An alternative solution to the Black Hole Information Paradox

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A short informal essay proposing that the Holographic Principle may offer a possible alternative solution to the Black Hole Information Paradox proposed by physicist Stephen Hawking. The actual concept of falling is re-examined. Objects that fall into a black hole have their information randomized. This information exists on a holographic boundary where it is randomized, but not lost or destroyed. That information on the holographic boundary in bits is equivalent, in our universe outside of the black hole's event horizon, to information measured in bits of the total change in distance to the black hole of all entities due to the change (increase or decrease) in black hole mass, after an object falls into it or it evaporates, supporting the theory of a universe that is foundationally a "network of relations." The total change to our universe as a superstructure relational network, as measured in bits of information, is equivalent to the total bits of information needed to describe an object as it disappears behind a black hole event horizon.

> *"It from bit symbolizes the idea that every item of the physical world has at bottom - at a very deep bottom, in most instances - an immaterial source and explanation; that what we call reality arises in the last analysis from the posing of yes-no questions and the registering of equipment-evoked responses; in short, that all things physical are information-theoretic in origin and this is a participatory universe.".*
> *-- John Wheeler*[1]

> *"Hawking and Kip Thorne bet Preskill that information that falls into a black hole gets destroyed and can never be retrieved. Called the black hole information paradox, this prospect follows from Hawking's landmark 1974 discovery about black holes - regions of inescapable gravity, where space-time curves steeply toward a central point known as the singularity. Hawking had shown that black holes are not truly black. Quantum uncertainty causes them to radiate a small amount of heat, dubbed "Hawking radiation." They lose mass in the process and ultimately evaporate away. This evaporation leads to a paradox: Anything that falls into a black hole will seemingly be lost forever, violating "unitarity" - a central principle of quantum mechanics that says the present always preserves information about the past. Hawking and Thorne argued that the radiation emitted by a black hole would be too hopelessly scrambled to retrieve any useful information about what fell into it, even in principle."*
> *-- Janna Levin*[2]

The last few decades have involved a tremendous amount of research and attention on solving what is known as the Black Hole Information Paradox.[3, 4] Many scientists believe the paradox to be resolved by various proposed solutions, but perhaps there is an alternative solution to the Black Hole Information Paradox.[5] If we consider the universe as a whole, and perhaps approach the problem from a perspective similar to the Holographic Principle, then maybe there is not a paradox of information loss or destruction at all.[6]

Black holes are considered perfect randomizers of information.[7] Many theories have been proposed that involve "local" solutions to prevent the loss of information that has fallen into a black hole. Theories, including the famous EP=EPR work of Leonard Susskind and Juan Maldacena, involving wormholes that extend from inside an event horizon to outside of it, that may also make up the very fabric of spacetime, all involve information directly connected to the black hole or involved with its slow evaporation into Hawking Radiation.[8, 9] But the Holographic Principle or Paradigm demonstrates how information can be located on a remote or boundary horizon. As Stanford physicist Leornard Susskind notes in his book *The Black Hole War*:

> "the three-dimensional world of ordinary experience - the universe filled with galaxies, stars, planets, houses, boulders, and people - is a hologram, an image of reality coded on a distant two-dimensional surface. This new law of physics, known as the Holographic Principle, asserts that everything inside a region of space can be described by bits of information restricted to the boundary."[10]

From this perspective, maybe the information that has fallen into a black hole is not evaporated or returns to our universe with the black hole directly connected to some nearby particles or object but, rather, the information remains connected to our universe via the holographic boundary that surrounds our universe which may directly or indirectly include the surface areas of black holes. As long as the information is conserved, in the spirit of mass and energy conservation laws, then perhaps we can speculate on *where* that information is conveyed back into our universe. One idea involves the information that has entered a black hole being returned to our universe outside the event horizon not as a single sequence but rather with it broken down into many separate miniscule bits. At the foundation of reality, we can consider a bit as a bit – or a qubit as a qubit.[1]

Recent theories, deriving from philosophical ideas going back centuries including concepts proposed by Leibniz, Mach, Stephen Wolfram, and Lee Smolin, propose that the structure of our reality, at a scale smaller than subatomic quarks, is a "network of relations."[11, 12, 13, 14, 15, 16] The famous philosopher Bertrand Russell even wrote how the genius Leibniz had declared space and time to be inherently relational.[10]

So let us imagine Isaac Newton under that English apple tree when he discovers gravity. Newton realizes that a falling apple is equivalent to a "falling" moon. He later discovers that the rate of the falling apple is an inverse square law and that the sideways velocity of the moon means it is always falling or in freefall and thus remains in an elliptical orbit around the earth.[17] But might we be able to redefine or elaborate on the concept of *falling*. Albert Einstein, in his General Theory of Relativity, considers *falling* as an object following the curvature of spacetime due to a massive body i.e., the apple is in a "gravitational well" or field.[18] All well and good, but let us consider this from a different (maybe equivalent) perspective.

Now a key difference between math and physics, as students encounter in high school, is that much of physics involves analyzing entities with both quantity and direction, i.e., a vector. So, returning to Newton's falling apple, consider that our apple does not just convey information that it and Newton is in a gravitational field (and the general strength of that field), but it also conveys *where* the gravitational field is - or where it is *centered* – in this case the center of the planet earth. But when we use the term *centered*, naturally one may ask, "centered relative to what?" We might answer, "relative to everything i.e., relative to nearby stars, planets, galaxies." Thus, in essence, gravity *is* information. Gravity e.g., our falling apple, conveys information at its most basic level, in the form of a *relational map*.

Almost all galaxies have been found to have a supermassive black hole at their center.[19] Not only is everything in the galaxy (stars, dust, radiation) attracted to the supermassive central blackhole, all those stars are, thus, also mapped relative to it. The number of stars (quantity) and the distance (direction) of each star to that black hole center, for all intents and purposes, defines each galaxy. The *shape* of a galaxy can also be considered a fundamental attribute but the shape will still derive from the direction and distances of the components.

In this proposal a black hole, or even an evaporating black hole, does not destroy information. The information it contains is "released" back into the Universe in the form of its changing influence to everything else in the universe i.e., to the nodal structure or "map" of the universe on the holographic boundary. As any black hole increases or decreases in size, and thus gravitational field strength, the nodal map or the universe changes equivalently i.e., the amount and direction of pull on nearby stars or spaceships or light rays. But fundamentally information that has fallen into a given black hole is thus "released" back into the universe, a la bits on the holographic boundary, as the sum of all the relational changes on our boundary map of the universe no matter how miniscule. An obvious analogy or inspiration here being Richard Feynman's *sum of all histories* formulation of quantum mechanics.[20] We can attempt to model or visualize these aggregate changes to an entire network universe as a large tinker toy creation where the removal of a single node results in a change, even if subtle, of the entire structure. Distances on our holographic boundary map are considered vector quantities but also information that can be measured in bits.

Consider how the black color of our poor yet famous cat, so often seen in modern physics models, as it falls into a black hole, is information stored as bits. Those same bits are then randomized in the black hole, and thus our holographic boundary (the surface area of a black hole inside its event horizon may even be a literal holographic boundary given models like the Bekenstein Bound[21]), but also distributed in the information associated with the sum of all the changes to distance from the apparent vanishing of the all the information associated with our cat behind the event horizon of the black hole. Note again the similarity to conservation of mass and energy laws as any black hole's increase or decrease in mass, and thus gravitational field, will lead to subsequent distance (direction) changes to the rest of the universe that can be represented as informational bits on the holographic boundary.

In summary, information on the holographic boundary in bits is equivalent, in our universe outside of the black hole's event horizon, to information measured in bits of the total change in distance to the black hole of all entities due to the change (increase or decrease) in a black hole mass, after an object falls into it or the black hole evaporates, supporting the theory of a universe that is foundationally a "network of relations." We propose that the total change to our universe as a superstructure relational network, as measured in bits of information, is equivalent to the total bits of information needed to describe an object as it disappears behind a black hole event horizon.

References

1) Wheeler, J. (1990). "Information, physics, quantum: The search for links". In Zurek, Wojciech Hubert (ed.). *Complexity, Entropy, and the Physics of Information.* Redwood City, California: Addison-Wesley.

2) Levin, J. (2024 April 11). Can Information Escape a Black Hole? *Quanta Magazine.* Retrieved January 4, 2025, from https://www.quantamagazine.org/can-information-escape-a-black-hole-20240411/

3) Ouellette, J. (2018 March 14). Why Stephen Hawking's Black Hole Puzzle Keeps Puzzling. *Quanta Magazine.* Retrieved January 4, 2025, from https://www.quantamagazine.org/stephen-hawkings-black-hole-paradox-keeps-physicists-puzzled-20180314/

4) Wikipedia contributors. (2024, October 24). Black hole information paradox. In *Wikipedia, The Free Encyclopedia.* Retrieved January 4, 2025, from https://en.wikipedia.org/w/index.php?title=Black_hole_information_paradox&oldid=1253088799

5) Musser, G. (2022 September). Paradox Resolved. *Scientific American Magazine.* Vol. 327 No. 3 doi:10.1038/scientificamerican0922-30. Retrieved January 4, 2025, from https://www.scientificamerican.com/article/how-physicists-cracked-a-black-hole-paradox/

6) Wikipedia contributors. (2025, January 2). Holographic principle. In *Wikipedia, The Free Encyclopedia.* Retrieved January 4, 2025, from https://en.wikipedia.org/w/index.php?title=Holographic_principle&oldid=1266831540

7) Hertog, T. (2023). *On the origin of time: Stephen Hawking's final theory. Penguin* Books.

8) Maldacena, J., & Susskind, L. (2013). Cool horizons for entangled black holes. *Fortschritte der Physik*, 61(9), 781-811.

9) Hawking, S. W. (1976). "Breakdown of predictability in gravitational collapse". *Physical Review D*. 14 (10): 2460–2473.

10) Susskind, L. (2008). *The Black Hole War: My battle with Stephen Hawking to make the world safe for Quantum Mechanics.* Little, Brown, and Company.

11) Wikipedia contributors. (2024, December 29). Gottfried Wilhelm Leibniz. In *Wikipedia, The Free Encyclopedia.* Retrieved January 4, 2025, from https://en.wikipedia.org/w/index.php?title=Gottfried_Wilhelm_Leibniz&oldid=1266026554

12) Russell, B. (1900). *A Critical Exposition of the Philosophy of Leibniz*. The University Press, Cambridge.

13) Greene, B. (2005). *The fabric of the cosmos: Space, time, and the texture of reality*. Bantam.

14) Wikipedia contributors. (2024, October 26). Mach's principle. In *Wikipedia, The Free Encyclopedia*. Retrieved January 4, 2025, from https://en.wikipedia.org/w/index.php?title=Mach%27s_principle&oldid=1253544914

15) Wolfram, S. (2020). *A project to find the fundamental theory of physics*. Wolfram Media, Inc.

16) Smolin, L., & McEwan, K. (2019). *Einstein's unfinished revolution: The search for what lies beyond the Quantum*. Penguin Books.

17) Wikipedia contributors. (2024, December 31). Isaac Newton's apple tree. In *Wikipedia, The Free Encyclopedia.* Retrieved January 4, 2025, from https://en.wikipedia.org/w/index.php?title=Isaac_Newton%27s_apple_tree&oldid=1266470252

18) Einstein, A. (2017). *Relativity: The special and the general theory.* Fingerprint! Classics.

19) Wikipedia contributors. (2024, November 28). Galaxy. In *Wikipedia, The Free Encyclopedia.* Retrieved January 4, 2025, from https://en.wikipedia.org/w/index.php?title=Galaxy&oldid=1259978371

20) Wikipedia contributors. (2024, December 4). Path integral formulation. In *Wikipedia, The Free Encyclopedia.* Retrieved January 5, 2025, from https://en.wikipedia.org/w/index.php?title=Path_integral_formulation&oldid=1261078587

21) Wikipedia contributors. (2025, January 2). Bekenstein bound. In *Wikipedia, The Free Encyclopedia*. Retrieved January 4, 2025, from https://en.wikipedia.org/w/index.php?title=Bekenstein_bound&oldid=1266831615