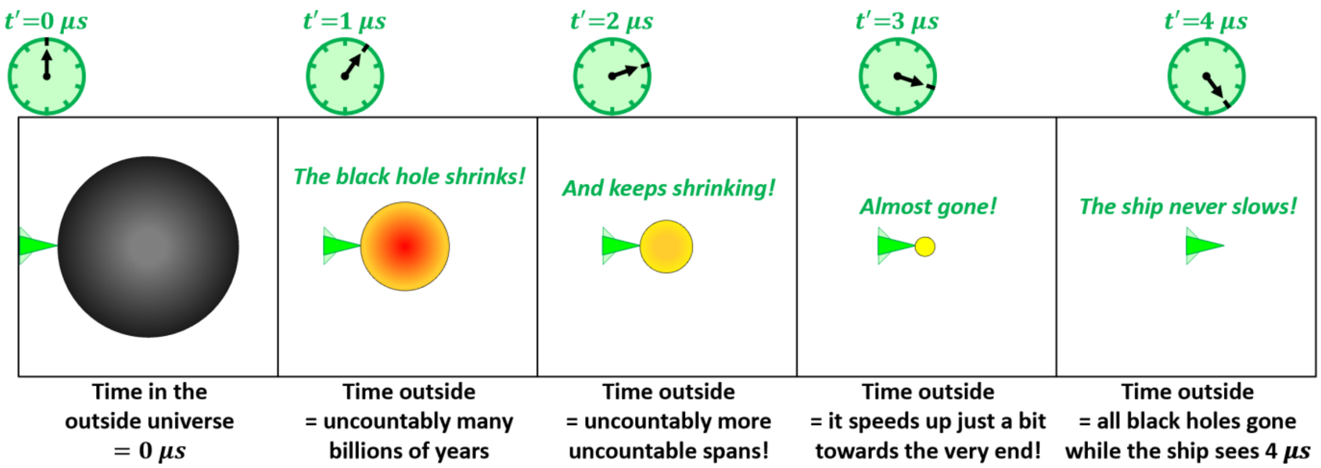
Why Black Holes Evaporate Before You Cross Their Event Horizons

Terry Bollinger
2020-12-12.15:39 EST (Sat) [Figure and References added 2025-05-21]



An invulnerable ship falling into a black hole would see the black hole shrink faster than the ship falls.

Terry Bollinger [1] 3:39 PM, December 12, 2020 [2]

Sabine,

You noted [3] that:

>… "There is actually nothing particularly interesting happening at the horizon. It's just the boundary of a region from which you cannot get out. Instead, once you cross the horizon, you will inevitably fall into the singularity."

I'm fine with the idea that such a transition would appear smooth, but I do have a trio of questions for anyone about how this would look to the infalling observer.

Firstly, as best I've been able to understand it, an infalling observer should see an image of the black hole surface rise up around her to form an ever-deepening well.

That's because light emanating from very close to the event horizon will behave like a weakly tossed ball, mostly falling back onto the horizon nearby before it can escape. Only light that is almost perfectly vertical will resist falling back, and even then only at a tremendous red-shift energy cost. The angle over which light can reach escape velocity grows narrower as the light source gets closer to the absolute horizon. Rather intriguingly, black hole information isolation thus begins *before* the object crosses the horizon, rather than behaving like an abrupt shut-off exactly at the horizon.

Since these ballistic light trajectories apply in both directions, the infalling observer will see an increasingly magnified image of the local event horizon, one that blocks most of her view of the outside universe. By the time she reaches the actual horizon, only an infinitesimally narrow cone of view pointing straight up will remain open.

Now to be honest, I'm not even sure this narrowing effect is all that critical to my main questions. But at the very least it shows how an infalling object can grow asymptotically *close* to full black-hole isolation from the rest of the universe *without actually falling past the event horizon*. And in any case, I want to frame my questions as closely as possible to what she would actually *see* as she falls in. So, three questions:

Question 1: As she peers upwards through her ever-dwindling cone of observation, will she see time speed up for events in the outside universe?

Question 2: At the instant before crossing the absolute event horizon, just as her observation cone becomes infinitely thin, will time for outside events appear to speed up infinitely? If so…

Question 3: If the infalling observer sees events in the outside universe occurring at infinite speed, doesn't that also mean that regardless of the size of the black hole into which she is falling, it will necessarily evaporate via Hawking radiation before she can actually cross its horizon?

A "yes" to all three of these questions would mean that singularities cannot form via infalling matter, since all infalling objects would *by their own observations* find themselves unable to cross the event horizon. Thus far from being a smooth transition, the absolute event horizon would behave like an impenetrable barrier, one that isolates infalling matter profoundly, but never completely, from the rest of the universe.

Incidentally, the other popular line of reasoning (from Thorne I think) for how matter ends up inside of black holes is that when a large star collapses, matter inside the star is pinched off from the rest of the universe by the formation of the observed event horizon, like a water drop from a dripping faucet.

The oddly simple argument (also from Thorne, ironically) against this singularity collapse mode is that the *absolute* event horizon — the only one that counts, since is the only one isolated from *all* inertial frames — forms first at the *center* of the star, and then moves outwards at incredible speed. If this moving event horizon is in fact impenetrable for the reasons I just described, it will push unabsorbed matter before it. That incidentally is my pet theory for how Type II supernova core rebound really works.

Finally, in terms of arguments about whether or not black holes destroy information, this analysis would fall on the "no information is ever lost" side.

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hector gomez rioja 5:01 AM, December 14, 2020

Does this imply that you need an infinite time to cross a horizon, which implies that in the entire history of the universe no horizon has yet been crossed, nothing has yet fallen into a black hole?

Sabine Hossenfelder 5:11 AM, December 14, 2020

No, you cross the horizon in finite proper time.

Rob van Son (Not a physicist, just an amateur) 6:12 AM, December 14, 2020

But the question is, how long does it take before I, a stationary outside observer, see you crossing the horizon if you fall into a black hole?

IIRC, Susskind once stated that black hole evaporation looked from the outside as if the material that is still outside the horizon boils off.

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hector gomez rioja 7:31 AM, December 14, 2020

I am not a physicist, but please allow me to raise the Gedankenexperiment of falling into a black hole.
Thinking that when approaching a black hole, due to the gravitational force, time slows down, what an imaginary entity would experience is that everything that is around it moves away from it.

As Lawrence Crowell also says in another comment "falling into a black hole is not so much crushed, but rather pulled apart."

If the time it takes to get to something tends to infinity, the distance to that something also tends to infinity.
When you reach an area in which you experience a time that tends to be infinitely slow, the horizon itself would also tend to be infinitely far away, just like any other entity.
All this happens for our imaginary entity in finite time and I am not sure at what moment what surrounds it stops making physical sense or if it stops being part of this universe. But I don't see how you can reach a singularity or how once a first unit of plank space reaches a density that generates a horizon, something that surrounds it can fall beyond this horizon.

That there are supermassive objects is unquestionable but that their structure is the one proposed by the mathematics of general relativity seems to me as likely as that subatomic particles
have no size and have infinite density.

As you say in the video, nobody really knows what is inside a black hole, perhaps we should take with more skepticism all the theories that explain it to us in such detail.
Thanks for indulge me with my naivety.

Terry Bollinger 11:40 AM, December 14, 2020 [4]

Sabine, since you did not object to any of them, may I assume your answer to each of my three questions is yes?

hector: Proper time is of course just local clock time, the time displayed by a clock that is close enough to the observer so that the temporal ambiguities of special relativity can be made negligible. Stated that way, proper time is just wristwatch time, your own personal clock.

That is why I phrased my questions *only* in terms of the time and frame of references of the infalling observer. Switching observer perspectives, for example, is guaranteed to give nonsensical answers.

Thus she sees the event horizon ahead of her and can calculate with precision when she will hit it. This is why folks nothing changes as she crosses the event horizon. That is simply true! So how can she *not* cross it a microsecond or so later?

The resolution is oddly simple: *The event horizon will no longer be there.*

That is, no matter how fast she is moving towards it, the event horizon will *evaporate* before she reaches it. In the case of a supermassive black hole she will have the unique experience of *watching the black hole shrink* at an astronomical rate, always maintaining a slight lead on her inward motion.

If she has an especially durable spaceship, by the time it reaches what should have been the center of the hole, it will have disappeared. She will instead find herself hurtling *outward* from where the hole was at very close to the speed of light. There's another way of saying that: *She has become part of the Hawking radiation released by the* *final explosion of the black hole.* That is, after falling in on one side of the hole, then by *her* clock she very quickly emerges from the other side of the hole, the *antipode* of her infall point.

This "other side" emergence idea was first identified and named *antipodal* by Norma Sánchez in 1986 [1]. Gerard 't Hooft rediscovered (or recalled?) Norma's idea three decades later [1], and elaborated upon it in terms of momentum waves moving across the spherical event horizon [2]. If you combine the 't Hooft elaboration of Norma's idea with the restriction that nothing can ever actually cross the event horizon, it becomes equivalent to forcing all particles into momentum states within a spherical surface, much like how electrons are quantum delocalized in mirrors. Like mirror electrons, such particles can be simultaneously very energetic yet "cold" to outside observers, due that energy being tightly sequestered in momentum space. My own term for this (I've used it here) is the dark mirror model.

The dark mirror model trivially allows the kinds of electrical conductivity and magnetic behaviors that have been postulated for black holes in recent years, and thus makes polar jets a lot easier. But unlike traditional super-simple black hole models, the states of matter in dark-mirror black holes are anything but simple. Such states might for example include band states and even forms of momentum-space interparticle bonding. With the exception of electromagnetism (think polar jets again), this complexity would just be highly sequestered.

Notice that in the dark mirror model, Hawking radiation barely qualifies as quantum. Black hole radiation is instead almost entirely relativistic, not much more than infalling particles emerging very belatedly from their Sánchez-'t Hooft antipodes. However, the buzzsaw effect of spending a few trillion eons within a ferociously compressive spherical momentum space will make the problem of calculating *exact* emergence points a bit, um, problematic.

[1] Norma Sánchez, Semiclassical Quantum gravity in Two and Four Dimensions. *Gravitation in Astrophysics*, Springer, 371–381 (1987). Preview pages: https://link.springer.com/chapter/10.1007/978-1-4613-1897-2_14 [5]

[2] Gerard 't Hooft, Black hole unitarity and antipodal entanglement. Foundations of Physics, Springer, **46**, 1185–1198 (2016). https://arxiv.org/abs/1601.03447 [6]

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hector gomez rioja 12:57 PM, December 14, 2020

If there is a physicist that I respect, it is Gerard 't Hooft and I think he is the first to take everything he proposes with a certain skepticism.

We take structures and effects like Hawking radiation for granted. We consider that from the remains of a supernova we obtain a black hole and from there we develop models and theories.

But do we have any idea how a horizon emerges? How happens in the place of greatest pressure in this supernova that a region of space is enveloped by a horizon and is separated from the rest of the universe? How is it possible, if, as we are proposing, nothing falls within a horizon before the hole evaporates, that mass is added to it? Supermassive objects exist and their mass is concentrated within a volume that resembles that of a theoretical black hole horizon, but is it configured as a singularity with its horizon, or are they crowded microholes? Or all the particles have become bosons and can occupy the same infinitesimal point? Or once a horizon is produced, it no longer makes sense to talk about mass and particles and what we observe is a tear in the fabric of space-time that cannot be re-sewn?

The only toys we can play with are quantum mechanics and general relativity, but if black holes teach us something, it is that our toys are useless for this game.

Terry Bollinger 11:05 AM, December 15, 2020

Addendum: Just to address a few questions folks might have about my earlier comments:

I mentioned that *if her spaceship survives*, the infalling observer will sail through the region of the black hole at full speed, watching it evaporate literally in front of her, and emerge out the other side as part of the Hawking radiation debris from the explosion of the final micro blackhole. But that kind of sail-through can't be the entire story for Hawking radiation, since otherwise how could the hole evaporate in front of her?

Do you recall the deep-well effect I mentioned earlier, in which curved trajectories of light seem to cause the local surface of the black hole to curve up and envelope the infalling observer? It results in an every-narrowing cone of communication back to the external world as she falls deeper.

Also, have you ever heard the explanation of Hawking radiation that compares the event horizon to a membrane that is thicker for large black holes and thinner for small ones? Particles quantum-tunnel across this membrane, with the probability of escape increasing as the membrane gets thinner. By the time you get to proton-sized black holes (mountain-ish mass range) the tunneling becomes so intense that the whole shebang just goes boom.

Think of the well as *being* that membrane, with the cone of access as the only path over which tunneling still leads to the outside universe. For a large black hole this well gets very deep very quickly, and the odds of tunneling grow very, very small… but never *quite* zero.

Such cones are the tunneling paths even for supermassive black holes, and that is how they evaporate. While the rate of evaporation is incredibly slow for outside observers, for the infalling ship the process occurs at blinding speed.

And that may be another question that comes to mind for some readers: If the hole is evaporating due to quantum events that have nothing to do with infalling ship, how why should the hole evaporation rate keep pace *exactly* with the speed of infalling ship, as viewed by the infalling observer?

The answer is that it's the other way around: The black hole always *slows down* the infalling observer time just enough to keep itself eternally ahead of the ship. To an outside observer the ship would appear to remain at the event horizon for an unimaginably long period of time. But none of that matters to the infalling observer, who only sees her own smooth motion and the black hole seemingly evaporating to match her motion, regardless of how the external universe might want to interpret the same event.

I also noticed that Lawrence Crowell aptly pointed out the incredible lateral ripping forces involved in falling onto an event horizon. Those are why anything surviving a black hole infall is, to say the least, problematic. But this is also where momentum space comes into play. Even in everyday physics, the *best* way to smear an electron out is not to tear it apart into still smaller "particle"-like pieces, but to transfer its bundle of conserved quantum numbers into *momentum space,* where they can then easily spread out into immensely thin sheets by xyz space standards. If you don't believe me, look in a mirror! The surface electrons in that Fermi sea within the very thin sheet of metal behind the glass are the ones that bounce your image back at you, and they exist mostly in momentum space. Metals really are quite a bit more six-dimensional than we give them credit for. The nuclei and core electrons stay mostly in xyz, but it is the conduction electrons smearing themselves out in momentum space that are largely responsible for making the metal strong, conductive, ductile, and reflective.

Terry Bollinger 1:12 PM, December 16, 2020

Addendum 2: Observational implications of the dark mirror interpretation

This literally was not on my agenda for the rest of this week, but some part of my brain refuses to ignore dangling strings. So, if only to get on to other things…

The most significant implication of the dark mirror model is that there is no such thing as Hawking radiation, and that its non-existence should be verifiable.

Dark mirrors replace Hawking radiation with what I'll call Sanchez-Whiting-'t Hooft or *antipodal* particle emission. This is accompanied by a purely electromagnetic form of radiative cooling whose rate depends inversely on the size of the body.

Hawking radiation fails because it assumes erasure of all quantum states except mass-energy, charge, and spin. That in turn allows blank-slate quantum emissions where for example matter and antimatter particle emissions are equally likely.

In the dark mirror interpretation the pro-matter quantum numbers get churned about but never erased. Any escaping quantum number bundles must still micro-collapse into ordinary matter particles, and that's just ordinary tunneling, not the freewheeling equations of Hawking radiation. It also significantly changes what happens to black holes over astronomical time spans.

Gerard 't Hooft suggested that the antipodal interpretation permits a time-symmetric equilibrium,[1] which in turn suggests there is a threshold mass at which infall and antipodal outflow become equal and time-symmetric. Below this 't Hooft threshold a dark mirror body can explode violently by emitting more particles than it takes in. This is the case I described earlier for a "smooth", antipodal-emergence relativistic journey through an evaporating black hole.

Larger bodies will no longer be capable of evaporating, since antipodal particle emission is neither as forgiving nor as forgetful as Hawking radiation. More bluntly, for larger black holes infalling objects just go splat, and are quickly and irreversibly converted into an excruciatingly compressed spherical state.

However, there is also that second component of pure electromagnetic cooling. An infall pit of the type I described earlier is about as literal of an example of a black box with a small hole as one can imagine, so it will exhibit black-body radiative cooling. However, since the size of this opening shrinks as the hole grows larger, stellar black holes should reach thermal equilibrium much faster than supermassive ones. One area in which the concept of diverse internal thermal states might be interesting to explore is in the transition that supermassive black holes undergo from quasar-like young states to quiescent modern galactic centers.

An interesting question is this: What is the final "cold" state of a dark mirror object after all of its internal heat has been dissipated?

My own speculation, based quite unfairly on 't Hooft's momentum wave analysis,[1] is that it will condense into multiple homogenous, 2D momentum space bands (Fermi seas) with collocated spherical symmetry in xyz. The bands would at least begin as electrons, protons, and neutrons, though an end state of electrons and quarks is quite plausible. If the latter occurs, I suspect the quark bands would remain cross-correlated to deal with color confinement. (Hmm… why do I keep thinking about stock market prediction models?)

If dark mirror objects — black holes — do indeed cool down to form homogenous electrically charged bands, there is a good chance the transition will affect the electromagnetic fields around black holes in odd and distinctive ways.[2]

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[1] ’t Hooft, G. *The Quantum Black Hole as a Hydrogen Atom: Microstates Without Strings Attached*, arXiv preprint arXiv:1605.05119 (2016). [9]
https://arxiv.org/abs/1605.05119

[2] Balazs, N. L. *Wave Propagation in Even and Odd Dimensional Spaces*. Proceedings of the Physical Society. Section A, IOP Publishing, **68**, 521, (1955). [10]

References

[1] T. Bollinger, *My Science Blog*, Blogger **2012**, 07 [Jul.] (2012). https://www.blogger.com/profile/03915136249111338024

[2] T. Bollinger, comment 1 of 4 on Backreaction, 2020-12-12.15:39 EST (Sat). https://backreaction.blogspot.com/2020/12/are-singularities-real.html?showComment=1607805558828#c2682181072735415087

[3] S. Hossenfelder, *Are Singularities Real?*, Backreaction **2020**, 1212 [Dec. 12] (2020). https://backreaction.blogspot.com/2020/12/are-singularities-real.html

[4] T. Bollinger, comment 2 of 4 on Backreaction, 2020-12-14.11:40 EST (Mon), https://backreaction.blogspot.com/2020/12/are-singularities-real.html?showComment=1607964003692#c2346909760942473536

[5] Norma Sánchez, Semiclassical Quantum gravity in Two and Four Dimensions. *Gravitation in Astrophysics*, Springer, 371–381 (1987). Preview pages: https://link.springer.com/chapter/10.1007/978-1-4613-1897-2_14

[6] Gerard ‘t Hooft, Black hole unitarity and antipodal entanglement. Foundations of Physics, Springer, **46**, 1185–1198 (2016). https://arxiv.org/abs/1601.03447

[7] T. Bollinger, comment 3 of 4 on Backreaction, 2020-12-15.11:05 EST (Tue), https://backreaction.blogspot.com/2020/12/are-singularities-real.html?showComment=1608048358615#c3611431586840050827

[8] T. Bollinger, comment 4 of 4 on Backreaction, 2020-12-16.13:12 EST (Wed), https://backreaction.blogspot.com/2020/12/are-singularities-real.html?showComment=1608142336414#c1322591173783042961

[9] G. ’t Hooft, *The Quantum Black Hole as a Hydrogen Atom: Microstates Without Strings Attached*, arXiv preprint arXiv:1605.05119 [May 17] (2016). https://arxiv.org/abs/1605.05119

[10] Balazs, N. L. *Wave Propagation in Even and Odd Dimensional Spaces*, Proceedings of the Physical Society. Section A, IOP Publishing **68**, 521 (1955). http://iopscience.iop.org/article/10.1088/0370-1298/68/6/307/meta (paywall)