

The observer-invariant end of spacetime at the horizon of Schwarzschild black holes
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Time is not absolute but observer-dependent: This groundbreaking revelation by Einstein in 1905 has the potential to settle the famous disagreement between external observer Bob and infalling observer Alice:

At first sight, the fact that Alice reaches the event horizon of a black hole within finite proper time prevails over Bob's "mere" observation that infalling matter does never reach the horizon. However, all external observers (even including Alice who is an external observer, too, before reaching the horizon) agree without exception that the horizon represents the ultimate simultaneity line ($t = \infty$), the temporal border of the spacetime manifold. Since spacetime is observer-dependent and thereby mere observation, this "concordant observation shared by all observers of the universe of spacetime" is perfectly adapted for determining extent and boundaries of spacetime.

As a result, there can't exist any spacetime beyond observation, and when Alice - subject to infinite gravitational time dilation - reaches the event horizon, she is leaving our observer-dependent spacetime manifold. Consequently, the mass of a Schwarzschild black hole is not located inside the horizon but outside, in the approximate form of a nearby membrane, avoiding the unsolvable dilemma of a central spacetime singularity.

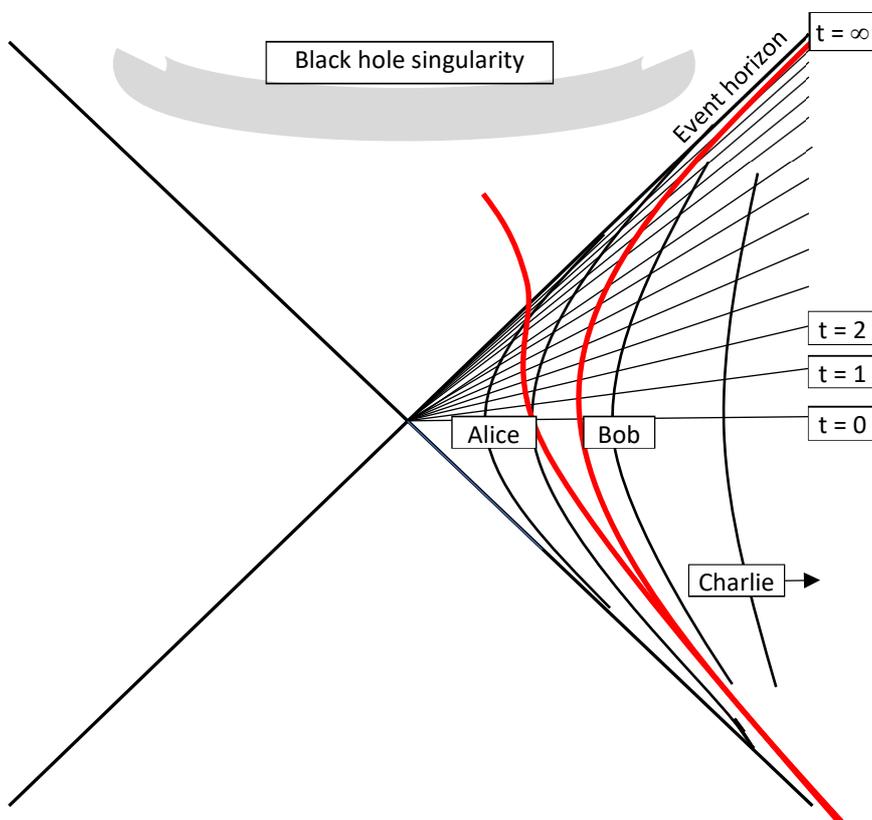
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1. Spacetime ends at the horizon

The time axis of spacetime is a strong tool for the understanding of black holes.

Before Einstein, the time axis was an absolute coordinate of the spacetime universe. With special relativity, time depends on the path taken by a clock. However, this discovery is so weird that its consequences have not yet been fully understood, in particular that with the absence of any preferred time, time is materialized by all clocks of all worldlines of the universe of spacetime, such that the time of spacetime consists of as many time axes as there are worldlines.

From each time axis, simultaneity lines are exploring space, and spacetime consists exactly of these simultaneity lines, spacetime is mere observation. Spacetime is redundant, because each time axis covers once the whole spacetime, just like several observers in the same room, each of them observing once the whole room, from his point of view, this is redundant observation.



For black holes, spacetime can be described with the Kruskal-Szekeres diagram, representing the viewpoint of a distant observer Charlie. The simultaneity lines of the Kruskal diagram are running upwards from $t = 0$ to infinity, and they converge to the event horizon, which represents the upper limit $t = \infty$ that is never reached.

In a gravitational field, the observer Bob is subject to gravitational time dilation, and his time axis is stretched by the time dilation factor $d\tau/dt$, with respect to the distant observer Charlie. If, as an example, from the viewpoint of Charlie, a distant galaxy in outer space takes one million years to perform one revolution, it might take only one year for Bob when he is nearby the event horizon, or maybe even only a second. However, there is one thing on which all external observers agree: That the

event horizon represents infinity, for the simple reason that infinity multiplied with any time dilation factor remains always infinity. This is a real exception to the principle of relativity of simultaneity.

It is currently believed that Bob's and Charlie's concordant perception of the end of spacetime at the horizon was disproved by the infalling observer Alice because she reaches the horizon within finite proper time.

However, this argument is not consistent. The problem is that Alice is not a good reference here: On her infalling path, Alice is exposed to gravity, and her clock is subject to time dilation. Alice overcomes the infinity of time only with her last infinitesimal step towards the horizon, where her time dilation goes to infinity (with $dt/d\tau = 0$), such that in an infinitesimally small proper time, she crosses an infinite number of Charlie's simultaneity lines. In doing so, she reaches the end of coordinate time $t = \infty$ of all external observers of the universe. So, Alice is right when she says that she reaches the horizon within finite proper time, but Bob and Charlie are right as well when they say that Alice will "never" reach it, if "never" is understood as "never within the time of spacetime," and we don't know where Alice goes from there, but one thing is sure: Beyond the horizon, she has left our spacetime.

By consequence, all observers, even including Alice, as long as she has not reached the horizon, agree that the horizon represents the end of spacetime, and this brings me to the crucial conclusion of this talk: For the question where spacetime is ending, we must refer to the observers, there is no absolute reference because spacetime is not absolute, it is mere observation (as shown before, spacetime is formed by the simultaneity lines of an observer), and therefore observer-dependent spacetime is observed to end at the horizon, and by this spacetime ends at the horizon.

2. A tremendous simplification of black holes!

This result entails a tremendous simplification of black holes, with several fundamental problems simply vanishing:

1. The observers are right: All infalling particles are initially accelerated, but near the event horizon they are slowed down by time dilation.

2. The horizon is therefore a sort of time curtain: The simple passing of time hinders the infalling particles from reaching the horizon before the end of spacetime. The closer a zone is to the horizon, the longer the particles remain in it, accumulating at an infinitesimal distance in the approximate form of a membrane, as a kind of stretched horizon, in compliance with the so-called "membrane paradigm".

[1] [2]

3. Gravitational time dilation has a repulsive effect on infalling particles, the repulsive gravity, simply because of the fact that their radial velocity v is time-dependent ($v=s/t$, of course, t is subject to time dilation). For the infalling observers themselves, this repulsive effect is not perceptible because their velocity relative to themselves is of course always 0. **[3] [4]**

4. However, this repulsive effect is perceptible for the infalling observer in the opposite case, if it is the horizon that expands, due to an increase in mass of the black hole, thereby pushing back nearby particles. **[5]**

5. The question arises what happens to the particles that were already inside the horizon and had originally contributed to the formation of the black hole.

The answer is that there are two mechanisms that prevent mass from ever being inside the horizon:

a) While mass is compressed to a black hole, the emerging event horizon necessarily forms out of a tiny single point that is increasing steadily, and with its expansion the horizon pushes back all the surrounding mass, due to the repulsive effect of time dilation.

b) Secondly, during the merger of two black holes, when their membranes approach each other, mass particles located within the contact zone are pushed back in tangential direction by the repulsive gravity. Both stretched horizons merge into one large membrane.

6. As a result, there is never any mass inside the horizon, event horizons are empty, and the entire mass of a black hole is located outside, such that, strictly speaking, the black hole has not even formed yet because its mass is still on its way to the horizon, which it only reaches at the end of time.

7. The crucial problem of the central singularity is eliminated, the problem is just vanishing because spacetime is ending at the horizon.

8. Moreover, no specific Kerr metric for rotating black holes is required because the rotation of the whole mass of the black hole takes place outside the horizon.

9. For the same reason, the information loss problem is eliminated: information remains outside the horizon "eternally", that means until the end of our spacetime, and also Hawking radiation happens only outside.

3. Outlook

Outlook, with a speculation on the end of the world: Will our universe end in a Big Rip or a Big Crunch? We don't know, but there is an interesting concept for the Big Crunch:

1. For infalling observers such as Alice, the time infinity at the horizon corresponds to a finite moment, namely her respective finite proper time at the horizon. However, this well-defined, precise moment is also the moment when all the mass that has ever fallen into any black hole in the universe reaches simultaneously the respective horizon. On this basis, one could imagine the Big Crunch as a merger of all existing black holes into one huge black hole, with the mass of the whole universe reaching simultaneously the final event horizon.

2. This final horizon would expand enormously, due to the huge increase of mass, leading to a tremendous gravitational repulsion of cosmological dimensions. We can speculate that in a cyclic cosmology, this could provide the energy source required for the following Big Bang. That would imply that the Big Bang would not originate from a point, but from the event horizon of a white hole. This could possibly avoid the problematic first era called the Planck era.

3. Moreover, the problem of the ever-increasing entropy - with the next following universe beginning with a heat death - could find a solution, at the condition that we assume that the second law of thermodynamics is an intrinsic law of our spacetime that does not apply "after spacetime". The Big Crunch, in which the entire universe converges to the final event horizon, could be characterized by a perfect ordering of the whole content of the universe, resulting in a sort of reset of entropy, such that the following universe is not doomed to begin with a heat death.

4. References

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