The Relationship between Black Holes and Quantum Bridges

Are black holes the beginning and end of quantum bridges?

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Abstract

The following extended essay aims to determine if ***black holes are the beginning and end of quantum bridges*** through the synthesis of literature and analyzing its limitations. This first involves selecting articles pertaining to black holes, quantum bridges, and/or their relationship. Each article is then read on its own and analyzed. Once all articles were analyzed, the information is extracted from each is compared. Points of agreement or similarity are then used to create claims. Points of disagreement are explored through the acquiring of more literature and consideration of the limitations of each argument until a claim can be made. The information gathered is then used to support the developed claims. Arguments are made assuming that the universe began with the inflation of a singularity, is finite, and part of a multiverse. The investigation leads one to two conclusions-the first being that by the confirmed duality between black holes and quantum bridges, that black holes are the beginning and end of quantum bridges and the second being that the multiple results that can be yielded by black holes under the conditions of loop quantum gravity only support black holes as the beginning of quantum bridges.

Word Count: 196

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Introduction

Man has had a longstanding obsession with wormholes or quantum bridges; they are consistently referenced during discussion of man's future, as solutions to fast-approaching issues, and works of science-fiction. Even though a quantum bridge has never been observed nor has the presence of one been confirmed, quantum bridges do not need to remain deep in the realm of theory or works of science-fiction. Quantum bridges are often thought of as a single phenomenon but in actuality they can be referred to as being part of a cycle with the foundation of the cycle being the question, "***are black holes the beginning and the end of quantum bridges***?" Black holes and quantum bridges share characteristics. Once the idea of a natural cycle that involves both black holes and quantum bridges is accepted, on the basis of the hypothesis that *black holes are quantum bridges in the making and collapse as a result of their inherent duality with quantum bridges and the nature of spacetime*, an analysis of these characteristics can lead one to conclude that quantum bridges would occur later in this cycle.

Understanding the role black holes play in the universe is crucial to man's advancement as a race. Man is slowly getting caught in the web of tradition as it faces biases in its Search for Extra-Terrestrial Intelligence (SETI). It has been postulated that advanced civilizations are 1.7 to eight billion years older than man. But as the properties of these civilizations are unknown, a plethora of search strategies need to be utilized. Currently, in SETI, there is only a focus on communication, such as radio, in the Milky Way out of the estimated $1.7x10^{11}$ galaxies. While being ranked a Type 0 civilization on the Kardashev scale and a BIV civilization on the Barrow scale, Vidal hypothesizes that black holes are attractors for intelligence for their versatility (Kaku). Energy could be extracted from the rotational energy or gravitational energy of colliding black holes. Black holes could act as solutions to waste-disposal and space-time travel.

Furthermore black holes allow the challenging of quantum mechanics, general relativity and thermodynamics and could be used as telescopes and communication devices. Furthermore, when man's sun reaches its red giant phase, black holes may act as a means of migration, or using its time dilation effects, a means of hibernation (Vidal, 2010).

Background

Black holes, solutions to Einstein's equations, are made from warped space and warped time and possess a singularity in which the surface of space's membrane forms a point that is infinitely warped. Black holes have an extreme density that results in a gravitational attraction so strong that even light cannot escape. The event horizon of a black hole is the point where light no longer can escape and gravity is constant. The cause of the warp of space is the energy of warping space because energy is stored in the warped space; "warping begets warping" (Thorne, 2014). A BTZ black hole has two asymptotic regions that are separated by an event horizon. A BTZ black hole is the most common spacetime constructed by researchers in later arguments. Figure 1 depicts a non-spinning black hole with one asymptotic region.

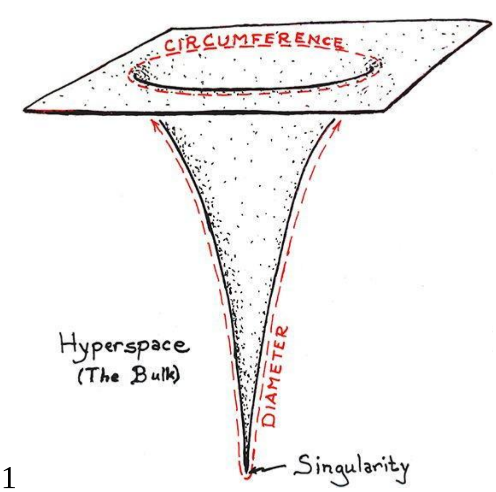
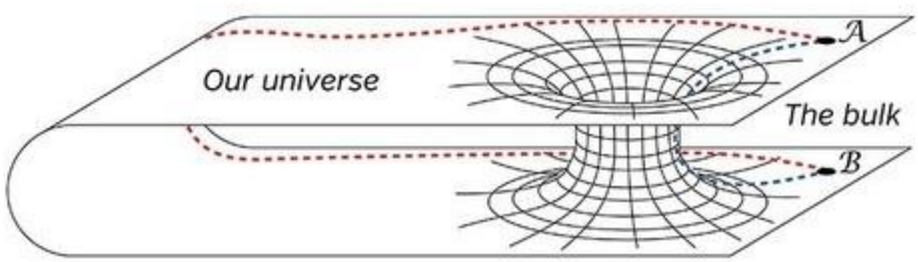


Figure 1

Quantum bridges, also named wormholes by John Wheeler, are solutions to Einstein's equations and analogous to those found in apples. They are a tunneling phenomenon through space that contain an interior that is not a part of the universe in which it is found but a fifth dimension, "the bulk," called hyperspace. Quantum bridges are "born, expand, contract, and then die" (Thorne, 2014). The first quantum bridge solutions were found by studying mathematical solutions for black holes. Quantum bridges can exist within the classical black hole solutions of Einstein's equations. Quantum bridges are simply two copies of black hole geometry connected by an Einstein-Rosen Bridge (Scientific American, 1997). Einstein's equivalence of mass and energy would dictate that quantum bridges be made up of an "exotic matter" that is negatively charged. What is thought to be this "exotic matter" has been produced in small amounts in laboratories (Thorne, 2014).



De Sitter space is spacetime with a slight curve in the absence of matter or energy and is equivalent to the cosmological constant in general relativity; while anti-de Sitter space has a negative curvature, hyperbolic geometry, and is equivalent to a negative cosmological constant. 2+1 anti-de Sitter space is a maximally symmetric Lorentzian manifold in which no point in space and time can be distinguished from another. A path can only be distinguished by whether or not it is spacelike, lightlike, or timelike. This type of space has a constant scalar curvature that is defined by a single number that is the same everywhere in spacetimes that have no matter or energy. A Lorentzian manifold is space modeled on Euclidean space with a metric tensor (1, n-1) which is equivalent to (n-1, 1).

Einstein's equations describe a curvature of spacetime and the distribution of matter throughout spacetime. Gravity is defined as the bending of space and time and comes from massive objects.

String Theory dictates that within background space, there are strings of about Planck length that have tension and that the excitation modes of these strings are the elementary particles that are observed.

Quantum Field Theory defines particles as excited states of a physical field. "[The physical field] contains all of physics" by describing many particles and their many interactions. And due to the Heisenberg uncertainty, empty space "froths and boils with particles and antiparticles (Tong)."

Assumptions

The following arguments are made assuming that the universe is finite and part of a multiverse and began with an event commonly referred to as the "Big Bang" 13.7 billion years ago in which a singularity inflated and cooled.

Duality

Åminneborg, Bengtsson, Brill, Holst, and Peldán find that differentspacetimes can be constructed by identifying points in 2+1 anti-de sitter space using transformations that preserve distance. Only spacetimes with one asymptotic region are constructed. Their work yielded noneternal black holes with collapsing quantum bridge topology. Such constructions assert black holes as being the end of a quantum bridge as a collapse is often considered the end; just as the collapse of a star is considered the star's end and the beginning of a new phase. Charged black holes in de Sitter space have quantum bridge properties (Mellor and Moss, 1989). Quantum bridges are temporal and require negative energy while black holes are spatial or null and utilize positive energy. It is theorized that quantum bridges would collapse into a black hole once they run out of negative energy. Furthermore, it is theorized that the final state of an evaporated black hole is a stationary quantum bridge; thus explaining why quantum bridges have not been observed and establishing how tight knit the relationship between black holes and quantum bridges. Black holes and quantum bridges are "interconvertible" (Hayward, 1999). Hayward's conclusion on energy's affect on the warping of spacetime supports black holes as the beginning and end of quantum bridges. The theory that evaporated black holes produce a stationary quantum bridge places black holes in the beginning of the cyclic relationship between black holes and quantum bridges. In addition, research into the stability of a quantum bridge shows that a quantum bridge would either inflate into a universe or black hole; though it should be noted that while Shinkai and Harvard paint black holes as the end of the aforementioned cycle, they present a diverging pathway out of this relationship (Shinkai and Harvard, 2002).

Loop Quantum Gravity

Hawking radiation is a principle that counters the argument made between the duality between black holes and quantum bridges. According to Hawking radiation black holes do not last forever and will eventually vanish because a gravitational field affects production of matching pairs of particles and anti-particles that are created just outside of the event horizon and the positive member of the pair escapes as the negative falls back in. Assuming that this negative energy does not cause the black hole to become temporal and a stationary quantum bridge, an information paradox is presented because information, like matter, cannot be created or destroyed. In 2004, Hawking retracts his stance on black hole evaporation in saying, “information is conserved, although not perhaps in our observable universe” (Kestin, 2014). He then goes on to assert that the information is scrambled – challenging Susskind’s two-dimensional copying of the information and smearing it around the edge of a black hole. However, Hawking does not provide any calculations to support this scrambling of information (Coleman, 1988). Referring back to Hawking’s mention of another universe, one must ask how information gets there besides Hayward’s theory of a stationary quantum bridge.Defining the spacetime in which these phenomena are set can provide a solution. Carlo Rovelli contests string theory with loop quantum gravity. Loop quantum gravity is the incorporation of general relativity into quantum field theory. In addition, it can be used to address the thermodynamics of black holes and the physics behind the big bang. According to loop quantum gravity, space is not infinitely divisible and has a granular structure. Everything is defined by fields, or lines that fill space, that start and end on electric charges and form closed loops and have independent dynamics in the absence of charge. Unlike string theory, loop quantum gravity is built on the concept that there is no background space. It is the mathematical description of the quantum gravitational field in terms of loops, and the quantum excitations of Faraday lines of force of the gravitational field appear as gravitons. The loops defined are not in space but are space. The loops form a net to which items are placed within the universe that evolves at discrete intervals as volume is quantified in loop quantum gravity. With the conditions created by loop quantum gravity, bounce quantum bridges become a possibility as the loops loop quantum gravity would halt the collapse of a black hole because a point would be reached in which the loops could not be compressed anymore and create and outward pressure called a quantum bounce. The Big Bounce is a theory that universes are created through the collapse of another; the “big bang” was a part of a cycle. Pullin and Gambini went beyond and applied the big bounce theory to a smaller scale of a black hole. Pullin and Gambini further support the aforementioned duality between black holes and quantum bridges by describing black holes as the method of transportation for information. This is done by arguing that there is not a singularity within a black hole and that information is conserved through transfer (Pullin and Gambini, 2013). This conclusion is supported by Hawking’s calculations on how quantum bridges lead to branching, closed universes (Hawking, 1988).

Analysis and Limitations

While there is no experimental evidence that quantum bridges exist, there is no evidence that can support the hypothesis that they do not exist (Scientific American, 1997). Åminneborg, Bengtsson, Brill, Holst, and Peldán’s solutions lack gravitational waves and do not account for angular momentum. Loop quantum gravity challenges string theory. Neither has been experimentally tested, though string theory does not treat general relativistic revolution as fundamental. However, the degrees of freedom of the field cannot be described for loop quantum gravity and the Immirzi parameter, that measures the quantum area in planck units, is not fixed. On the other hand, loop quantum gravity does not require super symmetry, proton decay, or a higher dimension (Rovelli). Shinkai and Harvard’s research into the stability of a quantum bridge consisted of constructions in a massless field when in reality the field would contain a mass. The limitations of the investigation made above include a lack of exploring how the thermodynamics of a black hole might influence its role in the black-hole quantum bridge cycle and that the constructions made in the different literature utilized for investigation used different spacetimes.

Also, different types of black holes are used to form the above arguments. Moreover, most of the arguments are formed under the assumption that there is a singularity at the core of a black hole yet the concept of a singularity is removed in the latter portion of the argument utilizing loop quantum gravity as a means of establishing the cyclic relationship between black holes and quantum bridges. Finally, the black holes observed in our universe are three dimensional but the mathematics used by the above researchers works with two dimensional spaces. Achúcarro and Oritz are able to dimensionally reduce three dimensional black hole solutions to solutions in "BTZ metrics" and find that the two have a relationship- making the following conclusion applicable to three dimensional black holes (Achúcarro and Oritz, 1993).

Conclusion

While investigating whether ***black holes are the beginning and the end of quantum bridges*** one can conclude that under the duality between black holes and quantum bridges, *black holes are the beginning and the end of the formation quantum bridges due to the ability of black holes and quantum bridges to take on energy that renders the space either spatial or temporal*. On the other hand under the conditions of loop quantum gravity, one can only conclude that *black holes are the beginning of quantum bridges* and not the end because of the possibility that the quantum bridge takes a diverging path, into a branching universe for example. Questions for future investigation that use the above conclusion as a foundation include whether the duality between black holes and quantum bridges or the affects of loop quantum gravity on the relationship, or both, are correct. Also, a new pathway into investigating whether the universe began with a big bang or big bounce can be taken.

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FOLLOW-UP: What exactly is a 'wormhole'? Have wormholes been proven to exist or are they still theoretical? (1997, September 15). *Scientific American*. Retrieved from http://www.scientificamerican.com/article/follow-up-what-exactly-is/.

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