is on the threshold of horizon formation

Mass of QBH

$$ds^2 = -N^2 dt^2 + dl^2 + g_{ab} dx^a dx^b$$

Size of body approaches gravitational radius

$$N \to 0$$

Mass formula for QBH vs. mass formula for BH

Tolman formula

$$M = \int d^3 x \sqrt{-g} (T_k{}^k - T_0{}^0)$$

$$\sqrt{-g} = N \sqrt{g_3}$$

$$M_{tot} = M_{in} + M_{surf} + M_{out}$$

Inner mass

$$M_{in} \le N_{\max} M_{pr} const \to 0$$

Surface mass

$$M_{surf} = \int_{surf} d^3x\sqrt{-g_3}\,N(T_k{}^k - T_0{}^0) \qquad\qquad T_\mu{}^\nu = S_\mu{}^\nu \delta(l)$$

$S_\mu{}^\nu$ Surface stresses in terms of jump of extrinsic curvature

$$M_{surf} = \frac{1}{4\pi}\int d\sigma[\left(\frac{dN}{dl}\right)_+ - \left(\frac{dN}{dl}\right)_-] \qquad S_a{}^b \sim \delta_a{}^b \frac{N'}{N} \qquad N \to 0$$

$\left(\frac{dN}{dl}\right)_- \to 0$ since N bounded and $N \to 0$

$\left(\frac{dN}{dl}\right)_+ \to \kappa$ Surface gravity $M_{surf} \to \frac{\kappa A}{4\pi}$

Now, we allow infinite stresses and non-extremal QBH

Mass formula

$$M_{tot} = \frac{\kappa A}{4\pi} + M_{out} \qquad M_{out} = \varphi_h Q + M^{matter}_{out}$$

Smarr; Bardeen, Carter and Hawking   Now: different meaning

Role of stresses: $$S_a^{\ b} \sim \delta_a^{\ b} \frac{N'}{N}$$

Non-extremal case: streses diverge, contribution to mass finite

Extremal case: streses finite, contribution to mass vanishes

Corollary: Abraham-Lorentz electron in GR

Pure field model: 1) absence of bare non-EM stresses, 2) pure EM mass
Attempt: Vilenkin and Fomin 1978

Now seen: 1) is NOT equivalent to 2) in general

On quasihorizon of extremal QBH: stresses do NOT vanish but

their contribution to mass DOES VANISH

Rotating black quasi- black holes

Meinel 2006 Limit of stationary configuraitons made from cold baryonic matter

Kerr limit

$$M = 2\Omega J$$

Angular velocity

Not possible for pure static case (Bouhdhal limit)

$$\Omega \to \Omega_H \qquad J = M^2$$

Mass formula, stresses

Rotating axially – symmetric metric

$$ds^2 = -N^2 dt^2 + dl^2 + g_{zz} dz^2 + g_{\phi\phi}(d\phi - \omega dt)^2,$$

Configuration depends on ε

a) For any ε it is regular, curvature invariants finite

b) Let the maximum value of N has order ε

c) $$\lim_{\varepsilon \to 0} \frac{\partial A}{\partial l}\Big|_{l^*} = 0$$

d) $\omega \to \omega_h = const$ everywhere in the inner region

$$J_i = -\int T_i^0 \sqrt{-g}\, d^3x,$$

$$J = -\int T^0_\phi N \sqrt{g_3}\, d^3x.$$

$$J_{\mathrm{tot}} = J_{\mathrm{in}} + J_{\mathrm{surf}} + J_{\mathrm{out}}.$$

$$J_{\mathrm{in}} \to 0.$$

stresses

Surface term

$$M_{\mathrm{surf}} = \frac{\kappa A_{\mathrm{h}}}{4\pi} + 2\omega_{\mathrm{h}} J_{\mathrm{h}}$$

Entropy of QBH

$r_B \to r_+$ $\qquad$ $S \to \dfrac{A}{4}$ $\qquad$ Near formation of horizon

Time-like surface vs. light-like one

Einstein equations and thermodynamic (Jacobson 1995): Rindler observer near (but not exactly on) horizon timelike, surface is lightlike

Limiting transition, continuity - ?

1) First law,
2) Temperature is equal to (or tends to) Hawking value

Assumptions:

1) First law,
2) Temperature is equal to (or tends to) Hawking value

Key role of surface stresses (no collapse – QBH!)

Unified approach
non-extremal, extremal

Basic formulas

$$ds^2 = -N^2 dt^2 + dl^2 + g_{ab} dx^a dx^b$$

$$T = \frac{T_0}{N}$$

Surface gravity

$$Td(\sqrt{g}s) = d(\sqrt{g}\varepsilon) + \frac{\theta^{ab}}{2}\sqrt{g}\,dg_{ab}$$

$\theta^a{}_b$ stresses

$$g = \det g_{ab}$$

$$\theta_{ab} = \theta^g{}_{ab} - \theta^0{}_{ab}$$

$$8\pi\theta^g{}_{ab} = K_{ab} - Kg_{ab} + \frac{N'}{N}$$

K_{ab} Extrinsic curvature tensor

Non-extremal case

$$K_{ab} \sim l \qquad \theta_{ab} \sim N^{-1}N' \sim \frac{\kappa}{N}$$

$$d(\sqrt{g}s) \approx \frac{\kappa}{16\pi T_0}\sqrt{g}\,g^{ab}dg_{ab} \qquad T_0 \to \frac{\kappa}{2\pi}$$

$$d(\sqrt{g}s) = \frac{1}{4}d(\sqrt{g}) \qquad S = \frac{A}{4}$$

Bekenstein-Hawking value!

Role of stresses

$p + \rho = Ts$ Euler relation valid near horizon

$$p = \frac{1}{2}\theta_a{}^a \approx \frac{\kappa}{8\pi N} \to \infty$$

BH entropy, membrane paradigme and QBH

Metric

$$ds^2 = -N^2 dt^2 + h_{ij}\, dx^i dx^j ,$$

In Gaussian coordinates

$$ds_3^2 = h_{ij}\, dx^i dx^j = dl^2 + \sigma_{ab}\, dx^a dx^b ,$$

$$ds^2 = -N^2 dt^2 + dl^2 + \sigma_{ab}\, dx^a dx^b .$$

Membrane $\quad l = \text{const}$

$$ds^2|_{\text{mb}} = \gamma_{mn}\, dx^m dx^n = -N_{\text{mb}}^2 dt^2 + \sigma_{ab}\, dx^a dx^b ,$$

Temperature

Tolman formula $T = \frac{T_0}{N}$

Canonical ensemble, Euclidean action, boundary data

membrane radius r_{eb}

physical results depend crucially on whether we impose boundary conditions on

$r_{mb} + \delta$ or $r_{mb} - \delta$ Boundary term in action

Case 1 $$I_{\mathrm{withoutbh1}} = \left(\int_{\mathrm{eb}} d\sigma \beta \varepsilon - \int_{\mathrm{mb}} d\sigma \beta \varepsilon \right) - S_{\mathrm{matter}}$$

Case 2 $$I_{\mathrm{withoutbh2}} = \int_{\mathrm{eb}} d\sigma \beta \varepsilon - S_{\mathrm{matter}} - S_{\mathrm{mb}},$$

$$S_{\mathrm{mb}} = \frac{\beta_0}{8\pi} \int_{\mathrm{mb}} d\sigma \left(\frac{\partial N}{\partial n} \right)_+,$$

$$\beta_0 = 1 / T_0$$

Black hole case

2nd version of formulas $N_{\mathrm{mb}} \rightarrow 0$

$$\left(\frac{\partial N}{\partial n}\right)_{+} \rightarrow \kappa$$ Surface graviity

$$S = \frac{A}{4}\frac{T_{\mathrm{H}}}{T_0} \qquad T_{\mathrm{H}} = \frac{\kappa}{2\pi}$$

In the state of thermal equilibrium $T_0 = T_{\mathrm{H}}$

$$\lim_{l \to 0} S_{\mathrm{mb}} = \frac{A}{4}. \qquad S_{\mathrm{tot}} = S_{\mathrm{matter}} + \frac{A}{4},$$

$$I_{\mathrm{withbh}} = \int_{\mathrm{eb}} d\sigma\beta\varepsilon - S_{\mathrm{tot}},$$

Membrame paradigme: thin shell around black hole

QBH: body as a whole on the threshold of black hole formation,
No actual black hole

Dilaton gravity, (quasi-) black holes, and scalar charge

K.A. Bronnikov

J.C. Fabris and R. Silveira

O. Z.

$$L = \frac{1}{16\pi}\Big[R + 2\varepsilon(\partial\chi)^2 - F^2 P(\chi)\Big] + L_m + A_\mu j^\mu + J\chi,$$

$$\begin{aligned} 4\varepsilon\Box\chi + F^2 P_\chi &= 16\pi J, \\ \nabla_\alpha(P(\chi)F^{\alpha\mu}) &= -4\pi j^\mu, \\ G_\mu^\nu &= -8\pi T_\mu^\nu, \end{aligned}$$

Static equilibrium

$$ds^2 = e^{2\gamma}dt^2 - e^{-2\gamma}h_{ik}dx^i dx^k,$$

$\gamma\,,\ h_{ik}\,,\ \phi,\ \chi$ functions of $x^i,\ i = 1, 2, 3\,.$

It is assumed that the spatial metric is flat.

$$\chi \equiv 0\,,\ \ P \equiv 1\,,\ \text{that is, electrically charged dust,}$$

MP systems

$$\mathrm{e}^{2\gamma}\,\gamma_i\gamma^k = \phi_i\phi^k.$$

$$\begin{aligned}\mathrm{e}^{\gamma} &= \pm\phi + C_1(x^2, x^3)\\ &= \pm\phi + C_2(x^1, x^3)\\ &= \pm\phi + C_3(x^1, x^2)\end{aligned}$$

boundary conditions that $\phi \to 0$

and $\mathrm{e}^{\gamma} \to 1$ at spatial infinity.

$$\pm\phi = \mathrm{e}^{\gamma} - 1.$$

$$\rho_{\mathrm{e}} = \pm \rho_m$$

for each smooth $\gamma = \gamma(x^i)$

one finds the proper charge and mass distribution

If the potential = const, electric field is absent,

Equailibrium is possible for phantom field only

General static equilibrium

$$e^{2\gamma}(\gamma_i\gamma^k + \varepsilon\chi_i\chi^k) = P\,\phi_i\phi^k$$

$\gamma\,,\ \chi$ and ϕ are functionally related

if $\gamma \neq \text{const}$

we can put $\phi = \phi(\gamma)$ and $\chi = \chi(\gamma)$

Proof. Two independent functions could be chosen as coordinates but this would lead to contradiction.

Spherically symmetric configurations

$$ds^2 = \mathrm{e}^{2\gamma} dt^2 - \mathrm{e}^{-2\gamma}(dx^2 + x^2 d\Omega^2),$$

Configurations with regular centre

$$\gamma(x) = \gamma_c + O(x^2), \qquad \gamma_c = \mathrm{const},$$

$$\phi(x) = \phi_c + O(x^2), \qquad \chi(x) = \chi_c + O(x^2),$$

Configurations with horizons

Regularity, finite area

Double horizon

Integral charges

$$\phi' = q/x^2 + o(1/x^2)$$

$$\chi' = D/x^2 + o(1/x^2)$$

$$e^{\gamma} \approx 1 - m/x$$

$$m^2 - q^2 + \varepsilon D^2 = 0,$$

$q = \pm m$ MP

$m^2 > q^2$ phantom

$m^2 < q^2$ canonical field

Example

$$\mathrm{e}^{2\gamma} \equiv A(x) = \frac{z^2}{(m+z)^2}, \qquad z := \sqrt{x^2 + c^2},$$

$$4\pi\rho_m = \frac{3mc^2}{z^2(m+z)^3} - \frac{z^2}{(m+z)^2}\varepsilon\chi'^2.$$

Positive density without phantoms

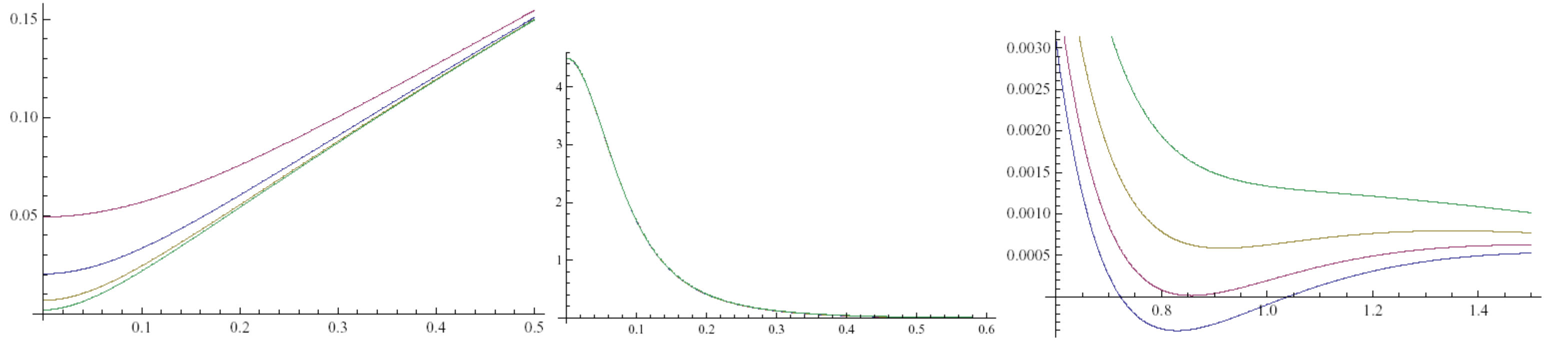


FIG. 2: Plots for Example QBH2. **Left:** the metric function $e^{2\gamma(x)}$ for $m = 1$, $a = 0.5$ and $c =$ 0.025, 0.5, 0.1, 0.2 (bottom-up). **Middle:** the density $\rho_m(x)$ at small x for $m = 1$, $a = 0.5$, $c =$ 0.1 and b ranging from 0.3 to 0.4: the b dependence is indistinguishable. **Right:** the same for $b =$ 0.39, 0.395, 0.398, 0.4 at larger values of x where the b dependence is significant (upside down).

Summary

- Different types of objects: NEBH-EBH-QBH-star
- Unified approach to diverse systems (continuous and compact distributions of extreme dust, gravitating monopoles, glued vacua). Physically reasonable systems. Extremal charged dust: indifferent equilibrium
- External observer cannot distinguish gravitationally BH and QBH
- Their nature is different. Mutual impenetrability for QBH (one way penetrability for BH)
- BH: separation of causal nature. QBH: separation of dynamic nature. Rescaling of time or tidal forces (in bulk or on surface).
- Non-trivial combination of singular and regular features, complimentary relations depending on observer.
- Mass of BH from QBH perspective
- Entropy of BH from QBH – nonextremal and extremal
- Role of surface stresses, holographic properties, QBH versus membrane
- MP systems versus DMP

- Alternative to gravastars as BH mimicker

Thank you!