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Information loss paradox resolved by nonsingular hyperbolic spacetime

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Abstract: Black holes owe their existence to the presence of singularity. Singularity appears theoretically as a result to the Schwarzschild solution in asymptotically flat spacetime. Such an approximated Schwarzschild solution creates singularity (when r = 0). This false paradigm constitutes our observation. The observer is operating within a "paradigm". Observations being made are not complete in themselves, they interpreted within a theory (a paradigm). Schwarzschild solution singularity paradigm works as a lunette, through which we imagine that we could observe Black holes. Black holes have never been seen directly, their existence is just a matter of illusion. We did prove that the spacetime of the actual Universe is hyperbolic [S. A. Mabkhout, Phys. Essays 25, 112. 2012)]. Neither Schwarzschild metric nor Kerr metric possess singularity in the hyperbolic spacetime [S. A. Mabkhout, Phys. Essays 26, 422. 2013)] . Singularity is the main character of the Black hole. If, in principle, singularity theoretically doesn't exist, Black holes also don`t exist. There is no singularity to crush and destruct the infalling information. In the actually hyperbolic spacetime infalling particles (information) have just come to rest at the origin (r = 0). Hence Information Loss Paradox does no longer exist.

Keywords: Information Loss Paradox, Black Hole, Nonsingularity, Hyperbolic Spacetime

1. Introduction

The principle of equivalence, which says that gravity couples to the energy-momentum tensor of matter and the quantum-mechanical requirement that energy should be positive imply that gravity is always attractive. This leads to singularities in any reasonable theory of gravitation. A singularity is a place where the classical concepts of space and time break down as do all the known laws of physics because they are all formulated on a classical spacetime background. The equivalence principle asserts that free-fall should feel the same as floating in empty space.

Quantum Theory is the mathematics that is currently believed to underlie all physical processes in nature. It can't be used to predict precisely what will happen, but only the probability for any particular thing to happen. But probabilities only make sense if, when you add up all the probabilities for all of the different things that can possibly happen, you find the sum is equal to one. A quantum theory where this isn't true makes no sense. One consequence of this is that in a quantum theory, information is never truly lost, nor is it truly copied; at least in principle, you can always determine how a system started (its "initial state") from complete information about how it ends (its "final state")[1]. According to the standard rules of quantum field theory in a fixed Minkowski spacetime, the time evolution of any system from a given initial state is described unambiguously by a unitary transformation acting on that state, and in this sense there is never any loss of fundamental information.

Monogamy is a rigorous result of quantum mechanics dubbed 'the monogamy of entanglement' says that one quantum system cannot be fully entangled with two independent systems at once. Monogamy stating that no particle can be entangled with two systems at the same time (while classical correlations can easily be shared by many parties, quantum correlations are harder to share). If Bob is highly entangled with Alice, that limits his ability to entangle with Carrie, and if he entangles with Carrie instead he can't entangle with Alice. Hence we say that entanglement is "monogamous".

Pure state is the quantum state where we have exact information about the quantum system. A system is said to be in a pure state if we have complete knowledge about that system, meaning we know exactly which state it's in. The S-matrix is the unitary operator S that determines the evolution of the initial state to the final state.

A system is in a mixed state if we only have partial (or no) knowledge of the system. In terms of a probability density, ρ say, this means that more than one of its eigenvalues must be non-zero. The mixed state is the combination of probabilities of the information about the quantum state of the quantum system. A mixed state described by a density matrix.

As you may recall, non-unitary evolution is not allowed to occur naturally in a quantum theory because it fails to preserve probability; that is, after non-unitary evolution, the sum of the probabilities of all possible outcomes of an experiment may be greater or less than one. Unitary evolution is reversible while non- unitary evolution is irreversible. Quantum theory is reversible.

Hyperbolic spacetime: The geometry of the universe, the spacetime, depends on the curvature k, if

K = 0, the universe is flat and open, or

K = 1, the universe is spherical and closed, or

K = -1, the universe is hyperbolic and open.

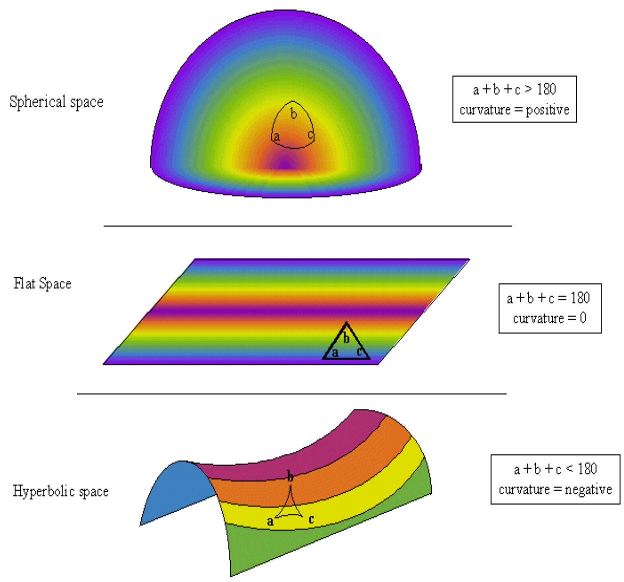

***Fig 1.** "curvature" of space-time* [20]

We did prove that the curvature of the Universe is negative (k=-1) in our previous paper "The hyperbolic geometry of the universe and the wedding of general relativity theory to quantum theory". Hence, the spacetime of the Universe is hyperbolic.

2. Hawking Radiation

S. W. Hawking, an English theoretical physicist, was one of the first to consider the details of the behavior of a black hole whose Schwarzschild radius was on the level of an atom. These black holes are not necessarily low mass, for example, it requires 1 billion tons of matter to make a black hole the size of a proton. But their small size means that their behavior is a mix of quantum mechanics rather than relativity. "However it is shown that quantum mechanical effects cause black holes to create and emit particles as if they were hot bodies "[2].

Before black holes were discovered it was know that the collision of two photons can cause pair production. This direct example of converting energy into mass (unlike fission or fusion which turn mass into energy). Pair production is one of the primary methods of forming matter in the early Universe. Note that pair production is symmetric in that a matter and antimatter particle is produced (an electron and an anti-electron, positron). Hawking showed that the strong gravitational gradients (tides) near black holes can also lead to pair production. In this case, the gravitational energy of the black hole is converted into particles.

"If the matter/anti-matter particle pair is produced below the event horizon, then particles remain trapped within the black hole. But, if the pair is produced above the event horizon, it is possible for one member to fall back into the black hole, the other to escape into space. Thus, the black hole can lose mass by a quantum mechanical process of pair production outside of the event horizon"[3].

The rate of pair production is stronger when the curvature of spacetime is high. Small black holes have high curvature, so the rate of pair production is inversely proportional to the mass of the black hole (this means it's faster for smaller black holes). Thus, Hawking was able to show that the mini or primordial black holes expected to form in the early Universe have since disintegrated, resolving the dilemma of where all such mini-black holes are today.

In 1975 Hawking published a shocking result: if one takes quantum theory into account, it seems that black holes are not quite black! Instead, they should glow slightly with "Hawking radiation", consisting of photons, neutrinos, and to a lesser extent all sorts of massive particles. Virtual particle pairs are constantly being created near the horizon of the black hole, as they are everywhere. Normally, they are created as a particle-antiparticle pair and they quickly annihilate each other. But near the horizon of a black hole, it's possible for one to fall in before the annihilation can happen, in which case the other one escapes as Hawking radiation. This has never been observed, since the only black holes we have evidence for are those with lots of hot gas falling into them, whose radiation would completely swamp this tiny effect. We won't see any of the black holes in the Milky Way explode any time soon though, not only are they likely still gaining mass (from the cosmic microwave background, at least), but a one sol black hole would take over 10^67 years to evaporate (the universe is only 13 billion years old)!

3. Information Loss Paradox

The black hole creates particles in pairs, with one particle always falling into the hole and the other possibly escaping to infinity. Because part of the information about the state of the system is lost down the hole, the final situation is represented by a density matrix rather than a pure quantum state. This means there is no S matrix for the process of black-hole formation and evaporation. Instead one has to introduce a new operator, called the superscattering operator, which maps density matrices describing the initial situation to density matrices describing the final situation. Hawking's argument basically comes down to the observation that in the quantum realm, 'empty' space isn't empty. Down at this sub-sub-microscopic level, it is in constant turmoil, with pairs of particles and their corresponding antiparticles continually popping into existence before rapidly recombining and vanishing. Only in very delicate laboratory experiments does this submicroscopic frenzy have any observable consequences. But when a particle–antiparticle pair appears just outside a black hole's event horizon, Hawking realized, one member could fall in before the two recombined, leaving the surviving partner to fly outwards as radiation. The doomed particle would balance the positive energy of the outgoing particle by carrying negative energy inwards — something allowed by quantum rules. That negative energy would then get subtracted from the black hole's mass, causing the hole to shrink. But with it came the disturbing realization that black-hole radiation leads to a paradox that challenges quantum theory.

In his 1976 article, "Breakdown of Predictability in Gravitational Collapse," [4] Stephen Hawking argues that his prediction that black holes emit thermal radiation implies that the evolution of black holes cannot be described by standard unitary quantum mechanical evolution. This nonunitary evolution is popularly described as representing a loss of "information" – if a pure state nonunitarily evolves into a mixture, then we can no longer predict with certainty the outcome of any complete set of measurements, thus it appears that some previously existing information has been destroyed. This conclusion has been generally viewed as unacceptable by high energy physicists – who have therefore characterized Hawking's argument as a "paradox that needs to be resolved" [5]. In principle, it should be possible to recover everything there is to know about the objects that fell in a black hole by measuring the quantum state of the radiation coming out. But Hawking showed that it was not that simple: the radiation coming out is random. Toss in a kilogram of rock or a kilogram of computer chips and the result will be the same. Watch the black hole even until it dies, and there would still be no way to tell how it was formed or what fell in it. The black hole is gone. Where did the information go? If it disappeared along with the black hole, that violates quantum theory. "Maybe the information came back out with the Hawking radiation? The problem is that the information in the black hole can't get out. So the only way it can be in the Hawking radiation (naively) as if what is inside is copied. Having two copies of the information, one inside, one outside, also violates quantum theory" [1].

This problem, dubbed the black-hole information paradox, divided physicists into two camps. Some, like Hawking, argued that the information truly vanishes when the black hole dies. If that contradicted quantum laws, then better laws needed to be found. Of course, it may simply be that quantum theory is incomplete, and that the physics of black holes forces us to extend that theory. And this is what Hawking believed for three decades.

"In order to understand why the *information loss problem* is a problem, we need first to understand what it is. Take a quantum system in a pure state and throw it into a black hole. Wait for some amount of time until the hole has evaporated enough to return to its mass previous to throwing anything in. What we start with is a pure state and a black hole of mass M. What we end up with is a thermal state and a black hole of mass M. We have found a process (apparently) that converts a pure state into a thermal state. But, and here's the kicker, a thermal state is a MIXED state (described quantum mechanically by a density matrix rather than a wave function). In transforming between a mixed state and a pure state, one must throw away information" [6]. As you may recall, non-unitary evolution is not allowed to occur naturally in a quantum theory because it fails to preserve probability; that is, after non-unitary evolution, the sum of the probabilities of all possible outcomes of an experiment may be greater or less than one.

4. Black Hole Complementarity (An Attempt to Resolve the Paradox)

Leonard Susskind [7] proposed a radical resolution to this problem by claiming that the information is both reflected at the event horizon and passes through the event horizon and can't escape, with the catch being no observer can confirm both stories simultaneously. According to an external observer, the infinite time dilation at the horizon itself makes it appear as if it takes an infinite amount of time to reach the horizon. He also postulated a stretched horizon, which is a membrane hovering about a Planck length outside the event horizon and which is both physical and hot. According to the external observer, infalling information heats up the stretched horizon, which then reradiates it as Hawking radiation, with the entire evolution being unitary. However, according to an infalling observer, nothing special happens at the event horizon itself, and both the observer and the information will hit the singularity. This isn't to say there are two copies of the information lying about — one at or just outside the horizon, and the other inside the black hole — as that would violate the no cloning theorem. Instead, an observer can only detect the information at the horizon itself, or inside, but never both simultaneously. Complementarity is a feature of the quantum mechanics of noncommuting observables, and Susskind proposed that both stories are complementary in the quantum sense.

Complementarity claims that an outside observer can effectively described the black hole as a heated membrane situated just above the event horizon. According to the outside observer, any infalling information will interact violently with this heated membrane, and will eventually be reemitted to exterior universe, thus keeping the late-time state pure. A difficulty facing this suggestion is the fact that the event horizon of a black hole is a globally defined property of a spacetime; we would not expect a freely falling observer to notice anything unusual at the horizon – and we certainly would not expect her to be destroyed there. Black hole complementarity postulates that from her perspective the infalling observer's passage through the heated membrane and the event horizon is indeed uneventful. Her description of the situation is claimed to be *complementary* to the external observer's description, rather in the way that the descriptions of a quantum particle in terms of position and momentum are complementary.

Hawking had shown that the quantum state of any one particle escaping from the black hole is random, so the particle cannot be carrying any useful information. But in the mid-1990s, Susskind and others "realized that information could be encoded in the quantum state of the radiation as a whole if the particles could somehow have their states 'entangled' — intertwined in such a way that measurements carried out on one will immediately influence its partner, no matter how far apart they are" [7].

G. 't Hooft [8] proposed, an approach to black hole quantization is proposed wherein it is assumed that quantum coherence is preserved. Pure states could evolve into mixed states, as the thermal character of Hawking radiation has been taken to indicate. At first sight it might seem that the question of whether quantum coherence gets lost has little to do with physics on Planckian energy scales. The original derivation by Hawking that the expectation values of all operators as experienced by late observers are described by mixed quantum states, seemed to be totally independent of Planck scale details. Yet, the argument did involve the spacetime geometry arbitrarily "close" to the classically determined horizon, and included energies for which the gravitational redshift had become arbitrarily large. Moreover, the fact that the outgoing particles look thermal will be affected by any interactions occurring very near the horizon and, in turn, these might even reconvert apparently mixed states back into pure states in such a way that an outside observer could hardly tell the difference, any more easily than he could for a bucket of water.

Does Complementarity Saving Quantum Theory? However, others felt that it was general relativity, not quantum theory, that would need to be changed. And a proposal was made in 1992, called "complementarity", suggested that the information was, in a sense, both inside and outside but without violating quantum theory. (This proposal was developed by Susskind). Specifically, observers who remain outside the black hole see the information accumulate at the horizon, and then come flying outward in the Hawking radiation. Observers who fall into the black hole see the information located inside. Since the two classes of observers cannot communicate, there is no paradox. Still, this suggestion is potentially self-contradictory, and requires a number of strange things be true. Among them is something called "holography", an idea developed by G. 't Hooft and further by Susskind. The idea is that the physics of the three-dimensional interior of the black hole, where gravity obviously plays a role, can instead be viewed, via a rather mysterious transformation, as physics just above the two-dimensional horizon, where it is described by two-dimensional equations that do not include gravity at all.

"Crazy at it sounds, considerable evidence arose in the late 1990s that it is true, at least in some situations! In 1997, Maldacena conjectured that under the right circumstances, string theory is actually equivalent to a quantum theory (specifically, a "quantum field theory") without gravity and with fewer dimensions. This relationship, known variously as "AdS/CFT" or the "field/string" correspondence, deserves an article all its own" [1]. The success of holography gave additional credence to the complementarity idea. Furthermore, the field/string correspondence allowed for a very strong argument that small black holes can form and evaporate in the string theory via a process that *can be described by the corresponding quantum field theory* (though not explicitly) — and which therefore, as in all processes in any quantum theory, does preserve information! By 2005, even Hawking had come around to this point of view — that in fact, as the complementarity proposal had suggested, black holes do not cause information to be lost, and that general relativity, but not quantum theory, must be modified. Still, there were loose ends in the complementarity proposal. Black hole evaporation is so subtle that there were still no quantum theory equations for complementarity that could describe the evaporation process.

5. Firewall

Black hole evaporation is so subtle that there were still no quantum theory equations for complementarity that could describe the evaporation process. While trying to find such equations, Ahmed Almheiri, Donald Marolf, Joseph Polchinski, and James Sully [9] discovered that in fact (at least under reasonable assumptions) complementarity contains a self-contradiction, which shows up when a black hole has evaporated about halfway. The argument is extremely subtle, involving the kind of "quantum entanglement". But crudely speaking, by the halfway point, so much information has departed the black hole in the Hawking radiation that there's not enough left at the horizon for holography to represent the black hole's interior. Consequently, instead of an in-falling observer smoothly entering the black hole through the harmless horizon, the observer finds there's no interior at all, and does so the hard way, by being fried to a crisp by a so-called "firewall" that hovers just outside the horizon[1]. In their account, quantum effects would turn the event horizon into a seething maelstrom of particles. Anyone who fell into it would hit a wall of fire and be burned to a crisp in an instant.

Such firewalls would violate a foundational tenet of physics that was first articulated almost a century ago by Albert Einstein, who used it as the basis of general relativity, his theory of gravity. Known as the equivalence principle, it states in part that an observer falling in a gravitational field — even the powerful one inside a black hole — will see exactly the same phenomena as an observer floating in empty space. Without this principle, Einstein's framework crumbles.

Well aware of the implications of their claim, Polchinski and his co-authors offered an alternative plot ending in which a firewall does not form. But this solution came with a huge price. Physicists would have to sacrifice the other great pillar of their science: quantum mechanics, the theory governing the interactions between subatomic particles.

Hawking had shown that the quantum state of any one particle escaping from the black hole is random, so the particle cannot be carrying any useful information. But in the mid-1990s, Susskind and others realized that information could be encoded in the quantum state of the radiation as a whole if the particles could somehow have their states 'entangled' — intertwined in such a way that measurements carried out on one will immediately influence its partner, no matter how far apart they are. But how could that be, wondered the Polchinski's team? For a particle to be emitted at all, it has to be entangled with the twin that is sacrificed to the black hole. And if Susskind and others were right, it also had to be entangled with all the Hawking radiation emitted before it. Yet a rigorous result of quantum mechanics dubbed 'the monogamy of entanglement' says that one quantum system cannot be fully entangled with two independent systems at once.

To escape this paradox, Polchinski and his co-workers realized, one of the entanglement relationships had to be severed. Reluctant to abandon the one required to encode information in the Hawking radiation, they decided to snip the link binding an escaping Hawking particle to its infalling twin. But there was a cost. "It's a violent process, like breaking the bonds of a molecule, and it releases energy," says Polchinski. The energy generated by severing lots of twins would be enormous. "The event horizon would literally be a ring of fire that burns anyone falling through," he says. And that, in turn, violates the equivalence principle and its assertion that free-fall should feel the same as floating in empty space — impossible when the former ends in incineration. So they posted a paper on the preprint server, arXiv, presenting physicists with a stark choice: either accept that firewalls exist and that general relativity breaks down, or accept that information is lost in black holes and quantum mechanics is wrong. Firewalls seem like the least crazy option. The paper rocked the physics community. It was outrageous to claim that giving up Einstein's equivalence principle is the best option. Raphael Bousso says: "A firewall simply can't appear in empty space; any more than a brick wall can suddenly appear in an empty field and smack you in the face." If Einstein's theory doesn't apply at the event horizon, cosmologists would have to question whether it fully applies anywhere.

"So now the paradox is back! And worse than ever. It seems that if quantum theory and complementarity are right, general relativity isn't just requiring some small modification — it requires major surgery! And there's no sign of such surgery in string theory, which provided the example of holography. But the field/string correspondence suggests quantum theory can describe black hole formation and evaporation, so information isn't lost" [1].

6. S. W. Hawking: Event Horizon Doesn't Exist

"Most physicists foolhardy enough to write a paper claiming that "there are no black holes" — at least not in the sense we usually imagine — would probably be dismissed as cranks. But when the call to redefine these cosmic crunchers comes from Stephen Hawking, it's worth taking notice. In a paper posted online, the physicist, based at the University of Cambridge, UK, and one of the creators of modern black-hole theory, does away with the notion of an event horizon, the invisible boundary thought to shroud every black hole, beyond which nothing, not even light, can escape. Hawking's radical proposal is a much more benign "apparent horizon", which only temporarily holds matter and energy prisoner before eventually releasing them, albeit in a more garbled form. There is no escape from a black hole in classical theory. Quantum theory, however, "enables energy and information to escape from a black hole". A full explanation of the process, the physicist admits, would require a theory that successfully merges gravity with the other fundamental forces of nature. But that is a goal that has eluded physicists for nearly a century. "The correct treatment," Hawking says, "remains a mystery."[10]

Hawking posted his paper on the arXiv preprint. He titled it, whimsically, 'Information preservation and weather forecasting for black holes' [11], and it has yet to pass peer review. The paper was based on a talk he gave via Skype at a meeting at the Kavli Institute for Theoretical Physics in Santa Barbara, California, in August 2013. Hawking's new work is an attempt to solve what is known as the black-hole firewall paradox, which has been vexing physicists for almost two years. Now Hawking proposes a third, tantalizingly simple, option. Quantum mechanics and general relativity remain intact, but black holes simply do not have an event horizon to catch fire. The key to his claim is that quantum effects around the black hole cause space-time to fluctuate too wildly for a sharp boundary surface to exist. In place of the event horizon, Hawking invokes an "apparent horizon", a surface along which light rays attempting to rush away from the black hole's core will be suspended. In general relativity, for an unchanging black hole, these two horizons are identical, because light trying to escape from inside a black hole can reach only as far as the event horizon and will be held there, as though stuck on a treadmill. However, the two horizons can, in principle, be distinguished. If more matter gets swallowed by the black hole, its event horizon will swell and grow larger than the apparent horizon. Conversely, in the 1970s, Hawking also showed that black holes can slowly shrink, spewing out 'Hawking radiation'. In that case, the event horizon would, in theory, become smaller than the apparent horizon. Hawking's new suggestion is that the apparent horizon is the real boundary. "The absence of event horizons means that there are no black holes — in the sense of regimes from which light can't escape to infinity," Hawking writes.

Hawking's attempt to resolve the paradox is criticized by:

Don Page [10], a physicist and expert on black holes at the University of Alberta in Edmonton, Canada, who collaborated with Hawking in the 1970s, says “The picture Hawking gives sounds reasonable,”. “You could say that it is radical to propose there’s no event horizon. But these are highly quantum conditions, and there’s ambiguity about what space-time even is, let alone whether there is a definite region that can be marked as an event horizon.” Although Page accepts Hawking’s proposal that a black hole could exist without an event horizon, he questions whether that alone is enough to get past the firewall paradox. The presence of even an ephemeral apparent horizon, he cautions, could well cause the same problems as does an event horizon. Unlike the event horizon, the apparent horizon can eventually dissolve. Page notes that Hawking is opening the door to a scenario so extreme “that anything in principle can get out of a black hole”. Although Hawking does not specify in his paper exactly how an apparent horizon would disappear, Page speculates that when it has shrunk to a certain size, at which the effects of both quantum mechanics and gravity combine, it is plausible that it could vanish. At that point, whatever was once trapped within the black hole would be released (although not in good shape).

If Hawking is correct, there could even be no singularity at the core of the black hole. Instead, matter would be only temporarily held behind the apparent horizon, which would gradually move inward owing to the pull of the black hole, but would never quite crunch down to the centre. Information about this matter would not destroyed, but would be highly scrambled so that, as it is released through Hawking radiation, it would be in a vastly different form, making it almost impossible to work out what the swallowed objects once were.

Joseph Polchinski, is skeptical that black holes without an event horizon could exist in nature. The kind of violent fluctuations needed to erase it are too rare in the Universe, he says. “In Einstein’s gravity, the black-hole horizon is not so different from any other part of space,” says Polchinski. “We never see space-time fluctuate in our own neighborhood: it is just too rare on large scales”[12]. "Notably, Hawking’s work has not yet been peer-reviewed, and it contains no equations, so there’s no way to test his new ideas, Polchinski said. Because of that, he added, his statement about black holes can’t be considered a breakthrough in science , yet" [16]. “It’s not so much that there’s a mistake, but somehow, some assumption that we believe about quantum mechanics and gravity is wrong, and we’re trying to figure out what it is,” Polchinski said. “It’s confusion, but it’s confusion that we hope makes us ripe for advance.”[13]

Raphael Bousso, a theoretical physicist at the University of California, Berkeley, and a former student of Hawking's, says that this latest contribution highlights how “abhorrent” physicists find the potential existence of firewalls. However, he is also cautious about Hawking’s solution. “The idea that there are no points from which you cannot escape a black hole is in some ways an even more radical and problematic suggestion than the existence of firewalls,” he says. "But the fact that we’re still discussing such questions 40 years after Hawking’s first papers on black holes and information is testament to their enormous significance."[12]

Matt Strassler, blogger and visiting theoretical physicist at Harvard University says "Everyone’s confused. There are lots and lots of proposals as to how to get out of this conundrum. You’re not hearing about most of them. The media told you about Hawking’s because he’s famous, but he’s really just one of many, many voices tossing ideas around. All of these ideas suffer from the same thing: not enough equations to provide evidence and details of how they’re supposed to work. And since not having enough equations is what led to the firewall paradox, we can hardly try to get out of this situation by relying on yet another argument that lacks equations for its details! Hawking points out that although exteriors of black holes quickly become simple, the interiors can become very complex. Complex systems, like weather, can exhibit chaos, which can make them unpredictable even before you think about quantum theory. He seems to suggest that the complexity itself destabilizes the horizon and allows the information, having been scrambled inside the black hole, to leak back out. Since this would violate Hawking’s own theorems about general relativity, I assume this means that general relativity must be modified. "But even though Hawking is just one person making a proposal, and even though his proposal lacks equations and is likely to be, at best (in my view), incomplete, and more likely just wrong," you probably want to know what he suggested" [1]. But there are many obvious problems with this proposal — not the least of which is that the firewall puzzle shows up already after the halfway point of black hole evaporation, not just at the end of the evaporation. And thus the black hole is still very large when the information has to be leaking out — which would seem very difficult to reconcile with a proposal like Hawking’s.

That’s where Hawking’s latest paper comes in, suggesting physicists need to rethink about event horizon. His latest proposal suggests that there is in fact no event horizon to burn up. Instead, the apparent horizon becomes the real boundary. If you’re confused, you’re not alone, said Matt Strassler. The entire theoretical physics community is still working on these problems, and this represents merely one proposal among dozens. "The problem is no one can come up, so far, with something you can actually calculate. So it’s ideas and proposals and approximations and guesses,” he said. How can any of these paradoxes around black holes be answered? For now, the mathematical formulas to test and solve these new hypotheses simply aren’t there, Strassler said" [13].

"In a perfect world, scientists might be willing to open up their work to criticism by pointing out the weak parts of their theories; under ideal conditions, scientists might willingly abandon pet theories as soon as they found them to be false. But in the real world things are quite different. Scientists have thick skins. They do not abandon a theory merely because facts contradict it. They normally invent some rescue hypothesis to explain what they then call a mere anomaly or, if they cannot explain the anomaly, they ignore it, and direct their attention to other problems" [14].

Hawking's proposal, no event horizon and hence no black holes is an attempt to keep its Hawking's radiation stay alive rather than to open up his work to criticism.

7. Laura Mersini-Houghton: Black Holes do not Exist

"S. Hossenfelder and L. Smolin. propose a novel scheme to classify the different options for resolution of the black hole loss of information problem that is independent of the details of the underlying theory of quantum gravity. We distinguish first between radical options, which require a quantum theory of gravity which has large deviations from semiclassical physics on macroscopic scales, such as nonlocality or endowing horizons with special properties not seen in the semiclassical approximation, and conservative options, which do not need such help. Among the conservative options, we conclude that *restoring unitary evolution relies on elimination of singularities*. We argue that this should hold also in the anti-de Sitter/conformal field theories correspondence"[15].

Laura Mersini-Houghton [16], a physics professor at UNC-Chapel Hill in the College of Arts and Sciences, has proven, mathematically, that black holes can never come into being in the first place. For a more than 50 years and this solution gives us a lot to think about." For decades, black holes were thought to form when a massive star collapses under its own gravity to a single point in space – imagine the Earth being squished into a ball the size of a peanut – called a singularity. So the story went, an invisible membrane known as the event horizon surrounds the singularity and crossing this horizon means that you could never cross back. It's the point where a black hole's gravitational pull is so strong that nothing can escape it. "Amidst all the puzzles and paradoxes, a trivial possibility is that black holes may not form. This possibility is the focus of the current study. Within a set of approximations, such as assumptions of spherical symmetry and homogeneity of a star collapsing into a black hole, this work shows that a black hole may not form when the backreaction of the quantum flux of particles created is taken into account in the collapse dynamics of the star"[17].

The reason black holes are so bizarre is that it pits two fundamental theories of the universe against each other. Einstein's theory of gravity predicts the formation of black holes but a fundamental law of quantum theory states that no information from the universe can ever disappear. Efforts to combine these two theories lead to mathematical nonsense, and became known as the information loss paradox. In 1974, Stephen Hawking used quantum mechanics to show that black holes emit radiation. Since then, scientists have detected *fingerprints* in the cosmos that are consistent with this radiation, identifying an ever-increasing list of the universe's black holes.

Mersini-Houghton describes an entirely new scenario. She and Hawking both agree that as a star collapses under its own gravity, it produces Hawking radiation. However, in her new work, Mersini-Houghton shows that by giving off this radiation, the star also sheds mass. So much so that as it shrinks it no longer has the density to become a black hole. Before a black hole can form, the dying star swells one last time and then explodes. A singularity never forms and neither does an event horizon. The take home message of her work is clear: there is no such thing as a black hole.

Mersini-Houghton's conclusions have already been severely criticized by William Unruh[17], a theoretical physicist from the University of British Columbia: "The [paper] is nonsense," Unruh said in an email to IFL Science media outlet. "Attempts like this to show that black holes never form have a very long history, and this is only the latest. They all misunderstand Hawking radiation, and assume that matter behaves in ways that are completely implausible," he claimed. Quite to the contrary of Mersini-Houghton calculations, Unruh maintains that black holes do not emit enough Hawking radiation to lose mass to avoid formation of a black hole"[17]. "It would take 10^53 (1 followed by 53 zeros) times the age of the universe to evaporate," Unruh explained, adding that it is a common mistake for those who do not understand Hawking's radiation theory in full, that the "outgoing energy back closer and closer to the horizon of the black hole, where its energy density gets larger and larger," he said. "Unfortunately, explicit calculations of the energy density near the horizon show it is really, really small instead of being large. Those calculations were already done in the 1970s. To call a bad speculation 'has been proven mathematically' is, shall we say, an overstatement,"[17] Unruh concluded .

Mersini-Houghton is cheating when she says: scientists have detected *fingerprints* in the cosmos that are consistent with this radiation, identifying an ever-increasing list of the universe's black holes. This is not true, since Hawking radiation has never been observed, since the only black holes we have evidence for are those with lots of hot gas falling into them, whose radiation would completely swamp this tiny effect.

8. Singularity, in Principle, Theoretically doesn't Exist

One of the most remarkable features of relativistic black holes is that they are purely gravitational entities. A pure black hole spacetime contains no matter whatsoever. It is a "vacuum" solution to the Einstein field equations, which just means that it is a solution of Einstein's gravitational field equations in which the matter density is everywhere zero. (Of course, one can also consider a black hole with matter present.) In pre-relativistic physics we think of gravity as a force produced by the mass contained in some matter. In the context of general relativity, however, we do away with gravitational force, and instead postulate a curved spacetime geometry that produces all the effects we standardly attribute to gravity. Thus a black hole is not a "thing" in spacetime; it is instead a feature of spacetime itself. Singularity appears theoretically as a result to the Schwarzschild solution in asymptotically flat spacetime. We did prove in our previous paper "The hyperbolic geometry of the universe and the wedding of general relativity theory to quantum theory"[18] that the spacetime is hyperbolic. Such an approximated Schwarzschild solution creates singularity (when r = 0). This false paradigm constitutes our observation. The observer is operating within a "paradigm". Paradigms are ways in which people think about things, and ways in which ideas and theories are communicated. They are always an approximation of the truth. Observations being made are not complete in themselves; they interpreted within a theory (a paradigm). Schwarzschild solution singularity paradigm works as a lunette, through which we imagine that we might see Black holes. Black holes have never been seen directly, their existence is just a matter of illusion. Singularity, in principle, theoretically doesn't exist, as we shall prove and consequently Black holes actually do not exist.

Note that our modified Schwarzschild[19] spherically symmetric metric in the hyperbolic spacetime for radial null trajectory is

Nonsingular Schwarzschild Black Hole

$$d\tau^2 = (1-2\mu/r-\mu/a)dt^2 - e^{2\mu/r}dr^2 - r^2 d\Omega^2$$
$$0 = (1-2\mu/r-\mu/a)dt^2 - e^{2\mu/r}dr^2$$
$$\frac{dr}{dt} = e^{-\mu/r}\sqrt{1-2\mu/r-\mu/a}$$

doesn`t possess singularity at $r=0$, since

$$\lim_{r\to 0}\frac{dr}{dt} = \lim_{r\to 0} e^{-\mu/r}\sqrt{1-2\mu/r-\mu/a}$$
$$= \lim_{r\to 0}\frac{\sqrt{1-2\mu/r-\mu/a}}{e^{\mu/r}} = \lim_{r\to 0}\frac{\left(2\mu/r^2\right)\Big/ 2\sqrt{1-2\mu/r-\mu/a}}{\left(-\mu/r^2\right)e^{\mu/r}}$$
$$= \lim_{r\to 0}\frac{-1}{\sqrt{1-2\mu/r-\mu/a}.e^{\mu/r}} = 0$$

Nonsingular Kerr Rotating Black Hole in the hyperbolic spacetime

Kerr metric of a rotating black hole is given by

$$d\tau^2 = \left(1-\frac{2\mu r}{\rho^2}\right)dt^2 + \frac{4\mu\alpha r\sin^2\theta}{\rho^2}d\phi dt - \frac{\rho^2}{\Delta}dr^2 - \rho^2 d\theta^2$$
$$-\left(r^2+\alpha^2+\frac{2\mu r\alpha^2\sin^2\theta}{\rho^2}\right)\sin^2\theta d\phi^2$$
$$\alpha \equiv \frac{J}{\mu}$$
$$\rho^2 = r^2+\alpha^2\cos^2\theta$$
$$\Delta = r^2+\alpha^2-2\mu r$$

The singularity arises when $\rho^2 = r^2+\alpha^2\cos^2\theta$

Kerr metric reduces to Schwarzschild metric when $\alpha=0$.

By analogy we can rewrite Kerr metric in hyperbolic spacetime that can be reduced to the modified Schwarzschild metric in hyperbolic space time, as follows:

$$\rho^2 = r^2+\alpha^2\cos^2\theta$$
$$\Delta = r^2+\alpha^2-2\mu r$$
$$\frac{\rho^2}{\Delta} = \left(\frac{r^2+\alpha^2-2\mu r}{r^2+\alpha^2\cos^2\theta}\right)^{-1}$$
$$\frac{\rho^2}{\Delta} = \left(\frac{r^2+\alpha^2\cos^2\theta-\alpha^2\cos^2\theta+\alpha^2-2\mu r}{r^2+\alpha^2\cos^2\theta}\right)^{-1}$$
$$\frac{\rho^2}{\Delta} = \left(1-\frac{\alpha^2\cos^2\theta-\alpha^2+2\mu r}{r^2+\alpha^2\cos^2\theta}\right)^{-1}$$
$$\frac{\rho^2}{\Delta} = \left(1+\frac{\alpha^2\cos^2\theta-\alpha^2+2\mu r}{r^2+\alpha^2\cos^2\theta}\right)$$
$$\frac{\rho^2}{\Delta} = e^{\frac{\alpha^2\cos^2\theta-\alpha^2+2\mu r}{r^2+\alpha^2\cos^2\theta}}$$
$$\frac{\rho^2}{\Delta} = e^{\frac{\alpha^2\cos^2\theta-\alpha^2+2\mu r}{r^2+\alpha^2\cos^2\theta}} \xrightarrow{\alpha\to 0} e^{\frac{2\mu}{r}}$$

The Hyperbolic spacetime Kerr metric can be rewritten as

$$d\tau^2 = \left(1-\frac{2\mu r}{\rho^2}-\frac{\mu}{a}\right)dt^2 + \frac{4\mu\alpha r\sin^2\theta}{\rho^2}d\phi dt - e^{\frac{\alpha^2\cos^2\theta-\alpha^2+2\mu r}{r^2+\alpha^2\cos^2\theta}}dr^2 - \rho^2 d\theta^2$$
$$-\left(r^2+\alpha^2+\frac{2\mu r\alpha^2\sin^2\theta}{\rho^2}\right)\sin^2\theta d\phi^2$$

which reduces to our modified Schwarzschild metric in the Hyperbolic spacetime when $\alpha=0$

$$d\tau^2 = (1-2\mu/r-\mu/a)dt^2 - e^{2\mu/r}dr^2 - r^2 d\Omega^2$$

The coefficient of dr^2, the exponential factor, can never be zero.

The Kerr metric in the hyperbolic spacetime for radial null trajectory doesn`t possess singularity at $r=0$, since

$$d\tau^2 = \left(1-\frac{2\mu r}{r^2+\alpha^2\cos^2\theta}-\frac{\mu}{a}\right)dt^2 - e^{\frac{\alpha^2\cos^2\theta-\alpha^2+2\mu r}{r^2+\alpha^2\cos^2\theta}}dr^2$$
$$0 = \left(1-\frac{2\mu r}{r^2+\alpha^2\cos^2\theta}-\frac{\mu}{a}\right)dt^2 - e^{\frac{\alpha^2\cos^2\theta-\alpha^2+2\mu r}{r^2+\alpha^2\cos^2\theta}}dr^2$$
$$\frac{dr}{dt} = e^{-\frac{1}{2}\frac{\alpha^2\cos^2\theta-\alpha^2+2\mu r}{r^2+\alpha^2\cos^2\theta}}\sqrt{1-\frac{2\mu r}{r^2+\alpha^2\cos^2\theta}-\frac{\mu}{a}}$$
$$\rho\to 0 \Rightarrow \theta=\pi/2, and, r\to 0$$
$$\frac{dr}{dt} = e^{-\frac{1}{2}\frac{-\alpha^2+2\mu r}{r^2}}\sqrt{1-\frac{2\mu r}{r^2}-\frac{\mu}{a}}$$
$$\lim_{r\to 0}\frac{dr}{dt} = 0$$

The limit is taken by L`Hospital`s rule where θ = π/2.

9. Conclusion

The black hole creates particles in pairs, with one particle always falling into the hole and the other possibly escaping to infinity. Because part of the information about the state of the system is lost down the hole, the final situation is represented by a density matrix rather than a pure quantum state. The doomed particle would balance the positive energy of the outgoing particle by carrying negative energy inwards, something allowed by quantum rules. That negative energy would then get subtracted from the black hole's mass, causing the hole to shrink. But with it came the disturbing realization that black-hole radiation leads to a paradox that challenges quantum theory. Stephen Hawking argues that his prediction that black holes emit thermal radiation implies that the evolution of black holes cannot be described by standard unitary quantum mechanical evolution. This nonunitary evolution is described as a loss of "information" – if a pure state nonunitarily evolves into a mixture, then we can no longer predict with certainty the outcome of any complete set of measurements, thus it appears that some previously existing information has been destroyed. This conclusion has been generally viewed as unacceptable paradox, that needs to be resolved. Physicists stuck between a rock and a hard place: Either information could be lost, or somehow something could escape from a black hole. A central tenet of quantum mechanics was pitted against the cornerstone of relativity. One theory, it seemed, had to give.

Complementarity, suggested that the information was, in a sense, both inside and outside but without violating quantum theory. Specifically, observers who remain outside the black hole see the information accumulate at the horizon, and then come flying outward in the Hawking radiation. Observers who fall into the black hole see the information located inside. Since the two classes of observers cannot communicate, there is no paradox.

For a particle to be emitted at all, it has to be entangled with the twin that is sacrificed to the black hole. And if complementarity was right, it also had to be entangled with all the Hawking radiation emitted before it. Yet a rigorous result of quantum mechanics dubbed 'the monogamy of entanglement' says that one quantum system cannot be fully entangled with two independent systems at once. To escape this paradox, Polchinski and his co-workers realized, one of the entanglement relationships had to be severed. Reluctant to abandon the one required to encode information in the Hawking radiation, they decided to snip the link binding an escaping Hawking particle to its infalling twin. But there was a cost. It's a violent process, like breaking the bonds of a molecule, and it releases energy. The energy generated by severing lots of twins would be enormous. The event horizon would literally be a ring of fire that burns anyone falling through. And that, in turn, violates the equivalence principle and its assertion that free-fall should feel the same as floating in empty space — impossible when the former ends in incineration. Hence complementarity should be rejected.

In place of the event horizon, Hawking invokes an "apparent horizon", a surface along which light rays attempting to rush away from the black hole's core will be suspended. Hawking's new suggestion is that the apparent horizon is the real boundary. "The absence of event horizons means that there are no black holes — in the sense of regimes from which light can't escape to infinity," Hawking does not specify in his paper exactly how an apparent horizon would disappear. Hawking's work has not yet been peer-reviewed, and it contains no equations, so there's no way to test his new ideas. But even though Hawking proposal lacks equations and is likely to be, at best, incomplete, and more likely just wrong.

S. Hossenfelder and L. Smolin. conclude that *restoring unitary evolution relies on elimination of singularities*

Mersini-Houghton describes an entirely new scenario. She and Hawking both agree that as a star collapses under its own gravity, it produces Hawking radiation. However, in her new work, Mersini-Houghton shows that by giving off this radiation, the star also sheds mass. So much so that as it shrinks it no longer has the density to become a black hole. Before a black hole can form, the dying star swells one last time and then explodes. A singularity never forms and neither does an event horizon. There is no such thing as a black hole.

Mersini-Houghton's conclusions have already been severely criticized by William Unruh[17], a theoretical physicist from the University of British Columbia: "The [paper] is nonsense". She misunderstand Hawking radiation, and assume that matter behaves in ways that are completely implausible," he claimed. Quite to the contrary of Mersini-Houghton calculations, Unruh maintains that black holes do not emit enough Hawking radiation to lose mass to avoid formation of a black hole"[17]. Unruh explained, adding that it is a common mistake for those who do not understand Hawking's radiation theory in full, that the "outgoing energy back closer and closer to the horizon of the black hole, where its energy density gets larger and larger," he said. "Unfortunately, explicit calculations of the energy density near the horizon show it is really, really small instead of being large. "The [paper] is nonsense".

In flat spacetime Schwarzschild metric (Kerr metric) possesses singularity (when r=0 , the velocity is infinite). We did prove mathematically that the spacetime of the Universe is hyperbolic. We show that neither the modified Schwarzschild metric nor the modified Kerr metric possess singularity in the hyperbolic spacetime. Singularity is the main character of the Black hole. If, in principle, singularity theoretically doesn't exist, Black holes also don`t exist. There is no singularity to crush and destruct the infalling information. In the actually hyperbolic spacetime infalling particles (information) have just come to rest at the origin (r = 0). Hence Information Paradox does no longer exist.

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