Black Hole Singularity, fact or fiction?

Introduction and relevance

Publications about black hole singularities and wormholes often directly refer to Schwarzschild or Einstein[1]. However, Karl Schwarzschild would have corrected the idea of singularities as a misinterpretation of his *exact* solutions[2][3]. Albert Einstein would have warned: he used his own theory for *approximations* only; they are not to be extrapolated to very strong gravitation in very large reference frames. The authors of this article will argue that black hole singularities are fiction, a sphere cannot collapse to within its Schwarzschild radius, the thermal counter pressure will always balance the gravitational (collapsing) pressure.

The authors will explain how these errors arose in history and how these errors must be repaired for the sake of science. The resulting formulas are elegant, consistent with all observations, and come with surprising results. Results include the merger of the repaired Schwarzschild Solution with Einstein's theory of Special Relativity and the minimal radius of a black hole. Practical and measurable outcomes include the escape speed from earth at any location and the core temperature of the earth, the sun, neutron stars, and black holes.

Current ideas about Black Holes

Eddington was the first scientist who published (1922) the solution of Einstein's theory of General Relativity[4] to a mass-point in clear English with ample description. The Eddington solution[5] describes a *coordinate* singularity when reaching the Schwarzschild radius or "event horizon" of a mass-point. According to Thorne's idea (see footnote 1), a sphere can collapse to within this "event horizon", while "tortoise coordinates", also called "Eddington-Finkelstein coordinates" allow for falling through this "event horizon". Let us see how these errors could have been made, to begin with the original Schwarzschild Solution.

The original Schwarzschild solution to a mass-point

Karl Schwarzschild presented Einstein's first exact solution on January 12, 1916: Über das Gravitationsfeld eines Massenpunktes nach der Einstein'schen Theorie (About the gravitational field of a mass-point according to Einstein's theory). This document is not easy to understand for reasons of its poor use of language and its complex differential mathematics.

Let us first describe a singularity. A singularity in mathematics is an unsolvable equation, for example: $t = 1 / 0$. Some people say that "t" is infinite, but no amount of summation of zeros can come to a total of more than zero. Let us stick to good mathematics, the equation $t = 1 / 0$ is *unsolvable*, it is a *singularity*. In the original Schwarzschild solution to a mass-point there is a *coordinate* singularity at distance zero ($r = 0$), at the mass-point. He introduced the famous Schwarzschild radius: $\alpha = 2G.M / c^2$ [m], in which the "G" is the Newton constant, "M" is the mass of the mass-point and "c" is the speed of light.

[1] Thorne, K (1994), "Black Holes and Time Warps, Einstein's Outrageous Legacy"
[2] Schwarzschild, K (1916), "On the Gravitational Field of a Mass-point"
[3] Schwarzschild, K (1916), "On the Gravitational field of a Sphere of incompressible Liquid"
[4] Einstein A. (1916) "The General Theory", Annalen der Physik, 49
[5] Eddington, A (1922), "The Mathematical Theory of Relativity"

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The mass-point that Schwarzschild was talking about, is a massive object concentrated in the origin of a reference frame. This is a technique to regard a real object like the earth or the sun as a single point within a reference frame, such that we can talk about distances. A mass-point in physics is a simplified model of a real object such that we can use our laws of physics. In the original Schwarzschild solution, the mass-point and singularity are both at r = 0. Karl Schwarzschild's conclusion about the orbits of mass-particles around the mass-point in the origin (r = 0) was as follows: He stated at the end of his solution:

$n^2 = \alpha / 2(r^3 + \alpha^3)$ [$rad^2.s^{-2}$] orbital speed "n" squared (1)

In this equation is "n" the orbital speed in [rad / sec], and "α" the Schwarzschild radius ($2G.M / c^2$). To put this in context, an orbital radius "r" at the Schwarzschild radius "α" has a speed of half the speed of light and an orbital radius close to the mass-point ($r \rightarrow 0$) has a speed "v" going close to zero (because v = n.r and thus is $v^2 = \alpha.r^2 / 2(r^3 + \alpha^3)$). Schwarzschild used an auxiliary variable "R" ($R^3 = r^3 + \alpha^3$). He stated:

Wenn für die Molekularkräfte ähnliche Gesetze herrschen, könnte dort dieser Umstand von Interesse sein (If, for molecular forces the same laws of nature apply, then this formula could be of interest). In other words, according to Schwarzschild's first and exact solution, there is no "last stable orbit", no "photon sphere", and light is able to escape from a singularity.

So, how did Thorne come to his solution in which there is a "last stable orbit" and a "photon sphere" and in which light is unable to escape from the same mass-point? The first step was taken by Eddington, when he invented the "event horizon" as a result of a modification to Schwarzschild's original solution. So let's get back to Eddington.

Eddington's modification created the "event horizon"

Eddington's solution of a mass-point described in his book "The Mathematical Theory of Relativity" of 1922 is a *poor copy* of Schwarzschild's solution. Did he copy the solution of the Dutchman J. Droste in 1917? Was it a language barrier? Was it the complicated mathematics and the confusing symbols? Was it Schwarzschild's use of symbols, which confused Eddington?

We don't know, but what we do know is that this solution differs from Schwarzschild's original solution in strong gravitation. Eddington changed the *auxiliary variable* "R" ($R^3 = r^3 + \alpha^3$) into the *coordinate* "r". When you look at formula (1) you see the impact if you replace R^3 ($= r^3 + \alpha^3$) by r^3, the orbital speed must then go to infinity when trying to orbit the singularity at close range, faster than the speed of light! This copy error migrated the singularity from zero (r = 0) to the Schwarzschild radius (r = α) which Thorne named the "event horizon".

This "event horizon" would be equal to the Schwarzschild radius "α", a radius at which time would stand still for the local observers, and from within which light would not be able to escape. So Eddington *created* the "photon sphere", "last stable orbit", and the "event horizon" effectively by his misinterpretation of Schwarzschild's solution and therefore his work should be considered of insufficient quality. To make his solution *look like* Schwarzschild's solution,

he also had to "drop the suffix" of an important variable "r_1" in another equation, motivated by the fact that "r_1" is, in *weak gravitation*, equal to the coordinate "r".
The difference however, between the two (r_1 and r) cannot be neglected so easily, as the relation between these two is a function of the coordinate "r": $r_1 = r.V(r)$. *As a consequence Eddington's solution is valid in weak gravitation only*! Formulated otherwise: When talking about black holes with strong gravitational fields, the difference between "R" and "r" is crucial to the existence of singularities. When mistakenly using "r" instead of "R", you get a black hole singularity. But, when using the original *second* solution of Karl Schwarzschild (On the Gravitational field of a Sphere of incompressible Liquid), a black hole is not at all a singularity. This is surprising and also reassuring: less mythical objects in our universe.

The modification by Misner, Thorne, and Wheeler (MTW)

The Schwarzschild solution, which MTW describe in their book "Gravitation"[6], is a *sphere of incompressible liquid*. So they should have based their solution on Schwarzschild's second solution of February 1916, which is the *exact solution* to a sphere of incompressible liquid (see next paragraph). However, they did not use the German version of Karl Schwarzschild, but copied the English version of Eddington; a solution to a *mass-point*. Was that also a language issue? Or perhaps did the influence of the Second World War, which also was a scientific battle for superiority, lead to an unfounded dismissal of Schwarzschild's work by MTW?

Furthermore, how could they use Eddington's solution to a *mass-point*? This is where Birkhoff's theorem steps in. Birkhoff's theorem states, in a simplified way, that all solutions in vacuum of a symmetrical body should have the "Schwarzschild format". This theorem is in itself based on Einstein's theory of General Relativity. Problem is that the two *original* Schwarzschild solutions (to a mass-point and to a sphere of incompressible liquid) do not comply with Birkhoff's theorem ($R^3 = r^3 + \alpha^3$ and $R^3 = r^3 + \rho$ result in different solutions for $r = \alpha$). Either Schwarzschild did not produce exact solutions, or Einstein's theory is not perfect, or Birkhoff's theorem is invalid.

To further complicate matters, Birkhoff's theorem is valid when you take Eddington's solution as basis, but invalid if you take the original Schwarzschild solutions as basis. Whatever the reason is, MTW did use Eddington's solution, including the *copy* error of the first original Schwarzschild solution, together with Birkhoff's unproven theorem to create their own "Schwarzschild solution". If you think this is confusing, wait and read further about Thorne's "black hole" solution. To understand this, we first need to present Schwarzschild's second solution of February 1916.

The second Schwarzschild solution to a sphere of incompressible liquid

Karl Schwarzschild presented his second *exact* solution to Einstein's theory on February 24, 1916: About the gravitational field of a sphere of incompressible liquid according to Einstein's theory. This document is even harder to understand for its poor use of language and its complex differential mathematics. Let us see what Schwarzschild had to say about the radius of the sphere (translated): "To an observer that measures from outside follows, according to formula

[6] Misner, Thorne, and Wheeler (1970), "Gravitation"

(40), that a sphere of a given gravitational mass of $\alpha / 2\kappa^2$ cannot have a smaller "measured from outside" radius "P_a" than "α". For a sphere of incompressible liquid this limit equals 9/8α. (For the sun this equals 3 km, for a small mass of 1 gram this equals 1.5 x 10^{-28} cm).
The radius "P_a" of a sphere of incompressible liquid cannot get any smaller than 9/8 times the Schwarzschild radius "α", according to Karl Schwarzschild! Such a sphere has a Schwarzschild radius *within* the sphere, and consequently cannot have an "event horizon" in vacuum. So, only in Eddington's *bad copy* you get an "event horizon" at the Schwarzschild radius, not in Schwarzschild's own solution! Now we come to Thorne's curious "solution".

Thorne's solution

Kip Thorne described his solution in his book "Black Holes & Time Warps", see footnote 1.
It is based on the MTW solution, which is based on Eddington's solution and Birkhoff's theorem, but with special coordinates: "tortoise coordinates", also called "Eddington-Finkelstein coordinates". These coordinates are designed to cope with the coordinate singularity of Eddington's copy error when the radius equals the Schwarzschild radius (r = α). A strange coordinate solution to an invented "event horizon", see figure 1:

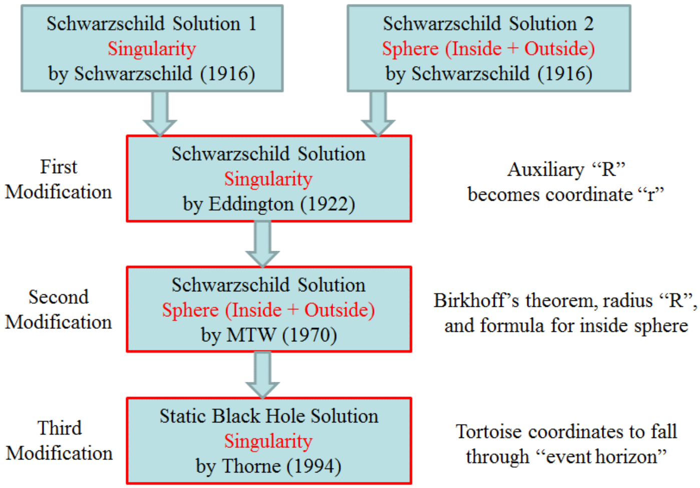

Figure 1: The curious evolution of the Schwarzschild Solutions

The key to this possibility is Einstein's principle of "covariance", which states that the laws of physics must be independent of the coordinate system chosen; allowing Eddington's coordinate singularity to be compensated for by these "tortoise coordinates". The real issue however comes next. In Thorne's book, a sphere of incompressible liquid cools down (cold dead matter) and shrinks because of gravitation. Above a certain mass (about ten sun masses), the sphere would get smaller than the Schwarzschild radius, the "event horizon" and the collapse would be total.

The temperature of the sphere is crucial. The *presumed* low temperature at the core would no longer be able to provide the thermal counter pressure needed to prevent collapse. The only counter pressure provided would then be the neutron degeneracy pressure. When the gravitational pressure then exceeds the neutron degeneracy pressure, the sphere would collapse into a *physical singularity*, according to Thorne.

Thorne versus Schwarzschild

We now have two solutions to a mass-point, Thorne's solution (as a totally collapsed sphere) and Schwarzschild's original solution to a mass-point. According to Thorne, light cannot escape and the mass-point cannot be orbited at close range. According to Schwarzschild, such a mass-point (as a model of a real object) can be seen and be orbited at low speeds at close range. According to Schwarzschild, a sphere cannot collapse to below 9/8 of the Schwarzschild radius. Who is right, Schwarzschild or Thorne? They cannot both be right. Let us first get back to real physics, measure and observe first, followed by the simplest theory according to Occam's razor.

Black Hole at the center of our Milky Way

What do we know about the black hole in the center of our Milky Way? We know that a certain star, designated "S2", describes an orbit that indicates a very large mass (more than four million sun masses) at the center of the orbit. The mass of this supermassive black hole is not in question, as it has been determined using Kepler's laws, whilst monitoring not just S2, but other stars in the vicinity of the supermassive black hole as well. The closest this star "S2" gets to the supermassive black hole, is 62,000 light-seconds.

The Schwarzschild radius of the supermassive black hole equals about 40 light-seconds. All we can say so far is that the radius of the object must be less than 62,000 light-seconds. We cannot observe this massive black hole, but that does not automatically mean that Thorne is right.

Cooled-down objects do not radiate any light or other electromagnetic waves. Fast-rotating cooled-down objects keep all the particles (mostly neutrons) in orbit, not colliding with each other and thus not radiating any electromagnetic waves according to Planck's law. The supermassive black hole can thus be a fast rotating object with a low temperature at its radiating surface but with a radius which is much larger than 40 light-seconds. Fast rotation also means deformation of the shape of the object, so in the case of a supermassive black hole it stands to reason that such fast rotation means that the *shape of the object cannot be spherical by nature*.

Thorne's solution is based on a cooled-down *static sphere*. However, neutron stars rotate fast, you may thus expect that a more compact object rotates even faster (conservation of angular momentum). Furthermore, a collapsed sphere cannot maintain angular momentum. The black hole must get into the shape of a torus or ring to maintain angular momentum. The idea of a sphere shaped supermassive black hole is simply out of the question if you consider angular momentum conservation according to Noether's laws, the subject of next paragraph.

The authors argue that cooled-down spherical objects can have a low temperature at its surface, but energy-momentum conservation requires its core to be hot. The more massive the object, the higher the core temperature gets. In other words, *if* this supermassive black hole in the center of our Milky Way would be a cooled-down static sphere, it would have an excessively high temperature at its core, in the order of many trillions of degrees Kelvin! This would certainly overwhelm neutron degeneracy, the *thermal* counter pressure would be dominant at its core. Temperatures at the core of neutron stars can reach 3 x 10^{12} [K], creating a tremendous thermal pressure!

In other words, a black hole does not exist out of "cold dead matter", on top of the fact that there is no "event horizon" to fall through!

Energy-momentum conservation according to Noether's laws

Emmy Noether published her theorem of energy-momentum conservation in 1918, a year after Einstein published his theory of General Relativity. She and her mentor Hilbert were clear about energy-momentum conservation of Einstein's theory: they stated that energy-momentum conservation cannot be proven in solutions to Einstein's theory. The essence of this problem is twofold: the absence of a *Euclidean* reference frame within which space-time curves, as well as the *variable* speed of light.

A wider Euclidean reference frame is needed to define coordinates, you cannot attach coordinates to an invisible, hypothetical, and immeasurable *curved* reference frame. According to Noether, a reference frame must be homogenous (the same everywhere) and isotropic (the same in all directions) in order to prove energy-momentum conservation. The constants of nature, including the speed of light, must be *constant* within the reference frame and *constant* over time. However, Einstein's theory of General Relativity has a *variable* speed of light within the wider frame.

We will see what Schwarzschild and Einstein have said about the variable speed of light in the next paragraph. When it comes to energy-momentum conservation within a static sphere of incompressible liquid, the surface has the *highest* gravitational potential and the core has the *lowest* gravitational potential. In an equilibrium of energy-momentum, like within the earth, the sun, or a neutron star, the kinetic energy at the core must be much higher than at its surface. The higher the mass of the object, the higher the core temperature will be. Black holes have an extremely high core temperature!

Einstein and Schwarzschild about the variable speed of light

Not everyone believes that Einstein worked with a variable speed of light. This is what Einstein and Schwarzschild themselves have said about this:

1) Einstein (translated): "The principle of the constancy of the velocity of light holds good according to this theory in a different form from that which usually underlies the ordinary theory of relativity"[7]. Einstein's formula: $c = c_0.(1 + \Phi / c^2)$, Einstein confirms that the speed of light depends on the gravitational potential "Φ".
2) Einstein (translated): "It will also be obvious that the principle of the constancy of the velocity of light *in vacuo* must be modified, since we easily recognize,

[7] Einstein A. (1911) "On the Influence of Gravitation on the Propagation of Light", Annalen der Physik 35

3) that the path of a ray of light with respect to K' must in general be curvilinear, if with respect to K light is propagated in a straight line with a definite constant velocity"[8].
4) Schwarzschild (translated from his 2nd solution): "The velocity of light inside our sphere becomes: $v = 2 / (3\cos\chi_a - \cos\chi)$, growing from $1/\cos\chi_a$ on the surface to $2 / (3\cos\chi_a - 1)$ at the core"[9]. Schwarzschild confirms the variable speed of light too, in his second solution.

In other words, both Einstein and Schwarzschild were very clear about the variable speed of light in the theory of General Relativity. We must come to the conclusion that the General Relativity solutions cannot ensure energy-momentum conservation according to Noether's laws.

General Relativity as description of gravitation

General Relativity is a better description of gravitation than Newton's laws are. The perihelion precession of Mercury, the bending of starlight around the sun at an Eclipse, gravitational redshift, and gravitational waves prove this point conclusively.

However, the theory is not a perfect description of gravitation. You might say that every scientific theory is but a model, an approximation to describe reality, and you would be right. But for us (the authors) as scientific enthusiasts in the field of theoretical physics, we like to find the areas in which we can improve this theory. And we like to think that our findings hold some scientific truth and have a strong potential to improve the current way of thinking about these matters. We will also show that the Shapiro Solution delay cannot be explained by the current Schwarzschild Solution, see figure 2. For more information download the first chapters

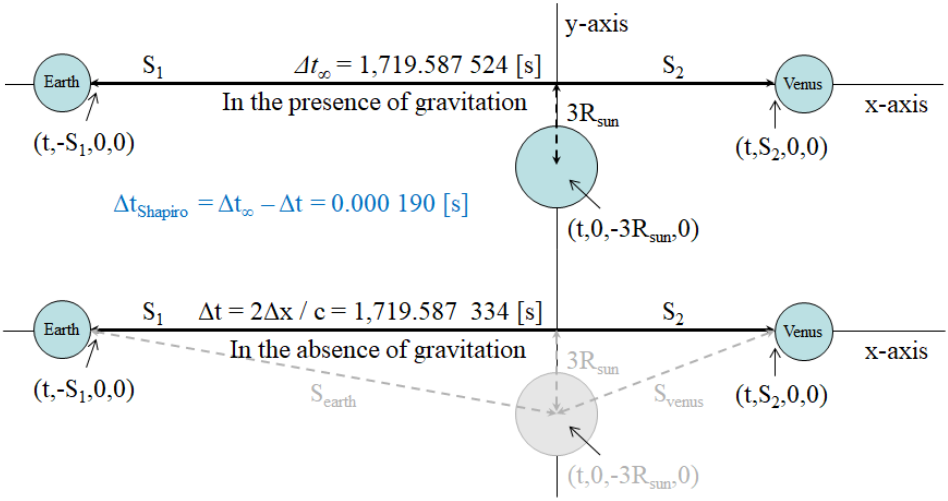

Figure 2: MTW Schwarzschild solution cannot explain Shapiro delay

[8] Einstein A. (1916) "The General Theory", Annalen der Physik, 49 paragraph 2
[9] Schwarzschild, K (1916), "On the Gravitational field of a Sphere of incompressible Liquid", formula (44)

of our book II.
Professor Shapiro could not use the Schwarzschild solution to explain the measured delay. The delay is at its largest close to the sun. However closest to the sun, in the transversal direction of the Schwarzschild Solution, the effect is zero. The lack of transversal terms in the Schwarzschild Solution ($r.d\theta$ and $r.\sin\theta.d\varphi$ for the experts) prevents an explanation of the Shapiro delay! Shapiro had to look for his own solution to find an outcome matching the delay! That begs the question as to why Eddington "dropped the suffix" and MWT "dropped the primes" just to get rid of the transversal terms. The transversal terms would have explained the Shapiro delay!

The authors must conclude that the MTW Schwarzschild solution (on which Thorne based later his theory of black holes and time warps) is only a good approximation in weak gravitation, and in radial direction only. Here is an inconsistency to be solved!

Summary and implications

Thorne's theory rests on Eddington who made a copy error, on Birkhoff who did not carefully read the German text of Schwarzschild's solutions, on MWT who used Birkhoff's theorem, and on General Relativity which cannot guarantee energy-momentum conservation. Thorne's theory therefore belongs in Hollywood, not in science. Einstein never claimed to have a perfect theory, he only used approximations in near Euclidean (flat) space for his own solutions.

The concept of a black hole as a collapsed static sphere, can neither be supported by Schwarzschild nor by Noether, nor by Einstein, and neither by observational evidence.

Presentations in which Schwarzschild or Einstein are mentioned as fathers of the black hole singularity are *outrageous*. The MTW Schwarzschild solution is only a good approximation in weak gravitation, better than Newton's laws are. So disregarding this solution is going too far. Repairing this solution for Noether's laws of energy-momentum conservation is the way to go, with beautiful results:

$E = \sigma.\gamma.m_0.c^2$ [J] energy of mass-particle in gravitation (2)

In this equation is "E" the energy of a mass-particle within an Euclidean reference frame (called "Noether frame" in honor of this brilliant mathematician), "σ" the gravitation-factor, while "σ^2" is the gravitational potential of the Schwarzschild solution, "γ" is the boost-factor of Special Relativity, "m_0" the rest mass of a mass-particle, and "c" the invariant speed of light.

The authors call their *repaired* Schwarzschild solution "Quantum Relativity for Gravitation".
See www.loop-doctor.nl if you want more information. The accomplishments of our theory are:

1. Special Relativity is united with the Schwarzschild solution,
2. The repaired Schwarzschild solution complies with Noether's conservation laws,
3. The Shapiro delay is explained with the repaired Schwarzschild solution.

Quantum Relativity for Gravitation predicts that:

1. Accurate cesium clocks will be able to confirm the combined effect of the rotational speed of the earth and gravitation (clock-factor $\delta = \sigma / \gamma$), which differs slightly from the current three-fold effect (Special Relativity, Sagnac effect, and radial Schwarzschild solution) as used by Hafele-Keating and others,
2. Geologists will be able to confirm that the high temperature at the core of the earth is *mainly* caused by its position at the center-of-mass (energy-momentum conservation),
3. Astronomers will at some point in time discover supermassive toroidal or ring-shaped black holes by the observation of orbiting stars or the trajectories of accretion disks.

We hope you get as many "aha" experiences as we did,

Rob Roodenburg (MSc, author)
Frans de Winter (MSc. coauthor)
Oscar van Duijn (MSc. coauthor)
Maarten Palthe (MSc. editor)

Schiedam, May 2018