IPI Letters

ISSN 2976 – 730X
IPI Letters, vol. 2 (1):3-8, 2024
https://doi.org/10.59973/ipil.47

Received: 2023-01-08
Accepted: 2023-01-24
Published: 2023-01-25

Article

Theoretical Possibility of Quantum Stabilization of Traversable Wormholes

Olivier Denis[1]*

[1] Information Physics Institute, Gosport, Hampshire, United Kingdom

*Corresponding author (Email: olivier.denis.be@gmail.com)

Abstract – In this article, we argue that we can explain quantum stabilization of Morris-Thorne traversable wormholes through quantum mechanics. We suggest that the utilization of dark matter and dark energy, conceptualized as negative mass and negative energy tied to the universe's information content, can stabilize these wormholes. This approach diverges from the original Morris-Thorne model by incorporating quantum effects, offering a credible and adequate source of the exotic matter needed to prevent wormhole collapse. We reassess the wormholes' stability and information content considering the new calculated revised vacuum energy based on the mass of bit of information. This new calculation makes the wormholes more viable within our universe's limits. Furthermore, we explore the connection between dark energy and the vacuum energy of space, highlighting the broader cosmological significance of traversable wormholes, particularly in relation to the universe's expansion. The quantum stabilization of Morris-Thorne traversable wormholes marks a pivotal advancement in the field of physics.

Keywords – Wormhole**,** Stabilized**,** Traversable**,** Dark matter; Dark energy; Casimir effect, Entropic information Theory.

1. Introduction

Wormholes are among the most fascinating and speculative subjects in the realm of theoretical physics. They have captured the imagination of scientists and the public alike, as structure linking disparate points in spacetime. In essence, a wormhole is a topological feature of spacetime, a 'shortcut' through space and time, potentially connecting different locations in the same universe, a concept stemming from Einstein's theory of general relativity.
Traversable wormholes are the kind that science fiction dreams are made of, permitting matter, including humans, to pass from one end of the wormhole to the other. This can, theoretically, allow for instantaneous travel across vast cosmic distances or even time travel.

The wormholes as features of spacetime are predicted by the equations of the general theory of relativity but for a wormhole to be traversable, it must have a throat which remains open during the transit time. That kind of traversable wormhole was proposed by Kip Thorne and his student Michael Morris in 1988 [1]. Nevertheless, these require the violation of certain energy conditions, such as the need for "exotic matter" with negative energy density to stabilize the throat of the wormholes against gravitational collapse. In this article, we argue that we can explain the quantum stabilization of Morris-Thorne traversable wormholes by the utilization of dark matter and dark energy, and by accounting quantum mechanics not initially part of Morris-Thorne model.

By considering the negative mass and the negative energy as being respectively dark matter and dark energy, studied as informational phenomena [2] we can provide a plausible source to negative mass/energy allowing to the traversable stabilized wormholes to exist by finding solutions to the violations of certain energy conditions required to stabilize the Morris-Thorne traversable wormholes. According to the entropic information theory framework, the revised calculation for the cosmological constant using the mass of bit of information instead of the Planck mass [2], offers a much lower value for vacuum energy, a reduced vacuum energy, altering the stability criteria for the Morris-Thorne wormholes, potentially making them more feasible within the constraints of our universe.

Additionally, still within the context of entropic information theory, there is a new understanding of how dark energy correlates with the vacuum energy of space [2], suggesting a connection between the nature of dark energy and the existence of wormholes. This insight is illuminating the potential impact of traversable wormholes on the universe's expansion. It means that the conditions necessary for wormholes are more common than previously thought.
The quantum stabilization of Morris-Thorne traversable wormholes quantumly stabilized by negative mass and negative energy from dark matter and dark energy, permits to envision profound repercussions such space travel and exploration, according to a better understanding of spacetime, allowing profound implications in various fields.

2. Historical presentation of the wormhole concept

Early science fiction, notably H.G. Wells' "The Time Machine" (1895) [3], introduced the notion of traversing vast distances through mystical means, but these ideas lacked scientific basis.
The concept of wormholes originated before the establishment of relativity theory, and wormholes as a scientific concept in mathematical relativity predate black holes. Just a year after Einstein formulated his field equations, Ludwig Flamm, a Viennese physicist, realized that Schwarzschild solution to the Einstein field equations represented a wormhole [4]. While Flamm is sometimes credited with suggesting wormholes' existence as early as 1916, it was Herman Weyl in the 1920s who speculated about the Schwarzschild and other wormholes' roles in physics. In 1928, Weyl proposed a wormhole hypothesis related to electromagnetic field energy's mass analysis [5, 6], referring to them as "one-dimensional tubes” [7].

Albert Einstein and Nathan Rosen's 1935 paper [8] was the first scientific suggestion of wormhole-like structures, proposing the "Einstein-Rosen bridge." These were solutions to the Einstein field equations in General Relativity, representing tunnels connecting two points in spacetime, but they were not meant to depict actual travel routes. Nonetheless, they laid the groundwork for the modern wormhole concept.

The term "wormhole" was coined by American theoretical physicist John Archibald Wheeler in 1957, inspired by Weyl's work [7] and in collaboration with Charles W. Misner [9]. The term was derived from the analogy of a worm traveling through an apple, a symbol of gravity since Isaac Newton, which can go directly to a diametrically opposite point, a spaceship could use the wormhole, like a shortcut, to emerge elsewhere in space and time [10]. The feasibility of traversable wormholes in general relativity was first shown in 1973 papers by Homer Ellis [11] and independently by K. A. Bronnikov [12]. Kip Thorne and his student Michael Morris rediscovered the Ellis wormhole in 1988, suggesting its use for teaching general relativity [1]. The traversable wormhole they proposed, sustained by a spherical shell of exotic matter, became known as the Morris–Thorne wormhole. Kip Thorne has also explored the idea of artificially creating wormholes [13].

3. The Morris-Thorne Wormhole

The most famous solution to Einstein's field equations that yields a wormhole is the Morris-Thorne metric, which describes a traversable wormhole.
The idea of traversable wormholes comes mainly from solutions to Einstein's field equations of General Relativity which describe the fundamental interaction of gravitation because of spacetime being curved by matter and energy. A traversable wormhole would be a structure linking disparate points in spacetime and is distinguishable from a black hole in that it would allow for travel in both directions. The conceptual framework for traversable wormholes was significantly advanced by the seminal paper by Morris and Thorne in 1988, titled "Wormholes in spacetime and their use for interstellar travel: A tool for teaching general relativity" [1]. Their work focused on the possibility of constructing a traversable wormhole that could be stable enough for human travel, or the transmission of information, from one part of the universe to another. The Morris-Thorne wormhole is not only a solution to the Einstein field equations but also a theoretical bridge between points in spacetime. A Morris-Thorne wormhole can be visualized as a tunnel with two ends at separate points in spacetime, which could be in different regions of the universe. This tunnel-like structure is often referred to as the "throat," which connects what are called the "mouths" of the wormhole. For a wormhole to be traversable, it must not contain any event horizons that would prevent two-way travel. The Morris-Thorne wormhole is designed to be free of horizons, thereby allowing travelers to pass through the wormhole in both directions freely.

One of the biggest challenges for a traversable wormhole is stability. According to classical general relativity, the throat of a Morris-Thorne wormhole would naturally collapse under gravitational attraction. To counteract this, the throat would need to be held open by a form of matter with negative energy density, referred to as "exotic matter." The requirement for exotic matter is one of the most significant aspects of Morris-Thorne wormholes. This exotic matter would need to have negative energy density to counteract the immense gravitational forces attempting to close the wormhole.

To maintain the throat of a wormhole open and prevent it from collapsing, one would need exotic matter with negative energy density or tensions that violate some of the energy conditions, known violations of the energy conditions are a key part of the Morris-Thorne wormhole problematic. The primary issue is that it is challenging to find physically plausible sources of exotic matter that would violate the energy conditions in a way that allows for stable and traversable wormholes.

4. Entropic information Theory Approach

The theoretical framework outlined from entropic information theory approach proposes a novel perspective on cosmological phenomena by linking the concept of information with physical properties such as entropy, dark matter, and dark energy, accounting the mass of the bit of information [2, 14].

The entropic information theory approach posits that information has an intrinsic mass and that negative entropy could be associated with the structured information content of the universe, moreover, this approach proposes that dark matter is an informational field with finite and quantifiable negative mass, distinct from the conventional fields of matter of quantum field theory and associated with the number of bits of information in the observable universe; while dark energy is negative energy, calculated as the energy associated with dark matter, dark energy being vacuum energy, a collective potential of all particles with their individual zero-point energy [2].

This proposed model has profound implications for various aspects of cosmology, including the theoretical possibility of stabilized Morris-Thorne traversable wormholes. The stability and information content of these wormholes must be reevaluated in the context of the entropic information theory approach. The introduction of the mass of bit of information and some novel entropy formulas associated to it provides a new perspective on the internal structure of wormholes [14].

One of the greatest obstacles in wormhole physics is the stabilization of the wormhole throat but negative mass and negative energy from the entropic information theory approach, provide repulsive gravitational effects, which are essential to counteract the attractive gravitational forces that otherwise cause the wormhole to collapse. The gravitational repulsion between negative and positive masses, as predicted, play a crucial role in the dynamics of traversable wormholes. The dynamics of wormholes, including their size, shape, and stability over time, are deeply influenced by the properties of negative mass and energy. If dark matter and dark energy can be manipulated or their densities can be varied, this will allow for the control of wormhole characteristics, such as the size of the throat and the duration for which the wormhole remains open. As dark energy is computed as negative energy linked with information content of the whole observable universe [2], it can provide a source of negative energy density to support wormhole stability without the need for exotic matter as traditionally conceived.

It is important to consider the role of quantum mechanics, which is not included in the classical Morris-Thorne wormhole model; indeed, quantum effects are crucial in the stability of wormholes, quantum effects can stabilize the wormhole or produce phenomena like Hawking radiation, which can have significant implications for the structure and stability of the wormhole. Quantum phenomena, including the Casimir effect, are constrained by the averaged null energy condition in regions of space that are flat [15], yet theoretical work in semiclassical gravity indicates the potential for these quantum phenomena to contravene this condition in areas of curved spacetime [16]. Despite recent aspirations that quantum effects would adhere to an achronal form of the averaged null energy condition [17], instances of non-compliance have been detected [18], leaving the door open to the theoretical use of quantum effects in the maintenance of a wormhole. Initial estimations indicate the necessity for a substantial volume of negative energy, but more recent studies reveal that the requisite negative energy could be reduced to a minimal amount [19]. Many physicists, such as Stephen Hawking [20], Kip Thorne [21], and others [22, 23, 24], argued that such effects might make it possible to stabilize a traversable wormhole [25]. The negative energy associated with the Casimir effect, which is a quantum field phenomenon, is similar to the negative energy associated to dark energy, described in the entropic information approach [2]. The revised calculation for the cosmological constant using the mass of bit of information, from the entropic information theory approach [2], offers a much lower value for vacuum energy, a reduced vacuum energy [2] which can alter the stability criteria for these wormholes, potentially making them more feasible within the constraints of our universe. The entropic information approach links dark energy to the vacuum energy of space [2], suggesting a connection between the nature of dark energy and the existence of wormholes. This connection can shed light on the cosmological implications of traversable wormholes and their role in the expansion of the universe.

5. Conclusions

After a brief historic presentation of the concept of wormhole, we focus on the Morris-Thorne wormhole which presents a fascinating theoretical possibility of travels through space and time; capturing the imagination of both physicists and science fiction enthusiasts alike, indeed, this kind of traversable wormholes permits matter, including humans, to pass from one end of the wormhole to the other. A crucial element of Morris-Thorne wormholes problematic is the necessity for exotic matter, which is a particular type of matter, this exotic matter is required to possess a negative energy density, which serves the purpose of balancing the powerful gravitational forces that would otherwise collapse the wormhole.

We argue that dark matter and dark energy can be harnessed to stabilize Morris-Thorne wormholes, as both have been computed in the entropic information theory framework, as respectively negative mass and negative energy; computed as dark matter and dark energy; dark matter being the number of bits of information content of the whole observable universe, associated with a quantifiable and definite negative mass; and dark energy being the energy associated to it, by the Landauer's principle; dark energy being computed as negative energy associated to the vacuum energy [2]; dark matter and dark energy offering a mechanism to achieve the quantum stabilization of Morris-Thorne traversable wormholes against the gravitational collapse attempting to close the wormhole.

By accounting the role of quantum mechanics, which is not included in the classical Morris-Thorne wormhole model; we are able, theoretically, to quantumly stabilize the wormhole by the negative energy associated to dark energy being vacuum energy, a collective potential of all particles with their individual zero-point energy, emerging, from dark matter by Landauer's principle [2], which can have significant implications for the structure and stability of the wormhole.

The negative energy associated with the Casimir effect, which is a quantum field phenomenon, is similar to the negative energy associated to dark energy, described in the entropic information theory approach [2].

Many physicists, such as Stephen Hawking [20], Kip Thorne [21], and others [22, 23, 24], argued that such quantum effects, as Casimir effect, might make it possible to stabilize a traversable wormhole [25]. Initial estimations indicated the necessity for a substantial volume of negative energy, but more recent studies have revealed that the requisite negative energy could be reduced to a minimal amount [19] to be able to stabilize the traversable Morris-Thorne wormhole. The negative energy associated with dark energy, especially in the context of quantum field theory, play a role in stabilizing wormholes at quantum scales. This lends some theoretical support to the possibility that quantum field effects could naturally produce the conditions suitable for wormhole stability.

In the entropic information theory framework, the cosmological constant wherein the mass of bit of information has been taken in consideration instead of Planck mass, reducing the discrepancy by almost 120 orders of magnitude in the prediction of the vacuum energy from a quantum point of view has been calculated [2]. The revised calculation for the cosmological constant using the mass of bit of information, from the entropic information theory approach [2], offers a much lower value for vacuum energy, a reduced vacuum energy, altering the stability criteria for the Morris-Thorne wormholes, potentially making them more feasible within the constraints of our universe.
The entropic information approach links dark energy to the vacuum energy of space [2], suggesting a connection between the nature of dark energy and the existence of wormholes. This connection sheds light on the cosmological implications of traversable wormholes and their role in the expansion of the universe. It means that the conditions necessary for wormholes are more common than previously thought.

By positing that dark matter and dark energy are informational with negative mass and negative energy [2], the entropic information theory approach suggests a possible mechanism for creating and sustaining traversable wormholes. The association of information with physical mass and energy might offer solutions to some of the theoretical challenges associated with wormhole physics, such as the requirement for exotic matter and the stability of the wormhole throat.

The entropic information approach offers a unique perspective on the universe as a whole. By calculating the number of bits of information contained in the observable universe and relating this information to dark matter and dark energy [2], this provides a framework for considering the universe's informational and energetic aspects, leading to a better understanding of the cosmic-scale implications of stabilized traversable wormholes.

The quantum stabilization of Morris Thorne wormholes leads to profound implications.

The quantum stabilization of Morris-Thorne traversable wormholes using dark matter and dark energy lending some theoretical support to the possibility that quantum field effects could naturally produce the conditions suitable for wormhole stability, making them more feasible within the constraints of our universe; by shedding light on the cosmological implications of traversable wormholes and their role in the expansion of the universe, that entropic information approach regarding to Morris-Thorne traversable wormholes is not only be a milestone in physics but also have far-reaching implications across technology, society, ethics, and philosophy. The most immediate implication would be revolutionizing space travel. A traversable wormhole could potentially allow for instantaneous travel across vast cosmic distances, making interstellar and even intergalactic travel feasible. This would vastly expand the scope of human exploration and colonization efforts in space. The technology required to create and stabilize a wormhole would represent a monumental leap in our scientific capabilities. This could spill over into other areas of technology, leading to unforeseen advancements. The ability to traverse vast distances almost instantaneously would have profound societal implications. It could lead to the reorganization of geopolitical and economic structures on Earth and raise complex ethical questions regarding space colonization. The realization of the quantum stabilization of traversable wormholes will have a deep philosophical impact, challenging our understanding of reality and our place in the universe. It could lead to new philosophical movements or cultural shifts in how humanity views itself and its capabilities.

Acknowledgments

To my family, Valérie and Léa without whom I would not be what I become.

References

[1] Morris, Michael S. & Thorne, Kip S. (1988). "Wormholes in spacetime and their use for interstellar travel: A tool for teaching general relativity". American Journal of Physics. **56** (5): 395–412. Bibcode:1988AmJPh..56..395M. doi:10.1119/1.15620

[2] Denis, O. (2023). Informational Nature of Dark Matter and Dark Energy and the Cosmological Constant. IPI Letters, 1, 66–77. https://doi.org/10.59973/ipil.36

[3] Robert W. Philmus and David Y. Hughes. Berkeley, Anthologized in H. G. Wells (1975). H. G. Wells: Early Writings in Science and Science-Fiction. University of California.

[4] (de) Ludwig Flamm, « Beiträge zur Einsteinschen Gravitationstheorie », Physikalische Zeitschrift, vol. 17, 1916, p. 448-454.

[5] Weyl, H. (1921). "Feld und Materie". Annalen der Physik. **65** (14): 541–563. Bibcode:1921AnP...370..541W. doi:10.1002/andp.19213701405.

[6] Scholz, Erhard, ed. (2001). Hermann Weyl's Raum – Zeit – Materie and a General Introduction to His Scientific Work. Oberwolfach Seminars. Vol. 30. Springer. p. 199. ISBN 9783764364762.

[7] "Hermann Weyl": entry in the Stanford Encyclopedia of Philosophy.

[8] Einstein, A., B. Podolsky, and N. Rosen, 1935, "Can quantum-mechanical description of physical reality be considered complete?", Physical Review, 47: 777–780 [Einstein, Podolsky, and Rosen 1935 available online].

[9] Misner, C. W.; Wheeler, J. A. (1957). "Classical physics as geometry". Ann. Phys. **2** (6): 525. Bibcode:1957AnPhy...2..525M. doi:10.1016/0003-4916(57)90049-0.

[10] Jean-Pierre Luminet, « Trou noir : la porte des étoiles ?», sur France Inter.fr, 21 août 2019.

[11] H. G. Ellis (1973). "Ether flow through a drainhole: A particle model in general relativity". Journal of Mathematical Physics. **14** (1): 104–118. Bibcode:1973JMP....14..104E. doi:10.1063/1.1666161.

[12] K. A. Bronnikov (1973). "Scalar-tensor theory and scalar charge". Acta Physica Polonica. **B4**: 251–266.

[13] Thorne, Kip S. (1994). Black holes and time warps: Einstein's outrageous legacy. New York. p. 493. ISBN 978-0393312768.

[14] Denis, O. (2023). The entropy of the entangled Hawking radiation. IPI Letters, 1, 1–17. https://doi.org/10.59973/ipil.9.

[15] Fewster, Christopher J.; Ken D. Olum; Michael J. Pfenning (2007). "Averaged null energy condition in spacetimes with boundaries". Physical Review D. **75** (2): 025007. arXiv:gr-qc/0609007. Bibcode:2007PhRvD..75b5007F. doi:10.1103/PhysRevD.75.025007. S2CID 119726654.

[16] Visser, Matt (1996). "Gravitational vacuum polarization. II. Energy conditions in the Boulware vacuum". Physical Review D. **54** (8): 5116–5122. arXiv:gr-qc/9604008. Bibcode:1996PhRvD..54.5116V. doi:10.1103/PhysRevD.54.5116. PMID 10021199. S2CID 31954680.

[17] Graham, Noah; Ken D. Olum (2007). "Achronal averaged null energy condition". Physical Review D. **76** (6): 064001. arXiv:0705.3193. Bibcode:2007PhRvD..76f4001G. doi:10.1103/PhysRevD.76.064001. S2CID 119285639.

[18] Urban, Douglas; Ken D. Olum (2010). "Spacetime averaged null energy condition". Physical Review D. **81** (6): 124004. arXiv:1002.4689. Bibcode:2010PhRvD..81l4004U. doi:10.1103/PhysRevD.81.124004. S2CID 118312373.

[19] Visser, Matt; Sayan Kar; Naresh Dadhich (2003). "Traversable wormholes with arbitrarily small energy condition violations". Physical Review Letters. **90** (20): 201102.1–201102.4. arXiv:gr-qc/0301003. Bibcode:2003PhRvL..90t1102V. doi:10.1103/PhysRevLett.90.201102. PMID 12785880. S2CID 8813962.

[20] "Space and Time Warps". Hawking.org.uk. Archived from the original on 2012-02-10. Retrieved 2010-11-11.

[21] Morris, Michael; Thorne, Kip; Yurtsever, Ulvi (1988). "Wormholes, Time Machines, and the Weak Energy Condition" (PDF). Physical Review Letters. **61** (13): 1446–1449. Bibcode:1988PhRvL..61.1446M. doi:10.1103/PhysRevLett.61.1446. PMID 10038800.

[22] Sopova; Ford (2002). "The Energy Density in the Casimir Effect". Physical Review D. **66** (4): 045026. arXiv:quant-ph/0204125. Bibcode:2002PhRvD..66d5026S. CiteSeerX 10.1.1.251.7471. doi:10.1103/PhysRevD.66.045026. S2CID 10649139.

[23] Ford; Roman (1995). "Averaged Energy Conditions and Quantum Inequalities". Physical Review D. **51** (8): 4277–4286. arXiv:gr-qc/9410043. Bibcode:1995PhRvD..51.4277F. doi:10.1103/PhysRevD.51.4277. PMID 10018903. S2CID 7413835.

[24] Olum (1998). "Superluminal travel requires negative energies". Physical Review Letters. **81** (17): 3567–3570. arXiv:gr-qc/9805003. Bibcode:1998PhRvL..81.3567O. doi:10.1103/PhysRevLett.81.3567. S2CID 14513456.

[25] Newfound Wormhole Allows Information to Escape Black Holes". Quanta Magazine. 23 October 2017.