

Lorentz interpretation and Kerr metric

J. Brandes

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Preliminary remark.

Lorentz interpretation of general relativity (LI of GRT) uses the same formulas and makes (nearly) the same experimental predictions as GRT. So, gravitational waves and all the other well-known relativistic experiments are predicted with the same formulas [1], [2]. But there is one important exception. Black holes differ in having no event horizon. How is that possible? All the formulas are the same! The reason is the different interpretation of the formulas of radial free fall. The Schwarzschild metric (SM) supplies two different formulas, $r = r(t)$ and $r = r(\tau)$, describing the radial position r of the free falling object as a function of coordinate time t or of proper time τ —s. common textbooks or [2]. The main difference between $r = r(t)$ and $r = r(\tau)$:

a.) Looking at coordinate time t , which is as well the time of a far-away observer, a free falling object (particle) never reaches the event horizon ($t = \infty$).

b.) Looking at proper time τ the particle reaches the event horizon within a finite interval. Within classical GRT (sometimes called Einstein interpretation of GRT abbreviated EI of GRT) proper time τ is the correct parameter and t is understood as a minor important coordinate time. Within LI of GRT it's the other way around. Coordinate time remains valid since it measures the time flow not influenced by the gravitational field while proper time of a free falling clock is the measurement of a clock which becomes retarded by the gravitational field and stands still when reaching the event horizon. This difference leads LI to postulate that there is no event horizon [2].

In the following, the assumptions of LI concerning Schwarzschild metric (SM) are transformed to Kerr metric and then the very impressing recent observations in the galactic center Sgr A* with the event horizon telescope [3] are discussed. It will be shown that there is no “*ultimate proof*” that black hole exists though stated otherwise [4] - a consequence of the fact not accepting LI of GRT as a serious alternative to EI of GRT. Also, it will be made reasonable that improved observations of Sgr A* in the future could answer whether black holes possess an event horizon or not.

EI of GRT: The dragging of inertial frames by the motion and rotation of nearby matter is called frame-dragging [5]“Frame-dragging is an effect on [spacetime](#).”[6] or LI of GRT: “Qualitatively, frame-dragging can be viewed as the gravitational analog of [electromagnetic induction](#).” [6]

Lorentz interpretation of Kerr metric

The Lorentz interpretation of the Schwarzschild metric (LI of SM) is explained in [2] and should be known. A short explanation is given in [7]. This article is an extension of these ideas to the Kerr metric which describes spinning black holes, the supermassive objects in the galactic centers.

The Kerr formulas used here are taken from the well formulated web contribution “The spinning black hole” [8]. None of the formulas is changed by LI and as in [8] we will not discuss the general case. “For simplicity we are going to study spacetime and particle motion in the equatorial plane of a symmetric spinning black hole of angular momentum J and mass M . The equatorial plane is the plane through the center of the spinning black hole and perpendicular to the spin axis.” [8] One can derive this special case from the general case by setting $\theta = 90^\circ$ and later $a = M$. The angular momentum parameter a is defined by $a = \frac{J}{M}$.

The Kerr metric in the equatorial plane (1) is expressed in what is called Boyer-Lindquist coordinates. The angular momentum parameter a appears in a few unaccustomed places. \tilde{r} is

the radial coordinate and is different from r in the Schwarzschild metric (SM) where spherical coordinates are used.

$$(1) \quad d\tau^2 = \left(1 - \frac{2M}{\tilde{r}}\right) dt^2 + \frac{4Ma}{\tilde{r}} dt d\varphi - \frac{d\tilde{r}^2}{1 - \frac{2M}{\tilde{r}} + \frac{a^2}{\tilde{r}^2}} - \left(1 + \frac{a^2}{\tilde{r}^2} + \frac{2Ma^2}{\tilde{r}^3}\right) \tilde{r}^2 d\varphi^2$$

The Schwarzschild metric reads

$$(2) \quad ds^2 = \frac{dr^2}{\left(1 - \frac{2M}{r}\right)} + (d\theta^2 + \sin^2\theta d\varphi^2)r^2 - \left(1 - \frac{2M}{r}\right) dt^2$$

r, θ, φ are the spherical coordinates.

ds is the measured interval between two near points of curved space time.

LI of SM makes the following four assumptions which transform the measured values ds into the real, finite values $dr_{rad}, dr_{tan}, dt, dm_r$. So formula (20.5) reads: Since clocks are slowed down in gravitational fields the measured time interval $d\tau$ is transformed into the real time interval not influenced by the gravitational field using (20.5). More s. [2].

$$(20.3) \quad dr_{rad} = ds(1 - 2M/r)^{1/2}$$

$$(20.4) \quad dr_{tan} = ds(1 - 2M/r)$$

$$(20.5) \quad dt = d\tau(1 - 2M/r)^{-1/2}$$

$$(20.6) \quad dm_r = dm(1 - 2M/r)^{1/2}$$

$2M$: Schwarzschildradius.

The similar formulas for the Kerr metric in the special case $\theta = 90^\circ$ $a = M$:

$$(3) \quad d\tilde{r}_{radial} = ds \left(1 - \frac{M}{\tilde{r}}\right)$$

$$(4) \quad d\tilde{r}_{tan} = ds \left(1 - \frac{2M}{R(\tilde{r})}\right)$$

$$(5) \quad dt = d\tau \left(1 - \frac{2M}{\tilde{r}}\right)^{-\frac{1}{2}}$$

$$(6) \quad dm_r = dm \left(1 - \frac{2M}{\tilde{r}}\right)^{\frac{1}{2}} \text{ if additionally, the particle is at rest in the gravitational field.}$$

These formulas are not proven for the general case but they show how LI of GRT will work when the supermassive objects called black holes will have a spin.

In the following the formulas are derived using [8]. Also, the radial free fall will be discussed.

(20.3) becomes for Kerr metric formula (3).

From formula (17) in [8] one gets

$$(3) \quad d\tilde{r}_{radial} = ds \left(1 - \frac{M}{\tilde{r}}\right) \text{ in Boyer-Lindquist coordinates } \tilde{r}, \theta, \varphi.$$

$\tilde{r} = M$ conforms with $r = 2M$, since $\tilde{r} = M$ means with

$$(8) \quad R^2 = \tilde{r}^2 + M^2 + \frac{2M^3}{\tilde{r}} \text{ which is Formula 13 of [8]}$$

$$(9) \quad R^2 = 4M^2$$

$$(10) \quad R = 2M$$

$\tilde{r} = M$ belongs to the 'reduced circumference' $R = 2M$

(20.4) becomes (4).

$$(4) \quad d\tilde{r}_{tan} = ds \left(1 - \frac{2M}{R(\tilde{r})}\right) \text{ or } d\tilde{r}_{tan} = dR(\tilde{r})$$

Within Kerr metric and $a = M, \theta = 90^\circ$ one has

$$(12) \quad R^2(\tilde{r}) = \tilde{r}^2 + M^2 + \frac{2M^3}{\tilde{r}}$$

$$(13) \quad R(\tilde{r} = M) = 2M$$

Since $R(\tilde{r})$ is the measurement result of circumference divided by 2π at the position $\tilde{r} = M$ one has

$$(14) \quad \int ds = 2\pi R(\tilde{r})$$

$$(15) \quad \int d\tilde{r}_{tan} = \int ds - 2\pi 2M \text{ with the same arguments as in [], page 307.}$$

(14) and (15) lead to (4).

$$(4) \quad d\tilde{r}_{tan} = ds \left(1 - \frac{2M}{R(\tilde{r})}\right)$$

(4) means that at $\tilde{r} = M$ one has $d\tilde{r}_{tan} = 0$. At $\tilde{r} = M$ the fast rotating black hole is a point in analogy to the situation of SM for which the black hole is a point at $r = 2M$. Within EI of GRT the black hole is a sphere of radius $\tilde{r} = M$ (Kerr metric) or $r = 2M$ (Schwarzschild metric).

In the case (20.5) one gets from (25) of [8] the formal identical result but with \tilde{r} instead of r .

$$(5) \quad dt = d\tau \left(1 - \frac{2M}{\tilde{r}}\right)^{-\frac{1}{2}}$$

In the case of $\tilde{r} = 2M$ one has

$$(18) \quad R^2 = (2M)^2 + M^2 + \frac{2M^3}{2M}$$

$$(19) \quad R = 2,4M \text{ instead } R = 2M \text{ in the case } r = 2M$$

Formula (5) can be proven experimentally by putting a clock into the gravitational field and comparing with a clock outside. But the two different interpretations remain. EI says: time becomes slowed down since spacetime is curved and LI says: not time but the clock runs slower on account of its interactions with the gravitational field.

Using formula 19 of [8] one gets

$$(20) \quad \frac{E}{m} = \left(1 - \frac{2M}{\tilde{r}}\right) \frac{dt}{d\tau} + \frac{2M^2}{\tilde{r}} \frac{d\varphi}{d\tau}$$

$\frac{E}{m}$ is constant and (20) is the energy conservation law for a free falling particle in the Kerr metric. Formula (20.6) is valid for a particle resting or moving at position r . For a resting particle in the Kerr metric one has $\frac{d\varphi}{d\tau} = 0$. It exists if $\tilde{r} > 2M$. If $\tilde{r} = 2M$ the rest mass becomes zero and if $\tilde{r} < 2M$ the rest mass is negative what might be interpreted as that such particles don't exist. Out of (20) one gets for a particle resting at $\tilde{r} > 2M$:

$$(21) \quad \frac{E}{m} = \left(1 - \frac{2M}{\tilde{r}}\right) \frac{dt}{d\tau}$$

Using formula 15 of [8] one gets

$$(22) \quad \frac{E}{m} = \left(1 - \frac{2M}{\tilde{r}}\right)^{\frac{1}{2}}$$

Setting $E = dm_r$ and $m = dm$ the result is

$$(6) \quad dm_r = dm \left(1 - \frac{2M}{\tilde{r}}\right)^{\frac{1}{2}}$$

dm is the rest mass outside the gravitational field.

dm_r is the rest mass within the gravitational field at position \tilde{r} .

(6) looks identical to (20.6). But the case $R(\tilde{r}) = r$ is physically more important than the case $\tilde{r} = r$ since in the former case the measured circumferences are the same. $R(\tilde{r}) = r$ means $\tilde{r} < r$ and a lower rest mass dm_r in (6). Within a rotating field (Kerr metric) a particle at a position geometrically equivalent to SM has a lower rest mass than in SM (with Newton: a more negative potential energy). You have to invest more energy).

The case of a free falling particle having $\frac{d\varphi}{d\tau} > 0$ is not discussed yet.

These considerations prove that LI of GRT is well extensible to the Kerr metric in the case $\theta = 90^\circ$ and $a = M$ and one can imagine that this remains true for the general case.

The next question: Does the main difference between $r = r(t)$ and $r = r(\tau)$ of free falling particles of SM remain valid for the Kerr metric? If so then:

- Looking at coordinate time t , which is as well the time of a far-away observer, a free falling object (particle) never reaches the event horizon ($t = \infty$).
- Looking at proper time τ the particle reaches the event horizon within a finite interval.

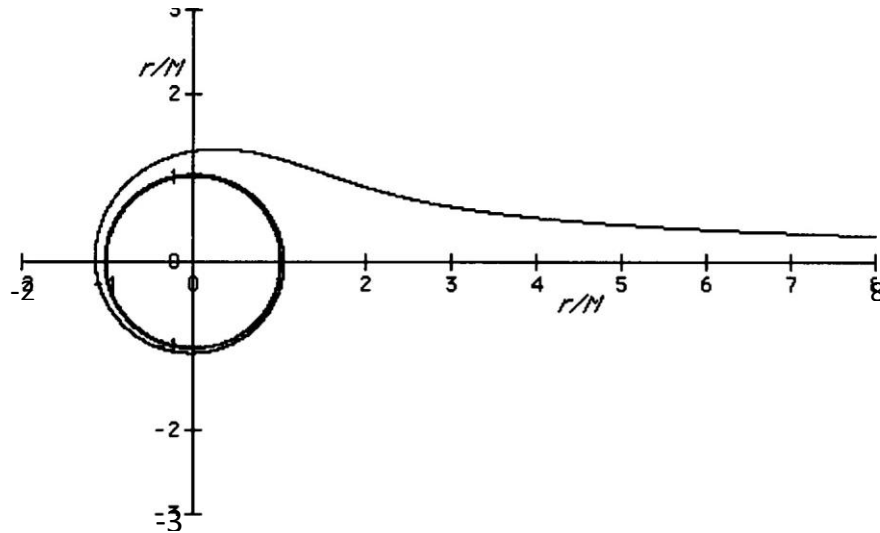


Fig. 1. Computer plot. Kerr map of the trajectory (24) in space of a stone dropped from rest far from a black hole (therefore with zero angular momentum). According to the far-away time t , the particle spirals in to the horizon at $\tilde{r} = 2M$ and circulates there forever. Taken from: Tomislav Prokopec Institute for Theoretical Physics and Spinoza Institute Utrecht University [8]

Fig. 1 is a computer plot using

$$(24) \quad d\tilde{r} = \frac{(\tilde{r}-m)^2}{\tilde{r}} \left[\frac{\tilde{r}^3}{2M^3} + \frac{\tilde{r}}{2M} \right]^{\frac{1}{2}} d\varphi, \text{ formula (24) in [8].}$$

Fig. 1 proves that the free falling particle as a function of t spirals around the black hole and circles for ever at $\tilde{r} = 2M$. The particle never reaches the center as a function of t .

Looking at

$$(25) \quad \left(\frac{d\tilde{r}}{d\tau} \right)^2 = \frac{2M}{\tilde{r}} \left(1 + \frac{M^2}{\tilde{r}^2} \right) \text{ formula (25) in [8]}$$

$\frac{d\tilde{r}}{d\tau}$ never becomes zero and as a function of τ the free falling particles reaches the center of the black hole within a finite time interval. So, the situation for LI of GRT and EI of GRT concerning the Kerr metric remains the same as for SM. EI: t is a coordinate time having restricted validity, only. The particle reaches the black hole center after a finite proper time. LI: Since the particle never reaches the black hole center in a finite far away time the interior of the black hole has no physical importance. In reality it is a point and circulation around the center in Fig. 1 can be understood as that a free falling particle gets a spin. The curved spacetime (especially the black hole sphere) *only visualizes* how bodies and measuring rods and clocks are affected by gravitational fields. In simple words: The measuring result around a black hole is a sphere but you have to correct this result by (4) because measuring rods contract and then you have a point.

[Understanding the measuring results of the event horizon telescope](#)

At first a comment on the manner how relativists present their - certainly important - investigations. These investigations are always “ultimate”, any rational alternative is ruled

out. But the fact: the important difference between classical GRT and LI of GRT is the question whether an event horizon does exist or not. This question is not answered, yet. So, no wonder, there are two “ultimate proofs” that black holes exist. The first one was done by [Genzel, Eisenhauer, Gillessen 2010](#) [14]. Some comments: “The outstanding, main result of our work is the proof of existence of an astrophysical massive black hole, *beyond any reasonable doubt*.”[9]. Another one: “[Reinhard Genzel](#) is the man who revealed the supermassive black hole at the very centre of our own galaxy, the Milky Way. The evidence gathered by [his research group](#) in Germany and by a group led by [Andrea Ghez](#) in California is now *so compelling that there is no longer a debate among astronomers that black holes really exist*” [10] The second “ultimate proof” is presented on the website of the Event Horizon Telescope. One of their “key science results so far: [Sgr A* is a black hole](#)”[12] is commented with “Within the BlackHoleCam project we [will]... provide the *ultimate proof* that black hole exists.” [13]

In spite of this, the observations and simulations of these groups are highly important and they state correctly: “One of the most fundamental predictions of GR are black holes (BHs). Their defining feature is the event horizon, the surface that even light cannot escape and where time and space exchange their nature. However, while there are many convincing BH candidates in the universe, there is no experimental proof for the existence of an event horizon yet.” [13]. But up to now, as far as I know, the LI of GRT is not considered.

The results by [14] are clearly no “ultimate proof” since LI of GRT leads to a supermassive object without any event horizon. The counter arguments against “key science results so far: [Sgr A* is a black hole](#)” are more difficult. Certainly, I have minor doubt that the important work of the Event Horizon Telescope collaboration and others will prove in the future whether an event horizon exists or not.

The main argument of [Sgr A* is a black hole](#): “Material is falling into the Sgr A* system. If Sgr A* had a surface no bigger than the size measured by the EHT, it would be a very bright source at infrared wavelengths. However, Sgr A* is a faint infrared source, indicating that energy is disappearing through an event horizon, the existence of which defines a black hole.” [12]

My understanding of this argument: The size of the surface of Sgr A* is larger than what is measured. But take what you see and you have a bright source without a black hole or a faint source if there is a black hole which absorbs radiation. The observations show a faint source and therefore the existence of an event horizon is proven. As will be shown, LI allows a faint source surrounded by a bright inner edge of an accretion disk and therefore could agree with the conclusion: “[The bright spot] is more likely a smaller region offset from the black hole, presumably in a compact portion of an accretion disk or jet that is Doppler-enhanced by its velocity along our line of sight.” [12]

Another possible convincing proof of black holes is discussed in Schutz [15] page 301ff, “The signature of a supermassive black hole in MCG-6-30-15”. “Their estimate is that the inner edge of the accretion disk is at just $1,24 GM/c^2$ ”. Since “accretion disks around a Schwarzschild black hole cannot extend within the last stable orbit at $6 GM/c^2$ ” “this black hole must be rotating almost as fast as the extremal Kerr hole”.

The counterarguments by LI of GRT: In my textbook [2] chapter 21.5 the different features of black holes in classical GRT and LI of GRT are explained and illustrated in two figures.

Black holes of LI are called supermassive stellar objects when it becomes necessary to distinguish with EI. Roughly black holes are spheres of radius $r = r_{SM}$ or $\tilde{r} = M$ (SM or Kerr metric). Supermassive stellar objects become a shell between $r = r_{SM}$ and $r = r_{SM} + d$ or $\tilde{r} = M$ and $\tilde{r} = M + d$. d is the thickness of the shell. The signature of a supermassive black hole in MCG-6-30-15 now reads: there is a supermassive object with an observed radius $\tilde{r} = 1,24 GM/c^2$. The accretion disk ends at $\tilde{r} = 1,24 GM/c^2$ since its inner edge collides with the surface of the supermassive object and in former times when the supermassive object

was less massive the inner edge did collide at say $\tilde{r} = 1,50 GM/c^2$. The conclusion about the Spin of the black hole in MCG-6-30-15 might be totally wrong.

The observation of [15] reads with LI: The bright source arises from the collision of the inner disk edge with the surface of the supermassive object. This source is brighter than the supermassive object itself on account of the same reasons as when a meteorite hits on earth producing a light flash. The necessary cooling may be done by jets and all the other forms of particle emission and only partly by radiation. A further argument that these processes are powerful: the inner disk edge and the surface of the supermassive object are co-rotating and may become a turbulent unit.

This are qualitative ideas, only and I don't exclude better ones. The differences between LI and EI are in general:

LI: Flares, jets, accretion on the supermassive object, large magnetic fields, particle emission are explained similar to sun or neutron stars. The supermassive object itself is some degenerated object similar to neutron stars. The inner disk edge is not only a bright source on account of inner friction but also because there is friction or collision with the surface of the supermassive stellar object.

EI: In principle, all these effects become understandable with the help of circulating matter in the ergosphere but with lesser efficiency. Up to now, the LI of GRT is not considered which may lead to wrong conclusions.

These considerations rest on the believe that the thickness d of the supermassive object becomes measurable with the event horizon telescope. If not let me give a picture. A particle comes from the near of $\tilde{r} = M$. LI of GRT says that it is ejected from the surface of the supermassive object and EI of GRT says no, it is from the inner edge of the accretion disc since $a = M$.

Literature

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